Forest Carbon Partnership Facility (FCPF) Carbon Fund ER Monitoring Report (ER-MR)	
ER Program Name and Country:	Zambézia Integrated Landscape Management Program (ZILMP) Republic of Mozambique
Reporting Period covered in this report:	01-01-2021 to 31-12-2022
Number of FCPF ERs:	0
Quantity of ERs allocated to the Uncertainty Buffer	0
Quantity of ERs to allocated to the Reversal Buffer	0
Quantity of ERs to allocated to the Reversal Pooled Reversal buffer	0
Date of Submission:	30-11-2023

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TABLE OF CONTENTS

LIST OF ACRONYMS

AD	Activity Data
AFS	Agro-Forestry Systems
ANAC	National Administration of Conservation Areas
AQUA	Nacional Agency for Environmental Quality Control
BSP	Benefit Sharing Plan
CATS	Carbon Assets Tracking System
CEAGRE	Centro de Estudos de Agricultura e Gestão de Recursos Naturais
CBNRM	Communities Based in Natural Resources Management
CBOs	Community-Based Organizations
CNG	National Management Committee
DINAF	National Directorate of Forest
EF	Emission Factor
EFF	Planted Forest Grant Scheme
ER	Emission Reduction
ERPA	Emission Reductions Program Agreement
ERDP	Emission Reductions Program Document
ESMP	Environmental and Social Management Plan
FCPF	Forest Carbon Partnership Facility
FDS	Semi-deciduos Forest
FGRM	Feedback and Grievance Redress Mechanism
FSSV	Evergreen Forest
FNDS	National Fund for Sustainable Development
FMS	Forest Monitoring System
FREL	National Forest Reference Emissions Level
FPS	Forest Plantation Scheme
GALs	Gender Action Learn System
GHG	Greenhouse Gases
GNR	Gile National Reserve
LULCC	Land Use and Land Cover Change
GoM	Government of Mozambique
GPM	Good Practice Manual
M&E	Monitoring and Evaluation
MEF	Ministry of Finance
MGS	Matching Grant Scheme
MoU	Memorandum of Understanding
MR	Monitoring Report
MSLF	Multi-stakeholder Landscape Forum

MRV	Monitoring, Reporting and Verification
MTA	Ministry of Land and Environment
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NTFP	Non-timber Forest products
PDD	Project Document
PDFs	Probability Density Functions
PDIZ	Zambézia Integrated Development Platform
PCUT	Community Land Use Plans
PIU	Project Implementation Unit
PMRV	Participatory Monitoring Report and Verification
PMP	Pest Management Plan
QAQC	Quality Assurance and Quality Control
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SDAE	District Service for Economic Activities
SESA	Social and Environmental Strategic Assessment
SECF	Small Emerging Commercial Farmers
SIS	Safeguards Information System
SOP	Standard Operating Procedure
UNFCCC	National Framework Convention on Climate Change
VCS	Verified Carbon Standard
VVB	Validation and Verification Body
WB	World Bank
WWF	World Wildlife Fund
ZILMP	Zambézia Integrated Landscape Management Program

1 IMPLEMENTATION AND OPERATION OF THE ER PROGRAM DURING THE REPORTING PERIOD

1.1 Implementation status of the ER Program and changes compared to the ER-PD

Unsustainable small-scale agriculture is the major driver of deforestation in Mozambique and within the Zambézia Emission Reduction (ER) Program. Illegal logging and informal charcoal production are the main drivers of forest degradation within the Program geographical area (CEAGRE and Winrock International, 2015). In order to address those drivers, the ER Program is based on a comprehensive approach that recognizes the link between agricultural development, natural resources management and governance. Since the ER Program only accounts for ERs resulting from reduced deforestation, activities focusing on the adoption of sustainable agricultural techniques will be key to its success. Nonetheless, the ER Program has four World Bank (WB) investment projects (the Agriculture and Natural Resources Landscape Management Project (Sustenta), Mozambique Conservation Areas for Biodiversity and Development Project (MozBio I), Dedicated Grant Mechanism for Local Communities project (MozDGM[1]) and Forest Investment Project (MozFIP), and those have a broader approach on land management: their activities extend beyond the agricultural sector. This is actually coherent with the overall scheme of the ER Program, based on an integrated land management approach. Other measures focus on livelihood and income generation through the strengthening of key value chains of cash crops that are not responsible for deforestation, on regularizing land tenure and on community awareness to secure stakeholders' commitment on the long run. Regarding the Emission Reductions Program Document (ERPD) was prepared and this is financing more activities aiming to generate ERs within the ER Program.

Crediting Period and Evidence of Implementation of Activities

The Crediting Period for Zambézia Integrated Landscape Management Program is from January 1st 2018 to December 31st 2024.

According to the FCPF's (Forest Carbon Partnership Facility) *Glossary of Terms* (link) the Crediting Period Start Date has to comply with several conditions:

i) it must not be earlier than the date of the first implementation of project activities;

ii) is justified with objective evidence;

iii) it cannot be earlier than January 1st 2016;

iv) cannot fall within the Reference Period; and

v) the activities must comply with safeguards requirements.

Table 1, which includes on-the-ground activities and enabling environment interventions for 3 of the projects: MozFIP[2], MozBio I[3] and Sustenta[4]. Sustenta, Support to the development of agricultural and forestry value chains of the Project approved in 2021 and 2022and new business plans for emerging small commercial farmers.

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[1] (https://mozdgm.org.mz/)

[2] (https://www.fnds.gov.mz/index.php/en/our-projects/project-list/MozFIP)

[3] (https://www.fnds.gov.mz/index.php/en/our-projects/project-list/mozbio)

[4] (https://www.fnds.gov.mz/index.php/en/resources/highlights/131-programa-sustenta-2)

Compliance with safeguard requirements is described in detail in Annex 1: Information on the implementation of the Safeguards Plans.

Table 1: Specific project activities conducted in the monitoring period in the ER Program Area.

Project	Activity	Evidence
MozFIP	Delimitation of communities	2021 Project Activity Report: (https://www.dropbox.com/scl/fi/qe5k9c3auh0t5e8phvog1/Relat-rio-Anual-2021_WB_02.docx?rlkey=ykmklg1e856cwsi13xdryujsx&dl=0)
		Website from Service Provider with Results Dashboard (https://sites.google.com/site/verdeazullandscape/rduat)
	Forest Plantation Scheme (FPS)	Contract with Consultant (https://www.dropbox.com/s/480cc7h8gai0g5y/Moz%20Agroforestry%20Contract%20signed.pdf?dl=0) and (https://www.dropbox.com/s/uowe3m4dourt04k/CONTRACTO%20HORFPEC.Lda.pdf?dl=0) Proof of payment of consultants (https://www.dropbox.com/s/wdiock76k6ilfls/Horfpec%20--%20267.721%2C90.pdf?dl=0) (https://www.dropbox.com/s/mjbhdgcnjaq18zb/HORFTEC%20--299.776%2C14.pdf?dl=0)
		Results of 2020/21 from Consultant NIRAS (https://www.dropbox.com/s/rbzj63pp35ujxpv/Apresenta%C3%A7%C3%A3o_Missao%20WB_23042021_v002.pdf?dl=0)
		Newsletter 2020/21 (https://www.dropbox.com/s/sa97rb88vfi4ov0/_6%20edi%C3%A7%C3%A3o%20do%20Boletim%20Informativo%20do%20EFF%20e%20SAFs%20.pdf?dl=0)
	Benefit Sharing Plan - First payment event	https://www.dropbox.com/sh/wu2h7lcc2eu9198/AAAQgTZHzetiUf7VF-n4tKv9a?dl=0
	Communication	https://www.dropbox.com/sh/e64veyfc78gzvxo/AADAfm3DfZgB8WOxJGDDlsXta?dl=0
	Capacity building for the local communities	Report from capacity building for communities in management of natural resources (https://www.dropbox.com/s/6v0ve29d2dp6rco/Relatorio%20Final%20do%20Curso%20de%20Governanca%20e%20MCRN%20-

		%20Zambezia.docx.pdf?dl=0)
		Report from capacity building for communities in Nipiode and Anawape (https://www.dropbox.com/s/dk4fptc9iksmrww/Relat%C3%B3rio%20Final%20do%20curso%20de%20Fiscaliza%C3%A7%C3%A3o%20e%20Legisla%C3%A7%C3%A3o%20Florestal.pdf?dl=0)
		Finance administration training reports (https://drive.google.com/file/d/1UrX1vK5gG7qfPV0pcytBbW3zhGjf68yI/view)
Sustenta	Agricultural development (16 SECF- Small emerging commercial farmers)	Proof of payment (https://www.dropbox.com/s/bddinbe55om4y40/Paces.pdf?dl=0)
	Restoration of degraded areas in the Sustenta Landscape	Proof of payment (https://www.dropbox.com/s/gxktce3laksahvy/Factura.pdf?dl=0)
		2019 Project Activity Report (https://www.dropbox.com/s/dn9gw1afx7w82zr/Relat%C3%B3rio%20Anual%20de%20Actividades%202019vvvv_25.02.2020.doc?dl=0)
		2020 Project Activity Report (https://www.dropbox.com/s/6ve8du56uymy1gx/Relat%C3%B3rio%20Anual%20de%20Actividades%202020.%20PGIARN.versao%20final.1.doc?dl=0).
	Support Micro, Small and Medium Enterprises to develop non-timber and non-wood forest products business plans	2021 Project Activity Report (https://www.dropbox.com/s/cr2pox82w10sff1/Relat%C3%B3rio%20Anual%202021_Integrado.%20Versao%2021%20Abril.docx?dl=0) 2022 Project Activity Report https://www.dropbox.com/scl/fi/lkfwo3h6zqxcomodlguuw/Relat-rio-Anual-2022_Integrado.-Versao-FINAL-2.docx?rlkey=8yiguxbbn15nb1gvhq55d5td4&dl=0
	Infrastructure	https://www.dropbox.com/sh/vuctt0dik4zynwk/AAAUeWD8NhPbmArHVqj8L7Cba?dl=0
	Maintenance	https://www.dropbox.com/sh/vuctt0dik4zynwk/AAAUeWD8NhPbmArHVqj8L7Cba?dl=0

MOZDGM	World Bank report and annual report	WB report https://www.dropbox.com/s/vwo3ms1dodzu9pz/AM_MozDGM_Nov%202021_FINAL%20%28002%29.pdf?dl=0 2021 Project Activity Report https://www.dropbox.com/scl/fi/mryd6omnij9bv1qwc18gi/MozDGM_semiAnnual-Report_Final_Report-2021.pdf?rlkey=jsz4l5phtm8r8rk6fqcblxchi&dl=0 2022 Project Activity Report https://www.dropbox.com/scl/fi/os2k7hfmgwnwgq2jweeoz/Report_MozDGM_July2022.pdf?rlkey=hpp4eeguay3yon409xepdzbdl&dl=0

1.1.1 Update on the strategy to mitigate and/or minimize potential Displacement.

The ER Program has done all efforts to minimize displacement of emissions to an area outside the Program boundaries and if present, it will be minimal, as most of the measures proposed to tackle the drivers of deforestation and forest degradation are primarily based on incentives and on the valorization of non-carbon benefits rather than coercive measures that will cause a displacement of drivers of deforestation. Therefore, the expectation is to lower the appeal of deforestation and forest degradation. As part of the strategy, the Monitoring, Report and Verification (MRV) Unit developed a tool to detect annual deforestation for the whole country and currently, the data is accessible through the geospatial platform where deforestation for 2017, 2018, 2019, 2020, 2021 and 2022in the Districts inside and outside of the ER Program and in other Provinces is displayed (See the link: https://bit.ly/GeoportalMRVOnline). Degradation is another component of forest monitoring that the MRV Unit is developing (see the first results of degradation in annex 6). One major driver of deforestation identified during the design of the program was unsustainable small-scale agriculture and two causes of forest degradation identified are illegal logging and charcoal production (these activities were identified during the verification process for 2020 monitoring report). The drivers of deforestation and forest degradation within the ER Program remain the same (see section 1.2). All strategies outlined in the ER-PD are being strictly implemented to avoid displacement and the risk of displacement still assessed and categorized as low for slash and burn agriculture, low for charcoal production and Medium for Illegal logging (Table 2).

Table 2: Updates on strategies being applied to the different drivers of deforestation or degradation to minimize potential displacement.

Small scale agriculture based on "slash and burn" techniques	
Risk of displacement	Low
Progress of the strategy in Place	There is a plan of involving 1500 farmers in technical assistance to adopt sustainable practices of agriculture such as Agroforest systems in about 750 ha. By the end of 2018, 550 farmers from Mulevala District (from 3 communities) were involved in a total area of 250ha. By 2020 the total area of agroforestry systems in the program area increased to a total of 931ha (click here for more information). Community delimitation is the first step towards a sustainable management of natural resources and land. The outputs of community delimitations are Certificates signed by the Provincial Geography and Cadastral Service (SPGC), the community zoning Land Use map, the Community Land Use Plan and the Community development agenda. According to the ERPD plan, the aim is to achieve 322,500 ha of community land supported by land use plans by the end of the crediting period. Sustenta and MozFIP projects delimited a total

	of 187 communities land in Mulevala (48), Gilé (5), Mocubela (27), Gurue (4), Maganja da Costa (81) e Pebane (22) Districts. This number is expected to increase in the following years. This will reduce nomadism thus avoiding displacement. To foster sustainable community management, individual farmers also benefited from Regularization of the Right to Use and Benefit from Land (*Regularização do Direito de Uso e Aproveitamento da Terra* - R-DUAT) in Mocuba, Mulevala e Gilé 37,671 farmers, in an area of 60,559 ha. More details regarding R-DUATs can be found in Annex 3. The District authorities are incentivizing the adoption of conservation agriculture practices to restore and maintain the soil fertility through public extension services. There are also efforts to promote plantation of cashew trees as part of the agricultural extension package.
Charcoal production	
Risk of displacement	Low
Progress of the strategy in Place	The focus in this component is the training of charcoal makers to incentivize them to use fuel-efficient technology, promote the sustainable management of forests for charcoal production and use of forest logging and sawmill residues. 168 people from communities were trained to adopt improved kilns to produce charcoal in Pebane, Mocubela, Maganja da Costa and Ile. In each community, 500 hectares were identified for sustainable logging to produce charcoal. Four companies from the private sector were also involved in processing sawmill residues to produce charcoal. The use of sustainable charcoal in these communities is also happening and the private sector is in the process of adopting new practices of charcoal production. To ensure the value for money for charcoal production, informal partnership between the private sector and trained communities was established.
Unsustainable forestry practices, including illegal logging	
Risk of displacement	Medium
Progress of the strategy in Place	The project is contributing significantly in strengthening the law enforcement in the forest sector. The Government moved this component from the National Directorate of Forest to the National Agency for Environmental Quality Control (AQUA). The support of the project was concentrated on the preparation of the strategy for law enforcement in forest, and investing on the creation of AQUA Delegation in Zambézia. MozFIP hired an international consultant to support AQUA in the production of the Law enforcement strategy. At the National level, by the recommendation of the last National Forestry Inventory (NFI), the Government of Mozambique (GoM) has recently taken strict actions over the most harvested tree species in Mozambique. For instance, harvesting of *Pterocarpus tinctorius* (Nkula), *Combretum imberbe* (Mondzo) and *Swartzia madagascariensis* (Pau-ferro) was banned as well exportation of *Pterocarpus angolensis* (Umbila), *Millettia stuhlmannii* (Jambirre, Panga-Panga), *Afzelia quanzensis* (Chanfuta) in form of logs was ceased. *Swartzia madagascariensis* (Pau-ferro) occurs mostly within the Gilé National Park reason why the GoM decided to take such measures as the last NFI indicates that the species' stock has steeply declined over the past 10 years (https://fnds.gov.mz/mrv/index.php/documentos/relatorios/26-inventario-florestal-nacional/file). The GoM conducted a nation-wide audit of licensed areas (forest concessions and simple licenses) to assess the extent to which sustainable forest management practices are improving within the ER Program area and results have shown improvements. This assessment happens every two years since 2016.

	The GoM put in place a new law on timber exports, including log export ban on all native species to incentivize domestic timber processing for adding value to the product whilst also creating more jobs for rural communities A tool of Minimum standards for sustainable management was developed in 2018, to translate into a legal instrument for evaluation of operators' performance to inform any suspension of licenses, with potential for a national certification standard to be developed. In 2018 additional forest inventory plots were sampled in Zambézia, which improved the biomass estimates (link) and was a critical input to the measures taken by the ministry regarding species exploitation and exportation ban.

1.1.2 Effectiveness of the organizational arrangements and involvement of partner agencies

The success of implementation of an ER program is dependent on the stakeholder engagement. The ER Program has been inclusive on all the decisions regarding interventions on the ground aiming to generate ERs. The major milestones achieved are:

- The creation of a multi-stakeholder landscape forum for sustainable management of natural resources, which is a crucial instrument for stakeholder's consultation and participation in the implementation of the activities within the ER Program. This forum involves different civil society organizations; the Government; Private sector; community organizations and academic institutions. The connection to the platform has been very positive and active..
- a committee for assessing the implementation of forest plantation scheme (Composed by National Directorate of Agriculture and Forestry (DINAS), National Directorate of Forest (DINAF) and Manica Forestry Industries (IFLOMA). This committee has the role of Assess and approve the conformance and eligibility of the proposals to the signature of contracts; Approve payments to beneficiaries of the projects; Monitor progress of the implementation of the scheme. With a committee, performance evaluation of forest plantations was carried out for all beneficiaries of the Forest Plantation Scheme (FPS), showing maintenance rates of the planted area that varies between 70 and 98%. As a result, subsidy payments were made, with the first installment (new beneficiaries) and the second installment (former beneficiaries)[5].

- Exchange of experience with New Forests Company (NFC) and World Wildlife Fund (WWF) Uganda with the support of NGP (New Generation Plantation) in how to engage the SME in forest plantations. A study visits and technological exchange was held in Uganda, which had as its main theme: "Sustainable Plantations for the Prosperity of Africa and was focused on the challenges and opportunities faced by forest companies in establishing sustainable plantations. This event was co-organized by NFC and WWF-Uganda with the support of the New Generation Plantations (NGP) Platform -. The Travel Report was shared with the World Bank.[6] Partnership between private sector and communities in small business enterprises (Sustainable charcoal production; non-timber forest products; community concessions, among others).

- Several Memoranda of Understanding (MoU) were signed between Community-Based Organizations (CBOs) and private sector, such as: MoU between Mocuba Honey Company and the associations of Nipiode and Uapé was signed, with a view to making the honey business viable. The National Fund for Sustainable Development (FNDS) promoted a new negotiation process for the partnership to make the

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[5] Source: MozFIP annual progress report 2021 (https://www.dropbox.com/s/8vjjlq4fatcw4gx/Relat%C3%B3rio%20Anual%202021_WB_02.docx?dl=0https://www.dropbox.com/s/n49lg01rpouw836/Relat%C3%B3rio%20Anual%202020_FINAL.docx?dl=0)

[6] Source: MozFIP annual progress report 2018 (https://www.fnds.gov.mz/index.php/en/our-projects/project-list/MozFIP)

mushroom business viable with the Divateches-Agri and Miruku consortium, having already signed the MoU. Some negotiations have not been successful, but efforts are still being made to promote more partnerships.

- FNDS signed MoUs with Portucel and Niras in 2020 (more details please click here). According to these agreements, Portucel and Niras will be responsible for: i) providing seedlings and other inputs at a subsidized price; ii) technical assistance; and iii) Training for extension technicians and beneficiaries (please see 2021 MozFIP reports for more details).

- The signature of the MoU between FNDS and Zambeze University (Unizambeze), to provide technical support for research and development; Supply interns (students) to help communities on the ground to comply with sustainable practices aiming to halt deforestation. The MoU has not yet been signed, but several activities are already underway, such as Unizambeze's involvement in the Forest Plantation Scheme, helping the NIRAS Service Provider and Portucel, during forestry operations.

The major milestones still to be achieved are:

- Insert information from unofficial certificates, Community Land Use Plans (*Planos Comunitários de Uso de Terra* PCUT) and DUATs elaborated throughout the project, in the geospatial platform;
- Promote training and technical demonstrations of planting associated with greater frequency of technical assistance to beneficiaries as well as exchange of experience between various stakeholders;
- Continue aerial monitoring in the areas of Forest Plantation Scheme beneficiaries via drones with the aim of evaluating the progress of tree cover;
- Forest monitoring by drone in the beneficiaries' area to evaluate the progress of the tree plantation;
- Disseminate the participatory MRV in others communities, in order to involve all actors, such as communities, civil society, private and public sector, in the assessment of deforestation and forest degradation. Therefore, capacity must be built at the level of provinces, districts and communities and training of community technicians.

1.2 Update on major drivers and lessons learned

Unsustainable small-scale agriculture still by far, the first driver of deforestation in the ER Program area. The monitoring data produced by the MRV unit in 2018 and 2019-2020 show that agriculture is the main drive of deforestation. Other drivers such as forest activities for timber and charcoal could not detected directly as drivers. The solution is to improve the tool to detect the forest degradation which combines with updated high-resolution imagery or/and field survey.

The charcoal production process is a result of agriculture expansion and small agriculturalists maximizing value from the land clearing process. As evidence, during the site visit of monitoring, the ZILMP team noted that expanding subsistence agriculture is the primary driver of deforestation. The ZILMP team had the opportunity to interview numerous small formers during the site visit and is reasonably assured that expanding subsistence agriculture remains the primary driver of deforestation. On other hands in June of 2021 started a study that aims to analyze the driver, economic and cultural factors in deforestation and forest degradation. This study conclude that the agriculture is the main driver of deforestation (see full report here). At the moment (December 2023), the MRV and BSP team are carrying out a survey of PMRV data in several districts of Zambézia to better understand the reason for the increase in deforestation in the years prior to this monitoring period

Unsustainable timber exploitation poses a medium risk for potential displacement of the activity to the districts outside of the ER Program because law enforcement was intensified. However, such intensification had taken place throughout the country also, thus minimizing this potential risk. No harmful activities were prohibited inside of the ER Program as part of the strategies to minimize potential displacement; conversely, improvements on practices are based on incentives for agricultural intensification and settlement within the ER Program area through systematic land use delimitation and titling for individuals and communities. The integration of sustainable practices in forestry, agriculture and land use in the program area with involvement of different stakeholders using the participatory approach generated ERs for this monitoring/reporting period.

The risk of displacement is low as other Government initiatives are taking place on the other districts outside of the ER Program. For more information on the drivers of deforestation and forest degradation within the ER Program, kindly refer to the Mozambique's ERPD. To sustain the generation of ERs in the program area and minimize the risk of displacement MozFIP will continue to monitor the dynamic of emissions from deforestation and forest degradation and invest in sustainable practices in agriculture, forestry and land.

2 SYSTEM FOR MEASUREMENT, MONITORING AND REPORTING EMISSIONS AND REMOVALS OCCURRING WITHIN THE MONITORING PERIOD

2.1 Forest Monitoring System

Mozambique has not formalized its national forest monitoring system (NFMS). There is a work in progress between the DINAF and FNDS and other relevant stakeholders to formalize the NFMS. This process started in 2019, with the establishment of the NFMS Task Force, responsible for designing, developing and operationalizing the NFMS. Technical officers of DINAF and FNDS (MRV unit) were appointed as its members.

The NFMS Working Group, as a group of stakeholders related to the NFMS with its role to provide related information, inputs and advice to the development and operationalization of the NFMS. The initial members included DINAF, National Directorate of Environment (DINAB), National Directorate of Land (DINAT), FNDS, Eduardo Mondlane University (UEM), Institute of Agricultural Research of Mozambique (IIAM), FAO (Food and Agriculture Organization of the United Nations), World Bank, International Union for Conservation of Nature (IUCN) and Federation of Timber Operators (AMOMA). However, the Working Group is, by its nature, an open forum which the members can change flexibly depending on the needs and interests.

The first version of the NFMS document was finalized in 2021 (link) and defines the NFMS as a system which enables accountable reporting of REDD+ results; monitoring the implementation and effectiveness of Policies and Measures (PaMs) for sustainable forest management, which include national and international purposes and beyond REDD+; and builds on robust IT system to support data management and transparency. The following principles are stated in the document as the basis of the NFMS:

- The NFMS shall be designed and operationalized under the full ownership of Ministry of Land and Environment (MTA), and in collaboration with relevant stakeholders;
- The NFMS should be target-driven, oriented towards specified sub-national, national and international objectives;
- The NFMS shall build on existing system as far as practical;
- The NFMS shall be developed through step-wise improvement, take into consideration the national circumstances, reflect the phased approach for the implementation of REDD+ activities, and sustainable in the long-run. The development shall be realistically feasible within the available time, financial and human resources; and
- The NFMS shall meet the international requirement under REDD+, and as appropriate, apply international and national good practices.

The current monitoring system has three sub-systems:

- Satellite and land monitoring system
- National forest inventory
- National Greenhouse Gases (GHG) inventory

Satellite and land monitoring system

The satellite and monitoring system is a sub-system within the NFMS that produces the activity data. The MRV Unit within FNDS is responsible for this system. It specifically generates the information on the number of hectares of deforestation within a given geographic area. This system produced information of deforestation that was used to produce the ER Program's RL and the National Forest Reference Emissions Level (FREL). This information was also used to generate historical deforestation statistics by Provinces, districts (link https://fnds.gov.mz/mrv/index.php/documentos/estudos/15-anuario-ambiental-para-instituto-nacional-de-estatistica-ine/file), conservation areas and Zambézia Integrated Landscape Management Program (ZILMP) using a systematic stratified sampling. With new tool to detect deforestation developed , it was possible to produce annual deforestation maps for 2017, 2018, 2019, 2020, 2021 and 2022 as shown through the link https://bit.ly/GeoportalMRVOnline for the whole country and the area estimates for Zambézia Province which are based on sampling approach. The MRV unit from FNDS is responsible to produce the activity data for the ZILMP as well as for the country, as it has gained experience and expertise from training provided by FCPF finance.

The process of generating activity data comprises five steps (Figure 5); they are *response design, map production, sampling design, data collection and analysis*. These steps mainly define the criteria for classification, produces a change map and area estimates.

To ensure a good quality of data the team developed and implemented Quality Assurance/Quality Control (QA/QC) processes in all production processes including the development of Standard Operating Procedures (SOPs). This ensures a high standard of quality of the data produced. To guarantee the replication of processes, the MRV unit developed a Portuguese version guideline to produce activity data, accessed through the link https://www.fnds.gov.mz/mrv/index.php/documentos/guioes/62-protocolo-de-monitoria-e-estimativa-de-emissoes-por-desmatamento-vmar2023/file. Data collection is conducted by a core team of professional interpreters who work permanently for FNDS and who have received adequate training in the implementation of the SOPs.

To disseminate the use of activity data to communities and other stakeholders to monitor deforestation, the MRV unit started in December of 2020 to set up participatory MRV (PMRV) systems as described below (Forest Monitoring System under the ZILMP).

National forest Inventory

The national forest inventory is the second sub-system within the NFMS, which produces the emission factors. They give the tonnage of carbon stored per unit hectare of forest. The tonnage of carbon per hectare varies from one type of forest to another. Mozambique has conducted four national forest inventories and the updating of NFI is carried out every 10 years. The last inventory in 2016-17 produced the emission factors used for the FREL submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2018 (report may be accessed in the link: https://redd.unfccc.int/files/moz_frel_report_final.v03_03102018.pdf). In order to have more accurate estimates for the ZILMP, the plots located in Zambézia Province were used to generate specific Emission Factors for ZILMP. The methods to generate the emissions factors for ZILMP are described in the Zambézia forest inventory report: https://fnds.gov.mz/mrv/index.php/documentos/relatorios/41-relatorio-de-inventario-florestal-da-zambezia-actualizado/file.

The process used to produce the emission factors followed these steps: Response design, Sampling design, Data collection and Data analysis (Details in Figure 5). The entity responsible for the National Forest Inventory is DINAF. The NFI report (https://fnds.gov.mz/mrv/index.php/documentos/relatorios/26-inventario-florestal-nacional/file) was produced by FNDS and DINAF. The data collection involved the IIAM, the Faculty of Agronomy and Forest Engineering (FAEF), the Department of Biological Sciences and Provincial Forest Services. The estimation of emissions also relies on the allometric equations that have been developed by Masters and PhD students and research projects from FAEF and the Department of Biological Sciences (DCB) of the UEM, as well as peer-reviewed publications.

To ensure the quality of the data collected, the team followed QAQC procedures defined by DINAF. To maintain the processes of the national forest inventory, the MRV unit developed a practical field manual for training teams in data collection that can be accessed on the link https://fnds.gov.mz/mrv/index.php/documentos/guioes/21-manual-do-inventario-florestal/file.

The Permanent Sample plots are another component of the National Forest Monitoring System that will improve the estimation of emissions factors and IIAM leads the process. Currently, under the MozFIP project, a joint group of institutions that involves IIAM, FNDS, UEM and DINAF are establishing the network of Permanent Sampling plots across the country, including Zambézia province.

National GHG inventory

The National GHG inventory for the purpose of REDD+ combines the Activity data and the emission factors (Figure 5) to estimate the annual emissions and the FREL.

At the national level, the recent experience of GHGs inventory was with the submission of the FRELs to the UNFCCC (https://redd.unfccc.int/files/moz_frel_report_final.v03_03102018.pdf). The National Directorate of Climate Change is responsible for the communication of GHG emissions of Mozambique, as the focal point for climate change with the UNFCCC. The National Directorate of Climate Change coordinates with DINAF and FNDS on the production of such information.

At the subnational level, the MRV unit from FNDS is currently responsible for the generation of all information related to emissions from deforestation for the ZILMP program. The MRV Unit is also generating estimates of emissions from deforestation at national, Provincial and District level. To maintain the quality standards in the production of emissions estimates from deforestation, the MRV unit has developed SOPs on how to produce the estimates.

Major institutional changes in institutional arrangements since the Approval of ERPD were: (1) Changes in the Ministries; (2) Change in the institutions. Before the approval of the ERPD, FNDS, DINAF, and the National Directorate of Environment were under the Ministry of Land, Environment and Rural Development (MITADER). IIAM was under the Ministry of Agriculture and Food Security (MASA); after the elections in 2019, the new Government was formed, and the result was the extinction of MITADER with the creation of Ministry of Land and Environment (MTA), the extinction of MASA with the creation of the Ministry of Agriculture and Rural Development (MADER). As a result, FNDS and IIAM were moved to MADER, while the National Directorate of Environment and DINAF moved to MTA. The climate change component of National Directorate of Environment was moved to a new Directorate, the National Directorate of Climate Change. This new setting is important as FNDS and DINAF now interact with the national Directorate of Climate Change on issues related to Reporting. Despite these changes on the institutional arrangements and lack of a formal institutional arrangement, the components of the Forest Monitoring System can deliver the function of producing the emissions from deforestation at all levels.

Forest Monitoring System under the ZILMP

The forest monitoring system (FMS) under the ZILMP is simpler in terms of processes and entities as it relies on the first and second system above and it is fully operated by the MRV unit within FNDS with collaboration of DINAF. Therefore, the system uses the standard technical procedures of the NFMS as required by Criterion 15 of the MF.

In December of 2020 (see section 1.2), the MRV Unit tested the introduction of participatory MRV (PMRV) for annual monitoring of deforestation under the ZILMP, which is part of the recommendation of civil society, decision makers and the scientific community in the measurement, reporting and verification (MRV) of stocks of carbon with the participation of the local community. In phase one, the PMRV was tested in twelve communities across the districts of Alto Molocué, Mocuba, Mulevala and Gilé, where three communities were selected per district. The results of the PMRV test can be found on MRV website (PRMV page - https://bit.ly/pmrvfndsredd).

The aim of the PMRV activities was to involve communities in deforestation reporting activities (confirming deforestation cases and reporting new cases in near-real time using GIS tools such as Survey123 for ArcGIS, ArcGIS Field Maps and ArcGIS Collector). In 2021 the field activity of PMRV was carried out in communities such as Munhiba in Mocuba district, Dindini and Sacane – Pebane district, Muapila and Cannaua – Mocubela district, Soares, Vacha, Muitchana, Mutchiua and Nehita in Alto Molocue district, and Namigonha, Vassele, Malema-Serra, and Namurua in Gilé district. This activity involved staff from government institutions, academia and civil society (BIOFUND, AQUA, ANAC, Unizambeze, Unilurio, Network for Community Management of Natural Resources (Regecom), DINAF and FNDS technicians to present and demonstrate the tool and its potential. For more details, please find the PMRV report here.

Information on the ZILMP can be found both on the FCPF website (https://www.forestcarbonpartnership.org/country/mozambique) and the MRV Unit website (https://www.fnds.gov.mz/mrv/). The ERPD is available online on the FCPF website (https://www.forestcarbonpartnership.org/system/files/documents/Mozambique_Revised%20ERPD_16April2018_CLEAN.pdf). The latest version of 2018 (first ER report) and 2019/2020 (second ER report) Monitoring Reports are also available online, on the FCPF website (https://www.forestcarbonpartnership.org/country/mozambique) and on the MRV Unit website (https://www.fnds.gov.mz/mrv/index.php/documentos/relatorios).

The organogram of the MRV Unit responsible for the ZILMP monitoring is described in

Figure 1. The MRV Unit was created in 2016, with a coordinator (Aristides Muhate) and 4 technicians (Alismo Herculano, Credêncio Maúnze, Délfio Mapsanganhe and Hercilo Odorico). Towards the end of 2016 a fifth element was added to the team (Muri Soares). In 2019 the unit added 3 new elements (Alex Boma, Orlando Macave and Sérgio João). In 2022, the MRV Unit added 3 new technicians to respond the demand of PMRV (Edna Munjovo, Felicio Guelume and Sadamo Ussene). Therefore, various efforts have been made in terms of personnel and resources in order to maintain the capacity of the MRV system to monitor and report emissions and emission reductions. The production of the various SOPs has contributed to the knowledge management of the MRV Unit. In addition, there is no task performed by only one person, which increases redundancy. The MRV Unit recognizes that there is a need for continuous improvement of its knowledge management process, to ensure that all activities are standardized and documented. The organizational structure for the Activity data (reference and annual) and NFI is described in Figure 2,Figure 3 and Figure 4.

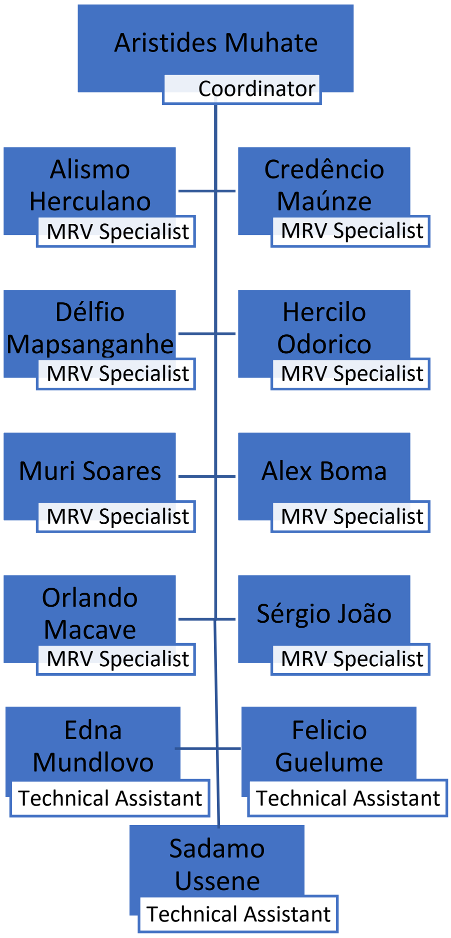

Figure 1: Organogram of MRV Unit responsible for ZILMP monitoring.

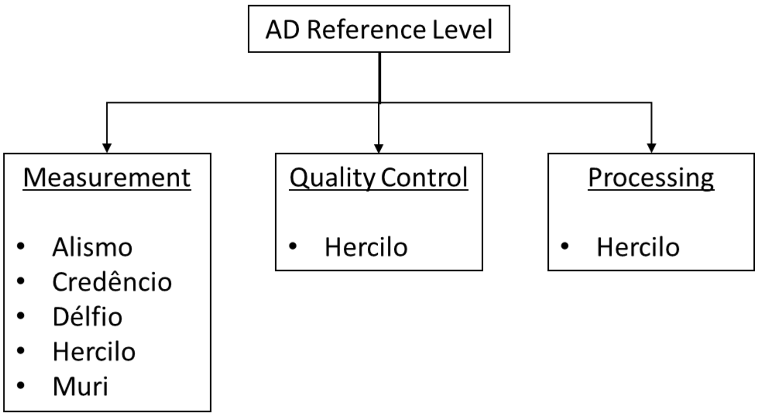

Figure 2: Organizational structure for Activity Data of Reference Level.

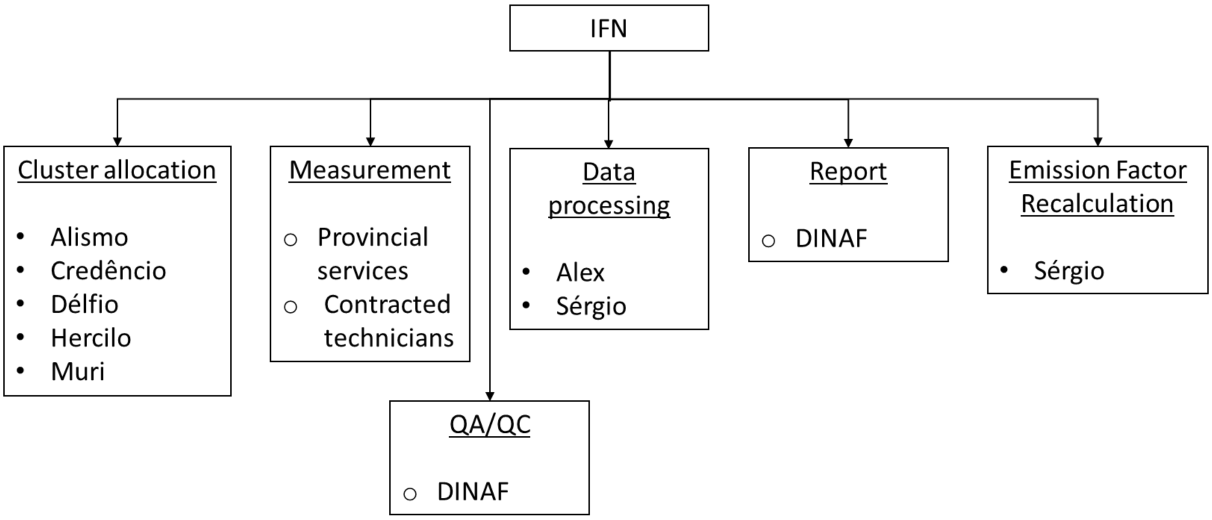

Figure 3: Organizational structure for National Forest Inventory.

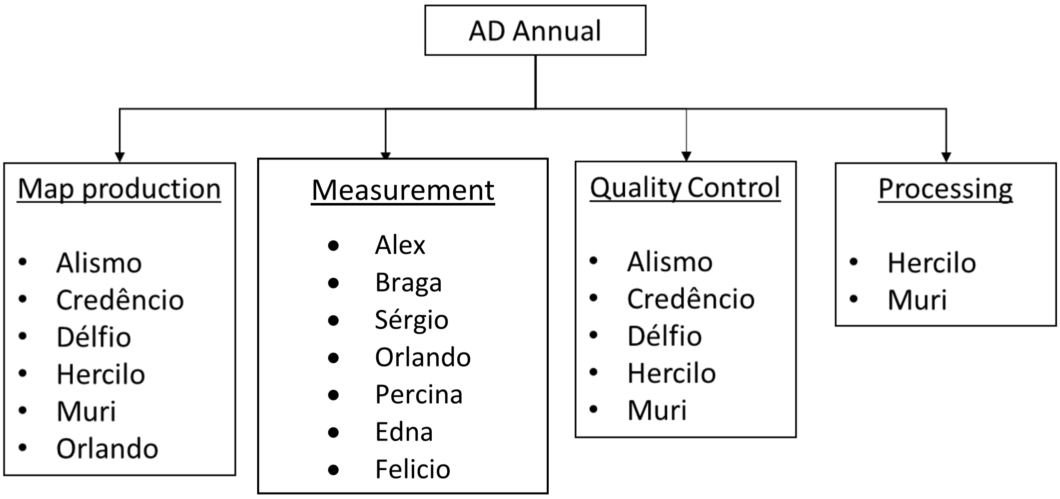

Figure 4: Organizational structure for Annual Activity Data.

i. **Systems and processes that support the Forest Monitoring System, including Standard Operating Procedures and QA/QC procedures;**

The developed SOPs are:

- Map production – SOP0
- Sampling Design – SOP1
- Response Design – SOP2
- Data Collection – SOP3
- Sample-based Area Estimation Analysis – SOP4

FNDS also has detailed QAQC procedures for the collection of reference data for the sample-based area estimation, which is described in the Standard Operating Procedures for Area Estimation document (link), which contains the above SOPs.

2.2 Measurement, monitoring and reporting approach

2.2.1 Line Diagram

The Figure 5 illustrates the emissions reductions calculation workflow during the Monitoring Period. It is important to note that as part of the ZILMP, all this workflow including the phase of reported is implemented by the MRV unit within FNDS.

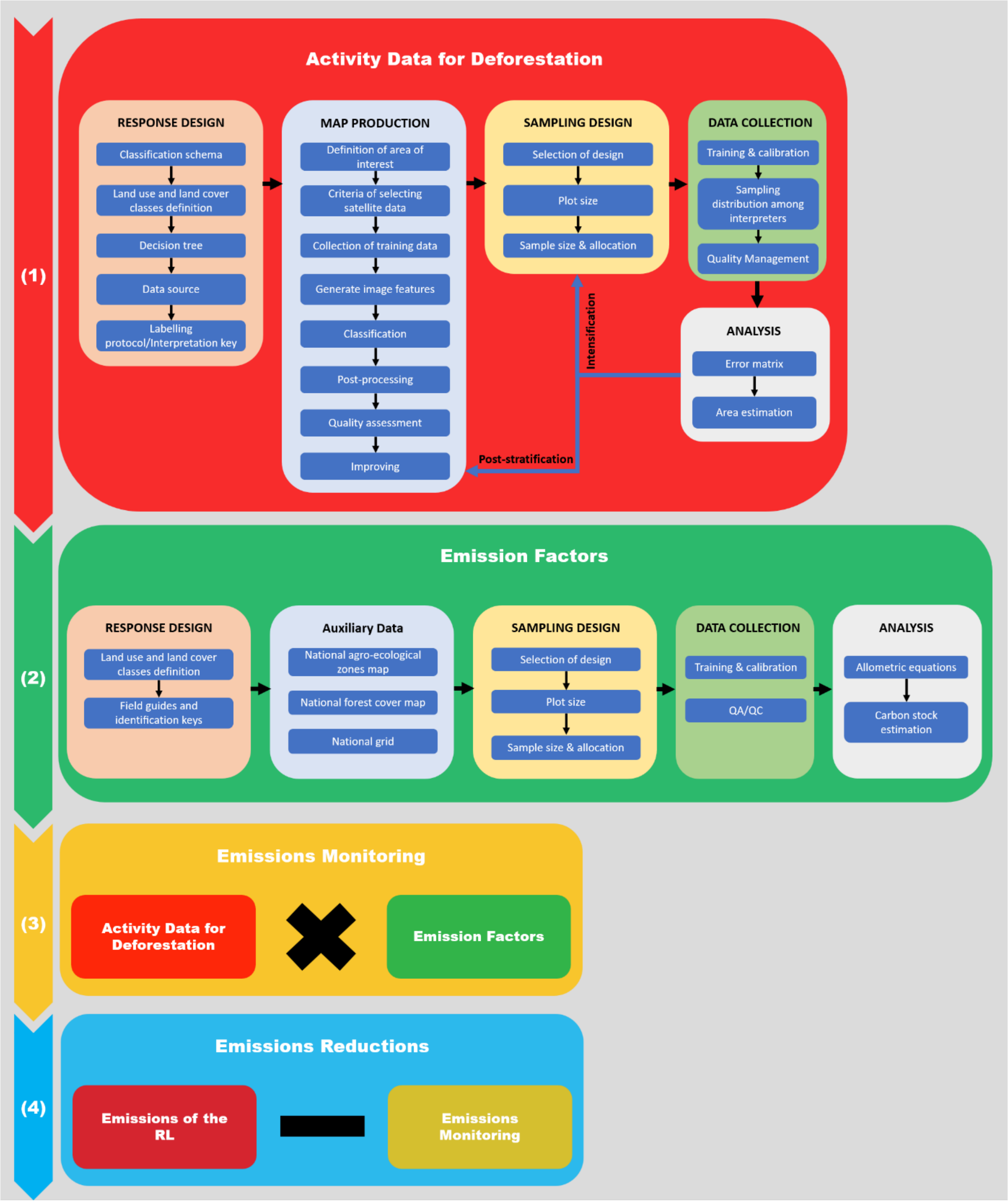

Figure 5: Emissions reductions calculation workflow.

2.2.2 Calculation

Emission reduction calculation

$$ER_{ERP,t} = RL_t - GHG_t$$ ***Equation 1***

Where:

ER_{ERP} = Emission Reductions under the ER Program in year t; *tCO_2e*year^{-1}*.

RL_{RP}	=	Gross emissions of the RL from deforestation over the Reference Period; *tCO_2e*$year^{-1}$*.
GHG_t	=	Monitored gross emissions from deforestation at year *t*; *tCO_2e*$year^{-1}$*;
T	=	Number of years during the monitoring period; *dimensionless*.

***Reference Level* (RL_t)**

Gross emissions of the RL from deforestation over the Reference Period (RL_{RP}) are estimated as the sum of annual change in total biomass carbon stocks (ΔC_{B_t}) during the reference period.

$$RL_{RP} = \frac{\sum_t^{RP} \Delta C_{B_t}}{RP}$$ ***Equation 2***

Where:

ΔC_{B_t}	=	Annual change in total biomass carbon stocks at year *t; tC*$year^{-1}$;*
RP	=	Reference period; *years.*

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

$$\Delta C_{B_t} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$ ***Equation 3***

Where:

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

Following the recommendations set in chapter 2.2.1 of the GFOI Methods Guidance Document for applying IPCC Guidelines and guidance in the context of REDD+[7], the above equation will be simplified and it will be assumed that:

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

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

$$\Delta C_{B_t} = \sum_{j,i} (B_{Before,j} - B_{After,i})\ x\ CF\ x \frac{44}{12} \times A(j,i)_{RP}$$ ***Equation 4***

Where:

$A(j,i)_{RP}$ Area converted/transited from forest type *j* to non-forest type *i* during the Reference Period, in *hectares per year*. In this case, three forest land conversions are possible:

- (Semi-)deciduous forest to Non-forest type *i*;
- (Semi-)evergreen forest to Non-forest type *i*; and

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[7] https://www.reddcompass.org/documents/184/0/MGD2.0_English/c2061b53-79c0-4606-859f-ccf6c8cc6a83

- Mangrove forest to Non-forest type *i*.

Five types of non-forest land are considered:

- Cropland (C);
- Grassland (P);
- Wetland (A);
- Settlement (U); and
- Other lands (O).

$B_{Before,j}$ Total biomass of forest type *j* before conversion/transition, in tons of dry matter per ha. This is equal to the sum of aboveground ($AGB_{Before,j}$) and belowground biomass ($BGB_{Before,j}$) and it is defined for each forest type.

$B_{After,i}$ Total biomass of non-forest type *i* after conversion, in *tons dry matter per ha*. This is equal to the sum of aboveground ($AGB_{After,i}$) and belowground biomass ($BGB_{After,i}$) and it is defined for each of the five non-forest IPCC Land Use categories.

This parameter was technically corrected so as to replace the estimates sourced from research by estimates given by the 2006 IPCC Guidelines.

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

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

$44/12$ Conversion of C to CO_2

***Monitored emissions** (GHG_t)*

Annual gross GHG emissions over the monitoring period in the Accounting Area (GHG_t) are estimated as the sum of annual change in total biomass carbon stocks (ΔC_{B_t}).

$$GHG_t = \frac{\sum_t^T \Delta C_{B_t}}{T}$$ ***Equation 5***

Where:

ΔC_{B_t} = Annual change in total biomass carbon stocks at year *t; tC*year^{-1}*

T = Number of years during the monitoring period; *dimensionless*.

Changes in total biomass carbon stocks

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category *(ΔC_B)* would be estimated through ***Equation 3*** above. Making the same assumptions as described above for the RL the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta C_B = \sum_{j,i} \left(B_{Before,j} - B_{After,i}\right) x\ CF\ x \frac{44}{12} \times A(j,i)_{MP}$$ ***Equation 6***

Where:

$A(j,i)_{MP}$ Area converted/transited from forest type *j* to non-forest type *i* during the Monitoring Period, in hectare per year. In this case, three forest land conversions are possible:

- (Semi-)deciduous forest to Non-forest type *i*;
- (Semi-)evergreen forest to Non-forest type *i*; and
- Mangrove forest to Non-forest type *i*.

Five types of non-forest land are considered:

- Cropland (C);
- Grassland (P);

	● Wetland (A); ● Settlement (U); and ● Other lands (O). These parameters may be found in **Section 3.2**.
$B_{Before,j}$	Total biomass of forest type *j* before conversion/transition, in tons of dry matter per ha. This is equal to the sum of aboveground ($AGB_{Before,j}$) and belowground biomass ($BGB_{Before,j}$) and it is defined for each forest type. This was defined ex-ante and is described in **Section 3.1**.
$B_{After,i}$	Total biomass of non-forest type *i* after conversion, in *tons dry matter per ha*. This is equal to the sum of aboveground ($AGB_{After,i}$) and belowground biomass ($BGB_{After,i}$) and it is defined for each of the five non-forest IPCC Land Use categories. This was defined ex-ante and is described in **Section 3.1**.
CF	Carbon fraction of dry matter in tC per ton dry matter. The value used is: ● **0.47** is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.
$44/12$	Conversion of C to CO_2

3 DATA AND PARAMETERS

3.1 Fixed Data and Parameters

Parameter:	$AGB_{before,j}$
Description:	Aboveground biomass of forest type *j* before conversion,
Data unit:	tons of dry matter per ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The data used for the present document are Tier 2 (country specific data or country level estimates or locally derived estimates) and they were sourced from the NFI (for deciduous and evergreen forests) or from a regional study conducted in the Zambezi River Delta for Mangrove forests. For semi-deciduous and evergreen forest, the data are from the Zambézia Forest Inventory. It includes data that was collected in Zambézia province during the NFI, in 2017 and 2018. Although the inventory covers the whole Zambézia province (ER ZILMP program and outside). This is still representative of the forests located in the ZILMP as forests across the province are homogenous (floristic and structural composition). Moreover, the higher sample size of the forest inventory covering the whole province will enable more precise estimates for emission factors. ***i. Sampling design*** Carbon stocks before conversion for deciduous and evergreen forests were estimated using data from the National Forest Inventory sample units that were located in Zambézia province. The sample units for surveying carbon stocks were allocated using restricted stratified random sampling, using 4 * 4 km systematic grid superimposed on the agro-ecological zoning map, and stratified among the 12 forest types. Was considered as the strata, the semi-deciduous forest "open and closed", Miombo forest "open and closed", semi-evergreen forest "open and closed", semi-evergreen Mountain forest "open and closed", Mopane forest "open and closed", and Mecrusse forest "open and closed", of which only the first eight types occur in Zambézia province. The total number of sample units was determined using the optimal allocation (assuming a maximum error of 10% for the total volume, and 5% of confidence level). Proportional allocation was used to determine the number of sample units per stratum (Husch, Beers, and Kershaw 2003). For Zambézia province, 128 clusters (512 plots) were distributed between the eight (8) forest types. The cluster was used as a sampling unit, and each cluster has 4 plots of 0.1 ha (20 * 50 m), where each plot was divided into 4 sub-plots of 0.025 ha (10 * 25 m) (Figure 6).

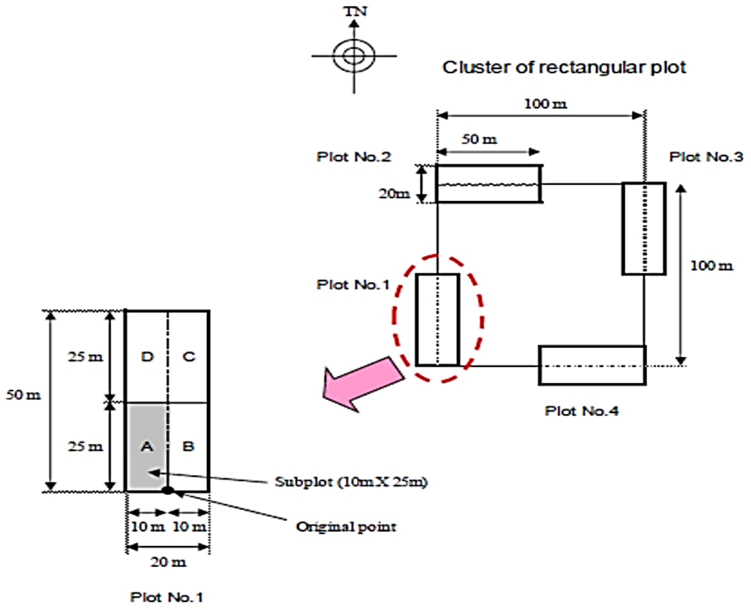

Figure 6: Design of each cluster used in the National Forest Inventory.

For estimating emission factors, the eight strata were aggregated into 2 (Semi-decíduous forest and semi-evergreen forest), and the similarity of the strata was used for the aggregation. The aggregation was done with the purpose of harmonizing the forest strata of the activity data with the emission factor data. Below the aggregation table.

Allocation stratum	EF Strata for MR
semi-deciduous open forest	semi-deciduous forest
semi-deciduous closed forest	
miombo open forest	
miombo closed forest	
semi-evergreen MoUntain open forest	semi-evergreen forest
semi-evergreen MoUntain closed forest	
semi-evergreen open forest	
semi-evergreen closed forest	

ii. Data collection

The plots were used for data collection of adult trees (diameter at breast height (dbh) ≥10cm), and the subplots "A" were used for data collection of established regeneration trees (10cm> dbh≥ 5 cm), which were included in the calculation of the carbon stocks. Data collected in the plots and subplots included tree information (dbh, scientific name, total and commercial height, stem quality), soil, forest type (this information was used to validate the information from agro-ecological zoning map), and other important information. Tree data were used to estimate above ground biomass (AGB) and below ground biomass (BGB).

The NFI did not cover Mangrove forests, so, data from the literature was used. For other strata, data from literature were also used.

Details of data collection can be found at https://www.fnds.gov.mz/mrv/index.php/documentos/guioes/35-directrizes-do-inventario-florestal-nacional/file.

iii. Prediction at plot level

Above ground biomass (AGB) and below ground biomass (BGB) were estimated using a series of allometric equations adjusted for ecosystems or tree species similar to those in the Zambézia province (Table 3), and this equation was applied at tree level.

The use of the equations meant, applying allometric equations of the specific species (*Millettia stuhlmannii* taub., *Pterocarpus angolensis* DC., *Afzelia quanzensis* Welw.) in all trees of these species to estimate AGB, regardless of forest types. The allometric equation of the semi-deciduous forest was applied for all trees of this forest type (except the species mentioned above), as well as in all trees of the species *Brachystegia spiciformis* Benth., and *Julbernardia globiflora* (Benth.) Troupin to estimate AGB and BGB, because they were the main species used to adjust this equation in this forest type. The equations of the semi-evergreen forest were applied in all remaining trees of this forest type to estimate AGB; and apply the semi-deciduous forest equation in all trees to estimate the BGB in this forest type (including species mentioned above in other forest type), and apply factor 0.275 (shoot ratio) to estimate the BGB of the semi-evergreen forest.

Table 3: List of allometric equations used to estimate above and below biomass

Forest Type	**Forest type or species**	**Above-ground biomass (AGB) [kg]**	**Below-ground biomass (BGB) [kg]**
Semi-deciduous forest	Semi-deciduous forest (open and closed)	$\hat{Y} = 0.0763 * DAP^{2.2046} * H^{0.4918}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mugasha *et al.* (2013)	Author: Mugasha *et al.* (2013)
	Millettia stuhlmannii taub.	$\hat{Y} = 5.7332 * DAP^{1.4567}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)
	Pterocarpus angolensis DC.	$\hat{Y} = 0.2201 * DAP^{2.1574}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)
	Afzelia quanzensis Welw.	$\hat{Y} = 3.1256 * DAP^{1.5833}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)
Evergreen forest	Evergreen forest (open and closed)	$\hat{Y} = \exp(-2.289 + 2.649\ln(DAP) – 0.021(\ln(DAP))^2)$	$\hat{Y} = AGB * R/S$; R/S= 0.275
		Author: IPCC (2003)	Author: Mokany *et al.* (2006)
		$\hat{Y} = 0.0613*DAP2.7133$	$\hat{Y} = AGB * R/S$; R/S= 0.275

	Evergreen Mountain forest (open and closed)	Author: Lisboa *et al*. (2018)	Author: Mokany *et al*. (2006)
	Millettia stuhlmannii taub.	$\hat{Y} = 5.7332 * DAP^{1.4567}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al*. (2014)	Author: Mugasha *et al*. (2013)
	Pterocarpus angolensis DC.	$\hat{Y} = 0.2201 * DAP^{2.1574}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al*. (2014)	Author: Mugasha *et al*. (2013)
	Afzelia quanzensis Welw.	$\hat{Y} = 3.1256 * DAP^{1.5833}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al*. (2014)	Author: Mugasha *et al*. (2013)

iv. Estimation

The estimation of mean and their respective uncertainties (standard error, sampling error, and confidence interval) for the variables biomass, carbon and carbon dioxide equivalent (above and below ground) for the two strata (semi-deciduous forest and semi-evergreen forest), were done using the forest inventory data analysis approach proposed by Bechtold & Patterson (2005) chapter 4 of the book "The Enhanced Forest Inventory and Analysis Program-National Sampling Design and Estimation Procedures". Details of this methodology are described in Zambézia inventory report, available at https://fnds.gov.mz/mrv/index.php/documentos/relatorios/41-relatorio-de-inventario-florestal-da-zambezia-actualizado/file.

For mangrove forests, data are secondary, extracted from existing literature. Stringer *et al.* (2015)[8] made an inventory on this ecosystem in the Zambezi delta in Mozambique; we can easily assume that carbon stocks are comparable to those of mangroves in Zambézia province. They divided mangroves into 5 strata and estimated carbon stocks in above and belowground biomass. Since we do not have information on these specific strata for ZILMP, the mean and standard error of biomass (AGB and BGB) of mangrove forest, comes indirectly from table 1 of the article by Stringer *et al.* (2015). For its determination, first the mean of carbon was found for the two pools (sum of overstory and understory carbon) for each stratum (Height Class 1, ..., Height Class 5), followed by the calculation of the mean of the ecosystem (mean weighted according to the stratum areas). Finally, the carbon was converted to biomass using the conversion factor of 0.47 proposed in the IPCC good practice guide.

Spatial level: Regional

Value applied:

Semi-deciduous forest (FSD)	144.69
Evergreen forest (FSSV)	123.13
Mangrove forest (FF)	269.01

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[8] Stringer, C. E.; Trettin, C. C.; Zarnoch, S. J. and Tang, W. 2015. Carbon stocks of mangroves within the Zambezi River Delta, Mozambique. Forest Ecology Management 354:139–148.

<table>
<tr><td></td><td>The values above are estimated and extracted in the "Emission factor v.2" workbook, and then they are recorded in the cells "B4", "B10" and "B16" respectively, of the "BIOMASS" worksheet tab in the "ZILMP_Emissions_Calculations_MR_(2021) and ZILMP_Emissions_Calculations_MR_(2022)" workbooks. These values are then applied in the range "C9:C20" of the "EMISSION MONITORING PERIOD(EMP)" worksheet tab in "ZILMP_Emissions_Calculations_MR_(2021) and ZILMP_Emissions_Calculations_MR_(2022)" workbooks for estimating emissions.</td></tr>
<tr><td>QA/QC procedures applied</td><td>The QA/QC procedures consisted on the following:
● SOPs were developed as described in <i>Section 2.1 - National Forest Inventory</i>.
● A training on the SOPs was conducted prior to the field work. This training lasted for 3 weeks, and consisted of training on the usage of all equipment and evaluating the specific skills of each participant, in order to determine the team and brigade leaders. On the start of the 2nd phase of the IFN (2017) an additional 1-week training was conducted, to refresh the participants and train any new members.
● The supervisor of each inventory team conducted a remeasurement of 4 trees per plot which means 16 trees per cluster. This served to ensure that the SOPs were adequately implemented.
● An independent measurement of 10% of the plots. This activity was conducted by technicians of the National Directorate of Forests, who had participated in the Provincial Inventories of Gaza and Cabo Delgado. Diameter error must be below 10%.
● The adequacy of the allometric models, including root-to-shoot ratios used was confirmed by experts of the Faculty of Agronomy and Forest Engineering (FAEF) and the Department of Biology Sciences (DCB) of the Eduardo Mondlane University (UEM).
● The World Bank conducted two regular supervision missions of the National Forest Inventories to confirm the adequate implementation of the SOPs and suggest areas for improvement. The report can be found here.
● An independent expert (Jim Alegria, ex-US Forestry Service) was hired in order to evaluate the methodology for the inventory and support in the estimation process, to address any gaps that were identified. The report can be found here. Many of the issues identified in the report have since been corrected, with the help of the independent expert.</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td>
<table>
<tr><td rowspan="2">Forest type</td><td colspan="5">Uncertainty estimate</td></tr>
<tr><td>Mean</td><td>Lower (5th percentile)</td><td>Upper bound (95th percentile)</td><td>Half-width confidence interval at 90%</td><td>Relative Margin</td></tr>
<tr><td>FSD</td><td>144.7</td><td>116.7</td><td>172.1</td><td>27.7</td><td>0.19</td></tr>
<tr><td>FSSV</td><td>123.1</td><td>101.1</td><td>145.1</td><td>22</td><td>0.18</td></tr>
<tr><td>FF</td><td>269</td><td>225.1</td><td>313.8</td><td>44.35</td><td>0.16</td></tr>
</table>
</td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

Parameter:	$BGB_{before,j}$
Description:	Belowground biomass of forest type *j* before conversion,
Data unit:	tons of dry matter per ha
Source of data or description of the method for developing the data	For semi-deciduous and evergreen forest, data are from the Zambézia Forest Inventory. It includes data that was collected in Zambézia province during the NFI, in 2017 and 2018. Please refer to parameter $AGB_{before,j}$ for more information on how the below ground biomass was estimated. For mangrove forests, please refer to parameter $AGB_{before,j}$ for more information.

<table>
<tr><td>including the spatial level of the data (local, regional, national, international):</td><td>Spatial level: Regional</td></tr>
<tr><td>Value applied:</td><td>
<table>
<tr><td>Semi-deciduous forest (FSD)</td><td>49.95</td></tr>
<tr><td>Evergreen forest (FSSV)</td><td>42.06</td></tr>
<tr><td>Mangrove forest (FF)</td><td>85.43</td></tr>
</table>
The values above are estimated and extracted in the workbook "Emission factor_v.2", and then they are recorded in the cells "B34", "B40" and "B46" respectively, of the "BIOMASS" worksheet tab in the "ZILMP_Emissions_Calculations_MR_(2021) and ZILMP_Emissions_Calculations_MR_(2022)" workbooks. These values are then applied in the range "E9:E20" of the "EMISSION MONITORING PERIOD(EMP)" worksheet tab in the "ZILMP_Emissions_Calculations_MR_(2021) and ZILMP_Emissions_Calculations_MR_(2022)" workbooks for estimating emissions.</td></tr>
<tr><td>QA/QC procedures applied</td><td>Please see section QA/QC procedures under parameter $AGB_{before,j}$.</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td>
<table>
<tr><th rowspan="2">Forest type</th><th colspan="5">Uncertainty estimate</th></tr>
<tr><th>Mean</th><th>Lower (5th percentile)</th><th>Upper bound (95th percentile)</th><th>Half-width confidence interval at 90%</th><th>Relative Margin</th></tr>
<tr><td>FSD</td><td>49.9</td><td>41.5</td><td>58.4</td><td>8.4</td><td>0.17</td></tr>
<tr><td>FSSV</td><td>42.1</td><td>35.3</td><td>48.9</td><td>6.8</td><td>0.16</td></tr>
<tr><td>FF</td><td>85.4</td><td>69</td><td>101.6</td><td>16.3</td><td>0.19</td></tr>
</table>
</td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

Parameter:	$AGB_{after,i}$
Description:	Aboveground biomass of non-forest type *i* after conversion
Data unit:	tons of dry matter per ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional,	For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used because there is no country-specific data. The agricultural land in Mozambique is mostly under the annual-crop farming practices that drive conversion of forest land to agricultural lands. So, according to 2006 IPCC GL (Volume 4, Chapter 5, Section 5.28), for lands planted in annual crops, the default value of growth in crops planted after conversion is 5 tonnes of C per hectare, based on the original IPCC Guidelines recommendation of 10 tonnes of dry biomass per hectare (dry biomass has been converted to tonnes carbon in Table 5.9) (2006 IPCC, Volume 4, Chapter 5, Section 5.28). For grassland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 6 are used because there is no country-specific data. As the climate in most of Mozambique is tropical dry to subtropical dry, the value for peak-above ground biomass for tropical dry climate was used. The default value 2.30 tonnes of C per hectare from TABLE 6.4 (2006 IPCC, Volume 4, Chapter 6, Section 6.3.1.2).

<table>
<tr><td>national, international):</td><td>For other lands: No default values exist for these conversions.
Spatial level: International</td></tr>
<tr><td>Value applied:</td><td><table><tr><td>Cropland (C)</td><td>10.00</td></tr><tr><td>Grassland (P)</td><td>2.30</td></tr><tr><td>Other lands (A|O|U)</td><td>0.00</td></tr></table>The values above are recorded in the ranges "B5:B9", "B11:B15" and "B17:B21" of the "BIOMASS" worksheet tab in the "ZILMP_Emissions_Calculations_MR_(2021)_ and ZILMP_Emissions_Calculations_MR_(2022)" workbooks. These values are then applied in the range "D9:D20" of the "EMISSION MONITORING PERIOD(EMP)" worksheet tab in the "ZILMP_Emissions_Calculations_MR_(2021) and ZILMP_Emissions_Calculations_MR_(2022)" workbooks for estimating emissions.</td></tr>
<tr><td>QA/QC procedures applied</td><td>The adequacy in the use of these default values was confirmed with the experts in GHG Inventory in DINAB.</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td><table>
<tr><th rowspan="2">Non-forest type</th><th colspan="5">Uncertainty estimate</th></tr>
<tr><th>Mean</th><th>Lower (5th percentile)</th><th>Upper (95th percentile)</th><th>Half-width confidence interval at 90%</th><th>Relative Margin</th></tr>
<tr><td>Cropland (C)</td><td>10</td><td>3.9</td><td>16.1</td><td>6.1</td><td>0.61</td></tr>
<tr><td>Grassland (P)</td><td>2.3</td><td>0.9</td><td>3.7</td><td>1.4</td><td>0.61</td></tr>
<tr><td>Other lands (A|O|U)</td><td>0</td><td>0</td><td>0</td><td>0</td><td>NA</td></tr>
</table></td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

<table>
<tr><td>Parameter:</td><td>$BGB_{after,i}$</td></tr>
<tr><td>Description:</td><td>Belowground biomass of non-forest type <i>i</i> after conversion</td></tr>
<tr><td>Data unit:</td><td>tons of dry matter per ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):</td><td>For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used because there is no country-specific data. Tier 2 may modify the assumption that carbon stocks immediately following conversion is zero. In this case, it is assumed that conversion leads to annual croplands and in the case the carbon stock in biomass after one year for annual crops provided in TABLE 5.9 is used.
For grassland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 6 are used because there is no country-specific data. As the climate in most of Mozambique is tropical dry to subtropical dry, the value for peak-above ground biomass for tropical dry climate was used. The default value 2.30 tonnes of C per hectare from TABLE 6.4 (2006 IPCC, Volume 4, Chapter 6, Section 6.3.1.2).
For other lands: No default values exist for these conversions.
Spatial level: International</td></tr>
<tr><td>Value applied:</td><td><table><tr><td>Cropland (C)</td><td>0.00</td></tr></table></td></tr>
</table>

Grassland (P)	6.40
Other lands (A|O|U)	0.00

The values above are recorded in the ranges "B35:E39", "B41:B45" and "B47:B51" of the "BIOMASS" worksheet tab in the "ZILMP_Emissions_Calculations_MR_(2021) and ZILMP_Emissions_Calculations_MR_(2022)" workbooks. These values are then applied in the range "F9:F20" of the "EMISSION MONITORING PERIOD(EMP)" worksheet tab in the "ZILMP_Emissions_Calculations_MR_(2021) and ZILMP_Emissions_Calculations_MR_(2022)" workbooks for estimating emissions.

QA/QC procedures applied

The adequacy in the use of these default values was confirmed with the experts in GHG Inventory in DINAB.

Uncertainty associated with this parameter:

Non-forest type	Uncertainty estimate				
	Mean	Lower (5th percentile)	Upper bound (95th percentile)	Half-width confidence interval at 90%	Relative Margin
Cropland (C)	0	0	0	0	NA
Grassland (P)	6.4	-0.2	12.8	6.5	1.02
Other lands (A|O|U)	0	0	0	0	NA

Any comment:

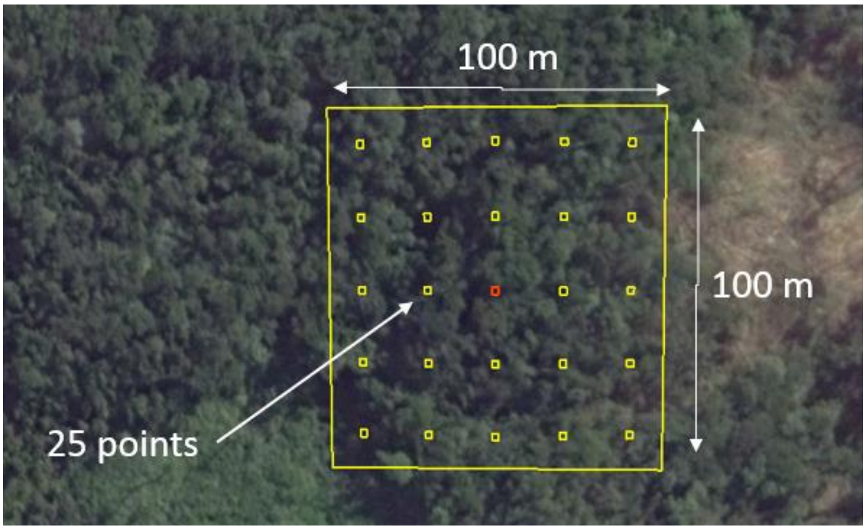
Parameter:	*A(j,i)*$_{RP}$
Description:	Area converted from forest type *j* to non-forest type *i* during the reference period.
Data unit:	hectare per year.
Source of data and description of measurement /calculation methods and procedures applied:	***i. Approach and source*** Activity data (AD) for deforestation were obtained from an annual historical time series analysis of land use, land-use change and forestry (LULUCF) carried out by five trained operators in approximately 98 effective working days (4.4 months), for the period of 2001 – 2016 across the country, using the Collect Earth Open tool. Activity data have been generated following IPCC Approach 3 for representing the activity data as described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 3, Section 3.13), i.e., using spatially-explicit observations of land-use categories and land-use conversions over time across the country, derived from sampling of geographically located points. The result was forest cover data for 2016 and forest cover change data for every year from 2001 to 2016. The period of AD analysis from 2005 to 2015 (11 years) considered for the ER Program area, could be adapted within the general period 2001 – 2016 with little effort, due to the operators collecting the date of the LULC change. ***ii. Sampling design***

A systematic 4 x 4 km grid consisting of a total of 48,894 sampling units was established at a national level to generate the historical activity data for the entire area of the country using high and medium resolution imagery. This is the same grid used to allocate the NFI clusters from the Stratified Random Sampling design. At jurisdictional level, this corresponds to 3,308 sampling units being interpreted. Each sampling unit was visually assessed and its information was collected and entered in a complete database on LULC changes at the national level.

iii. Response design

Spatial sampling unit

The spatial sampling unit was defined as a square with 1 ha (100m x 100m), where an internal grid of 5 x 5 points (20m x 20m grid) is overlapped. Each point from the internal grid has a weight coverage of 4%.



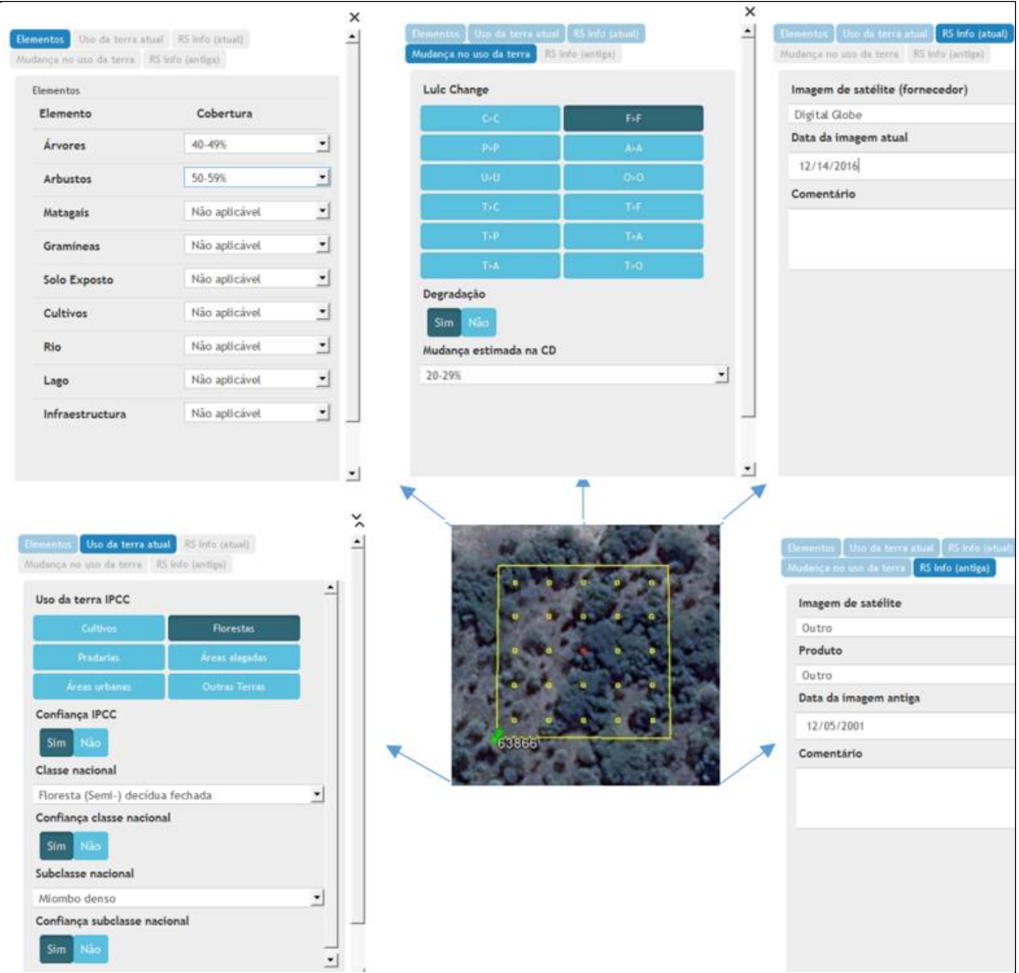
Spatial sampling unit for the reference period

Source of reference data

The sampling approach for historical AD calculation based on the regular National 4 x 4 km grid has been designed and conducted using the high and medium resolution images repository available through Google Earth and Earth Engine as a visual assessment exercise. These imageries with digital forms designed to collect the LULCC information on the points of the grid are automatically accessible through the Collect Earth tool (www.openforis.org) along with scripts accessible through Earth Engine code that facilitate vegetation type's interpretation (e.g. MODIS or Landsat NDVI time series). Each point of the grid is photo-interpreted thanks to Collect Earth tool and the year and type of changes are also collected.

The use of various scripts programmed on Earth Engine Code facilitates the interpretation of the vegetation type and the determination of LULC changes. Specifically, the MOD13Q1 (NDVI 16-day Global Modis 250 m) graphic from 2001-2016, most recent Sentinel-2 image, most recent Landsat-8 pan sharpened image, Landsat-7 pan sharpened image (2000, 2004, 2008, 2012), etc.

The completeness of the series is guaranteed using remote sensing products from medium resolution imagery repositories from 2001 (e.g. Annual TOA Reflectance Composite, Annual NDVI Composite, Annual EVI Composite, Annual Greenest-Pixel TOA Reflectance Composite, etc. from Landsat 5 TM) and the most recent Sentinel-2 image from 2016. In this way, a temporal analysis of LULC changes has been completed for each sampling point of the national 4 x 4 km grid (48,894 records).



Elementos

Elemento	Cobertura
Árvores	40-49%
Arbustos	50-59%
Matagais	Não aplicável
Gramíneas	Não aplicável
Solo Exposto	Não aplicável
Cultivos	Não aplicável
Rio	Não aplicável
Lago	Não aplicável
Infraestructura	Não aplicável

Lulc Change

C>C [✓ F>F]
P>P A>A
U>U O>O
T>C T>F
T>P T>A
T>A T>O

Degradação

[✓ Sim] Não

Mudança estimada na CD

20-29%

Imagem de satélite (fornecedor)

Digital Globe

Data da imagem atual

12/14/2016

Comentário

Uso da terra IPCC

Cultivos [✓ Florestas]
Pradarias Áreas alagadas
Áreas urbanas Outras Terras

Confiança IPCC

[✓ Sim] Não

Classe nacional

Floresta (Semi-) decidua fechada

Confiança classe nacional

[✓ Sim] Não

Subclasse nacional

Miombo denso

Confiança subclasse nacional

[✓ Sim] Não

Imagem de satélite

Outro

Produto

Outro

Data da imagem antiga

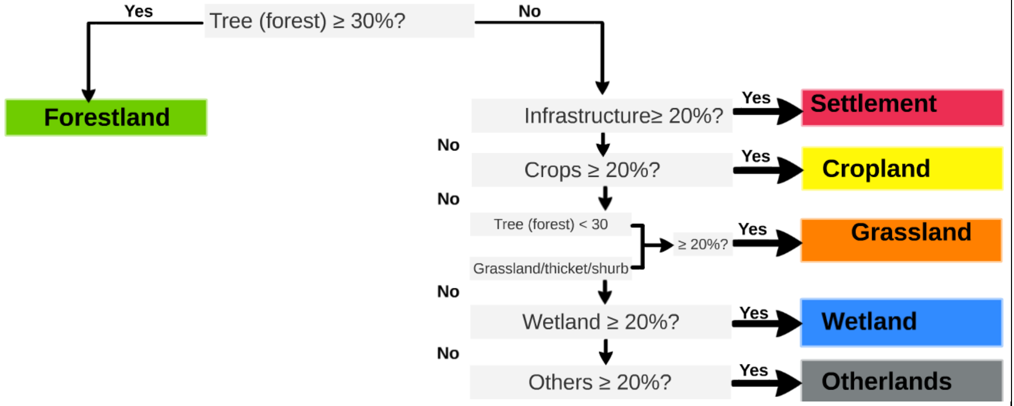
12/05/2001

Comentário

LULCCF detection using Collect Earth Tool (www.openforis.org). Digital forms designed with Collect Tool.

<u>Reference labelling protocol</u>

The activity data was generated considering the national land use and land cover classification system, which reflects the six broad IPCC Land Use categories. A set of hierarchical rules were established and used to determine the LULCCF category based on a certain percentage and taking into account the national forest definition as well. A single land use class is easier to classify, but it becomes challenging when there is a combination of two or more land use classes within the area of interest. Thus, this is where the hierarchical rules are important to determine the land use. Any sampling unit that has 30% of tree canopy cover is considered a forest, according to the national forest definition, even if it has more than 20% of settlements, crops or other land use, the forest has priority. In the case the sampling unit was classified as forest land and different forest types were present in the sampling unit, a majority rule was used in this case, i.e. the largest forest class is the winner.



Decision tree for the attribution of the LULCCF category based on the percentage cover of the elements present in the sampling unit of 1 ha.

iv. Analysis

The estimation of the areas corresponding to a certain category changes from a forest type to a non-forest type in the framework of this systematic sampling approach was based on assessments of area proportions. According to 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 3, Section 3.33), the proportion of each land-use or land-use change category is calculated by dividing the number of points located in the specific category by the total number of points, and area estimates for each land-use or land-use change category are obtained by multiplying the proportion of each category by the total area of interest, in this case, the ER Program accounting area.

$$A_i = p_i \times A$$ ***Equation 7***

Where:

A_i	Area estimate on forest type *j* converted to non-forest type *i;* hectare
p_i	Proportion of points on forest type *j* converted to non-forest type *i;* dimensionles
A	Total area of interest; hectare

$$p_i = \frac{n_i}{N}$$ ***Equation 8***

Where:

n_i	Number of points on forest type *j* converted to non-forest type *i;* number
N	Total number of points; number

Uncertainties in activity data were derived using non-parametric bootstrapping, where reference data points were re-sampled with replacement 100,000 times. For each permutation of reference data points, the bias-corrected area estimates were produced following the methods described in Olofsson *et al*. (2014). Uncertainty was estimated from the resulting distribution of area estimates. Although more complex to implement, bootstrapping has the advantages of not requiring any assumption about the shape of the probability distribution function of each land cover transition class, and avoids the generation of negative areas in rare classes where a probability distribution function crosses zero. The method was implemented in R, and the scripts used are available in the "*Mozambique ERPA 2020*" shared folder.

The impact of using non-parametric bootstrapping to estimate uncertainties vs other methods was tested with a comparison of deforested areas derived from bootstrapping against sampling from a normal distribution with standard error calculated with the methods described in Olofsson *et al*. (2014) (Figure 7). For the latter case two uncertainties were derived: one retaining any negative area estimates for rare transition classes, and another setting these to zero. The result indicates that there is very little difference between any of the methods in either reference or monitoring periods, with the result that any chosen approach would produce equivalent emissions estimates.

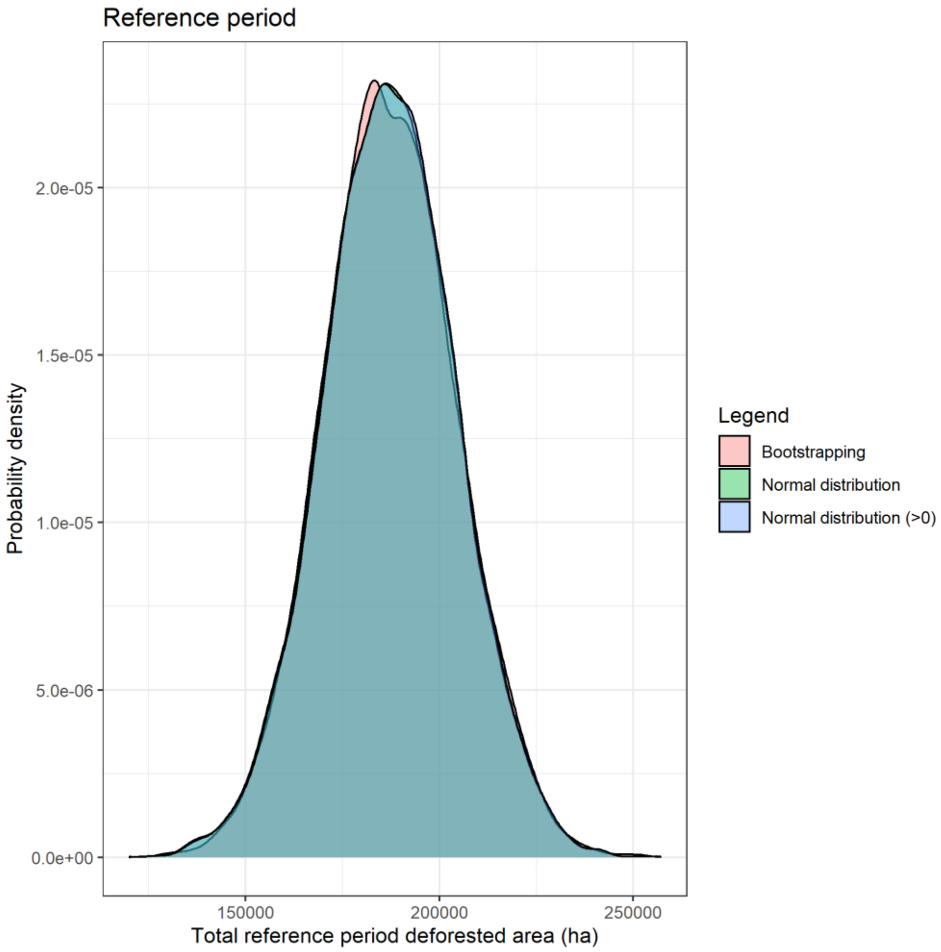


Figure 7: Total activity data area estimates for reference period using normal distributions for each transition class (red), normal distributions with a minimum area of 0 ha (green), and non-parametric bootstrapping (blue). All three methods result in equivalent uncertainty estimates.

Value applied

Semi-deciduous forest to cropland	11,785.07
Semi-deciduous forest to grassland	1,745.94
Semi-deciduous forest to other lands	145.49
Evergreen forest to cropland	3,200.88
Evergreen forest to grassland	145.49
Evergreen forest to other lands	0.0
Mangrove forest to cropland	0.0
Mangrove forest to grassland	0.0
Mangrove forest to other lands	0.0

QA/QC procedures applied:

Quality Control consisted in having a team of 5 technicians with experience in forests and remote sensing, all trained together by an MRV specialist. The team worked in the same office, and discussed any classification issues with each other.

Quality Assurance was conducted using the SAIKU extension of Collect Earth. This tool allows the detection of whether:

- i) Data point was not filled
- ii) The class assigned followed the classification hierarchy, based on the % of individual element cover
- iii) Year of the Old image/Change image was less than the current image
- iv) Change classes are consistent with previous and current classes
- v) Open and closed forest was correctly classified, based on the 30% (open) and 65% (closed) cover threshold

In the case of any error being detected, the ID of the data point was registered and the user performed the necessary corrections.

Uncertainty associated with this parameter:

Category change	Uncertainty estimate (from non-parametric bootstrapping)				
	Median	Lower bound (5th percentile)	Upper bound (95th percentile)	Half-width confidence interval at 90%	Relative Margin
FSD>(A|O|U)	291	0	873	436.5	1.5
FSD>C	23570.1	19496.3	27935	4219.4	0.18
FSD>P	3491.9	2036.9	5237.8	1600.4	0.46
FSSV>C	6401.8	4364.8	8729.7	2182.5	0.34
FSSV>P	291	0	873	436.5	1.5

Any comment:

3.2 Monitored Data and Parameters

Parameter: $A(j,i)_{MP}$

Description: Area converted from forest type *j* to non-forest type *i* during the Monitoring Period.

Data unit: hectare per year.

Value monitored during this Monitoring / Reporting Period:

Type of change	**2021**	**2022**
Semi-deciduous forest to cropland	33577.09	17939.15
Semi-deciduous forest to grassland	250.14	719.44
Semi-deciduous forest to other lands	0	679.08
Evergreen forest to cropland	1878.42	1792.63
Evergreen forest to grassland		
Evergreen forest to other lands		
Mangrove forest to cropland	98.91	
Mangrove forest to grassland		
Mangrove forest to other lands		
Total	35,804.56	21130.3

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

i. Source

Activity data used for the monitoring period are obtained from a combination of an annual wall-to-wall deforestation map with sampling to generate deforested area estimates through a stratified estimator.

ii. Variable of interest

The variable of interest are all the transitions specified above. It is important to note that the variables of interest are not aligned to the strata as this is not required. Strata is linked to the likelihood of presence of deforestation events, whereas the variable of interest is linked to the possible transitions of deforestation per forest type and post-deforestation type.

ii. Annual deforestation map

The workflow used to produce annual deforestation map for the ZILMP program area follows the steps below:

1. Produce two Sentinel-2 satellite imagery composites for the monitoring area, containing all images of wet season (i.e. January - May). For 2021 deforestation map, the first composite (reference period) comprises the period between January 2021 to May 2021 and January 2022 to May 2022 for 2022 deforestation map and the second composite (actual period) comprises the period from January 2022 to May 2022 and January 2023 to May 2023 respectively. The reason behind the selection of January - May as a reference and actual period of monitoring resides on the fact that it is the wet season, where the NDVI stability is very high in relation to the dry season, which starts in June to October, when most trees lose their foliage and makes it difficult the analysis of deforestation.
2. Generate image features from reference period and actual period from the composites generated in previous step, to identify changes in forest cover. The image features have different vegetation indexes, namely, NDVI, EVI, SAVI, NBR, NDWI with respective sub-products such as NDVI 90th percentile, Normalized NDVI, and variation on NDVI.
3. Generate training data on classes of deforestation, stable forest and stable non-forest by visual interpretation of composites from the reference and actual periods, and NDVI change detection image. The NDVI change detection image is a result of the difference of NDVI from the composites of reference and actual periods. The calculated NDVI change detection image helps the interpreter to locate where the changes of forest cover are occurring.
4. Produce a categorical deforestation map from training data and image features through a process of classification using Random Forest classifier. The Categorical deforestation map includes non-forest stable and stable forest classes. Because errors of omission of deforestation have a very large impact on the final estimates, it is important to reduce these errors as much as possible.
5. To improve the efficacy of the sampling the deforestation class on the map is reclassified as:
    a) High probability deforestation (cluster of more than 10 pixels of deforestation, corresponding to at least 40% of one hectare);
    b) Low probability of deforestation (cluster of less than 10 pixels and greater than 2 pixels, corresponding at least 12% to 40% of one hectare) and;

c) Non-forest (cluster of less than 3 pixels, corresponding to less than 12% of one hectare).

6. To reduce the risk of omission errors, a Buffer of 60 meters is added around the high probability of deforestation class. The result is a deforestation map with five classes: *High probability of deforestation; buffer; low probability of deforestation; stable forest and stable non-forest.*

v. Sampling design

Sampling method

Monitoring of activity data for annual reporting is conducted using a stratified estimator, where deforestation map (which includes classes of forest and non-forest) is used for stratification and reference-sampling units are used for estimate activity data and associated confidence intervals.

Sample size determination

The sample size *n* was determined from the equation:

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

Equation 9

Where:

N	Number of units in the ROI
$S(\hat{O})$	Standard error of the estimated overall accuracy that we would like to achieve
W_i	Mapped proportion of area of class *i*; and
S_i	Standard deviation of stratum *i*.

The standard deviation of stratum *i* is given by the formula:

$$S_i = \sqrt{U_i(1 - U_i)}$$

Equation 10

Where:

U_i	Proportion of area of deforestation in stratum *i.*

In order to obtain approximate values of proportion of deforestation in each stratum (U_i), a pilot sampling is conducted. This pilot consists of 100 sample units per stratum.

Sample units per stratum

After the pilot sampling, sample units may need to be added to each stratum, in order to achieve 20% relative margin error at 95% confidence level. It was decided to use the Optimum (Neyman) allocation for each change stratum, where the stratum standard deviation $S_i = \sqrt{U_i \cdot (1 - U_i)}$ increases the number of plots (ensuring larger numbers of plots in rare classes or strata) and sampling unit costs are constant:

$$n_i = n \frac{w_i \cdot S_i}{\sum_{i=1}^{I} w_i \cdot S_i}$$

Equation 11

For each stable stratum, the proportional allocation is applied if deforestation omission errors are completely absent from these strata. In stratified sampling the sample size for proportional allocation is given by:

$$n_i = n \cdot w_i$$ ***Equation 12***

The number of reference points is presented in Table 4.

Table 4: Number of reference sampling units per map stratum for each classes of the 2021 and 2022 maps.

Stratum	**Number of sample units (2021)**	**Number of sample units (2022)**
High probability of deforestation	100	105
60 m Buffer	309	445
Low probability of deforestation	100	100
Forest	300	300
Non-forest	300	300
Total	1,109	1,250

v. *Response design*

Sampling unit and spatial support

The sampling unit is a 20 m pixel of the stratification map that was produced. The spatial support used is a 100m x 100m plot (1ha). Each Spatial sampling unit contains an internal grid of 5 x 5 points (20m x 20m grid) to aid in the labelling attribution (Figure 8).

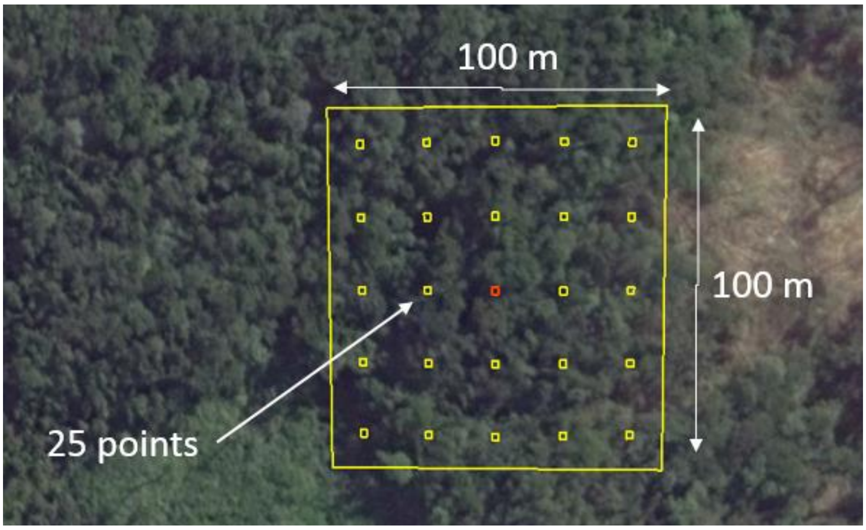
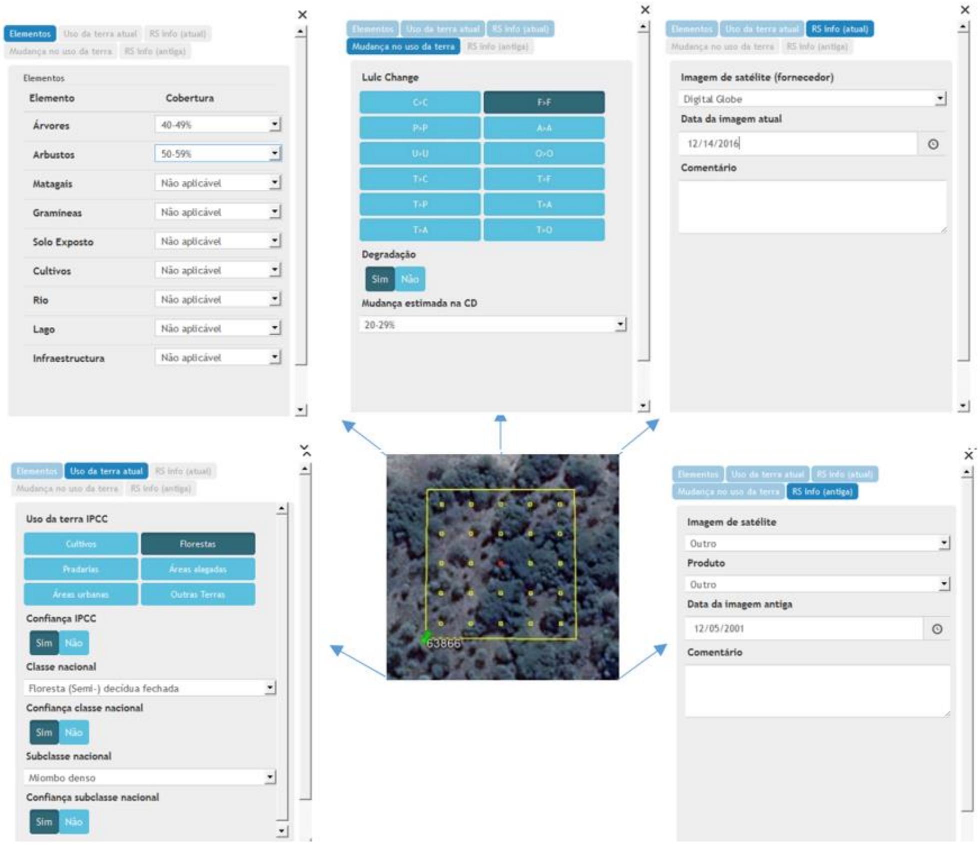


Figure 8: Spatial sampling unit.

Source of reference data

Each sampling unit was evaluated using Collect Earth (http://www.openforis.org/). This tool enables access to high-resolution images in Google Earth, Bing Maps and Planet Labs, as well as a medium resolution image repository available through Google Earth Engine Explorer and Code Editor (Landsat and Sentinel-2). The tool enables to display digital forms designed to collect the Land-Use Land Cover Change and Forestry (LULCCF) information on the sampling points (Figure 9). The Earth Engine Code Editor facilitates the interpretation of the vegetation type and the determination of LULC changes, by displaying the historical MOD13Q1 (NDVI 16-day Global Modis 250 m) graphic as well as monthly mosaics of Sentinel-2 images. The main source of data to identify changes in land cover, is Sentinel-2 15 days’ reflectance composite. However, Planet data is also used in cases of doubt or excessive cloud cover with Sentinel-2.



Elementos

Elemento	Cobertura
Árvores	40-49%
Arbustos	50-59%
Matagais	Não aplicável
Gramíneas	Não aplicável
Solo Exposto	Não aplicável
Cultivos	Não aplicável
Rio	Não aplicável
Lago	Não aplicável
Infraestructura	Não aplicável

Lulc Change

Degradação
Sim
Mudança estimada na CD
20-29%

Imagem de satélite (fornecedor)
Digital Globe
Data da imagem atual
12/14/2016
Comentário

Uso da terra IPCC

Confiança IPCC
Sim
Classe nacional
Floresta (Semi-) decídua fechada
Confiança classe nacional
Sim
Subclasse nacional
Miombo denso
Confiança subclasse nacional
Sim

Imagem de satélite
Outro
Produto
Outro
Data da imagem antiga
12/05/2001
Comentário

Figure 9: LULCCF detection using Collect Earth Tool (www.openforis.org). Digital forms designed with Collect Tool.

Reference labelling protocol

The activity data was generated considering the national land use and land cover classification system, which reflects the six broad IPCC Land Use categories.

A set of hierarchical rules were established and used to determine the LULCCF category based on a certain percentage and taking into account the national forest definition as well (Figure 10). A single land use class is easier to classify, but it becomes challenging when there is a combination of two or more land use classes within the area of interest. Thus, this is where the hierarchical rules are important to determine the land use. Any sampling unit that has 30% of tree canopy cover is considered a forest, according to the national forest definition, even if it has more than 20% of settlements, crops or other land use, the forest is priority.

In the case the sampling unit was classified as forest land and different forest types were present in the sampling unit, a majority rule was used in this case, i.e. the largest forest class is chosen (please click here for more details).

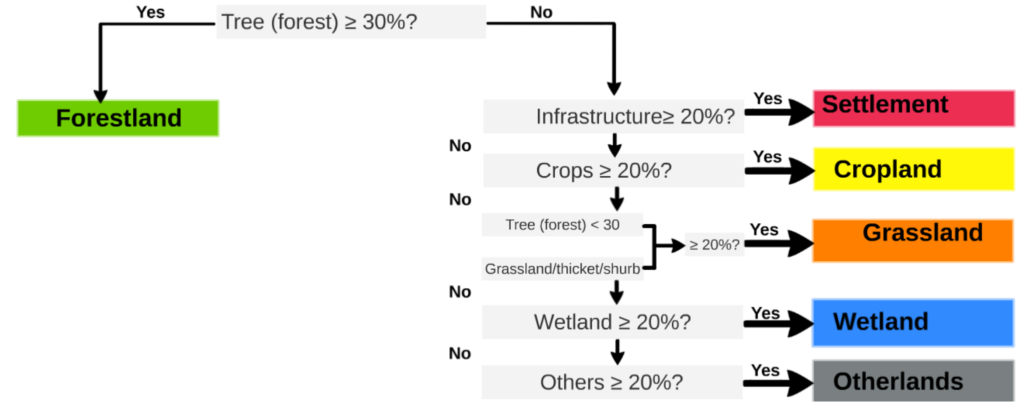


Figure 10: Decision tree for the attribution of the LULCCF category based on the percentage cover of the elements present in the sampling unit of 1 ha.

vi. Analysis

Applying the methodology described in Olofsson *et al.* (2014)[9] and the GFOI MGD (https://www.reddcompass.org/download-the-mgd), the estimations of the areas corresponding to land-use and land-cover change categories, more specifically the activity data for deforestation, in the framework of this stratified random sampling approach (based on the visual assessment of the 1 ha plots) was based on assessments of area proportions. A sample error matrix is constructed where the map classes (*h*=1, 2,…,q) are represented by rows and the reference data (*k*=1, 2,…,*q*) by columns as shown in Table 5. The size of strata and original proportion matrix can the found in 2021 and 2022 spreadsheets.

Table 5: Error matrix of area proportions.

Map data	Reference data					Total	User's accuracy ($\hat{U}_i$)
	Deforestation			Stable forest	Stable non-forest		
	High probability of deforestation	40 m Buffer	Low probability of deforestation				
High probability of deforestation	$\hat{p}_{11}$	$\hat{p}_{12}$	$\hat{p}_{13}$	$\hat{p}_{14}$	$\hat{p}_{15}$	$\hat{p}_{1.}$	$\hat{p}_{11}/\hat{p}_{1.}$
40 m Buffer	$\hat{p}_{21}$	$\hat{p}_{22}$	$\hat{p}_{23}$	$\hat{p}_{24}$	$\hat{p}_{25}$	$\hat{p}_{2.}$	$\hat{p}_{22}/\hat{p}_{2.}$
Low probability of deforestation	$\hat{p}_{31}$	$\hat{p}_{32}$	$\hat{p}_{33}$	$\hat{p}_{34}$	$\hat{p}_{35}$	$\hat{p}_{3.}$	$\hat{p}_{33}/\hat{p}_{3.}$
Stable forest	$\hat{p}_{41}$	$\hat{p}_{42}$	$\hat{p}_{43}$	$\hat{p}_{44}$	$\hat{p}_{45}$	$\hat{p}_{4.}$	$\hat{p}_{44}/\hat{p}_{4.}$
Stable non-forest	$\hat{p}_{51}$	$\hat{p}_{52}$	$\hat{p}_{53}$	$\hat{p}_{54}$	$\hat{p}_{55}$	$\hat{p}_{5.}$	$\hat{p}_{55}/\hat{p}_{5.}$
Total	$\hat{p}_{.1}$	$\hat{p}_{.2}$	$\hat{p}_{.3}$	$\hat{p}_{.4}$	$\hat{p}_{.5}$	1	
Producer's accuracy (P_i)	$\hat{p}_{11}/\hat{p}_{.1}$	$\hat{p}_{22}/\hat{p}_{.2}$	$\hat{p}_{33}/\hat{p}_{.3}$	$\hat{p}_{44}/\hat{p}_{.4}$	$\hat{p}_{55}/\hat{p}_{.5}$		$Overall\ accuracy\ (\hat{O})$ $= \hat{p}_{11} + \hat{p}_{22} + \hat{p}_{33} + \hat{p}_{44} + \hat{p}_{55}$

The mean estimator for the area of each class can be directly obtained from the error matrix. Unbiased stratified estimators are provided using reference class area proportions ($\hat{p}_{\cdot k}$):

$$\hat{p}_{\cdot k} = \sum_{h=1}^{H} w_h \cdot \frac{n_{hk}}{n_{h\cdot}} = \sum_{h=1}^{H} \hat{p}_{hk}$$ ***Equation 13***

Where:

$\hat{p}_{\cdot k}$ Area proportions of reference data class *k*. These proportions of reference data for deforestation classes as a whole are collapsed in three possible types of conversions/transitions from forest type *j* to non-forest type *i*, namely:

- Broadleaved (Semi-) deciduous to Non-forest type *i*;
- Broadleaved (Semi-) evergreen to Non-forest type *i*; and
- Mangrove to Non-forest type *i*.

Five types of non-forest land are considered:

- Cropland (C);
- Grassland (P);
- Wetland (A);
- Settlement (U); and
- Other lands (O).

w_h Proportion of area mapped as class *h*;

n_{hk} Sample count at cell (*h,k*);

$n_{h.}$ Sum of sample counts across row *h*; and

$\hat{p}_{hk}$ Proportion of area in cell (*h,k*).

Once the estimated reference class area proportions ($\hat{p}_{\cdot k}$) are obtained, the mean total area per class is calculated by multiplying them with the total reporting area ***a***:

$$\hat{A}_j = \hat{p}_{\cdot k} \cdot a$$ ***Equation 14***

Uncertainty in activity data were derived using non-parametric bootstrapping, where reference data points were re-sampled with replacement 100,000 times. For each permutation of reference data points, the bias-corrected area estimates were produced following the methods described in Olofsson *et al*. (2014). Uncertainty was estimated from the resulting distribution of area estimates. Although more complex to implement, bootstrapping has the advantages of not requiring any assumption about the shape of the probability distribution function of each land cover transition class, and avoids the generation of negative areas in rare classes where a probability distribution function crosses zero. The method was implemented in R, and the scripts used are available in the "*Mozambique Monitoring report*" shared folder.

The impact of using non-parametric bootstrapping to estimate uncertainties vs other methods was tested with a comparison of deforested areas derived from bootstrapping against sampling from a normal distribution with standard error calculated with the methods described in Olofsson et al. (2014). For the latter case, two uncertainties were derived: one retaining any negative area estimates for rare transition classes, and another setting these to zero. The result indicates that there is very little difference between any of the methods in either reference or monitoring periods, with the result that any chosen approach would produce equivalent emissions estimates.

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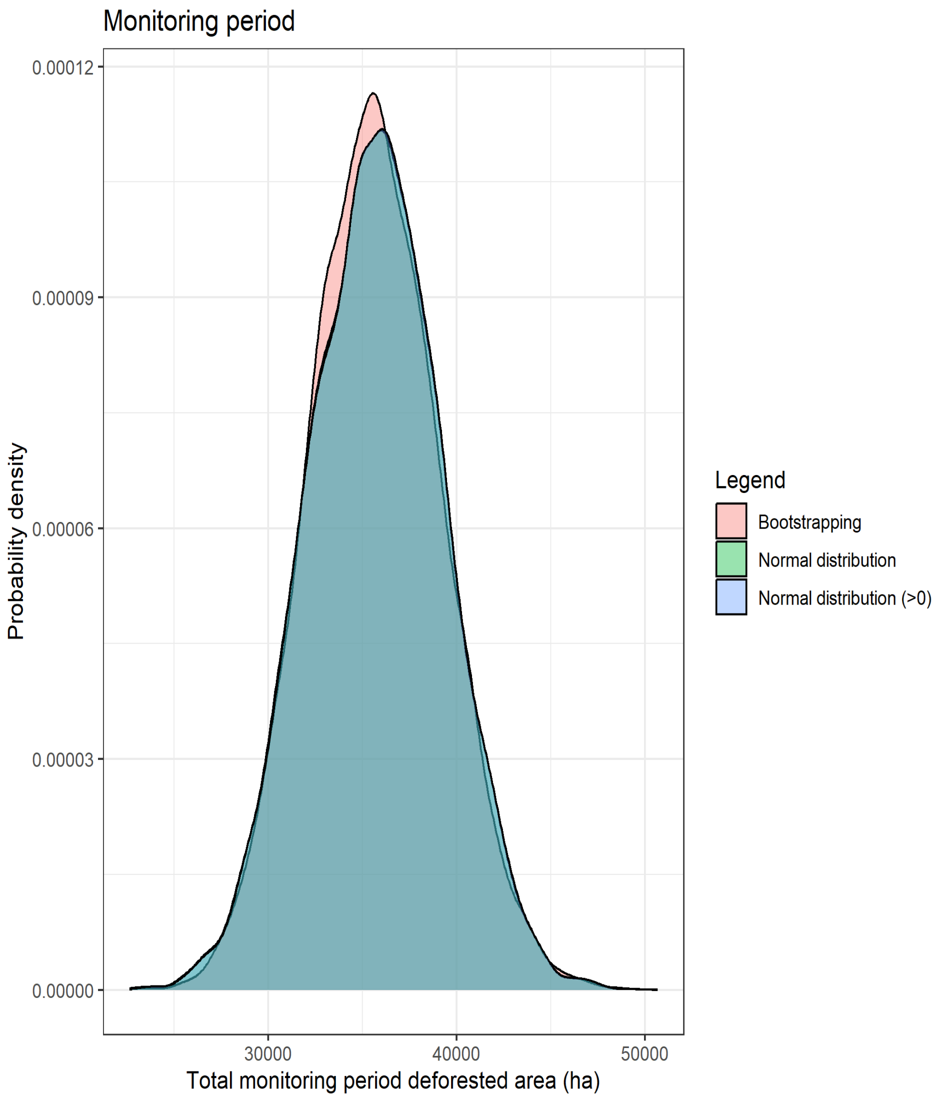
[9] Olofsson, P., Foody, G.M., Herold, M., Stehman, S.V., Woodcock, C.E., & Wulder, M.A. 2014. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment. 148:42-57.

	 *Figure 11: Total activity data area estimates for the monitoring period using normal distributions for each transition class (red), normal distributions with a minimum area of 0 ha (green), and non-parametric bootstrapping (blue). All three methods result in equivalent uncertainty estimates.*
QA/QC procedures applied:	The QA/QC procedures consisted on the following: ● SOPs were developed as described in *Section 2.1 - Satellite and land monitoring system* and training; and ● Interpretation is done by highly qualified professionals which are specialized in land cover interpretation with satellite imagery. They were trained and a robust control system is in place to ensure that they are correctly calibrated throughout the data collection process. ● All reference data interpreted as deforestation or forest degradation, and an additional 20% of the remaining reference data were evaluated. The quality control is carried out by two independent supervisors, who after the independent evaluation compare the two evaluations and consensually compile a single comment for each sample. The parameters to be taken into account in the evaluation for identifying errors are: a) the percentage of coverage for each element within the plot; b) the current land cover/land use class (levels 1 and 2); c) the land cover/land use change class; d) the former land cover/land use class (levels 1 and

2); and e) the date of occurrence of land cover/land use change, or evidence date of remaining land cover/land use. If there are gross errors related to the parameters b), c) and d) in at least 20% of samples from the 20% mentioned initially, the respective interpreter should review all samples from the batch, otherwise the interpreter reviews only the samples evaluated by the supervisors, that present gross errors. On the other hand, in relation to all samples interpreted as deforestation, the interpreter reviews only the samples that present gross errors according to the evaluation from the supervisors. The process is cyclical until the interpreter achieves values less than 20% of gross errors in the batch.

- The uncertainty analysis approach was reviewed by Philip Mundhenk, a professor of the University of Hamburg specialized in Monte Carlo simulations.

Uncertainty for this parameter:

Category change	Uncertainty estimate (from non-parametric bootstrapping)				
	Median	Lower bound (5th percentile)	Upper bound (95th percentile)	Half-width confidence interval at 90%	Relative Margin
FSD>C	51,476.8	45,202.2	58,146.2	6,472	0.13
FSD>P	943.5	0	2,004.2	1,002.1	1.06
FSSV>C	3,586.3	1,978.3	5,670.6	1,846.15	0.51

Any comment: -

4 QUANTIFICATION OF EMISSION REDUCTIONS

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

Year of Monitoring/Reporting period *t*	Average annual historical emissions from deforestation over the Reference Period (tCO$_{2-e}$/yr)	If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO$_{2-e}$/yr)	If applicable, average annual historical removals by sinks over the Reference Period (tCO$_{2-e}$/yr)	Adjustment, if applicable (tCO$_{2-e}$/yr)	Reference level (tCO$_{2-e}$/yr)
2021	5,253,267.99	-	-	-	5,253,267.99
2022	5,253,267.99				5,253,267.99
Total	**10,506,535.98**	**-**	**-**	**-**	**10,506,535.98**

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

The following table shows the emissions results obtained per category changes from a forest type to a non-forest type during the Monitoring Period. The emissions are generated relating the data and parameters described in Section 3 and summarized in the Table 6, by applying **Equation 6.**

Table 6: Calculation of the emissions from the ER Program during the Monitoring Period (2021 and 2022).

Category changes	**$AGB_{before,j}$ (tdm/ha)**	**$BGB_{before,j}$ (tdm/ha)**	**$AGB_{after,i}$ (tdm/ha)**	**$BGB_{after,i}$ (tdm/ha)**	**2021**		**2022**	
					$A_{(j,i)MP}$ (ha)	**Emissions (tCO_2e)**	**$A_{(j,i)MP}$ (ha)**	**Emissions (tCO_2e)**
Semi-deciduous forest to cropland	144.69	49.95	10.00	0.00	33577.09	10,683,828	17,939.15	5,708,024
Semi-deciduous forest to grassland	144.69	49.95	2.30	6.40	250.14	80,133	719.44	230,479
Semi-deciduous forest to other lands	144.69	49.95	0.00	0.00	0.00	0.00	679.08	227,779
Evergreen forest to cropland	123.13	42.06	10.00	0.00	1878.42	502,364	1,792.63	479,419
Evergreen forest to grassland	123.13	42.06	2.30	6.40	0.00	0.00	0.00	0.00
Evergreen forest to other lands	123.13	42.06	0.00	0.00	0.00	0.00	0.00	0.00
Mangrove to cropland	269.01	85.43	10.00	0.00	98.91	58,709	0.00	0.00
Mangrove to grassland	269.01	85.43	2.30	6.40	0.00	0.00	0.00	0.00
Mangrove to other lands	269.01	85.43	0.00	0.00	0.00	0.00	0.00	0.00
Total					**35,804.55**	**11,325,034**	**21,130.30**	**6,645,702**

Year of Monitoring/Reporting Period	**Emissions from deforestation (tCO_{2-e}/yr)**	**If applicable, emissions from forest degradation (tCO_{2-e}/yr)***	**If applicable, removals by sinks (tCO_{2-e}/yr)**	**Net emissions and removals (tCO_{2-e}/yr)**
2021	**11,325,034**	-	-	**11,325,034**
2022	**6,645,702**			**6,645,702**
Total	**17,970,736**	-	-	**17,970,736**

4.3 Calculation of emission reductions

Total Reference Level emissions during the Reporting Period (tCO2-e)	**10,506,535.98**
Net emissions and removals under the ER Program during the Reporting Period (tCO2-e)	17,970,736
Emission Reductions during the Reporting Period (tCO2-e)	-(7,464,200.02)

5 UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS

5.1 Identification, assessment and addressing sources of uncertainty

Table 7: Sources of uncertainty to be considered under the FCPF MF.

Sources of uncertainty	**Analysis of contribution to overall uncertainty**	**Contribution to overall uncertainty (High / Low)**	**Addressed through QA/QC?**	**Residual uncertainty estimated?**
Activity Data				
Measurement	This error represents the operator error during the interpretation of LULCC on sampled points and inconsistencies between operators. This error is reduced by extensive QA/QC procedures. Quality control was guaranteed by having a team of technicians with experience in forests and remote sensing, all trained using the same methodology. The team worked in the same office, and discussed any classification issues with each other. Moreover, specific SOPs were defined in order to ensure the consistency in the interpretations. Quality control was conducted using the SAIKU extension of Collect Earth. This tool allows the detection of whether: (i) Data point was not filled (ii) The class assigned followed the classification hierarchy, based on the % of individual element cover (iii) Year of the Old image/Change image was less than the current image (iv) Change classes are consistent with previous and current classes (v) Open and closed forest was correctly classified, based on the 30% (open) and 65% (closed) cover threshold In the case of any error being detected, the ID of the data point was registered and the user performed the necessary corrections.	High (bias/random)	YES	NO

	All sampling units detected as deforestation and 20% of the remaining sampling units are subjected to quality assurance (QA). This QA is performed by 2 independent reviewers, who compare their evaluations of each sampling unit, to reach a decision on whether the chose sampling unit was correctly evaluated or not. The critical evaluated parameters, which determine whether a sample has to be reviewed by the user are: land cover class (level 1 and 2), land cover change class and previous land cover class (in case of change). If errors are detected in at least 20% of the reviewed sampling units from the 20% mentioned initially, then the operator has to reanalyze their lot. This process is cyclical, until less than 20% of the sampling units are found to have errors.			
Representativeness	This source of error is related to the representativeness of the estimate which is related to the sampling design. We produce annual deforestation maps as the basis for stratification, to ensure that our sample is representative of the area of interest. We applied a probabilistic-based sampling, where all areas have an inclusion probability larger than zero	Low	YES	NO
Sampling	Sampling error is the statistical variance of the estimate of area for the applicable forest transitions that are reported by the ER Program. This source of error is random. Mozambique has followed Good Practices regarding estimating the contribution of this error. For the reference period we used systematic sampling, which does not have an unbiased estimator for the variance. The variance estimation formulae for simple random sampling were used as a conservative option. For the monitoring period we used stratified sampling and the method described by Olofsson (2014).	High (bias/random)	YES	YES
Extrapolation	This source of uncertainty is not applicable to our approach. We generate estimates of deforestation per forest type, based on reference data.	N.A.	N.A.	NO
Approach 3	This source of uncertainty exists when there is no tracking of lands or IPCC Approach 3, which is the case for Mozambique. We do not consider that the time-span of the Reference Period + Monitoring Period is sufficient for a land to have been deforested, grown back to forest and then deforested again. With the methodology used in the reference period, it was not possible to double count deforestation events, as we analyzed the entire period. On the other hand, this is a possibility in the monitoring period. Because we are only accounting for deforestation this is conservative with regards to our emissions reductions estimate. Mozambique does not have a clear definition of the time-span required for a land to be considered to have been converted "back" to forest after a deforestation event.	H/L (bias)	YES	NO

Emission factor				
DBH measurement	Strong QA/QC processes were implemented: ● SOPs were developed as described in *Section 2.1 - National Forest Inventory*. ● A training on the SOPs was conducted prior to the field work. This training lasted for 3 weeks, and consisted of training on the usage of all equipment and evaluating the specific skills of each participant, in order to determine the team and brigade leaders. On the start of the 2nd phase of the IFN (2017) an additional 1-week training was conducted, to refresh the participants and train any new members. ● The supervisor of each inventory team conducted a remeasurement of 4 trees per plot which means 16 trees per cluster. This served to ensure that the SOPs were adequately implemented. ● An independent measurement of 10% of the plots. Technicians of the National Directorate of Forests, who had participated in the Provincial Inventories of Gaza and Cabo Delgado, conducted this activity. Diameter below 10%. ● The World Bank conducted two regular supervision missions of the National Forest Inventories to confirm the adequate implementation of the SOPs and suggest areas for improvement. As a result of these QA/QC procedures the possible bias in the measurement of DBH and H have been addressed and the measurement random error is considered to be low. Hence, this source of error will not be propagated.	H (bias) & L (random)	YES	NO
H measurement		H (bias) & L (random)	YES	NO
Plot delineation		H (bias) & L (random)	YES	NO
Wood density measurement	The allometric equations used by Mozambique do not include wood density, so this source of error will not be propagated.	N.A.	N.A.	NO
Other parameters (e.g. Carbon Fraction, root-to-shoot ratios)	Carbon fraction parameter was taken from the 2006 IPCC Guidelines. Error, as provided from the IPCC Guidelines, has been propagated. Sensitivity analysis showed a very small effect of this parameter. Root-to-shoot ratios were used for one of the strata (Evergreen Forest), with the value taken from the 2006 IPCC Guidelines. Within this stratum, we only applied the root-to-shoot ratio to species which were not covered by specific equations, as described in Section 3.1 of this report. Since the previous MR (2018) Mozambique has integrated emission factor estimation within the automated processing chain. As a result, we have propagated Root-to-shoot ratios as per the guidelines.	*H (bias) & L (random)*	YES	YES
Biomass allometric equation	Allometric equations used ranged from national (specific species, and evergreen MoUntain forest), to regional (for mangrove), international (Semi-deciduous forest) and IPCC defaults (evergreen forests). However, effect on emission reductions is expected to be low, as emission factors remain	*H (random/bias)*	*YES*	*YES*

(Model error)	constant from reference to monitoring period. Additionally, the overall effect of emission factor uncertainty on total uncertainty is low (10.4%). The equations used for semi-deciduous forest and evergreen forest were not validated with data from Mozambique, which is a source of bias. Unfortunately, this was not feasible due to financial reasons. As QA/QC procedure, the selection of the equations was discussed with experts from the Eduardo Mondlane University and IIAM who confirmed that these are the most representative and best available equations, which will provide accurate estimates, as far as practice. According to the experts, although there might be an associated bias from using the equation, it is safer to use the equation of Mugasha et al. 2013 (more representative "ecosystems and species") than using the adjusted equations in Mozambique (less representative "ecosystems and species"). It is because the adjusted equations in Mozambique mostly recommended for specific areas (example of one of the best-adjusted Miombo equation “Guedes et al. 2018” recommended only to estimate biomass in low Miombo of Beira corridor). In addition, if they are applicable to extensive ecosystems, they present a high level of uncertainty (example is the equation of Miombo adjusted by Chaúque 2004, which has R2 = 0.78), which is associated with low representation of species and diameter range of the trees used during equation adjustment. On the other hand, Mugasha et al 2013 used data from 60 species (about half of which occur in Zambézia) from 1 to 110 cm of dbh, coming from Miombo woodland (which according to Chidumayo & Gumbo, 2010 "The Dry Forests and Woodlands of Africa", this forest type are similar in terms of floristic composition and structure to those of Mozambique). In addition, the last paragraph of conclusion of the authors' article where they show no reservations about the use of the equation in other regions of southeastern Africa. Currently the MRV unit has plans to establish MoU with research institutions to develop and/or adjust more accurate allometric equations for various ecosystems in the country, and thus update the emission factors. Since the previous MR (2018) Mozambique has included propagation of this source of error in MC simulations for all the strata and pools for which allometric equations are used. As a result the previous application of increased sampling uncertainty of AGB and BGB (of FSD and FSSV forest types) by 10% at 90% confidence level using the quadrature approach has been removed, with the exception of FSSV BGB, which does not have an allometric equation, but rather uses R:S ratio.			
Sampling	Sampling error is the statistical variance of the estimate of aboveground biomass, dead wood or litter. This source of error is random and is considered to be high and it has been propagated.	H (random/bias)	YES	YES

	The estimation of mean and their respective uncertainties (standard error, sampling error, and confidence interval) for the variables biomass, carbon and carbon dioxide equivalent (above and below ground) for the two strata (semi-deciduous forest and semi-evergreen forest), were done using the forest inventory data analysis approach proposed by Bechtold & Patterson (2005), as suggested by the independent expert (Jim Alegria, ex-US Forestry Service) hired to evaluate the methodology for the inventory.			
Representativeness error	This source of error is related to the representativeness of the estimate which is related to the sampling design. For semi-deciduous and evergreen forest, data are from the Zambézia Forest Inventory. It includes data that was collected in Zambézia province during the NFI, in 2017 and 2018. Although the inventory covers the whole province of Zambézia, this is still representative of the forests located in the ZILMP as forests across the province are homogenous (floristic and structural composition). Moreover, the higher sample size of the inventory covering the whole province will enable more precise estimates for emission factors. This source of uncertainty is considered to be low.	*H/L (bias)*	YES	NO
Integration				
Model error	The combination of AD & EF does not necessarily need to result in additional errors. Usually, sources of both random and systematic error are the calculations themselves (e.g. mistakes made in spreadsheets). The spreadsheets used for activity data and emissions estimation are derived from multiple past implementations and have been refined over several years. The MRV team has implemented an automated script to calculated emissions and uncertainty. This should greatly reduce the possibility of mistakes in the calculations. The outputs of the activity data and emissions spreadsheets were checked against R implementation and they matched. The worksheet for emission factor estimation was developed in consultation with, and checked by, an independent expert (Jim Alegria, ex-US Forestry Service).	*L (bias)*	YES	NO
Integration	This source of error is linked to the lack of comparability between the transition classes of the Activity Data and those of the Emission Factors. Considering the homogeneity of forests in Zambézia, the distinguishing feature of the two land strata (semi-deciduous and evergreen) are the phenological behavior. The *Collect Earth* software provides a time-series of NDVI over the plot, which is used to determine whether a forest is deciduous or evergreen. More detail of this can be seen in our step-by-step description of activity data collection (https://www.fnds.gov.mz/mrv/index.php/documentos/gui	L (bias)	YES	NO

	oes/46-protocolo-de-monitoria-e-estimativa-de-emissoes-por-desmatamento-vjun2021/file).			

5.2 Uncertainty of the estimate of Emission Reductions

Parameters and assumptions used in the Monte Carlo method

Uncertainty in estimates of emission reductions were quantified using a Monte Carlo approach, based on 10,000 random permutations of model parameters (Table 8). The parameter values for AD in the monitoring period are an average of the activity data for 2019 and 2020, as they are calculated in the same way as the reference level AD (sum of area divided by number of years). All Monte Carlo simulation was done using scripts in R (see the full project here)

Several types of Probability Density Functions (PDFs) are used as part of the Monte Carlo simulation. These are:

- t-distribution: Emission factors for FSD and FSSV vegetation classes
- Normal: Emission factors derived from IPCC defaults (cropland, grassland, other land use)
- Uniform: Default root:shoot ratio, for species where local data are not available.
- Non-parametric bootstrapping: Used for activity data.
- Triangular: Carbon fraction derived from IPCC defaults.

In each of these cases, the distributions were selected for their suitability for the data source.

Root to shoot ratio

A uniform distribution is used for estimation of BGB for species where specific local allometric models aren't available (derived from IPCC given the range 0.27 - 0.28). Without further information provided, a uniform distribution was selected for its conservative nature.

Carbon fraction

The triangular distribution used for the carbon fraction was selected to account for the asymmetric nature of the uncertainty range associated with the IPCC default used (0.47 (0.44 - 0.49)). In any case, emissions estimates show very little sensitivity to changes in this parameter (see sensitivity analysis), so it would not be expected that any reasonable alternative PDF would have any impact on overall uncertainties.

Emission factors

FSD/FSSV emission factors use a t-distribution to account for low sample sizes. IPCC tier 1 emission factors are presented with a nominal estimate of error equivalent to two times the standard deviation, for which a normal distribution is considered a reasonable PDF.

Activity data

Uncertainties for activity data were captured using non-parametric bootstrapping, where sample units were resampled (with replacement) from the Collect Earth points. This has the advantage of not needing to specify a PDF a priori, and removing the impact of generating impossible negative areas of deforestation where the uncertainty range crosses 0.

The impact of this decision over two other reasonable approaches (a normal distribution, and a truncated normal distribution removing any negative deforestation areas) was assessed by comparison. In all cases the uncertainty ranges are almost identical, so any reasonable PDF would not be expected to have any impact on overall uncertainty of emissions.

Table 8: Parameter specifications used in the Monte Carlo simulations for the monitoring period.

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Carbon fraction	0.47	Measurement	Triangular (lower bound = 0.44, upper bound = 0.49, mode = 0.47)	(IPCC 2006)
Ratio of molecular weights of CO_2 and C	44/12			Default
Root to shoot ratio	0.275	Measurement	Uniform (lower bound = 0.27, upper bound = 0.28)	(IPCC 2006)
Length of reference period	11 years		-	ER program design
Project area	5310265.16 ha		-	ER program design
Area of FSD>(A|O|U) in reference period	1600.4 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>C in reference period	129635.8 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>P in reference period	19205.3 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>C in reference period	35209.7 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>P in reference period	1600.4 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>C in monitoring period	27838 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>P in monitoring period	288.7 ha	Sampling	Non-parametric bootstrapping	

Area of FSSV>C in monitoring period	2338.6 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>P in monitoring period	205.3 ha	Sampling	Non-parametric bootstrapping	
Aboveground biomass of FSD	144.7 t/ha	Sampling	t-distribution (mean = 144.7, sd = 16.33, df = 28.7)	
Aboveground biomass of FSSV	123.1 t/ha	Sampling	t-distribution (mean = 123.1, sd = 10.73, df = 5.2)	
Aboveground biomass of FF	269 t/ha	Sampling	Normal distribution (mean = 269, sd = 27.03)	
Aboveground biomass of C	10 t/ha	Sampling	Normal distribution (mean = 10, sd = 3.75)	
Aboveground biomass of P	2.3 t/ha	Sampling	Normal distribution (mean = 2.3, sd = 0.86)	
Aboveground biomass of (A|O|U)	0 t/ha	Sampling	Normal distribution (mean = 0, sd = 0)	
Belowground biomass of FSD	49.9 t/ha	Sampling	t-distribution (mean = 49.9, sd = 4.98, df = 25.99)	
Belowground biomass of FSSV	42.1 t/ha	Sampling	t-distribution (mean = 42.1, sd = 3.29, df = 4.01)	
Belowground biomass of FF	85.4 t/ha	Sampling	Normal distribution (mean = 85.4, sd = 10)	
Belowground biomass of C	0 t/ha	Sampling	Normal distribution (mean = 0, sd = 0)	
Belowground biomass of P	6.4 t/ha	Sampling	Normal distribution (mean = 6.4, sd = 3.9)	
Belowground biomass of (A|O|U)	0 t/ha	Sampling	Normal distribution (mean = 0, sd = 0)	

Quantification of the uncertainty of the estimate of Emission Reductions

		Reporting Period	Crediting Period
		Total Emission Reductions	Total Emissions Reductions
A	**Median**	-7,070,898	-10,618,444
B	**Upper bound 90% CI** (Percentile 0.95)	-4,319,200	-1,589,160
C	**Lower bound 90% CI** (Percentile 0.05)	-10,164,970	-21,824,203
D	**Half Width Confidence Interval at 90% (B – C / 2)**	2,922,885	10,117,521.50
E	**Relative margin (D / A)**	0.41	0.95
F	**Uncertainty discount**	8%	15%

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

Sensitivity analysis was conducted by setting one parameter at a time to its nominal value, while retaining uncertainty of all other parameters generated from Monte Carlo (Table 9). The major contributor to uncertainty of ERs was Activity data for the reference period, followed by activity data for the monitoring period. Uncertainty from emission factors and carbon fraction was negligible.

The obvious target for reduction of the uncertainty of the ER estimates would be improving the Reference Level AD uncertainty. The MRV Unit is capable of conducting this improvement, which would rely on post-stratification of deforestation and application of updated QA/QC protocols, which have been improved upon since the collection of the reference data. However, FCPF guidelines preclude technical corrections of the Reference Level after validation and first verification (link).

Table 9: Sensitivity analysis for the monitoring period.

Sensitivity test	Uncertainty estimate					Reduction in confidence interval (%)
	Median	Lower bound (5th percentile)	Upper bound (95th percentile)	Half-width confidence interval at 90%	Relative Margin	
Nominal	-7,070,897.51	-10,164,970.1	-4,319,200.05	2,922,885.06	0.41	0
AD (reference)	-7,055,115.68	-9,696,377.60	-4,800,028.29	2,448,174.65	0.35	16.2
AD (monitoring)	-7,097,507.80	-9,227,301.14	-5,138,684.62	2,044,308.26	0.29	30.1
EF AGB	-7,094,266.00	-9,802,327.17	-4,512,170.11	2,645,078.53	0.37	9.5
EF BGB	-7,074,069.24	-10,121,245	-4,332,138.87	2,894,553.11	0.41	1
CF	-7,116,571.03	-10,227,787.77	-4,370,700.15	2,928,543.81	0.41	-0.2

6 TRANSFER OF TITLE TO ERS

6.1 Ability to transfer title

In Mozambique, the main legal and regulatory frameworks concerning to the land and forests that support the Program Entity ability to transfer title to ERs are: **The Constitution of the Republic of Mozambique (CRM, 2004), the Law on Forests and Wildlife (1999), the Land Law (1997) and the REDD+ Decree (2018).** The REDD+ Decree provides all the principles and procedures to be respected for the design and implementation of the ER Program. It deals with, inter alia: (i) the institutional framework, which is greatly clarified; (ii) the process for the approval and issuing of licenses for projects involving carbon credits and the procedures for the approval of REDD+ projects, putting great emphasis on community consultations; (iii) **establishes the uncontested ownership of ER titles to the State of Mozambique**; and (iv) **details administrative procedures for the management of the ER Transactions Registry and the REDD+ Project and Data Management Registry**.

In Mozambique, **Carbon is a State property** - Carbon is a constituent element of forests. If carbon is seen a constituent part of all natural resources, which exists per se, current constitutional and sectorial legislation is adequate for establishing that ownership over carbon resides with the State. The starting point is Article 98 of the CRM, of which the clause 1 clearly states: "Natural resource in the soil and the subsoil, in inland waters, in the territorial sea, on the continental shelf and in the exclusive economic zone shall be the property of the State". In addition, Article 102 of the CRM goes on to say that "The State shall promote the knowledge, surveying and valuing of natural resources, and shall determine the conditions under which they may be used and developed subject to national interests".

The concept of "use and development" of natural resources - The intention of the Constitution in this overall context is clear: **the State as owner shall determine how natural resources are "used and developed" and, further, this determination can include selling the natural resource once it has gone through this process of "use and development"**. In other words, the carbon can be sold if it is subject to some sort of **conversion or transformation into a marketable commodity.** In the specific context of natural forests, which are State property, and which are in the public domain, the key legislation is the 1999 Forest and Wildlife Law (Law 10/99), which gives mandated agencies in the Government the right to assess requests to "use and develop" natural resources.

ERs are products of "use and development" of carbon natural resources - Precisely, ERs can be seen as a product of this "use and development" process. ERs are not a natural resource, as opposed to carbon: they are the outcome of a decision by the State and/or others with rights over natural resources, and can only be produced by a transformational process or action implying to reduce deforestation and forest degradation. As such, they could be considered as "environmental commodities", identifiable and marketable in their own right. As a consequence, the CRM and existing natural resources laws are sufficient for determining ownership of ERs through the application of the "use and development" concept: the "user and developer" of the natural resources (in this case, forest carbon stocks) implements activities that result in ERs being produced.

Until recently, State ownership of ERs was only clearly established by law for those generated within conservation areas. Although this right seems clearly established for conservation areas such as Gilé National Park where, in principle there will be few, if any, other pre-existing rights or claims over the resources in question, this may not have been true for other types of areas. In this situation, potential claims of rights on the ERs could have led the GoM to negotiate partnership or intermediation agreements with potential DUAT holders. Given the unfamiliar nature of the carbon and ER issues, it was therefore forecasted that specific legislation could greatly clarify the question of title and ER sales.

The REDD+ Decree clearly establishes State property on all ER generated in the country (Articles 4 and 6): although non-state DUAT holders and communities will have to benefits from the sale of ERs generated in the country, through specific benefit sharing plans, no formal agreements will need to be reached between each individual DUAT holders or local communities and the State. However, they will have to be properly consulted, as per national law. In order that the process has been implemented, taking into account national legislation, several meetings have taken place, between 2018 and 2019, from where 564 individuals participated in 6 consultation events at national, provincial and district level. The main objectives of these consultations were to discuss the program approach, the percentages of benefit allocation to each group of beneficiaries, allocation models/processes, priorities areas and benefits sharing challenges of the Benefit Sharing Plan (BSP). For further details of public consultations, please see on the following site below[10]:

As such, the REDD+ Decree clarifies the **"legitimacy and ownership of the State in the creation, generation, emission, validation, verification and withdrawal of emission reductions and corresponding titles of emission reductions" (Article 4).** As such, in the current ER Program in Mozambique, the State retains control over the remaining natural forests and ownership over the ERs that are generated and the GoM, promoting behavioral change on the part of forest users, and is therefore free to sell the titles over these ERs, following the arguments presented above. Furthermore, the ability of the State of Mozambique to dispose of ER titles as financial products that can be traded is established in the REDD+ Decree, which states that ER titles "**may be disposed of, transferred to national and international exchanges of environmental and financial assets, under the applicable laws and standards and within the limits of the current national legislation**" and that such ER titles "**may also be transferred and offset in future under the international agreements concluded by the State of Mozambique within the framework of its international competences and its commitments and cooperation programs with public and private entities**" **(Article 15).** In the same way, Article 7 of the REDD+ Decree confirms that, for the implementation of REDD+ programs and projects, "The government can sign compensation agreements with international partners".

Admittedly, the overall ability of the State to transfer the titles over ERs requires these ERs to be monitored, reported, verified and certified accordingly with UNFCC procedures and FCPF CF methodological guideline. The discussion of certification and negotiations underlines how the Ministry of Economy and Finance (MEF) is really the entity able to enter into international negotiations over ER titles transfers, whenever the ERs are generated. As stated in the REDD+ Decree, "**The Ministry responsible for the financial sector is the legitimate issuer and manager of the Titles of Emission Reductions, being able to create and manage property rights, including the validation, verification, emission, transfer, transaction and withdrawing of the titles of emission reductions at national and international level" (Article 6).** In the context of the ER Program, the MEF was therefore the ER Program entity authorizing the ER Program and signing the ERPA with the FCFP CF. According to the administrative and legal procedures, the title of ERs is registered and ERs certificates issued by the MEF, after validation and verification of the monitoring report, provided by FNDS. Until now, MEF has not ER Transaction Registry established. However, FNDS is committed to working with the MEF, this year, in order to speed up the process of registering transactions. **As such, the MEF will be responsible the sale of ERs to the Carbon Fund.**

This REDD+ Decree clarifies the institutional arrangements for the implementation of REDD+ projects in Mozambique and clearly specifies the responsibilities of the FNDS and other key institutions. The institutional arrangement for the ER Program will fully respect the layout describes in the REDD+ Decree. According to the REDD+ Decree, The Ministry of Economy and Finance (MEF) is responsible for signing the Emission Reduction Payment Agreement (ERPA) with the FCPF CF ERPA and management of ER Titles transfer. FNDS will work closely with the MEF after the verification process, in order to provide technical support on this process.

Prior to the establishment of ZILMP, there was a VCS REDD project, called the Gilé National Reserve REDD Project, which was developed in the buffer zone of the Gilé National Park[11], Zambézia Province (Figure 12). This Park is managed by the National Administration of Conservation Areas (ANAC). It is a national public agency that is responsible for the management of protected areas, and the project proponent of the above REDD Project.

This project was originally designed to have a crediting period of 20 years, from January 1, 2012, until December 31, 2031. However, once the ZILMP project was being developed, it became clear that, since the Gilé National Reserve REDD Project was fully included in the ZILMP program area, it would no longer be able to generate Carbon Credits from the date of the start of the ZILMP project. This is made clear in the project's PDD[12]. The project was successfully validated for the monitoring period of 01-January-2012 to 31-December-2016. It is

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[10] https://docs.google.com/spreadsheets/d/1LOo1dvQyUOXMHOU20Djg61E3ECM7OgDbJEhf68jPZ5c/edit?usp=sharing

[11] Previously it was known as the Gilé National Reserve

[12] Sections 1.8.5 and 1.12.4 of joint PD & monitoring report (doc. Ref. 1) https://registry.verra.org/app/projectDetail/VCS/1674

currently inactive for the duration of the ZILMP ERPA. This project is registered in the (http://bit.ly/sistemaregistoREDD). Several meetings between ANAC and FNDS have occurred in order to prevent double counting and a conflict of interest between the two REDD Programs.

Other than the Gilé National Park REDD Project, the program has not become aware of an inability or any contesting party during this reporting period, also there has not been any challenge, no one disputing the REDD+ decree and no title contested".

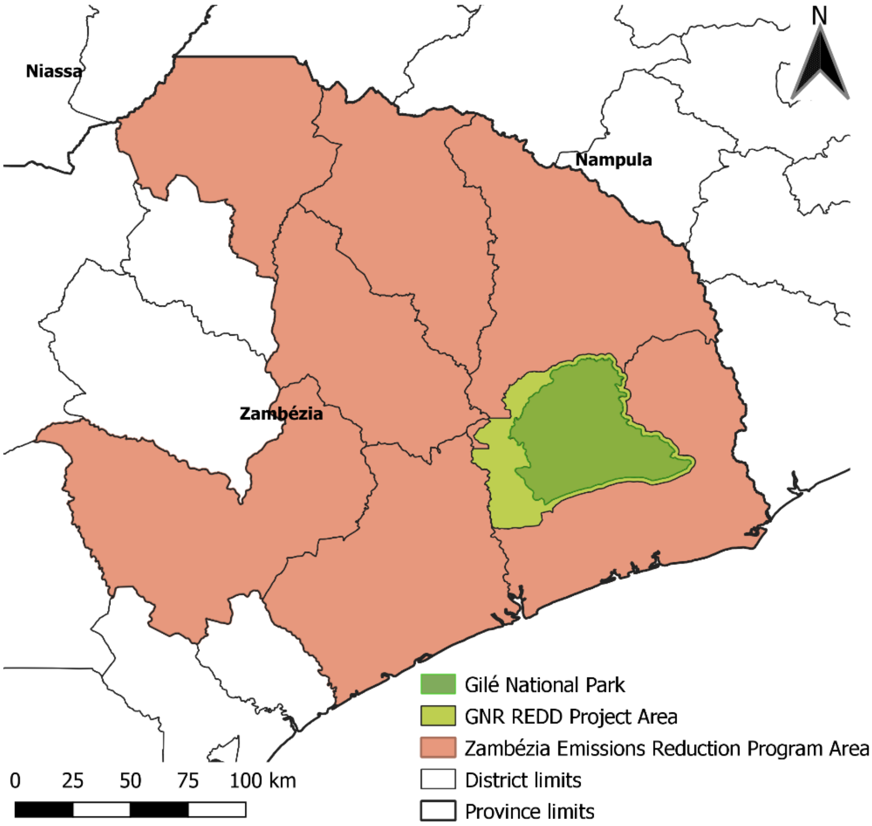


Figure 12: Location of Gilé National Reserve REDD Project Area (buffer zone of Gilé National Park) and Zambézia Emissions Reduction Program Area.

6.2 Implementation and operation of Program and Projects Data Management System

The National Fund for Sustainable Development (FNDS) will be in charge of supervising and coordinating the ER Program at central level. As such, in the REDD+ Decree, the FNDS is confirmed as the entity in charge of approving all REDD+ programs and projects in Mozambique and in charge of managing REDD+ resources. As clarified in the REDD+ Decree (Article 10), the FNDS supports all institutions engaged in REDD+ policies. Its main responsibilities are:

a. Establish, operationalize and ensure the maintenance of the components of the National MRV System;

b. Propose and approve standards and technical methodologies for establishing the levels of reference, the monitoring, the evaluation of emission reductions, the reporting, the verification and the validation of REDD+ programs and projects;

c. Receive, assess and evaluate the REDD+ projects proposals and annual monitoring reports;

d. Monitor the reduction of greenhouse gas emissions and the achievements of ERs objectives of REDD+ projects;

e. Management of the Safeguards Information System (SIS), including the REDD+ Feedback and Grievance Mechanism (FGRM);

f. Enable the dissemination of data and relevant information on REDD+ projects, which should be made public respecting the policies of intellectual property privacy established with the different actors; (vii) To disseminate all information on the Programs and Projects and their social and environmental safeguards, Dialogue Mechanism and Complaints on existing platforms and their benefit sharing plan. With regard to the ER Program, the FNDS will therefore play a crucial role in the monitoring of the ERs generated by the ZILMP and of the safeguard policies - see section 14. In addition, and importantly for the ER Program, as stated in the REDD+ Decree (article 10) the FNDS is responsible for

g. Managing the national REDD+ Programs and Projects Data Management System and for

h. Communicating to the entity in charge of the ER Transactions Registry all information related to ERs generated by REDD+ projects – this is the MEF.

According to the REDD+ Decree (article 10), the **FNDS will be responsible for managing the national REDD+ Programs and Projects Data Management System** and for communicating to the entity in charge of managing the ER Transactions Registry (who will be the MEF, according to the same decree – Articles 14 and 26) all information related to ERs generated by REDD+ projects, including by the Zambézia Emission Reduction Program.

Mozambique is developing and implementing its own comprehensive national REDD+ Program and Projects Data Management System. The system is hosted and managed by FNDS as per de REDD+ decree "the FNDS is responsible for (vi) managing the national REDD+ Programs and Projects Data Management System and for (vii) communicating to the entity in charge of the ER Transactions Registry all information related to ERs generated by REDD+ projects". Currently the system is implemented through a WebGIS platform (https://bit.ly/srppmozfnds) alongside with the NFMS and the projects M&E Web portal. The system is still under development, as currently Mozambique only has one ER program.

The actual Content of the REDD+ Program and Project Data Management System is below:

- The proponent of the ER Program or project;
- Geographical boundaries of the ER Program or project;
- Scope of REDD+ activities and Carbon Pools;
- The Reference Level used;
- MRV data to specific REDD+ projects/programs; and
- Safeguards plans in specific REDD+ projects/programs

6.3 Implementation and operation of ER transaction registry

As mentioned at 6.1, in this report, only after the approval of the REDD + decree in 2018, this is the first program to be implemented in the country. For this reason, it is still preparing to implement and operationalize the registration of ER transactions for future programs. Thus the GoM has decided to use a centralized ER Transaction Registry managed by a third party on its behalf: **the GoM will use the CATS Transaction Registry**.

6.4 ERs transferred to other entities or other schemes

The Zambézia Emission Reduction Program is the first REDD+ program that occurs in Mozambique, after the approval of the Monitoring report and according with Contract ER, the volume will be transferred to the FCPF CF on a 100% basis. No ERs will be transferred to other entities during the crediting period.

As mentioned in section 6.1, there is a prior REDD project within ZILMP, but it is currently inactive and only generated Emission Reductions from 1 January 2012 to 31 December 2016.

7 REVERSALS

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

A study carried out in the program area shows that shifting cultivation is the main cause of deforestation, contributing to more than 80% of the total deforestation in the program area. Of particular importance is an increase in the production of pigeon pea inside and outside the program area to later be exported to Asia through local intermediaries. The results obtained during the study by the MRV unit are available here:

https://storymaps.arcgis.com/stories/8ffacb098c97469e897a94cd596da01a

It is also speculated that the COVID-19 pandemic triggered a series of socioeconomic impacts that may have contributed to the increase in deforestation in vulnerable communities. Economic restrictions, lack of supervision, displacement of workers and the search for alternative sources of income may have led to deforestation practices for subsistence, which possibly contributed to an increase in deforestation in reporting period: 2020, 2021 and 2022, but with a small downward trend in 2022 (year in which COVID-19 pandemic restrictions reduced).

This possible impact of COVID-19 is supported by anecdotal evidence collected in the field, specifically during the country visit in the previous verification report. We interviewed farmers who had recently opened new agricultural areas around the city of Mocuba and at least one reported that they had lost their income in the city as a result of COVID-19 impacts.

7.2 Quantification of Reversals during the Reporting Period

A.	**ER Program Reference level for this Reporting Period (tCO_2-e)**	*from section 4.1*	**10,506,535.98**	
B.	**ER Program Reference level for all previous Reporting Periods in the ERPA (tCO2-e).**	*from previous ER Monitoring Reports*	15,759,803.97	+
C.	**Cumulative Reference Level Emissions for all Reporting Periods [A + B]**		26,266,339.95	
D.	**Estimation of emissions by sources and removals by sinks for this Reporting Period (tCO_2-e)**	*from section 4.2*	17,970,736.00	

E.	**Estimation of emissions by sources and removals by sinks for all previous Reporting Periods in the ERPA (tCO_2-e)**	*from previous ER Monitoring Reports*	11,613,545.53	
F.	**Cumulative emissions by sources and removals by sinks including the current reporting period (as an aggregate accumulated since beginning of the ERPA) [D + E]**		29,584,281.53	–
G.	**Cumulative quantity of Total ERs estimated including the current reporting period (as an aggregate of ERs accumulated since beginning of the ERPA) [C – F]**		-3,317,941.57	
H.	**Cumulative quantity of Total ERs estimated for prior reporting periods (as an aggregate of ERs accumulated since beginning of the ERPA)**	*from previous ER Monitoring Reports*	4,146,258.45	–
I.	**[G – H], negative number indicates Reversals**		-7,464,200.02	
If I. above is negative and reversals have occurred complete the following:				
J.	**AMoUnt of ERs that have been previously transferred to the Carbon Fund, as Contract ERs and Additional ERs**		2,524,661	
H.	**Quantity of Buffer ERs to be canceled from the**		4,544,960	

Reversal Buffer account **[J / H × (H – G)]**		

7.3 Reversal risk assessment

The reversal risk assessment using the CF Buffer Guidelines has changed since the preparation of the revised final ERPD. Due to the COVID situation, the Validation and Verification Body (VVB) was not able to conduct a country visit which could constrain the assessment process. However, it was identified that the assessment of the Risk Factor "Lack of broad and sustained stakeholder support" could not be concluded with a reasonable level of assurance without a country visit. In order to solve this, the reversal risk for this factor has been changed to the highest possible, at 10%.

It is important to note that the estimate provided in the revised final ERPD is conservative as required by the Carbon Fund Participants through resolution CFM/17/2018/1.

Risk Factor	**Risk indicators**	**Default Reversal Risk Set-Aside Percentage**	**Discount**	**Resulting reversal risk set-aside percentage**
Default risk	*N/A*	**10%**	*N/A*	10%
Lack of broad and sustained stakeholder support	• Existence of a transparent Benefit Sharing Mechanism • Existence of legal mechanism for the systematization of community consultation • Signature of MoU with implementing partners Existence of a Feedback and Grievance Redress Mechanism during the ER Program implementation, likely to generate the implementation of long-term efficient practices beyond the project life time • Existence of consultative forums and platforms involving various stakeholders with concrete and immediate perception of benefits, likely to make consultation become a long-term concern (including out of the scope of the ER Program) • Implementation of an efficient and large enough land titling and delimitation process to ensure stability of land rights in the long run	**10%**	Reversal risk is considered High: 10% discount	10%
Lack of institutional capacities and/or ineffective vertical/cross sectorial coordination	• Existence of designated and empowered relevant structure for ER Program implementation • Experience in multi-sectorial project implementation • Experience of collaboration between different levels of government • Existence of dedicated mechanism or body for inter-sectorial cooperation	**10%**	Reversal risk is considered Medium: 5% discount	5%

	● Support from additional projects and programs for institutional capacities strengthening ● Deployment of relevant staff on the ground ● Training for long-term capacities on forest management and monitoring			
Lack of long term effectiveness in addressing underlying drivers	● Experience in decoupling deforestation and degradation from economic activities ● Support from completing projects and programs oriented on deforestation and forest degradation reduction ● Existence of a relevant legal and regulatory environment conducive to REDD+ objectives in the long run ● Creation of relevant incentives for adoption of sustainable agricultural practices in the long run, including beyond the project lifetime ● Clear perception of non-carbon benefits for stakeholders at long term and especially beyond the terms of the ERPA ● Deployments of efficient and committed extension-agents at long-term ● Adaptation of promoted sustainable practices to local constraints and dynamic in order to make it possible for them to be maintained in the long run ● Potential administrative changes are expected to be progressive and participatory. However, potential risk may exist due to the fact that the ER program area doesn't cover the whole Province and additional coordination might be required. ● Well defined structures to ensure ensures the continuation of the ER Program beyond government term ● Pre-identification of financing sources	**5%**	Reversal risk is considered High: 0% discount	5%
Exposure and vulnerability to natural disturbances	● Vulnerability to fires, storms and droughts ● Capacities and experiences in effectively preventing natural disturbances or mitigating their impacts ● Promotion of climate smart agricultural practices ● Existence of a Pest Management Plan	**5%**	Reversal risk is considered High: 0% discount	5%
		Total reversal risk set-aside percentage		35%

Total reversal risk set-aside percentage from ER-PD or previous monitoring report (whichever is more recent)	35%

8 EMISSION REDUCTIONS AVAILABLE FOR TRANSFER TO THE CARBON FUND

A.	**Emission Reductions during the Reporting period (tCO_2-e)**	*from section 4.3*	- -7,464,200.0
B.	**If applicable, number of Emission Reductions from reducing forest degradation that have been estimated using proxy-based estimation approaches (use zero if not applicable)**		0
C.	**Number of Emission Reductions estimated using measurement approaches (A-B)**		-7,464,200.0
D.	**Percentage of ERs (A) for which the ability to transfer Title to ERs is clear or uncontested**	*from section 6.1*	100%
E.	**ERs sold, assigned or otherwise used by any other entity for sale, public relations, compliance or any other purpose including ERs accounted separately under other GHG accounting schemes or ERs that have been set-aside to meet Reversal management requirements under other GHG accounting schemes .**	*from section 6.4*	0
F.	**Total ERs (B+C)*D-E**		-7,464,200
G.	**Conservativeness Factor to reflect the level of uncertainty from non-proxy based approaches associated with the estimation of ERs during the Crediting Period**	*from section 5.2*	15%

H.	**Quantity of ERs to be allocated to the Uncertainty Reversal Buffer (0.15*B/A*F)+(G*C/A*F)**	*From section 6.4*	-1,119,630
I.	**Total reversal risk set-aside percentage applied to the ER program**	*From section 7.3*	0.35
J.	**Quantity of ERs to allocated to the Reversal Buffer (F-H)*(I-5%)**		-1,903,371
K.	**Quantity of ERs to be allocated to the Pooled Reversal Buffer (F-H)*5%**		-317,229
L.	**Number of FCPF ERs (F-H-J-K)**		-4,123,970.5

ANNEX 1: INFORMATION ON THE IMPLEMENTATION OF THE SAFEGUARDS PLANS

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

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

ANNEX 5: ER MONITORING REPORT (ER-MR) ON THE AREA OUTSIDE THE SCOPE OF ZAMBÉZIA INTEGRATED LANDSCAPE MANAGEMENT PROGRAM (ZILMP)

This annex was prepared as part of the Government's commitment to monitor and report in parallel the annual emissions reduction in the area outside the scope of Zambézia Integrated Landscapes Management Program (ZILMP) within the Zambézia province under the Emission Reductions Purchase Agreement (ERPA) signature.

5.1CARBON POOLS, SOURCES AND SINKS

5.1.1 Description of Sources and Sinks selected

Sources/Sinks	Included?
Emissions from deforestation	Yes
Emissions from forest degradation	No
Enhancement of carbon stocks	No
Sustainable management of forests	No
Conservation of carbon stocks	No

5.1.2 Description of carbon pools and greenhouse gases selected

Carbon Pools	Selected?
Above Ground Biomass (AGB)	Yes
Below Ground Biomass (BGB)	Yes
Biomass in non-woody vegetation	No
Dead organic matter	No
Soil Organic Carbon (SOC)	No

GHG	Selected?
CO_2	Yes
CH_4	No
N_2O	No

5.2 REFERENCE LEVEL

5.2.1 Reference Period

The reference period is from 2005 – 2015 (11 years).

5.2.2 Forest definition used in the construction of the Reference Level

According to the national REDD+ strategy and to the Final Report on Forest Definition (Falcão and Noa, 2016) approved by MITADER in November 2016, forest in Mozambique is defined as followed: **minimum area of 1 ha, minimum height at maturity of 3 m and minimum tree cover of 30%**.

The previous GHG inventories used the previous forest definition of Mozambique (minimum area of 0.5 ha, minimum height of 5m and minimum tree cover of 10%). However, future GHG inventories will use the updated forest definition.

5.2.3 Average annual historical emissions over the Reference Period

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

The UNFCCC does not give any directives with regards to the reference period for the RL. However, the Forest Carbon Partnership Facility (FCPF) have specific guidelines, setting a minimum of 10 years and a maximum of 15 years. The chosen period for the construction of the RL is from 2005 to 2015, 11 years.

In accordance with the UNFCCC decisions, the method used to assess emissions is the one described in IPCC (2006) for Land (Forest land in the present case) converted to other land use (e.g., croplands, grasslands, etc.) consisting on the multiplication of activity data – area of land converted from forest land to other land (e.g., cropland or grassland in the present case) – by emission factors – difference of carbon stocks before and after deforestation – as presented on the following equations. The data used for the present document are Tier 2 (country specific data or country level estimates) or Tier 3 (data specifically produced for the ER Program) when possible. Activity data are produced on the reference period with spatially explicit method based on available satellites images. Emissions factors are derived from literature or forest inventory in the accounting area.

In compliance with criterion 13 of FCPF MF (FCPF, 2016) that specifies that RL should not exceed the average annual historical emissions, different activity data of the reference period will be averaged to produce annual deforestation areas over the whole period.

As analysis is done over the reference period, long term (11 years) changes (increase or decrease) of carbon stocks on deforested areas (land converted to another land use) are considered instead of annual increase or decrease - see the **Equation 16**.

Gross emissions of the RL from deforestation over the Reference Period (RL_{RP}) are estimated as the sum of annual change in total biomass carbon stocks (ΔC_{B_t}) during the reference period as shown in the equation below.

$$RL_{RP} = \frac{\sum_{t}^{RP} \Delta C_{B_t}}{RP}$$

Equation 15

Where:

ΔC_{B_t} = Annual change in total biomass carbon stocks at year *t; tC*year^{-1};*

RP = Reference period, *years.*

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

$$\Delta C_{B_t} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$ ***Equation 16***

Where:

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

Following the recommendations set in chapter 2.2.1 of the GFOI Methods Guidance Document for applying IPCC Guidelines and guidance in the context of REDD+[13], the above equation will be simplified and it will be assumed that:

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

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

$$\Delta C_{B_t} = \sum_{j,i} \left(B_{Before,j} - B_{After,i} \right) x\ CF\ x \frac{44}{12} \times A(j,i)_{RP}$$ ***Equation 17***

Where:

$A(j,i)_{RP}$	Area converted/transited from forest type *j* to non-forest type *i* during the Reference Period, in *hectares per year*. In this case, three forest land conversions are possible: • (Semi-)deciduous forest to Non-forest type *i*; • (Semi-)evergreen forest to Non-forest type *i*; and • Mangrove forest to Non-forest type *i*. Five types of non-forest land are considered: • Cropland (C); • Grassland (P); • Wetland (A); • Settlement (U); and • Other lands (O). •
$B_{Before,j}$	Total biomass of forest type *j* before conversion/transition, in tons of dry matter per ha. This is equal to the sum of aboveground ($AGB_{Before,j}$) and belowground biomass ($BGB_{Before,j}$) and it is defined for each forest type.
$B_{After,i}$	Total biomass of non-forest type *i* after conversion, in *tons dry matter per ha*. This is equal to the sum of aboveground ($AGB_{After,i}$) and belowground biomass ($BGB_{After,i}$) and it is defined for each of the five non-forest IPCC Land Use categories.
CF	Carbon fraction of dry matter in tC per ton dry matter. The value used is: • **0.47** is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.
$44/12$	Conversion of C to CO_2

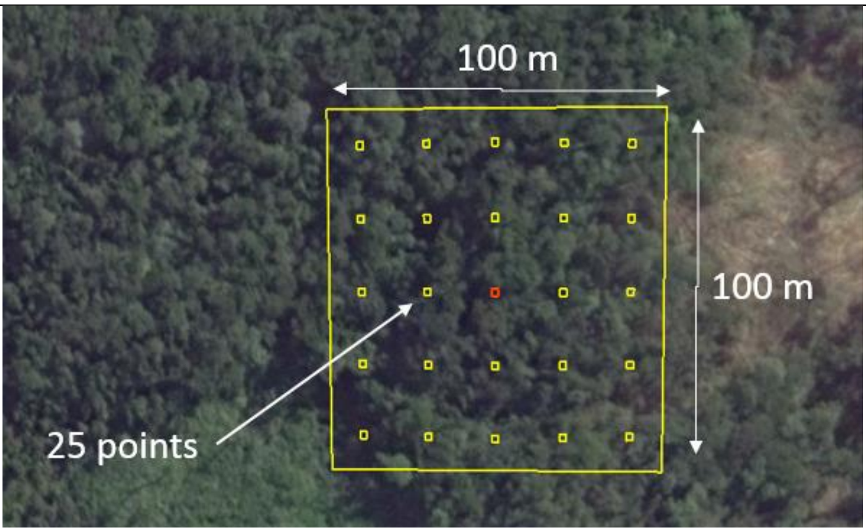
---

[13] https://www.reddcompass.org/documents/184/0/MGD2.0_English/c2061b53-79c0-4606-859f-ccf6c8cc6a83

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

Activity data

Parameter:	*A(j,i)*$_{RP}$
Description:	Area converted from forest type *j* to non-forest type *i* during the reference period.
Data unit:	hectare per year.
Source of data and description of measurement/calculation methods and procedures applied:	***i. Approach and source*** Activity data for deforestation were obtained from an annual historical time series analysis of land use, land-use change and forestry (LULUCF) carried out by five trained operators in approximately 98 effective working days (4.4 months), for the period of 2001 – 2016 across the country, using the Collect Earth Open tool. Activity data have been generated following IPCC Approach 3 for representing the activity data as described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 3, Section 3.13), i.e., using spatially-explicit observations of land-use categories and land-use conversions over time across the country, derived from sampling of geographically located points. The result was forest cover data for 2016 and forest cover change data for every year from 2001 to 2016. The period of AD analysis from 2005 to 2015 (11 years) considered for the ER in the area outside the scope of ZILMP within the Zambézia province, could be adapted within the general period 2001 – 2016 with little effort, due to the operators collecting the date of the LULC change. ***ii. Sampling design*** A systematic 4 x 4 km grid consisting of a total of 48, 894 sampling points was established at a national level to generate the historical activity data for the entire area of the country using high and medium resolution imagery, which is the same grid used to allocate the NFI clusters from the Stratified Random Sampling design. At jurisdictional level, this corresponds to 2,984 points being interpreted. Each sampling point was visually assessed and its information was collected and entered in a complete database on LULC changes at the national level. ***iii. Response design*** <u>Spatial sampling unit</u> The spatial sampling unit from each point was defined as a point with a spatial support consisting of a 100m x 100m plot (1 ha), where an internal grid of 5 x 5 points (20m x 20m grid) is overlapped. Each point from the internal grid has a weight coverage of 4% (Annex-Figure 1).



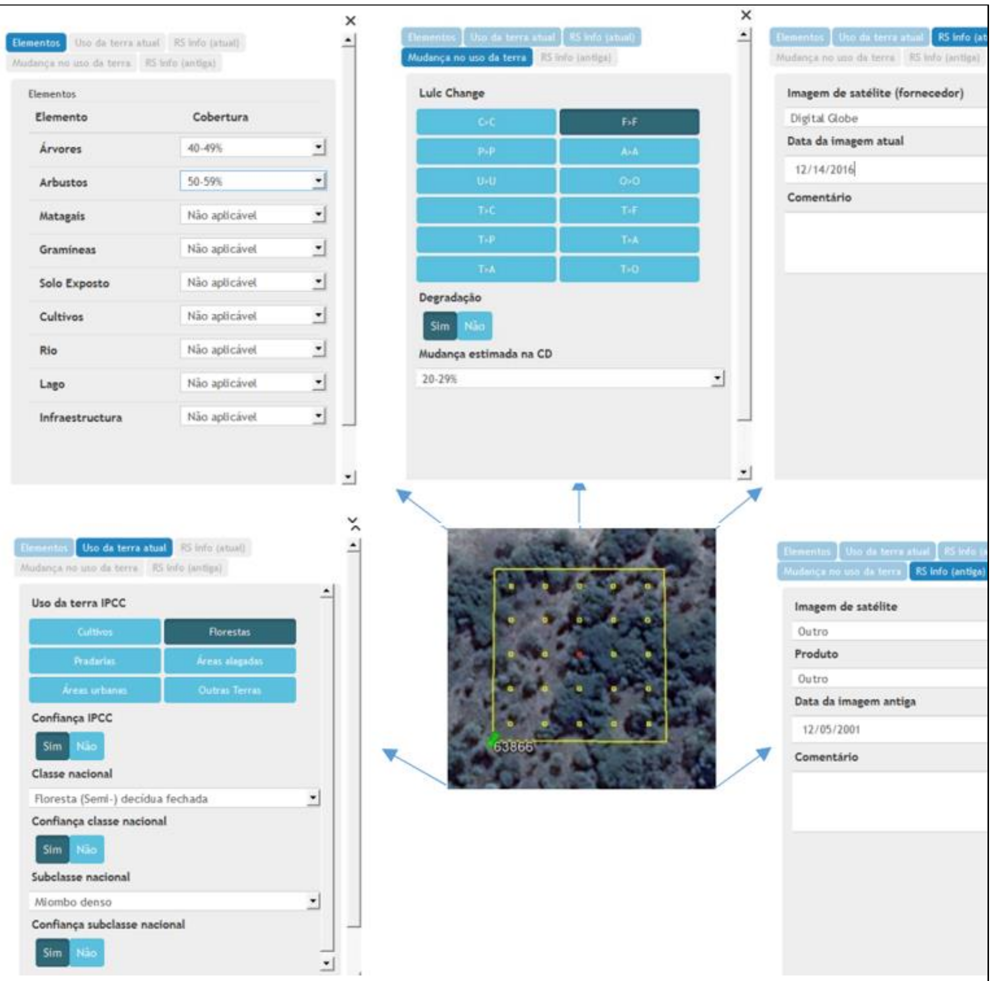
Annex-Figure 1: Spatial sampling unit

<u>Source of reference data</u>

The sampling approach for historical AD calculation based on the regular National 4 x 4 km grid has been designed and conducted using the high and medium resolution images repository available through Google Earth and Earth Engine as a visual assessment exercise. These imagery with digital forms (Annex-Figure 2) designed to collect the LULCC information on the points of the grid are automatically accessible through the Collect Earth tool (www.openforis.org) along with scripts accessible through Earth Engine code that facilitate vegetation type's interpretation (e.g. MODIS or Landsat NDVI time series). Each point of the grid is photo-interpreted thanks to Collect Earth tool and the year and type of changes are also collected.

The use of various scripts programmed on Earth Engine Code facilitates the interpretation of the vegetation type and the determination of LULC changes. Specifically, the MOD13Q1 (NDVI 16-day Global Modis 250 m) graphic from 2001-2016, most recent Sentinel-2 image, most recent Landsat-8 pan sharpened image, Landsat-7 pan sharpened image (2000, 2004, 2008, 2012), etc.

The completeness of the series is guaranteed using remote sensing products from medium resolution imagery repositories from 2001 (e.g. Annual TOA Reflectance Composite, Annual NDVI Composite, Annual EVI Composite, Annual Greenest-Pixel TOA Reflectance Composite, etc. from Landsat 5 TM) and the most recent Sentinel-2 image from 2016. In this way, a temporal analysis of LULC changes has been completed for each sampling point of the national 4 x 4 km grid (48,894 records).



Elementos

Elemento	Cobertura
Árvores	40-49%
Arbustos	50-59%
Matagais	Não aplicável
Gramíneas	Não aplicável
Solo Exposto	Não aplicável
Cultivos	Não aplicável
Rio	Não aplicável
Lago	Não aplicável
Infraestructura	Não aplicável

Degradação: Sim

Mudança estimada na CD: 20-29%

Imagem de satélite (fornecedor): Digital Globe

Data da imagem atual: 12/14/2016

Comentário:

Confiança IPCC: Sim

Classe nacional: Floresta (Semi-) decidua fechada

Confiança classe nacional: Sim

Subclasse nacional: Miombo denso

Confiança subclasse nacional: Sim

Imagem de satélite: Outro

Produto: Outro

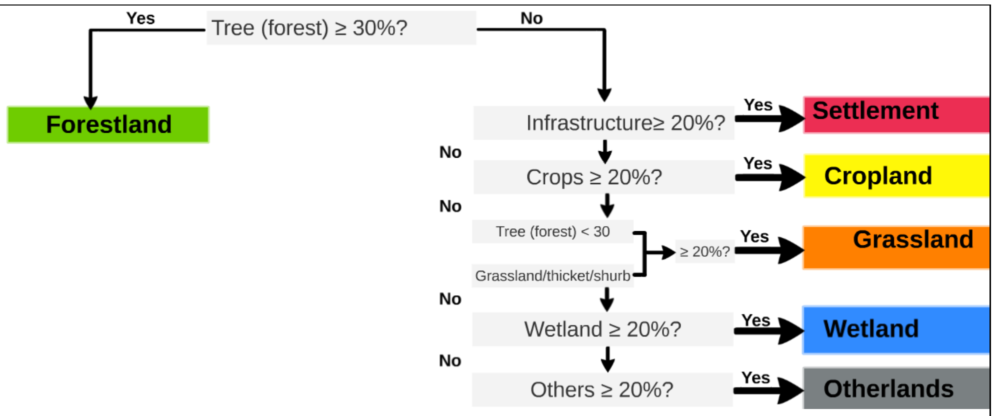
Data da imagem antiga: 12/05/2001

Comentário:

Annex-Figure 2: LULCCF detection using Collect Earth Tool (www.openforis.org). Digital forms designed with Collect Tool.

Reference labelling protocol

The activity data was generated considering the national land use and land cover classification system, which reflects the six broad IPCC Land Use categories. A set of hierarchical rules were established and used to determine the LULCCF category based on a certain percentage and taking into account the national forest definition as well (Annex-Figure 3). A single land use class is easier to classify, but it becomes challenging when there is a combination of two or more land use classes within the area of interest. Thus, this is where the hierarchical rules are important to determine the land use. Any sampling unit that has 30% of tree canopy cover is considered a forest, according to the national forest definition, even if it has more than 20% of settlements, crops or other land use, the forest is priority. In the case the sampling unit was classified as forest land and different forest types were present in the sampling unit, a majority rule was used in this case, i.e. the largest forest cover class is considered as forest type within the plot.



Annex-Figure 3: Decision tree for the attribution of the LULCCF category based on the percentage cover of the elements present in the sampling unit of 1 ha.

iv. Analysis

The estimation of the areas corresponding to a certain category changes from a forest type to a non-forest type in the framework of this systematic sampling approach was based on assessments of area proportions. According to 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 3, Section 3.33), the proportion of each land-use or land-use change category is calculated by dividing the number of points located in the specific category by the total number of points, and area estimates for each land-use or land-use change category are obtained by multiplying the proportion of each category by the total area of interest, in this case, the area outside the scope of ZILMP within the Zambézia province.

$$A_i = p_i \times A$$ ***Equation 18***

Where:

A_i	Area estimate on forest type *j* converted to non-forest type *i;* hectare
p_i	Proportion of points on forest type *j* converted to non-forest type *i;* dimensionles
A	Total area of interest; hectare

$$p_i = \frac{n_i}{N}$$ ***Equation 19***

Where:

n_i	Number of points on forest type *j* converted to non-forest type *i;* number
N	Total number of points; number

The standard error (ha) of an area estimate was obtained as (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 3, Section 3.33):

$$e_i = A_i \times \sqrt{\frac{p_i \times (1 - p_i)}{N - 1}}$$ ***Equation 20***

Where:

A	Area of interest, ha.
p_i	Proportion of points on land use change category *i*, dimensionless.
n	Number of sampling units, number.

The 90% confidence interval for A_i, the estimated area of land-use category i, was given approximately by ±1.64 times the standard error.

Value applied

Type of change	2005-2015
Semi-deciduous forest to cropland	17,505.56
Semi-deciduous forest to grassland	2,435.56
Semi-deciduous forest to other lands	0.00
Evergreen forest to cropland	4,566.67
Evergreen forest to grassland	152.22
Evergreen forest to other lands	152.22
Mangrove forest to cropland	0.00
Mangrove forest to grassland	152.22
Mangrove forest to other lands	304.44

QA/QC procedures applied:

Quality Control consisted in having a team of 5 technicians with experience in forests and remote sensing, all trained together by an MRV specialist. The team worked in the same office, and discussed any classification issues with each other.

Quality Assurance was conducted using the SAIKU extension of Collect Earth. This tool allows the detection of whether:

i) Data point was not filled
ii) The class assigned followed the classification hierarchy, based on the % of individual element cover
iii) Year of the Old image/Change image was less than the current image
iv) Change classes are consistent with previous and current classes
v) Open and closed forest was correctly classified, based on the 30% (open) and 65% (closed) cover threshold

In the case of any error being detected, the ID of the data point was registered and the user performed the necessary corrections.

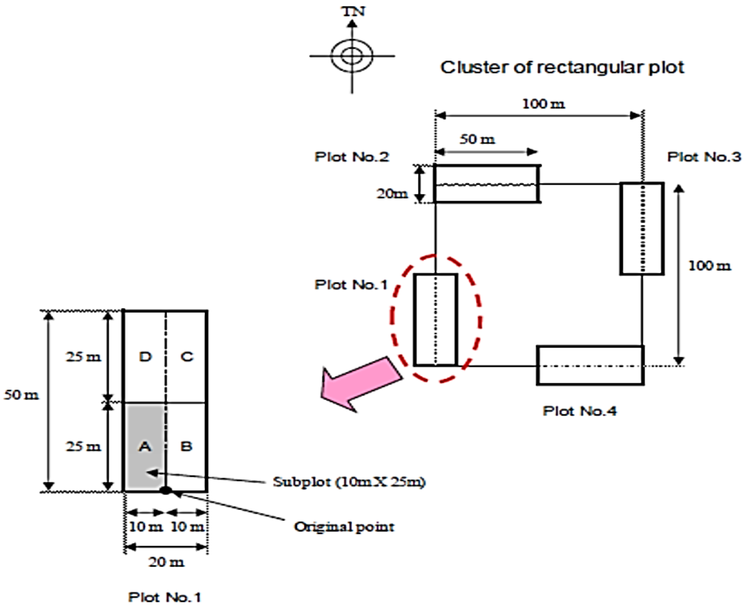
Uncertainty associated with this parameter:

Category change	Uncertainty estimate (confidence interval at 95%)
Semi-deciduous forest to cropland	17.92%
Semi-deciduous forest to grassland	48.88%
Semi-deciduous forest to other lands	-
Evergreen forest to cropland	35.61%
Evergreen forest to grassland	196.00%
Evergreen forest to other lands	196.00%
Mangrove forest to cropland	-
Mangrove forest to grassland	196.00%
Mangrove forest to other lands	138.57%

Any comment:

Emission factors

Parameter:	$AGB_{before,j}$
Description:	Aboveground biomass of forest type *j* before conversion,
Data unit:	tons of dry matter per ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):	The data used for the present document are Tier 2 (country specific data or country level estimates or locally derived estimates) and they were sourced from the NFI (for deciduous and evergreen forests) or for Mangrove forests. For semi-deciduous and evergreen forest, data are from the Zambézia Forest Inventory. It includes data that was collected in Zambézia province during the NFI, in 2017 and 2018. Although the inventory covers the whole province of Zambézia this is still representative of the forests located in the ZILMP as forests across the province are homogenous (floristic and structural composition). Moreover, the higher sample size of the inventory covering the whole province will enable more precise estimates for emission factors. ***i. Sampling design*** Carbon stocks before conversion for deciduous and evergreen forests were estimated using data from the National Forest Inventory sample units that were located in Zambézia province. The sample units for surveying carbon stocks were allocated using restricted stratified random sampling, using 4 * 4 km systematic grid superimposed on the agro-ecological zoning map, and stratified among the 12 forest types. Was considered as the strata, the semi-deciduous forest “open and closed”, Miombo forest “open and closed”, semi-evergreen forest “open and closed”, semi-evergreen Mountain forest “open and closed”, Mopane forest “open and closed”, and Mecrusse forest “open and closed”, of which only the first eight types occur in Zambézia province. The total number of sample units was determined using the optimal allocation (assuming a maximum error of 10% for the total volume, and 5% of confidence level). Proportional allocation was used to determine the number of sample units per stratum (Husch, Beers, and Kershaw 2003). For Zambézia province, 128 clusters (512 plots) were distributed between the eight (8) forest types. The cluster was used as a sampling unit, and each cluster has 4 plots of 0.1 ha (20 * 50 m), where each plot was divided into 4 sub-plots of 0.025 ha (10 * 25 m) (Annex-Figure 4).



Annex-Figure 4: Design of each cluster used in the National Forest Inventory.

For estimating emission factors, the eight strata were aggregated into 2, and the similarity of the strata was used for the aggregation. The aggregation was done with the purpose of harmonizing the forest strata of the activity data with the emission factor data. Below the aggregation table.

Allocation stratum	EF Strata for MR
semi-deciduous open forest	semi-deciduous forest
semi-deciduous closed forest	
miombo open forest	
miombo closed forest	
semi-evergreen Mountain open forest	semi-evergreen forest
semi-evergreen Mountain closed forest	
semi-evergreen open forest	
semi-evergreen closed forest	

ii. Data collection

The plots were used for data collection of adult trees (dbh≥10cm), and the subplots "A" were used for data collection of established regeneration trees (10cm> dbh≥ 5 cm), which were included in the calculation of the carbon stocks. Data collected in the plots and subplots included tree information (dbh, scientific name, total and commercial height, stem quality), soil, forest type (this information was used to validate the information from agro-ecological zoning map), and other important information. Tree data were used to estimate above ground biomass (AGB) and below ground biomass (BGB).

The NFI did not cover Mangrove forests, so, data from the literature was used. For other strata, data from literature were also used.

Details of data collection can be find at https://www.fnds.gov.mz/mrv/index.php/documentos/guioes/35-directrizes-do-inventario-florestal-nacional/file .

iii. Prediction at plot level

Above ground biomass (AGB) and below ground biomass (BGB) were estimated using a series of allometric equations adjusted for ecosystems or tree species similar to those in the Zambézia province (Annex-Table 1), and this equation was applied at tree level.

The use of the equations meant, applying allometric equations of the specific species (*Millettia stuhlmannii* taub., *Pterocarpus angolensis DC., Afzelia quanzensis* Welw.) in all trees of these species to estimate AGB, regardless of forest types; The allometric equation of the semi-deciduous forest was applied for all trees of this forest type (except the species mentioned above), as well as in all trees of the species *Brachystegia spiciformis* Benth., and *Julbernardia globiflora (Benth.) Troupin* to estimate AGB and BGB, because they were the main species used to adjust this equation in this forest type. The equations of the semi-evergreen forest were applied in all remaining trees of this forest type to estimate AGB; and apply the semi-deciduous forest equation in all trees to estimate the BGB in this forest type (including species mentioned above in other forest type), and apply factor 0.275 (shoot:ratio) to estimate the BGB of the semi-evergreen forest.

Annex-Table 1: List of allometric equations used to estimate above and below biomass.

Stratum	**Forest type or species**	**Above-ground biomass (AGB) [kg]**	**Below-ground biomass (BGB) [kg]**
Semi-deciduous forest	Semi-deciduous forest (open and closed)	$\hat{Y} = 0.0763 * DAP^{2.2046} * H^{0.4918}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mugasha *et al.* (2013)	Author: Mugasha *et al.* (2013)
	Millettia stuhlmannii taub.	$\hat{Y} = 5.7332 * DAP^{1.4567}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)
	Pterocarpus angolensis DC.	$\hat{Y} = 0.2201 * DAP^{2.1574}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)
	Afzelia quanzensis Welw.	$\hat{Y} = 3.1256 * DAP^{1.5833}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)
Evergreen forest	Evergreen forest (open and closed)	$\hat{Y} = \exp(-2.289 + 2.649\ln(DAP) – 0.021(\ln(DAP))^2)$	$\hat{Y} = AGB * R/S$; R/S= 0.275
		Author: IPCC (2003)	Author: Mokany *et al.* (2006)
		$\hat{Y} = 0.0613*DAP2.7133$	$\hat{Y} = AGB * R/S$; R/S= 0.275

	Evergreen MoUntain forest (open and closed)	Author: Lisboa *et al.* (2018)	Author: Mokany *et al.* (2006)
	Millettia stuhlmannii taub.	$\hat{Y} = 5.7332 * DAP^{1.4567}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)
	Pterocarpus angolensis DC.	$\hat{Y} = 0.2201 * DAP^{2.1574}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)
	Afzelia quanzensis Welw.	$\hat{Y} = 3.1256 * DAP^{1.5833}$	$\hat{Y} = 0.1766 * DAP^{1.7844} * H^{0.3434}$
		Author: Mate *et al.* (2014)	Author: Mugasha *et al.* (2013)

iv. Estimation

The estimation of mean and their respective uncertainties (standard error, sampling error, and confidence interval) for the variables biomass, carbon and carbon dioxide equivalent (above and below ground) for the two strata (semi-deciduous forest and semi-evergreen forest), were done using the forest inventory data analysis approach proposed by Bechtold & Patterson (2005) chapter 4 of the book "The Enhanced Forest Inventory and Analysis Program-National Sampling Design and Estimation Procedures". Details of this methodology are described in Zambézia inventory report, available at https://fnds.gov.mz/mrv/index.php/documentos/relatorios/41-relatorio-de-inventario-florestal-da-zambezia-actualizado/file. For mangrove forests, data are secondary, extracted from existing literature. Stringer *et al.* (2015)[14] made an inventory on this ecosystem in the Zambezi delta in Mozambique; we can easily assume that carbon stocks are comparable to those of mangroves in Zambézia province. They divided mangroves into 5 strata and estimated carbon stocks in above and belowground biomass. Since we do not have information on these specific strata for ZILMP, the mean and standard error of biomass (AGB and BGB) of mangrove forest, comes indirectly from table 1 of the article by Stringer *et al.* (2015). For its determination, first the mean of carbon was found for the two pools (sum of overstory and understory carbon) for each stratum (Height Class 1, ..., Height Class 5), followed by the calculation of the mean of the ecosystem (mean weighted according to the stratum areas). Finally, the carbon was converted to biomass using the conversion factor of 0.47 proposed in the IPCC good practice guide.

Spatial level: Regional

Spatial level: Regional

Value applied:

Semi-deciduous forest (FSD)	144.69
Evergreen forest (FSSV)	123.13
Mangrove forest (FF)	269.01

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[14] Stringer, C. E.; Trettin, C. C.; Zarnoch, S. J. and Tang, W. 2015. Carbon stocks of mangroves within the Zambezi River Delta, Mozambique. Forest Ecology Management 354:139–148.

<table>
<tr><td></td><td>The values above are estimated and extracted in the "Emission factor_v.2" workbook, and then they are recorded in the cells "B4", "B10" and "B16" respectively, of the "BIOMASS" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_RL_(2005_2015)_28_10_20" workbook. These values are then applied in the range "C9:C26" of the "Reference Level" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_RL_(2005_2015)_28_10_20" workbook for estimating emissions.</td></tr>
<tr><td>QA/QC procedures applied</td><td>The QA/QC procedures consisted on the following:

SOPs were developed.
A training on the SOPs was conducted prior to the field work. This training lasted for 3 weeks, and consisted of training on the usage of all equipment and evaluating the specific skills of each participant, in order to determine the team and brigade leaders. On the start of the 2nd phase of the IFN (2017) an additional 1-week training was conducted, to refresh the participants and train any new members.
The supervisor of each inventory team conducted a remeasurement of 4 trees per plot which means 16 trees per cluster. This served to ensure that the SOPs were adequately implemented.
An independent measurement of 10% of the plots. This activity was conducted by technicians of the National Directorate of Forests, who had participated in the Provincial Inventories of Gaza and Cabo Delgado. Diameter below 10%.
The adequacy of the allometric models, including root-to-shoot ratios used was confirmed by experts of the Faculty of Agronomy and Forest Engineering (FAEF) and the Department of Biology Sciences (DCB) of the Eduardo Mondlane University (UEM).
The World Bank conducted two regular supervision missions of the National Forest Inventories to confirm the adequate implementation of the SOPs and suggest areas for improvement. The report can be found here.
An independent expert (Jim Alegria, ex-US Forestry Service) was hired in order to evaluate the methodology for the inventory and support in the estimation step. The report can be found here.
</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td>
<table>
<tr><th>Forest type</th><th>Uncertainty estimate (confidence interval at 95%)</th></tr>
<tr><td>FSD</td><td>19.72%</td></tr>
<tr><td>FSSV</td><td>18.33%</td></tr>
<tr><td>FF</td><td>8.00%</td></tr>
</table></td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

Parameter:	$BGB_{before,j}$
Description:	Belowground biomass of forest type *j* before conversion,
Data unit:	tons of dry matter per ha
Source of data or description of the method for developing the data including the spatial level of the data (local, regional,	For semi-deciduous and evergreen forest, data are from the Zambézia Forest Inventory. It includes data that was collected in Zambézia province during the NFI, in 2017 and 2018. Please refer to parameter $AGB_{before,j}$ for more information. For mangrove forests, please refer to parameter $AGB_{before,j}$ for more information. Spatial level: Regional

<table>
<tr><td>national, international):</td><td></td></tr>
<tr><td>Value applied:</td><td>
<table>
<tr><td>Semi-deciduous forest (FSD)</td><td>49.95</td></tr>
<tr><td>Evergreen forest (FSSV)</td><td>42.06</td></tr>
<tr><td>Mangrove forest (FF)</td><td>85.43</td></tr>
</table>
<p>The values above are estimated and extracted in the workbook "Emission factor_v.2" and then they are recorded in the cells "B45", "B51" and "B57" respectively, of the "BIOMASS" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_RL_(2005_2015)_28_10_20" workbook. These values are then applied in the range "E9:E26" of the "Reference Level" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_RL_(2005_2015)_28_10_20" workbook for estimating emissions.</p>
</td></tr>
<tr><td>QA/QC procedures applied</td><td>Please see section QA/QC procedures under parameter $AGB_{before,j}$.</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td>
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<tr><th>Forest type</th><th>Uncertainty estimate (confidence interval at 95%)</th></tr>
<tr><td>FSD</td><td>16.58%</td></tr>
<tr><td>FSSV</td><td>16.71%</td></tr>
<tr><td>FF</td><td>10.00%</td></tr>
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</table>

<table>
<tr><td>Parameter:</td><td>$AGB_{after,i}$</td></tr>
<tr><td>Description:</td><td>Aboveground biomass of non-forest type <i>i</i> after conversion</td></tr>
<tr><td>Data unit:</td><td>tons of dry matter per ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):</td><td>
<p>For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used because, unfortunately, there aren't country-specific data. The agricultural land in Mozambique is mostly under the annual-crop farming practices that drive conversion of forest land to agricultural lands. So, according to 2006 IPCC GL (Volume 4, Chapter 5, Section 5.28), for lands planted in annual crops, the default value of growth in crops planted after conversion is 5 tonnes of C per hectare, based on the original IPCC Guidelines recommendation of 10 tonnes of dry biomass per hectare (dry biomass has been converted to tonnes carbon in Table 5.9) (2006 IPCC, Volume 4, Chapter 5, Section 5.28).</p>
<p>For grassland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 6 are used because, unfortunately, there aren't country-specific data. As the climate in most of Mozambique is tropical dry to subtropical dry, the value of peak-above ground biomass for tropical dry of TABLE 6.4 is assumed.</p>
<p>For other lands: No default values exist for these conversions.</p>
<p>Spatial level: International</p>
</td></tr>
<tr><td>Value applied:</td><td>
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<tr><td>Cropland (C)</td><td>10</td></tr>
<tr><td>Grassland (P)</td><td>2.3</td></tr>
<tr><td>Other lands (A|O|U)</td><td>0.0</td></tr>
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<p>The values above are recorded in the ranges "B5:B9", "B11:B15" and "B17:B21" of the "BIOMASS" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_RL_(2005_2015)_28_10_20" workbook. These values</p>
</td></tr>
</table>

<table>
<tr><td></td><td>are then applied in the range "D9:D26" of the "Reference Level" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_RL_(2005_2015)_28_10_20" workbook for estimating emissions.</td></tr>
<tr><td>QA/QC procedures applied</td><td>The adequacy in the use of these default values was confirmed with the experts in GHG Inventory in DINAB.</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td>
<table>
<tr><th>Non-forest type</th><th>Uncertainty estimate (Confidence interval at 95%)</th></tr>
<tr><td>Cropland (C)</td><td>75.00%</td></tr>
<tr><td>Grassland (P)</td><td>75.00%</td></tr>
<tr><td>Other lands (A|O|U)</td><td>-</td></tr>
</table>
</td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

<table>
<tr><td>Parameter:</td><td>$BGB_{after,i}$</td></tr>
<tr><td>Description:</td><td>Belowground biomass of non-forest type <i>i</i> after conversion</td></tr>
<tr><td>Data unit:</td><td>tons of dry matter per ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):</td><td>For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used. Tier For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used because, unfortunately, there aren't country-specific data. Tier 2 may modify the assumption that carbon stocks immediately following conversion are zero. In this case, it is assumed that conversion leads to annual croplands and in the case the carbon stock in biomass after one year for annual crops provided in TABLE 5.9 is used.
For grassland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 6, TABLE 6.1 and TABLE 6.4 are used because, unfortunately, there aren't country-specific data. As the climate in most of Mozambique is tropical dry to subtropical dry, the value for semi-arid grassland in tropical dry climate zone is used, therefore a root-shoot ratio of 2.8 (TABLE 6.1) is applied to the value of peak above-ground biomass, 2.3 tonnes of dry biomass per hectare (TABLE 6.4), generating the expected values 6.4 tonnes of dry biomass per hectare.
For other lands: No default values exist for these conversions.
Spatial level: International</td></tr>
<tr><td>Value applied:</td><td>
<table>
<tr><td>Cropland (C)</td><td>0.00</td></tr>
<tr><td>Grassland (P)</td><td>6.44</td></tr>
<tr><td>Other lands (A|O|U)</td><td>0.00</td></tr>
</table>
The values above are recorded in the ranges "B46:E50", "B52:B56" and "B58:B62" of the "BIOMASS" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_RL_(2005_2015)_28_10_20" workbook. These values are then applied in the range "F9:F26" of the "Reference Level" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_RL_(2005_2015)_28_10_20" workbook for estimating emissions.</td></tr>
<tr><td>QA/QC procedures applied</td><td>The adequacy in the use of these default values was confirmed with the experts in GHG Inventory in DINAB.</td></tr>
</table>

<table>
<tr>
<td>Uncertainty associated with this parameter:</td>
<td>
<table>
<tr><th>Non-forest type</th><th>Uncertainty estimate (Confidence interval at 95%)</th></tr>
<tr><td>Cropland (C)</td><td>-</td></tr>
<tr><td>Grassland (P)</td><td>121.04%</td></tr>
<tr><td>Other lands (A|O|U)</td><td>-</td></tr>
</table>
</td>
</tr>
<tr>
<td>Any comment:</td>
<td></td>
</tr>
</table>

1.1.2.1.1.3 Calculation of the average annual historical emissions over the Reference Period

The following table shows the average annual historical emissions results obtained per category changes from a forest type to a non-forest type over the Reference Period. The emissions are generated relating the data and parameters described above (Activity data and Emission Factors) and summarized in the Annex-Table 2, by applying **Equation 17**.

Annex-Table 2: Calculation of the average annual historical emissions over the Reference Period.

Category changes	**Average annual historical activity data$_{j,i}$ (ha/yr)**	**AGB$_{before,j}$ (tdm/ha)**	**BGB$_{before,j}$ (tdm/ha)**	**AGB$_{bafter,i}$ (tdm/ha)**	**BGB$_{after,i}$ (tdm/ha)**	**Average annual historical emissions (tCO$_2$e/yr)**
Semi-deciduous forest to cropland	17,505.56	144.69	49.4995	10.00	0.00	5,570,060.47
Semi-deciduous forest to grassland	2,435.56	144.69	49.4995	2.30	6.44	780,253.50
Semi-deciduous forest to other lands	0.00	144.69	49.4995	0.00	0.00	0.00
Evergreen forest to cropland	4,566.67	123.13	42.0626	10.00	0.00	1,221,308.32
Evergreen forest to grassland	152.22	123.13	42.066	2.30	6.44	41,040.81
Evergreen forest to other lands	152.22	123.13	42.0626	0.00	0.00	43,333.57
Mangrove to cropland	0.00	269.01	85.43	0.00	0.00	0.00
Mangrove to grassland	152.22	269.01	85.43	2.30	6.44	90,687.38
Mangrove to other lands	304.44	269.01	85.43	0.00	0.00	185,960.28
Total						**7,932,644.34**

5.2.4 Estimated Reference Level

ER Program Reference level

Crediting Period year *t*	Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO_{2-e}/yr)	If applicable, average annual historical removals by sinks over the Reference Period (tCO_{2-e}/yr)	Adjustment, if applicable (tCO_{2-e}/yr)	Reference level (tCO_{2-e}/yr)
2018	7,932,644.34	-	-	-	7,932,644.34
2019	7,932,644.34	-	-	-	7,932,644.34
2020	7,932,644.34	-	-	-	7,932,644.34
2021	7,932,644.34	-	-	-	7,932,644.34
2022	7,932,644.34	-	-	-	7,932,644.34
2023	7,932,644.34	-	-	-	7,932,644.34
2024	7,932,644.34	-	-	-	7,932,644.34

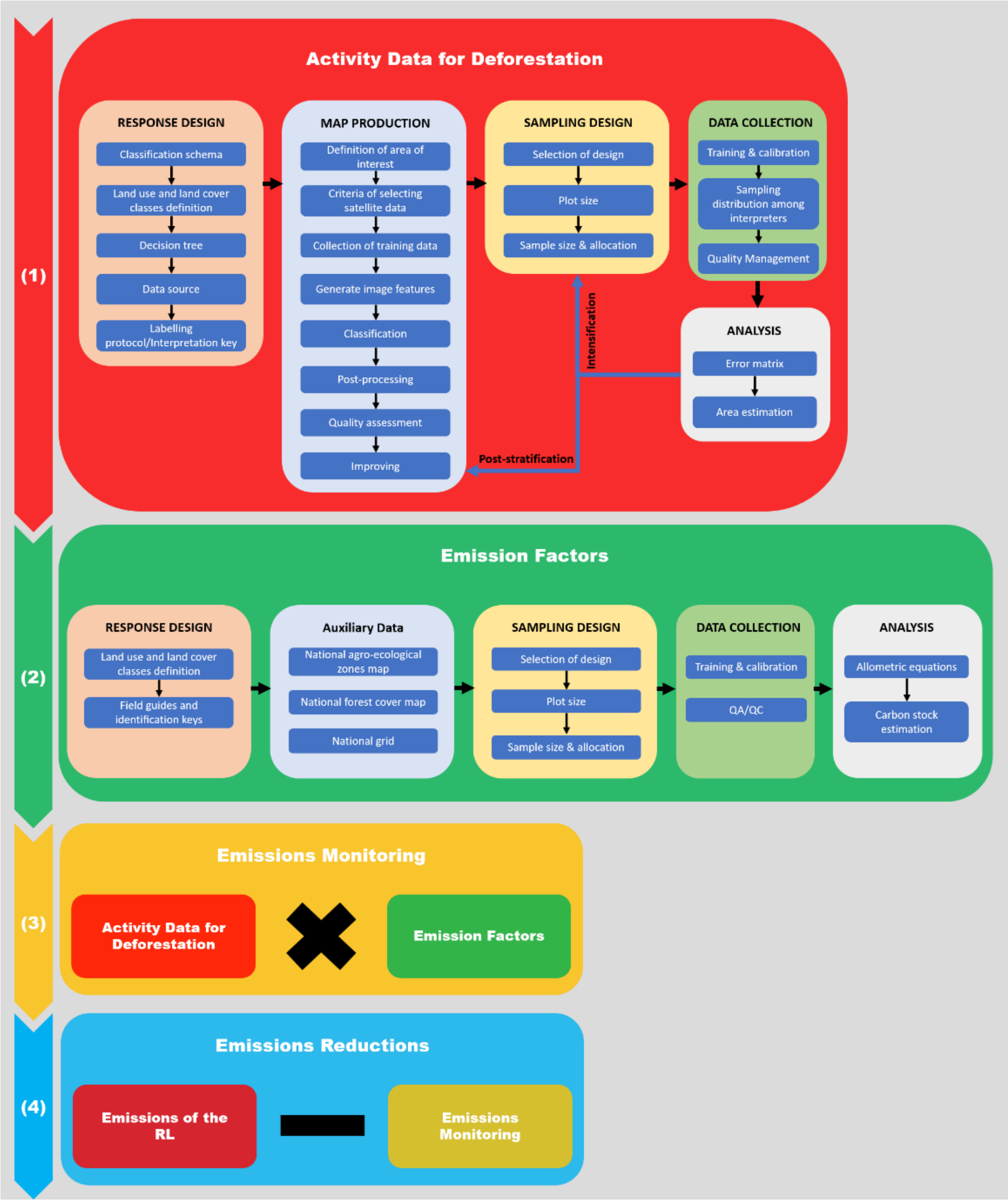
5.3MONITORING AND REPORTING PERIOD

The monitoring and reporting period covers emissions in 2021 outside of ZILMP program.

5.3.1 Measurement, monitoring and reporting approach

1.1.3 Line Diagram

The Annex-Figure 5 illustrates the emissions reductions calculation workflow during the Monitoring Period.



Annex-Figure 5: Emissions reductions calculation workflow.

1.1.4 Calculation

$$ER_{ERP,t} = RL_t - GHG_t$$ ***Equation 21***

Where:

ER_{ERP}	=	Emission Reductions under the area outside the scope of ZILMP in year *t*; *tCO₂e*year⁻¹*.
RL_{RP}	=	Gross emissions of the RL from deforestation over the Reference Period; *tCO₂e*year⁻¹*.
GHG_t	=	Monitored gross emissions from deforestation at year *t*; *tCO₂e*year⁻¹*;
T	=	Number of years during the monitoring period; *dimensionless*.

Reference Level **(**RL_t**)**

Gross emissions of the RL from deforestation over the Reference Period (RL_{RP}) are estimated as the sum of annual change in total biomass carbon stocks (ΔC_{B_t}) during the reference period.

$$RL_{RP} = \frac{\sum_t^{RP} \Delta C_{B_t}}{RP}$$ ***Equation 22***

Where:

ΔC_{B_t}	=	Annual change in total biomass carbon stocks at year *t; tC*year⁻¹;*
RP	=	Reference period; *years.*

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

$$\Delta C_{B_t} = \Delta C_G + \Delta C_{CONVERSION} - \Delta C_L$$ ***Equation 23***

Where:

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

Following the recommendations set in chapter 2.2.1 of the GFOI Methods Guidance Document for applying IPCC Guidelines and guidance in the context of REDD+[15], the above equation will be simplified and it will be assumed that:

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

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

---

[15] https://www.reddcompass.org/documents/184/0/MGD2.0_English/c2061b53-79c0-4606-859f-ccf6c8cc6a83

$$\Delta C_{B_t} = \sum_{j,i} \left(B_{Before,j} - B_{After,i}\right) \; x \; CF \; x \frac{44}{12} \times A(j,i)_{RP}$$ **Equation 24**

Where:

$A(j,i)_{RP}$	Area converted/transited from forest type *j* to non-forest type *i* during the Reference Period, in *hectares per year*. In this case, three forest land conversions are possible: ● (Semi-)deciduous forest to Non-forest type *i*; ● (Semi-)evergreen forest to Non-forest type *i*; and ● Mangrove forest to Non-forest type *i*. Five types of non-forest land are considered: ● Cropland (C); ● Grassland (P); ● Wetland (A); ● Settlement (U); and ● Other lands (O).
$B_{Before,j}$	Total biomass of forest type *j* before conversion/transition, in tons of dry matter per ha. This is equal to the sum of aboveground ($AGB_{Before,j}$) and belowground biomass ($BGB_{Before,j}$) and it is defined for each forest type.
$B_{After,i}$	Total biomass of non-forest type *i* after conversion, in *tons dry matter per ha*. This is equal to the sum of aboveground ($AGB_{After,i}$) and belowground biomass ($BGB_{After,i}$) and it is defined for each of the five non-forest IPCC Land Use categories.
CF	Carbon fraction of dry matter in tC per ton dry matter. The value used is: ● **0.47** is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.
$44/12$	Conversion of C to CO_2

***Monitored emissions* (GHG_t)**

Annual gross GHG emissions over the monitoring period in the Accounting Area (GHG_t) are estimated as the sum of annual change in total biomass carbon stocks (ΔC_{B_t}).

$$GHG_t = \frac{\sum_t^T \Delta C_{B_t}}{T}$$ **Equation 25**

Where:

ΔC_{B_t} = Annual change in total biomass carbon stocks at year *t; tC*year*$^{-1}$

T = Number of years during the monitoring period; *dimensionless*.

Changes in total biomass carbon stocks

Following the 2006 IPCC Guidelines, the annual change in total biomass carbon stocks forest land converted to other land-use category *(ΔC_B)* would be estimated through **Equation 23**. Making the same assumptions as described above for the RL the change of biomass carbon stocks could be expressed with the following equation:

$$\Delta C_B = \sum_{j,i} \left(B_{Before,j} - B_{After,i}\right) \; x \; CF \; x \frac{44}{12} \times A(j,i)_{MP}$$ **Equation 26**

Where:

$A(j,i)_{MP}$	Area converted/transited from forest type *j* to non-forest type *i* during the Monitoring Period, in hectare per year. In this case, three forest land conversions are possible: ● (Semi-)deciduous forest to Non-forest type *i*; ● (Semi-)evergreen forest to Non-forest type *i*; and ● Mangrove forest to Non-forest type *i*. Five types of non-forest land are considered: ● Cropland (C); ● Grassland (P); ● Wetland (A); ● Settlement (U); and ● Other lands (O).
$B_{Before,j}$	Total biomass of forest type *j* before conversion/transition, in tons of dry matter per ha. This is equal to the sum of aboveground ($AGB_{Before,j}$) and belowground biomass ($BGB_{Before,j}$) and it is defined for each forest type.
$B_{After,i}$	Total biomass of non-forest type *i* after conversion, in *tons dry matter per ha*. This is equal to the sum of aboveground ($AGB_{After,i}$) and belowground biomass ($BGB_{After,i}$) and it is defined for each of the five non-forest IPCC Land Use categories.
CF	Carbon fraction of dry matter in tC per ton dry matter. The value used is: ● **0.47** is the default for (sub)tropical forest as per IPCC AFOLU guidelines 2006, Table 4.3.
$44/12$	Conversion of C to CO_2

5.3.2 Data and parameters

1.1.5 Fixed Data and Parameters

<table>
<tr><td>Parameter:</td><td>$AGB_{before,j}$</td></tr>
<tr><td>Description:</td><td>Aboveground biomass of forest type <i>j</i> before conversion,</td></tr>
<tr><td>Data unit:</td><td>tons of dry matter per ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):</td><td>The data used for the present document are Tier 2 (country specific data or country level estimates or locally derived estimates) and they were sourced from the NFI (for deciduous and evergreen forests) or for Mangrove forests.

For semi-deciduous and evergreen forest, data are from the Zambézia Forest Inventory. It includes data that was collected in Zambézia province during the NFI, in 2017 and 2018. Although the inventory covers the whole province of Zambézia this is still representative of the forests located in the ZILMP as forests across the province are homogenous (floristic and structural composition). Moreover, the higher sample size of the inventory covering the whole province will enable more precise estimates for emission factors.

<i>i. Sampling design</i>

Carbon stocks before conversion for deciduous and evergreen forests were estimated using data from the National Forest Inventory sample units that were located in Zambézia province. The sample units for surveying carbon stocks were allocated using restricted stratified random sampling, using 4 * 4 km systematic grid superimposed on the agro-ecological zoning map, and stratified among the 12 forest types. Was considered as the strata, the semi-deciduous forest “open and closed”, Miombo forest “open and closed”, semi-evergreen forest “open and closed”, semi-evergreen Mountain forest “open and closed”, Mopane forest “open and closed”, and Mecrusse forest “open and closed”, of which only the first eight types occur in Zambézia province.

The total number of sample units was determined using the optimal allocation (assuming a maximum error of 10% for the total volume, and 5% of confidence level). Proportional allocation was used to determine the number of sample units per stratum (Husch, Beers, and Kershaw 2003). For Zambézia province, 128 clusters (512 plots) were distributed between the eight (8) forest types. The cluster was used as a sampling unit, and each cluster has 4 plots of 0.1 ha (20 * 50 m), where each plot was divided into 4 sub-plots of 0.025 ha (10 * 25 m) (Figure 6).

For estimating emission factors, the eight strata were aggregated into 2, and the similarity of the strata was used for the aggregation. The aggregation was done with the purpose of harmonizing the forest strata of the activity data with the emission factor data. Below the aggregation table.

<table>
<tr><th>Allocation stratum</th><th>EF Strata for MR</th></tr>
<tr><td>semi-deciduous open forest</td><td rowspan="4">semi-deciduous forest</td></tr>
<tr><td>semi-deciduous closed forest</td></tr>
<tr><td>miombo open forest</td></tr>
<tr><td>miombo closed forest</td></tr>
<tr><td>semi-evergreen Mountain open forest</td><td rowspan="2">semi-evergreen forest</td></tr>
<tr><td>semi-evergreen Mountain closed forest</td></tr>
</table>
</td></tr>
</table>

semi-evergreen open forest	
semi-evergreen closed forest	

ii. Data collection

The plots were used for data collection of adult trees (dbh≥10cm), and the subplots "A" were used for data collection of established regeneration trees (10cm> dbh≥ 5 cm), which were included in the calculation of the carbon stocks. Data collected in the plots and subplots included tree information (dbh, scientific name, total and commercial height, stem quality), soil, forest type (this information was used to validate the information from agro-ecological zoning map), and other important information. Tree data were used to estimate above ground biomass (AGB) and below ground biomass (BGB).

The NFI did not cover Mangrove forests, so, data from the literature was used. For other strata, data from literature were also used.

Details of data collection can be find at https://www.fnds.gov.mz/mrv/index.php/documentos/guioes/35-directrizes-do-inventario-florestal-nacional/file .

iii. Prediction at plot level

Above ground biomass (AGB) and below ground biomass (BGB) were estimated using a series of allometric equations adjusted for ecosystems or tree species similar to those in the Zambézia province (Table 1), and this equation was applied at tree level.

The use of the equations meant, applying allometric equations of the specific species (*Millettia stuhlmannii* taub., *Pterocarpus angolensis* DC., *Afzelia quanzensis* Welw.) in all trees of these species to estimate AGB, regardless of forest types. The allometric equation of the semi-deciduous forest was applied for all trees of this forest type (except the species species mentioned above), as well as in all trees of the species *Brachystegia spiciformis* Benth., and *Julbernardia globiflora* (Benth.) Troupin to estimate AGB and BGB, because they were the main species used to adjust this equation in this forest type. The equations of the semi-evergreen forest were applied in all remaining trees of this forest type to estimate AGB; and apply the semi-deciduous forest equation in all trees to estimate the BGB in this forest type (including species mentioned above in other forest type), and apply factor 0.28 (shoot ratio) to estimate the BGB of the semi-evergreen forest.

Since Mozambique was not able to propagate this source of error through Monte Carlo (MC) simulation we have increased the sampling uncertainty of AGB and BGB for forest strata by 10% at 90% confidence level using the quadrature approach and the combined error was propagated in the MC simulation.

iv. Estimation

The estimation of mean and their respective uncertainties (standard error, sampling error, and confidence interval) for the variables biomass, carbon and carbon dioxide equivalent (above and below ground) for the two strata (semi-deciduous forest and semi-evergreen forest), were done using the forest inventory data analysis approach proposed by Bechtold & Patterson (2005) chapter 4 of the book "The Enhanced Forest Inventory and Analysis Program-National Sampling Design and Estimation Procedures". Details of this methodology are described in Zambézia inventory report, available at https://fnds.gov.mz/mrv/index.php/documentos/relatorios/41-relatorio-de-inventario-florestal-da-zambezia-actualizado/file. For mangrove forests, data are secondary, extracted

<table>
<tr><td></td><td>from existing literature. Stringer *et al*. (2015)[16] made an inventory on this ecosystem in the Zambezi delta in Mozambique; we can easily assume that carbon stocks are comparable to those of mangroves in Zambézia province. They divided mangroves into 5 strata and estimated carbon stocks in above and belowground biomass. Since we do not have information on these specific strata for ZILMP, the mean and standard error of biomass (AGB and BGB) of mangrove forest, comes indirectly from table 1 of the article by Stringer *et al.* (2015). For its determination, first the mean of carbon was found for the two pools (sum of overstory and understory carbon) for each stratum (Height Class 1, ..., Height Class 5), followed by the calculation of the mean of the ecosystem (mean weighted according to the stratum areas). Finally, the carbon was converted to biomass using the conversion factor of 0.47 proposed in the IPCC good practice guide.

Spatial level: Regional</td></tr>
<tr><td>**Value applied:**</td><td>
<table>
<tr><td>Semi-deciduous forest (FSD)</td><td>144.69</td></tr>
<tr><td>Evergreen forest (FSSV)</td><td>123.13</td></tr>
<tr><td>Mangrove forest (FF)</td><td>269.01</td></tr>
</table>
The values above are estimated and extracted in the "Emission factor_v.2" workbook, and then they are recorded in the cells "B4", "B10" and "B16" respectively, of the "BIOMASS" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_MR_(2021)" and "Outside_ZILMP_Emissions_Calculations_MR_(2022)" workbooks. These values are then applied in the range "C9:C20" of the "EMISSION MONITORING PERIOD(EMP)" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_MR_(2021)" and "Outside_ZILMP_Emissions_Calculations_MR_(2022)" workbooks for estimating emissions.</td></tr>
<tr><td>**QA/QC procedures applied**</td><td>The QA/QC procedures consisted on the following:

SOPs were developed as described in *Section 2.1 - National Forest Inventory*.
A training on the SOPs was conducted prior to the field work. This training lasted for 3 weeks, and consisted of training on the usage of all equipment and evaluating the specific skills of each participant, in order to determine the team and brigade leaders. On the start of the 2nd phase of the IFN (2017) an additional 1-week training was conducted, to refresh the participants and train any new members.
The supervisor of each inventory team conducted a remeasurement of 4 trees per plot which means 16 trees per cluster. This served to ensure that the SOPs were adequately implemented.
An independent measurement of 10% of the plots. This activity was conducted by technicians of the National Directorate of Forests, who had participated in the Provincial Inventories of Gaza and Cabo Delgado. Diameter error must be below 10%.
The adequacy of the allometric models, including root-to-shoot ratios used was confirmed by experts of the Faculty of Agronomy and Forest Engineering (FAEF) and the Department of Biology Sciences (DCB) of the University Eduardo Mondlane (UEM).
The World Bank conducted two regular supervision missions of the National Forest Inventories to confirm the adequate implementation of the SOPs and suggest areas for improvement. The report can be found here.
An independent expert (Jim Alegria, ex-US Forestry Service) was hired in order to evaluate the methodology for the inventory and support in the estimation step. The report can be found here.
</td></tr>
<tr><td>**Uncertainty associated with this parameter:**</td><td>
<table>
<tr><td>Forest type</td><td>Uncertainty estimate (confidence interval at 95%)</td></tr>
</table></td></tr>
</table>

---

[16] Stringer, C. E.; Trettin, C. C.; Zarnoch, S. J. and Tang, W. 2015. Carbon stocks of mangroves within the Zambezi River Delta, Mozambique. Forest Ecology Management 354:139–148.

<table>
<tr><td></td><td><table><tr><td>FSD</td><td>19.72%</td></tr><tr><td>FSSV</td><td>18.33%</td></tr><tr><td>FF</td><td>8.00%</td></tr></table></td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

<table>
<tr><td>Parameter:</td><td>$BGB_{before,j}$</td></tr>
<tr><td>Description:</td><td>Belowground biomass of forest type <i>j</i> before conversion,</td></tr>
<tr><td>Data unit:</td><td>tons of dry matter per ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):</td><td>For semi-deciduous and evergreen forest, data are from the Zambézia Forest Inventory. It includes data that was collected in Zambézia province during the NFI, in 2017 and 2018. Please refer to parameter $AGB_{before,j}$ for more information.
For mangrove forests, please refer to parameter $AGB_{before,j}$ for more information.
Spatial level: Regional</td></tr>
<tr><td>Value applied:</td><td><table><tr><td>Semi-deciduous forest (FSD)</td><td>49.95</td></tr><tr><td>Evergreen forest (FSSV)</td><td>42.06</td></tr><tr><td>Mangrove forest (FF)</td><td>85.43</td></tr></table>The values above are estimated and extracted in the workbook "Emission factor_v.2" and then they are recorded in the cells "B46", "B52" and "B58" respectively, of the "BIOMASS" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_MR_(2021)" and "Outside_ZILMP_Emissions_Calculations_MR_(2022)" workbook. These values are then applied in the range "E9:E20" of the "EMISSION MONITORING PERIOD(ERL)" worksheet tab in the "Outside_ZILMP_Emissions_Calculations_MR_(2021)" and "Outside_ZILMP_Emissions_Calculations_MR_(2022)" workbook for estimating emissions.</td></tr>
<tr><td>QA/QC procedures applied</td><td>Please see section QA/QC procedures under parameter $AGB_{before,j}$.</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td><table><tr><td>Forest type</td><td>Uncertainty estimate (confidence interval at 95%)</td></tr><tr><td>FSD</td><td>16.58%</td></tr><tr><td>FSSV</td><td>16.71%</td></tr><tr><td>FF</td><td>10.00%</td></tr></table></td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

Parameter:	$AGB_{after,i}$
Description:	Aboveground biomass of non-forest type *i* after conversion
Data unit:	tons of dry matter per ha

<table>
<tr><td>Source of data or description of the method for developing the data including the spatial level of the data (local, regional, national, international):</td><td>For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used because, unfortunately, there aren't country-specific data. The agricultural land in Mozambique is mostly under the annual-crop farming practices that drive conversion of forest land to agricultural lands. So, according to 2006 IPCC GL (Volume 4, Chapter 5, Section 5.28), for lands planted in annual crops, the default value of growth in crops planted after conversion is 5 tonnes of C per hectare, based on the original IPCC Guidelines recommendation of 10 tonnes of dry biomass per hectare (dry biomass has been converted to tonnes carbon in Table 5.9) (2006 IPCC, Volume 4, Chapter 5, Section 5.28).

For grassland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 6 are used because, unfortunately, there aren't country-specific data. As the climate in most of Mozambique is tropical dry to subtropical dry, the value of peak-above ground biomass for tropical dry of TABLE 6.4 is assumed.

For other lands: No default values exist for these conversions.

Spatial level: International</td></tr>
<tr><td>Value applied:</td><td><table>
<tr><td>Cropland (C)</td><td>10</td></tr>
<tr><td>Grassland (P)</td><td>2.3</td></tr>
<tr><td>Other lands (A|O|U)</td><td>0.0</td></tr>
</table>
The values above are recorded in the ranges "B5:B9", "B11:B15" and "B17:B21" of the "BIOMASS" worksheet tab in the "Outside ZILMP Emissions Calculations MR (2021)" and "Outside ZILMP Emissions Calculations MR (2022)" workbook. These values are then applied in the range "D9:D20" of the "EMISSION MONITORING PERIOD(ERL)" worksheet tab in the "Outside ZILMP Emissions Calculations MR (2021)" and "Outside ZILMP Emissions Calculations MR (2022)" workbook for estimating emissions.</td></tr>
<tr><td>QA/QC procedures applied</td><td>The adequacy in the use of these default values was confirmed with the experts in GHG Inventory in DINAB.</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td><table>
<tr><td>Non-forest type</td><td>Uncertainty estimate (confidence interval at 95%)</td></tr>
<tr><td>Cropland (C)</td><td>75.00%</td></tr>
<tr><td>Grassland (P)</td><td>75.00%</td></tr>
<tr><td>Other lands (A|O|U)</td><td>-</td></tr>
</table></td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

<table>
<tr><td>Parameter:</td><td>$BGB_{after,i}$</td></tr>
<tr><td>Description:</td><td>Belowground biomass of non-forest type <i>i</i> after conversion</td></tr>
<tr><td>Data unit:</td><td>tons of dry matter per ha</td></tr>
<tr><td>Source of data or description of the method for developing the data including the</td><td>For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used because, unfortunately, there aren't country-specific data. Tier 2 may modify the assumption that carbon stocks immediately following conversion are zero. In this case, it is assumed that conversion leads to annual croplands and in the case the carbon stock in biomass after one year for annual crops provided in TABLE 5.9 is used.

For grassland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 6, TABLE 6.1 and TABLE 6.4 are used because, unfortunately, there aren't country-specific data. As the climate in most of Mozambique is tropical dry to subtropical dry, the value for semi-arid grassland in</td></tr>
</table>

spatial level of the data (local, regional, national, international):

tropical dry climate zone is used, therefore a root-shoot ratio of 2.8 (TABLE 6.1) is applied to the value of peak above-ground biomass, 2.3 tonnes of dry biomass per hectare (TABLE 6.4), generating the expected values 6.4 tonnes of dry biomass per hectare.

For other lands: No default values exist for these conversions.

Spatial level: International

Value applied:

Cropland (C)	0.00
Grassland (P)	6.44
Other lands (A|O|U)	0.00

The values above are recorded in the ranges "B47:E51", "B53:B57" and "B59:B63" of the "BIOMASS" worksheet tab in the "Outside ZILMP Emissions Calculations MR (2021)" and "Outside ZILMP Emissions Calculations MR (2022)" workbooks. These values are then applied in the range "F9:F20" of the "EMISSION MONITORING PERIOD(ERL)" worksheet tab in the "Outside ZILMP Emissions Calculations MR (2021)" and "Outside ZILMP Emissions Calculations MR (2022)" workbook for estimating emissions.

QA/QC procedures applied

The adequacy in the use of these default values was confirmed with the experts in GHG Inventory in DINAB.

Uncertainty associated with this parameter:

Non-forest type	Uncertainty estimate (confidence interval at 95%)
Cropland (C)	-
Grassland (P)	121.04%
Other lands (A|O|U)	-

Any comment:

-

1.1.6 Monitored Data and Parameters

Parameter: $A(j,i)_{MP}$

Description: Area converted from forest type *j* to non-forest type *i* during the Monitoring Period.

Data unit: hectare per year.

Value monitored during this Monitoring / Reporting Period:

Type of change	2021	2022
Semi-deciduous forest to cropland	26,873.1	23,034.76
Semi-deciduous forest to grassland	1,119.9	59.60
Semi-deciduous forest to other lands	0.00	811.45
Evergreen forest to cropland	1,557.9	1,243.81
Evergreen forest to grassland	296.2	532.51
Evergreen forest to other lands	0.00	
Mangrove forest to cropland	0.00	
Mangrove forest to grassland	0.00	
Mangrove forest to other lands	0.00	

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

(i) Source

Activity data used for the monitoring period are obtained from a combination of an annual wall-to-wall deforestation map with sampling to generate deforested area estimates through a stratified estimator.

(ii) Variable of interest

The variable of interest are all the transitions specified above. It is important to note that the variables of interest are not aligned to the strata as this is not required. Strata is linked to the likelihood of presence of deforestation events, whereas the variable of interest is linked to the possible transitions of deforestation per forest type and post-deforestation type.

(iii) Annual deforestation map

The workflow used to produce annual deforestation map for the area outside the scope of ZILMP follows the steps below:

1. Produce two Sentinel-2 satellite imagery composites for the monitoring area, containing all images of wet season (i.e. January - May). The first composite for the 2021 deforestation map comprises the period between January to May 2021 denoted as the reference period and the second composite comprises the period from January to May 2022, referred as actual period. For the 2022 deforestation map the selected images comprises the period between January to May 2022 and January to May 2023. The reason behind the selection of January - May as a reference and actual period of monitoring resides on the fact that it is the wet season, where the NDVI stability is very high in relation to the dry season, which starts in June to October, when most trees lose their foliage and makes it difficult the analysis of deforestation.
2. Generate image features from reference period and actual period from the composites generated in previous step, to identify changes in forest cover. The image features have different vegetation indexes, namely, NDVI, EVI, SAVI, NBR, NDWI with respective sub-products such as NDVI 90th percentile, Normalized NDVI, and variation on NDVI.

3. Generate training data on classes of deforestation, stable forest and stable non-forest by visual interpretation of composites from the reference and actual periods, and NDVI change detection image. The NDVI change detection image is a result of the difference of NDVI from the composites of reference and actual periods. The calculated NDVI change detection image helps the interpreter to locate where the changes of forest cover are occurring.

4. Produce a categorical deforestation map from training data and image features through a process of classification using Random Forest classifier. The Categorical deforestation map includes non-forest stable and stable forest classes. Because errors of omission of deforestation have a very large impact on the final estimates, it is important to reduce these errors as much as possible.

5. To improve the efficacy of the sampling the deforestation class on the map is reclassified as:
   a) High probability deforestation (cluster of more than 10 pixels of deforestation, corresponding to at least 40% of one hectare);
   b) Low probability of deforestation (cluster of less than 10 pixels and greater than 2 pixels, corresponding at least 12% to 40% of one hectare) and;
   c) Non-forest (cluster of less than 3 pixels, corresponding to less than 12% of a hectare).

6. To reduce the risk of omission errors, a Buffer of 60 meters is added around the high probability of deforestation class. The result is a deforestation map with five classes: High

probability of deforestation; buffer; low probability of deforestation; stable forest and stable non-forest.

(iv) Sampling design

Sampling method

Monitoring of activity data for annual reporting is conducted using a stratified estimator, where deforestation map (which includes classes of forest and non-forest) is used for stratification and reference-sampling units are used for estimate activity data and associated confidence intervals.

Sample size determination

The sample size *n* was determined from the equation:

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

Equation 24

Where:

N	Number of units in the ROI
S(Ô)	Standard error of the estimated overall accuracy that we would like to achieve
W_i	Mapped proportion of area of class *i*; and
S_i	Standard deviation of stratum *i*.

The standard deviation of stratum *i* is given by the formula:

$$S_i = \sqrt{U_i(1 - U_i)}$$

Equation 25

Where:

U_i	Proportion of area of deforestation in stratum *i.*

In order to obtain approximate values of proportion of deforestation in each stratum (U_i), a pilot sampling is conducted. This pilot consists of 100 sample units per stratum.

Sample units per stratum

After the pilot sampling, sample units may need to be added to each stratum, in order to achieve 20% relative margin error at 95% confidence level. It was decided to use the Optimum (Neyman) allocation for each change stratum, where the stratum standard deviation $S_i = \sqrt{U_i \cdot (1 - U_i)}$ increases the number of plots (ensuring larger numbers of plots in rare classes or strata) and sampling unit costs are constant:

$$n_i = n\frac{w_i \cdot S_i}{\sum_{i=1}^{I} w_i \cdot S_i}$$

Equation 26

And for each stable stratum, the proportional allocation is applied if deforestation omission errors are completely absent from these strata. In stratified sampling the sample size for proportional allocation is given by:

$$n_i = n \cdot w_i$$ ***Equation 27***

The number of reference points is presented in Annex-Table 3.

Annex-Table 3: Number of reference sampling units per map stratum for monitoring period (2021 and 2022).

Stratum	**Number of sample units 2021**	**Number of sample units 2022**
High probability of deforestation	100	100
60 m Buffer	277	300
Low probability of deforestation	100	100
Forest	300	300
Non-forest	300	300
Total	1,077	1,100

(v) Response design

Sampling unit and spatial support

The sampling unit is a 20 m pixel of the stratification map that was produced. The spatial support used is a 100m x 100m plot (1ha). Each Spatial sampling unit contains an internal grid of 5 x 5 points (20m x 20m grid) to aid in the labelling attribution (Annex-Figure 6).

Source of reference data

Each sampling unit was evaluated using Collect Earth (http://www.openforis.org/). This tool enables access to high-resolution images in Google Earth, Bing Maps and Planet Labs, as well as a medium resolution image repository available through Google Earth Engine Explorer and Code Editor (Landsat and Sentinel-2). The tool enables to display digital forms designed to collect the Land-Use Land Cover Change and Forestry (LULCCF) information on the sampling points (Annex-Figure 7). The Earth Engine Code Editor facilitates the interpretation of the vegetation type and the determination of LULC changes, by displaying the historical MOD13Q1 (NDVI 16-day Global Modis 250 m) graphic as well as monthly mosaics of Sentinel-2 images. The main source of data to identify changes in land cover, is Sentinel-2 15 days TOA reflectance composites. However, Planet data is also used in cases of doubt or excessive cloud cover with Sentinel-2.

Reference labelling protocol

The activity data was generated considering the national land use and land cover classification system, which reflects the six broad IPCC Land Use categories.

A set of hierarchical rules were established and used to determine the LULCCF category based on a certain percentage and taking into account the national forest definition as well (Annex-Figure 8). A single land use class is easier to classify, but it becomes challenging when there is a combination of two or more land use classes within the area of interest. Thus, this is where the hierarchical rules are important to determine the land use. Any sampling unit that has 30% of tree canopy cover is considered a forest, according to the national forest definition, even if it has more than 20% of settlements, crops or other land use, the forest is priority.

In the case the sampling unit was classified as forest land and different forest types were present in the sampling unit, a majority rule was used in this case, i.e. the largest forest class is chosen (please click here for more details).

(vi) Analysis

Applying the methodology described in Olofsson *et al.* (2014)[17] and the GFOI MGD the estimations of the areas corresponding to land-use and land-cover change categories, more specifically the activity data for deforestation, in the framework of this stratified random sampling approach (based on the visual assessment of the 1 ha plots) was based on assessments of area proportions. A sample error matrix is constructed where the map classes (h=1, 2,…,q) are represented by rows and the reference data (k=1, 2,…,q) by columns as shown in Annex-Table 4.

Annex-Table 4: Error matrix of area proportions.

Map data	Reference data					Total	User's accuracy ($\hat{U}_i$)
	Deforestation			Stable forest	Stable non-forest		
	High probability of deforestation	40 m Buffer	Low probability of deforestation				
High probability of deforestation	$\hat{p}_{11}$	$\hat{p}_{12}$	$\hat{p}_{13}$	$\hat{p}_{14}$	$\hat{p}_{15}$	$\hat{p}_{1\cdot}$	$\hat{p}_{11}/\hat{p}_{1\cdot}$
40 m Buffer	$\hat{p}_{21}$	$\hat{p}_{22}$	$\hat{p}_{23}$	$\hat{p}_{24}$	$\hat{p}_{25}$	$\hat{p}_{2\cdot}$	$\hat{p}_{22}/\hat{p}_{2\cdot}$
Low probability of deforestation	$\hat{p}_{31}$	$\hat{p}_{32}$	$\hat{p}_{33}$	$\hat{p}_{34}$	$\hat{p}_{35}$	$\hat{p}_{3\cdot}$	$\hat{p}_{33}/\hat{p}_{3\cdot}$
Stable forest	$\hat{p}_{41}$	$\hat{p}_{42}$	$\hat{p}_{43}$	$\hat{p}_{44}$	$\hat{p}_{45}$	$\hat{p}_{4\cdot}$	$\hat{p}_{44}/\hat{p}_{4\cdot}$
Stable non-forest	$\hat{p}_{51}$	$\hat{p}_{52}$	$\hat{p}_{53}$	$\hat{p}_{54}$	$\hat{p}_{55}$	$\hat{p}_{5\cdot}$	$\hat{p}_{55}/\hat{p}_{5\cdot}$
Total	$\hat{p}_{\cdot 1}$	$\hat{p}_{\cdot 2}$	$\hat{p}_{\cdot 3}$	$\hat{p}_{\cdot 4}$	$\hat{p}_{\cdot 5}$	*1*	
Producer's accuracy (P_i)	$\hat{p}_{11}/\hat{p}_{\cdot 1}$	$\hat{p}_{22}/\hat{p}_{\cdot 2}$	$\hat{p}_{33}/\hat{p}_{\cdot 3}$	$\hat{p}_{44}/\hat{p}_{\cdot 4}$	$\hat{p}_{55}/\hat{p}_{\cdot 5}$		*Overall accuracy* ($\hat{O}$) $= \hat{p}_{11} + \hat{p}_{22} + \hat{p}_{33} + \hat{p}_{44} + \hat{p}_{55}$

The mean estimator for the area of each class can be directly obtained from the error matrix. Unbiased stratified estimators are provided using reference class area proportions ($\hat{p}_{\cdot k}$):

$$\hat{p}_{\cdot k} = \sum_{h=1}^{H} w_h \cdot \frac{n_{hk}}{n_{h\cdot}} = \sum_{h=1}^{H} \hat{p}_{hk}$$

Equation 28

Where:

$\hat{p}_{\cdot k}$ Area proportions of reference data class k. These proportions of reference data for deforestation classes as a whole are collapsed in three possible types of conversions/transitions from forest type j to non-forest type i, namely:

- Broadleaved (Semi-) deciduous to Non-forest type *i*;
- Broadleaved (Semi-) evergreen to Non-forest type *i*; and
- Mangrove to Non-forest type *i*.

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[17] Olofsson, P., Foody, G.M., Herold, M., Stehman, S.V., Woodcock, C.E., & Wulder, M.A. 2014. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment. 148:42-57.

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Five types of non-forest land are considered:

- Cropland (C);
- Grassland (P);
- Wetland (A);
- Settlement (U); and
- Other lands (O).

w_h Proportion of area mapped as class *h*;
n_{hk} Sample count at cell (*h*,*k*);
$n_{h.}$ Sum of sample counts across row *h*; and
$\hat{p}_{hk}$ Proportion of area in cell (*h*,*k*).

Once the estimated reference class area proportions ($\hat{p}_{\cdot k}$) are obtained, the mean total area per class is calculated by multiplying them with the total reporting area ***a***:

$$\hat{A}_j = \hat{p}_{\cdot k} \cdot a$$ ***Equation 29***

The estimated standard error for the reference class area proportions was given by:

$$S(\hat{p}_{\cdot j}) = \sqrt{\sum_{h=1}^{H} w_h^2 \cdot \frac{\hat{p}_{hj} \cdot (1 - \hat{p}_{hj})}{n_{h\cdot} - 1}}$$ ***Equation 30***

where the term inside the root is the variance of the reference class area proportion. Translated to actual area,

$$S(\hat{A}_j) = S(\hat{p}_{\cdot j}) \cdot a$$ ***Equation 31***

Given the confidence level (i.e., 95%, expressed as a fraction, that is, 0.95), the significance level is $\alpha = 1 - confidence\ level$, one must use Student's t given α and the degrees of freedom, $df = n_{h\cdot} - 1$. For large samples, $df \rightarrow 1.96$. Then the confidence interval of the estimated area per class was given by:

$$CI(\hat{A}_j) = t_{\alpha,df} \cdot S(\hat{p}_{\cdot j})$$ ***Equation 32***

The uncertainty, usually represented as a percentage, then becomes:

$$U(\hat{A}_j) = \frac{CI(\hat{A}_j)}{\hat{A}_j} \cdot 100$$ ***Equation 33***

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<tr>
<td>QA/QC procedures applied:</td>
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The QA/QC procedures consisted on the following:

- SOPs were developed as described in **Section 2.1** - *Satellite and land monitoring system* and training; and
- Interpretation is done by highly qualified professionals which are specialized in land cover interpretation with satellite imagery. They were trained and a robust control system is in place to ensure that they are correctly calibrated throughout the data collection process.
- All reference data interpreted as deforestation or forest degradation, and an additional 20% of the remaining reference data were evaluated. The quality control is carried out by two independent supervisors, who after the independent evaluation compare the two evaluations and consensually compile a single comment for each sample. The parameters to be taken into account in the evaluation for identifying errors are: a) the

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	percentage of coverage for each element within the plot; b) the current land cover/land use class (levels 1 and 2); c) the land cover/land use change class; d) the former land cover/land use class (levels 1 and 2); and e) the date of occurrence of land cover/land use change, or evidence date of remaining land cover/land use. If there are gross errors related to the parameters b), c) and d) in at least 20% of samples from the 20% mentioned initially, the respective interpreter should review all samples from the batch, otherwise the interpreter reviews only the samples evaluated by the supervisors, that present gross errors. On the other hand, in relation to all samples interpreted as deforestation, the interpreter reviews only the samples that present gross errors according to the evaluation from the supervisors. The process is cyclical until the interpreter achieves values less than 20% of gross errors in the batch. ● The sampling design and estimation was reviewed by an international renowned expert (Steve Stehman), a statistics professor of State University of New York.
Uncertainty for this parameter:	see table below
Any comment:	-

Category change	Uncertainty estimate (Confidence interval at 95%) 2021	Uncertainty estimate (Confidence interval at 95%) 2022
FSD>C	20.49%	± 21.42%
FSD>P	82.13%	± 196.21%
FSD>(A|O|U)	-	± 140.00%
FSSV>C	92.42%	± 119.69%
FSSV>P	159.06%	± 196.21%

5.4 QUANTIFICATION OF EMISSION REDUCTIONS

5.4.1 Reference level for the Monitoring / Reporting Period covered in this report

Year of Monitoring/Reporting period *t*	**Average annual historical emissions from deforestation over the Reference Period (tCO$_{2-e}$/yr)**	**If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO$_{2-e}$/yr)**	**If applicable, average annual historical removals by sinks over the Reference Period (tCO$_{2-e}$/yr)**	**Adjustment, if applicable (tCO$_{2-e}$/yr)**	**Reference level (tCO$_{2-e}$/yr)**
2021	7,932,644.34	-	-	-	7,932,644.34
2022	7,932,644.34				7,932,644.34
Total	15,865,288.68	**-**	**-**	**-**	15,865,288.68

5.4.2 Estimation of emissions by sources and removals by sinks included

The following table shows the emissions results obtained per category changes from a forest type to a non-forest type during the Monitoring Period. The emissions are generated relating the data and parameters described in Subsection 5.3.2 and summarized in the Annex-Table 5, by applying **Equation 14**.

Annex-Table 5: Calculation of the emissions during the Monitoring Period (2021 and 2022).

Category changes	**AGB$_{before,j}$ (tdm/ha)**	**BGB$_{before,j}$ (tdm/ha)**	**AGB$_{after,i}$ (tdm/ha)**	**BGB$_{after,i}$ (tdm/ha)**	**2021**		**2022**	
					A$_{(j,i)MP}$ (ha)	**Emissions (tCO$_2$e)**	**A(j,i)MP (ha)**	**Emissions (tCO2e)**
Semi-deciduous forest to cropland	144.69	49.95	10	0	26,873.1	8,550,698	23,034.76	7,329,385
Semi-deciduous forest to grassland	144.69	49.95	2.3	6.4	1,119.9	358,762	59.60	19,093
Semi-deciduous forest to other lands	144.69	49.95	0	0	0	0	811.45	272,176
Evergreen forest to cropland	123.13	42.06	10	0	1,557.9	416,643	1,243.81	332,644
Evergreen forest to grassland	123.13	42.06	2.3	6.4	296,2	79,870	532.51	143,570

Evergreen forest to other lands	123.13	42.06	0	0	0	0	0	0
Mangrove to cropland	269.01	85.43	10	0	0	0	0	0
Mangrove to grassland	269.01	85.43	2.3	6.4	0	0	0	0
Mangrove to other lands	269.01	85.43	0	0	0	0	0	0
Total						**9,405,973**		**8,096,868**

Year of Monitoring/Reporting Period	**Emissions from deforestation (tCO_{2-e}/yr)**	**If applicable, emissions from forest degradation (tCO_{2-e}/yr)***	**If applicable, removals by sinks (tCO_{2-e}/yr)**	**Net emissions and removals (tCO_{2-e}/yr)**
2021	**9,405,973**	-	-	**9,405,973**
2022	8,096,868			8,096,868
Total	17,502,841	-	-	**17,502,841**

5.4.3 Calculation of emission reductions

Total Reference Level emissions during the Reporting Period (tCO2-e)	15,865,288.68
Net emissions and removals under the ER Program during the Reporting Period (tCO2-e)	17,502,841.14
Emission Reductions during the Reporting Period (tCO2-e)	-1,637,552.46

5.5UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS

Uncertainties were propagated using the Approach 1 of the 2019 Refinement to the 2006 IPCC GL, i.e. propagation of uncertainties. The following equations were used for addition or multiplication.

For addition or subtraction:

$$U_{total} = \frac{\sqrt{(U_1.x_1)^2 + \cdots + (U_i.x_i)^2 + \cdots + (U_n.x_n)^2}}{|x_1 + \cdots + x_i + \cdots + x_n|}$$

Equation 34

Where:

U_i The percentage uncertainties associated with each of the quantities;

X_i Quantities to be combined; x_i may be a positive or a negative number; and

U_{total} The percentage uncertainty in the sum of the quantities (half the 95 percent confidence interval divided by the total (i.e., mean) and expressed as a percentage)

For multiplication:

$$U_{total} = \sqrt{{U_1}^2 + \cdots + {U_i}^2 + \cdots + {U_n}^2}$$

Equation 35

Where:

X_i The percentage uncertainties associated with each of the quantities; and

U_{total} The percentage uncertainty in the product of the quantities (half the 95 percent confidence interval divided by the total and expressed as a percentage)

	2021	2022
Uncertainty of Reference Level emissions during the Monitoring Period (%)	19.34	19.34
Uncertainty of net emissions and removals under the ER Program during the Monitoring Period (%)	24.57	25.71
Uncertainty of Emission Reductions during the Reporting Period (%)	-188.3	-1575

ANNEX 6: DEGRADATION IN THE SCOPE OF ZAMBÉZIA INTEGRATED LANDSCAPE MANAGEMENT PROGRAM (ZILMP)

Since 2020, Mozambique has been developing a methodology for estimating forest degradation. This methodology was developed taking into account the process used to estimate deforestation to allow for consistency over time. This chapter (Annex 6) was prepared only to demonstrate the country's process and progress regarding estimates of emissions from forest degradation for 2021.

1.1. Overview of the approach to estimate degradation

FCPF methodological guidance provides few limits to the approach for monitoring degradation. Degradation is required to be accounted for where emissions are estimated to be significant (>10% of total forest-related emissions). Where included degradation should be estimated using 'best available data (including proxy activities or data)'. While 'direct' methods are preferred, 'activity data may be derived using indirect methods such as survey data, proxies derived from landscape ecology, or statistical data on timber harvesting and regrowth if no alternative methods are available'.

Mozambique has been testing a range of approaches for expanding its existing monitoring procedures to include estimates of degradation. Five broad options for estimation emissions from degradation were identified:

1. Remote sensing based estimates (e.g. changes in land cover maps)
2. Forestry statistics (e.g. timber production statistics)
3. Forest inventory plot data (e.g. cyclical NFI plots)
4. Model-based estimates (e.g. modelling woodfuel demand)
5. Sample-based estimation

Of these, only sample based area estimation was considered feasible for ZILMP. Remote sensing based estimates [1] were not yet considered sufficiently reliable for degradation, a problem that is particularly great in the dry tropics where satellite monitoring of forest cover can be problematic. Forestry statistics [2] and forest inventory plot data [3] are not currently systematically collected for the ZILMP region, and would require an unrealistically large data collection effort to implement. Model or proxy based estimates [4] were considered challenging for ZILMP on account of difficulty in implementation and given limited evidence that they could work.

Sample based area estimation [5] fits well within existing MRV workflows, and has the potential to be applied to existing monitoring datasets. Methods are also well-developed for emissions estimation using sample-based data, and development of a transparent process for estimating emissions uncertainty was considered possible.

Methodological development work is described in more detail in the report: 'FNDS degradation: final report' (March 2023). This technical annex describes the finalised approach for measuring degradation, plans for future improvements of estimates, and provides provisional estimates of degradation-related emissions for ZILMP in 2021.

1.2. Methods descriptions

In summary, degradation is defined as the loss of canopy cover that transforms a 'closed canopy' forest (greater than or equal to 65% canopy cover) to an 'open canopy' forest (less than 65% canopy cover, but still at least 30%). Emissions are estimated from the difference of carbon density between a 'closed' and 'open' canopy woodland. Activity data are derived from systematic (reference period) or stratified random (monitoring period) sampling, using high-resolution imagery to record degradation where canopy cover of closed canopy forest is reduced to that of open canopy forest. Uncertainty estimates are derived using a Monte Carlo method adapted from the existing deforestation emissions methods.

1.2.1. Definition of degradation

Degradation is defined as the loss of canopy cover such that a formerly ‘closed-canopy’ forest (≥65% canopy cover) is modified to ‘open-canopy’ forest (≥30% to <65% canopy cover) as the result of human action. Thresholds for closed- and open-canopy forest are derived from Mozambique’s existing forest cover definitions. The degradation is recorded in the case that a dense forest transitions to open forest. A separate carbon density is applied to each of open and closed forests, and transitions between these two classes are associated with emissions or removals equivalent to the difference between the carbon stocks of a dense vs sparse forest. This method should prevent double-counting of emissions between deforestation and degradation, as deforestation that follows from degradation will be associated with lowered emissions.

1.2.2. Emission factor

ZILMP uses a single emission factor for each forest stratum in the region, consisting of Semi-deciduous forest (FSD), Evergreen forest (FSSV), and Mangrove forest (FF) strata. Above-ground biomass is estimated using data from Mozambique’s National Forest Inventory in combination with a series of allometric models. Below-ground biomass is estimated using root:shoot ratios, and emissions are assumed to be instantaneous following deforestation.

The updated method uses a similar approach, but rather than a single biomass density per forest stratum, separate biomass densities are estimated for closed-canopy and open-canopy forests (Annex 6 - Table 1). No changes are made to other elements of emission factor estimation, including allometric models, root:shoot ratios, or uncertainty estimation methods. Forests in the FF stratum are not currently given separate emission factors for closed and open canopy areas, as no suitable data currently exist for this assessment, and examples of degradation in this stratum have not yet been observed.

The Emission factors were previously estimated in a complex Excel spreadsheet, which outputs estimates of above- and below- ground biomass in each relevant forest type, along with an estimate of uncertainty (t-distribution). These methods provide functionality to re-estimate emission factors given permuted root:shoot ratios.

Annex 6 - Table 1: Biomass densities used for emission factors in the existing ZILMP emissions estimation procedures (level 1) and updated biomass densities for open-canopy and closed-canopy forests (level 2)

	Biomass (tonnes/ha)		**Uncertainty (%)**		**Degrees of freedom**	
Stratum	**Above-ground**	**Below-ground**	**Above-ground**	**Below-ground**	**Above-ground**	**Below-ground**
Level 1						
Semi-deciduous forest	144.69	49.95	13.3	9.97	28.7	26.0
Evergreen forest	123.13	45.06	8.71	7.83	5.2	4.01
Mangrove	269.01	85.43	10	85.4	-	-
Level 2						
Semi-deciduous open forest	128.47	43.79	14.4	43.8	17.8	11.8

Semi-deciduous closed forest	174.11	61.11	10.9	61.1	15.1	15.5
Evergreen open forest	114.65	41.02	6.59	41.0	3.52	3.43
Evergreen closed forest	174.11	47.23	19.8	47.2	3.37	3.14
Non-forest						
Cultivation	10	0	37.5	0	-	-
Grassland	2.3	6.44	37.5	60.5	-	-
(A|O|U)	0	0	0	0	-	-

1.2.3. Activity data

Activity data derive from the same sample-based method that is used to quantify rates of deforestation (see section 3 of this report). Collect Earth is used to label land use and land use changes using high-resolution satellite imagery over a series of sample points. Sample points are based either on a systematic sample (reference period) or a stratified sample (monitoring period). Stratification is based on an existing deforestation mapping tool and buffer regions designed to minimise errors of omission.

Two methods are used to identify degradation using outputs from Collect Earth:

Pre-2021 Historically FNDS-MRV have recorded all canopy cover changes in each Collect Earth sample unit, in addition to monitoring of degradation. These records are somewhat limited, only recording final canopy cover (to the nearest 10%), and canopy cover losses and gains in 10% bins. From this information points of degradation can be flagged where final canopy cover falls between 30% - 65% (open-canopy), and canopy cover losses were sufficiently large to mean that initial forest cover must have been ≥65% (closed-canopy). This approach is somewhat limited, as little quality assurance was conducted on this aspect of the data, and historical satellite imagery is sometimes insufficient to identify small-scale forest changes.

Post-2021 FNDS-MRV updated its Collect Earth survey to require that operators record the initial canopy cover of each point in addition to the final canopy cover. Alongside, operators are asked to flag degradation where canopy cover losses are such that a sample unit meets the definition of degradation. This approach can be considered considerably more robust, and quality assurance procedures have been updated to ensure that data quality is high.

In 2021 a further change was implemented for mapping procedures to improve monitoring of degradation. Errors of omission were observed of degradation points from the map change classes, resulting in a high degree of uncertainty in emissions estimates. Larger buffer regions were included to capture minor changes on the periphery of deforestation, and smaller areas of forest change (previously excluded) were included in change classes. For consistency, these same changes were rolled out for deforestation monitoring from 2021 onwards. It is not anticipated this will impact uncertainty of deforestation estimates. The Annex 6 - Table 2 show the modifications to standard operating procedures for map production to improve monitoring of canopy forest change for degradation

Annex 6 - Table 2. Modifications to standard operating procedures for map production to improve monitoring of canopy forest change for degradation

Class	**Colour**	**Label**	**Modifications**
1	#CE0000	High probability deforestation	-
2	#FFA500	Buffer deforestation	Buffer size increased from 40 m to 60 m
3	#FFFF00	Low probability deforestation	Minimum of 3 connected pixels in place of 6

4	#367D49	Stable forest	-
5	#FFFBCC	Stable non-forest	-

The Sample data collected across the five map strata are summarised in Annex 6 - Table 3. Notably, no errors of omission were detected in either deforestation or degradation classes in 2021 (map strata 4 and 5). Without this property, attaining reasonably constrained estimates on emissions reductions associated with degradation is not possible. Also notable is the absence of enhancement points detected in the monitoring period. This is likely down to monitoring on a year-to-year basis not being sufficiently long to reliably identify forest regrowth.

Annex 6 - Table 3: Sample counts from systematic sampling (reference period) and stratified random sampling (monitoring period).

Stratum	**Number of samples**	**Deforestation**	**Degradation**	**Enhancement**	**Area (ha)**
Reference period					
-	3,318	117	46	22	5,310,265
Monitoring period 2021					
1 - high probability deforestation	100	69	4	0	25,013
2 - buffer deforestation	309	21	9	0	226,309
3 - low probability deforestation	100	32	5	0	9,891
4 - stable forest	300	0	0	0	2,225,307
5 - stable non-forest	300	0	0	0	2,823,745

Activity data resulting from stratified area estimation (2021) are shown in Annex 6 - Table 4. Outputs indicate that the area of forest impacted by degradation is around a quarter to one third of that subject to deforestation, and that it impacts FSD and FSSV forest strata in a proportion similar to deforestation. Uncertainties associated with deforestation and forest degradation are of comparable magnitude. The area of deforestation is larger in 2021, while degradation appears roughly stable.

Annex 6 - Table 4: Areas of deforestation, degradation and enhancement observed in the ZILMP reference period and the monitoring period of 2021.

	Reference period		**Monitoring period 2021**	
	Area (ha/yr)	**SE (ha/yr)**	**Area (ha/yr)**	**SE (ha/yr)**
Deforestation total	**17,023**	-	**35,805**	-
Semi-deciduous open forest > other land (A|O|U)	145	145	-	-
Semi-deciduous open forest >	7,857	1,060	27,097	3,365

cultivation				
Semi-deciduous open forest > grassland	1,309	436	250	250
Semi-deciduous closed forest > cultivation	3,928	753	6,480	1,277
Semi-deciduous closed forest > grassland	436	252	-	-
Evergreen open forest > cultivation	1,600	482	1,681	860
Evergreen open forest > grassland	145	145	-	-
Evergreen closed forest > cultivation	1,600	482	198	139
Mangrove> cultivation	-	-	99	99
Degradation total	**6,256**	-	**8,087**	-
Semi-deciduous closed forest > Semi-deciduous open forest	5,529	892	8,087	2,234
Evergreen closed forest > Evergreen open forest	727	325	-	-
Enhancement total	**3,201**	-	**0**	-
Semi-deciduous open forest > Semi-deciduous closed forest	2,764	632	-	-
Evergreen open forest > Evergreen closed forest	436	252	-	-

1.2.4. Emission estimation

Methods for emissions estimation remain unchanged from existing documentation for ZILMP. The only difference is that now more land cover transitions are possible, including to and from open- and closed-canopy forest types. New forest transition types are summarised in Annex 6 - Table 5.

Summary of forest change classes following from the inclusion of degradation.

Annex 6 - Table 5: Summary of forest change classes following from the inclusion of degradation.

From ↓	To →	Closed-canopy forest	Open-canopy forest	Non-forest
Closed-canopy forest		-	Degradation	Deforestation
Open-canopy forest		Enhancement	-	Deforestation
Non-forest		Afforestation	Afforestation	-

1.2.5. Uncertainty estimation

Uncertainty estimation follows the same approach as estimates for deforestation. Uncertainties in emission factors are estimated using National Forest Inventory, but with the addition of further forest classes to account for closed and open canopy variants. Uncertainties in activity data are derived from non-parametric bootstrapping (resampling with replacement), again with new classifications for the transitions between open- and closed-canopy forests. Uncertainty in emissions reductions estimates are estimated using Monte Carlo analysis, using at least 10,000 parameter sets. Methods for uncertainty estimation are described in more detail in section 5 of this report.

1.2.6. Results

Emission

Emissions increased in 2021, with a marked increase in deforestation emissions (please see the section 4.3 of this report). Emissions from degradation are an order of magnitude smaller than those from deforestation (~10%), and show a small increase in 2021 relative to the reference period (Annex 6 - Table 6).

Annex 6 - Table 6: Nominal emissions reductions for deforestation and degradation. *Note: negative emissions reductions indicate increased emissions in the monitoring period.

	Emissions (tCO_2/yr)		
	Reference period	**Monitoring period 2021**	**Reductions***
Degradation total	**671,556**	**877,431**	**-205,875**
Semi-deciduous closed forest > Semi-deciduous open forest	599,899	877,431	-277,532
Evergreen close forest > Evergreen open forest	71,657	-	71,657

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

Year of Monitoring/Reporting period *t*	**Average annual historical emissions from deforestation over the Reference Period (tCO_{2-e}/yr)**	**If applicable, average annual historical emissions from forest degradation over the Reference Period (tCO_{2-e}/yr)**	**If applicable, average annual historical removals by sinks over the Reference Period (tCO_{2-e}/yr)**	**Adjustment, if applicable (tCO_{2-e}/yr)**	**Reference level (tCO_{2-e}/yr)**
2021	5,253,267.99	671,556	-	-	5,924,823.99
Total	**5,253,267.99**	671,556	**-**	**-**	**5,924,823.99**

Estimation of emissions by sources and removals by sinks included

Year of Monitoring/Reporting Period	Emissions from deforestation (tCO_{2-e}/yr)	If applicable, emissions from forest degradation (tCO_{2-e}/yr)*	If applicable, removals by sinks (tCO_{2-e}/yr)	Net emissions and removals (tCO_{2-e}/yr)
2021	11,325,034	877,431	-	12,202,465
Total	**11,325,034**	877,431	-	**12,202,465**

Calculation of emission reductions

Total Reference Level emissions during the Reporting Period (tCO2-e)	5,924,823.99
Net emissions and removals under the ER Program during the Reporting Period (tCO2-e)	12,202,465
Emission Reductions during the Reporting Period (tCO2-e)	**-6,277,641.01**

Monte Carlo analysis

Uncertainties are estimated using a Monte Carlo approach, where model parameters are repeatedly resampled and overall uncertainty estimated from the resulting distribution (Figure 3). This process, like with deforestation, indicates with a high degree of confidence that emissions have increased in 2021 relative to the reference period (Annex 6 - Table *7*).

Annex 6 - Table 7: Monte Carlo analysis

Model parameters	Median estimate (tCO_2)	95% C.I.	Relative margin (%)
Reference period	5,540,513	4,542,735 to 6,615,100	18.7%
Monitoring period	11,489,514	9,402,131 to 13,693,718	18.7%
Emissions reductions	-5,936,199	-7,963,573 to -3,972,248	33.6%

A model sensitivity analysis was conducted using the same procedures as the ER monitoring report, fixing parameters at their nominal values one-at-a-time and reporting the reduction in overall uncertainty (Annex 6 - Table 8). The greatest source of uncertainty is from monitoring period activity data, followed by reference period activity data and above-ground biomass estimates. Notable is that the main sources of uncertainty are identical to those associated with deforestation emissions estimates. Therefore, any efforts to reduce uncertainty in these estimates are likely to also have a positive impact on reducing uncertainty in emissions from degradation.

Annex 6 - Table 8: Sensitivity analysis

	Reduction in uncertainty (%)	
Model parameters	**Deforestation only**	**Deforestation + degradation**
Nominal	0	0
Reference area	11.0	8.3
Monitoring area	44.2	34.9
AGB	17.0	5.7
BGB	7.2	1.7
CF	6.4	-0.8