Timor-Leste's National REDD+ Forest Reference Level

Submission for UNFCCC Technical Assessment in 2023

Contents

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 since 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 North West of Australia at a distance of about 500 km. The total area of TL is approximately of 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 of 140 km2 and Jaco Island of 8 km2.

Originally, the natural vegetation that are 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 statistic 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 concluding 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 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 of 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 internalizing 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 response to climate change. As a result, the Secretary of State for the Environment and Directorate General for Forestry, Coffee and Industrial Plants had placed much efforts into country's REDD+ readiness project, with support from the FAO.

1.2 Background on the MRV for REDD+ under the UNFCCC

When taking part of the UNFCCC, the developing countries is called to 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 sectoral Working Group and worked mostly on development of Greenhouse Gases (GHG) Inventory and mitigation scenario.

Timor-Leste had also submitted its Intended National Contribution (INDC) in 2016. The NDC also indicates several options for climate change mitigation and adaptation in the LUCF sector that have guided the development of TL FRL, among them exploring opportunities to assess the potential for climate change mitigation through REDD+ activities that should be led by domestic laws and regulations and based on the national priorities. The NDC indicates forestry mitigation options and several options for climate change adaptation in the LUCF. Furthermore, NDC identifies capacity building activities as one of the priorities. 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+. As a result, a project proposal was formulated and submitted and were 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 facilate 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.

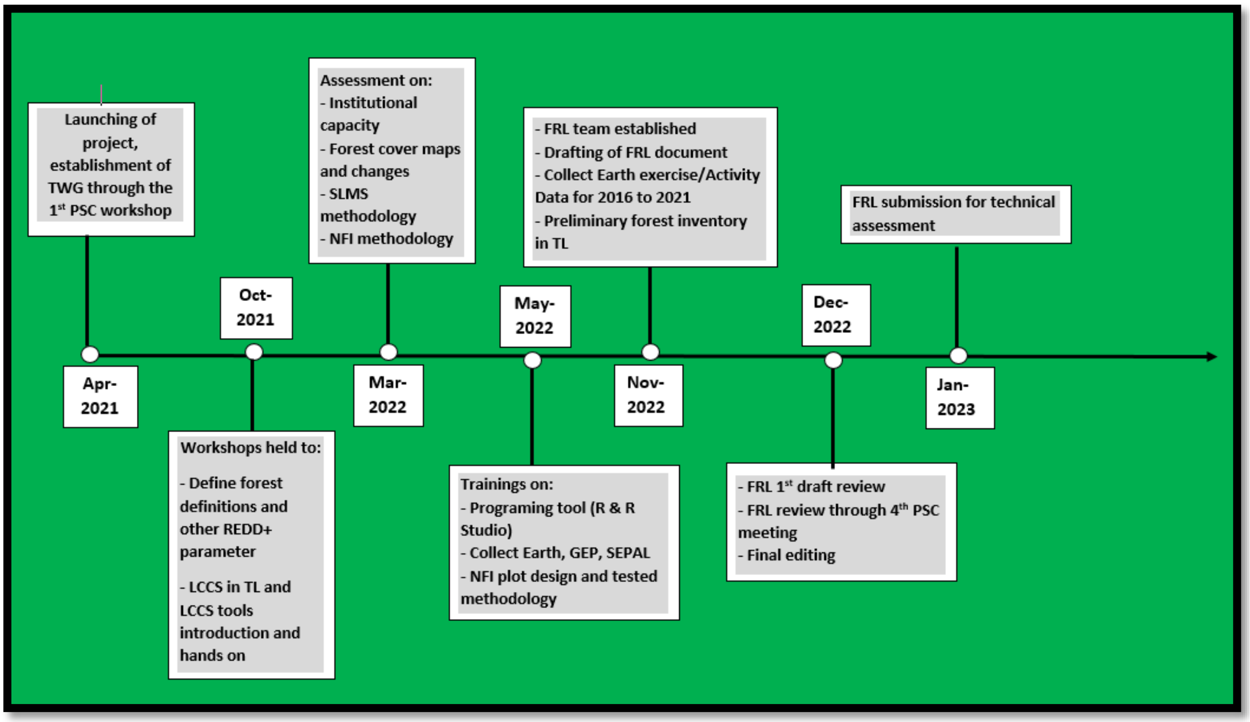

Figure 1.1: Milestone of the Development of TL's FRL

1.4.1 The National Forest Inventory

The capacity on forest monitoring of TL is still premature. A large information gap still 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 when funding 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. A number of 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 expected end in early 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 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 TL's Intended Nationally Determined Contribution (INDC). The intended Nationally Determined Contribution (INDC) was previously submitted to the UNFCCC on November 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. Some of which includes: 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 and drafting of Climate Change Policy (2016).

In 2012, the GoTL through 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 created 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 forest reference levels, 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 also 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 meters, 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-agricultural 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.

This definition is worded slightly differently from the definition which was reported to FAO's FRA 2015, which defined forests as "*Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use*".

Forestland in TL is classified into Natural and Plantation forest and subdivided based on the vegetation and plantations types. Vegetation type is classified based on the structural formation and described in TL Resource 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 re-arranged based on data available and the limitations of visual interpretation of remotre 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		herbland, 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
- Forest degradation
- Carbon stock enhancement

The REDD+ activities not currently covered are:

- Sustainable management of forest
- Conservation of carbon stocks

The three activities above is 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. There is no data currently available that would allow for including 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

The IPCC 2006 Guidelines stated that litter is treated identical as dead wood. However IPCC 2006 Guidelines provides default values of carbon stock in Litter only for broadleaf deciduous and needleleaf evergreen forest for tropical region. 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 and litter is insignificant carbon pool, it is not covered in the FRL. Country specific data will be available when the full implementation of Forest Inventory taken 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

Dead wood should be estimated at a tier 1 level for deforestation and carbon stock enhancement (land that is converted from forest land to any other land use and vice versa) according to the 2006 IPCC Guidelines. For forest degradation (forestland remaining forestland), deadwood carbon stocks are assumed to be in equilibrium under tier 1 subsequently emissions are zero. However 2006 IPCC Guidelines do not provide default values of deadwood carbon stock in forest because of the paucity of published data. TL has no country specific carbon stock value for dead wood to allow for reliable estimation. Since no reasonably reliable data is available to use in TL, carbon pools in Deadwood is not covered in the FRL. Dead wood is potentially a large carbon pool, particularly in disturbed forest, and may constitute 10-40% of aboveground biomass (Uhl & Kauffman 1990).

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 2006 IPCC guidelines soil organic carbon should be estimated at a tier 1 level for all considered REDD+ activities. However TL forest soil have not been classified into the soil types provide in 2006 IPCC Guidelines for their default values. It is currently not possible to estimate the emissions from soil organic carbon pool. On the other hand, it is possible to identify the soil type and climate of all the point where forest conversion occurred using Collect Earth tool. However, TL does not have capacity 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 and also they are likely insignificant. In principle, these would occur due to burning during the forest degradation, drainage of organic soils upon deforestation and mineralization of carbon after deforestation. Forest in TL is affected by fire mostly but year of fire occurrance 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 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 reflets 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, a part from Landsat 7 and 8 (30m) since 2000 and 2013 respectively.

5. Scale

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, most notably; 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 forest reference levels 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 recmoval factors are based on stock difference between the old and new land use types in tCO2e/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 plantations types. Vegetation type is classified based on the structural formation and described in TL Resource 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 abioatic categories have been grouped (carbon stock assumed to be 0), leading to 7 forest types, 4 other vegetated categories and 3 abiotic categories (Table 1).

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 meters from the coast line, 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	S	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 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 thes 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 to record more trees, following a nested subplot approach (Figure 1).

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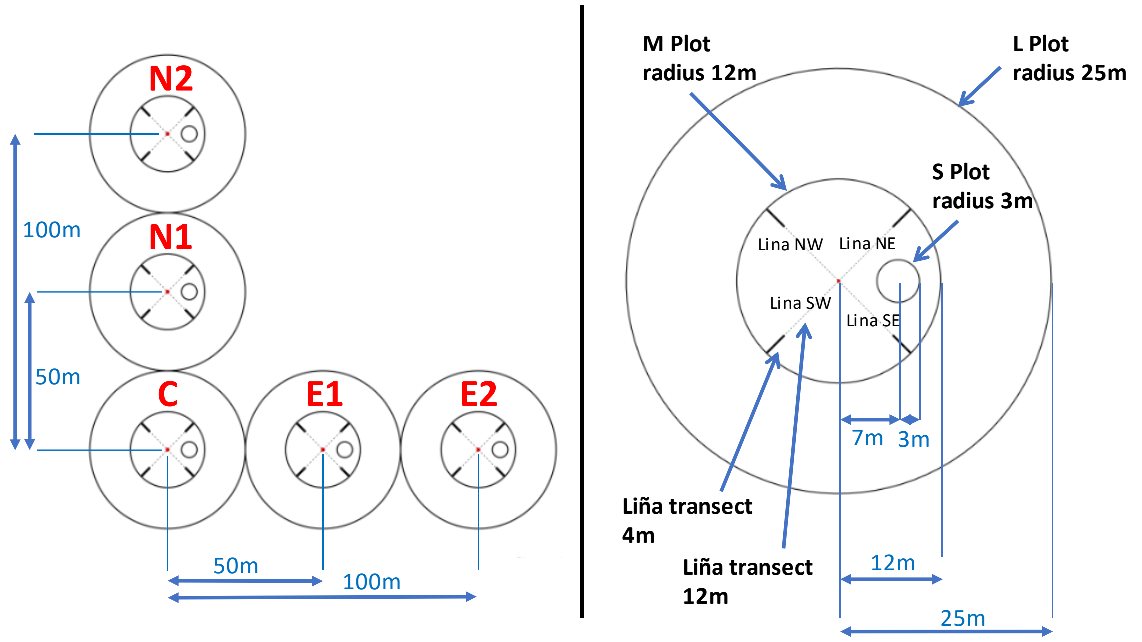
[1] First forest inventory of Timor-Leste: districts of Bobonaro and Covalima: 2008-2009, UTAD 2010, ISBN 978-972-669-998-9.



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 1: National Foret Inventory plot design for the testing phase.

At the time of FREL/FRL reporting the first 6 plots were measured (4 plots in Suai, moist lowland forest conditions and 2 plots in Dili area, dry lowland forest conditions), and while not being fully representative of the whole country, these are the only plots usable for deriving forest carbon stock and therefore they were used to estimate the carbon stock of Moist an Dry lowland forests.

For the other 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 didn’t 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
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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 ().

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[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

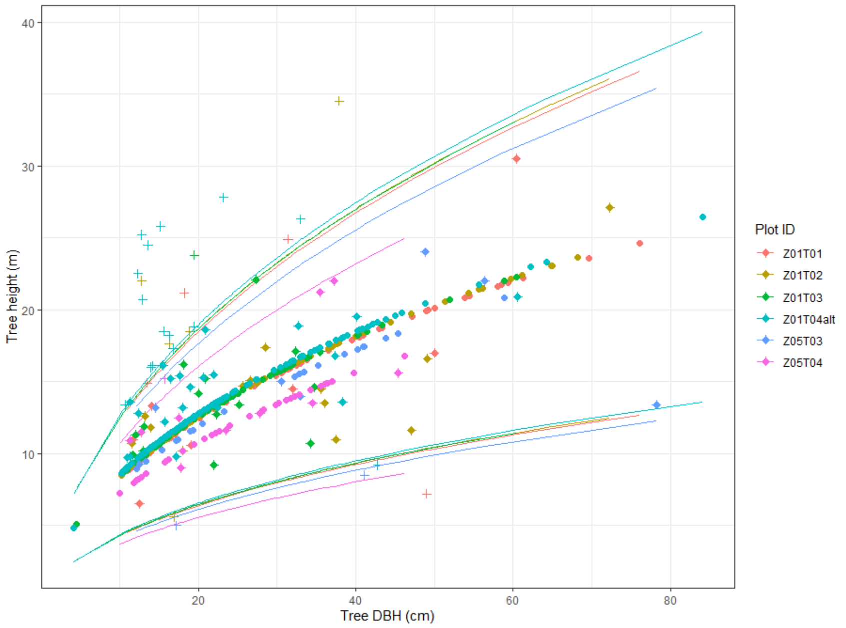

Figure 2: Tree height correction based on Chave et al. 2014 model. Cross represent measurements, dots the estimated heights and the line represent the upper and lower limit of the confidence interval of the model.

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 onn 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

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

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

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[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.

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

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

Table 3: Root-to-Shoot ratios applied to TL aboveground biomass esitmates

Land use category	Root-to-shoot ratio	Source
Moist Highland Forest	0.323 (AGB ≥ 125 t/ha) 0.246 (AGB < 125 t/ha)	IPCC 2019 refinement, V4 Ch4 table 4.4
Moist Lowland Forest	0.323 (AGB ≥ 125 t/ha) 0.246 (AGB < 125 t/ha)	IPCC 2019 refinement, V4 Ch4 table 4.4
Dry Lowland Forest	0.440 (AGB ≥ 125 t/ha) 0.379 (AGB < 125 t/ha)	IPCC 2019 refinement, V4 Ch4 table 4.4
Montane Forest	0.345	IPCC 2019 refinement, V4 Ch4 table 4.4
Coastal Forest	0.323 (AGB ≥ 125 t/ha) 0.246 (AGB < 125 t/ha)	IPCC 2019 refinement, V4 Ch4 table 4.4
Mangrove Forest	0.29	IPCC 2013 Wetlands supplement
Forest Plantations	0.379	IPCC 2019 refinement, V4 Ch4 table 4.4

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 initial NFI testing data (6 plots)

Plot ID	Density (#/ha)	AGB (t/ha)	Land use	Climate	BGB (t/ha)	Total Carbon (tC/ha)
Z01T01	177.5	72.0	Moist Lowland Forest	Moist	17.7	42.2
Z01T02	342.4	106.4	Moist Lowland Forest	Moist	26.2	62.3
Z01T03	330.9	59.5	Forest plantation	Moist	14.6	34.8
Z01T04alt	717.2	126.1	Forest plantation	Moist	40.7	78.4
Z05T03	64.9	23.5	Forest plantation	Dry	8.9	15.2
Z05T04	162.3	48.1	Dry Lowland Forest	Dry	18.2	31.2

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

Due to the lack of data at this very first stage of NFI development and implementation, and the similarities between carbon stock in planted vs natural forest, plot level estimates were combined by climatic zones rather than land use (

Table 5). The results are slightly lower than using BCEF with an average volume but come with confidence interval. Unfortunately, the confidence interval for dry condition is very high as only two plots were measured at the time of submission.

Table 5: Carbon stocks in dry and moist climatic conditions.

Climate	Plot count	AGB (t/ha)	Total carbon (tC/ha)	Confidence interval (%)
Dry	2	35.8	23.2	436
Moist	4	91.0	54.4	58

These estimated carbon stocks were applied to several of the reported land uses and for other default factors were used (Table 6).

Table 6: Carbon stock used in the FREL/FRL and their source.

IPCC	FRL classes	Carbon total (tC/ha)	CI (%)	Carbon stock source
Forest Land	Moist Highland Forest	54.4	58	NFI test 2022 (moist)
	Moist Lowland Forest	54.4	58	NFI test 2022 (moist)
	Dry Lowland Forest	23.2	436	NFI test 2022 (dry)
	Montane Forest	42	-	IPCC 2019
	Coastal Forest	54.4	58	NFI test 2022 (moist)
	Mangrove Forest	71.6	-	Indonesia FREL/FRL[5] + IPCC 2013 Wetlands
	Forest Plantations	58.3	-	IPCC 2019
Grassland	Grassland	1.1	75	IPCC 2006 (v4 ch6 table 6.4)
	Shrubland	2.9	75	IPCC 2006 (v4 ch6 table 6.4)
	Other Wooded Land	2.9	75	IPCC 2006 (v4 ch6 table 6.4)
Cropland	Cropland	4.7	75	IPCC 2019 (V4 ch5 table 5.9)
Settlements	Settlements	0		
Wetland	Wetlands	0		
Other land	Other land	0		

Step 7: Emission and removal factors (EFRF)

Emissions and removal factors were calculated for each categories 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 1/20th of their value is applied every year to afforestation lands to take into account that afforested land reach maturity in around 20 years.

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[5] Table annex 4.2 in: https://redd.unfccc.int/files/2nd_frl_indonesia_final_submit.pdf
Since the IPCC 2013 Wetlands supplement differentiate between dry and moist climate but TL activity data doesn't, an average abovreground biomass value from a neighbouring country was preferred.

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 results

With the approach described above the following emission and removal factor matrice is applied in this FREL/FRL (Table 7).

Table 7: Emission and removal factors for Timor-Leste FREL/FRL (tCO_2e/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	114	45	0	-63	-14	195	189	189	182	199	199	199
	FML	0	0	114	45	0	-63	-14	195	189	189	182	199	199	199
	FDL	-114	-114	0	-69	-114	-177	-129	81	74	74	68	85	85	85
	FM	-45	-45	69	0	-45	-109	-60	150	143	143	137	154	154	154
	FC	0	0	114	45	0	-63	-14	195	189	189	182	199	199	199
	MF	63	63	177	109	63	0	49	259	252	252	245	263	263	263
	FP	14	14	129	60	14	-49	0	210	203	203	197	214	214	214
	G	-10	-10	-4	-7	-10	-13	-10	0	-7	-7	-13	4	4	4
	Sh	-9	-9	-4	-7	-9	-13	-10	7	0	0	-7	11	11	11
	OWL	-9	-9	-4	-7	-9	-13	-10	7	0	0	-7	11	11	11
	C	-9	-9	-3	-7	-9	-12	-10	13	7	7	0	17	17	17
	Se	-10	-10	-4	-8	-10	-13	-11	-4	-11	-11	-17	0	0	0
	W	-10	-10	-4	-8	-10	-13	-11	-4	-11	-11	-17	0	0	0
	O	-10	-10	-4	-8	-10	-13	-11	-4	-11	-11	-17	0	0	0

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

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 (JICS) (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 3). 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

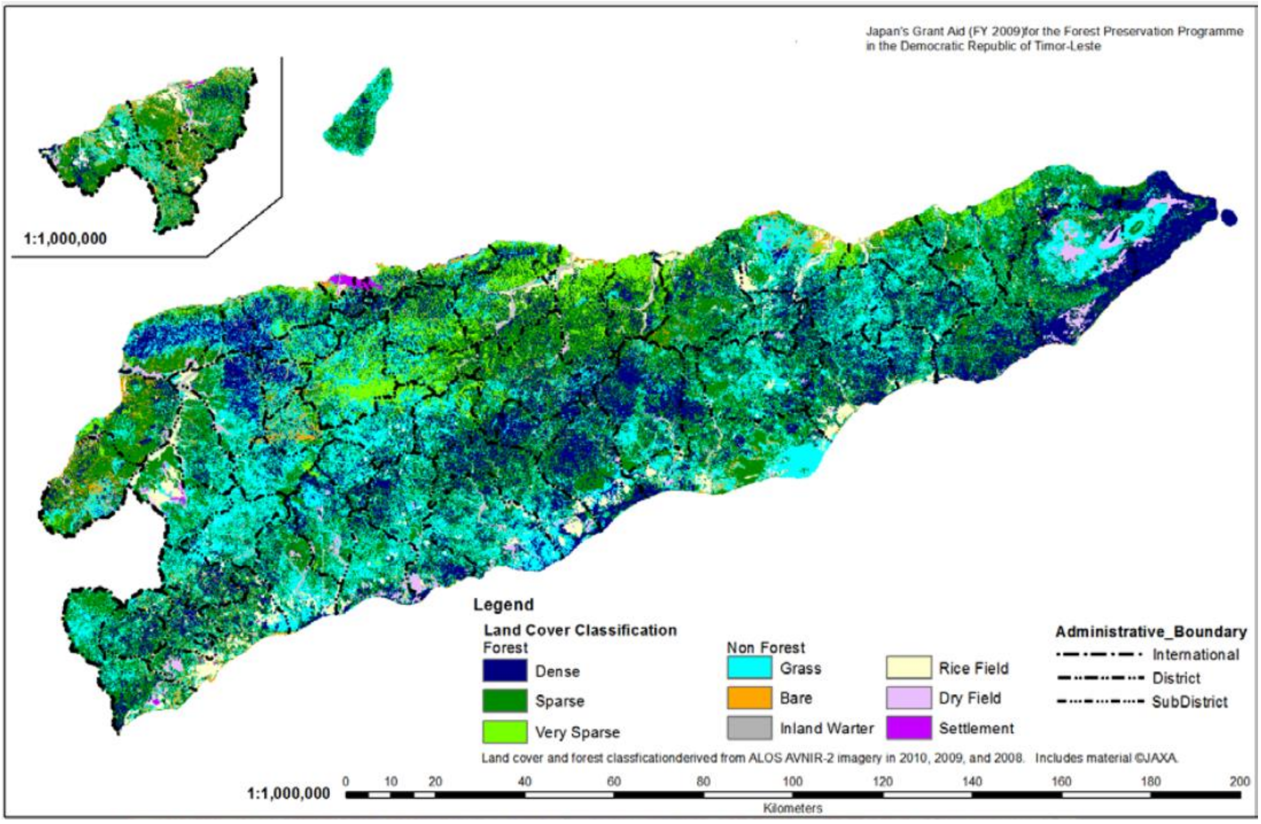


Figure 3 Land cover and forest classification map of Timor-Leste for 2010 made by JICS and MAF.

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 and UNEP, 2011). This map was produced from SPOT images (30 m spatial resolution) from 2007 and 2009 (Figure 4). No documentation on this map have been found.

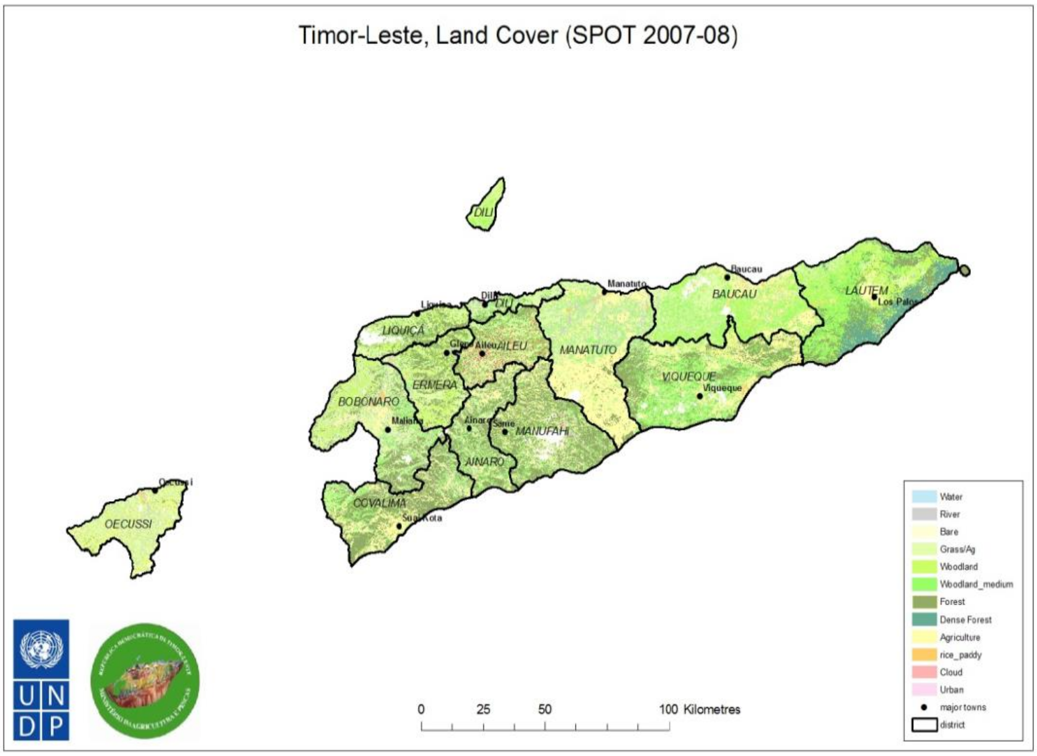
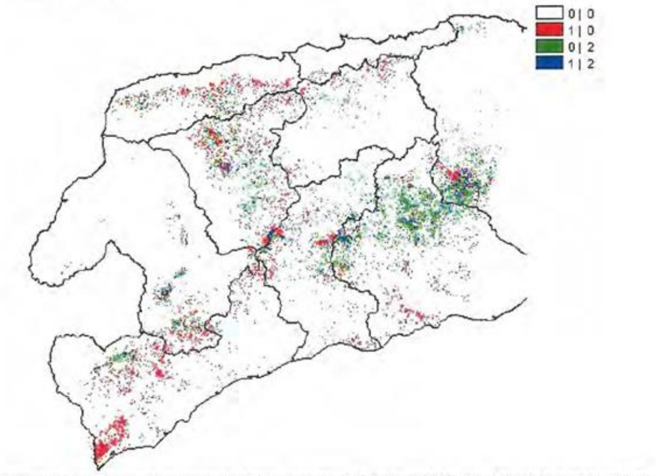


Figure 4 Land cover map of Timor-Leste for 2007-8 made by David Adams.

Bouman & Kobryn, 2002

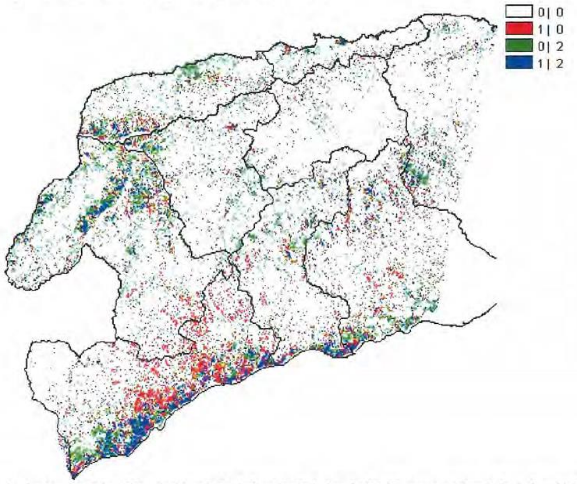
Forest cover change maps between 1989 and 1999 for the country western area were produced by the Environmental Protection Unit (EPU) of the UN East Timor Transitional Administration (ETTA) in collaboration with the Australian Centre for Remote Sensing (ACRES) (Bouma and Kobryn, 2002). These maps were produced from Landsat TM 5 and 7 images, by comparison of 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



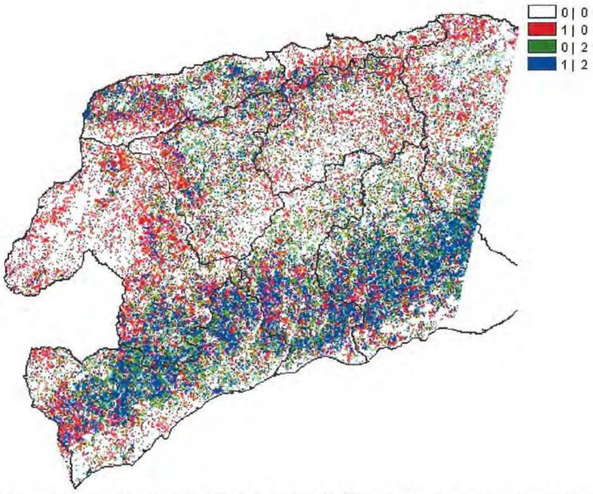
0|0=background, no data; 1|0=red patches indicate dense forest in 89 but not in 99; 0|2=green patches indicate dense forest in 89 and 99; 1|2=blue patches indicate dense forest in 99 but not in 89.

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 5 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 8 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 8 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 9 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. FRA 2015 (FAO, 2015a) is based on Bouma & Kobryn and the partial NFI of 1997, among other sources of information (FAO, 2015b). FRA 2000 (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 include 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 2000 to 2020 (loss/gain/stable), as results fro m 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 & 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 9 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 and 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. So, it seems 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 6).

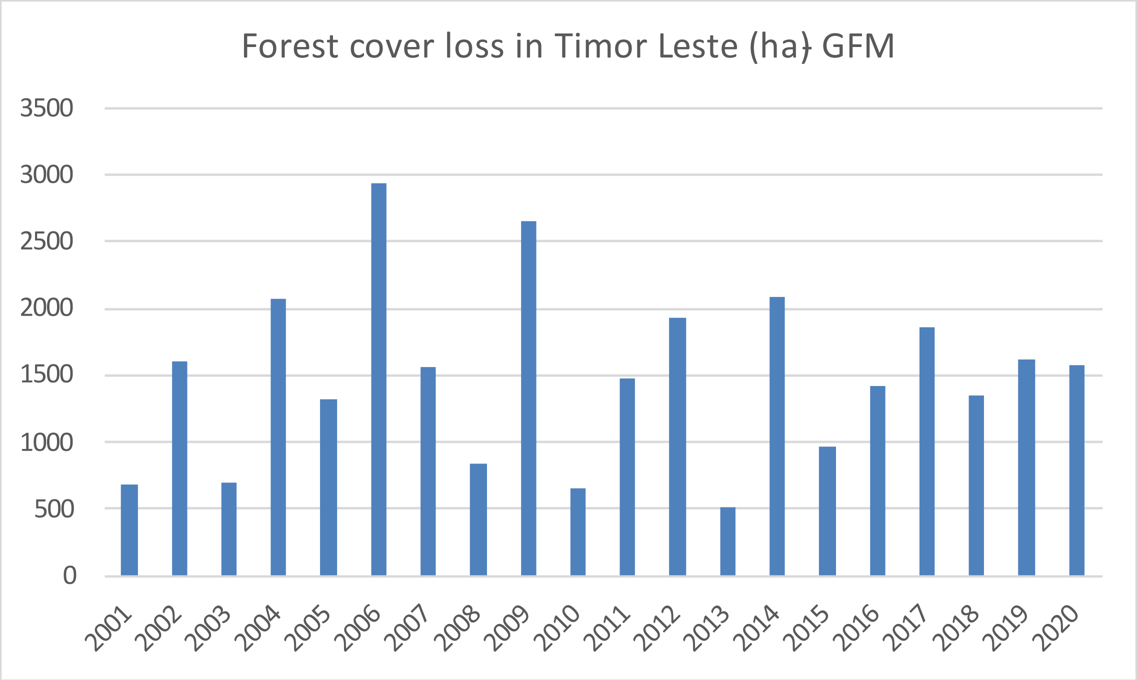


Figure 6 Forest cover loss in Timor-Leste according to the GFM.

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; Eriksad 2001; Bouma & Kobryn, 2002; Nippon Koei 2010; JICS, 2013; INC 2014; FAO-FRA 2015; FAO FRA, 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 and (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 couldn't be based on previous methodology for FREL 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.

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 on a hexagonal grid, and the samples are located at the central point of each hexagon. Hexagonal grid has the adventage 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, with the selection of a equal area projection, has some statistical advantages when extrapolating results a national scale. Finally, DGGRID is hierarchical allowing easily the intensification of the sampling in the future.

The resolution 15 (around 2 km between hexagon center points) was selected based on the deforestation trend for Global Forest Watch.

Visual interpretation

Samples were visually interpreted by national experts. 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 experts listed in *Anex 1*.

Plots were designed in square shape, with an area of 0.5ha and were centered 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 recodered. 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 10. Land cover classes in the survey.

Table 10. 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 11*. Land use subdivision was also recorded for the land use assigned to the plot.

Table 11. 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 subivision 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 experts 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 12*.

Table 12. Disturbances 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 points fall on the same class.

- **Interpretation protocol**
  A part from Google Earth Pro, several integrated services can be connected to Collect Earth through Google Chrome, Firefox or Edge. They offer different sources of information for the plot area to help in the visual interpretation that automatically open when selecting a plot. The experts 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 doesn't 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 dont 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 basemaps

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 mosaic of the last 12 months, valid for checking the exacy 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 Continuos 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, experts 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 ocurrs in small aras 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 previous recent years it wasn't a forest, most probably will be shrub.
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 13. The national forest definition exclude 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 13. Cases on control points 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)
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.

Equivalence of the number of control points categories and the plot 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

Satellite imagery

The quality of the satellite imagery available for Timor Leste is very good, especially for recent years. Very High Resolution imagery is available for almost all plots in the country. Google Earth very high resolution images are available for 4210 plots and Bing Maps for 1 addition; only 4 plot had no VHR images.

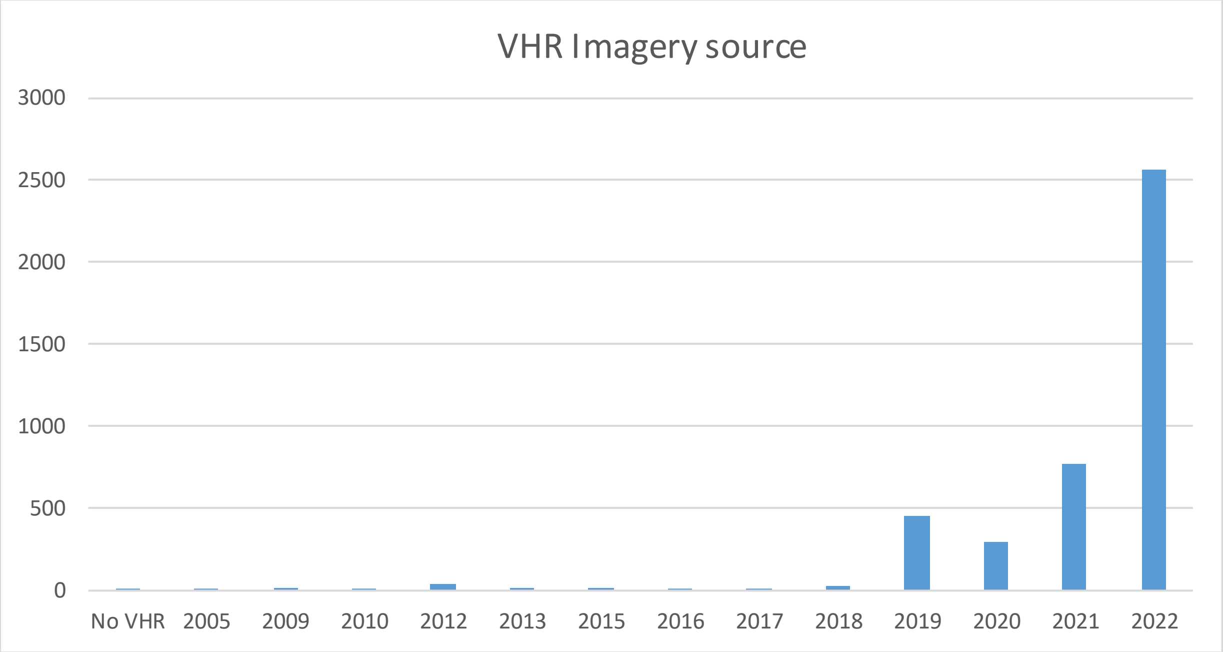


Figure 7. Number of plots with availability of high resolution imagery and the closest year of the images to the year 2021.

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 expert knowledge of the terrain.

A part from this each interpreter was assigned 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 has been simplified grouping the land uses changes in 4 classes: deforestation, aforestation, estable forest and estable non-forest. In this way the overall accuracy reaches more than 73% .

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

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

6.4.5 Summary of Preliminary Activity Data Results

Status of Forest Land in 2021

Table 15. Land use distribution in 2021 in Timor-Leste according to AD estimation

Forest (%)	Grassland (%)	Cropland (%)	Settlement (%)	Wetland (%)	Other land (%)
57.5	25.5	8.5	2.2	2.9	3.4

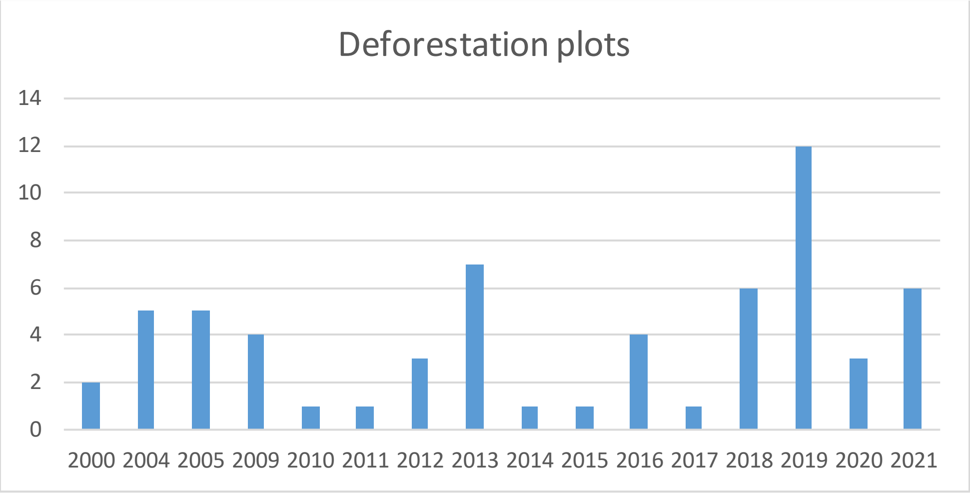
Forest Composition and distribution

Table 16 Distribution of land use subdivisions and forest types in 2021 in Timor-Leste according to AD estimation

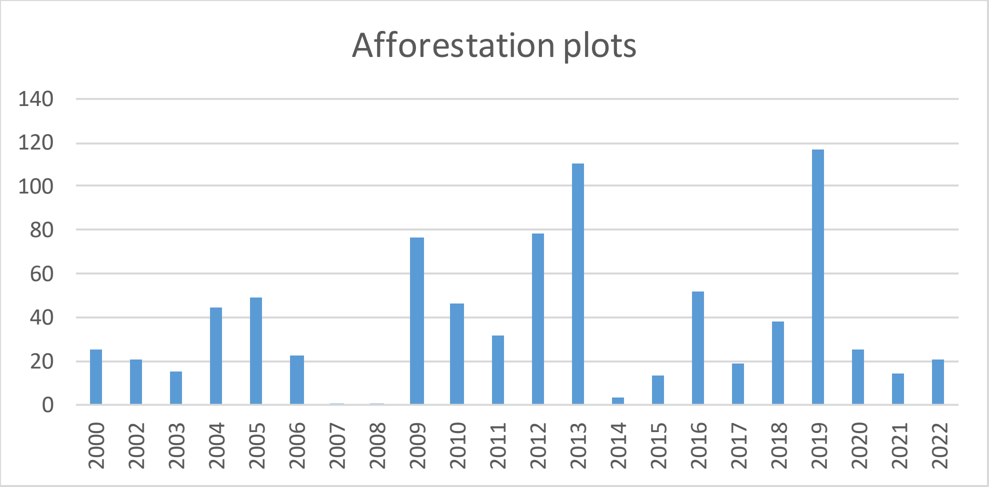
Land use class	Total %	Land use subdivision	Class %
Forest	73.3		
		Montane forest	1.6
		Moist highland forest	23.4
		Moist lowland forest	39.7
		Dry lowland forest	30.8
		Coastal forest	2.1
		Mangroves	0.2
		Forest plantation	1.2
Grassland	13.1		
		Shrubs	52.0

		Grassland	46.8
		Other wooded land	1.3
Cropland	6.8		
Settlement	2.9		
		Settlement	83.1
		Infrastructure	16.1
		Mining	0.8
Wetland	2.0		
		Lakes/Lagoons/Reservoirs	7.1
		River	85.9
		Wetlands	7.1
Other land	1.8		
		Other bare land	80.0
		Rocks	4.0
		Sand	10.7

Afforestation and deforestation long term trends



Afforestation



6.4.6 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 color cells represent Deforestation and green color cells Afforestation. Grey cells represent non forest remaining non forest.

2017	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH															0
FML											1				1
FDL											2				2
FM															0
FC															0
MF															0
FP															0
G	2	3	3								2				10
Sh	2	1	6								1				10
OWL		1													1
C			2												2
Se															0
W															0
O			1												1
Sum	4	5	12	0	0	0	0	0	0	0	6	0	0	0	27

2018	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH															0
FML											3				3
FDL									1		2				3
FM															0
FC															0
MF															0
FP									1						1
G	7	2	10								3			2	24
Sh	2	2	8												12
OWL	2		1												3
C	1	1	7				1	1				1			12
Se		1													1
W								1			1				2
O															0
Sum	12	6	26	0	0	0	1	2	2	0	9	1	0	2	61

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.

2019	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH															0
FML												1			1
FDL								1	7		2				10
FM															0
FC												1			1
MF															0
FP															0
G	10	18	24		2						4	1		1	60
Sh	3	13	19												35
OWL	1		1				1							1	4
C	1	3	11				3								18
Se											1				1
W	1		3												4
O	0	0	4		0		0	1	1		0	0		0	6
Sum	16	34	62	0	2	0	4	2	8	0	7	3	0	2	140

2020	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH															0
FML											1				1
FDL											1				1
FM															0
FC															0
MF															0
FP															0
G	1	3	8								1	1			14
Sh	2	4	4											1	11
OWL															0
C		2	1				1	1							5
Se															0
W															0
O									1						1
Sum	3	9	13	0	0	0	1	1	1	0	3	1	0	1	33

2021	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH															0
FML															0
FDL								3	1		2				6
FM															0
FC															0
MF															0
FP															0
G	1	3	3											1	8
Sh		2	2											1	5
OWL															0
C		1	1				1								3
Se															0
W															0
O															0
Sum	1	6	6	0	0	0	1	3	1	0	2	0	0	2	22

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 new														
		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML											355				355
	FDL											711				711
	FM															0
	FC															0
	MF															0
	FP															0
	G	711	1,066	1,066								711				3,554
	Sh	711	355	2,133								355				3,554
	OWL		355													355
	C			711												711
	Se															0
	W															0
	O			355												355
	Sum	1,422	1,776	4,265	0	0	0	0	0	0	0	2,132	0	0	0	9,595

ER - tCO2e/year

LU class new

		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML											64,610				64,610
	FDL											48,348				48,348
	FM															0
	FC															0
	MF															0
	FP															0
	G	-7,110	-10,660	-4,264								-9,243				-31,277
	Sh	-6,399	-3,195	-8,532								-2,485				-20,611
	OWL		-3,195													-3,195
	C			-2,133												-2,133
	Se															0
	W															0
	O			-1,420												-1,420
	Sum	-13,509	-17,050	-16,349	0	0	0	0	0	0	0	101,230	0	0	0	54,322

2018 land use change and ERs matrices

AD - Area (ha)

		LU class new														
		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML											1,066				1066
	FDL									355		711				1066
	FM															0
	FC															0
	MF															0
	FP									355						355
	G	2,488	711	3,555								1,066			711	8531
	Sh	711	711	2,844												4266
	OWL	711		355												1066
	C	355	355	2,488				355	355				355			4263
	Se		355													355
	W								355			355				710
	O															0
	Sum	4265	2132	9242	0	0	0	355	710	710	0	3198	355	0	711	21678

ER - tCO2e/year

									LU class new							
		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML											194,012				194,012
	FDL									26,270		48,348				74,618
	FM															0
	FC															0
	MF															0
	FP									72,065						72,065
	G	-24,880	-7,110	-14,220								-13,858			2,844	-57,224
	Sh	-6,399	-6,399	-11,376												-24,174
	OWL	-6,399		-1,420												-7,819
	C	-3,195	-3,195	-7,464				-3,550	4,615				6,035			-6,754
	Se		-3,550													-3,550
	W								-1,420			-6,035				-7,455
	O															0
	Sum	-40,873	-20,254	-34,480	0	0	0	-3,550	3,195	98,335	0	222,467	6,035	0	2,844	233,719

2019 land use change and ERs matrices

AD - Area (ha)

		LU class new														
		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML												355			355
	FDL								355	2,488		711				3554
	FM															0
	FC												355			355
	MF															0
	FP															0
	G	3,555	6,399	8,531		711						1,422	355		355	21328
	Sh	1,066	4,621	6,754												12441
	OWL	355		355				355							355	1420
	C	355	1,066	3,910				1,066								6397
	Se											355				355
	W	355		1,066												1421
	O	0	0	1,422		0		0	355	355		0	0		0	2132
	Sum	5686	12086	22038	0	711	0	1421	710	2843	0	2488	1065	0	710	49758

ER - tCO2e/year

		LU class new														
		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML												70,645			70,645
	FDL								28,755	184,112		48,348				261,215
	FM															0
	FC												70,645			70,645
	MF															0
	FP															0
	G	-35,550	-63,990	-34,124		-7,110						-18,486	1,420		1,420	-156,420
	Sh	-9,594	-41,589	-27,016												-78,199
	OWL	-3,195		-1,420				-3,550							3,905	-4,260
	C	-3,195	-9,594	-11,730				-10,660								-35,179
	Se											-6,035				-6,035
	W	-3,550		-4,264												-7,814
	O	0	0	-5,688		0		0	-1,420	-3,905		0	0		0	-11,013
	Sum	-55,084	-115,173	-84,242	0	-7,110	0	-14,210	27,335	180,207	0	23,827	142,710	0	5,325	103,585

2020 land use change and ERs matrices

AD - Area (ha)

LU class new

		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML											355				355
	FDL											355				355
	FM															0
	FC															0
	MF															0
	FP															0
	G	355	1,066	2,844								355	355			4975
	Sh	711	1,422	1,422											355	3910
	OWL															0
	C		711	355				355	355							1776
	Se															0
	W															0
	O									355						355
	Sum	1066	3199	4621	0	0	0	355	355	355	0	1065	355	0	355	11726

ER - tCO2e/year

LU class new

		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML											64,610				64,610
	FDL											24,140				24,140
	FM															0
	FC															0
	MF															0
	FP															0
	G	-3,550	-10,660	-11,376								-4,615	1,420			-28,781
	Sh	-6,399	-12,798	-5,688											3,905	-20,980
	OWL															0
	C		-6,399	-1,065				-3,550	4,615							-6,399
	Se															0
	W															0
	O									-3,905						-3,905
	Sum	-9,949	-29,857	-18,129	0	0	0	-3,550	4,615	-3,905	0	84,135	1,420	0	3,905	28,685

2021 land use change and ERs matrices

AD - Area (ha)

LU class new

LU class old

	FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
FMH															0
FML															0
FDL								1,066	355		711				2132
FM															0
FC															0
MF															0
FP															0
G	355	1,066	1,066											355	2842
Sh		711	711											355	1777
OWL															0
C		355	355				355								1065
Se															0
W															0
O															0
Sum	355	2132	2132	0	0	0	355	1066	355	0	711	0	0	710	7816

ER - tCO2e/year

		LU class new														
		FMH	FML	FDL	FM	FC	MF	FP	G	Sh	OWL	C	Se	W	O	Sum
LU class old	FMH															0
	FML															0
	FDL								86,346	26,270		48,348				160,964
	FM															0
	FC															0
	MF															0
	FP															0
	G	-3,550	-10,660	-4,264											1,420	-17,054
	Sh		-6,399	-2,844											3,905	-5,338
	OWL															0
	C		-3,195	-1,065				-3,550								-7,810
	Se															0
	W															0
	O															0
	Sum	-3,550	-20,254	-8,173	0	0	0	-3,550	86,346	26,270	0	48,348	0	0	5,325	130,762

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:

	Afforestation sample count						
Land use	**2017**	**2018**	**2019**	**2020**	**2021**	**Carbon total (tC/ha)**	**Annual gain (tCO2e/ha/year)**
FMH	4	11	16	3	1	54.4	10.0
FML	6	5	35	8	6	54.4	10.0
FDL	9	22	61	13	6	23.2	4.3
FP		1	3	1	1	58.3	10.7
FC			2			54.4	10.0

	Cumulative Afforestation gain (tCO2e)				
Land use	**2017**	**2018**	**2019**	**2020**	**2021**
FMH	14,219	53,321	110,197	120,861	124,416
FML	21,328	39,102	163,518	191,956	213,284
FDL	13,757	47,385	140,625	160,496	169,668
FP	0	3,804	15,214	19,018	22,821
FC	0	0	7,109	7,109	7,109
Total	**49,304**	**143,612**	**436,663**	**499,440**	**537,298**

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:

	Emissions and Removals (tCO2e)				
	2017	**2018**	**2019**	**2020**	**2021**
E-Deforestation	112,958	340,695	402,505	88,750	160,964
E-Degradation	0	0	0	0	0
Total Emissions	112,958	340,695	402,505	88,750	160,964
R-Enhancements NF-F	-46,908	-99,157	-275,819	-61,485	-35,527
R-Enhancements F-F	0	0	0	0	0

R-Enhancements AF growth	-49,304	-143,612	-436,663	-499,440	-537,298
Total Removals	-96,212	-242,769	-712,482	-560,925	-572,825

Figure 8: 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:

Forest Reference Emission Levels (tCO2e/year)	**221,174**
Average annual Removals (tCO2e/year)	**-437,043**
Forest Reference Level (net, tCO2e/year)	**-215,868**

9. Uncertainty analysis

The proposed FREL/FRL comes from a combination of recently introduced methods and tools to the country and at the time of the submission the uncertainty of the activity data was not estimated. The emissions and removal factors uncertainty are mentioned in the Table 6. Once the AD uncertainty are estimateds the overall FREL/FRL uncertainty can be calculated with the propagation formula from IPCC 2019 guidelines (equation 3.2A, Volume2):

$$U_{emission} = \sqrt{{U_{AD}}^2 + {U_{EF}}^2}$$

As the Forest inventory data come from a preliminary NFI design exercise, the full range of QAQC procedures are not applied yet to data collection practices. However the NFI teams have been trained and hot checks are performed in 50% of the plots.

10. Proposed improvements

On Land use stratification, Land Cover Classification System has been introduced in Timor-Leste, but more practice and field data collection is 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 gvt human resources.

On Emission factors, additional points are being collected to reach 40 plots by June 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.

The Uncetainty analysis is another area for future irrpromvement, with uncertainty calculation for the Activity Data to be added in the short future.

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Annexes

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

Name	Institution	Position
Albino da Silva Barbosa	General Directorate of Forestry, Coffe 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)	
Celeste Francisca Pinto	FAO-TL	National GIS expert
Elvino Aparicio de Oliveira	FAO-TL	
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Table 17. Confusion matrix of land uses changes from 2017 until 2021 from the cross-interpretation of 10% of the samples.

Round 1/2	CC	CF	CG	FC	FF	FG	FS	GF	GG	GS	GO	OF	OO	SF	SS	WF	WW	Total	Comission
CC	6	1	0	0	13	1	0	0	3	0	0	0	0	0	0	0	0	24	0.75
CF	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	4	1
CG	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
FC	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
FF	5	2	0	0	249	0	0	13	15	0	0	1	1	0	1	0	0	287	0.13
FG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FS	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
GF	3	0	0	0	10	1	0	4	1	0	0	0	0	0	0	0	0	19	0.79
GG	6	0	0	0	22	0	0	1	17	0	0	0	0	0	2	0	0	48	0.65
GS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GO	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1
OF	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	1
OO	1	0	0	0	3	0	0	1	3	0	0	0	4	0	1	0	0	13	0.69
SF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SS	1	0	0	0	3	0	0	0	1	0	0	0	0	1	5	0	0	11	0.55
WF	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	1
WW	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	6	10	0.4
Total	25	3	0	0	310	2	0	20	41	1	0	1	5	1	9	1	6		
Omission	0.76	1	0	0	0.20	1	0	0.8	0.59	1	0	1	0.2	1	0.44	1	0		

Change classes are represented by two letters, the class before and after the change: C= cropland, F= forest, G= grassland, S= shrub, W= wetland, 0= Other land.

Table 18. Matrix of plots with land use subdivision changes during 2017-21 and country area estimation

2017/2021	Coastal forest	Dry lowland forest	Forest plantation	Grassland	Infrastructure	Lakes/Lagoons/Reservoirs	Mangroves	Mining	Moist high land forest	Moist lowland forest	Montane forest	Other bareland	Other wooded land	River	Rocks	Sand	Settlement	Shrubs	Wetlands	Cropland	Plot sum	Area (km2)	Country area (%)
Coastal forest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	3.55	0.02
Dry lowland forest	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9	22	78.05	0.52
Forest plantation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	3.55	0.02
Grassland	2	48	0	0	1	0	0	0	21	29	0	3	0	0	0	1	1	0	0	10	116	411.56	2.75
Infrastructure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
Lakes/Lagoons/Reservoirs	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3.55	0.02
Mangroves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
Mining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	7.10	0.05
Moist high land forest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
Moist lowland forest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	6	21.29	0.14
Montane forest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
Other bareland	0	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	21.29	0.14
Other wooded land	0	2	1	0	0	0	0	0	3	1	0	1	0	0	0	0	0	0	0	0	8	28.38	0.19
River	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	10.64	0.07
Rocks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
Sand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
Settlement	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2	7.10	0.05
Shrubs	0	39	0	0	0	0	0	0	9	22	0	2	0	0	0	0	0	0	0	1	73	259.00	1.73
Wetlands	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	10.64	0.07
Cropland	0	22	6	2	0	0	0	0	2	8	0	0	0	0	0	0	2	1	0	0	43	152.56	1.02
Plot sum	2	119	7	9	1	0	0	0	36	61	0	6	0	0	0	1	5	13	0	27	287		
Area (km2)	7.10	422.20	24.84	31.93	3.55	0.00	0.00	0.00	127.73	216.42	0.00	21.29	0.00	0.00	0.00	3.55	17.74	46.12	0.00	95.79			
Country area (%)	0.05	2.82	0.17	0.21	0.02	0.00	0.00	0.00	0.85	1.45	0.00	0.14	0.00	0.00	0.00	0.02	0.12	0.31	0.00	0.64		6.81	