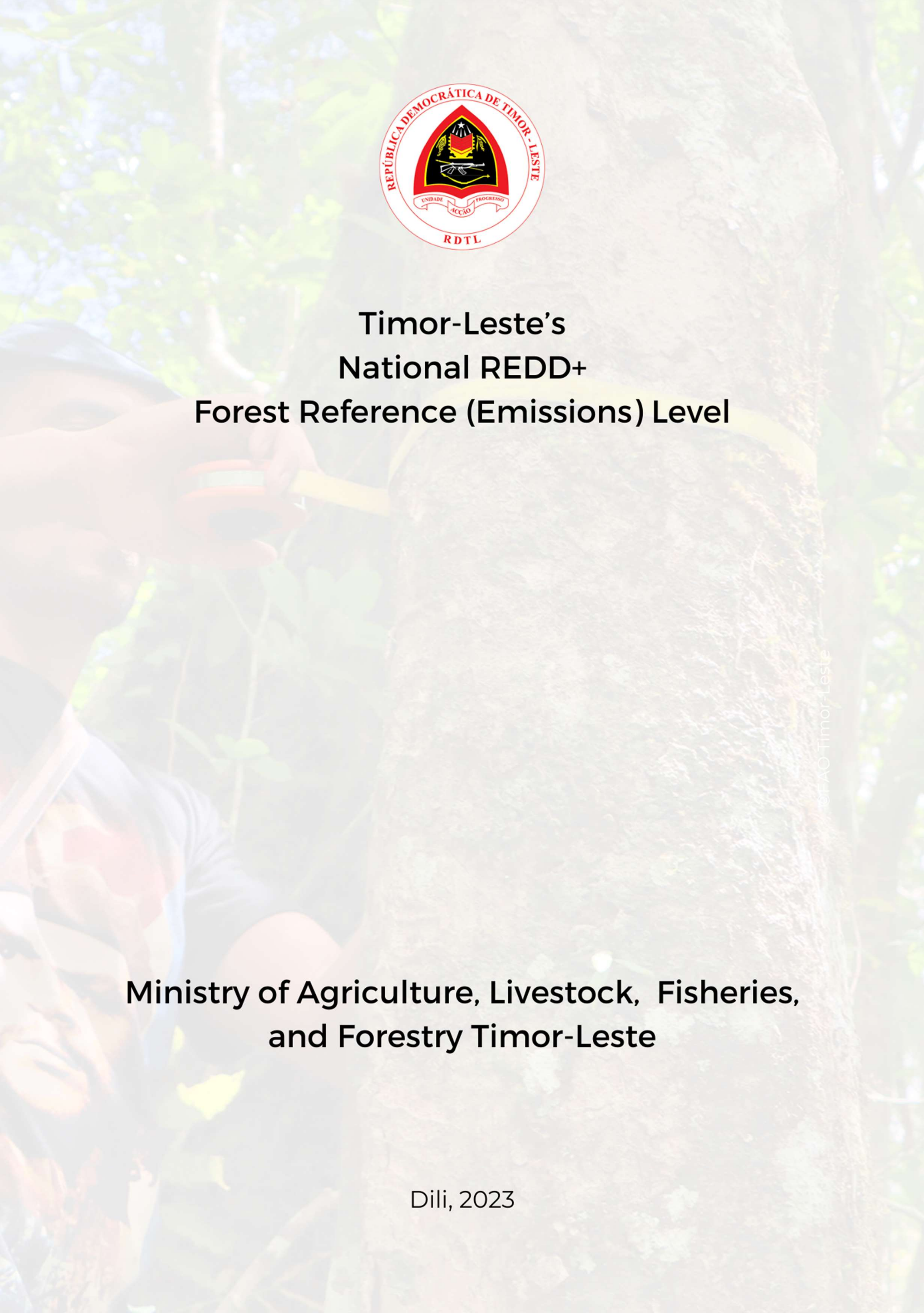
Food and Agriculture Organization of the United Nations

GREEN CLIMATE FUND

Timor-Leste's

National REDD+ Forest Reference Level

Modified Submission to UNFCCC



Timor-Leste's National REDD+ Forest Reference (Emissions) Level

Ministry of Agriculture, Livestock, Fisheries, and Forestry Timor-Leste

Dili, 2023

Foreword

Timor-Leste (TL) ratified the United Nations Framework Convention on Climate Change in October 2006, only few years after gaining independence in 2002. Despite having one of the lowest carbon emissions among Parties, TL anticipates being a major victim of climate change and aims to play a part in mitigating and adapting to its consequences.

Forests are vital for Timor-Leste's population. Most forests are under customary ownership and play an important role in sustaining traditional livelihood. TL forests are a net sink, but deforestation and forest degradation remain issues that the government wants to address. Engaging in the UNFCCC mechanism to reduce emissions from deforestation, forest degradation and the role of conservation, sustainable management and enhancement of forest carbon stocks (REDD+) provides a great opportunity to improve forest monitoring systems, build country capacities and make progress towards addressing deforestation and forest degradation.

With this first Forest Reference Emissions Level/ Forest Reference Level (FREL/FRL) submission, Timor-Leste wants to share with the world robust, consistent, and transparent data on the state of TL forests and their impact on climate change, as well as future improvements that constitute a roadmap for the next submissions. The FREL/FRL construction was led by national experts representing forestry and environment agencies and respected academic institutions with technical assistant from Food and Agriculture Organization.

This opportune submission marks Timor-Leste's first FREL to the UNFCCC and prominently displays the various component activities undertaken under the REDD+ Readiness Project. These include Activity Data (AD), the National Forest Inventory (NFI) methodology and comprehensive carbon calculations, carefully accompanied by an uncertainty analysis. This FREL/FRL is an extension of the existing document, including the National Determined Contribution (NDC), which the country has diligently prepared and submitted to the UNFCCC in 2016 and its revised NDC 2022-2030. Certainly, this submission is perfectly in line with the stringent requirements set by the COP and exemplifies our unwavering commitment to adhere to the technical assessment guidelines and the unwavering principles of transparency, accuracy, completeness and consistency.

As we move forward in our collective quest to combat climate change and promote sustainable development, Timor-Leste remains resolute in its commitment to protect our environment and build a prosperous future for our nation and its people.

Eng. Marcos da Cruz, MAgSt

Minister of Agriculture, Livestock, Fisheries and Forestry

Preface

The Democratic Republic of Timor-Leste is committed to fulfilling the requirements of the multi-lateral processes established by the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. As a member, Timor-Leste has taken conscious steps to address climate change. In 2016, the country submitted its first Nationally Determined Contributions (NDCs) and later revised them for the period 2022-2030. These contributions play an important role in addressing climate change, implementing initiatives and promoting climate risk management, nature-based growth, low-carbon development, climate change adaptation and resilience building with support of national as well as international partners. The importance of forestry in reducing emissions from deforestation and forest degradation was specifically highlighted in Timor-Leste's NDC. Timor-Leste launched its first REDD+ readiness project in August 2020 to set initial steps in achieving its land use, land use change, and forestry (LULUCF) emissions reduction targets.

The implementation of REDD+ readiness projects has led to the development of Forest Reference (Emissions) Level (FREL/FRL), a critical element that serves as a benchmark for measuring the success of REDD+ implementation. In accordance with UNFCCC COP Decision 12/CP.17, paragraph 12, the FREL/FRL must be updated periodically to reflect scientific advances, changing emissions trends, and changes in scope and methodology. The FREL/FRL, once submitted to the UNFCCC is subject to technical evaluation by the UNFCCC Secretariat to ensure its accuracy and credibility. We are pleased to announce that the technical assessment process of our first national FREL successfully completed in March 2023.

The key elements of the first FREL/FRL document are.

a) Consideration of REDD+ activities and emissions: the document includes deforestation and forest carbon enhancement as key components of the emission reduction strategy.
b) Inclusion of carbon pools: the calculated carbon pools refer to aboveground biomass, while the IPCC guidance is used for belowground biomass (excluding litter, deadwood, and soil organic carbon pool).
c) Calculation method used: the net emissions calculation method was used, which contributes to a comprehensive assessment of REDD+ implementation.
d) Uncertainty analysis: due to the nature of the sample data collection, which used a 2-kilometer grid with 4215 activity data (AD) sample plots, there is some uncertainty in the analysis. It is important to recognize that this method may not capture all changes in each area.

Using a methodical and REDD+ guidelines a phased calculation of the Forest Reference Level (FRL) was constructed. This strategic measure allows Timor-Leste to continuously refine and enrich the FREL/FRL by incorporating improved data of 40 plots and methodologies. We highly appreciate the paramount importance of ensuring adequate and predictable support, in accordance with paragraph 71 of Decision 1/CP.16.

In order to improve above-mentioned key elements of the first FREL/FRL documents the following recommendations have been made to enhance the accuracy and quality of the future FREL/FRL of the country:

a). Sample intensifications;

Recognizing the importance of robust data, sample intensification to increase assessment accuracy of deforestation on the ground by increasing the number of sample plots, the accuracy of carbon stock estimation can be significantly enhanced.

b). Full National Forest Inventory (NFI);

A full-scale NFI is highly recommended to comprehensively assess the state of Timor-Leste's forests. This endeavour will provide detailed information on forest cover, carbon stocks from different carbon pools, and land-use changes, supporting more informed decision-making.

We wish to express our sincere gratitude and deep appreciation to whole team who involved in constructing our 1st National FREL/FRL for their unwavering commitment, intellectual contributions, tireless dedication of time and financial resources from GCF have been indispensable in the meticulous preparation of the National 1st FREL/FRL document. Their efforts have made the realisation of this milestone possible. In addition, we extend our gratitude to the esteemed UNFCCC expert whose commendable technical assessment, with the invaluable support of the esteemed UNFCCC Secretariat, has lent an unprecedented level of credibility to this submission.

AND, I.P.
Autoridade Nacional Designada Para Combate As Alterações Climaticas

Pedro Godinho dos S. Marçal da Costa

President of National Designated Authority (NDA) of Green Climate Fund

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Acronyms

AGB	Above Ground Biomass
AD	Activity Data
AFOLU	Agriculture, Forestry and Other Land Use
ALGIS	Agriculture Land Use and Geographic Information System
EF	Emission Factor
FAO	Food and Agriculture Organization of the United Nations
FREL/FRL	Forest Reference Emission Levels/Forest Reference Levels
GFM	Global Forest Maps
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
GIS	Geographic Information System
GoTL	Government of Timor-Leste
IPCC	Intergovernmental Panel on Climate Change
JICA	Japanese International Corporation Agency
LANDSAT	Land and Satellite Imagery
LULUCF	Land Use, Land Use Change and Forestry
MRV	Monitoring, Reporting and Verification
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NGO	Non-Government Organisations
PSP	Permanent Sample Plots
QA/QC	Quality Assurance/Quality Control
REDD+	Reduced Emissions from Deforestation and Degradation, Enhancement of Forest Carbon Stocks, Sustainable management of forests and Conservation
SLMS	Satellite Land Monitoring System
TWG	Technical Working Group
UNFCCC	United Nations Framework Convention on Climate Change
UNREDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Degradation in developing countries

1. Introduction

1.1 Timor-Leste and its efforts to combat climate change

Timor-Leste (TL) is the newest country in Southeast Asia after gaining independence in 2002. Geographically, TL occupies the eastern half of the island of Timor and is situated at the eastern end of the Lesser Sunda Islands of the Indonesian archipelago and Northwest of Australia at about 600 km. The total area of TL is approximately 14,954 km^2. Its main land area is 13,989 km^2, the Special Administrative Region Authority of Oé-Cusse Ambeno (RAEOA) is 817 km2, Atauro Island 140 km2 and Jaco Island of 8 km2.

Originally, the natural vegetation that is dominant in TL consisted of closed forest with areas of natural sedge and grassland vegetation on the floodplains of Lake Iralalaru. Forests in TL are mostly under customary ownership and play an important role in sustaining the traditional subsistence livelihoods of most of TL's population. However, basic statistical data to provide information in forest cover alone is not consistent. Timor-Leste's Forest Resource Assessment (FRA, 2020) indicates a forest area of 921,000 ha in 2020. According to Timor-Leste's Initial National Communication to the UNFCCC (2014), the annual loss of forest cover between 2004-2010 was around 2.23% per year. Whereas the NDC and the National Forest Policy (NFP, 2017), states that approximately 869,000 ha of the total land area of the country is covered by forest and that the annual loss of forest cover between 2004-2010 was about 1.7% per year. Nonetheless, human impacts, including repeated burning and clearing land for cultivation, hunting and grazing have resulted in the loss of most of the original forests. Very little primary forest remains. Vegetation now largely consists of secondary forest, savanna, and grasslands (Ministry of Economy and Development, February 2012). Dense forests are estimated at 30 % of total forests (or 300,000 ha). A significant reduction in Timor-Leste's forest cover had been documented by the JICS forest and land cover survey in between 2003 and 2012. This documentation concludes that deforestation is widespread in all districts for dense and sparse forests and that the reduction in dense forest cover has been particularly high around the major municipalities found in the southern part of the country (JICS and NDF. 2013b).

Despite having the lowest carbon emission among the UNFCCC parties where it is responsible for 0.003% of global emission, TL considers the rapid national widespread deforestation an issue and considers itself as one of the major victims of climate change. Thus, TL has made a conscious decision to outline commitments to reduce emissions through various activities in various sectors including forestry. In its effort to combat climate change, TL has established its institutional arrangements and pursued policies and regulations to facilitate its response to climate change. A process of internalising international conventions' obligations and responsibilities into national development processes. Some of which:

- Established 1) National Focal Point to United Nations Framework Convention on Climate Change (UNFCCC) in 2006, following the ratification to UNFCCC in October 2006 and Kyoto Protocol to UNFCCC in October 2008. As a party to UNFCCC, Timor-

Leste has an obligation to report its National Communication to the Conference of the Parties (COP); 2) National Designated Authority (NDA) to facilitate the Clean Development Mechanism (CDM) project; 3) Focal Point for Green Climate Fund (GCF); 4) Research Centre related to climate change in cooperation with universities and 5) working group for climate change, and

- Formulations of laws and strategic plans related to climate and environment.

Since then, Timor-Leste has been receiving international climate finance and assistance to respond to climate change. As a result, the Ministry of Environment and Secretary of State for Forestry had placed much effort into the country's REDD+ readiness project, with support from the Food and Agriculture Organization of the United Nations (FAO).

1.2 Background on the MRV for REDD+ under the UNFCCC

When taking part in the UNFCCC, the developing countries are aiming to access performance-based payments for the implementation of REDD+ activities. To implement the REDD+ activities, there are four REDD+ design elements that should be developed which are as followed:

- A national strategy or action plan;
- A national forest reference emission level and/ or forest reference level (FREL/FRL);
- A national forest monitoring system;
- A system for providing information on how the REDD+ safeguards are being addressed throughout the implementation of REDD+ activities.

The national forest monitoring system provides transparent information on the status of forests and REDD+ implementation in a country. It has two core functions:

1. Monitoring national policies and measures for REDD+.
2. Measuring, Reporting and Verifying (MRV) national scale GHG emissions and removals in the forest sector.

The UNFCCC has defined FREL/FRLs as benchmarks for assessing each country's performance in implementing and reducing emissions and increasing removals associated with the implementation of REDD+ activities. The Conference of the Parties (COP16) in Cancun encouraged developing country parties to contribute to mitigation actions in the forest sector, in accordance with their respective capabilities and national circumstances, and stated that, "more broadly, FREL/FRLs are considered relevant to assess country's performance in contributing to mitigation of climate change through actions related to their forests."

According to UNFCCC COP decision 12/CP.17, developing countries aiming to implement REDD+ activities are invited to submit a national forest reference level to the secretariat, on a voluntary basis and when deemed appropriate. The information contained in the submission should be transparent, accurate, complete, and consistent. It also be developed pursuant to recent IPCC guidelines as adopted or encouraged by the COP. In agreement with these decisions, TL has held extensive consultations and technical analysis for the development of its FRL.

1.3 Objectives of developing a national FRL

TL recognises that a country may consider using variations of FRLs for different or combined reasons. Nonetheless, the FRL for TL is prepared to achieve the following national and international objectives:

Nationally:

- To assess TL's performance in implementing REDD+ activities; and
- To assess TL's performance in contributing to national climate change mitigation actions related to its forests.

Internationally: In accordance with decision 12 of COP 17, there are three (3) other reasons TL has undertaken to come up with its FRLs:

- To access results-based payments for REDD+ results-based actions;
- To assess progress on the outcomes of the policies and measures taken to mitigate climate change in the forestry sector for domestic reasons;
- To contribute to international mitigation efforts through REDD+ actions under the UNFCCC.

1.4 Background on work towards developing the FRL

Timor-Leste ratified UNFCCC in October 2006 and Kyoto Protocol to UNFCCC in October 2008. As a party to UNFCCC, Timor-Leste has an obligation to report its National Communication to the Conference of the Parties (COP). With support from Global Environment Facility (GEF) and United Nations Development Program (UNDP), Timor-Leste had submitted its Initial National Communication (INC) in 2014 and started the development of Second National Communication (SNC) in 2017. Development of the SNC involved representation from local government institutions who are grouped into a sectoral Working Group and worked mostly on development of Greenhouse Gases (GHG) Inventory and mitigation scenarios.

Timor-Leste also submitted its first Intended National Determined Contribution (NDC) in 2016. The NDC emphasized several key approaches such as sustainable agriculture, livestock management and sustainable forestry for climate change mitigation and adaption in Land Use and Land Use Change and Forestry (LULUCF) sector. These highlighted approaches were further formalised through revised NDC 2022-2030 which calls for further integrated approaches to mitigation, adaptation, and sustainable socio-economic development through an enhanced focus on nature-based solution (NDC, 2022-2030).

In the revised NDC there are four important pillars such as climate risk governance, nature-positive growth and transition, low carbon development and climate change adaptation and resilience building. Among them, nature-positive growth and transition emphasized the importance of forestry in increasing carbon sequestration in LULUCF sector.

The revised NDC also identifies national institutional capacity development as one of the priorities which has been implemented since 2007 through National Capacity Self-Assessment. As stated in its NDC, the GoTL welcomes the ability to access international finance to support NDC implementation and has already started working with the GCF. A USD 300,000 readiness funding request was approved in 2016 to establish the NDA, prepare the National Accredited Entities and build capacity of the Government. This led to a national strategic framework for GCF readiness and full project support programme, detailing national climate investment priorities and outlines of potential projects. Several areas directly relevant to the LUCF sector were listed as priorities for adaptation and mitigation effort, one of which is REDD+ mechanism. As a result, a project proposal was formulated and submitted and was approved towards the end of 2020.

Some of the key milestones on the development of the REDD+ FRL for TL included establishment of a Technical Working Group to facilitate discussion between DGFCIP, NDCC, ALGIS, NDA, and other key stakeholders with the objective of finalising the National FRL Report before its submission to the UNFCCC. Specific workshops to define the forest definition and other parameters, training to progress on NFI design and Activity Data, and meetings continually update stakeholders on progress.

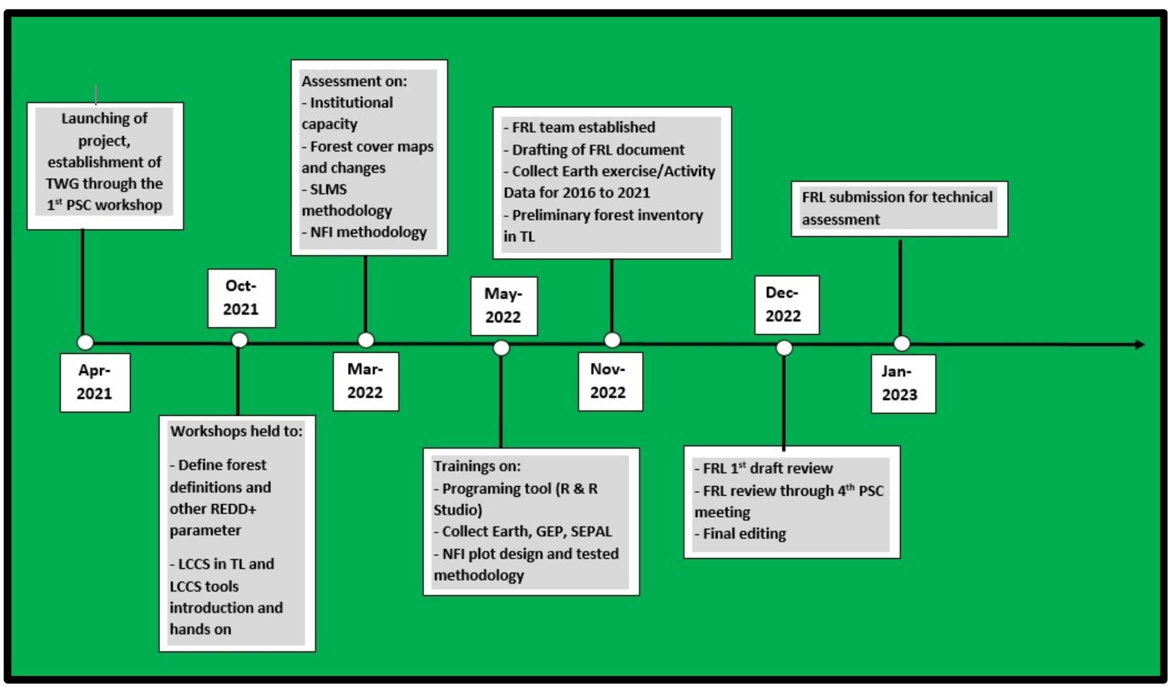

Figure 1 Milestone of the Development of TL's FRL.

1.4.1 The National Forest Inventory

The capacity on forest monitoring of TL is still premature. A large information gap remains. National scale information on carbon stock in the diverse forests subject to different disturbances is poorly known. Previous studies were not detailed enough. The necessity for a National Forest Inventory (NFI) to better understand, plan and manage TL's Forest has been recognized for many years. Designing and planning an NFI for TL has been attempted a number of times but was never implemented due to lack of funding and capacity. There was an inventory activity happening in two municipalities (Bobonaro and Covalima) in 2009, funded by the European Union (EU) and implemented through GiZ and Universidade Trans Montana. However, data from this inventory was not supportive for a full scale NFI to consider.

Under the recent REDD+ readiness project, GoTL through DGFCIP, NDA, NDCC and ALGIS and its collaborating partners established the methodology for NFI and prepared important field design and process for the implementation of NFI. Several trainings, including programming language for carbon calculation, field design, data management and plot measurement were also conducted, and significant capacities built. NFI field implementation commenced in November 2022 and was expected to end in early 2023, however due to climatic constraints during the rainy season it was then extended until mid-May 2023. Beyond REDD+, TL's preliminary NFI will also make a significant scientific contribution to the understanding of TL's Forest and to take it forward for a full NFI scale once the budget becomes available.

So far only initial data has been derived from the preliminary exercise. Information availability on land use and land use change and forestry will be a major step forward and a milestone achievement for the country. Based on this forest inventory and via inputs obtained from respective stakeholders, important measures such as a national land use plan for the country and full scale NFI implementation will be a possible future objective and a major advantage for the country.

1.4.2 Complementarity with the NDCs

The submission of TL's FRL is also in line with revised TL's Intended Nationally Determined Contribution 2022 – 2030 (INDC). The Intended Nationally Determined Contribution 2022-2030 (INDC) was previously revised built on first submitted INDC in 2016. TL has stated in its INDC that it has no set targets for emission reductions, rather, it has pursued policies and regulations to facilitate its response to climate change following the ratification of the UNFCCC. These include: The Environmental Basic Law (Decree Law 26/2012); The Decree Law 41/2022 creation of public institution of National Authority of Environmental Licencing; The Decree Law 42/2022 creation of public institution of National Designated Authority (NDA) for combating climate change; The Decree Law on Export, Import and Use of Ozone Depleting Substances (Decree Law 36/2012); Environmental Strategic Plan; The Decree Law on Protected Areas (Decree Law 5/2016);

GoTL's SDP vision to promote renewable energy; Biodiversity Decree Law and drafting of Climate Change Policy (2016).

In 2012, the GoTL through National Directorate of Climate Change (NDCC) created a working group for climate change adaptation which brings together relevant stakeholders from various government and non-government agencies (e.g., UNDP, GiZ, Camoes, USP, World Vision, Mercy Corps, CRS, Hivos, Water Aid, Oxfam, Care International, FAO) in the area of climate change to facilitate and exchange of data and best practices to support the National Directorate of Climate Change in fulfilling its mandate. GoTL also established a technical working group of technical experts to develop the country's FRL. This team consists primarily of technical experts from the DGFCIP, NDCC, NDA, ALGIS and UNTL and has taken the leading role in steering this initiative with active participation. The substantive technical support had been provided by FAO and funded by the Green Climate Fund.

2. TL's National Forest Definition

Prior to determining whether deforestation, afforestation or reforestation is occurring, and to define the areas within which degradation and the other REDD+ activities may occur, it is paramount that the forest has to be defined first. As part of the guidelines for submission of information on FRL, country Parties should provide the definition of forest used.

Under the IPCC 2003 GPG the forest includes "*all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, subdivided into managed and unmanaged, and by ecosystem type as specified in the IPCC Guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category*." The 2006 Guidelines make reference to *threshold values* for the forestland definition. This indicates that the IPCC anticipates countries to define their forest with quantitative thresholds.

TL's national forest definition is "*the area of at least 0.5 hectares with trees of actual or potential size greater than 5 metres, which grew naturally, forming a natural ecosystem, or that have been planted, and with a higher degree of cover at 15%, which is not under agricultural or other non-forestry use, forest, or area to which the classification of forest, in terms of the law*". This national definition was endorsed by the TL National Parliament in General Regime Law of Forest No. 14/2017 of 2 August.

Forestland in TL is classified into Natural and Plantation Forest and subdivided based on the vegetation and plantation types. Vegetation type is classified based on the structural formation and described in Agriculture Land Use Geographic Information System (ALGIS). The Table 1 presents subdivisions commonly used in Timor-Leste for the IPCC land use categories. However, for the purpose of the FREL, some of these classes have been combined or rearranged based on data available and the limitations of visual interpretation of remote sensing images (see FREL/FRL construction section).

Table 1. IPCC Land Use Categories and sub-division used in Timor-Leste.

IPCC Land use Category	**Sub-type Category**	**Sub-division category**
Forestland	Natural Forest	Low altitude forest on plains and fans, Low altitude forest on uplands, Lower montane forest, Montane Forest, Montane coniferous forest, Dry seasonal forest, Littoral Forest, Seral Forest, Swamp Forest, Savanna, Woodland, Scrub, Mangrove
	Plantation Forest	Eucalyptus, Araucaria, Pinus, Acacia, Terminalia, Teak, Rubber, Other Forest Plantation
Cropland	Subsistence Agriculture	Shifting, Permanent
	Commercial Agriculture	rice, spices, tea, sugar, coffee, palm oil, cocoa, coconut, cocoa/coconut, other
Grassland		herb land, rangeland, other
Wetland		river, lake, dam, nipa swamp, other swamp
Settlement		Village, Hamlet, large settlement, infrastructure
Otherland		bare, sand, rock
*No data		cloud, sea, other reasons

**This is an additional option apart from the six IPCC land use categories.*

3. Scope

The FRL's scope is set in terms of the REDD+ activities, the carbon pools and the greenhouse gases included in the FRL.

3.1 REDD+ activities

The REDD+ activities covered are:

- Deforestation
- Carbon stock enhancement in afforestation (change from non-forest to forest)

The REDD+ activities not currently covered are:

- Sustainable management of forest
- Conservation of carbon stocks
- Forest degradation

The two activities above are decided to be included, considering that there is well developed methodology, included by most countries based on the report and limited technical capacity that the country has. The sustainable management of forest and the conservation of carbon stocks both concern the accumulation of carbon in existing forests, especially forests managed through sustainable harvesting practices. Similarly, forest degradation would provide baseline information of emission of degradation of carbon. There is no data currently available that would allow for including these estimates.

3.2 Carbon pools

The carbon pools covered are:

- Above-ground biomass
- Below-ground biomass (IPCC default ratio)

The carbon pools not currently covered are:

- Litter
- Deadwood
- Soil-organic carbon

Justification of carbon pools that are not currently covered:

3.2.1 Litter

TL has no country specific carbon stock value for litter to allow for reliable estimation. Since no reasonably reliable data for estimating carbon stock in litter is available in TL, it is not covered in the FRL. Country specific data will be available when the full implementation of Forest Inventory takes place. As of now, it is uncertain whether the full NFI scale could be implemented due to lack of capacity and funding.

3.2.2 Deadwood

TL has no country specific carbon stock value for deadwood to allow for reliable estimation. Since no reasonably reliable data is available to use in TL, carbon pool in Deadwood is not covered in the FRL. Deadwood is potentially a large carbon pool, particularly in disturbed forest, and may constitute 10-40% of aboveground biomass (Uhl & Kauffman 1990). It will be included in future submissions once a national forest inventory will be implemented.

3.2.3 Soil organic carbon

Land use can have a large effect on the size of this pool through activities such as conversion of Forest Land to Cropland, where 20-40% of the original soil C stocks can be lost (IPCC, 2006). Emissions from this carbon pool as the results of deforestation could be significant. According to the IPCC (2006) guidelines soil organic carbon should be estimated at a tier 1 level for all considered REDD+ activities. However, TL forest soil has not been classified into the soil types provided in IPCC (2006) Guidelines for their default values. It is currently not possible to estimate the emissions from soil organic carbon pools. On the other hand, it is possible to identify the soil type and climate of all the points where forest conversion occurred using Collect Earth tool. However, TL does not have adequate resources to include this yet in its FRL.

3.2.4 Non-CO2 emissions

The emissions from non-CO2 GHG are not included in the FRL because the reliable data is lacking. In principle, these would occur due to burning during the forest degradation, drainage of organic soils upon deforestation and mineralization of carbon after deforestation. Forests in TL are affected by fire mostly, but year of fire occurrence and frequency are not known in most cases. There is no reliable data of distribution of organic soil and their drainage, which could cause CH_4 and N_2O emissions.

4. Reference period

As a result of a broader stakeholder consultation workshop held during the technical working group meeting, it was agreed that the preferred reference period to use for TL would be from the 1st of January 2017 until the 31st of December 2021, which comprises 5 years of changes (2017, 2018, 2019, 2020 and 2021). This period was considered to have two main advantages, firstly, it reflects better the current situation in the country, and secondly it allows the use of higher resolution satellite imagery; Sentinel-2 (10 m spatial resolution) is available since 2016-17 and PLANET (3 m) biannual mosaics since 2016, apart from Landsat 7 and 8 (30m) since 2000 and 2013, respectively.

5. Scale

The scale of the FREL/FRL is nationwide.

The GoTL values the importance of forests and indicates in its NDC to the UNFCCC in 2016 that the forestry sector can play a significant role to mitigate climate change. The dangers posed from climate change and the importance of forests in tackling this issue is a key concern for the GoTL. In line with this objective, TL's political leadership called for tangible actions be taken to reduce GHG emissions through REDD+ and put in place long-term political visions, plans and strategies. These include: The Environmental Basic Law (Decree Law 26/2012); The Environmental License Decree Law 2011 and climate change issues (Decree Law 5/2011); The Operational Law of Clean Development Mechanism under the Kyoto Protocol (2010); The Decree Law on Export, Import and Use of Ozone Depleting Substances (Decree Law 36/2012); Environmental Strategic Plan; The Decree Law on Protected Areas (Decree Law 5/2016); GoTL's SDP vision to promote renewable energy; Biodiversity Decree Law, drafting of Climate Change Policy (2016) and Timor-Leste Strategic Development Plan 2011-2030.

TL aims to address REDD+ at the national level where reducing emissions from the forest sector becomes an important policy priority. As such, TL has decided to develop its FRL at this scale, where all REDD+ efforts are also better monitored and measured, as a result of the latest GIS and Satellite Land Monitoring Systems, equipment and tools which have been introduced and built into the country's existing national agencies. This will effectively contribute towards the country's policy directions and act as a guide for its forest policy.

6. Transparent, complete, consistent, and accurate information used in the construction of the FREL/FRL

6.1 Consistency

The methodology applied for the FREL/FRL calculations follows the IPCC 2006 Guidelines, its 2019 refinement and the Wetlands' supplement from 2013. The general method follows a carbon stock change approach, with activity data based on hectares of land use change per year and the emission and removal factors are based on stock difference between the old and new land use types in tCO_2e/ha.

6.2 Land use categories used in the FREL/FRL

Forest land in TL is classified into Natural and Plantation forests and subdivided based on the vegetation and plantation types. Vegetation type is classified based on the structural formation and described in Agriculture Land Use Geographic Information System (ALGIS). Several forest classifications have been used in historical forest cover maps (see historical maps in the Activity Data section), combining altitude, climate, density and/or primary/secondary to differentiate between forest types.

For the purpose of the FREL/FRL, land use stratification has been redesigned to combine categories that can be identified using visual interpretation with a little help (for example altitude can be added from remote sensing data), while meaningful for carbon accounting a priori (expert-based discussion as no full scale NFI is available to test the best forest stratification for carbon and other purposes).

For the Activity Data, 20 land use categories were defined and in the FREL/FRL, several abiotic categories have been grouped (carbon stock assumed to be 0), leading to 7 forest types, 4 other vegetated categories and 3 abiotic categories (Table 2).

Table 2. Land use categories used in the FREL/FRL.

IPCC	Activity Data classes	FREL/FRL classes	FREL/FRL class code	Description
Forest Land	Moist Highland Forest	Moist Highland Forest	FMH	Natural forest with altitude ranging from 600m to 100m.
	Moist Lowland Forest	Moist Lowland Forest	FML	Natural forest with altitude below 600m in moist climatic conditions.
	Dry Lowland Forest	Dry Lowland Forest	FDL	Natural forest with altitude below 600m in dry climatic conditions.
	Montane Forest	Montane Forest	FM	Natural forest with altitude above 1000m.
	Coastal Forest	Coastal Forest	FC	Natural forest typically within a few hundred metres from the coastline, with an altitude ranging fom 0 to 50 m.
	Mangrove Forest	Mangrove Forest	MF	Natural forest located in the coastal intertidal zone.
	Forest Plantations	Forest Plantations	FP	Planted forests.
Grassland	Grassland	Grassland	G	Natural land dominated by grass with shrubs and trees < 10 % cover.
	Shrubland	Shrubland	Sh	Natural land with shrubs cover > 10 % and trees cover < 10 %.
	Other Wooded Land	Other Wooded Land	OWL	Natural land with trees but tree cover < 10%, not dominated by shrub or grass
Cropland	Cropland	Cropland	C	Cultivated land with tree cover < 10% or mixing tree and crops (agroforestry).
Settlements	Settlements	Settlements	S	Generally abiotic land characterized by built-up areas. Settlements can include trees, garden, and parks but due to lack of country specific data, the carbon stock of settlements is assumed to be 0
	Infrastructures			
Wetland	Wetlands	Wetlands	W	Land covered by water.
	Lake / Lagoon / Reservoir			
	River			
Other land	Mining	Other land	O	Other abiotic lands.
	Rock			
	Sand			
	Other bare land			

6.3 Emission and removal factors

6.3.1 Historical forest inventories in TL

There has been no national forest inventory implemented since Timor-Leste independence and only few project-based local inventories known to date. The projects are listed below.

2008-9: Forest inventory in two districts

The main historical inventory was implemented in 2 districts in 2008 and 2009[1], but unfortunately the raw data was not handed over to the TL government and is not available. From the report, the only information indirectly related to tree carbon was an average merchantable volume of 31.3 m^3/ha. With default biomass conversion and expansion factors (BCEF, IPCC 2006 V.4 Ch.4 Table 4.5), potential aboveground biomass averages for Tropical dry and humid forest would be 59 and 126 t/ha respectively (BCEF values of 1.9 and 4).

2020: Community Forestry management inventories

This activity was part of the Timor-Leste GCF REDD+ Readiness project and aimed at providing community forestry monitoring practices. The project only included a testing phase, and a few plots were measured, mostly in dry lowland forest conditions. The plot sizes of these testing inventories were 30 x 50 m for the largest nested subplots and only few trees were recorded in these small areas.

2022: National Forest Inventory design testing phase

Also, part of the TL GCF REDD+ Readiness project, a full national scale forest inventory design was initiated, and a testing phase included in the project. The plot size of this inventory design allowed the recording of more trees, following a nested subplot approach (Figure 2).

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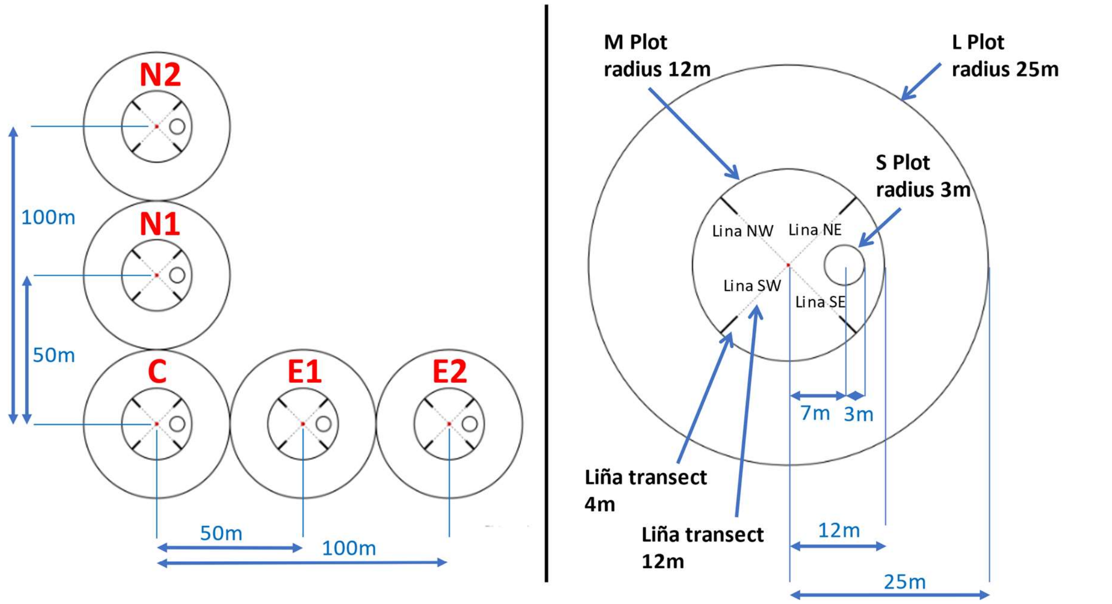
[1] First forest inventory of Timor-Leste: districts of Bobonaro and Covalima: 2008-2009, UTAD 2010, ISBN 978-972-669-998-9.



Subplot name	Radius or length	Measurements
L	25 m	Large trees only (Ø ≥ 30 cm) Large standing dead trees (Ø ≥ 30 cm) Large stumps (Ø ≥ 30 cm)
M	12 m	All trees (Ø ≥ 10 cm) All standing dead trees (Ø ≥ 10 cm) All stumps (Ø ≥ 10 cm) Lianas Bamboo culms Rattan
S	3 m	Sapling (10 cm > Ø ≥ 2 cm) Seedling (Ø < 2 cm)
Line transects	12 m (from subplot centre)	Coarse woody debris (intersect ≥ 10 cm)
Line transects	4 m (8 to 12 m from subplot centre)	Fine woody debris (10 cm > intersect ≥ 1 cm)

Figure 2. National Forest Inventory plot design for the testing phase.

In the current modified FREL/FRL submission a total of 40 plots were measured and these are the only plots usable for deriving forest carbon stock and estimating carbon stock of respective forest categories of FREL/FRL.

For the other non-forest land use types, IPCC default factors are used.

6.3.2 Methodology for inventory based aboveground biomass calculations

In the NFI testing phase tree species and diameter at breast height (DBH, in cm) were recorded for all trees and tree total height (H, in m) was measured every 5 trees (diameter bigger or equal to 10 cm).

Step 1: Tree height correction

No outlier was immediately obvious in the tree DBH recorded, but some of the tree heights seemed either too low for large trees or too high for smaller trees. The NFI teams also did not have a lot of practice with the recording device (Vertex IV), and tree height measurements can be challenging in closed canopy conditions.

For these reasons, tree height was estimated with Chave et al. 2014[2] model based on an environmental stress climatic factor with the formula:

```
H_model = exp(0.893 - E + 0.760 * log(DBH) - 0.0340 * (log(DBH))^2)
                        with RSE = 0.243
```

With E the environmental stress available as a world cover spatial raster file and log the natural logarithm.

Then the estimated height from Chave's model was chosen for trees with no recorded height or for trees with a measured height outside of the confidence limits of the model (figure 3).

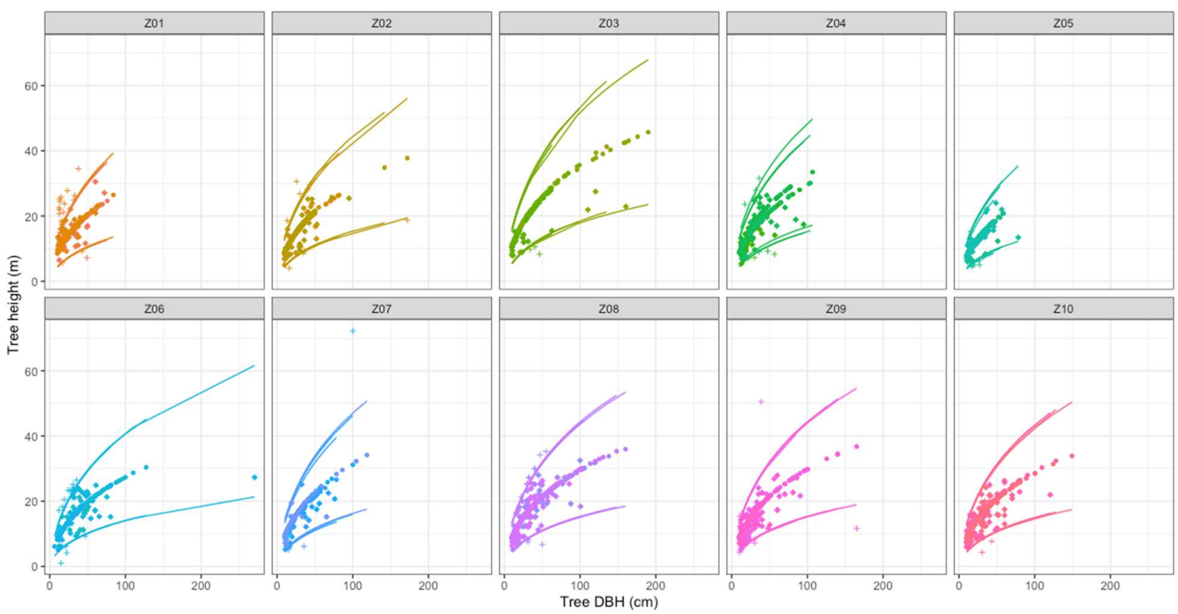


Figure 3. Tree height correction based on Chave et al. 2014 model. Cross represent measurements, dots the estimated heights and the line represent the upper and lower limit of the confidence interval of the model.

[2] Chave, J., et al. (2014), Improved allometric models to estimate the aboveground biomass of tropical trees. Glob Change Biol, 20: 3177-3190. https://doi.org/10.1111/gcb.12629

Step 2: Wood density values at species level

The Global Wood Density database[3] was used to associate average wood density values to each tree based on their species. An average wood density value was calculated for each species based on the data available in the Asia region. For trees that could not be identified a default value of 0.57 g/cm3 was assigned based on Reyes et al 1992[4].

Step 3: Tree level aboveground biomass (AGB)

Tree aboveground biomass was calculated with Chave et al. 2014 AGB model:

```
AGB = 0.0673 * (WD * DBH^2 * H_corr)^0.976
```

With AGB the aboveground biomass in kg, WD the wood density in g/cm3, DBH the diameter at breast height in cm and H_corr the corrected tree height in m.

Step 4: Propagation from tree to plot level

Tree level AGB was propagated to plot level by summing the AGB of all trees multiplying the outputs by a scale factor to take into consideration the nested structure of the plots. It resulted in AGB values in t / ha at the plot level (Table 4).

Step 5: Adding belowground biomass and carbon fraction from IPCC default factors

The Root-to-Shoot ratios presented in Table 3 were used to estimate the belowground biomass (BGB) associated with the AGB estimates.

---

[3] Zanne, Amy E. et al. (2009), Data from: Towards a worldwide wood economics spectrum, Dryad, Dataset, https://doi.org/10.5061/dryad.234

[4] Reyes, Gisel et al. 1992. Wood Densities of Tropical Tree Species. Gen. Tech. Rep. SO-88. New Orleans, LA: U.S. Dept of Agriculture, Forest Service, Southern Forest Experiment Station. 15 p.

Table 3. Root-to-Shoot ratios applied to TL aboveground biomass estimates.

FRL classes	Root to shoot ratio	RS source
Moist Highland Forest	0.323 / 0.246 (calculated at plot level)	IPCC 2019
Moist Lowland Forest	0.323 / 0.246 (calculated at plot level)	IPCC 2019
Dry Lowland Forest	0.440/0.379 (calculated at plot level)	IPCC 2019
Montane Forest	0.345 (calculated at plot level)	IPCC 2019
Coastal Forest	0.323 / 0.246 (calculated at plot level)	IPCC 2019
Mangrove Forest	0.29	IPCC 2013
Forest Plantation	0.379 (calculated at plot level)	IPCC 2019

The carbon fraction applied to convert woody biomass to carbon was 0.47. With the AGB, BGB and carbon fraction, the total carbon stock was calculated for each plot (Table 4).

Table 4. Aboveground biomass at the plot level from the 2022 and 2023 initial NFI testing data (40 plots).

Plot ID	AGB (t/ha)	Land use	Climate	BGB (t/ha)	Total Carbon (tCO2/ha)
Z01T01	72.56	Moist lowland forest	Moist	17.85	42.49
Z01T02	105.21	Moist lowland forest	Moist	25.88	61.62
Z01T03	57.76	Forest plantation	Moist	21.89	37.44
Z01T04alt	126.83	Forest plantation	Moist	48.07	82.20
Z02T01	107.12	Moist lowland forest	Moist	26.35	62.73
Z02T02	62.12	Moist lowland forest	Moist	15.28	36.38
Z02T03	91.39	Forest plantation	Moist	34.64	59.23
Z02T04	91.86	Moist lowland forest	Moist	22.60	53.79
Z03T01	154.36	Montane forest	Moist	49.86	95.98
Z03T02alt	312.58	Non forest	Moist	100.96	194.37
Z03T03	188.25	Non forest	Moist	60.80	117.05
Z03T04alt	72.34	Montane forest	Moist	17.80	42.36
Z04T01	73.43	Dry lowland forest	Dry	27.83	47.59
Z04T02	82.58	Dry lowland forest	Dry	31.30	53.52
Z04T03alt	136.26	Dry lowland forest	Dry	59.95	92.22
Z04T04	81.45	Dry lowland forest	Dry	30.87	52.79
Z05T01	18.79	Dry lowland forest	Dry	7.12	12.18
Z05T02	41.81	Dry lowland forest	Dry	15.85	27.10
Z05T03	23.59	Non forest	Dry	8.94	15.29

Plot ID	AGB (t/ha)	Land use	Climate	BGB (t/ha)	Total Carbon (tCO2/ha)
Z05T04	47.47	Dry lowland forest	Dry	17.99	30.77
Z06T01	105.93	Mangrove forest	Moist	26.06	62.04
Z06T02	115.26	Mangrove forest	Moist	28.35	67.50
Z06T03	256.87	Mangrove forest	Moist	82.97	159.73
Z06T04	27.83	Non forest	Moist	6.85	16.30
Z07T01	189.56	Montane forest	Moist	61.23	117.87
Z07T02	94.50	Montane forest	Moist	23.25	55.34
Z07T03	48.79	Montane forest	Moist	12.00	28.57
Z07T04	121.65	Montane forest	Moist	29.93	71.24
Z08T01	205.73	Moist lowland forest	Moist	66.45	127.93
Z08T02	273.41	Moist lowland forest	Moist	88.31	170.01
Z08T03	307.94	Moist lowland forest	Moist	99.46	191.48
Z08T04alt	80.29	Moist lowland forest	Moist	19.75	47.02
Z09T01	75.27	Moist lowland forest	Moist	18.52	44.08
Z09T02	238.41	Moist lowland forest	Moist	77.01	148.25
Z09T03	175.19	Moist lowland forest	Moist	56.59	108.93
Z09T04	102.31	Moist lowland forest	Moist	25.17	59.91
Z10T01	184.02	Coastal forest	Moist	59.44	114.42
Z10T02	91.53	Coastal forest	Moist	22.52	53.60
Z10T03	138.56	Coastal forest	Moist	44.75	86.16
Z10T04	200.82	Coastal forest	Moist	64.86	124.87

Step 6: Forest type level carbon stocks from inventory data and default factors

Among the 40 plots measured during the NFI testing phase, 4 plots fell outside forest land and the 36 other plots covered all the land use classes except Moist Highland Forest (FMH), for which the same carbon stock as Moist Lowland Forest (FML) was applied (Table 5). The uncertainty of the carbon stock was found to be acceptable given the small number of plots measured except for Mangrove Forests (MF) and Forest Plantations (FP) due the heterogeneity of forest conditions there. The carbon stocks and their uncertainties are expected to be improved once a full scale NFI is implemented.

Table 5. Carbon stock used in the FREL/FRL and their source.

FRL classes	class code	# Plots	Carbon total (tC/ha)	CI(%)	Carbon stock source
Moist Highland Forest	FMH	0	88.8	37	NFI test 2022 (same as lowland)
Moist Lowland Forest	FML	13	88.8	37	NFI test 2022
Dry Lowland Forest	FDL	7	45.2	53	NFI test 2022
Montane Forest	FM	6	68.6	51	NFI test 2022
Coastal Forest	FC	4	94.8	54	NFI test 2022
Mangrove Forest	MF	3	96.6	132	NFI test 2022
Forest Plantations	FP	3	59.6	93	NFI test 2022
Grassland	G		1.1	75	IPCC 2006 (v4 ch6 table 6.4)
Shrubland	S		2.9	75	IPCC 2006 (v4 ch6 table 6.4)
Other Wooded Land	OWL		2.9	75	IPCC 2006 (v4 ch6 table 6.4)
Cropland	C		4.7	75	IPCC 2019 (V4 ch5 table 5.9)
Settlements	S		0	0	
Wetlands	W		0	0	
Other land	O		0	0	

Step 7: Emission and removal factors (EFRF)

Emissions and removal factors were calculated for each category of land use change as the difference between them multiplied by the ratio of atomic masses between CO_2 and C:

```
EFRF = (Cstock_old – Cstock_new) * 44/ 12
```

In this way, Emission factors and Emissions have a positive value while Removal factors and Removals have a negative value.

In the case of removals, the removal factors are divided by 20 and $1/20^{th}$ of their value is applied every year to afforestation lands to consider that afforested land reach maturity in around 20 years.

To keep track of removals in afforested land Activity Data sample points that are afforested are recorded in a registry. It also allows to correctly assign deforestation carbon stock in case afforested samples return to non-forest before they reach maturity.

6.3.3 Emission and removal factors result

With the approach described above the following emission and removal factor matrices is applied in this FREL/FRL (Table 6). Carbon stock changes in forest remaining forest are not accounted for as the land uses are based on ecological conditions and there should be no activity data there. Stable forest is assumed to have 0 carbon stock change.

Table 6. Emission and removal factors for Timor-Leste FREL/FRL (tCO2e/ha).

		New land use category													
		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O
Old land use category	FMH	0	0	0	0	0	0	0	322	315	315	308	326	326	326
	FML	0	0	0	0	0	0	0	322	315	315	308	326	326	326
	FDL	0	0	0	0	0	0	0	162	155	155	149	166	166	166
	FM	0	0	0	0	0	0	0	248	241	241	234	252	252	252
	FC	0	0	0	0	0	0	0	344	337	337	330	348	348	348
	MF	0	0	0	0	0	0	0	350	344	344	337	354	354	354
	FP	0	0	0	0	0	0	0	215	208	208	201	219	219	219
	G	-16	-16	-8	-12	-17	-18	-11	0	0	0	0	0	0	0
	Sh	-16	-16	-8	-12	-17	-17	-10	0	0	0	0	0	0	0
	OWL	-16	-16	-8	-12	-17	-17	-10	0	0	0	0	0	0	0
	C	-15	-15	-7	-12	-17	-17	-10	0	0	0	0	0	0	0
	Se	-16	-16	-8	-13	-17	-18	-11	0	0	0	0	0	0	0
	W	-16	-16	-8	-13	-17	-18	-11	0	0	0	0	0	0	0
	O	-16	-16	-8	-13	-17	-18	-11	0	0	0	0	0	0	0

Afforestation is coloured in green, deforestation in red, stable forest in blue and stable non-forest in grey. With Land use codes: FMH = Moist Highland Forest, FML = Moist Lowland Forest, FDL = Dry Lowland Forest, FM = Montane Forest, FC = Coastal Forest, MF = Mangrove Forest, FP = Forest Plantations, G = Grassland, Sh = Shrubland, OWL = Other Wooded Land, C = Cropland, Se = Settlements, W = Wetlands, O = Other land

6.4 Activity Data

6.4.1 Historical forest and land cover maps

Japan International Cooperation System (JICS), 2013

The most recent survey on forest and land cover at national scale was made in 2013, as part of the National Conservation Plan (NCP), by the Ministry of Agriculture and Fisheries (MAF) in cooperation with the National Directorate of Forestry (NDF) and the Japan International Cooperation System (GovTL et al., 2013). Two maps were produced, for 2003 and 2010, using Landsat imagery (30m spatial resolution), and for 2010 also ALOS AVNIR-2 (10m spatial resolution) (Figure 4). The availability of ALOS AVNIR-2 was limited for the country, therefore images from different seasons (from 2008, 2009 and 2010) were combined to develop the map. The map was developed by visual interpretation using ALOS-PRISM and aerial photo. As a combination of two different spatial resolution in the imagery used for the map of 2010, this resulted with some artifacts. The comparison of both maps reports a significant reduction in Timor-Leste's forest cover between 2003-2010

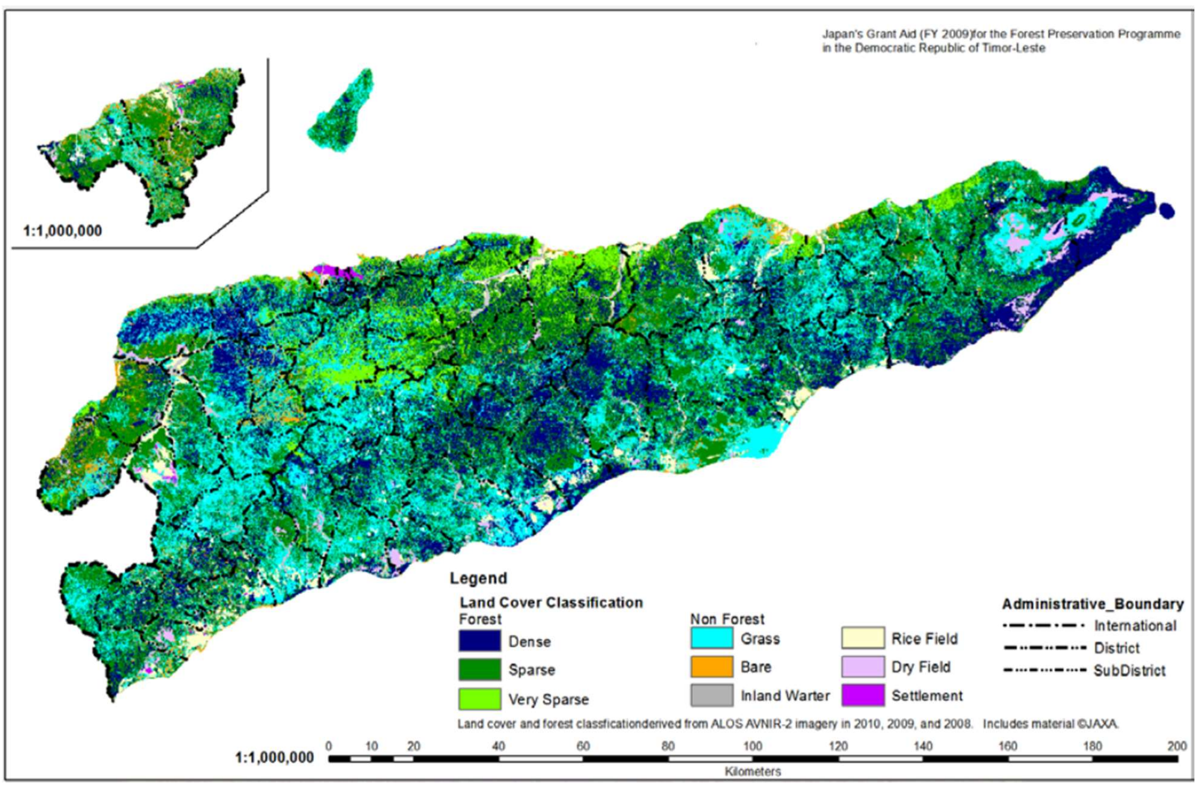


Figure 4. Land cover and forest classification map of Timor-Leste for 2010 made by JICS and MAF.

David Adams, 2009

The Sustainable Land Management (SLM) project, from the MAF through cooperation with UNDP under the GEF, included the production of a land use map (MAF & UNEP, 2011). This map was produced from SPOT images (30 m spatial resolution) from 2007 and 2009 (Figure 5). No documentation on this map have been found.

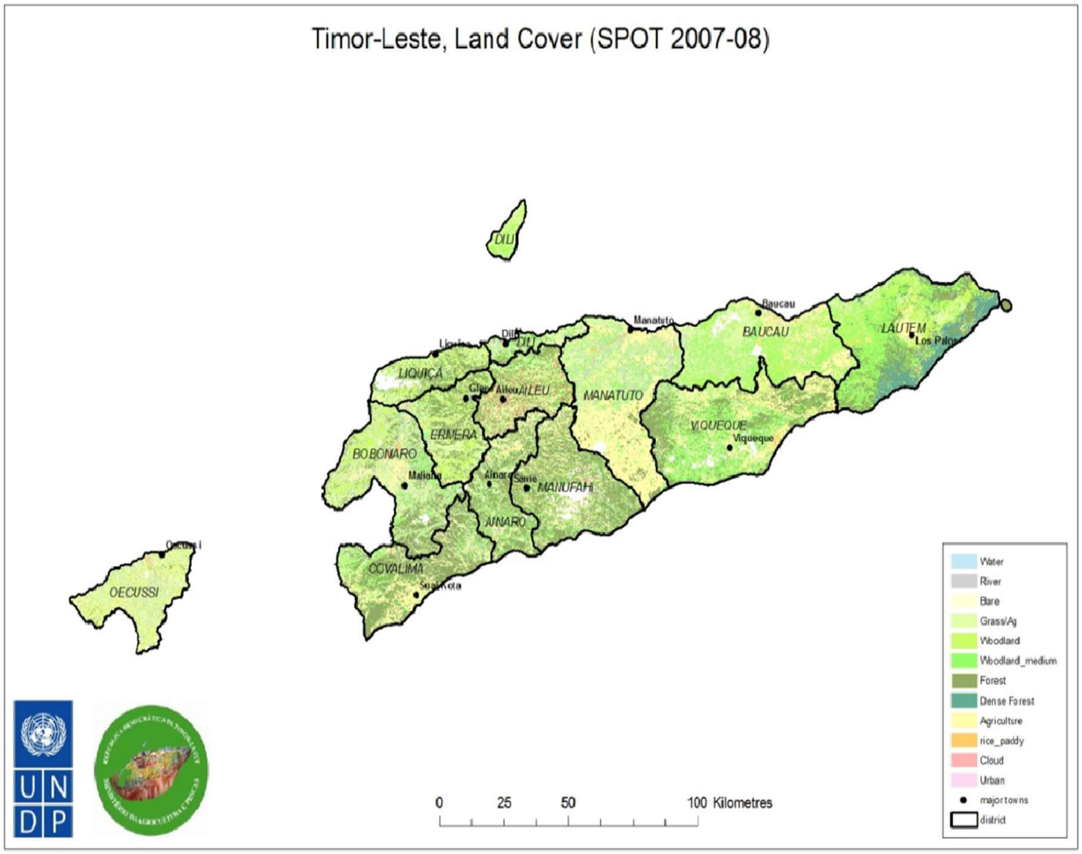
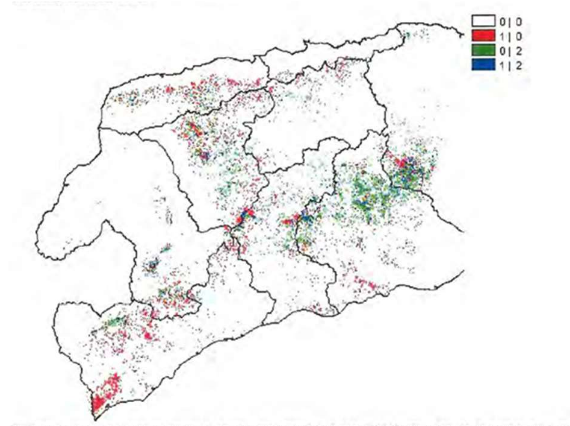


Figure 5. Land cover map of Timor-Leste for 2007-8 made by David Adams.

Bouman and Kobryn, 2002

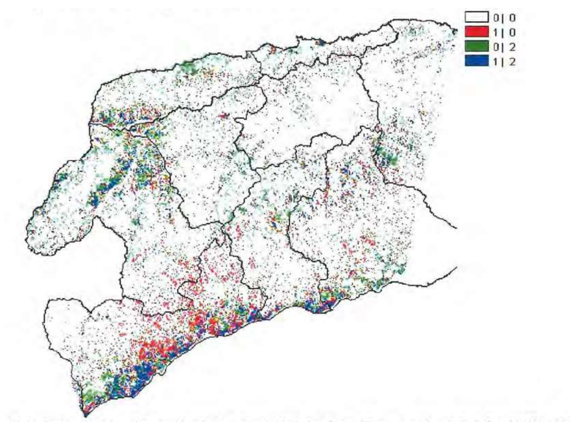
Forest cover change maps between 1989 and 1999 for the country western area were produced by the Environmental Protection Unit (EPU) of the UN East Timor Transitional Administration (ETTA) in collaboration with the Australian Centre for Remote Sensing (ACRES) (Bouma & Kobryn, 2002). These maps were produced from Landsat TM 5 and 7 images, comparing results from maximum likelihood classification of vegetation index between both years. They showed a decline in dense forest, sparse forest, and woodland areas (Figure 5). Woodland particularly displayed the largest decline in area. Increases in human modified plantation areas and coffee areas were also apparent. However, the largest increase occurred in the degraded woodlands category. Two of the most significant causes of land cover conversion were the intensification of land cleared for cultivation by slashing and burning vegetation and fire.

Dense forest



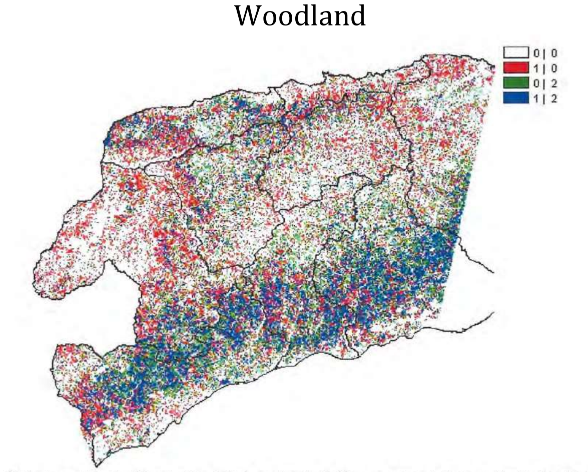
0|0=background, no data; 1|0=red patches indicate dense forest in 89 but not in 99; 0|2=green patches indicate dense forest in 89 and 99; 1|2=blue patches indicate dense forest in 99 but not in 89.

Forest



0|0=background no data; 1|0=red patches indicate forest in 89 but not in 99; 0|2=green patches indicate forest in 89 and 99; 1|2= forest in 99 but not in 89.

Woodland



0|0=background no data; 1|0=red patches indicate woodland in 89; 0|2=green patches indicate woodland in 89 and 99; 1|2=blue patches indicate woodland in 99 but not in 89

Figure 6. Forest change maps (dense forest, forest, and woodland) of western Timor-Leste between 1989 and 1999 (Bouman & Kobryn, 2002).

6.4.2 Historical forest and land cover classification systems

Table 7 compiles the classification systems used by the historical forest and land cover maps produced for Timor-Leste and their potential inclusion under the higher land cover land use categories for greenhouse gas (GHG) inventory reporting of the IPCC (2006). It also collects the country coverage percentage of each class.

Forest land classes are different among the different classification systems. JICS include dense forest (forests with a canopy coverage greater than 60%), sparse forest (forests with a canopy coverage between 20 and 60%) and very sparse forest (forests with canopy coverage about 5-20%). Adams, and Bouma and Kobryn differentiate between forest and dense forest, and woodland and sparse woodland. However, forest coverage is quite similar in almost all of them, around 60% of the total land area, indicating that forest remains the largest land use/cover category in the country. The second largest is grassland and shrubs occupying about 25% in JICS and Adams. Therefore, the differences come from the distribution of the forest land in different class definitions.

Table 7. IPCC top-level land cover land use categories and existing forest and land cover classification systems for Timor-Leste with coverage percentage by class.

IPCC, 2006	JICS, 2010		Adam, 2007-8		Bouma & Kobryn, 1999		Hunt, 2001		Eriksad, 1999	
class	class	%	class	%	class	%	class	%	class	%
Forest land	Dense forest (>60%)	21	Forest dense	2	Dense forest (>70%)	3	Forest (>30%)	74	Dense forest	16
	Sparse forest (20-60%)	38	Forest medium	27	Forest (30-70%)	9			Sparse forest	19
	Very sparse forest (5-20%)	4	Woodland medium	20	Woodland (10-30%)	19				
			Woodland sparse	8	Woodland poor	22				
					Forest/Coffee (30-70%)	7				
	Total forest	59	Total forest	57	Total forest	60		74		35
Grassland	Grassland/Shrub	27	Grassland	22	Heath/Shrub	5	Non-productive dryland and wetlands	3.6		
Cropland	Rice field	2.8	Rice paddy				Agriculture	16		
	Rainfed crop	1.5	Agriculture	12			Commercial agriculture	4.3		
	Total	4.3	Total	13	Plantation	5	Total	20.3		
Settlement	Settlement	0.2	Urban	0.1			Villages and scattered gardens, settlements and Industrial land	1.6		
Other land	Water bodies	1.6	Water	0.1			Lakes	0.4		
	Bare land	3.3	River bed / erosion	7						
				0.8						

6.4.3 Historical forest cover trends

Table 8 collects the forest cover and annual deforestation rates for Timor-Leste according to different studies for different years and periods. Some of them have estimated their own data and others are based on data from other studies, e.g., forest resource assessment in 2015 (FAO, 2015a) is based on Bouma & Kobryn and the partial NFI of 1997, among other sources of information (FAO, 2015b). Forest resource assessment in 2020 (FAO, 2020a)

and INC (Timor-Leste's State Secretariat for Environment and GovTL, 2014) are based on JICS (FAO, 2020b). In general, there are important differences in forest cover extend and deforestation rates. These can come from the methodologies employed, but they can also be due to differences in the forest definition employed in the studies.
The table includes the Global Forest Maps (GFM) from the University of Maryland (Hansen et al., 2013), that characterize forest extent for the year 2000 (percentage of tree cover) and annual changes for the period of 2000 to 2020 (loss/gain/stable), as results from time-series analysis of Landsat images. The percentage of total forest cover estimated for 2010 (46%) is less than the national studies, but the default minimum canopy cover of the forest definition is 30%.
In the Interactive World Forest Map (GFM) & Tree Cover Change Data based on the GFM by Global Forest Watch (https://www.globalforestwatch.org/map/), the minimum canopy cover of the forest definition can be reduce to 10%, thus increasing the forest cover to 54% in 2010 (comparable to the 59% of JICS' map) and 57% in 2000 (very similar to the 60% of Bouma & Kobryn 1999 map).

Table 8. Forest cover and annual deforestation rates for Timor-Leste according to different sources.

Forest cover (ha)								
	GFM	**JICS, 2013**	**FAO-FRA 2020**	**Bouma & Kobryn, 2002**	**FAO-FRA 2015**	**Nippon Koei 2010**	**Eriksad 2001**	**INC 2014**
	canopy cover >30%	canopy cover > 20%	based on JICS	canopy cover >30%	based on B&K and NFI of 1997			Based JICS
1972							646,100*	
1989				369,999				
1990			963,000		966,000			
1999				359,785			453,850*	
2000	720,240		949,000		854,000			
2003		1053,018						
2005					798,000			
2010	693,000	869,130			742,000			855,797*
2015			935,000		686,000			
2020	691,540		921,000					
Annual deforestation rate (%)								
	2000-20	2003-10	1990-2020	1989-99	1990-15	2003-10	1972-99	2004-10
	0.2	1.94	0.15	0.27	1.4	2.18	1.1	2.23

*dense and sparse forest

According to the Timor-Leste Initial National Communication (Timor-Leste's State Secretariat for Environment & GovTL, 2014), total emissions resulting from land use change and forestry have a decreasing tendency since 2006, and the main sources of these emissions are forest and grassland conversion. It portraits that deforestation is decreasing since 2006, but there is no recent data after 2010.

The GFM are not valid for accurate country level studies, however, they may be useful to give an idea of the forest cover trend in recent years. In general terms, they show an increment of forest loss in the country from 2000 to 2006 (Timor-Leste ratified the UNFCCC in October 2006), a decline until 2015, and a stabilization since 2016 (Figure 7).

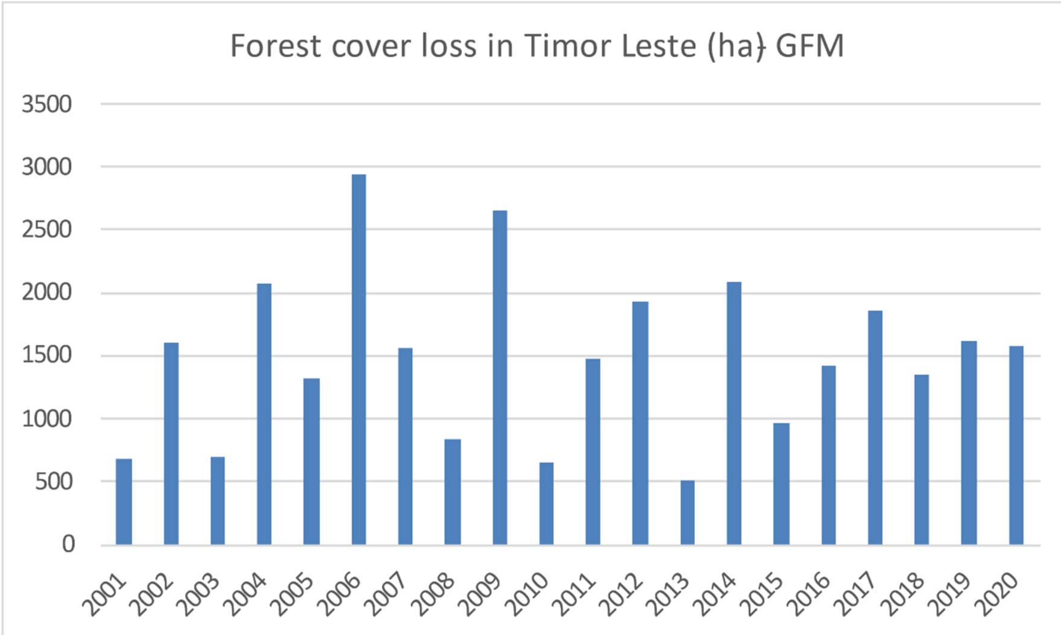


Figure 7. Forest cover loss in Timor-Leste according to the GFM.

The national data available in terms of historical trend on the forest cover is quite challenging. There are inconsistencies in forest cover and deforestation rate reported from different studies (GFM, n.d; Eriksad 2001; Bouma & Kobryn, 2002; Nippon Koei, 2010; GovTL et al., 2013; INC, 2014; FAO, 2015; FAO, 2020). The reasons could be due to different forest definition and/or methodologies applied. According to Timor-Leste's INC, forest loss has a decreasing tendency since 2006. This information seems to be compatible from what is reported in GFM. Thus, considering data from GFM, starting from 2006, forest cover lost in Timor-Leste is decreasing and stabilised from 2015 till 2020.

6.4.4 Activity Data: Step by step description of data processing

Land cover and forest map of 2021

As described in previous section, there are three main forest maps produced in the past studies in Timor-Leste (GovTL et al., 2013; David Adams, 2009; Bouma and Kobryn, 2002), with the one from JICS for 2010 as the most recent, which most of forestry programs and activities in the country are based on. Due to the need for an updated forest and land cover map for Timor-Leste, new maps for 2021 were developed. Based on the evaluation of previous maps, it was concluded that the new map could not be based on previous methodology for FRL reporting because they were not reproducible and were not recommended by producers for having technical issues (e.g., resolution, seasonality) and being manually too intensive. The forest classification map (Figure 7) considering the forest classes of Table 2 can be accessed with the following link:

https://code.earthengine.google.com/11663009678dd9ba0504694f78c0ab24

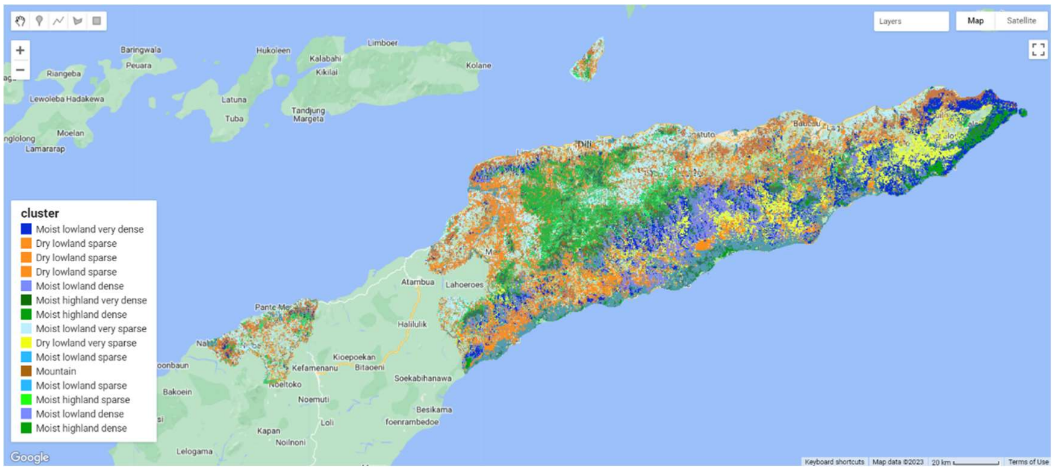


Figure 8. Forest classification map of 2021 for Timor-Leste.

Sampling design

Due to the lack of consistent historical maps and a validated recent map of Timor-Leste, it was decided to use a systematic sampling approach at country level, based on DGGRID grid system grid (https://discreteglobal.wpengine.com/). This consist of a hexagonal grid, and the samples are located at the central point of each hexagon. Hexagonal grid has the advantage of being consistent, minimizing the distance difference of the centre between its maximum and minimum towards the border. Also, the distance to each surrounding point is the same. This, coupled with the selection of an equal area projection, has some statistical advantages when extrapolating results a national scale.

DGGRID (Sahr, 2019) consist of a **hexagonal grid** using an icosahedral Snyder equal area projection (Carr et al., 1997). The samples are located at the central point of each hexagon. Hexagonal grid has the advantage of being consistent, minimizing the distance difference of the centre between its maximum and minimum towards the border, and equalizing the distance to each surrounding point. This translates into more evenly distributed hexagons (more compacts) all with the same area. This, together with the selection of an equal area projection, has some statistical advantages when extrapolating results to a national scale. DGGRID is moreover hierarchical, easily allowing the intensification of the sampling in the future.

The grid is also compatible with the NFI and the FAO FRA assessment.

Sample size calculation was based on the Central Limit Theorem. To determine the overall sampling size, a priori land cover dynamics information is necessary, for example, from global products (i.e., GFMs), to get an approximation of expected land cover change. Then, the calculation was applied:

Given the confidence level (i.e., 90%), the significance level is α=1-confidence level, an approximate estimated total sample size n is assessed by Cochran 1977:

$$n \approx \frac{z_{\alpha/2}^{2} \cdot \hat{O} \cdot (1-\hat{O})}{d^2}$$

where;

$\hat{O}$ = Expected *overall feature area* expressed as a fraction

z = Percentile from the *standard normal distribution* (z = 1.645 for a 90% confidence interval; the value 1.64 is used in the simple error propagation)

d = The allowable margin of error. This is the maximum half-width of the confidence interval we aim towards in our estimate. It is given as area fraction, not as percentage. It should be the precision level, taken as a confidence interval, required for the feature to measure.

For estimating Ô the tree cover loss between 2017 and 2021 from the GFM data has been used, which is equal to 8103.12 ha:

$$\hat{O} = \frac{deforestation\ area\ 2017 - 2021}{country\ area}$$

The sampling intensity to capture deforestation has been estimated for different target precisions with a 90% of confidence interval (Figure 9).

Figure 9. Sample size needed to reach margin of errors between 10% and 37% (CI 90%).

The grid spacing of 2 km (distance between sample centers) was finally selected as not 'optimal' but rather as small as practicable considering available time, human, and financial resources. Sample size should be dense enough to capture change (e.g., contain at least 30 sample units within the change class of interest).

Visual interpretation

Samples were visually interpreted by national technical personnel. For this a project (timor_leste_2022_frel_v11_en.cep) was created in **Open Foris Collect** (https://openforis.org/tools/collect/) and imported in **Collect Earth** (https://openforis.org/tools/collect-earth/). The samples were randomly divided to be validated by 8 national technical personnel.

Plots were designed in square shape, with an area of 0.5 ha and were centred at the systematic samples. Each one has 7x7 control points of 2x2 m each, equally distributed inside and separated 10m from each other.

A survey was designed to collect information about the satellite imagery availability, the land cover distribution and land use distribution in the plot, the land uses changes and disturbances.

- **Satellite imagery**
  The availability of the type of satellite imagery to support the decision making for each plot was recorded. In case of satellite images of very high spatial resolution, the source was also recorded. Collect Earth is integrated into Google Earth Pro, with time

series of historical images, and to Bing Maps, with high spatial resolution images of no specific date.

- **Land cover in 2021**

The land cover distribution of each plot was recorded as the number of control points that fall into the land cover categories in *Table 9. Land cover classes in the survey*.

Table 9. Land cover classes in the survey.

Land cover	
Trees (in forest/grassland)	
Trees (in agriculture/settlement)	
Crops	
Grass	
Bushes/Shrubs	
Built up	
Infrastructures	
Water Body	
Bare soil	

- **Land Use in 2021**

The land use distribution in the plot was recorded as homogeneous or heterogeneous and the number of control points that fall into land use categories in *Table 10*. Land use subdivision was also recorded for the land use assigned to the plot.

Table 10. Land use categories in the survey.

Land use	**Land subdivision**
Forest	Moist highland
	Moist lowland
	Dry lowland
	Montane
	Coastal
	Mangroves
	Plantation
Cropland	Cropland*
Grassland**	Shrubs
	Other wooded land
	Grassland
Settlement	Settlement
	Infrastructure
	Mining
Wetland	Lakes, lagoons, reservoirs
	River
	Wetlands
Otherland	Rocks
	Sand
	Other bareland

*Agroforestry was specifically recorded.

** Grassland management (grazing/no grazing) when possible was identified.

- **Land use changes**
  Land use and land use subdivision changes were recorded since the year 2000 until the year 2022, with the initial land use and land use subdivision categories and the year of conversion. Up to two changes were recorded. Also, the confidence of the national technical personnel about the land use and land use change assigned to the plots was recorded.
- **Disturbances**
  In case of changes, disturbances were recorded from the primary up to a tertiary one from *Table 11*.

Table 11. Disturbance types in the survey.

Disturbances
Fire
Logging
Grazing
Permanent crops
Annual crops
Flooding
Paths
Settlement
Drought
Animal/Parasite/Invasion
Other

- **Map validation**
  The land cover map class of the central control point was recorded for potential validation of the Land cover of 2021. The suitability of the plot for validating the map is considered when at least the 8 control points surrounding the central point's fall on the same class.
- **Interpretation protocol**
  Apart from Google Earth Pro, several integrated services were connected to Collect Earth to offer different sources of information for the plot area. The national technical personnel were trained together in their use following the same protocol to fill out the survey.

Description of the interpretation tools:
Google Earth Pro

Check the historical images for reviewing:
1) Very high-resolution image closest to December 2021 for land cover and use classification and control point counting.
2) Historical images for land cover and use type assessment (seasonality) and land use change assessment.
In case the image closest to the end of the reference period does not have a good quality, a previous or later can be used for control point counting when there are no visible land cover/use changes.

Bing Maps

In case of absence of very high-resolution images in Google Earth for a plot, Bing Maps offer very high-resolution images. They do not have the exact date of acquisition but a range of several years, but they can help to interpret the type of land cover / use.

NICFI Planet base maps

Through the Norway's International Climate & Forests Initiative (NICFI), Planet's high-resolution bi-annual mosaic since December 2015 and monthly mosaics since September 2020 with a 3-5 m spatial resolution can be accessed in a double window. They can be used to check the seasonality of the plot by comparing mosaics of the wet and dry seasons, being April and October the months where vegetation appears 'greenest' and driest, respectively. Moreover, they can be used to identify the year of change when this is not possible to deduced from Google Earth Pro.

Google Earth Engine APP

Finally, a Google Earth Engine App was developed to show:
1) Annual Landsat 7-8 mosaics and Sentinel mosaics of the last 12 months, valid for checking the exact years of changes, especially if these occurred before 2016. The year of the mosaic that shows a different land cover/use is considered the year of change
2) Time series of the average NDVI vegetation index value of the pixels contained in a plot from Landsat (30m) since the year 2000 and from Sentinel (10m) since 2016. Singles dated images can be visualised. They show the historical vegetation tendency.
4) Time series of the Continues Change Detection and Classification (CCDC) algorithm applied to the NDFI vegetation index average value of the pixels contained in a plot based on Landsat 7 and 8 since the year 2000. This graphic is very useful to detect long-term vegetation trends, abrupt vegetation changes and identifying vegetation seasonality.
3) MODIS Burned Area Monthly Global product (500m) which detect possible fires in the plot since the year 2000.

Response design

Before and during the sampling collection, the national technical personnel agreed on a series of interpretation rules in order to obtain consistent results.

1. When estimating canopy cover in plots with changes between dry and wet season, control points are counted on the wet seasonal images. Dry seasonal images are useful to differentiate different cover types, for example between shrubs, grassland and/or bare soil.

2. Special emphasis was placed on the difference between land use and land cover.

3. When assessing land use change special attention has to be made to not confusing seasonal changes with land use changes.

4. When possible, the exact year of change should be identified with the very high-resolution images or the Landsat and Sentinel mosaics, in order to provide correct deforestation data per year. When changes are recognized only on Google Earth Pro images, for example, when changes occurs in small areas of the plots, and there are no images for consecutive years, the middle year between the image before the change and the image with the visible change should be considered to minimise errors (for example an image with forest in 2010 and the following images from 2016 has been deforested, 2013 was considered the year of change).

5. When there are doubts between forest and shrub classes, it may be useful to check the previous images, i.e., If, in the preceding years, the area was not a forest, it is highly likely that it has transitioned into a shrubland.

6. Unless there is evidence of grazing, 'no grazing' was selected by default.

7. For map validation only the classes of the map are taken into account, so for example, if the 8 control points fall on grassland and shrubs, the class will be considered grassland (as in the map they belong to the same class) and the point will be considered suitable for validation.

8. Decisions taken for the specific cases of trees inside and outside forest cover falling on different land uses are collected in Table 12. The national forest definition excludes those areas under agricultural use, however, in cases 6 and 7, trees that provide shadow for coffee plantations and trees that provide shadow for livestock, where the land are subject to two different uses, the country has decided to give priority to forest.

Table 12. Cases on trees outside and inside forest and decisions agreed on land cover and land use.

Control points on trees outside/inside forest	Land cover	Land use	Land use (subtype)
1. Trees in agriculture (not fruit trees or planted trees) *	Trees (in agriculture)	Cropland (even when >15%)	Cropland (annual or permanent)
2. Tree plantations	Trees (in forest)	Forest (when >15%)	Forest (plantation)
3. Tree plantations in agriculture	Trees (in agriculture)	Cropland (even when >15%)	Cropland (Agroforestry)

Control points on trees outside/inside forest	Land cover	Land use	Land use (subtype)
4. Fruit trees	Cropland	Cropland	Croplands (permanents)
5. Fruit trees in agriculture (e.g., horticulture)	Cropland	Cropland	Croplands (permanents)
6. Trees that provide shadow for coffee plantations**	Trees (in agriculture)	Forest (when >15%)	Forest
7. Trees that provide shadow for livestock (e.g., animal grazing)	Trees (in agriculture)	Forest (when >15%)	Forest
8. Trees in built-up areas	Trees (in settlement)	Settlement	Settlement

*Shifting cultivation may leave or produce natural forest (e.g., some areas after shifting cultivation might naturally grow trees).
** Difficult to see from the images.

The application of land use hierarchical rules

The sum of the control points in land cover must be at least of 45 to 49 (table 13). Equivalence of the number of control points categories and the plot coverage

Table 13. Number of control points in land cover and their respective coverage (%).

Number of control points	Coverage (%)
0	0
1	2
2	4
3	6
4	8
5-9	15
10-14	25
15-19	35
20-24	45
25-29	55
30-34	65
35-39	75
40-44	85
45-49	95

Plot description refers to 'coverage', and it helps to validate land use.

The LULUC class of the plot is taken from the majority class, but when canopy cover forest points are 5-9 or more on grassland/forest, then forest have priority and land use will be classified as forest, so to apply the national forest definition. 7 points equal to 15% of the plot area.

In land cover of 'trees in agriculture', at least one or more control points should be counted as crop (even if the trees cover all the cropland area), so the land use can be cropland with no error.

Quality Assurance and Quality Control

Interpretation accuracy

The subjective confidence of the experts about the land use and land use change assigned to the plots was very high: 3904 plots were recorded with (high) confidence and 307 with low/no confidence. This was based not only on the quality of the images, but also on the technical knowledge of the terrain.

Apart from this each interpreter was assigned with 53 plots from other of the 7 groups for cross-referencing. In total 425 plots, 10% of the total plots, were re-interpreted. The confusion matrix of the land uses changes between 2017 until 2021 is found in *Table 17* in the annexes, with the omission and commission errors for each class. An overall accuracy of almost 70% has been reached considering the six main IPCC land uses classes, which makes a total of 36 possible changes classes. This means that both interpreters assigned the same class change to 291 of the 425 plots.

The confusion matrix per the land uses changes had an overall accuracy of 73%, however the error in Afforestation and Deforestation were very high.

Table 14. Simplified confusion matrix of the land uses classes between 2017 and 2021.

	Afforestation	**Deforestation**	**Stable forest**	**Non-stable forest**	**Total**	**Commission**
Afforestation	4	1	17	5	27	0.85
Deforestation	1	0	0	1	2	1.00
Stable forest	16	0	249	22	287	0.13
Non-stable forest	5	1	44	59	109	0.46
Total	26	2	310	87	425	
Omission	0.85	1.00	0.20	0.32		

An additional activity data (AD) revision was implemented in June 2023, during that time 245 plots were revisited. Around half of these plots were already part of the validation subset, to check whether the validation was misleading, or the AD were incorrectly interpreted. The other half corresponded to samples that disagreed with global remote sensing products:

- Tree cover loss in GFC but stable land use in the AD samples,
- Deforestation in the AD samples but no tree cover loss in GFC,
- Afforestation in the AD samples but no gain in the ESRI land cover change.

These revised points, grouped with the initial validation exercise, resulted in 530 points measured more than once (table 15).

Table 15. Updated revised samples vs original interpretation of land use change.

Original \revised	AF	DF	StableF	StableNF	Total AD	Commission error
AF	8	0	16	10	34	76%
DF	0	2	6	18	26	92%
StableF	20	4	275	53	352	22%
StableNF	5	1	37	75	118	36%
total revised	33	7	334	156	530	
Omission error	76%	71%	18%	52%	94%	
Overall accuracy	68%					

Comparing the revised with original samples showed still very large omission and commission errors, especially for forest changes. Therefore, it was decided to replace the original AD samples that have been revised with the corrected version, noting that for future submission, the number of samples should be increased and the staff better trained. Timor-Leste lands are fragmented, and interpretation can be difficult.

6.4.5 Activity Data: Results

Since the Activity Data is sample based, the following matrices present the land use changes per year for the period 2017-2021 in sample count. In the FREL/FRL presentation, these values are converted to area using the DGGRID equal area resolution tier. DGGRID is a worldwide equal area set of nested hexagonal grid. For TL FREL/FRL, the resolution 15 was used, meaning all samples represent exactly 3.554735 sq. km or 355.4735 hectares.

In the following matrices, red colour cells represent Deforestation and green colour cells Afforestation. Grey cells represent non forest remaining non forest.

The land use codes are: FMH = Moist Highland Forest, FML = Moist Lowland Forest, FDL = Dry Lowland Forest, FM = Montane Forest, FC = Coastal Forest, MF = Mangrove Forest, FP = Forest Plantations, G = Grassland, Sh = Shrubland, OWL = Other Wooded Land, C = Cropland, Se = Settlements, W = Wetlands, O = Other land.

The values are areas in hectares and the matrices and step by step calculations are presented in the attached calculation spreadsheet.

LU class end of year (columns); LU class start of year (rows)

2017	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	240,300	0	0	0	0	0	0	0	0	0	0	0	0	0	240,300
FML	0	417,681	0	0	0	0	0	0	0	0	355	0	0	0	418,036
FDL	0	0	315,660	0	0	0	0	0	0	0	0	0	0	0	315,660
FM	0	0	0	18,485	0	0	0	0	0	0	0	0	0	0	18,485
FC	0	0	0	0	22,039	0	0	0	0	0	0	0	0	0	22,039
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	11,020	0	0	0	0	0	0	0	11,020
G	711	1,066	1,422	355	0	0	0	124,771	0	0	1,066	0	0	0	129,391
Sh	355	711	2,133	0	0	0	0	0	114,818	0	355	0	0	0	118,372
OWL	0	355	0	0	0	0	0	0	0	5,688	0	0	0	0	6,043
C	0	355	355	0	0	0	0	0	355	0	110,197	0	0	0	111,262
Se	0	0	355	0	0	0	0	0	0	0	0	49,055	0	0	49,410
W	0	0	0	0	0	0	0	355	0	0	0	0	32,348	0	32,703
O	0	0	0	0	0	0	0	0	0	0	355	0	0	23,106	23,461
Sum	241,366	420,168	319,925	18,840	22,039	2,133	11,020	125,126	115,173	5,688	112,328	49,055	32,348	23,106	1,498,315

LU class end of year (columns); LU class start of year (rows)

2018	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	241,367	0	0	0	0	0	0	0	0	0	0	0	0	0	241,367
FML	0	419,814	0	0	0	0	0	0	0	0	0	355	0	0	420,169
FDL	0	0	319,926	0	0	0	0	0	0	0	0	0	0	0	319,926
FM	0	0	0	18,840	0	0	0	0	0	0	0	0	0	0	18,840
FC	0	0	0	0	22,039	0	0	0	0	0	0	0	0	0	22,039
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	11,020	0	0	0	0	0	0	0	11,020
G	2,844	711	3,199	0	0	0	0	116,595	0	0	1,422	0	0	355	125,126
Sh	711	711	3,199	0	0	0	0	0	110,197	0	355	0	0	0	115,173
OWL	711	0	0	0	0	0	0	0	0	4,977	0	0	0	0	5,688
C	711	355	1,422	0	0	0	355	355	0	0	108,775	355	0	0	112,328
Se	0	355	0	0	0	0	0	0	0	0	0	48,700	0	0	49,055
W	0	0	0	0	0	0	0	355	0	0	355	0	31,637	0	32,347
O	0	0	0	0	0	0	0	0	0	0	0	0	0	23,106	23,106
Sum	246,344	421,946	327,746	18,840	22,039	2,133	11,375	117,305	110,197	4,977	110,907	49,410	31,637	23,461	1,498,317

LU class end of year (columns); LU class start of year (rows)

2019	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	246,343	0	0	0	0	0	0	0	0	0	0	0	0	0	246,343
FML	0	421,947	0	0	0	0	0	0	0	0	0	0	0	0	421,947
FDL	0	0	326,680	0	0	0	0	0	0	0	1,066	0	0	0	327,746
FM	0	0	0	18,840	0	0	0	0	0	0	0	0	0	0	18,840
FC	0	0	0	0	22,039	0	0	0	0	0	0	0	0	0	22,039
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	11,375	0	0	0	0	0	0	0	11,375
G	0	2,133	3,555	0	355	0	0	109,486	0	0	1,422	355	0	0	117,306
Sh	0	355	1,777	0	0	0	0	0	108,064	0	0	0	0	0	110,196
OWL	0	0	0	0	0	0	0	0	0	4,621	0	0	0	355	4,976
C	0	1,422	1,066	355	0	0	355	711	0	0	106,998	0	0	0	110,907
Se	0	0	0	0	0	0	0	0	355	0	355	48,700	0	0	49,410
W	0	355	355	0	0	0	0	0	0	0	355	0	30,571	0	31,636
O	0	355	0	0	0	0	0	355	0	0	0	0	0	22,750	23,460
Sum	246,343	426,567	333,433	19,195	22,394	2,133	11,730	110,552	108,419	4,621	110,196	49,055	30,571	23,105	1,498,314

LU class end of year (rows: LU class start of year)

2020	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	246,343	0	0	0	0	0	0	0	0	0	0	0	0	0	246,343
FML	0	425,502	0	0	0	0	0	0	0	0	1,066	0	0	0	426,568
FDL	0	0	332,723	0	0	0	0	0	0	0	711	0	0	0	333,434
FM	0	0	0	19,196	0	0	0	0	0	0	0	0	0	0	19,196
FC	0	0	0	0	22,395	0	0	0	0	0	0	0	0	0	22,395
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	11,731	0	0	0	0	0	0	0	11,731
G	0	1,066	1,777	0	0	0	0	106,642	0	0	711	355	0	0	110,551
Sh	355	711	1,777	0	0	0	0	0	105,220	0	0	0	0	355	108,418
OWL	0	0	0	0	0	0	0	0	0	4,621	0	0	0	0	4,621
C	0	711	355	0	0	0	355	0	0	0	108,775	0	0	0	110,196
Se	0	0	0	0	0	0	0	0	355	0	0	48,700	0	0	49,055
W	0	0	0	0	0	0	0	0	0	0	0	0	30,571	0	30,571
O	0	0	355	0	0	0	0	0	0	0	355	0	0	22,395	23,105
Sum	246,698	427,990	336,987	19,196	22,395	2,133	12,086	106,642	105,575	4,621	111,618	49,055	30,571	22,750	1,498,317

LU class end of year (rows: LU class start of year)

2021	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	246,699	0	0	0	0	0	0	0	0	0	0	0	0	0	246,699
FML	0	427,990	0	0	0	0	0	0	0	0	0	0	0	0	427,990
FDL	0	0	336,989	0	0	0	0	0	0	0	0	0	0	0	336,989
FM	0	0	0	19,196	0	0	0	0	0	0	0	0	0	0	19,196
FC	0	0	0	0	22,395	0	0	0	0	0	0	0	0	0	22,395
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	12,086	0	0	0	0	0	0	0	12,086
G	355	355	1,422	0	0	0	0	104,154	0	0	0	0	0	355	106,641
Sh	0	711	0	0	0	0	0	0	104,154	0	355	0	0	355	105,575
OWL	0	0	0	0	0	0	0	0	0	4,621	0	0	0	0	4,621
C	0	0	0	0	0	0	355	0	0	0	111,263	0	0	0	111,618
Se	0	0	0	0	0	0	0	0	0	0	0	49,055	0	0	49,055
W	0	0	0	0	0	0	0	0	0	0	0	0	30,571	0	30,571
O	0	0	0	0	0	0	0	0	0	0	0	0	0	22,750	22,750
Sum	247,054	429,056	338,411	19,196	22,395	2,133	12,441	104,154	104,154	4,621	111,618	49,055	30,571	23,460	1,498,319

In a summary the Land use change sample count and areas per REDD+ activity is presented in Table 16.

Table 16. Summary of REDD+ activities areas.

	2017	2018	2019	2020	2021
Deforestation					
- Sample count	1	1	3	5	0
- Area (ha)	355	355	1,066	1,777	0
- % of country area	0.02	0.02	0.07	0.12	0.00
Afforestation					
- Sample count	23	43	35	21	9
- Area (ha)	8,173	15,284	12,438	7,462	3,198
- % of country area	0.55	1.02	0.83	0.5	0.21

6.4.1 Activity Data: Uncertainty

Uncertainty of the activity data was based on the sampling design used to measure the land use and land use change. It was applied to each category of land use change with the cochran 1977 formula for proportions:

$$U_{AD}\,(\%) = z \times \sqrt{\frac{p \times (1-p)}{n}}$$

With z = 1.96, p the proportion of the area (i.e., the number of samples in each land use change class divided by the total number of samples) and n the total number of samples.

7. Adjustment

No adjustments are proposed for Timor-Leste FREL/FRL.

8. The Forest Reference Level

The FREL/FRL is calculated as the average emission and net average emission and removals for the period 2017-2021. Emissions and Removals are calculated as the product of the activity data and emission factors.

8.1 Emission and removal matrices

For each year, the activity data land use change matrices are converted from sample count to hectares and multiplied by the emission or removal factors associated to the changes.

2017 land use change and ERs matrices

AD - Area (ha)															
	LU class end of year														
LU class start of year	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	240,300	0	0	0	0	0	0	0	0	0	0	0	0	0	240,300
FML	0	417,681	0	0	0	0	0	0	0	0	355	0	0	0	418,036
FDL	0	0	315,660	0	0	0	0	0	0	0	0	0	0	0	315,660
FM	0	0	0	18,485	0	0	0	0	0	0	0	0	0	0	18,485
FC	0	0	0	0	22,039	0	0	0	0	0	0	0	0	0	22,039
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	11,020	0	0	0	0	0	0	0	11,020
G	711	1,066	1,422	355	0	0	0	124,771	0	0	1,066	0	0	0	129,391
Sh	355	711	2,133	0	0	0	0	0	114,818	0	355	0	0	0	118,372
OWL	0	355	0	0	0	0	0	0	0	5,688	0	0	0	0	6,043
C	0	355	355	0	0	0	0	0	355	0	110,197	0	0	0	111,262
Se	0	0	355	0	0	0	0	0	0	0	0	49,055	0	0	49,410
W	0	0	0	0	0	0	0	355	0	0	0	0	32,348	0	32,703
O	0	0	0	0	0	0	0	0	0	0	355	0	0	23,106	23,461
Sum	241,366	420,168	319,925	18,840	22,039	2,133	11,020	125,126	115,173	5,688	112,328	49,055	32,348	23,106	1,498,315

2018 land use change and ERs matrices

AD - Area (ha)

LU class start of year \ LU class end of year	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	241,367	0	0	0	0	0	0	0	0	0	0	0	0	0	241,367
FML	0	419,814	0	0	0	0	0	0	0	0	0	355	0	0	420,169
FDL	0	0	319,926	0	0	0	0	0	0	0	0	0	0	0	319,926
FM	0	0	0	18,840	0	0	0	0	0	0	0	0	0	0	18,840
FC	0	0	0	0	22,039	0	0	0	0	0	0	0	0	0	22,039
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	11,020	0	0	0	0	0	0	0	11,020
G	2,844	711	3,199	0	0	0	0	116,595	0	0	1,422	0	0	355	125,126
Sh	711	711	3,199	0	0	0	0	0	110,197	0	355	0	0	0	115,173
OWL	711	0	0	0	0	0	0	0	0	4,977	0	0	0	0	5,688
C	711	355	1,422	0	0	0	355	355	0	0	108,775	355	0	0	112,328
Se	0	355	0	0	0	0	0	0	0	0	0	48,700	0	0	49,055
W	0	0	0	0	0	0	0	355	0	0	355	0	31,637	0	32,347
O	0	0	0	0	0	0	0	0	0	0	0	0	0	23,106	23,106
Sum	246,344	421,946	327,746	18,840	22,039	2,133	11,375	117,305	110,197	4,977	110,907	49,410	31,637	23,461	1,498,317

2019 land use change and ERs matrices

AD - Area (ha)																
		LU class end of year														
		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class start of year	FMH	246,343	0	0	0	0	0	0	0	0	0	0	0	0	0	246,343
	FML	0	421,947	0	0	0	0	0	0	0	0	0	0	0	0	421,947
	FDL	0	0	326,680	0	0	0	0	0	0	0	1,066	0	0	0	327,746
	FM	0	0	0	18,840	0	0	0	0	0	0	0	0	0	0	18,840
	FC	0	0	0	0	22,039	0	0	0	0	0	0	0	0	0	22,039
	MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
	FP	0	0	0	0	0	0	11,375	0	0	0	0	0	0	0	11,375
	G	0	2,133	3,555	0	355	0	0	109,486	0	0	1,422	355	0	0	117,306
	Sh	0	355	1,777	0	0	0	0	0	108,064	0	0	0	0	0	110,196
	OWL	0	0	0	0	0	0	0	0	0	4,621	0	0	0	355	4,976
	C	0	1,422	1,066	355	0	0	355	711	0	0	106,998	0	0	0	110,907
	Se	0	0	0	0	0	0	0	0	355	0	355	48,700	0	0	49,410
	W	0	355	355	0	0	0	0	0	0	0	355	0	30,571	0	31,636
	O	0	355	0	0	0	0	0	355	0	0	0	0	0	22,750	23,460
	Sum	246,343	426,567	333,433	19,195	22,394	2,133	11,730	110,552	108,419	4,621	110,196	49,055	30,571	23,105	1,498,314

2020 land use change and ERs matrices

AD - Area (ha)

LU class start of year		LU class end of year														
	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	246,343	0	0	0	0	0	0	0	0	0	0	0	0	0	246,343
FML	0	425,502	0	0	0	0	0	0	0	0	1,066	0	0	0	426,568
FDL	0	0	332,723	0	0	0	0	0	0	0	711	0	0	0	333,434
FM	0	0	0	19,196	0	0	0	0	0	0	0	0	0	0	19,196
FC	0	0	0	0	22,395	0	0	0	0	0	0	0	0	0	22,395
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	11,731	0	0	0	0	0	0	0	11,731
G	0	1,066	1,777	0	0	0	0	106,642	0	0	711	355	0	0	110,551
Sh	355	711	1,777	0	0	0	0	0	105,220	0	0	0	0	355	108,418
OWL	0	0	0	0	0	0	0	0	0	4,621	0	0	0	0	4,621
C	0	711	355	0	0	0	355	0	0	0	108,775	0	0	0	110,196
Se	0	0	0	0	0	0	0	0	355	0	0	48,700	0	0	49,055
W	0	0	0	0	0	0	0	0	0	0	0	0	30,571	0	30,571
O	0	0	355	0	0	0	0	0	0	0	355	0	0	22,395	23,105
Sum	246,698	427,990	336,987	19,196	22,395	2,133	12,086	106,642	105,575	4,621	111,618	49,055	30,571	22,750	1,498,317

2021 land use change and ERs matrices

AD - Area (ha)															
	LU class end of year														
LU class start of year	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH	246,699	0	0	0	0	0	0	0	0	0	0	0	0	0	246,699
FML	0	427,990	0	0	0	0	0	0	0	0	0	0	0	0	427,990
FDL	0	0	336,989	0	0	0	0	0	0	0	0	0	0	0	336,989
FM	0	0	0	19,196	0	0	0	0	0	0	0	0	0	0	19,196
FC	0	0	0	0	22,395	0	0	0	0	0	0	0	0	0	22,395
MF	0	0	0	0	0	2,133	0	0	0	0	0	0	0	0	2,133
FP	0	0	0	0	0	0	12,086	0	0	0	0	0	0	0	12,086
G	355	355	1,422	0	0	0	0	104,154	0	0	0	0	0	355	106,641
Sh	0	711	0	0	0	0	0	0	104,154	0	355	0	0	355	105,575
OWL	0	0	0	0	0	0	0	0	0	4,621	0	0	0	0	4,621
C	0	0	0	0	0	0	355	0	0	0	111,263	0	0	0	111,618
Se	0	0	0	0	0	0	0	0	0	0	0	49,055	0	0	49,055
W	0	0	0	0	0	0	0	0	0	0	0	0	30,571	0	30,571
O	0	0	0	0	0	0	0	0	0	0	0	0	0	22,750	22,750
Sum	247,054	429,056	338,411	19,196	22,395	2,133	12,441	104,154	104,154	4,621	111,618	49,055	30,571	23,460	1,498,319

8.2 Afforestation registry

For each afforestation sample, only 1/20th of the full land use class carbon stock is attributed initially then this sample is added to a registry and each subsequent year and additional 1/20th carbon stock is added unless the land use is converted again or reaches maturity.

During the reference period no sample was converted back to non-forest, so the registry is a cumulative sum of carbon updated annually:

Table 17. Cumulative sample count of carbon within reference period.

Afforestation sample count							
Land use	**Carbon total (tCO2/ha)**	**Annual gain (tCO2e/ha/year)**	2017	2018	2019	2020	2021
FMH	88.8	16	3	14	0	1	1
FML	88.8	16	7	6	13	7	3
FDL	45.2	8	12	22	19	12	4
FM	68.6	13	1	0	1	0	0
FC	94.8	17	0	0	1	0	0
MF	96.6	18	0	0	0	0	0
FP	59.6	11	0	1	1	1	1
		TOTAL	23	43	35	21	9

Table 18. Cumulative afforestation gain sample count.

Land use	**2017**	**2018**	**2019**	**2020**	**2021**
FMH	3	17	17	18	19
FML	7	13	26	33	36
FDL	12	34	53	65	69
FM	1	1	2	2	2
FC	0	0	1	1	1
MF	0	0	0	0	0
FP	0	1	2	3	4
Total	**23**	**66**	**101**	**122**	**131**

8.3 Annual GHG emissions and removals

From the emissions and removals matrices and the afforestation registry, the annual emissions and removal per REDD+ activity are as follow:

Table 19. Emissions and removals (tCO2e/year from 2017-2021.

	Emissions and Removals (tCO2e/year)				
	2017	**2018**	**2019**	**2020**	**2021**
Area-Deforestation (ha)	355	355	1,066	1,777	0
Area-Afforestation (ha)	8,173	15,284	12,438	7,462	3,198
E-Deforestation (tCO2e)	109,340	115,730	158,834	434,267	0
E-Deforestation U (%)	199	199	123	96	-
R-Enhancements NF-F (year 1)	-94,518	-177,366	-139,301	-82,084	-37,662
R-Enhancements NF-F (year 1) U (%)	46	35	39	48	72
Cum. Sum enhancements	0	-94,518	-271,884	-411,185	-493,269
Cum. Sum enhancements U (%)	0	46	28	23	21
R-Enhancements total	-94,518	-271,884	-411,185	-493,269	-530,931
R-Enhancements total U (%)	46	28	23	21	20

Figure 10. Annual emissions and removals and their averages over the reference period.

No clear trend can be observed in the emissions and removals between the different years and the FREL and FRL are calculated as the average annual emissions and removals over the reference period:

Table 20. Annual emissions and removals and their averages over 5-year reference period 2017-2021.

	tCO2e/year	Uncertainty (%)
Forest Reference Emissions Level (tCO2e/year)	**163,634**	**68**
Average Annual Removals (tCO2e/year)	**-360,357**	**11**
Forest Reference level (net, tCO2e/year)	**-196,723**	**60**

9. Uncertainty analysis

The proposed FRE/FRL comes from a combination of recently introduced methods and tools to the country and the uncertainty analysis was not estimated in first draft of FREL/FRL submitted for UNFCCC technical assessment in January 2023, and it is now included in the modified submission. The emissions and removal factors uncertainty are mentioned in the Table 6. Once the AD uncertainty is estimated the overall FREL/FRL uncertainty could be calculated with the propagation formula from IPCC 2019 guidelines (equation 3.2A, Volume 2):

Figure 11. Equation used for calculating uncertainty analysis.

EQUATION 3.1 (UPDATED)
COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

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

Where:

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

U_i = the percentage uncertainties associated with each of the quantities

EQUATION 3.2 (UPDATED)
COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

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

Where:

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

x_i = quantities to be combined; x_i may be a positive or a negative number

U_i = the percentage uncertainties associated with each of the quantities

10. Proposed improvements

On Land use stratification, Land Cover Classification System has been introduced in Timor-Leste, but more practice and field data collection are required to better describe land uses with an object-based system. Without a dedicated object-based land cover description system, the current classes come from experts' discussions and in-country knowledge. Additional field data would be crucial to further comprehend to which point the existing classification could be changed to better reflect altitude, soil etc. For example, Highland, Lowland, and coastal class might not need to be separated if further field studies and a full scale NFI would show that carbon stock differences are not very high.

On the activity data side, a grid intensification to 1 km or lower could allow to better track forest changes and ensure that the sample-based approach is not missing large areas of REDD+ activities. With further capacity building and practice, algorithms could help "visualize" more points without too much constraint on Timor-Leste Government human resources. Additional training will also be needed for the interpreters as the landscapes in Timor-Leste are quite fragmented and can be difficult to properly analyse.

On Emission factors for modified submission derived from a total of 40 plots of NFI data collection from November 2022 to May 2023, covering 10 different forest conditions across the whole country, but a full-scale multi-purpose national forest inventory would be key to better understand forest composition and the impact of various ecological and climatic constraints of species and biomass distribution. It would also come with additional QA/QC procedures to ensure the quality of the data collection.

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Annexes

Annex 1. List of participants in the activity data sampling interpretation

Name	Institution	Position
Albino da Silva Barbosa	General Directorate of Forestry, Coffee and Industrial Plants, Ministry of Agriculture and Fisheries	Technical staff in GIS and Mapping Unit.
Virgilio Maria de Carvalho	National Designated Authority (NDA), Secretary of Environment	Technical staff under the directorate Clean Development Mechanism (CDM) connected to the carbon farming in Timor-Leste
Calisto Afoan	Diresaun Nacional Gestaun das Floresta Bacias Hidrograficas e Areas Mangais (DGCFIP), Ministry of Agriculture	Staff supporting reforestation activities
Jose Ronaldo Oqui Fernandes	General Directorate of Forestry, Coffe and Industrial Plants, Ministry of Agriculture and Fisheries	Technical staff of GIS and Mapping
Adina Alves	Agriculture Land Use and Geographic Information System (ALGIS)	Technical staff of GIS and Mapping
Celeste Francisca Pinto	FAO-TL	National GIS expert
Elvino Aparicio de Oliveira	FAO-TL	National Forest Inventory Expert
Marcia e Silva	FAO-TL	National REDD+ project coordinator and forestry specialist