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:	16-05-2018 to 31-12-2018
Number of FCPF ERs:	1,340,317
Quantity of ERs allocated to the Uncertainty Buffer	79,781
Quantity of ERs to allocated to the Reversal Buffer	478,685
Quantity of ERs to allocated to the Reversal Pooled Reversal buffer	95,737
Date of Submission:	21-08-2020

Notice

This ER Monitoring Report is made public for validation and verification purposes. Annex 1, 2, and 3 are not included in this version since they are being assessed by The World Bank for their accuracy and completeness. The full Report will be made available as soon as The World Bank´s assessment and the validation/verification are concluded as outlined in the FCPF Process Guidelines.

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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 ER-Program (Winrock International and CEAGRE, 2015 & Mercier et al., 2016). Illegal logging and informal charcoal production are the main drivers of forest degradation within the Program geographical area. 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 WB investment projects (the "Sustenta" project, MozBio, MozDGM and MozFIP), and those have a broader approach on land management: their activities extend beyond the agricultural sector per se. 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 financial plan as mentioned already on the ER-PD, there is no gap to put in place all interventions within the ER Program, at least until 2022. Sustenta 2 Project was approved when the ERPD was prepared and this will financially support more activities aiming to generate ERs within the ER Program.

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 MRV team 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 and 2018 in the Districts outside of the ER Program and in other Provinces is displayed (See the link: https://bit.ly/geoportalmrvfnds). Degradation is another component of forest monitoring that the MRV is developing and expecting to be available in 2021. 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. The drivers of deforestation and forest degradation within the ER Program remain the same (see section 1.2). All strategies outlined on 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 1).

Table 1: 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. During this period, FNDS was carrying this activity while the process of contracting a Service Provider. Community delimitation is the first step towards a sustainable management of natural resources and land. The outputs documents of community's delimitation are Certificates

	signed by the SPGC, the community zoning Land Use map, Community Land Use Plan, Community development agenda. According to the ERPD plan, the aim is to achieve 322,500 ha of community land supported by land use plans. Sustenta and MozFIP projects delimited a total of 57 communities land in Mulevala, Gilé and Mocuba Districts comprising an area of 180,139ha. It is expected an increase of these number in the following years. This will reduce nomadism thus avoiding displacement. To foster the sustainable community management, individual farmers also benefited from R-DUATs in Mocuba, Mulevala e Gilé 37,671 farmers, in an area of 60,559 ha. It is expecting to increase in the following years to come. 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 spread the cashew trees as part of the 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 forest management for charcoal and use of forest logging and sawmill residues as it contributes to emissions from deforestation and forest degradation. 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. From the private sector, four companies 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 process of adopting the 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, the 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 Reserve reason why the GoM decided to take such measures as the last National Forest Inventory indicates that the species' stock has steeply declined over the past 10 years. 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 Developed in 2018 a tool of Minimum standards for sustainable management (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. Apart of the National Forestry Inventory, in 2018 conducted an inventory in Zambézia, which was critical input to the measures taken by the ministry regarding species exploitation and exportation ban.

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 that have been 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. In December 2019, as part of its work program, the discussion and consultation point of the most recent version of the BSP in Quelimane was placed.
- Creation of a committee for assessing the implementation of forest plantation scheme (Composed by DINAS, DINAF and IFLOMA). The role of this committee is: Assess and approve the conformance and eligibility of the 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 FEP, 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)[1].
- Exchange of experience with NFC and WWF Uganda with the support of NGP (New Generation Plantation) in how to engage the SME in forest plantations. A study visit 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 the forestry company New Forests (NFC) and WWF-Uganda with the support of the NGP Platform - New Generation Plantations). The Travel Report was shared with the World Bank.[2] Partnership between private sector and communities in small business enterprises (Sustainable charcoal production; non-timber forest products; community concessions, among others). Several MOU were signed between 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 FNDS promoted a new negotiation process for the partnership to make the mushroom business viable with the Divateches-Agri

[1] Source: MozFIP annual progress report 2020

[2] Source: MozFIP annual progress report 2018

and Miruku consortium, having already signed the MoU. Some negotiations have not been successful, but efforts are still being made to promote more partnerships.

The major milestones still to be achieved are:

- Signature of MOU with FNDS, Portucel and NIRAS (Service Provider for Forest Plantation Scheme) to supply seedling for MozFIP and provide technical assistance to the PFGS beneficiaries; All the discussions were made, and the draft of MOU was already discussed as yet to be signed by Portucel, FNDS and NIRAS. Although there are important activities already taking place, such as: i) providing seedlings and other inputs at a subsidized price; ii) technical assistance; and iii) Training for extension technicians;
- Signature of MOU with 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, during forestry operations.

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 data showed clearly that more than 70% of the changes detected were due to unsustainable small-scale agriculture both in the program area and outside. 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 ground trothing.

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 out 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 monitoring system (NFMS). There is a work in progress between the National Directorate of Forest (DINAF) and FNDS and other relevant stakeholders to formalize the NFMS. The current monitoring system has three sub-systems:

- Satellite and land monitoring system
- National forest inventory

- National 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 FREL. This information was also used to generate historical deforestation statistics for 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 ZILMP using a systematic stratified sampling. With the development of methodologies to generate statistics and spatially explicit data of deforestation, it was possible to produce annual deforestation maps for 2017, 2018 and 2019 as shown on the link https://gis.fnds.gov.mz/arcgis/apps/webappviewer/index.html?id=dc26e4d6025e4d059085657a3804f57e for the whole country and the area estimates for Zambézia Province which are based on sampling. 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 with FCPF finance.

The process of generating activity data comprises five steps (Figure 1); 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 QA/QC processes in all production processes including the development of 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://fnds.gov.mz/mrv/index.php/documentos/guioes/28-protocolo-ce/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.

It is the intention to disseminate the use of activity data to communities and other stakeholders to monitor deforestation in their area of interest in the coming future. The implementation will be effective in 2021 as the COVID 19 situation did not allow the project to test the methodology in 2020.

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. The information from these inventories were used to produce information for timber purposes. The last inventory in 2016-17 produced the emission factors used for the FREL submitted to the UNFCCC in 2018 (report may be accessed in the following 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 the Province of Zambezia were used to generate ZILMP-specific Emission Factors. The methods to generate the emissions factors for ZILMP is described in the link https://fnds.gov.mz/mrv/index.php/documentos/relatorios/18-relatorio-de-inventario-florestal-zambezia/file.

The process used to produce the emission factors followed these steps: Response design, Sampling design, Data collection and Data analysis (Details in figure 1). The entity responsible for the National forest inventory is the National Directorate of Forest. The National forest inventory 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 Institute of Agricultural Research (IIAM), the Faculty of Agronomy and Forest Engineering, 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 the Faculty of Agronomy and Forest Engineering (FAEF) and the Department of Biology Sciences (DCB) of the University Eduardo Mondlane (UEM).

To ensure the quality of the data collected, the team followed QAQC procedures defined by the National Directorate of Forest. 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 Sampling plots are another component of the National Forest Monitoring System that will improve the estimation of emissions factors and the IIAM leads it. 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. However, this the Permanent Sampling plot network is not relevant for the ZILMP.

National GHG inventory

The National GHG inventory for the purpose of REDD+ combines the Activity data and the emission factors (Figure 1) to estimate the annual emissions and the FREL.

A 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 and the national data, Provincial and District FRELs. 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 since the Approval of ERPD in institutional arrangements 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 was 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 has 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. Community monitoring is not relevant for the FMS of the ZILMP as it has not been used to monitor GHG emissions and Emission Reductions, yet this is still used for monitoring of implementation of program activities. There have been meetings held at district level and some communities. However, local community participation has not yet been fully achieved. This is something that FNDS will work on improving over the next year.

The organogram of the MRV Unit responsible for the ZILMP monitoring is described in Figure 1. The MRV Unit was created in 2016, with the coordinator and 4 technicians (Alismo, Credêncio, Délfio and Hercilo). 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). 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 that is 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 Figures 2, 3 and 4.

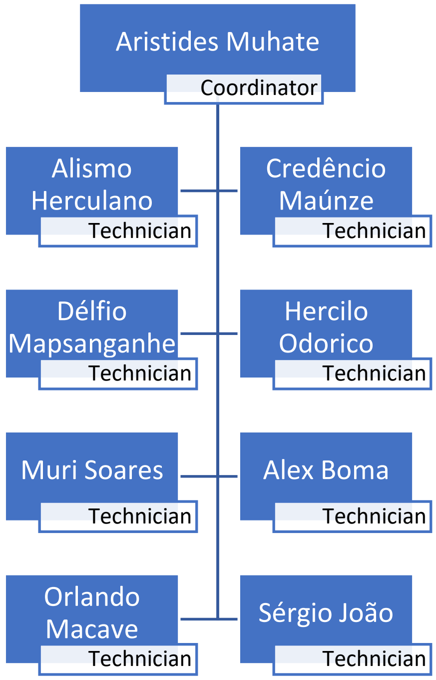


Figure 1: Organogram of MRV Unit responsible for ZILMP monitoring.

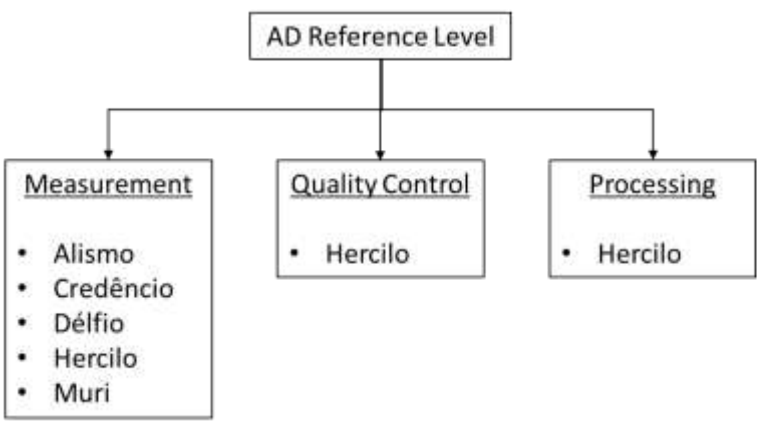


Figure 2: Organizational structure for Activity Data of Reference Level.

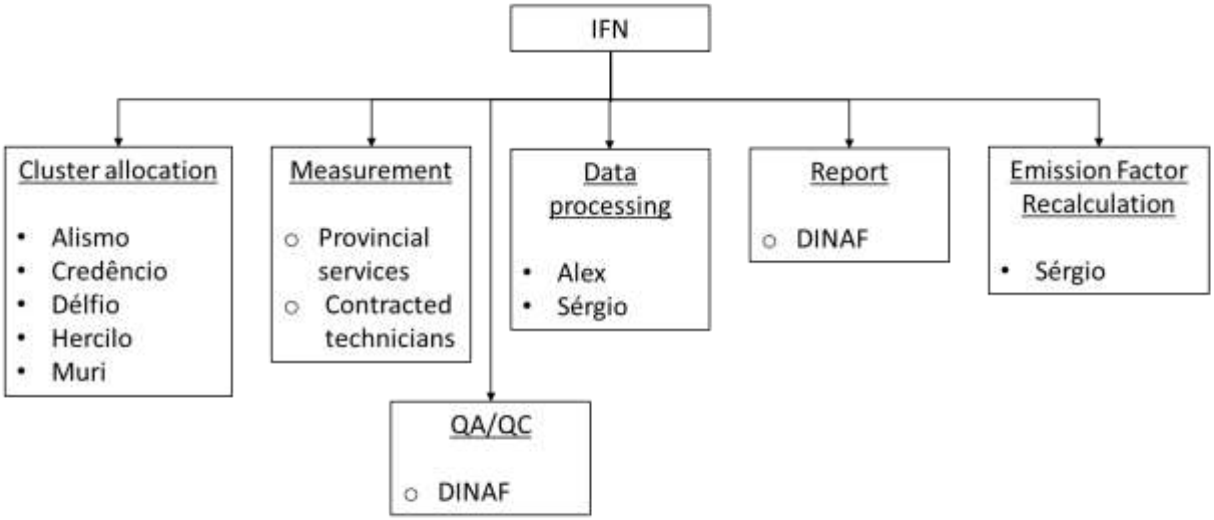


Figure 3: Organizational structure for National Forest Inventory.

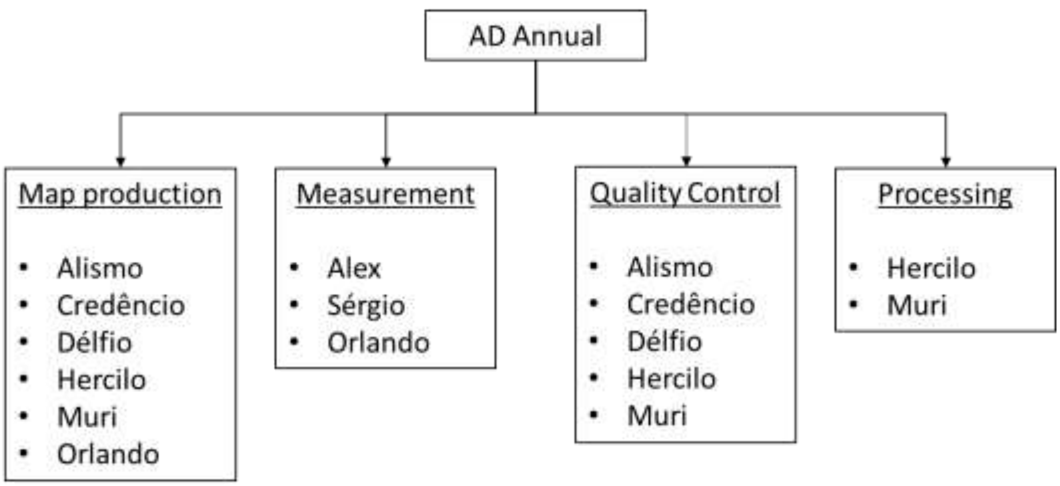


Figure 4: Organizational structure for Annual Activity Data.

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 FNDS (2020).

2.2 Measurement, monitoring and reporting approach

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.

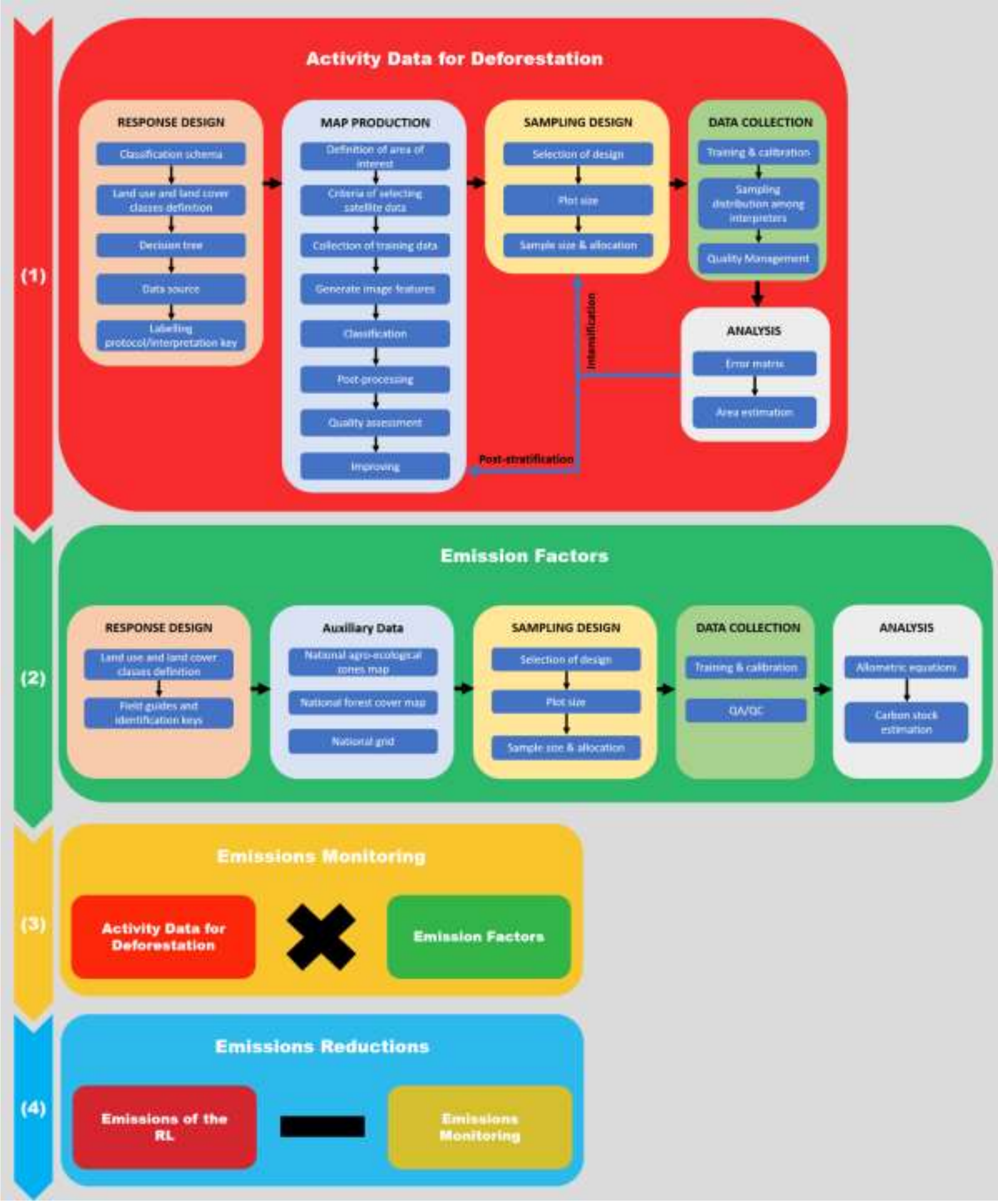


Figure 5: Emissions reductions calculation workflow.

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}*. This is sourced from Annex 4 to the ER Monitoring Report and equations are provided below.
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* ($\mathrm{RL_t}$)**

The RL estimation may be found in Annex 4, yet a description of the equations is provided below.

Gross emissions of the RL from deforestation over the Reference Period ($\mathrm{RL_{RP}}$) are estimated as the sum of annual change in total biomass carbon stocks ($\Delta\mathrm{C_{B_t}}$) 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+[3], 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 *($\Delta C_{CONVERSION}$)*;

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

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 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
- 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).

Some of the technical corrections applied pertain this parameter:

- The activity data was corrected by correcting two mistakes that were identified, one related to the length of the period of analysis (10 years instead of 11 years)
- The final ERPD applied a post-deforestation carbon density for each of the forest types, whereas in the technically corrected RL the five non-forest IPCC Land Use categories have been used instead.

The description of this parameter may be found in *Annex 4 – Section Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period.*

$B_{Before,j}$ 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 parameter was technically corrected so as to replace the estimates using the estimates from the NFI for the province of Zambezia.

Description of this parameter may be found in *Annex 4 - Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period*.

$B_{After,i}$ 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 IPCC Guidelines.

Description of this parameter may be found in *Annex 4 - Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period*.

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 $(\mathbf{GHG_t})$

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

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

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

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 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. The following methods were used from the sampling design to estimation: ***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 4 forest types (semi-deciduous forest, semi-evergreen forest, Mopane and Mecrusse forest), of which only semi-deciduous forest and semi-evergreen forest 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 two 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).

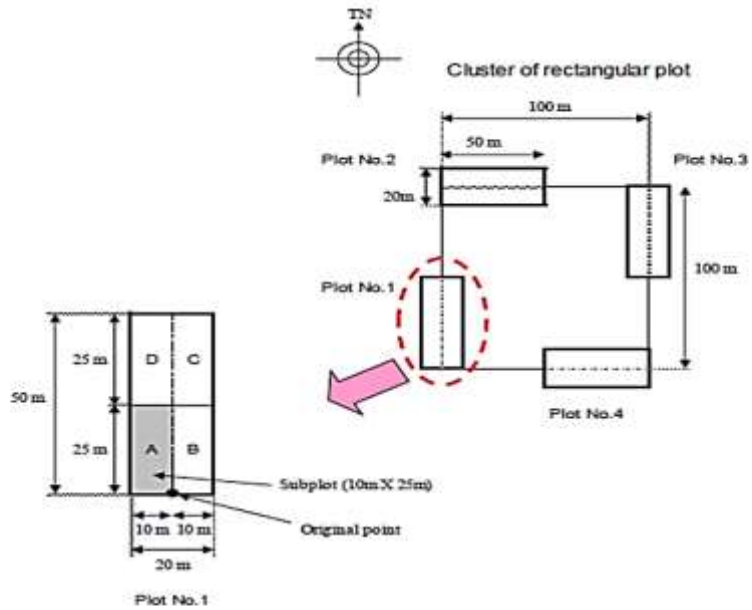


Figure 6: Design of each cluster used in the National Forest Inventory.

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 2), 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 above species), 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.

Table 2: 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= 0.28
		Author: IPCC (2003)	Author: Mokany *et al*. (2006)
	Evergreen mountain forest (open and closed)	$\hat{Y} = 0.0613*DAP2.7133$	$\hat{Y} = AGB * R/S$; R/S= 0.29
		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://www.fnds.gov.mz/mrv/index.php/documentos/relatorios/18-relatorio-de-inventario-florestal-zambezia/file. The approach of Bechtold & Patterson (2005), was used to correct the problem of sample units (clusters) with variable areas. This occurred because the forest type information collected in each cluster at the field level, showed that the clusters transcended the boundaries of the strata (cluster with more than one strata). For mangrove forests, data are secondary, extracted from existing literature. Stringer *et al.* (2015)[4] 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. Spatial level: Regional			
Value applied:	Semi-deciduous forest (FSD): 144.69 Evergreen forest (FSSV): 123.13 Mangrove forest (FF): 269.00			
QA/QC procedures applied	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 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			

Semi-deciduous forest (FSD)	144.69
Evergreen forest (FSSV)	123.13
Mangrove forest (FF)	269.00

[4] 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.

	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.
Uncertainty associated with this parameter:	(see table below)
Any comment:	-

Forest type	Uncertainty estimate				
	Mean	Lower (5th percentile)	Upper bound (95th percentile)	Half-width confidence interval at 90%	Relative Margin
FSD	144.7	121.8	167.6	22.9	16%
FSSV	123.1	108.7	137.6	14.4	12%
FF	92	79.9	104.1	12.1	13%

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, national, international):	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, data are secondary, extracted from existing literature. Stringer et al. (2015) 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. Spatial level: Regional
Value applied:	(see table below)
QA/QC procedures applied	Please see section QA/QC procedures under parameter $AGB_{before,j}$.
Uncertainty associated with this parameter:	

Semi-deciduous forest (FSD)	49.98
Evergreen forest (FSSV)	42.24
Mangrove forest (FF)	85.40

Forest type	Uncertainty estimate					
	Mean	Lower (5th percentile)	Upper bound (95th percentile)	Half-width confidence interval at 90%	Relative Margin
FSD	50	43.4	56.6	6.6	13%
FSSV	42.2	38	46.5	4.2	10%
FF	26.7	22.3	31.1	4.4	17%

Any comment:	

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, national, international):	For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used. 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 are used. 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
Value applied:	(see table below)
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:	(see table below)

Value applied:

Cropland (C)	10
Grassland (P)	2.3
Other lands (A|O|U)	0.0

Uncertainty associated with this parameter:

Non-forest type	Uncertainty estimate				
	Mean	Lower (5th percentile)	Upper (95th percentile)	Half-width confidence interval at 90%	Relative Margin
Cropland (C)	10	3.8	16.2	6.2	62%
Grassland (P)	2.3	0.9	3.7	1.4	61%
Other lands (A|O|U)	0.0	0.0	0.0	0.0	-

Any comment:	Negative lower estimates of uncertainty are set to 0 when running Monte Carlo Simulations.

Parameter:	$BGB_{after,i}$
Description:	Belowground 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, national, international):	For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used. 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, TABLE 6.4 are used. The value for semi-arid grassland in tropical dry climate zone is used, therefore a root-shoot ratio of 2.8 is applied to the value of aboveground biomass. For other lands: No default values exist for these conversions. Spatial level: International
Value applied:	(see table below)
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:	(see table below)
Any comment:	Negative lower estimates of uncertainty are set to 0 when running Monte Carlo Simulations.

Value applied:

Cropland (C)	0.0
Grassland (P)	6.4
Other lands (A|O|U)	0.0

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	0.0	-	-
Grassland (P)	6.4	2.5	10.3	3.9	61%
Other lands (A|O|U)	0.0	0.0	0.0	-	-

3.2 Monitored Data and Parameters

<table>
<tr><td>Parameter:</td><td>$A(j,i)_{MP}$</td></tr>
<tr><td>Description:</td><td>Area converted from forest type j to non-forest type i during the Monitoring Period.</td></tr>
<tr><td>Data unit:</td><td>hectare per year.</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td>
<table>
<tr><td>Semi-deciduous forest to cropland</td><td>5,840.16</td></tr>
<tr><td>Semi-deciduous forest to grassland</td><td>0.0</td></tr>
<tr><td>Semi-deciduous forest to other lands</td><td>115.10</td></tr>
<tr><td>Evergreen forest to cropland</td><td>319.50</td></tr>
<tr><td>Evergreen forest to grassland</td><td>4.20</td></tr>
<tr><td>Evergreen forest to other lands</td><td>0.0</td></tr>
<tr><td>Mangrove forest to cropland</td><td>0.0</td></tr>
<tr><td>Mangrove forest to grassland</td><td>0.0</td></tr>
<tr><td>Mangrove forest to other lands</td><td>0.0</td></tr>
</table>
</td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>
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. November - May). The first composite comprises the period between November 2017 to May 2018 denoted as the reference period and the second composite comprises the period from November 2018 to May 2019, referred as actual period. The reason behind the selection of November- 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
</td></tr>
</table>

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 6 pixels, corresponding at least 24%- to 40% of one hectare) and;
   c) Non-forest (cluster of less than 6 pixels, corresponding to less than 20% of a hectare).
6. To reduce the risk of omission errors, a Buffer of 40 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:

$$n = \frac{(\sum W_i S_i)^2}{\left[S(\hat{O})\right]^2 + (\frac{1}{N})\sum W_i S_i} \approx \left(\frac{\sum W_i S_i}{S(\hat{O})}\right)^2 \qquad \textbf{Equation 7}$$

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:

$$S_i = \sqrt{U_i(1-U_i)} \quad \textbf{Equation 8}$$

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 reach the desired relative error. It was decided to use the Optimum (Neyman) allocation, where the stratum standard deviation $S_h = \sqrt{U_h \cdot (1-U_h)}$ increases the number of plots (ensuring larger numbers of plots in rare classes or strata) and sampling unit costs are constant:

$$n_h = n \frac{w_h \cdot S_h}{\sum_{h=1}^{H} w_h \cdot S_h} \quad \textbf{Equation 9}$$

The technical team, with support from a renowned international expert (Steve Stehman) decided that there should be a minimum of 300 sample units in the stable classes. The reason behind this minimum is that if no deforestation events are found in the 100 sample units of each stable stratum, then *pi* will be 0, and we would require no further sampling of these strata. This would mean that our sample size for the stable strata would be much smaller than for the change strata.

Post-stratification of stable classes

After the initial stratification be conducted and the reference data collected, visual inspection of the map showed that there were errors of omission, even though the reference data did not include any. The original deforestation map for Zambézia 2017-2018 was produced with a rudimentary version of our map production workflow, which was improved since then. The technical team, with the support from a renowned international expert (Steve Stehman) decided to produce a post-stratification of the stable classes using the new map production workflow. This stratification was composed of the same classes of change: high probability of deforestation, buffer and low probability of deforestation. However, these were merged prior to the collection of reference data, in order to reduce the effort in collection of new reference data. The final number of reference points is presented in Table 3.

Table 3: Number of reference sampling units per map stratum. “New deforestation” stratum represents the post-stratification conducted on the stable classes, after it was found that the original map was omitting deforestation.

Stratum	Number of sample units
High probability of deforestation	260
40 m Buffer	431
Low probability of deforestation	125
Forest	300

Non-forest	300
New deforestation	100
Total	1516

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 7).

Figure 7: 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 8). 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 monthly composites. However, Planet data is also used in cases of doubt or excessive cloud cover with Sentinel-2.

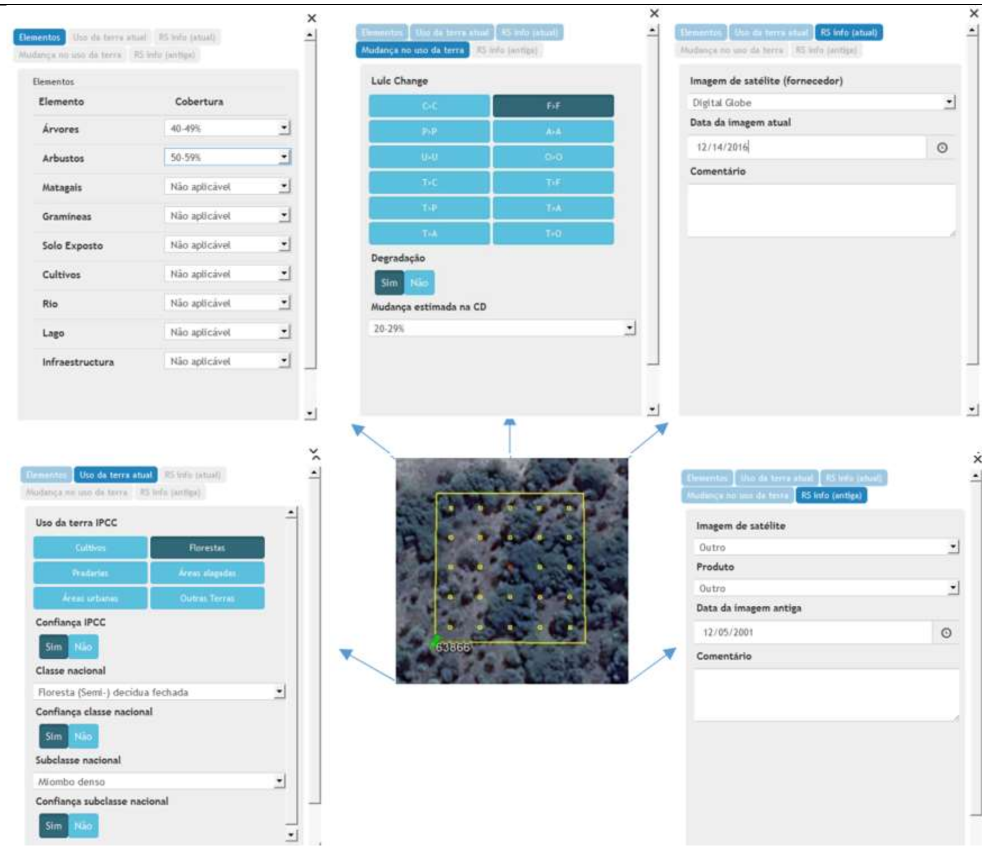


Figure 8: LULCCF detection using Collect Earth Tool (www.openforis.org). Digital forms designed with Collect Tool.

<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 (Figure 9). 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.

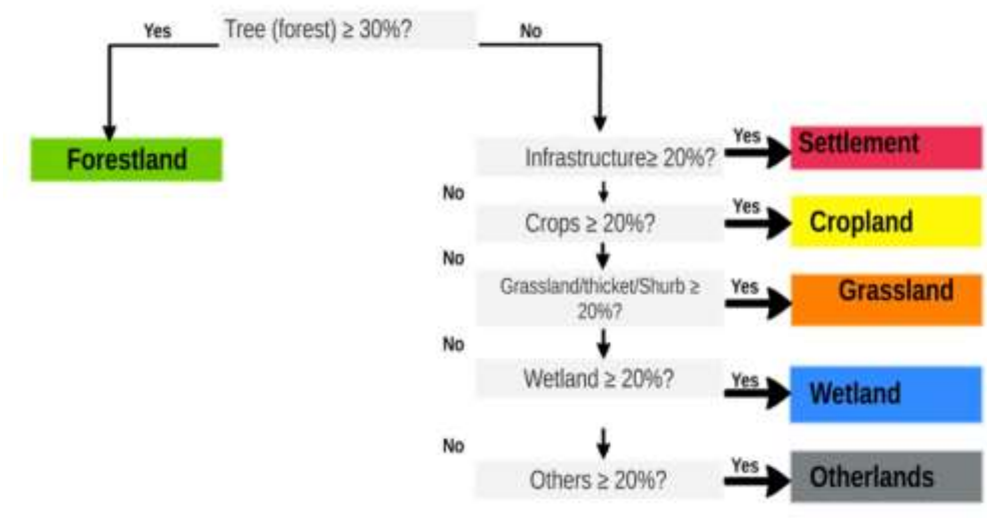


Figure 9: Decision tree for the attribution of the LULCCF category based on the percentage cover of the elements present in the sampling unit of 1 ha.

vi. Analysis

Applying the methodology described in Olofsson *et al*. (2014)[5] 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.

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 ($\hat{p}_{\cdot k}$):

$$\hat{p}_{\cdot k} = \sum_{h=1}^{H} w_h \cdot \frac{n_{hk}}{n_{h\cdot}} = \sum_{h=1}^{H} \hat{p}_{hk} \qquad \textbf{Equation 10}$$

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:

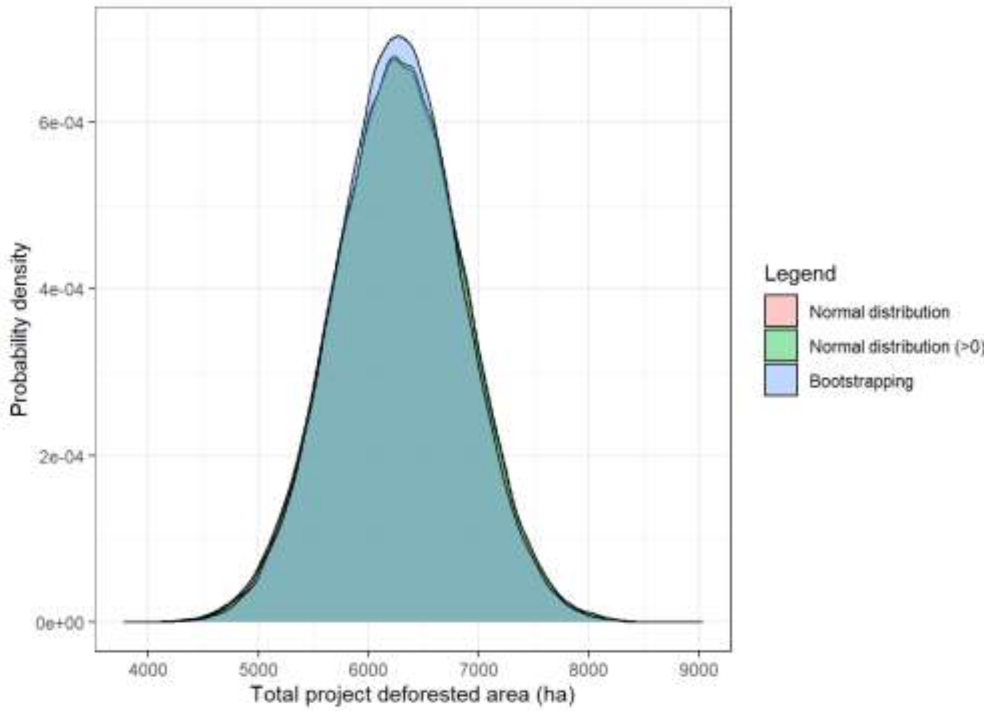
- Broadleaved (Semi-) deciduous to Non-forest type *i*;
- Broadleaved (Semi-) evergreen to Non-forest type *i*; and
- Mangrove to Non-forest type *i*.

Five types of non-forest land are considered:

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

[5] 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.

	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 11*** 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 ERPA 2018*" 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 (Figure 10) 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 10: Total activity data area estimates for 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, and an additional 20% of the remaining reference data. 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.

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The sampling design and estimation was reviewed by an international renowned expert (Steve Stehman), a statistics professor of State University of New York.
The uncertainty analysis approach was reviewed by Philip Mundhenk, a professor of the University of Hamburg specialized in Monte Carlo simulations.

</td></tr>
<tr><td>Uncertainty for this parameter:</td><td>
<table>
<tr><th rowspan="2">Category change</th><th colspan="5">Uncertainty estimate (from non-parametric bootstrapping)</th></tr>
<tr><th>Median</th><th>Lower bound (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>C</td><td>5840.2</td><td>4923.4</td><td>5836.4</td><td>6771.6</td><td>924.1</td></tr>
<tr><td>FSD>(A|O|U)</td><td>115.1</td><td>0</td><td>111.7</td><td>338.5</td><td>169.2</td></tr>
<tr><td>FSSV>C</td><td>319.5</td><td>81.6</td><td>308.5</td><td>617.4</td><td>267.9</td></tr>
<tr><td>FSSV>P</td><td>4.2</td><td>0</td><td>4.1</td><td>12.4</td><td>6.2</td></tr>
</table>
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<tr><td>Any comment:</td><td>-</td></tr>
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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)
2018	5,119,652.91	-	-	-	5,119,652.91
Total	**5,119,652.91**	**-**	**-**	**-**	**5,119,652.91**

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 4, by applying ***Error! Reference source not found.***.

Table 4: Calculation of the emissions from the ER Program during the Monitoring Period

Category changes	$A_{(j,i)MP}$ (ha)	$AGB_{before,j}$ (tdm/ha)	$BGB_{before,j}$ (tdm/ha)	$AGB_{after,i}$ (tdm/ha)	$BGB_{after,i}$ (tdm/ha)	Emissions (tCO_2e)
Semi-deciduous forest to cropland	5,840.16	142.52	50.03	10.00	0.00	1,837,228.50
Semi-deciduous forest to grassland	0.00	142.52	50.03	2.30	6.40	0.00
Semi-deciduous forest to other lands	115.10	142.52	50.03	0.00	0.00	38,190.89
Evergreen forest to cropland	319.50	110.63	41.00	10.00	0.00	77,984.48
Evergreen forest to grassland	4.20	110.63	41.00	2.30	6.40	1,033.67
Evergreen forest to other lands	0.00	110.63	41.00	0.00	0.00	0.00
Mangrove to cropland	0.00	269.00	85.40	10.00	0.00	0.00
Mangrove to grassland	0.00	269.00	85.40	2.30	6.40	0.00
Mangrove to other lands	0.00	269.00	85.40	0.00	0.00	0.00
Total						**1,954,437.54**

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)
2018	1,954,437.54	-	-	1,954,437.54
Total	1,954,437.54	-	-	**1,954,437.54**

4.3 Calculation of emission reductions

Total Reference Level emissions during the Monitoring Period (tCO_2-e)	5,119,653
Net emissions and removals under the ER Program during the Monitoring Period (tCO_2-e)	1,954,438
Emission Reductions during the Monitoring Period (tCO_2-e)	3,165,215

Length of the Reporting period / Length of the Monitoring Period (# days/# days)	230/365
Emission Reductions during the Reporting Period (tCO_2-e)	**1,994,519**

5 UNCERTAINTY OF THE ESTIMATE OF EMISSION REDUCTIONS

5.1 Identification, assessment and addressing sources of uncertainty

Table 5. 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 error	This error represents the operator error during the interpretation of LULCC on sampled points and inconsistencies between operators. This error is reduced by extensive QAQC 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. Training samples are collected by an operator, identifying 3 classes: stable forest, stable non-forest and deforestation. These training samples are used to calibrate a Random Forest classifier, which outputs a categorical map of deforestation. For the purpose of area estimation, it's important to minimize errors of omission in the deforestation class. Buffer regions of 50 m width are added around deforestation events to reduce the likelihood of any deforestation events being missed. An additional stratum is used, based on a low deforestation probability threshold.	Low	YES	NO
Sampling error	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.	High	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.	Low	YES	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 the deforested again. Additionally, in the rare cases where this might occur, such double counting would be conservative for our emissions reductions estimate.	H/L (bias)	YES	NO

	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.			
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. 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 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 QAQC 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.	*H (bias) & L (random)*	YES	NO
Root-to-shoot ratio measurement	Below ground biomass is mostly estimated directly with country-specific allometric equations, therefore the propagation of errors it is not applicable. Root-to-shoot ratios were used for one of the strata (Evergreen Forest), with the value taken from the 2006 IPCC Guidelines. The impact of this parameter on overall uncertainty would be negligible.	*H (bias) & L (random)*	YES	NO
Carbon Fraction	Carbon fraction parameter was taken from the 2006 IPCC Guidelines. Error, as provided from the IPCC Guidelines, has been propagated.	*H (bias) & L (random)*	YES	YES

Biomass allometric equation (Model error)	Allometric equations used ranged from national (specific species), 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 constant from reference to monitoring period. Additionally, the overall effect of emission factor uncertainty on total uncertainty is low (7.4%)	*H (random/bias)*	*YES*	*YES*
Sampling error	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)	YES	YES
Representativeness error	This source of error is related to the representativeness of the estimate which is related to the sampling design. The forests of Zambézia province are quite homogeneous, with widespread occurrence of miombo forests. The stratification between evergreen and semi-deciduous forests allows to cover both the more humid miombo and wetter miombo. 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 MRV team has implemented an automated script to calculated emissions and uncertainty. This should greatly reduce the possibility of mistakes in the calculations.	*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.	L	YES	NO

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 100,000 random permutations of model parameters. Uncertainty deriving from the carbon fraction of biomass were derived from literature values (IPCC 2006) where the minimum and maximum expected values form the bounds of a triangular distribution.

Table 6. Parameter specifications used in the monte carlo simulations.

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
Length of reference period	11 years		-	ER program design
Project area	5310265.16 ha		-	ER program design
Area of FSD>C in reference period	11770.9 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>P in reference period	1743.8 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>(A|O|U) in reference period	145.3 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>C in reference period	3197.0 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>P in reference period	145.3 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>C in monitoring period	5829.9 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>(A|O|U) in monitoring period	110.7 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>C in monitoring period	307.0 ha	Sampling	Non-parametric bootstrapping	

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Area of FSSV>P in monitoring period	4.1 ha	Sampling	Non-parametric bootstrapping	
Aboveground biomass of FSD	144.7 t/ha	Sampling	Normal distribution (mean = 144.7 sd = 13.93)	
Aboveground biomass of FSSV	123.1 t/ha	Sampling	Normal distribution (mean = 123.1 sd = 8.78)	
Aboveground biomass of FF	92 t/ha	Sampling	Normal distribution (mean = 92 sd = 7.36)	
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	50 t/ha	Sampling	Normal distribution (mean = 50 sd = 4.02)	
Belowground biomass of FSSV	42.2 t/ha	Sampling	Normal distribution (mean = 42.2 sd = 2.56)	
Belowground biomass of FF	26.7 t/ha	Sampling	Normal distribution (mean = 26.7 sd = 2.67)	
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 = 2.4)	
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

		Total Emission Reductions
A	**Median**	3,293,237.94

B	**Upper bound 90% CI** (Percentile 0.95)	2,398,332.40
C	**Lower bound 90% CI** (Percentile 0.05)	4,332,171.55
D	**Half Width Confidence Interval at 90% (B – C / 2)**	966,919.60
E	**Relative margin (D / A)**	29%
F	**Uncertainty discount**	4%

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. As a result it can be seen that the main source of uncertainty is the Activity Data estimated for the reference period. Considering the high impact of reference AD on total uncertainty, Mozambique will attempt to reduce the uncertainty of this parameter in the next monitoring cycle.

Table 7: Sensitivity analysis.

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	3,293,238	2,398,332	4,332,172	966,920	0.29	0
AD (reference)	3,181,167	2,727,632	3,667,614	469,991	0.15	51.4
AD (monitoring)	3,343,781	2,501,559	4,346,716	922,579	0.28	4.6
EF	3,310,167	2,448,561	4,239,781	895,610	0.27	7.4
CF	3,317,788	2,422,484	4,351,329	964,423	0.29	0.3

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, conversely 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 the GNR 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[6]:

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**

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

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.

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".

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/RegistoDeProgramas) 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 FCPF ER 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, only 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.

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)

Intentionally left blank.

7.2 Quantification of Reversals during the Reporting Period

Intentionally left blank.

7.3 Reversal risk assessment

The reversal risk assessment using the CF Buffer Guidelines has not changed since the preparation of the revised final ERPD. 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 (FGRM) 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 Medium: 5% discount	5%
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. But 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	30%
Total reversal risk set-aside percentage from ER-PD or previous monitoring report (whichever is more recent)	30%

8 EMISSION REDUCTIONS AVAILABLE FOR TRANSFER TO THE CARBON FUND

A.	**Emission Reductions during the Reporting period (tCO_2-e)**	*from section 1.5.3*	1,994,519
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)**		0.0
C.	**Number of Emission Reductions estimated using measurement approaches (A-B)**		1,994,519
D.	**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 1.6.4*	0.04
E.	**Calculate (0.15 * B) + (C * D)**		79,781
F.	**Emission Reductions after uncertainty set-aside (A – E)**		1,914,739
G.	**Number of ERs for which the ability to transfer Title to ERs is still unclear or contested at the time of transfer of ERs**	*from section 2.1*	0.0
H.	**ERs sold, assigned or otherwise used by any other entity for sale, public relations, compliance or any other purpose including ERs that have been set-aside to meet**	*From section 2.4*	0.0

	Reversal management requirements under other GHG accounting schemes		
I.	**Potential ERs that can be transferred to the Carbon Fund before reversal risk set-aside (F – G – H))**		1,914,739
J.	**Total reversal risk set-aside percentage applied to the ER program**	*From section 3.3.2*	0.3
K.	**Quantity of ERs to allocated to the Reversal Buffer and the Pooled Reversal Buffer (multiply I and J)**		574,422
L.	**Number of FCPF ERs (I – L).**		1,340,317

The following annexes are being completed and will be made public as soon as they are available:

- Annex 1: Information on the Implementation of the Safeguards Plans
- Annex 2: Information on the Implementation of the Benefit Sharing Plan
- Annex 3: Information on the Generation and/or Enhancement of Priority Non-Carbon Benefits

ANNEX 4: CARBON ACCOUNTING - ADDENDUM TO THE ERPD

Technical corrections

The FMT was notified on the 29th of March 2019 of the intention to apply technical corrections.

This complete description of Technical Corrections applied to the FREL of the Zambézia ER Program are limited to the positive list described on the FCPF *Guidelines on the application of the Methodological Framework (MF) Number 2: Technical corrections to the GHG emissions and removals reported in the reference period*:

a) Replacement of **emission factors** used in the construction of the forest reference emission level by others with improved accuracy
b) Corrections to historical **activity data** resulting from improvements to quality assurance/quality control procedures.

Summary of corrections

a) Replacement of emission factors used in the construction of the forest reference emission level by others with improved accuracy

(i) Corrections to Forest Emission Factors

The emission factors were updated to use the data from the NFI collected in Zambézia province, for the semi-deciduous and evergreen forest strata (Table 8). Additionally, the approach was changed from the one used in the NFI. The initial methodology used the plot as the sampling unit, due to some clusters containing multiple strata in different plots. The corrected methodology now uses ratio estimators to correct for this situation. That methodology is described below and will be described in detail in the revised Report of the Forest Inventory of Zambézia province. The emission factors for Mangrove were not altered, as the NFI did not cover this forest type.

Table 8: Changes in emission factors (tCO2e ± confidence interval) for semi-deciduous and evergreen forest strata

Stratum	Pool	Original (α = 90%)	Corrected (α = 95%)
Semi-deciduous forest	AGB	257 ± 18	243.60 ± 53.17
	BGB	71.9 ± 3.45	86.13 ± 14.96
Evergreen forest	AGB	369.89 ± 40.68	206.15 ± 32.68
	BGB	99.89 ± 10.98	72.80 ± 10.43

(ii) Corrections to Non-forest Emission Factors

The ERPD included emission factors for post-deforestation strata as a single value for each forest stratum. That is, it did not differentiate between the new use of the land, it only considered what the previous forest type was. This is not consistent with the approach adopted by Mozambique in the FREL, where emissions factors are determined for all possible combinations of changes of forest to non-forest. As a result, the non-forest emission factors (previously post-deforestation strata) have been changed, to the values used in the determination of the National FREL of Mozambique, which are sourced from the default IPCC 2006 values.

b) Corrections to historical activity data resulting from improvements to quality assurance/quality control procedures.

The QA/QC procedures implemented led to the identification of two errors that needed to be corrected:

(i) *The reference period used to estimate the RL for ZILMP is 2005-2015 and approved by the FCPF, equates to a duration of 11 years not 10 years as initially used in the calculations.*

The number of years of the reference period is 11, and not 10. The reference period of the Program is 2005-2015. In a preliminary phase of the ERPD, the approach to determining activity data was based on map comparison. In this case, when comparing a map of 2005 with a map of 2015, the deforestation of 2015 is not measured, as it occurs towards the end of the year, and the map is usually produced with early/mid-year satellite images. In this case, the reference period is 10 years. However, the approach to activity data was later changed to reflect the approach used in the National Forest Reference Level. In this approach deforestation is analyzed for each year, based on visual interpretation of samples taken from a systematic grid. Therefore, all years in the reference period are analyzed, including 2015.

(ii) *Accounting Area of the ER Program*

The accounting area of the ER Program is not 6,009,414 hectares but 5,310,265 hectares. There are two reasons for this:

- A transfer error between the areas of the Districts of Ile and Pebane (Table 9). Ile was incorrectly assigned the area of Pebane.
- The areas for each district were taken from the official documentation, rather than from the shapefile of the districts of the country. Although this is not incorrect in and of itself, the problem is that all analyses are geospatial in nature and as such, use the shapefile to set the boundaries of the maps.

Table 9: Corrections made to district areas of Program Area. District of Ile and original area of Pebane highlighted in yellow, to show source of error.

District	Original area (ha)	Corrected area (ha)
Alto Molocué	630,812	634,001
Gilé	896,516	897,702
Gurué	564,933	564,345
Ile	1,005,479	293,349
Maganja da Costa	267,925	287,284
Mocuba	877,351	877,225
Mocubela	499,234	476,080
Mulevala	261,685	270,099
Pebane	1,005,479	1,010,182
Program area	**6,009,414**	**5,310,265**

The result of these two changes is that the reference emissions reduced from ***6,487,447 tCO2e/yr to 5,119,653 tCO2e/yr.***

7 CARBON POOLS, SOURCES AND SINKS

7.1 Description of Sources and Sinks selected

Sources/Sinks	Included?	Justification/Explanation
Emissions from deforestation	Yes	At a minimum, ER Programs must account for emissions from deforestation.
Emissions from forest degradation	No	In the ER Program area, forest degradation is mainly caused by forest exploitation and, to a lesser extent, by charcoal production. Emissions related to those two sources were estimated in the ZILMP Background Study (Mercier et al., 2016). However, it is likely that emissions related to charcoal production have been overestimated because tree cuts for this production were accounted for separately from slash-and-burn agriculture whereas, on the fields, it can actually be observed that charcoal is produced on land areas that would deforested for agriculture purpose the same year or the year after. Hence, charcoal production is more to be considered as part of the slash-and-burn cycle (occurring at the beginning of the cycle) and as a by-product of agriculture, which is itself the main cause of deforestation. As a consequence, the impact of charcoal production on the ER Program emissions is already accounted for in the estimation of emissions due to deforestation and it was decided to not include it as a source of emissions related to degradation (which is conservative). Two options to estimate emissions related to forest exploitation were considered and are summarized hereafter. The analysis based on exploited volume (as presented in the ZILMP Background Study) is detailed in Annex 3. Since those emissions represent less than 10% of global program emissions, it was decided to not include forest degradation in the sources of emissions for the ER Program. Moreover, small-scale agriculture being the main cause of deforestation, there is no indication that measures intended to reduce deforestation would result in leakage towards degradation. Rather, with the ER Program enabling activities such as land tenure clarification or national policies to reduce illegal logging, both deforestation and degradation would probably be reduced if the program succeeds. Hence, it is conservative to not account for degradation and it is estimated to not be a significant source for the following reasons: ● While analyzing the factors to delimitate intact and degraded forest, we considered distance to anthropic activities (i.e. distance to deforestation patches of deforestation) or to forest edge in relation to carbon stocks – from biomass inventory data for the present program. It shows that proximity to anthropic activities or to forest edge does not have a significant impact on carbon stocks. Moreover, carbon stocks have an unexpected negative correlation to distance of deforestation patches. On this basis, it is not possible to delimitate degraded forest with the indirect approach of the GOFC-GOLD. ● As a consequence, the method presented in the ZILMP Background Study (Mercier et al., 2016) using exploited volumes seems to be the most suitable. Based on estimation of exploited volumes in Zambézia (legal and

		illegal logging) with secondary data from the literature, it gives an estimation of emissions due to forest exploitation in the accounting area of 37,945 tCO_2e (Mercier et al., 2016), which corresponds to less than 10% of emissions due to deforestation. The method to estimate those emissions is described in Annex 3 of the ERPD.
Enhancement of carbon stocks	No	This activity can encompass carbon sequestration through tree plantation or assisted regeneration of natural forest (non-forestland to forestland or in forestland remaining forestland). It was decided to not account for enhancement of carbon stocks. First, this decision is conservative; second, these sinks are not considered as sufficient in the accounting area: ● Some plantations exist in the ZILMP area, but not all of them respect the UNFCCC safeguards requiring that activities included in REDD+ programs do not lead to the conversion of natural forest. In addition, in the ZILMP Background Study, emission reductions potential associated with carbon stock enhancement was not estimated as significant enough (Mercier et al., 2016). ● Although assisted natural regeneration activities are part of the proposed ER Program interventions (see section 4.3), the few areas managed for natural regeneration actually represent a small part of the ER Program area. They would be limited to 1,000 ha. Carbon sequestration for such an area, based on inventories on follows (see following section) would not be significant enough
Sustainable management of forests		Although some ER Program activities focus on improved forest management and planning, those would only result reduced degradation that is not accounted for. Moreover, it is conservative to not include this activity.
Conservation of carbon stocks		In the ER Program accounting area, this would concern the Gilé National Reserve. Since its creation the GNR has proved to have efficiently maintained its forest cover (except for forest degradation due to illegal logging of specific tree species) in its central zone. However, a REDD+ project is developed in its buffer zone – where deforestation does occur – and the GRN will benefit from the program funds

7.2 Description of carbon pools and greenhouse gases selected

Carbon Pools	**Selected?**	**Justification/Explanation**
Above Ground Biomass (AGB)	Yes	Most significant pool
Below Ground Biomass (BGB)	Yes	This pool is usually significant in the case of deforestation because BGB is supposed to degrade itself after tree cut.
Biomass in non-woody vegetation	No	This pool is usually non-significant and it is conservative to exclude it.

Dead organic matter	No	This pool is probably not significant as dead wood is collected for firewood or burnt during bush fires of the dry season. It is conservative to not account for this pool in the ER Program RL.
Soil Organic Carbon (SOC)	No	Data from literature show that this pool is not significant: emission factors related to SOC would be between 5.1 tC/ha (Mercier et al., 2016) and 12.7 tC/ha (Williams et al. 2008a)

GHG	Selected?	Justification/Explanation
CO2	Yes	The ER Program shall always account for CO_2 emissions and removals
CH4	No	Source of emission from this gas are not significant in the context of the ZILMP.
N2O	No	Source of emission from this gas are not significant in the context of the ZILMP.

8 REFERENCE LEVEL

8.1 Reference Period

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

8.2 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.

8.3 Average annual historical emissions over the Reference Period

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

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 (10 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 3.

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

$$RL_{RP} = \frac{\sum_t^{RP} \Delta C_{B_t}}{RP}$$ ***Equation 12***

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 13***

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:

$$\Delta C_{B_t} = \sum_{j,i} \left(B_{Before,j} - B_{After,i}\right) x\ CF\ x \frac{44}{12} \times A(j,i)_{RP}$$ ***Equation 14***

Where:

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

$A(j,i)_{RP}$ 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).

Some of the technical corrections applied pertain this parameter:

- The activity data was corrected by correcting two mistakes that were identified, one related to the length of the period of analysis (10 years instead of 11 years)
- The final ERPD applied a post-deforestation carbon density for each of the forest types, whereas in the technically corrected RL the five non-forest IPCC Land Use categories have been used instead.

The description of this parameter may be found in *Annex 4 – Section Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period*

$B_{Before,j}$ 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 parameter was technically corrected so as to replace the estimates using the estimates from the NFI for the province of Zambezia.

Description of this parameter may be found in *Annex 4 - Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period*.

$B_{After,i}$ 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 IPCC Guidelines.

Description of this parameter may be found in *Annex 4 - Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period*.

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

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 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 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 3,308 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*** Spatial sampling unit 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% (Figure 11). 

	Figure 11: Spatial sampling unit. 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 imagery with digital forms (Figure 12) 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 RS 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).

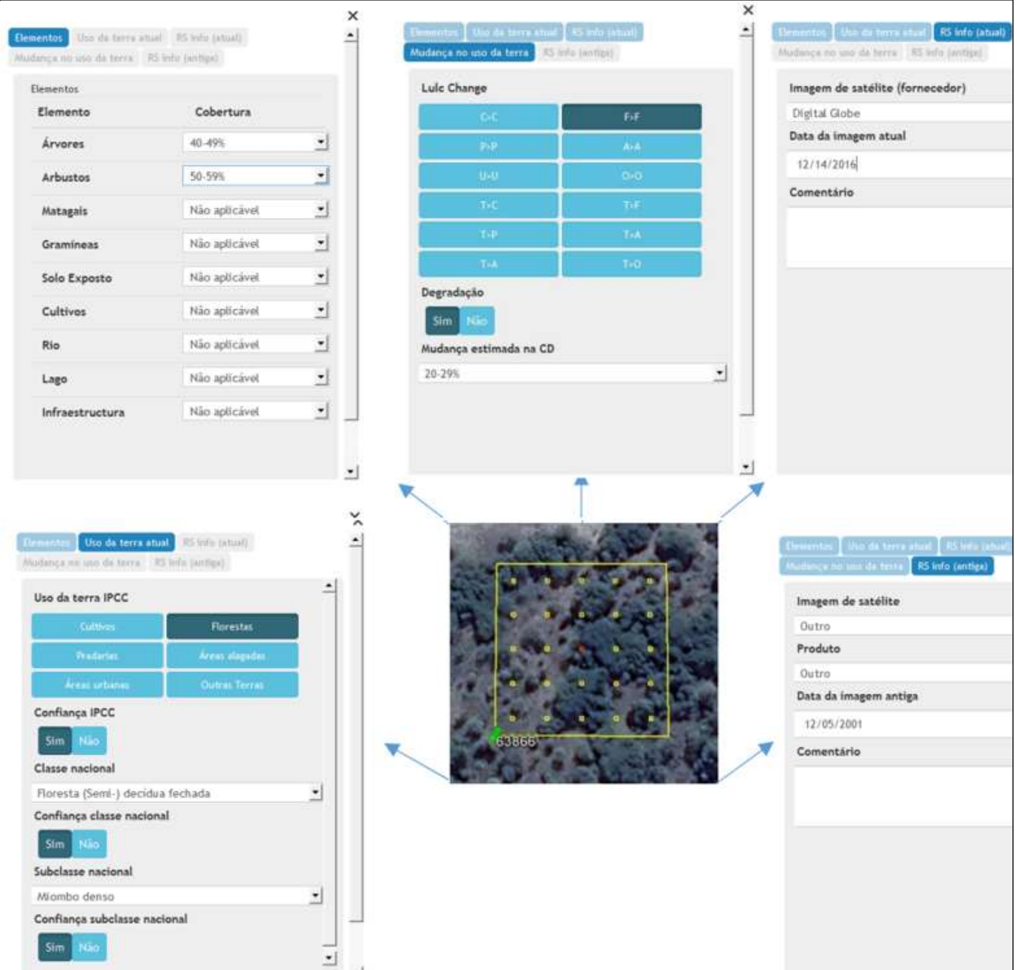

Figure 12: LULCCF detection using Collect Earth Tool (www.openforis.org). Digital forms designed with Collect Tool.

<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 (Figure 13). 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.

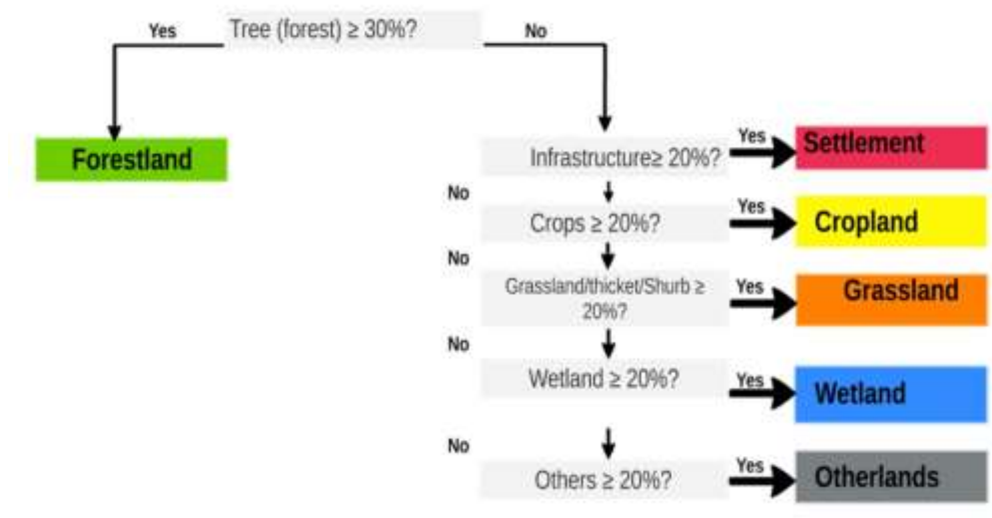

Figure 13: Decision tree for the attribution of the LULCCF category based on the percentage cover of the elements present in the sampling unit of 1 ha.

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 15*

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;* dimensionless
A	Total area of interest; hectare

$$p_i = \frac{n_i}{N}$$ *Equation 16*

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 2018*" 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 (Figure 14) 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.

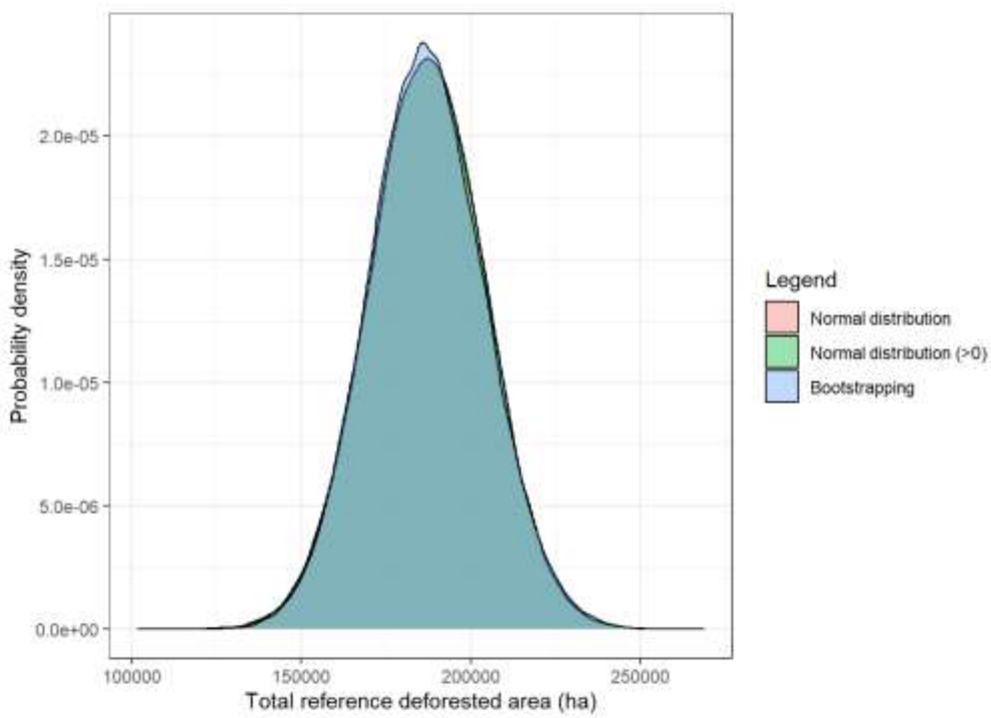

Figure 14: Total activity data area estimates for reference period using normal distributions for each transition class (red), normal distributions with a minimum area of 0 ha (green), and non-parametric bootstrapping (blue). All three methods result in equivalent uncertainty estimates.

Value applied

Semi-deciduous forest to cropland	11,770.88
Semi-deciduous forest to grassland	1,743.83
Semi-deciduous forest to other lands	145.32
Evergreen forest to cropland	3,197.03
Evergreen forest to grassland	145.32
Evergreen forest to other lands	0.0
Mangrove forest to cropland	0.0
Mangrove forest to grassland	0.0

<table>
<tr><td></td><td><table><tr><td>Mangrove forest to other lands</td><td>0.0</td></tr></table></td></tr>
<tr><td>QA/QC procedures applied:</td><td>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.</td></tr>
<tr><td>Uncertainty associated with this parameter:</td><td><table>
<tr><td rowspan="2">Category change</td><td colspan="5">Uncertainty estimate (from non-parametric bootstrapping)</td></tr>
<tr><td>Median</td><td>Lower bound (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>C</td><td>11,770.9</td><td>9,736.4</td><td>13,950.7</td><td>2,107.2</td><td>0.18</td></tr>
<tr><td>FSD>P</td><td>1,743.8</td><td>1,017.2</td><td>2,615.8</td><td>799.3</td><td>0.46</td></tr>
<tr><td>FSD>(A|O|U)</td><td>145.3</td><td>0</td><td>436.0</td><td>218.0</td><td>1.5</td></tr>
<tr><td>FSSV>C</td><td>3,197.0</td><td>2,179.8</td><td>4,359.6</td><td>1,089.9</td><td>0.34</td></tr>
<tr><td>FSSV>P</td><td>145.3</td><td>0</td><td>436.0</td><td>218.0</td><td>1.5</td></tr>
</table></td></tr>
<tr><td>Any comment:</td><td></td></tr>
</table>

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	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. The following methods were used from the sampling design to estimation:

<table>
<tr>
<td>including the spatial level of the data (local, regional, national, international):</td>
<td>

v. 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 4 forest types (semi-deciduous forest, semi-evergreen forest, Mopane and Mecrusse forest), of which only semi-deciduous forest and semi-evergreen forest 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 two 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 15).

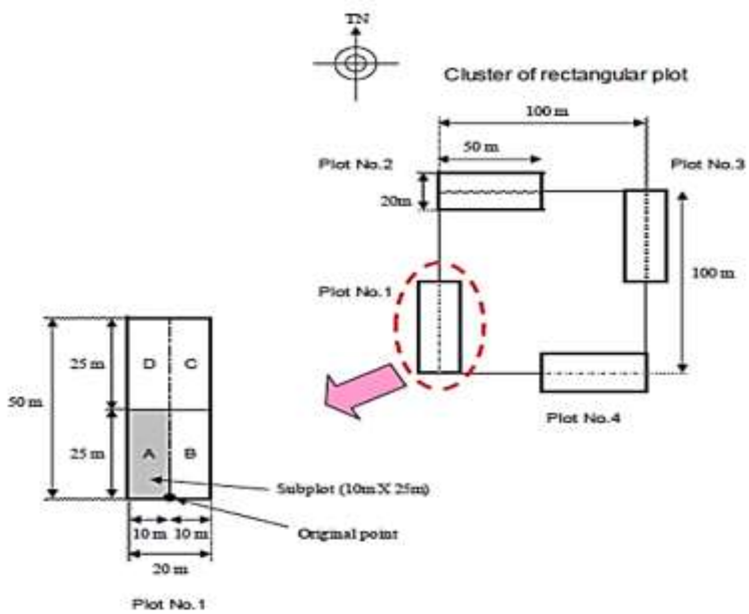

Figure 15: Design of each cluster used in the National Forest Inventory.

vi. 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.

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

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 .

vii. 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 10), 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 above species), 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.

Table 10: 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)	$\hat{Y} = \exp(-2.289 + 2.649\ln(DAP) - 0.021(\ln(DAP))^2)$	$\hat{Y} = AGB * R/S$; $R/S = 0.28$
		Author: IPCC (2003)	Author: Mokany *et al.* (2006)

	Evergreen mountain forest (open and closed)	Ŷ = 0.0613*DAP2.7133	Ŷ = AGB * R/S; R/S= 0.29
		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)

viii. 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://www.fnds.gov.mz/mrv/index.php/documentos/relatorios/18-relatorio-de-inventario-florestal-zambezia/file.

The approach of Bechtold & Patterson (2005), was used to correct the problem of sample units (clusters) with variable areas. This occurred because the forest type information collected in each cluster at the field level, showed that the clusters transcended the boundaries of the strata (cluster with more than one strata).

For mangrove forests, data are secondary, extracted from existing literature. Stringer et al. (2015) 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.

Spatial level: Regional

Value applied:

Semi-deciduous forest (FSD)	144.69
Evergreen forest (FSSV)	123.13
Mangrove forest (FF)	269.00

QA/QC procedures applied	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 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.
Uncertainty associated with this parameter:	(see table below)
Any comment:	-

Forest type	Uncertainty estimate				
	Mean	Lower (5th percentile)	Upper bound (95th percentile)	Half-width confidence interval at 90%	Relative Margin
FSD	144.7	121.8	167.6	22.9	16%
FSSV	123.1	108.7	137.6	14.4	12%
FF	92	79.9	104.1	12.1	13%

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, data are secondary, extracted from existing literature. Stringer et al. (2015) 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. Spatial level: Regional

national, international):	
Value applied:	Semi-deciduous forest (FSD): 49.98 Evergreen forest (FSSV): 42.24 Mangrove forest (FF): 85.40
QA/QC procedures applied	Please see section QA/QC procedures under parameter $AGB_{before,j}$.
Uncertainty associated with this parameter:	see table below
Any comment:	

Forest type	Uncertainty estimate				
	Mean	Lower (5th percentile)	Upper bound (95th percentile)	Half-width confidence interval at 90%	Relative Margin
FSD	50	43.4	56.6	6.6	13%
FSSV	42.2	38	46.5	4.2	10%
FF	26.7	22.3	31.1	4.4	17%

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, national, international):	For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used. 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 are used. 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
Value applied:	Cropland (C): 10 Grassland (P): 2.3 Other lands (A|O|U): 0.0

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:	(see table below)
Any comment:	Negative lower estimates of uncertainty are set to 0 when running Monte Carlo Simulations.

Non-forest type	Uncertainty estimate				
	Mean	Lower (5th percentile)	Upper (95th percentile)	Half-width confidence interval at 90%	Relative Margin
Cropland (C)	10	3.8	16.2	6.2	62%
Grassland (P)	2.3	0.9	3.7	1.4	61%
Other lands (A|O|U)	0.0	0.0	0.0	0.0	-

Parameter:	$BGB_{after,i}$
Description:	Belowground 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, national, international):	For cropland: The values and assumptions of 2006 IPCC GL, Volume 4, Chapter 5 are used. 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, TABLE 6.4 are used. The value for semi-arid grassland in tropical dry climate zone is used, therefore a root-shoot ratio of 2.8 is applied to the value of aboveground biomass. For other lands: No default values exist for these conversions. Spatial level: International
Value applied:	Cropland (C): 0.0 Grassland (P): 6.4 Other lands (A|O|U): 0.0
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	0.0	-	-
	Grassland (P)	6.4	-1.5	14.3	7.9	61%
	Other lands (A|O|U)	0.0	0.0	0.0	-	-
Any comment:	Negative lower estimates of uncertainty are set to 0 when running Monte Carlo Simulations.					

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 Table 11, by applying **Error! Reference source not found.**.

Table 11: 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_2e/yr)
Semi-deciduous forest to cropland	11,770.88	142.52	50.03	10.00	0.00	3,702,946
Semi-deciduous forest to grassland	1,743.83	142.52	50.03	2.30	6.44	552,371
Semi-deciduous forest to other lands	145.32	142.52	50.03	0.00	0.00	48,220
Evergreen forest to cropland	3,197.03	110.63	41.00	10.00	0.00	780,331
Evergreen forest to grassland	145.32	110.63	41.00	2.30	6.44	35,785
Evergreen forest to other lands	0.00	110.63	41.00	0.00	0.00	0.00
Mangrove to cropland	0.00	269.00	85.40	0.00	0.00	0.00
Mangrove to grassland	0.00	269.00	85.40	2.30	6.44	0.00

Mangrove to other lands	0.00	269.00	85.40	0.00	0.00	0.00
Total						**5,119,653**

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

- ***Explanation and justification of proposed upward or downward adjustment to the average annual historical emissions over the Reference Period***

Intentionally left blank.

- ***Quantification of the proposed upward or downward adjustment to the average annual historical emissions over the Reference Period***

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8.5 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	5,119,653	-	-	-	5,119,653
2019	5,119,653	-	-	-	5,119,653
2020	5,119,653	-	-	-	5,119,653
2021	5,119,653	-	-	-	5,119,653
2022	5,119,653	-	-	-	5,119,653
2023	5,119,653	-	-	-	5,119,653
2024	5,119,653	-	-	-	5,119,653

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

The Reference Level has been constructed in alignment with the methodology used in the National FREL. The activity data used to construct the Reference Level is a subset of the National FREL Data, for the Program Area. The Emission Factors for the Reference Level and the FREL also come from the National Forest Inventory. For the Reference Level only data from NFI plots from Zambézia Province were used, whereas the FREL used data from the entire dataset.

The last greenhouse gas inventory of Mozambique dates from 1994. The country is in the process of producing a Biannual Update Report (BUR) for the UNFCCC. The AFOLU Section of the BUR will be aligned with the methodology used in the National FREL.

9 APPROACH FOR MEASUREMENT, MONITORING AND REPORTING

Monitoring of deforestation

The original Monitoring Plan already predicted a transition from the systematic sampling approach to a stratified sampling approach using a LULC change map. The original approach has changed in the following ways:

a) It was predicted that LULC maps and LULC change maps would be produced every year. However, the current approach is to only produce annual LULC change maps. The base LULC map remains the 2016 map.
b) It was planned to conduct estimates of activity data using a stratified sampling approach biennially. However, we are not producing annual activity data estimates.
c) The change maps were planned to be produced using 2 composites from 2 dates in a year: May/June and August/September. However, the new approach allows the classification of deforestation using only 1 composite, with images from January to May.

Monitoring of degradation

During the preparation of the ERPD, there was no concrete plan on how to monitor forest degradation. Tests were being conducted on using ALOS-PALSAR radar data to map biomass changes and consequently degradation. However, several critical issues remain:

a) ALOS-PALSAR mosaics are released by JAXA at uncertain dates, more frequently between May and August of the following year. This delays by one year the production of the biomass change maps and prevents timely reporting.
b) It is currently impossible to validate the biomass change maps, unless clear cuts have occurred. Validation currently occurs using medium-high resolution imagery (Sentinel-2 and Planet). But these images do not have the required quality to detect loss of individual trees.
c) Radar backscatter is significantly affected by soil moisture, which can lead to severe under or overestimation of biomass.
d) No clear good practice guidance exists on how to validate biomass change, including how to avoid double counting of degradation and deforestation.

As a result, Mozambique is still to define a methodology for monitoring forest degradation.

9.1 Measurement, monitoring and reporting approach for estimating emissions occurring under the ER Program within the Accounting Area

Line diagrams

Figure 16 illustrates the measurement, monitoring and reporting approach for estimating emissions and emissions reductions occurring under the ER Program within the Accounting Area during the Monitoring Period.

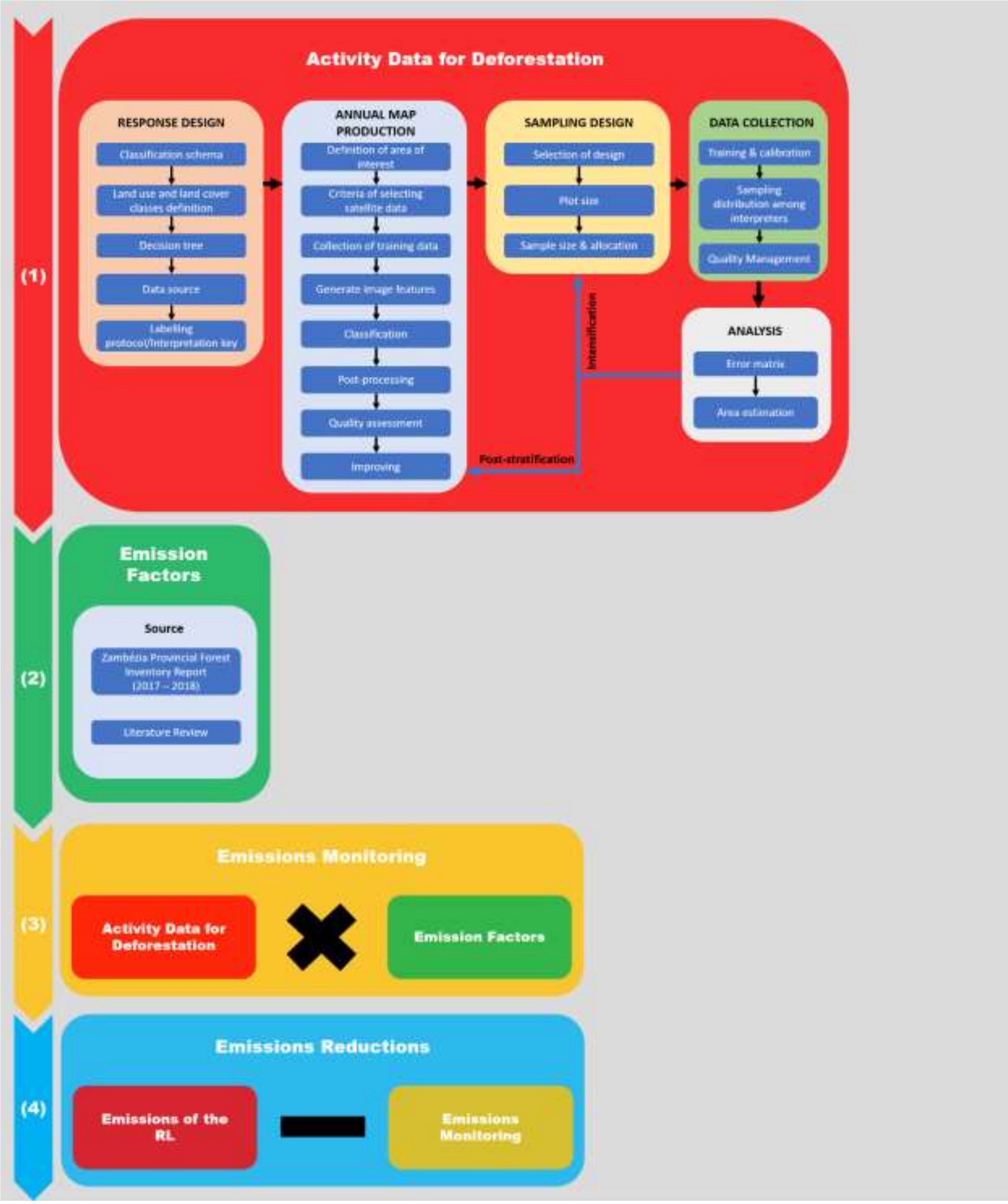


Figure 16 The measurement, monitoring and reporting approach for estimating emissions and emissions reductions

Calculation steps

Emission reduction calculation

$$ER_{ERP,t} = RL_t - GHG_t \qquad \textbf{Equation 17}$$

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; *$tCO_2e*year^{-1}$*. This is sourced from Annex 4 to the ER Monitoring Report.
GHG_t	=	Monitored gross emissions from deforestation at year *t*; *$tCO_2e*year^{-1}$*;
T	=	Number of years during the monitoring period; *dimensionless*.

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}).

$$GHG_t = \frac{\sum_t^T \Delta C_{B_t}}{T} \qquad \textbf{Equation 18}$$

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*.

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

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:

$$\Delta C_B = \sum_{j,i} \left(B_{Before,j} - B_{After,i}\right) x\ CF\ x \frac{44}{12} \times A(j,i)_{MP} \qquad \textbf{Equation 19}$$

Where:

$A(j,i)$ 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 described below.

$B_{Before,j}$	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 *Annex 4 - Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period*.
$B_{After,i}$	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 *Annex 4 - Activity data and emission factors used for calculating the average annual historical emissions over the Reference Period*.
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

Parameters to be monitored

<table>
<tr><td>Parameter:</td><td>A(j,i)_{MP}</td></tr>
<tr><td>Description:</td><td>Area converted from forest type j to non-forest type i during the Monitoring Period.</td></tr>
<tr><td>Data unit:</td><td>hectare per year.</td></tr>
<tr><td>Value monitored during this Monitoring / Reporting Period:</td><td><table>
<tr><td>Semi-deciduous forest to cropland</td><td></td></tr>
<tr><td>Semi-deciduous forest to grassland</td><td></td></tr>
<tr><td>Semi-deciduous forest to other lands</td><td></td></tr>
<tr><td>Evergreen forest to cropland</td><td></td></tr>
<tr><td>Evergreen forest to grassland</td><td></td></tr>
<tr><td>Evergreen forest to other lands</td><td></td></tr>
<tr><td>Mangrove forest to cropland</td><td></td></tr>
<tr><td>Mangrove forest to grassland</td><td></td></tr>
<tr><td>Mangrove forest to other lands</td><td></td></tr>
</table></td></tr>
<tr><td>Source of data and description of measurement /calculation methods and procedures applied:</td><td>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.

ii. Sampling design

<u>Sampling method</u>

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.

<u>Sample size determination</u></td></tr>
</table>

The sample size n was determined from the equation:

$$n = \frac{(\sum W_i S_i)^2}{\left[S(\hat{O})\right]^2 + (\frac{1}{N})\sum W_i S_i} \approx \left(\frac{\sum W_i S_i}{S(\hat{O})}\right)^2 \qquad \textbf{\textit{Equation 20}}$$

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:

$$S_i = \sqrt{U_i(1 - U_i)} \qquad \textbf{\textit{Equation 21}}$$

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 reach the desired relative error. It was decided to use the Optimum (Neyman) allocation, where the stratum standard deviation $S_h = \sqrt{U_h \cdot (1 - U_h)}$ increases the number of plots (ensuring larger numbers of plots in rare classes or strata) and sampling unit costs are constant:

$$n_h = n\frac{w_h \cdot S_h}{\sum_{h=1}^{H} w_h \cdot S_h} \qquad \textbf{\textit{Equation 22}}$$

The technical team decided that there should be a minimum of 300 sample units in the stable classes. The reason behind this minimum is that if no deforestation events are found in the 100 sample units of each stable stratum, then *pi* will be 0, and we would require no further sampling of these strata. This would mean that our sample size for the stable strata would be much smaller than for the change strata.

Post-stratification of stable classes

After the initial stratification be conducted and the reference data collected, if the visual inspection of the map shows that there are errors of omission, even though the reference data did not include any. The technical team should produce a post-stratification of the stable classes using the new map production workflow. This stratification is composed of the same classes of change: high probability of deforestation, buffer and low probability of deforestation. However, these are merged prior to the collection of reference data, in order to reduce the effort in collection of new reference data. The final number of reference points should be presented in Table 12.

Table 12: Number of reference sampling units per map stratum. "New deforestation" stratum represents the post-stratification conducted on the stable classes, after it is found that the original map was omitting deforestation.

Stratum	**Number of sample units**
High probability of deforestation	n1
40 m Buffer	n2
Low probability of deforestation	n3
Forest	n4
Non-forest	n5
New deforestation	n6
Total	N = n1 +…+ n6

viii. *Response design*

Spatial sampling unit

The spatial sampling unit from each sample is defined as a pixel of the deforestation map. The spatial support to enable interpretation is a 100m x 100m plot (1ha). Each Spatial sampling unit contains an internal grid of 5 x 5 points (20m x 20m grid). Each point weights 4% (Figure 17).

Figure 17: 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 8). 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 monthly composites. However, Planet data is also used in cases of doubt or excessive cloud cover with Sentinel-2.

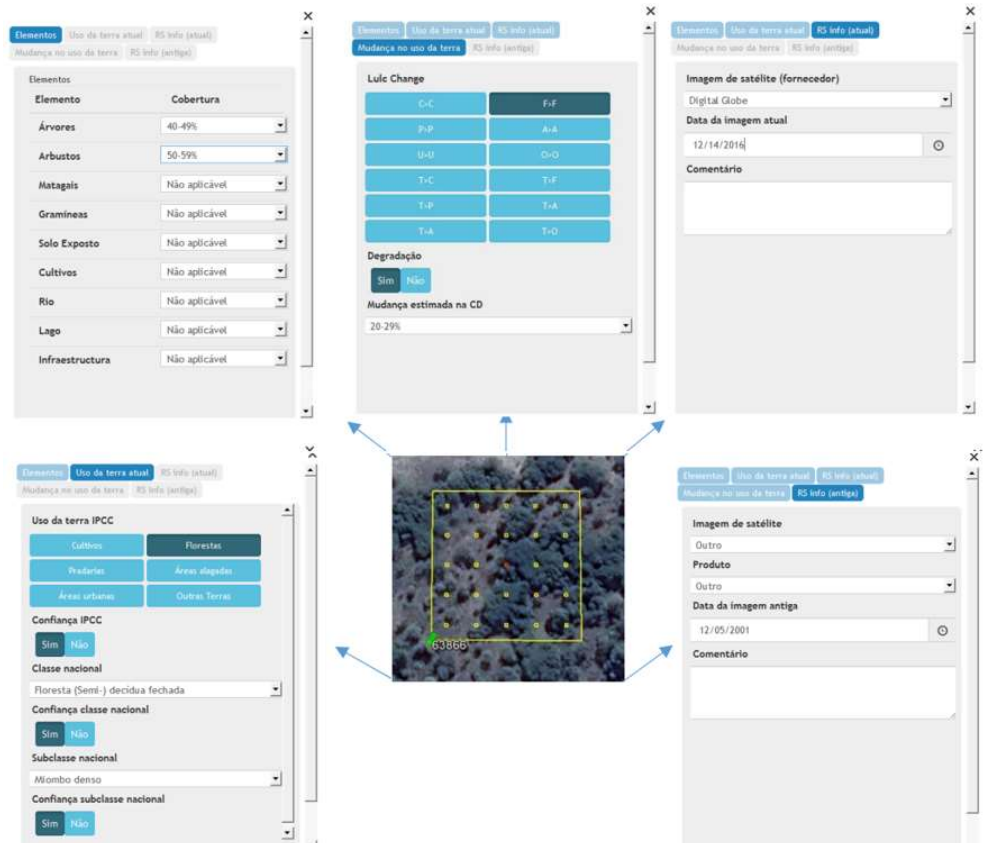


Figure 18: LULCCF detection using Collect Earth Tool (www.openforis.org). Digital forms designed with Collect Tool.

<u>Reference labelling protocol</u>

The activity data is 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 is established and used to determine the LULCCF category based on a certain percentage and taking into account the national forest definition as well (Figure 19). 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 is classified as forest land and different forest types are present in the sampling unit, a majority rule is used, i.e. the largest forest class is the winner.

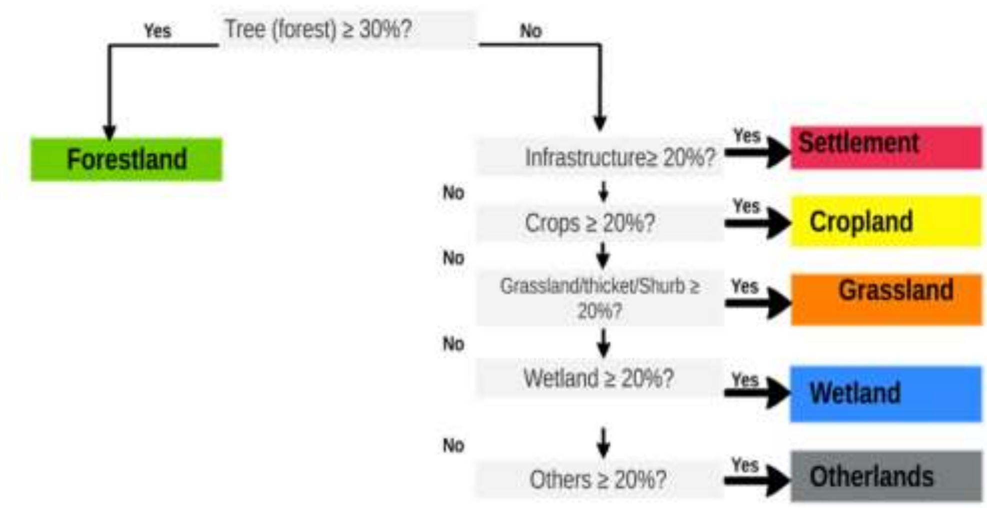


Figure 19: Decision tree for the attribution of the LULCCF category based on the percentage cover of the elements present in the sampling unit of 1 ha.

ix. Analysis

Applying the methodology described in Olofsson *et al*. (2014)[8], 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) are 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.

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 23***

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);

[8] 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.

- Settlement (U); and
- Other lands (O).

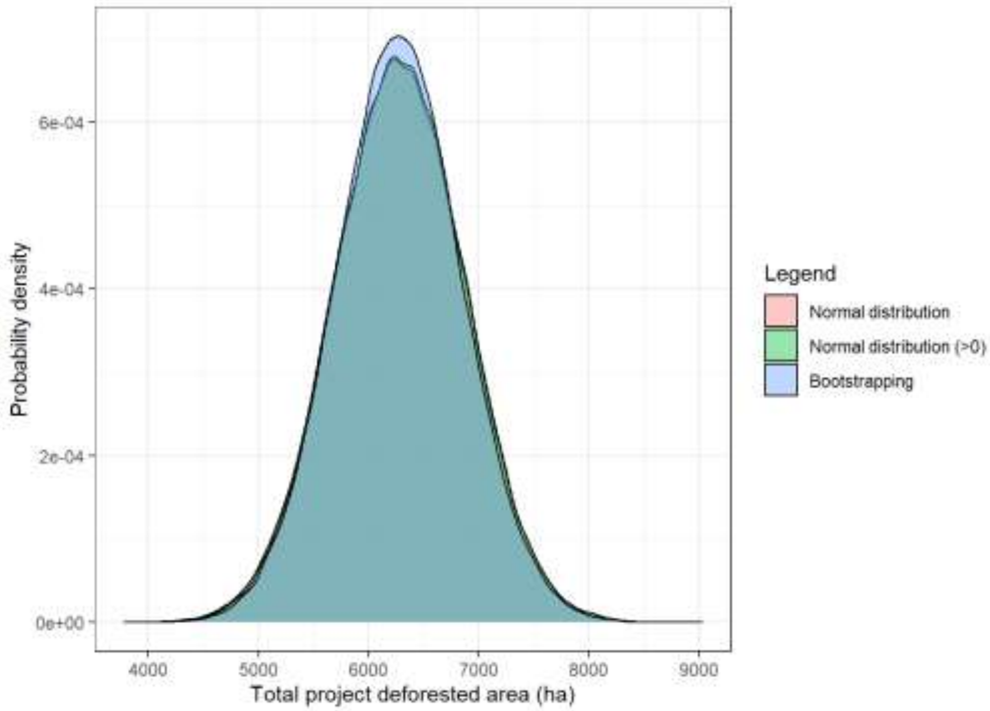
w_h	Proportion of area mapped as class *h*;
n_{hk}	Sample count at cell (*h,k*);
$n_{h.}$	Sum of sample counts across row *h*; and
$\hat{p}_{hk}$	Proportion of area in cell (*h,k*).

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 24***

Uncertainties in activity data are derived using non-parametric bootstrapping, where reference data points are re-sampled with replacement 100,000 times. For each permutation of reference data points, the bias-corrected area estimates are produced following the methods described in Olofsson *et al*. (2014). Uncertainty is 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 is implemented in R, and the scripts used are available in the "*Mozambique ERPA 2018*" 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 (Figure 20) 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 20: Total activity data area estimates for 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 quality assurance consists of documenting and standardizing data collection processes and training. Quality control consists of evaluating all reference data interpreted as deforestation, and an additional 20% of the remaining reference data. 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.
Uncertainty for this parameter:		Uncertainty estimate (from non-parametric bootstrapping)	

Category change	Median	Lower bound (5^{th} percentile)	Upper bound (95^{th} percentile)	Half-width confidence interval at 90%	Relative Margin
FSD>C	5840.2	5836.4	4923.4	6771.6	924.1
FSD>(A|O|U)	115.1	111.7	0	338.5	169.2
FSSV>C	319.5	308.5	81.6	617.4	267.9
FSSV>P	4.2	4.1	0	12.4	6.2

Any comment:	

9.2 Organizational structure for measurement, monitoring and reporting

Mozambique has not formalized its national monitoring system (NFMS). There is a work in progress between the National Directorate of Forest (DINAF) and FNDS and other relevant stakeholders to formalize the NFMS. The current monitoring system has three sub-systems:

- Satellite and land monitoring system
- National forest inventory
- National 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 FREL. This information was also used to generate historical deforestation statistics for 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 ZILMP using a systematic stratified sampling. With the development of methodologies to generate statistics and spatially explicit data of deforestation, it was possible to produce annual deforestation maps for 2017, 2018 and 2019 as shown on the link https://gis.fnds.gov.mz/arcgis/apps/webappviewer/index.html?id=dc26e4d6025e4d059085657a3804f57e for the whole country and the area estimates for Zambézia Province which are based on sampling. 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 with FCPF finance.

The process of generating activity data comprises five steps (Figure 1); 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 QA/QC processes in all production processes including the development of 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://fnds.gov.mz/mrv/index.php/documentos/guioes/28-protocolo-ce/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.

It is the intention to disseminate the use of activity data to communities and other stakeholders to monitor deforestation in their area of interest in the coming future. The implementation will be effective in 2021 as the COVID 19 situation did not allow the project to test the methodology in 2020.

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. The information from these inventories were used to produce information for timber purposes. The last inventory in 2016-17 produced the emission factors used for the FREL submitted to the UNFCCC in 2018 (report may be accessed in the following 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 the Province of Zambezia were used to generate ZILMP-specific Emission Factors. The methods to generate the emissions factors for ZILMP is described in the link https://fnds.gov.mz/mrv/index.php/documentos/relatorios/18-relatorio-de-inventario-florestal-zambezia/file.

The process used to produce the emission factors followed these steps: Response design, Sampling design, Data collection and Data analysis (Details in figure 1). The entity responsible for the National forest inventory is the National Directorate of Forest. The National forest inventory 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 Institute of Agricultural Research (IIAM), the Faculty of Agronomy and Forest Engineering, 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 the Faculty of Agronomy and Forest Engineering (FAEF) and the Department of Biology Sciences (DCB) of the University Eduardo Mondlane (UEM).

To ensure the quality of the data collected, the team followed QAQC procedures defined by the National Directorate of Forest. 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 Sampling plots are another component of the National Forest Monitoring System that will improve the estimation of emissions factors and the IIAM leads it. 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. However, this the Permanent Sampling plot network is not relevant for the ZILMP.

National GHG inventory

The National GHG inventory for the purpose of REDD+ combines the Activity data and the emission factors (Figure 1) to estimate the annual emissions and the FREL.

A 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 and the national data, Provincial and District FRELs. 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 since the Approval of ERPD in institutional arrangements 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 was 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 has 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.

The organogram of the MRV Unit responsible for the ZILMP monitoring is described in Figure 1. The MRV Unit was created in 2016, with the coordinator and 4 technicians (Alismo, Credêncio, Délfio and Hercilo). 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). The organizational structure for the Activity data (reference and annual) and NFI is described in Figures 2, 3 and 4.

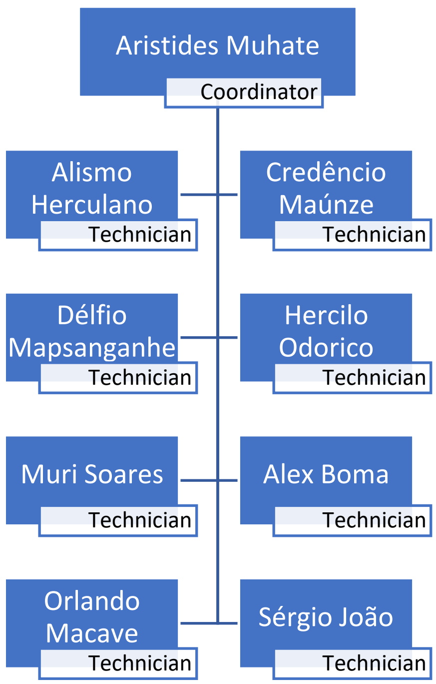


Figure 21: Organogram of MRV Unit responsible for ZILMP monitoring.

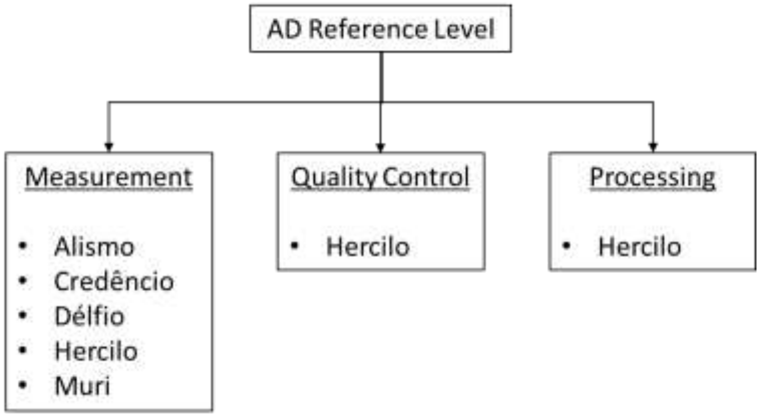


Figure 22: Organizational structure for Activity Data of Reference Level.

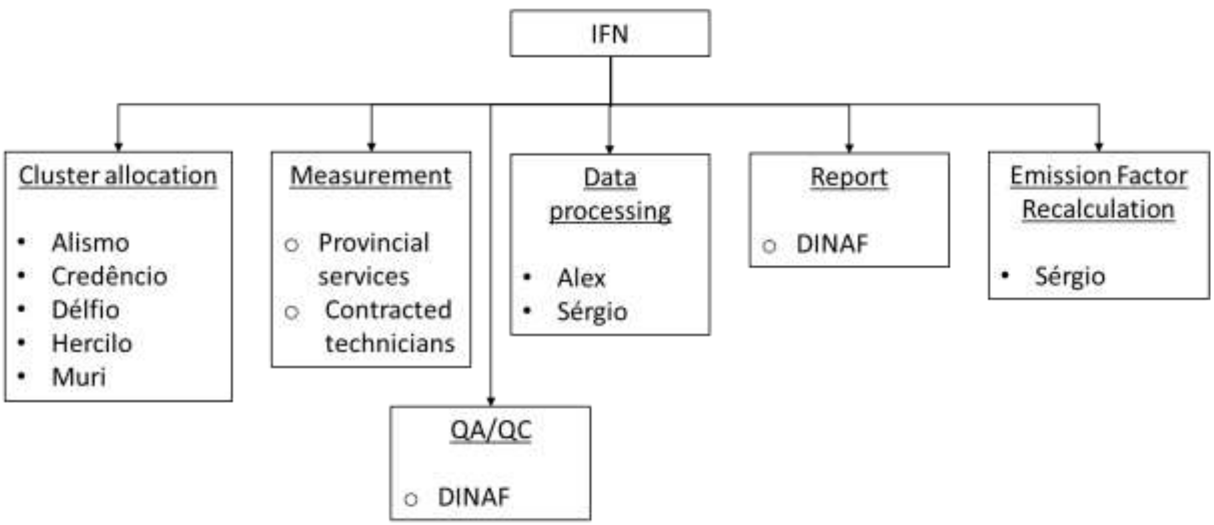


Figure 23: Organizational structure for National Forest Inventory.

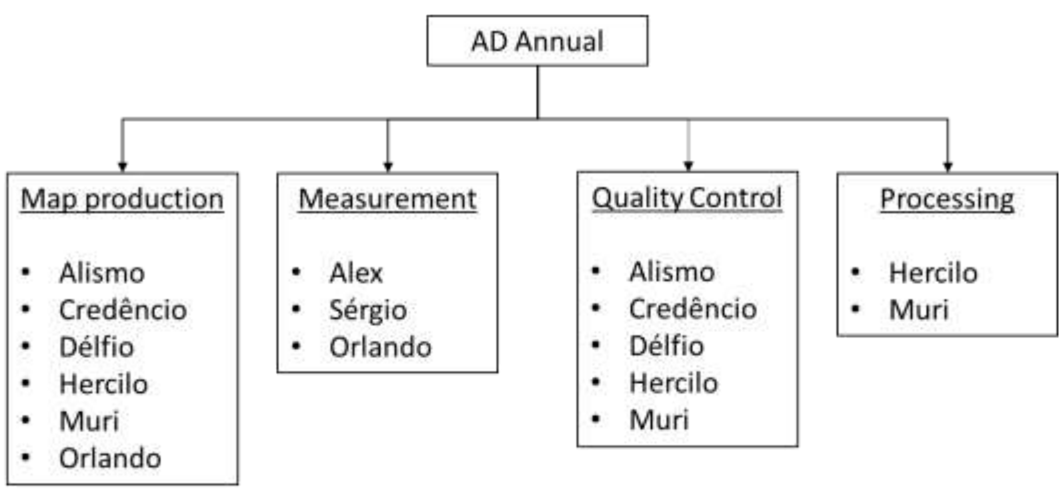


Figure 24: Organizational structure for Annual Activity Data.

ii. **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 FNDS (2020).

9.3 Relation and consistency with the National Forest Monitoring System

Mozambique does not have official standard technical procedures in place for GHG monitoring. The MRV Unit of FNDS is developing the SOPs for Activity Data and GHG emission monitoring. Mozambique is still developing its NFMS and FNDS is coordinating with DINAF National Directorate of Climate Change on this issue. The emerging NFMS is being developed at the same time as the approach presented in this report. As a result, the approach presented in this report will be fully consistent with the emerging NFMS.

12 UNCERTAINTIES OF THE CALCULATION OF EMISSION REDUCTIONS

12.1 Identification and assessment of sources of uncertainty

Table 1. Sources of uncertainty to be considered under the FCPF MF. Cells with H/L are used to indicate where the ER Program is required to assess the contribution to overall uncertainty of that particular component. Cells with YES/NO indicate that it is the ER Program's choice in how they deal with the particular component. The cells labelled without a choice (e.g. H, Yes, No) are prescribed.

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 error	This error represents the operator error during the interpretation of LULCC on sampled points and inconsistencies between operators. This error is reduced by extensive QAQC 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	High (bias/random)	YES	NO

	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: (vi) Data point was not filled (vii) The class assigned followed the classification hierarchy, based on the % of individual element cover (viii) Year of the Old image/Change image was less than the current image (ix) Change classes are consistent with previous and current classes (x) 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. All sampling units detected as deforestation and 20% of the remaining sampling units are subjected to 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. Training samples are collected by an operator, identifying 3 classes: stable forest, stable non-forest and deforestation. These training samples are used to calibrate a Random Forest classifier, which outputs a categorical map of deforestation. For the purpose of area estimation, it's important to minimize errors of omission in the deforestation class. Buffer regions of 50 m width are added around deforestation events to reduce the likelihood of any deforestation events being missed. An additional stratum is used, based on a low deforestation probability threshold.	Low	YES	NO
Sampling error	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.	High	YES	YES

	Mozambique has followed Good Practices regarding estimating the contribution of this error.			
Extrapolation	This source of uncertainty is not applicable to our approach. We generate estimates of deforestation per forest type, based on reference data.	Low	YES	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 the deforested again. Additionally, in the rare cases where this might occur, such double counting would be conservative for 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. 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 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 QAQC 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.	*H (bias) & L (random)*	YES	NO
Root-to-shoot ratio measurement	Below ground biomass is mostly estimated directly with country-specific allometric equations, therefore the propagation of errors it is not applicable. Root-to-shoot ratios were used for one of the strata (Evergreen Forest), with the value taken from the 2006 IPCC Guidelines. The impact of this parameter on overall uncertainty would be negligible.	*H (bias) & L (random)*	YES	NO
Carbon Fraction	Carbon fraction parameter was taken from the 2006 IPCC Guidelines. Error, as provided from the IPCC Guidelines, has been propagated.	*H (bias) & L (random)*	YES	YES
Biomass allometric equation (Model error)	Allometric equations used ranged from national (specific species), 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 constant from reference to monitoring period. Additionally, the overall effect of emission factor uncertainty on total uncertainty is low (7.4%)	*H (random/bias)*	*YES*	*NO*
Sampling error	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)	YES	YES
Representativeness error	This source of error is related to the representativeness of the estimate which is related to the sampling design. The forests of Zambézia province are quite homogeneous, with widespread occurrence of miombo forests. The stratification between evergreen and semi-deciduous forests allows to cover both the more humid miombo and wetter miombo. 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 MRV team has implemented an automated script to calculated emissions and uncertainty. This should greatly reduce the possibility of mistakes in the calculations.	*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	L	YES	NO

	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.			

12.2 Quantification of uncertainty in Reference Level Setting

Parameters and assumptions used in the Monte Carlo method

Parameter included in the model	**Parameter values**	**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
Length of reference period	11 years		-	ER program design
Project area	5310265.16 ha		-	ER program design
Area of FSD>C in reference period	11770.9 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>P in reference period	1743.8 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>(A|O|U) in reference period	145.3 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>C in reference period	3197.0 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>P in reference period	145.3 ha	Sampling	Non-parametric bootstrapping	

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Area of FSD>C in monitoring period	5829.9 ha	Sampling	Non-parametric bootstrapping	
Area of FSD>(A|O|U) in monitoring period	110.7 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>C in monitoring period	307.0 ha	Sampling	Non-parametric bootstrapping	
Area of FSSV>P in monitoring period	4.1 ha	Sampling	Non-parametric bootstrapping	
Aboveground biomass of FSD	144.7 t/ha	Sampling	Normal distribution (mean = 144.7 sd = 13.93)	
Aboveground biomass of FSSV	123.1 t/ha	Sampling	Normal distribution (mean = 123.1 sd = 8.78)	
Aboveground biomass of FF	92 t/ha	Sampling	Normal distribution (mean = 92 sd = 7.36)	
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	50 t/ha	Sampling	Normal distribution (mean = 50 sd = 4.02)	
Belowground biomass of FSSV	42.2 t/ha	Sampling	Normal distribution (mean = 42.2 sd = 2.56)	
Belowground biomass of FF	26.7 t/ha	Sampling	Normal distribution (mean = 26.7 sd = 2.67)	
Belowground biomass of C	0 t/ha	Sampling	Normal distribution (mean = 0 sd = 0)	

Parameter included in the model	Parameter values	Error sources quantified in the model (e.g. measurement error, model error, etc.)	Probability distribution function	Assumptions
Belowground biomass of P	6.4 t/ha	Sampling	Normal distribution (mean = 6.4 sd = 2.4)	
Belowground biomass of (A|O|U)	0 t/ha	Sampling	Normal distribution (mean = 0 sd = 0)	

Quantification of the uncertainty of the estimate of the Reference level

		Deforestation
A	**Median**	5,311,557
B	**Upper bound 90% CI** (Percentile 0.95)	4,337,819
C	**Lower bound 90% CI** (Percentile 0.05)	6,452,017
D	**Half Width Confidence Interval at 90% (B – C / 2)**	1,057,099
E	**Relative margin (D / A)**	20%
F	**Uncertainty discount**	4%

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. As a result it can be seen that the main source of uncertainty is the Activity Data estimated for the reference period. Considering the high impact of reference AD on total uncertainty, Mozambique will attempt to reduce the uncertainty of this parameter in the next monitoring cycle.

Table 13: Sensitivity analysis. Sensitivity test consists of setting the parameter to its nominal value, while retaining uncertainty of all other parameters generated from Monte Carlo.

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	3,293,238	2,398,332	4,332,172	966,920	0.29	0
AD (reference)	3,181,167	2,727,632	3,667,614	469,991	0.15	51.4
AD (monitoring)	3,343,781	2,501,559	4,346,716	922,579	0.28	4.6
EF	3,310,167	2,448,561	4,239,781	895,610	0.27	7.4
CF	3,317,788	2,422,484	4,351,329	964,423	0.29	0.3

Document history

Version	Date	Description
2	June 2020	Version approved virtually by Carbon Fund Participants. Changes made: ● Update to consider the changes made to the Methodological Framework (Version 3.0) and Buffer Guidelines (Version 2.0) ● Update to consider the changes made to the Validation and Verification Guidelines
1	January 2019	The initial version approved by Carbon Fund Participants during a three-week non-objection period.