Second Forest Reference Level for Cambodia under the UNFCCC Framework

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Ministry of Environment (MoE)

H.E. Say Samal, Minister of the Ministry of Environment
H.E. Chea Sam Ang, Secretary of State
H.E. Choup Paris, Director General, General Directorate of Environmental Knowledge and Information

Forestry Administration (FA), Ministry of Agricuture, Forestry and Fisheries (MAFF)

Dr. Keo Omalis, Director General, Forestry Administration.
Dr. Khorn Saret, Deputy Director General, Forestry Administration.
Dr. Samret Vanna, Deputy Director of Department of Forestry and Community Forestry.

Fisheries Administration (FiA), Ministry of Agriculture, Forestries and Fisheries (MAFF)

Mr. Ouk Vibol, Director of Department of Fisheries Conservation, REDD+ Taskforce member.

MRV Technical Team

GDEKI - MOE

- Mr. Uy Kamal
- Mr. Leng Chivin
- Ms. Hout Naborey
- Mr. Menh Khidorang
- Mr. Net Norin
- Mr. Leng Serey Oddom
- Mr. Dy Lihong
- Mr. Nop Chaya

FA-MAFF

- Mr. Pak Chealy
- Mr. Chea Nareth
- Ms. Koh Sotheavy
- Mr. Phan Phearum

FiA-MAFF

- Mr. Ouch Vutha

GDA-MAFF

- Mr. Seng Vang
- Mr. Veasna Chaya
- Mr. Mon Sophorn

NCSD

- Mr. Leang Sophal

Technical Support

UNDP

- Mr. Carlos Riano
- Mr. Sovanna Nhem
- Mr. Javier Cano (consultant)

FAO

- Ms. Ann Chansopheak
- Ms. Sar Sophyra
- Mr. So Than
- Mr. Mathieu Vanrijn
- Mr. Gael Sola
- Ms. Naila Jasmin

Content

1 INTRODUCTION 1

1.1 FRL Submission 1

1.2 Objectives of developing the Second National FRL. 2

1.3 FRL Modalities 2

1.3.1 FRL Submission Guidelines 2

1.4 CAMBODIA´S FOREST SECTOR 3

1.4.1 Forest Governance 3

1.4.2 Forest Communities and Women 4

1.4.3 Climate Change and the Nationally Determined Contribution (NDC) 4

1.5 The REDD+ Process 6

1.5.1 The Nested System 7

1.6 CONSISTENCY WITH NATIONAL GHG REPORTING 8

2 FOREST DEFINITION, SCOPE AND REFERENCE PERIOD 9

2.1 Forest Definition 9

2.2 Activities, Pools and Gases 9

2.3 Reference Period 9

3 ACTIVITY DATA 10

3.1 FOREST COVER CHANGE MAPS 11

3.2 REFERENCE DATA 14

3.2.1 Sampling Design 14

3.2.2 Response Design 16

3.3 ANALYSIS PROTOCOL 18

3.4 RESULTS 19

3.4.1 Integrating the samples with the expansion area map. 19

3.4.2 Post-stratification 19

3.4.3 Estimation of accuracy, area and confidence intervals. 19

4 EMISSION FACTORS 22

4.1 Updated Emission Factors by forest class. 25

4.2 EFs used in the Second FRL. 26

5 UNCERTAINTY ANALYSIS 28

5.1 SOURCES OF SYSTEMATIC ERROR 28

5.2 UNCERTAINTY PROPAGATION....29
6 FRL RESULT....30
7 SUMARY RESULTS....32
8 AREAS OF IMPROVEMENT....33
9 REFERENCES....34

Annex 1. Error matrix, proportion matrix and variance matrix....1
Annex 2. Detailed methodology for acquiring activity data....7
Annex 3. Updated Forest carbon stocks for REDD+ Emission and Removal Factors in Cambodia....15
Annex 4. Forest biomass in Cambodia: from field plots to national estimates....16

Figures

Figure 1. Methods used to assess deforestation in FRL submitted to the UNFCCC. Source: FAO, 2019....10
Figure 2. Procedure for FCC Maps. Source: Technical Annex to the BUR (2020)....12
Figure 3. FCC Map 2010-2014. Source: MoE....13
Figure 4. FCC Map 2014-2016. Source: MoE....13
Figure 5. FCC Map 2016-2018. Source: MoE....14
Figure 6. Expansion area by sampling grid. Each color represent the area covered by each of the GRIDs....15
Figure 7. Plots by sampling grid. Each point represents a plot; the color indicates the corresponding GRID....15
Figure 8. Collect Earth survey used to carry out the spatial response....16
Figure 9. Distribution of forest inventory plots used to develop EF. Source: FAO 2019....22
Figure 10. Comparison of historical emissions and FRL by option in Ton CO_2eq year....30
Figure 11 The procedure for LULC 2016 map....7
Figure 12. Satellite imageries used for classification and accuracy assessment of forest cover 2016....8
Figure 13. Location of verification points for the accuracy assessment of LULC 2016 and verification based on Google Earth interpretation....9
Figure 14. Summary of random sample point assess by province....9
Figure 15. The procedure for LULC 2018 map....11
Figure 16. Interpretation of randome point in Google Earth....13

Tables

Table 1. Land use maps classification system. Source: Technical Annex to the BUR (2020)....11
Table 2. Reference label protocol hierarchy system and thresholds....17
Table 3. Estimated proportions of area for the period 2010-2014....20
Table 4. Estimated proportions of area for the period 2014-2016....21
Table 5. Estimated proportions of area for the period 2016-2018....21
Table 6. Summary of existing forest inventory data in Cambodia....23
Table 7. Developing tree height-diameter allometric equations....24
Table 8. Allometric equations applied to estimate Aboveground biomass....25
Table 9. Estimation of above-ground biomass (ton ha-1) by forest types in Cambodia....25
Table 10. forest type used to estimate the AGB and BGB for “Other Forest”....26
Table 11. Forest Types Deforestation National EF....26
Table 12. The bias of the H-D models....29
Table 13. Forest Reference Emission Level by option in Ton CO_2eq year....30
Table 14. Second FRL results and uncertainty....31

Table 15. 2010-2014 error matrix, proportion matrix and variance matrix. 1
Table 16. 2014-2016 error matrix, proportion matrix and variance matrix.. 3
Table 17. 2016-2018 error matrix, proportion matrix and variance matrix. 5
Table 18. Confusion matrix of 2016map 10
Table 19. Confusion matrix of 2018 map 14

Equations

Equation 1. Olofsson et al., 2014......18
Equation 2. Olofsson et al., 2014......18
Equation 3. Olofsson et al., 2014......18
Equation 4. Olofsson et al., 2014......18
Equation 5. Conversion from AGB to Carbon Stock......24
Equation 6. sum of AGB and BGB......26
Equation 7. Eq. 3.2 IPCC 2006......27
Equation 8. Eq. 3.1 IPCC, 2006......29
Equation 9. Eq. 3.2 IPCC 2006......29

ABBREVIATIONS

ACRONYM	FULL WORD
AD	Activity Data
AGB	Aboveground Biomass
AIP	Action and Investment Plan
BGB	Belowground Biomass
EF	Emission Factor
ELCs	Economic Land Concessions
FA	Forestry Administration
FAO	Food and Agriculture Organization of the United Nations
FCC	Forest Cover Change
FiA	Fisheries Administration
FREL	Forest Reference Emission levels
FRL	Forest Reference Level
GDANCP	General Directorate of Administration for Nature Conservation and Protection
GDEKI	General Directorate of Environmental Knowledge and Information
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change and Forestry
MAFF	Ministry of Agriculture Forestry and Fisheries
MMU	Minimum Mapping Unit
MoE	Ministry of Environment
NDC	Nationally Determined Contribution
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NPASMP	National Protected Areas Strategic Management Plan
NRS	National REDD+ Strategy
NSDP	National Strategic Development Plan
ODA	Official Development Assistance
PA	Protected Area
PFE	Permanent Forest State
PFR	Permanent Forest Reserve
PSP	Permanent Sample Plots
REDD	Reducing Emission from Deforestation and Forest Degradation
RGC	Royal Government of Cambodia
SIS	Safeguard Information System
SLCs	Social Land Concessions

1 INTRODUCTION

1.1 FRL Submission

In accordance with decisions 4/CP.15, 1/CP.16, 12/CP.17, 13/CP.19, Cambodia is submitting voluntarily for consideration by the UNFCCC its Second Forest Reference Level (FRL).

In this report, Cambodia provides an overview of the data and methodologies used to voluntary develop the Second FRL. The information presented is intended to be transparent, complete, consistent, and accurate, and is guided by the most recent IPCC guidance and guidelines (IPCC,2003a, 2003b,2006a, 2006b).

A technical set of experts representing sectoral ministries and national institutions were requested to actively participate in a stepwise and scientific-based construction process of this technical report, with the support of different international organizations and stakeholders present in the country.

The Second FRL is based as much as possible on the criteria, definitions, and assumptions used to build the First FRL submitted by Cambodia in 2017. However, several elements have been updated, aiming to:

- Increase transparency, consistency, coherence, and accuracy,
- incorporate newly available information and methodologies, and
- construct the FRL to facilitate the upcoming nesting process.

In this regard, fundamental elements and issues to develop the Second FRL need to be addressed, tested and analyzed to facilitate decision making.

The following elements remain from the definitions and choices used on the First FRL:

- Forest definition: Minimum area of 0.5 ha, a minimum height of 5 m or more, and at least 10 percent canopy cover. Rubber plantations, oil palm plantations, and perennial crops are excluded.
- Pools: above-ground Biomass (AGB) and Below -ground Biomass (BGB) are included, while Litter, Deadwood, and Soil Organic Carbon (SOC) are excluded.
- Gases: CO2 emissions are included, while CH4 and N20 are excluded

On the other hand, the following elements have been updated:

- Reference Period: 2010-2018
- Activity Data approach: Stratify Area Estimator approach has been used to estimate AD.
- Emission Factors: Calculation and protocols have been updated, and new data has been integrated.
- Uncertainty analysis is included in the report.

The Second FRL development follows the Modalities and Submission Guidelines described by the UNFCCC (COP, 2013)

1.2 Objectives of developing the Second National FRL.

The first objective of the submission of the Second FRL is to obtain and receive payments for results from Cambodia's REDD+ program implementation.

The second objective is to provide to different stakeholders a transparent, more accurate, complete and consistent estimation of the historical emissions of the forest sector, including for this purpose the most updated information and methods available after the submission of the First FRL.

1.3 FRL Modalities

The FRL expressed in tons of carbon dioxide equivalent per year is a benchmark for assessing each country´s performance in implementing the following activities:

- Reducing emissions from deforestation;
- Reducing emissions from forest degradation;
- Conservation of forest carbon stocks;
- Sustainable management of forests;
- Enhancement of forest carbon stocks.

The FRL shall be established, maintaining consistency with anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks as contained in the national greenhouse gas inventories.

Parties are invited to submit information and rationale on the development of their FRL, including details of national circumstances and, if adjusted, includes details on how the national circumstances were considered.

A step-wise approach may be useful, enabling Parties to improve the FRL by incorporating better data, improved methodologies, and, where appropriate, additional pools.

Parties should update a FRL periodically as appropriate, taking into account new knowledge, new trends and any modification of scope and methodologies

1.3.1 FRL Submission Guidelines

Submission of FRL should include information that is transparent, complete, consistent with guidance agreed by the Conference of the Parties (COP), and accurate for allowing a technical assessment of the data, methodologies, and procedures used in the construction of a FRL. The information provided should be guided by the most recent IPCC guidance and guidelines, as appropriate, and include:

a) Information that was used, including historical data, comprehensively and transparently;

b) Transparent, complete, consistent and accurate information, including methodological information, used at the time of construction of FRL, including, among other things, as appropriate, a description of data sets, approaches, methods, models and assumptions used, specifications of relevant policies and plans, and descriptions of changes from previously submitted information;

c) Pools and gases, and activities which have been included and the reasons for omitting a pool and/or activity from the construction of FRL, noting that significant pools and/or activities should not be excluded;

d) The definition of forest used, if appropriate, in case there is a difference with the definition used in the national GHG Inventory or in reporting to other international organizations, an explanation of why and how the definition used was chosen.

1.4 CAMBODIA´S FOREST SECTOR

Cambodia covers a total area of 181,607 km^2. Cambodia is categorized as a least developed, low-income country. Relative peace and stability over the past decade have brought steady economic growth, averaging between 7 and 10 percent since 1998, leading to substantial reductions in poverty, but also increased pressure on Cambodia's natural resources. Cambodia was able to maintain a relatively high forest cover, with one of the highest levels of forest cover in Southeast Asia. While the current forest cover is still relatively high, Cambodia lost a considerable amount of forest over the last two decades, and the pace of land use and forest conversion has seen acceleration.

1.4.1 Forest Governance

Cambodia's forest area is governed by three institutions: Forestry Administration (FA) of the Ministry of Agriculture, Forestry and Fisheries, Fisheries Administration (FiA) of the Ministry of Agriculture, Forestry and Fisheries (MAFF), General Directorate of Administration for Nature Conservation and Protection (GDANCP) of the Ministry of Environment (MoE).

FA is the government authority under MAFF, in managing forest and forest resources of the Permanent Forest Estate (PFE), which comprises naturally growing and planted state forest resources, and is subdivided into the Permanent Forest Reserve (PFR) and Private Forest. The PFR is composed of Production Forest, Protection Forest, and Conversion Forestland. Private Forests shall be maintained by owners with interesting right to manage, develop and harvest, use, sell, and distribute the product by themselves (Forestry Law 2002).

The policy objectives of the forestry sector under Permanent Forest Estate (PFE) are synthesized into an overarching strategic framework set out in the National Forest Programme 2010-2029, which defines the policy and implementation strategies for the sustainable management of the nation's forestry sector under a series of programmes, including (a) forest demarcation, classification and registration; (b) Conservation and Development of Forest Resource and biodiversity; (c) forest law enforcement and governance; (d) community forestry programme; (e) capacity and research development; and (f) sustainable forest financing.

Forest resources within Protected Areas (PA) are under the jurisdictional management and regulatory authority of the General Directorate of Administration for Nature Conservation and Protection (GDANCP) of the Ministry of Environment (MoE) under the 2008 Protected Areas Law. Cambodia's 65 protected areas and biodiversity corridors conservations, about 7.2 million ha or 40% of total land area. The National Protected Areas Strategic Management Plan (NPASMP) 2016-2030 outlines the implementation framework for achieving its vision of effective, efficient and equitable management of the national protected area system in Cambodia.

Under the 2006 Fisheries Law, inundated forests and mangrove areas outside of PAs are managed and regulated by the Fisheries Administration (FiA), set out in the Strategic Planning Framework for Fisheries 2010-2019.

Government policies related to climate change adaptation and mitigation include the National Climate Change Strategic Plan 2014-2023, National Strategic Plan on Green Growth Development 2013-2030, and the White Paper on Land Policy, enacted in 2015, which seeks to harmonize cross-sectoral land-use policy to ensure sustainability. In addition, a law on Environmental Impact Assessment and an Environmental Code have been developed. The National Council for Sustainable Development (NCSD) was recently formed to spearhead the harmonization of Cambodia's sustainable development efforts. These various efforts by RGC are expected to support to mitigate emissions from the forestry sector by improving governance, inter-ministerial coordination and coherence of land use policy.

Specifically for REDD+, a number of institutions and mechanisms have been established to streamline REDD+ in government policy and pave the way for the implementation of activities. The REDD+ Taskforce and Taskforce Secretariat were established in 2012. A number of technical teams have been created to oversee day-to-day operations, and key components, including the NRS, SIS, and NFMS are being developed. Participation by all major stakeholders, including local communities, indigenous groups, donors and civil society groups has been ensured.

1.4.2 Forest Communities and Women

Forests are of vital importance to Cambodia and many communities rely on them for their livelihoods. 41% of rural households in Cambodia obtain 20 to 50% of their total livelihood value from forest use, while 15% of households obtain more than half of their total livelihoods from forest use. Women's harvesting is central to maintaining family livelihoods through the utilization of forest resources. Around 80% of rural women collect non-timber forest products (NTFPs) for household consumption and sell. In forest management, women play an especially important role by engaging in a variety of activities such as patrolling, conducting forest inventory and collecting NTFPs. Access to and use of forest resources and knowledge is often differentiated by gender[1].

Despite the vital role of forests to human wellbeing, the country suffers from shortfalls in policy, governance and resources which hinders good forest management. In addition, current gender inequalities in the country exist which results in women being minimally engaged in decision-making processes related to forest management, and their representation in forest management institutions remains low. They also receive less information, education and training opportunities than men, especially on the withdrawal and use of, and dissemination on the conservation and protection of natural resources and environment[2].

1.4.3 Climate Change and the Nationally Determined Contribution (NDC)

According to indices of vulnerability and readiness for climate change, Cambodia is one of the most at-risk countries globally, specifically its reliance on rice and inland fisheries[3], and the threats to population that rely on these activities from flooding and drought.

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[1] Mainstreaming Gender into Cambodia's REDD+ Action and Investment Plan WOCAN 2019

[2] Mainstreaming Gender into Cambodia's REDD+ Action and Investment Plan WOCAN 2019

[3] http://sdwebx.worldbank.org/climateportal/countryprofile/doc/GFDRRCountryProfiles/wb_gfdrr_climate_change_country_profile_for_KHM.pdf

Cambodia is considered one of the 10 countries most vulnerable to climate change and one of the three in Asia[4]. Based on the Notre Dame Global Adaptation Index (ND-GAIN) model of vulnerability[5] Cambodia is ranked 134 (out of 181), and of even higher concern is that for 'readiness', i.e. its 'ability to leverage investments and convert them to adaption action[6]', it is ranked 141 in the world (of 191 countries).

The RGC recognises challenges posed by global climate change and has actively included the prioritization of action on climate change in its national policies.

As a Least-Developed Country (LDC) and highly vulnerable to climate change, Cambodia understood the necessity and importance to fight climate change. Thus, the country submitted its Nationally Determined Contribution[7] (NDC) on the 6th February 2017, and the updated version in December 2020, which is confident that it will contribute to addressing climate issues.

Cambodian's vulnerability is focused on 5 specific areas: agriculture, infrastructure, forestry, human health and coastal zones. NDC 'actions' comply with the Reduced Emissions from Deforestation and Degradation (REDD+) process which is mentioned in the NDC document. Key sectors for mitigation actions are energy production, manufacturing industries, transport, waste and renewable energy for irrigation and solar lamps, which shows the importance for the REDD+ process to not only address the forestry sector.

The revised version of the NDC, submitted in December 2020, states that the contribution from the LULUCF (Land-Use, Land-Use Change and Forestry) sector is mainly based on '**reducing the historic emissions from forest sector by half in 2030**', which is also in accordance with the national forest policies and strategies of the National Protected Areas Strategic Management Plan[8] 2017-2031 (NPASMP) and the Production Forest Strategic Plan 2018-2032 (PFSP). For Cambodia to achieve this ambitious goal, an Action and Investment Plan (AIP) of the NRS was set to (i) reduce deforestation and (ii) increase forest cover, in the framework of the revised NDCs.

In Cambodia, as elsewhere, forests and agriculture are intrinsically linked to climate change. Forests are converted to agriculture, contributing to climate change through the release of vast amounts of greenhouse gases stored in the trees and forest soil. At the same time, millions of Cambodians rely on these same forests for a significant portion of their household consumption and income, especially in (increasing) years where drought or floods impact on farming and fishing[9].

If forests in Cambodia are not urgently protected, and degraded forests are not managed for recovery '*loss of productive forests, as well as biodiversity, will lead to loss of income or livelihood options for forest-*

4 https://www.voanews.com/a/changing-climate-has-major-impacts-for-under-prepared-cambodia/3075404.html

5 https://gain-new.crc.nd.edu/ranking/vulnerability - Vulnerability measures a country's exposure, sensitivity and ability to adapt to the negative impact of climate change. ND-GAIN measures the overall vulnerability by considering vulnerability in six life-supporting sectors – food, water, health, ecosystem service, human habitat and infrastructure.

6 https://gain-new.crc.nd.edu/ranking/readiness - economic readiness, governance readiness and social readiness

7 https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party=KHM

8 Previously the National Forestry Plan (2010 – 2029) was effective but since jurisdictional reform over the forestry sector in 2016 all forest has been included in protected areas; therefore, NFP policies and strategies are now included/amended into the NPASMP and PFSP.

9 http://www.kh.undp.org/content/dam/cambodia/docs/HDR/2011CHDRClimateChangeandForestry.pdf

dependent communities[10]'. This situation will only get worse as the effects of climate change manifest themselves in the coming decades.

While large areas of Cambodia's 9 million ha of forest are protected under Cambodian laws and regulations, Cambodia needs to enhance law enforcement and protection of forest resources to reduce the forest loss and forest degradation. RGC has approved a long vision for forestry sector governance by reducing GHG emissions from the forestry sector to Zero percent by 2040. To achieving these vision, some policies have taken place under the REDD+ mechanism. Besides, the participation of local communities, indigenous groups and the private sector in the implementation of REDD+ policies and measure is fundamental to promote sustainable activities in the AFOLU sector.

Two RGC Ministries are responsible for forests in Cambodia, MAFF and MoE. Due to its mandate over protected areas, the MoE is the principal agency for forest management and conservation, and responsible for approximately 74% of all land area under forest, which, by 2020, is distributed in 65 protected areas and three biodiversity corridors (around 40% of Cambodia's land area).

Therefore, the RGC is firmly committed to forest conservation and has identified REDD+ as a mechanism to mitigate '*impacts of climate change in agriculture, forestry and related sectors*'. Moreover, the RGC has a '*clear vision that REDD+ is the national mechanism that provides an opportunity to support the sustainable management of forest resources in the country*'[11].

Agricultural development is seen as a pillar of Cambodia's National Development; MAFF is responsible for large areas of the country which are significant, in terms of LULUCF, for REDD+, and, therefore, if the goal of the NRS to 'reduce deforestation and forest degradation while promoting sustainable management, conservation of natural resources and contribute to poverty alleviation' is to be met, MoE and MAFF need to work in close partnership to ensure a successful REDD+ outcome under sustainable national development.

1.5 The REDD+ Process

The RGC recognises that deforestation and forest degradation are significant sources of greenhouse gas emissions both nationally and regionally. As an active Party to the United Nations Framework Convention on Climate Change (UNFCCC), Cambodia fully supports actions to reduce emissions and also wishes to implement more climate-friendly sustainable management of its natural resources, particularly in relation to forest conservation and protection of biodiversity.

RGC has been a strong supporter of the adoption of REDD+ and has started its REDD+ Readiness process in 2008; two Verified Carbon Standard[12] (VCS) projects were established the same year. In 2010, the National Roadmap was finalised and a National REDD+ Programme was established in 2012, leading to stakeholder engagement, capacity building and development of institutional arrangements[13].

[10] Climate Change and Forestry: Human Development Report (MoE/UNDP 2011).
[11] His Excellency, Prime Minister Hun Sen, 2017 in the National REDD+ Strategy 2017 - 2026
[12] VCS was previously 'Voluntary Carbon Standard' and changed to 'Verified'
[13] RGC - National REDD+ Strategy 2017 - 2026

As a result, the RGC to develop the National REDD+ Strategy and meet the other requirements of the Warsaw Framework for REDD+

a. **National REDD+ Strategy**[14] **(**NRS): In 2017, the RGC endorsed its NRS to set vision, strategies and key actions to achieve REDD+ in Cambodia. The NRS primarily builds upon three national policy frameworks that guide forest management: (i) the Production Forests Strategic Plan (2018-2032), (ii) the National Protected Areas Strategic Management Plan (2017-2030) and (iii) the Strategic Planning Framework for Fisheries (2010-2019). The RGC has also finalized the **Action & Investment Plan** (AIP) for the implementation of the NRS. While ensuring a *gender-responsive*[15] *approach*, the AIP sets up the *Policies & Measures* as well as the *Implementation Framework* and *Financial Plan* needed to achieve REDD+ objectives.
b. **First Forest Reference Level**[16]: the RGC has submitted its first national FRL (for the 2006-2014 reference period) in 2017, and is in the process of the FRL revision (for the 2010-2018 reference period) to be submitted in 2021.
c. **National Forest Monitoring System**[17] (NFMS): Cambodia has launched its NFMS in 2017 to monitor REDD+ activities and is continuously working to improve methodologies for *Emission Factors* (i.e. data on forest carbon stocks) and *Activity Data* (i.e. data on forest cover change) estimation.
d. **Safeguards Information System** (SIS): the RGC has submitted to the UNFCCC its first *Summary of Information* [18] on how Cancun Safeguards will be addressed and respected during REDD+ implementation.

1.5.1 The Nested System

RGC has acknowledged the need for clear rules regarding the way actors interested in forest carbon finance operate, engage with, and report to the government. Therefore, to maximize opportunities for forests and people and to overcome the challenges in the AFOLU sector, the nested system aims to i) Enable Cambodia to participate in mechanisms/opportunities as framed by the Article 6 of the Paris Agreement, through fair rules, clear systems and transparency; ii) Enable multiple sources of finance to support forest and climate goals of Cambodia, including private sector finance and participation in voluntary carbon markets; iii) Supplement government capacity to implement the NRS through support for site-based activities; iv) Drive projects to areas of higher risk and promote equity among them; v) Promote alignment in how projects and the national government measure GHG performance; and vi) Support Cambodia's NDC achievement and prevent the double counting of ERs

Since the Nested system is closely related to the FRL, the RTS is designing an allocation method of its Second FRL. This allocation schema allows for jurisdictional REDD+ efforts (national or subnational) to integrate with smaller (project scale) REDD+ activities while generating RBPs at the jurisdictional scale. ERs will be measured and accounted for at multiple scales including national level – where targets are set under the NDC, sub-national level, i.e. Provinces that can set their baselines and measure performance against this (and make sales of ERs) and local levels including projects and communities (also able to develop baselines, measure performance and generate and sell ER credits).

14 https://redd.unfccc.int/files/20180813_national_redd__strategy_cambodia.pdf
15 http://www.cambodia-redd.org/wp-content/uploads/2020/03/FINAL-Draft-Gender-Mainstreaming-AIP-NRS.pdf
16 https://redd.unfccc.int/files/camfrl_may_22_2017.pdf
17 www.cambodia-nfms.org
18 https://redd.unfccc.int/files/6._cambodia_1st_summary_of_information_on_safeguards-final-oct-2019.pdf

1.6 CONSISTENCY WITH NATIONAL GHG REPORTING

The National GHG Inventory compilation cycle and the and preparation of the Second FRL of Cambodia do not precisely match on the reporting schedules. Therefore, the information sources and data used to estimate emissions in both reports, in several cases, are not the same. The National GHG Inventory included in the First BUR and Second National Communication of Cambodia was developed in early 2019, using the data and information of the first FRL. **Thus, consistency between reports has a transition period.** The GHG inventory, included in the First BUR of Cambodia, is totally consistent with the First FRL of the country. All the updates, improvements and methodological changes applied in the Second FRL (built-in 2020) are going to be implemented in the next GHG Inventory cycle.

It is important to highlight that the MRV technical team responsible for the elaboration of the Second FRL, is also responsible for the elaboration of the GHG Inventory in the LULUCF sector. Thus, it ensures the consistency between both national reports, FRL and GHG inventories.

2 FOREST DEFINITION, SCOPE AND REFERENCE PERIOD

2.1 Forest Definition

The forest definition adopted by Cambodia for REDD+ follows the National Forest Programme definition for forest and is consistent with the FAO FRA definition but differs in the fact that rubber plantations, oil palm plantations and perennial crops are not reported as forests.

To implement the Cambodia REDD+ programme, the forest definition has been re-defined as follows:

Forest under the REDD+ programme refers to a unit of an ecosystem in the form of wetland and dry land covered by natural or planted vegetation with a height from 5 meters on an area of at least 0.5 hectares, and canopy crown cover of more than 10%. Areas also included in the REDD+ programme are forest regrowth and areas under afforestation or reforestation. Rubber, oil palm plantations and perennial crops are excluded from this definition (RGC, 2016).

2.2 Activities, Pools and Gases

The REDD+ activities "reduce emission from deforestation" (forest land converted to other land types), and "enhancements of forest carbon stock", through afforestation/reforestation actions (other land uses converted to forest land) are included in the Second FRL.

Out of five carbon pools, as described per IPCC guidelines (IPCC, 2006), two pools, above-ground biomass, and below-ground biomass are included for the Second FRL of Cambodia. Litter, deadwood, and soil organic carbon are excluded from the estimation due to the lack of data.

Regarding the gases included, only CO2 is included because in Cambodia. CH_4 and N_2O emissions from land use and land use change are considered to be minor, and the current information is constrained.

2.3 Reference Period

UNFCCC Decision 12/CP.17 set that FRLs shall be established, taking into account historical data. Thus, the reference period will be determined by the availability and reliability of historical data.

However, UNFCCC does not provide further criteria that countries should consider establishing the reference period, such as the length, or the number of years from the end of the reference period to the submission date. A relatively long period would better capture historical emission patterns or trends. However, overstretching the reference period may result in the inclusion of emission trends that are not representative of expected future emissions and, therefore, may not provide a reasonable basis for the FRL construction (FAO, 2019).

Considering the current and emerging recommendations from various initiatives and standards, reference periods over 10 years and under 5 years may not be representative of the deforestation trends. In this regard, the agreed **reference period to the FRL updates covers the period from 2010 to 2018**.

3 ACTIVITY DATA

To estimate the Activity Data (AD) countries have typically used three methods, i) pixel counts method from wall-to-wall change maps, ii) areas from stratified samples using wall-to-wall maps as described by Olofsson (2014), iii) areas from systematic sampling (FAO, 2016). Since 2016, the stratified area method is reaching more relevance, being the most used method in the years 2018 and 2019. Systematic sampling is also being used more often by countries (Figure 1).

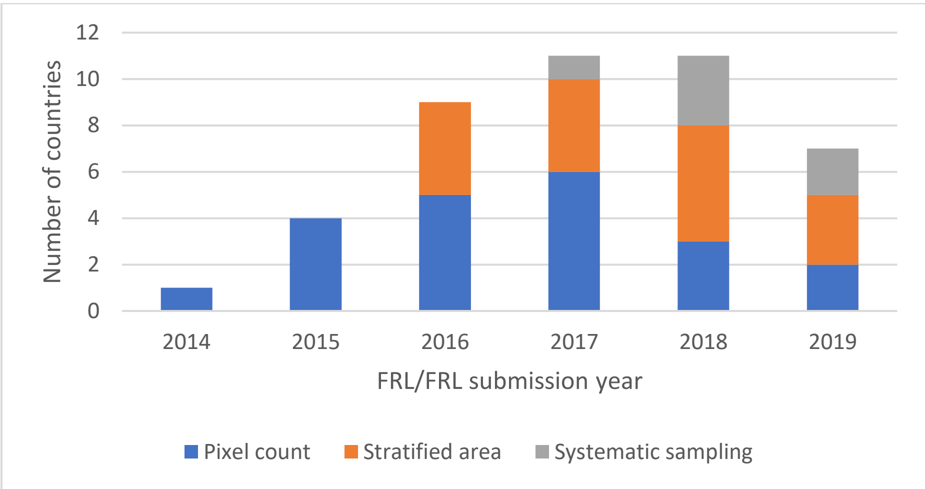


Figure 1. Methods used to assess deforestation in FRL submitted to the UNFCCC. Source: FAO, 2019.

The main reasons for the increased adoption of sampling-based methods are:

1. Confusion or error matrices and map accuracy from **pixel count** methods do not produce the information necessary to construct confidence intervals. Therefore, pixel count methods do not assure that estimates are "neither over- nor under-estimates" or that "uncertainties are reduced as far as practicable" as required by IPCC definition of good practice (FAO, 2016).

2. Mapping approaches are not well developed because i) wall-to-wall land use/cover change maps do not exist in the country, ii) Historical FCC maps were commonly based on land use/cover maps from different years, which were developed using different methodologies or land classifications, iii) accuracy of the land use/cover change maps is low (FAO, 2019). Besides, sample-based methods can provide more accurate estimates for multiple land use change categories.

The information resources available together with the capabilities to integrate existing data and to provide uncertainty information were decisive for the MRV team to define the integration of the Stratify Area Estimator (SAE) approach to estimate AD within the developing of the Second FRL of Cambodia.

The SAE method compares map data with higher quality data collected through a sample based approach or reference data. As a result, the country obtains accuracy measures and adjusted area estimates for each map category. This process is broken down into four major components: (i) a map to stratify the classes, (ii) the sampling design (iii) the responsive design, and (iv) the analysis (FAO, 2016).

The primary information sources to estimate AD at the national level in Cambodia are the forest cover change (FCC) maps and a dataset of sampling plots used as the reference data.

3.1 FOREST COVER CHANGE MAPS

The FCC Maps are based on the estimation of changes from the land use maps developed by the Royal Government of Cambodia for the years 2010, 2014, 2016, and 2018.

The land use maps are wall-to-wall maps for the whole country using available satellite images (Spot, Landsat, and Sentinel). Each of those maps was classified using the same stratification system (Table 1).

Table 1. Land use maps classification system. Source: Technical Annex to the BUR (2020)

Land use/cover		
Category		Sub-category
Forest land	Natural forest	Evergreen
		Semi-evergreen
		Deciduous
		Pine forest
		Bamboo
		Mangrove
		Rear mangrove
		Flooded forest
		Forest regrowth
	Planted Forest	Pine plantation
		Tree plantation
Cropland		Rubber plantation
		Oil palm plantation
		Cropland
		Paddy field
Grassland		Grassland
		Wood shrub
Wetland		Water
Settlement		Village
		Built-up area
Other lands		Rock
		Sand

The Land cover maps of 2010 and 2014 are the same presented in the First Forest Reference Level. For the 2016 and 2018, Cambodia followed the same methodology described in the Annex 3 of the First Forest Reference Level[19], obtaining land cover maps with the same classification and a minimum mapping unit of 5 Ha.

To develop the Forest Cover Change (FCC) maps, which record any class change between two times, the land cover class of each segment in the initial map is comparing with the corresponding segment of the

[19] https://redd.unfccc.int/files/camfrl_may_22_2017.pdf#page=44

following map. FCC of each period was quantified using a GIS technique for geo-processing and logical functions. The geoprocessing tools used for the detection of land use change are intersection, union, dissolve, and elimination of segments. The statistical tabulation of the land use change was then utilized with the histograms of change.

For the FCC maps periods 2010-2014 (Figure 3), 2014-2016 (Figure 4) and 2016-2018 (Figure 5), the MRV team followed the procedure explained in Figure 2 (T.A. BUR, 2020).

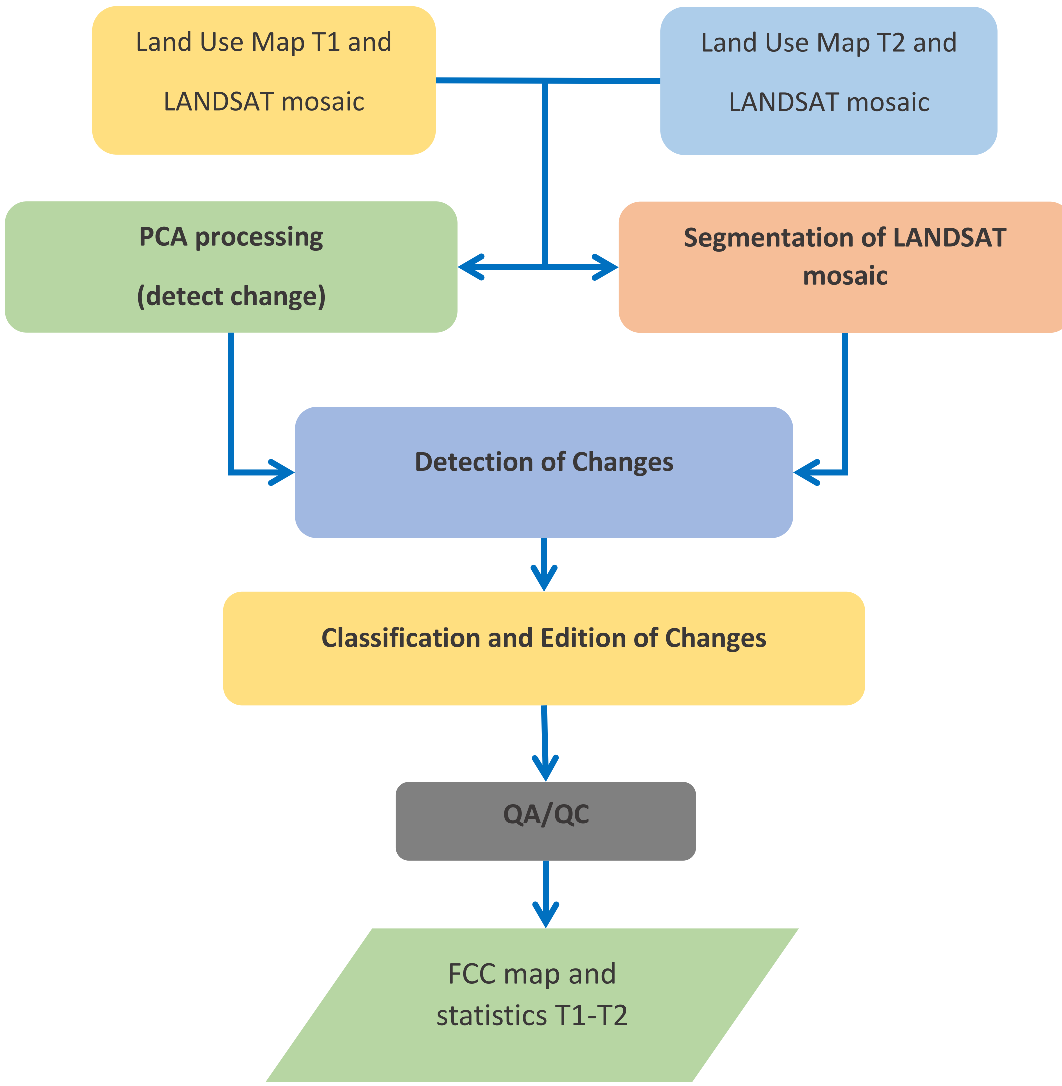


Figure 2. Procedure for FCC Maps. Source: Technical Annex to the BUR (2020)

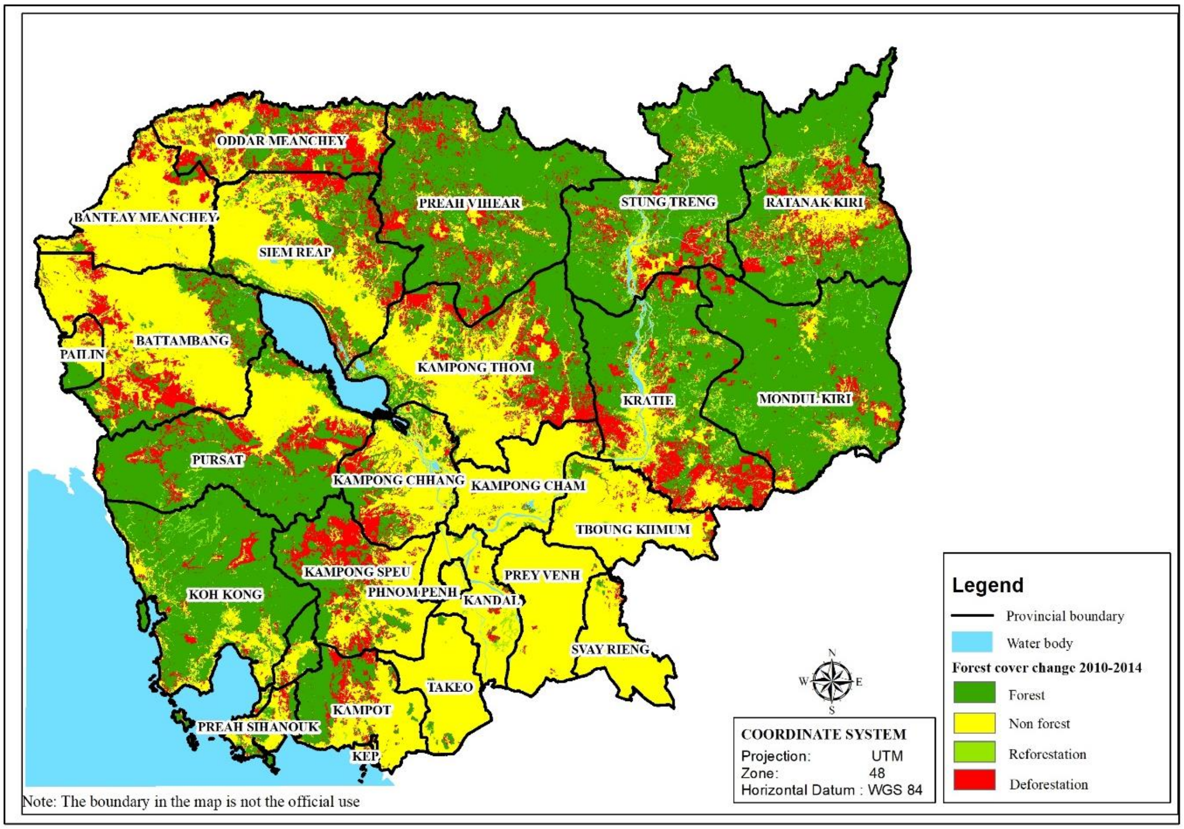


Figure 3. FCC Map 2010-2014. Source: MoE.

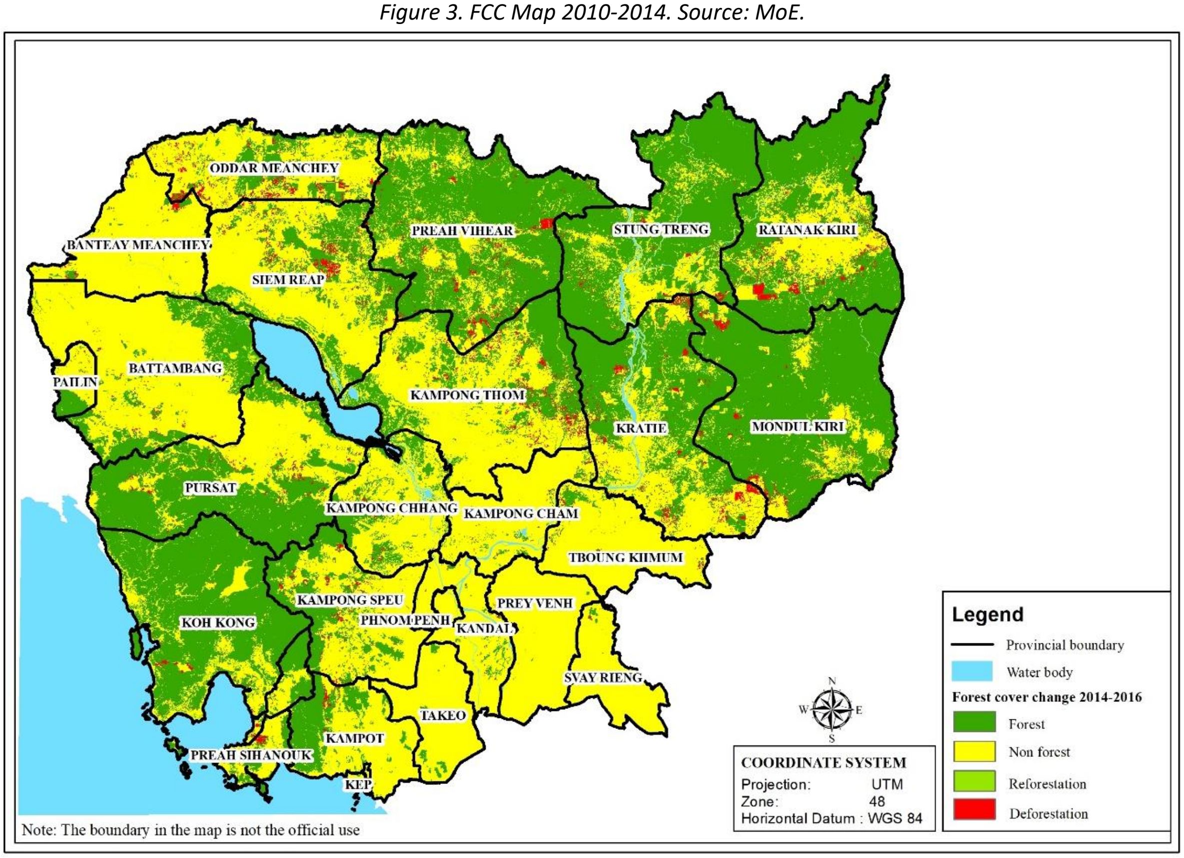


Figure 4. FCC Map 2014-2016. Source: MoE.

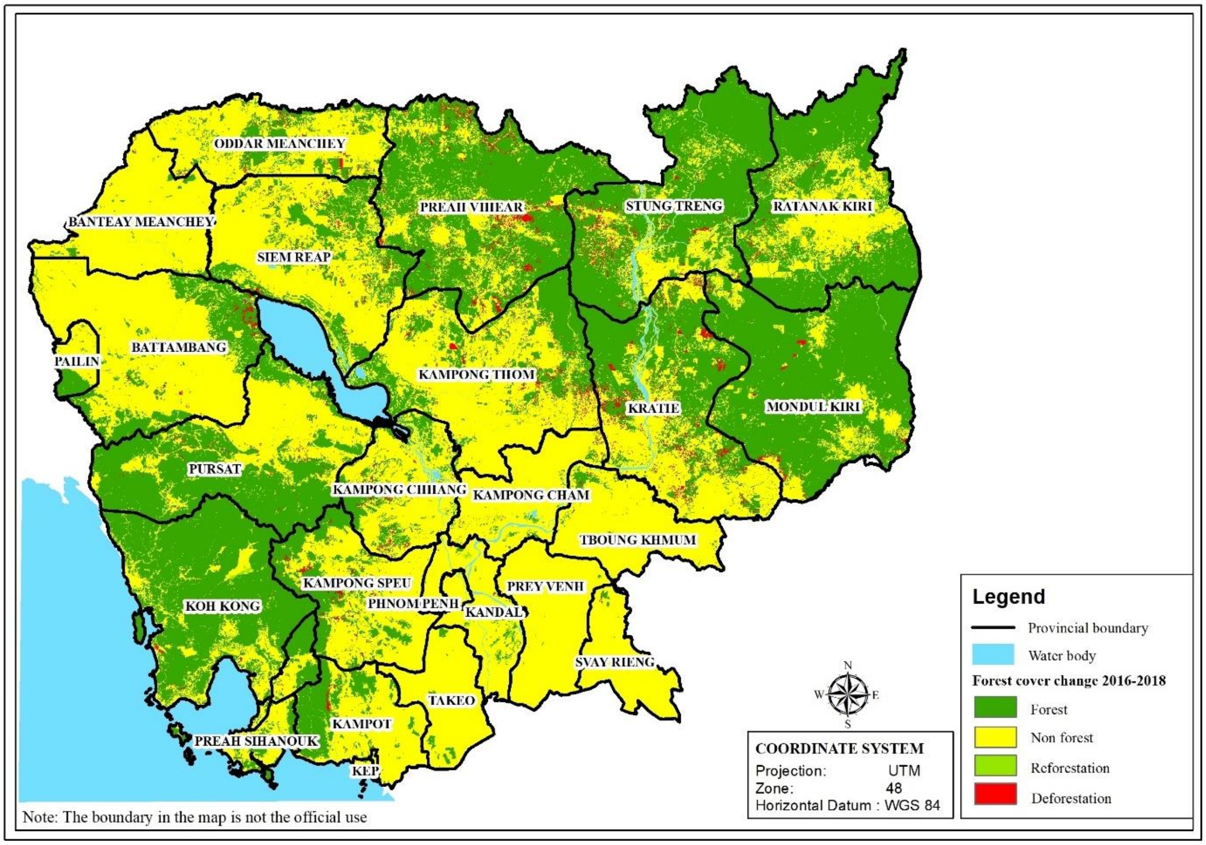


Figure 5. FCC Map 2016-2018. Source: MoE.

3.2 REFERENCE DATA

During the first quarter of 2019, the MRV team effectuated a campaign to collect reference data, called Mapathon. The purpose of the mapathon was to understand the drivers of deforestation at different spatial scales. Besides, the MRV team adapted this dataset to estimate the accuracy and uncertainty of the FCC Maps.

The reference data was generated from the visual and spectral interpretation of land use for each year, throughout the period 2001-2018. The information was collected in a central database, where each sample plot represents a 0,5 ha. The MRV team use Collect Earth and Google Earth Engine to integrate multitemporal high-resolution image, together with the time-series of each sample based on Landsat

3.2.1 Sampling Design

The sampling design was based on a systematic grid with some densification areas to better describe the drivers of land cover change. Since the deforestation in the period 2010-2014 was much higher than in the subsequent periods, the original grid was only densified around the forest area change of the periods 2014-2016 and 2016-2018.

The total plots collected were 8,917. The protocol for selecting the plots was based on the following systematic samplings:

- **NFI Grid**: A regular 6x6 km grid designed for the implementation of the National Forest Inventory. After Quality Control, 4.921 plots were available.
- **DEF14-16 Grid**: An intensified sampling grid in a 4 km buffer from deforested areas identified in the 2014-2016 FCC Map. After Quality Control, 1.474 plots were available.
- **DEF16-18 Grid**: An intensified sampling grid within deforested areas identified in the 2016-2018 FCC Map. After Quality Control, 2.522 plots were available.

The Figure 6 is represented the area covered by each of the sampling and Figure 7 represents the location of each plot by sampling..

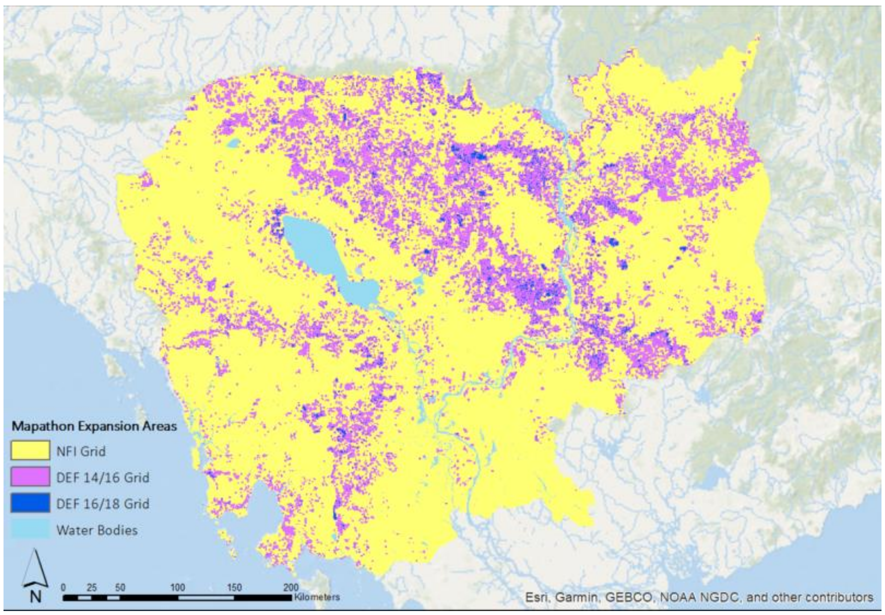


Figure 6. Expansion area by sampling grid. Each color represent the area covered by each of the GRIDs

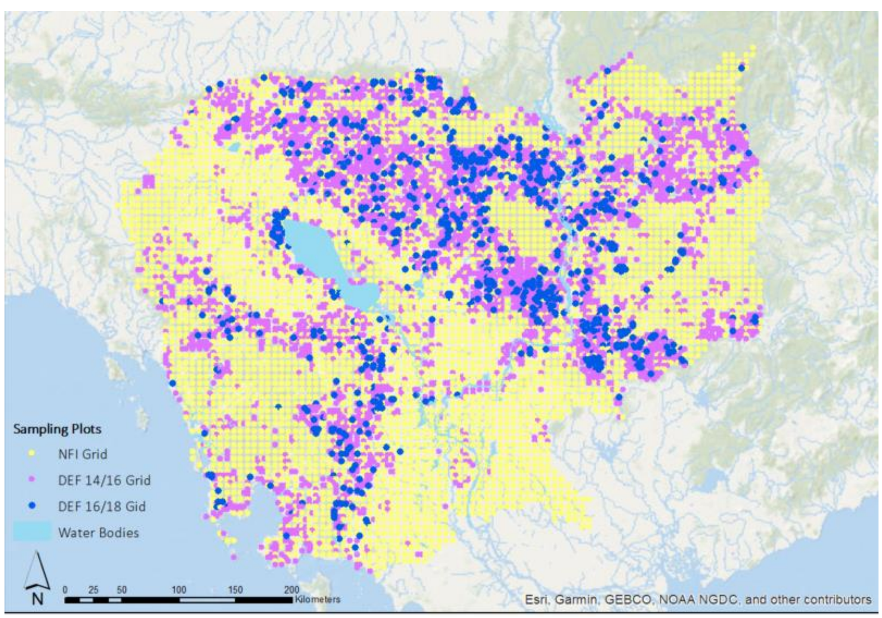


Figure 7. Plots by sampling grid. Each point represents a plot; the color indicates the corresponding GRID.

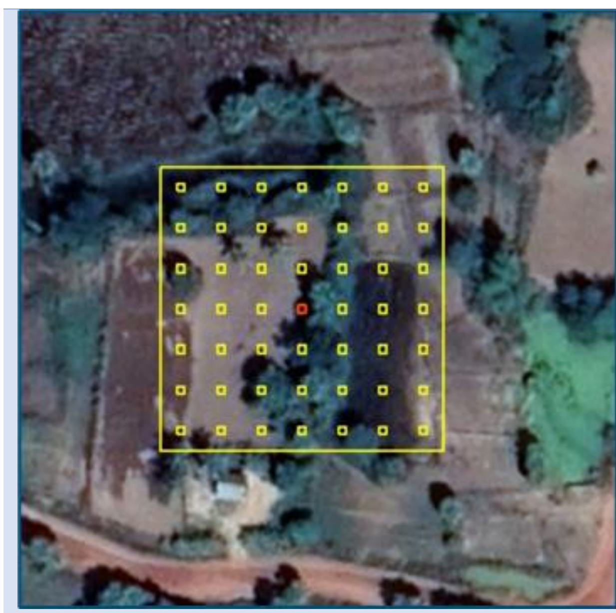
3.2.2 Response Design

The data collection was conducted by a group of 20 interpreters from the Ministry of Environment (MoE), Ministry of Agriculture (MAFF), Forestry Administration (FA), Fishery Administration (FiA), Royal University of Phnom Penh, SERVIR Mekong, FAO and UNDP.

The survey to collect the land use information of each plot from 2005 to 2019 (Figure 8) was designed in Collect Earth.

Collect earth was synchronized with Earth Engine and with the tree canopy cover developed by the University of Maryland[20] to select the appropriate land cover and the land cover change.

Example of the Collect Earth Survey
Land use of 2019
Type (IPCC) and subtype of land use
Land use change
Year of land use change
Elements inside the plot
Year of the image.



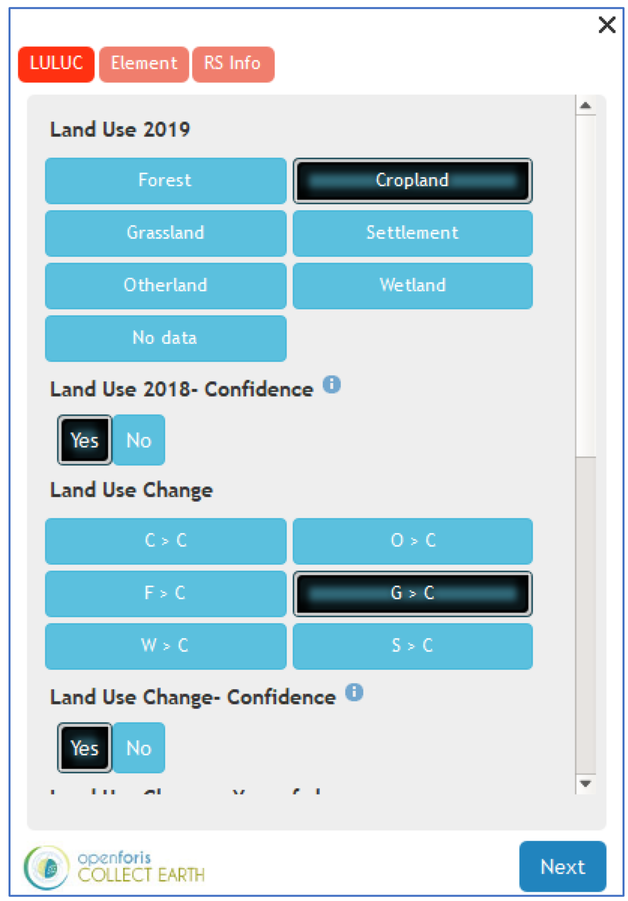


Figure 8. Collect Earth survey used to carry out the spatial response

A reference label protocol was defined to avoid bias due to different interpretation criteria. Having a general approach to classify the land-use was a key factor to ensure all interpreters follow the same rules

[20] The time-series of the Tree canopy cover and the Landsat spectral reponse of each plot is available in *https://glad.umd.edu/Potapov/Cambodia/Samples_UNDP/index.html*

to label the reference data, a hierarchy system was proposed, where if a minimum area inside the plot corresponded to the first category on the list, the plot will be labelled with this class. If the area was lower, the interpreter looks for the class on the list that covers the minimum area required. Following the IPCC good practices, Settlement and Cropland classes are above Forest, because both are anthropogenic land-use. The thresholds of the classes are detailed in Table 2.

Table 2. Reference label protocol hierarchy system and thresholds.

Class	Rank	Threshold
Settlement	1	20%
Cropland	2	20%
Forest	3	10%
Grassland	4	20%
Wetland	5	20%
Otherland	6	20%

Box 1. Example of Reference Label Protocol.

Plot classified as Settlement

Type : Village

Collect Earth plot design

Each control dot = 2% of the total plot

Classification of the control dots:
Settlement
Cropland
Forest land
Grassland
Wetland
Otherland

Plot classified as Forest Land

Type : Plantation
Subtype : Coniferous plantation

Collect Earth plot design

Each control dot = 2% of the total plot

Classification of the control dots:
Settlement
Cropland
Forest land
Grassland
Wetland
Otherland

3.3 ANALYSIS PROTOCOL

The analysis allows the conversion of the information contained in the comparison of the map and reference data into accuracy and area estimates. Most of the calculations are based on the error matrix, which contrasts the maps and the reference classification (FAO, 2016). The error matrix is a simple cross-tabulation of the class labels allocated by the classification of the map against the reference data for the sample plots, summarizing the results and quantifying the accuracy and area (Olofsson et al., 2014).

Since a systematic sampling design was used, the reference data absolute counts, $\mathrm{n_{ij}}$, can be converted into estimated area proportions, $\hat{\mathrm{p}}_{\mathrm{ij}}$, using Equation 1:

Equation 1. Olofsson et al., 2014

$$\hat{\mathrm{p}}_{\mathrm{ij}} = \mathrm{W_i}\frac{\mathrm{n_{ij}}}{\mathrm{n_i}}$$

Where $\hat{\mathbf{p}}_{\mathbf{ij}}$ represents the proportion of area for the population that has map class *i* and reference class *j*, and $\mathbf{W_i}$ is the proportion of area classified as class *i*.

Together with information on accuracy and uncertainty (further discussed on the Uncertainty Analysis chapter), the error matrix provides the basis to adjust the area estimation obtained from the maps.

The estimation was based on the proportion of area derived from the reference classification, $\boldsymbol{p_{.k}}$, because it is considered that should have smaller bias than the proportion mapped classification, $\boldsymbol{p_k}$.

The estimator is the sum of the estimated area proportions of class *k* as determined from the reference classification (Equation 2).

Equation 2. Olofsson et al., 2014

$$\hat{\mathrm{p}}_{.\mathrm{k}} = \sum_{\mathrm{i}=1}^{\mathrm{q}} \mathrm{W_i}\frac{\mathrm{n_{ik}}}{\mathrm{n_i}}$$

For the stratified estimator of proportion of area (Equation 2), the standard error is estimated by:

Equation 3. Olofsson et al., 2014

$$\boldsymbol{S(\hat{p}_{.k})} = \sqrt{\sum_i \frac{\boldsymbol{W_i \hat{p}_{ik} - \hat{p}_{ik}^2}}{\boldsymbol{n_i - 1}}}$$

Where $\boldsymbol{\hat{p}_{ik}}$ is the sample count at cell $\boldsymbol{i}, \boldsymbol{k}$ in the error matrix, $\boldsymbol{W_i}$the area proportion of map class $\boldsymbol{i}$,and the summation is over the q classes. The estimated area of class $\boldsymbol{k}$ is $\boldsymbol{\tilde{A}_k = A \times \hat{p}_k}$, where $\boldsymbol{A}$ is the total map area. The standard error of the estimated area is given by:

Equation 4. Olofsson et al., 2014

$$\boldsymbol{S(\hat{A}_{.k}) = A \times S(\hat{p}_{.k})}$$

An approximate 95% confidence interval is obtained as $\boldsymbol{\tilde{A}_k \pm 1.96 \times S(\hat{A}_{.k})}$

3.4 RESULTS

The result of labelling the samples and the quality control was stored in a central database and exported in excel format to the final analysis. To estimate AD, it was decided to use all available plots that correspond to the three reference data grid collected during the Mapathon: 1) 4.921 plots corresponding to NFI grid, 2) 1.474 plots on an intensified sampling grid in a 4 km buffer from deforested areas in the 2014-2016 period, and 3) 2.522 plots on an intensified sampling grid within deforested areas in the period 2016-2018.

3.4.1 *Integrating the samples with the expansion area map.*

To integrate the information from different grids, it was necessary to carry out a pre-stratification. Thus, the first step was to weight the total area of the country, using the map presented in Figure 6, into three first-order strata (pre-stratification), corresponding to the area covered by each grid. Then, the area for each land cover class in the map was calculated by strata, and the reference data was categorized by these first-order strata (grid).

As a result each sample has a final class code as follow:

0: Sample in stable forest area
1: Sample in an area high probability of change (2014-2016)
2: Sample in an area high probability of change (2016-2018)

3.4.2 *Post-stratification*

In a second step, the pre-stratified map was subdivided into the most representative Forest Types in Cambodia:

- Evergreen Forest,
- Semi-evergreen Forest,
- Deciduous Forest,
- Other Forests.

Other forest types class aggregates the following sub-categories from FCC maps and Reference Data: Pine forest, Mangrove, Rear mangrove, Flooded Forest, Forest regrowth, Pine plantation, and Tree plantation.

As a result of this stratification, 21 classes were created:

- Forest remaining Forest within strata 0, strata 1, and strata 2;
- Evergreen Deforestation within strata 0, strata 1, and strata 2;
- Semi-evergreen Deforestation within strata 0, strata 1, and strata 2;
- Deciduous Deforestation within strata 0, strata 1, and strata 2;
- Other Forest Deforestation within strata 0, strata 1, and strata 2;
- Reforestation within strata 0, strata 1, and strata;
- Non-Forest remaining Non-Forest within strata 0, strata 1, and strata 2;

3.4.3 *Estimation of accuracy, area and confidence intervals.*

Overall accuracy of LCC Maps was 72.7% for 2010-2014, 77.5% for 2014-2016, and 76.8% for 2016-2018. Producer and user accuracy for stable lands (forest remaining forest and non-forest remaining non-forest) is within the range from 44% to 96% across all periods. In the case of deforestation highest user accuracy was 47.6% for deforestation of Evergreen forest in strata "1", during the period 2010-2014. The highest producer accuracy was 53.3% for the same period and forest type.

The overall accuracy adjusted (to the proportion of area for each class), increases in all the periods: 80.0% for the period 2010-2014, 86.4% for 2014-2016, and 87.1% for 2016-2018. However, the producer accuracy was low in the cases of deforestation classes.

Based on proportion matrix analysis, the area for each class was recalculated and the Confidence Interval estimated. The estimated proportion area for each period are presented in tables 3, 4 and 5. These results demonstrate that the deforestation trend is decreasing in Cambodia. Detailed information on error matrix, proportion matrix and variance matrix are presented in the Annex 1.

Table 3. Estimated proportions of area for the period 2010-2014

MAP1014	AREA(Ha)	AREA Prop	AREA estimate	CI (ha)	CI (%)
F > F 0	5,900,604	33.22%	9,065,965	127,048	1.4%
F > F 1	1,975,597	11.12%			
F > F 2	258,530	1.46%			
E>NF 0	305,832	1.72%	407,626	45,946	11.3%
E>NF 1	289,765	1.63%			
E>NF 2	-	0.00%			
Se>NF 0	169,731	0.96%	175,652	35,279	20.1%
Se>NF 1	123,664	0.70%			
Se>NF 2	-	0.00%			
D>NF 0	673,771	3.79%	566,048	64,618	11.4%
D>NF 1	465,230	2.62%			
D>NF 2	-	0.00%			
Of>NF 0	195,268	1.10%	99,301	31,530	31.8%
Of>NF 1	93,894	0.53%			
Of>NF 2	-	0.00%			
NF>F 0	218,099	1.23%	9,020	8,329	92.3%
NF>F 1	145,370	0.82%			
NF>F 2	19,877	0.11%			
NF > NF 0	6,631,075	36.51%	7,801,746	132,721	1.7%
NF > NF 1	694,368	3.82%			
NF > NF 2	-	0.00%			
TOTAL	18,160,674	100.00%	18,160,674		

Table 4. Estimated proportions of area for the period 2014-2016

MAP1416	AREA(Ha)	AREA Prop	AREA estimate	CI (ha)	CI (%)
F > F 0	6,118,476	34.45%	8,582,481	128,828	1.5%
F > F 1	1,757,232	9.89%			
F > F 2	278,407	1.57%			
E>NF 0	68	0.00%	139,934	21,939	15.7%
E>NF 1	112,374	0.63%			
E>NF 2	-	0.00%			
Se>NF 0	14	0.00%	80,718	19,443	24.1%
Se>NF 1	36,718	0.21%			
Se>NF 2	-	0.00%			
D>NF 0	24	0.00%	246,278	42,903	17.4%
D>NF 1	149,019	0.84%			
D>NF 2	-	0.00%			
Of>NF 0	122	0.00%	33,636	16,194	48.1%
Of>NF 1	65,625	0.37%			
Of>NF 2	0	0.00%			
NF>F 0	20,211	0.11%	4,491	7,356	163.8%
NF>F 1	7,856	0.04%			
NF>F 2	-	0.00%			
NF > NF 0	7,955,467	43.81%	9,026,848	135,366	1.5%
NF > NF 1	1,659,064	9.14%			
NF > NF 2	-	0.00%			
TOTAL	18,160,674	100.00%	18,160,446		

Table 5. Estimated proportions of area for the period 2016-2018

MAP1618	AREA(Ha)	AREA Prop	AREA estimate	CI (ha)	CI (%)
F > F 0	6,137,818	34.56%	8,203,692	129,571	1.6%
F > F 1	1,763,551	9.93%			
F > F 2	-	0.00%			
E>NF 0	0	0.00%	90,927	23,959	26.4%
E>NF 1	112	0.00%			
E>NF 2	64,733	0.36%			
Se>NF 0	-	0.00%	42,081	15,653	37.2%
Se>NF 1	79	0.00%			
Se>NF 2	32,464	0.18%			
D>NF 0	23	0.00%	201,158	39,735	19.8%
D>NF 1	567	0.00%			
D>NF 2	132,093	0.74%			
Of>NF 0	844	0.00%	51,753	21,867	42.3%
Of>NF 1	779	0.00%			
Of>NF 2	49,116	0.28%			
NF>F 0	16,779	0.09%	1,813	2,565	141.5%
NF>F 1	2,334	0.01%			
NF>F 2	-	0.00%			
NF > NF 0	7,938,916	43.71%	9,527,735	132,677	1.4%
NF > NF 1	2,020,465	11.13%			
NF > NF 2	-	0.00%			
TOTAL	18,160,674	100%	18,159,694		

4 EMISSION FACTORS[21]

Currently, Cambodia has not a National Forest Inventory to provide unbiased estimates of carbon stocks and Emission Factors (EF) at the national scale. However, as an alternative, most project-based forest inventory data has been collected by the government of Cambodia in partnership with different institutions providing estimates of forest biomass across the country (Sola, Vanna, Vesa, Van Rijn, & Henry, 2014).

In order to update the information presented in the First Reference Level, Cambodia collected new data to increase the quality of EF by forest type(Sola, Van Rijn, & So, 2019). Such information is the data source for the emission factors used in the Second FRL.

Data from all plots were harmonized by selecting relevant information from project files, adding forest type and wood density information, and estimating tree height and aboveground biomass with a common set of allometric equations.

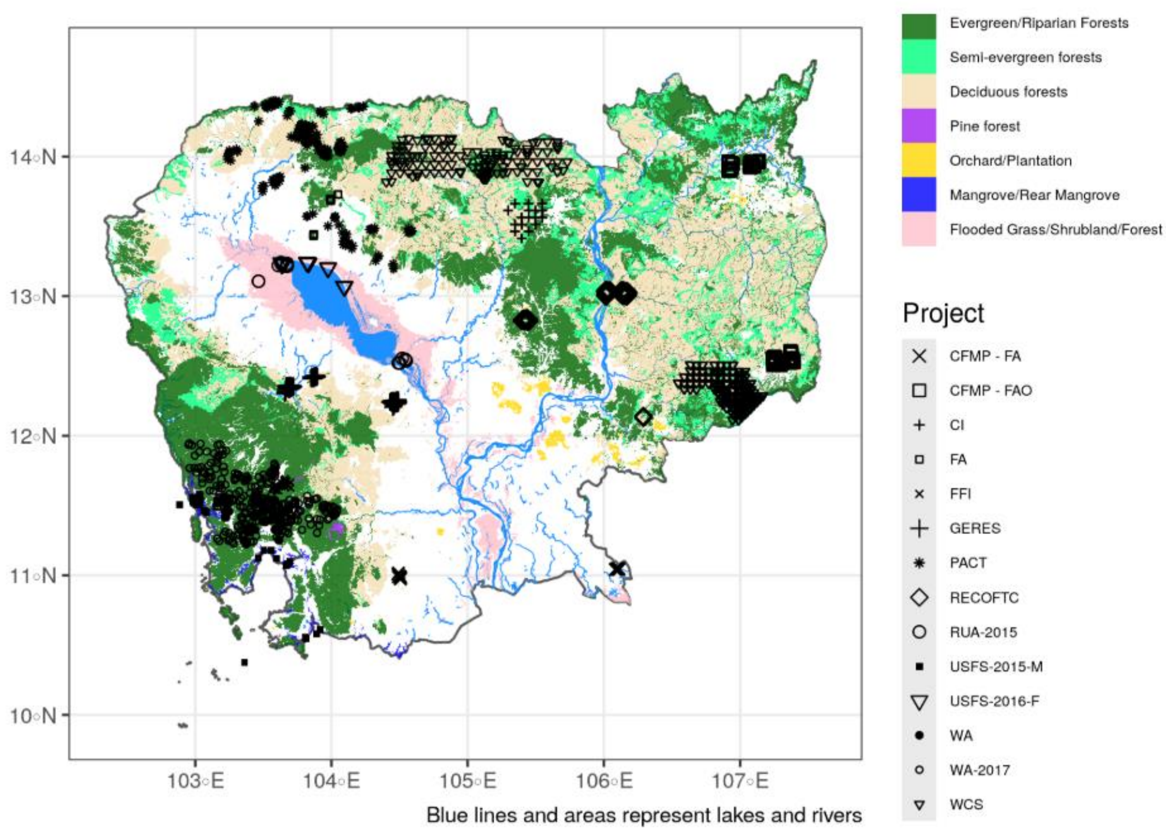


Figure 9. Distribution of forest inventory plots used to develop EF. Source: FAO 2019.

[21] Information in this section is based on the annex 3 and annex 4

Table 6. Summary of existing forest inventory data in Cambodia.

Project	Year (approx)	Plot size (m2)	Number of plots	Number of trees
FA-PSP	1998	2500.00	20	545
FA-CF	2010	2500.00	20	1268
CFMP - FA	2012	2500.00	40	2717
CI	2013	1256.64	51	1056
WCS-KP/PV	2011	3769.91	118	7096
WCS-SEIMA	2009	1256.64	308	7819
WCS-Cherndar	2004	5000.00	15	1465
WA	2010	10000.00	105	20657
WA-2017	2017	707.00	247	7837
FFI	2011	615.75	71	1476
GERES	2012	600.00	349	3648
RECOFTC	2011	5000.00	249	10564
PACT	2009	2500.00	201	14045
FAO-CF	2012	5000.00	218	16485
RUA-Tonle Sap	2015	1500.00	18	325
USFS-2015-M	2015	2500.00	48	6206
USFS-2016-F	2016	380.00	33	1206

The forest inventory data, detailed in Table 6 and Figure 9, was provided by the following institutions:

- Forest Administration (FA): 40 plots from the Permanent Sampling Plots (PSP) system in Koh Kong and Siem Reap provinces, and 40 plots from Community Forest (CF) projects located in Kampot and Svay Rieng provinces,
- Conservation International (CI): 51 plots from Prey Long REDD+ project.
- Wildlife Conservation Society (WCS): 57 plots from the Kulen Promtep Wildlife Sanctuary, 61 plots from Preah Vihear Protected Forest, 308 plots form the Seima REDD+ Project, and 15 plots from Cherndar logging company.
- Wildlife Alliance (WA): 105 plots from Southern Cardamoms REDD+ Project from 2014, and 247 plots from 2017.
- Fauna & Flora International (FFI): 71 plots from Siem Reap Community Forestry REDD+ project.
- Groupe Energies Renouvelables Et Solidarités (GERES): 349 plots from Community Forest Projects in Kampong Chnang and Pursat provinces.
- RECOFTC: 249 plots from Kratie and Kampong Thom provinces
- Pact International: 151 plots from Oddar Manchey REDD+ project and 51 plots from Siem Reap provinces
- FAO: 218 plots from Community Forest projects in Kratie, Mondolkiri, Ratanakiri and Stung Treng provinces-
- Royal University of Agriculture (RUA): 18 plots collected in the Tonle Sap flooded forests.
- United States Forest Service (USGS): 48 plots collected on mangrove forests and 33 plots collected in the Tonle Sap flooded forests.

The 2007 vegetation map from MoE and the Land Use Map from 2016 were used to identify forest types at the plot level.

Wood density was added to the tree-level data based on species and genus averages from the Global Wood Density (GDW) Database ((Jerome Chave et al., 2009);(Zanne et al., n.d.)). The data from Southeast Asia and Southeast Asia Tropical were selected, and averages calculated for each species and genus. Wood density for each tree was based on species if available in the GWD, genus if species were not available, or a default value of 0.57 g/cm3 if both species and genus were unknown, not recorded or not in the data. The default value was based on a wood density average for Tropical Asia in Reyes et al. (Reyes, Gisel, Sandra Brown, Jonathan Chapman, 1992).

When not recorded in the field, tree height was estimated using forest type based allometric equations, developed with the other available data on tree H and DBH (Table 7).

Table 7. Developing tree height-diameter allometric equations .

Forest type 'mix'	Model
Community land	H = 1.3 + 14.3706 * (1 - exp(-0.0407 * DBH^0.8198))
Deciduous	H = 1.3 + 21.986 * (1 - exp(-0.0407 * DBH^0.8198))
Evergreen	H = 1.3 + 29.9423 * (1 - exp(-0.0407 * DBH^0.8198))
Flooded forest	H = 1.3 + 18.6158 * (1 - exp(-0.0407 * DBH^0.8198))
Mangrove	H = 1.3 + 36.8175 * (1 - exp(-0.0407 * DBH^0.8198))
Semi-evergreen	H = 1.3 + 29.0446 * (1 - exp(-0.0407 * DBH^0.8198))

Aboveground biomass was estimated using different allometric equations for different forest types or species for mangrove. The equation from Chave et al. (Jérôme Chave et al., 2014) was applied to evergreen forest, the equation developed in Cambodia for upland forest (Kim, Sola, et al. 2019) was used for semi-evergreen and deciduous forest, as well as community land and non-forest. The equation developed in Cambodia for flooded forest (Kim, S., S. Horn, T. So, G. Sola, 2019) was applied to flooded forest data and species specific equations were applied to mangrove forest, based on the SWAMP protocol (Kauffman, J.B., 2012) and the report from USFS on the methodology to calculate mangrove carbon stock in Cambodia.

Trees' aboveground biomass was summed to plot level and converted to ton per hectare. Given that most projects covered different areas, a simple average was used. A 95 % confidence interval was calculated with the forest type average aboveground biomass. The carbon stocks were finally calculated as the sum of aboveground and belowground biomass multiplied by conversion factors:

Equation 5. Conversion from AGB to Carbon Stock

$$\mathrm{C_{stock}} = \mathrm{AGB} * (1 + \mathrm{RS}) * \mathrm{CF} * 44/12$$

Where:

- RS: Root-to-shoot ratio. Different root-to-shoot ratios were applied to the different forest types: 0.49 for mangrove (IPCC 2013), 0.37 for evergreen forest (IPCC 2006) and 0.2 for all other types (IPCC 2006).
- CF: Carbon fraction, using the carbon fraction value 0.47 (IPCC 2006)

- 44/12: Atomic mass conversion from carbon to CO2.

Table 8. Allometric equations applied to estimate Aboveground biomass.

Forest type	Equation
Evergreen	AGB = 0.0673 * (DBH^2 * H * WD)^ 0.976
Semi-evergreen	AGB = 0.0607 * DBH^2.2692 * H^0.5122 * WD^0.3183
Deciduous	AGB = 0.0607 * DBH^2.2692 * H^0.5122 * WD^0.3183
Community land	AGB = 0.0607 * DBH^2.2692 * H^0.5122 * WD^0.3183
Non forest	AGB = 0.0607 * DBH^2.2692 * H^0.5122 * WD^0.3183
Flooded forest	AGB = 3238.2787 * (1 - exp(-0.00000837 * (DBH^2 * H)))
Mangrove	
Avicennia alba	AGB = 0.1848 * DBH^2.3524
Avicennia marina	AGB = 0.1848 * DBH^2.3524
Bruguiera cylindrica	AGB = 0.0754 * WD * DBH^2.505 + 0.0679 * DBH^1.4914
Bruguiera gymnorhiza	AGB = 0.0754 * WD * DBH^2.505 + 0.0679 * DBH^1.4914
Rhizophora apiculata	AGB = 0.043 * DBH^2.63
Rhizophora mucronata	AGB = 0.043 * DBH^2.63
Rhizophora sp.	AGB = 0.043 * DBH^2.63
Sonneratia alba	AGB = 0.3814 * WD * DBH^2.101 + 10^(-1.1679 + 1.4914 * log10(DBH))
Sonneratia ovata	AGB = 0.3814 * WD * DBH^2.101 + 10^(-1.1679 + 1.4914 * log10(DBH))
Xylocarpus granatum	AGB = 0.3814 * WD * DBH^2.101 + 10^(-1.1679 + 1.4914 * log10(DBH))
Xylocarpus moluccensis	AGB = 0.3814 * WD * DBH^2.101 + 10^(-1.1679 + 1.4914 * log10(DBH))
Other mangrove species	AGB = 0.251 * WD * DBH^2.46

4.1 Updated Emission Factors by forest class.

Based on the information described above the "*table 4-4: Estimation of above-ground biomass (ton ha-1) by forest types in Cambodia*" of the first Forest Reference Level was updated as follow:

Table 9. Estimation of above-ground biomass (ton ha-1) by forest types in Cambodia

Forest type	AGB ton ha-1	R	BGB	C ton ha-1 *	CO^2 ton ha-1**	Source
Evergreen forest	133.12	0.37	49.25	85.72	314.29	FAO 2019
Semi-evergreen forest	165.23	0.20	33.05	93.19	341.70	FAO 2019
Deciduous forest	70.87	0.20	14.17	39.97	146.56	FAO 2019
Forest regrowth	75.00	0.20	15.00	42.30	155.10	CFI (2008) cited in Sar (2010)
Flooded forest	79.73	0.20	15.95	44.97	164.88	FAO 2019
Tree plantation	100.00	0.20	20.00	56.40	206.80	IPCC (2003), MoE/UNDP (2003)
Pine plantation	100.00	0.20	20.00	56.40	206.80	IPCC (2003), MoE/UNDP (2003)
Mangrove	95.25	0.49	46.67	66.70	244.58	FAO 2019
Rear mangrove	165.00	0.49	80.85	115.55	423.68	Tran (2015)
Bamboo* **	0.00	0.20	0.00	0.00	0.00	(Nil)

**0.47 was used as Carbon fraction (ton C /ton d.m.) from the default value in IPCC (2006b).*
***One carbon equals 44/12 carbon dioxide.*
****Bamboo=0, mean that area land cover represented bamboo class are very small*

4.2 EFs used in the Second FRL.

To be aligned with the activity data's stratification the emission factors (EF) of Evergreen, Semi-evergreen, and Deciduous Forest were utilized in combination with Forest Types stratification of the activity data.

In the case of the class "Other Forest", the EF was derived from the weighted average of forest classes that had not enough samples in the activity data Table 10.

Table 10. forest type used to estimate the AGB and BGB for "Other Forest"

Class	10-14	14-16	16-18	Def Area Mean	Def Area %	AGB	BGB	C Stock	CO2	CI	SQ_prod CI Mean
Bamboo	3392.55	3202.02	2,059	2,885	7%	-	-	-	-	50%	-
Mangrove	447.26	628.79	34	370	1%	95	47	66.70	245	19%	0.163
Flooded forest	29270.12	5392.35	8,758	14,473	34%	80	16	44.97	165	17%	90.745
Forest regrowth	35741.52	20533.95	11,511	22,596	53%	75	15	42.30	155	50%	1,692.986
Pine forest	0.00	0.00	5	2	0%	100	20	56.40	207	50%	0.000
Pine plantation	0.00	55.31	3	19	0%	100	20	56.40	207	50%	0.002
Tree plantation	1349.71	2500.70	2,877	2,242	5%	100	20	56.40	207	50%	29.644
Total	**70,201**	**32,313**	**25,247**	**42,587**							

The final EFs used to construct the Forest Reference Level and its respective CI´s are detailed in Table 11.

Table 11. Forest Types Deforestation National EF

Forest type	# plots	AGB	BGB	Total Biomass	Total Carbon	Total CO2e	CI (%)
Deciduous	132	70.87	14.17	85.04	39.97	146.55	10%
Evergreen	446	133.12	49.26	182.38	85.72	314.30	5%
Semi-evergreen	49	165.23	33.05	198.28	93.19	341.70	19%
Other Forest	54	73.03	14.85	87.88	41.30	151.43	0%

In order to obtain the EFs of "Other forest", the AGB and BGB values of each classed were obtain by summing the products of the deofretsation area and the biomass using the Equation 6:

Equation 6. sum of AGB and BGB

$$\sum_{i}^{Class} Biomass_i * (Def\ Area\ \%)_i$$

Where:

$Biomass_i$ = above-ground biomass (AGB), below -ground biomass (BGB) of each class.

Def Area $\%_i$ = Proportion of the deforestation area of each class respect of the total deforestation area.

To obtain the uncertainty, the Equation 7 was used

Equation 7. Eq. 3.2 IPCC 2006.

$$U_{total} = \sqrt{\frac{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}{|x_1 + x_2 + \cdots + x_n|}}$$

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). This term ‘uncertainty’ is thus based upon the 95 percent confidence interval.

x_i and U_i = the uncertain quantities and the percentage uncertainties associated with them, respectively.

5 UNCERTAINTY ANALYSIS

Accuracy and precision of the FRL estimation are following analyzed, including the sources of non-systematic error or bias, and the precision of results based on the confidence interval of AD and EF.

5.1 SOURCES OF SYSTEMATIC ERROR

Several sources of systematic error or bias could affect the accuracy of the FRL. The most relevant sources identified has been the following:

Regarding AD, besides the error in the maps and its uncertainty, which was estimated and reported in the uncertainty propagation, the interpretation of reference data has been identified as the significant risk of bias.

During the collection of reference data, several interpreters analyze high spatial resolution satellite imagery from 2001 to 2019 to identify the land use and the land use changes.

Different criteria during the interpretation could provoke errors in the data collected. To minimize the potential error, a reference label protocol, described in the above section “Activity Data”, was implemented.

Further, a Quality Control procedure was established to avoid errors and to analyze mismatches during this activity. A random subset of 585 plots was independently assessed by three different interpreters, the overall average correspondence when the three interpreters agree on the classification was 79.7% (88.1% for the forest, and 66% for non-forest)., the overall average correspondence when there was an agreement between the interpreter and one reviewer was 97.9% (95.7% for the forest and 90.0% for non-forest).

In the case of the EF, the distribution of forest inventory was identified as the most critical risk of bias. As explained in the above section “Emission Factors”, Cambodia has not implemented an NFI yet, however, the country has managed to gather information from various local forest inventories associated with specific projects. Out 627 inventory plots, used to estimate EF for the forest types Evergreen, Semi-evergreen and Deciduous, 607 are located inside protected areas, which includes 358 plots inside REDD+ projects. Considering that, generally, 1) the forests located inside protected areas have a higher biomass density, and 2) the deforestation rate inside protected areas is notably lower than outside them, hence, there are a high risk of oversized EFs and, therefore, to overestimate emissions. To minimize the overestimation risk, as explained above, plots collection from the very high-value forest were removed from the final forest carbon stocks.

Another important element related to the EF´s bias is the information missed or not collected due to the different forest inventory methods applied. To apply the allometric equation used in the EF´s estimation, information from diameter at the breast height (DBH) and tree height is needed. However, several collected data do not include information on tree height. When this information is missed, an H-D model by forest type was developed and applied, using information from 8059 trees for model development and 4035 trees for validation. The model had a 17% bias overall and less than 20% bias in all forest type classes.

Table 12. The bias of the H-D models.

Forest Type	Bias (%)
Evergreen	18
Deciduous	15
Semi-evergreen	17
Overall	17

5.2 UNCERTAINTY PROPAGATION

Confidence Intervals for AD and EFs developed to estimate the FRL were evaluated and reported in their corresponding sections. Then both Confidence Interval were combined to propagate the uncertainty. Uncertainty propagation was developed following Approach 1 from IPCC (2006). The Approach 1 analysis estimates uncertainties by using the error propagation equation in two steps:

In the first step the Equation 8. Eq. 3.1 from IPCC (2006) is used to combine emission factor and activity data.

Equation 8. Eq. 3.1 IPCC, 2006.

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2}$$

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.

In the second step the Equation 3.2 from IPCC (2006) is used to arrive at the overall uncertainty.

Equation 9. Eq. 3.2 IPCC 2006.

$$U_{total} = \sqrt{\frac{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}{|x_1 + x_2 + \cdots + x_n|}}$$

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). This term 'uncertainty' is thus based upon the 95 percent confidence interval.

x_i and U_i= the uncertain quantities and the percentage uncertainties associated with them, respectively.

Results by periods, strata, and propagation are presented together with the Second FRL options in the following section.

6 FRL RESULT

The Second FRL of Cambodia is calculated as the average of annual emissions during the reference period: 44.695.152 t CO_2eq/year ±12,09%.

The combination of AD and EF allow estimating annual emissions summarized in Table 12 and Figure 11

Table 13. Forest Reference Emission Level by option in Ton CO_2eq year

YEAR	FREL (t CO2e)	Deforestation (t CO2e)	Enhancement (t CO2e)	Historical emissions (t CO2e)	Uncertainty (%)
2010-2011	59,959,491	71,840,311	-350,231	71,490,080	**9.37%**
2011-2012	59,959,491	71,840,311	-350,231	71,490,080	**9.37%**
2012-2013	59,959,491	71,840,311	-350,231	71,490,080	**9.37%**
2013-2014	59,959,491	71,840,311	-350,231	71,490,080	**9.37%**
2014-2015	59,959,491	56,818,352	-354,265	56,464,087	**12.11%**
2015-2016	59,959,491	56,818,352	-354,265	56,464,087	**12.11%**
2016-2017	59,959,491	40,531,030	-137,313	40,393,717	**15.46%**
2017-2018	59,959,491	40,531,030	-137,313	40,393,717	**15.46%**
FREL	**59,959,491**	**60,257,501**	**-298,010**	**59,959,491**	**6.79%**

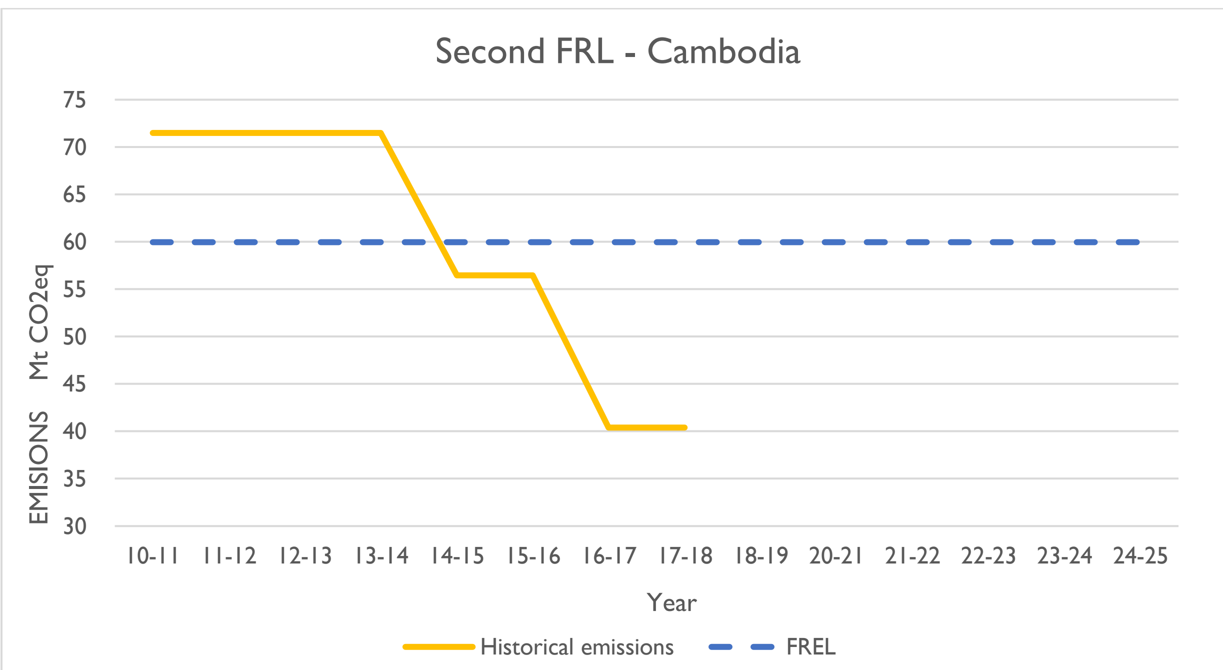


Figure 10. Comparison of historical emissions and FRL by option in Ton CO_2eq year

Table 14. Second FRL results and uncertainty.

PERIOD 2010-2014	AD ha year-1	Û AD %	EF CO2e ha -1	Û EF %	EMISSIONS CO2e year -1	Û combined %	Û comb/em %
Deforestation Evergreen forest	102,253	11.3%	314.30	5.0%	32,138,212	12.4%	5.5%
Deforestation Semievergreen forest	43,971	20.1%	341.70	19.0%	15,024,929	27.7%	5.8%
Deforestation Decidious forest	142,493	11.5%	146.55	10.0%	20,882,676	15.2%	4.4%
Deforestation Other forest	25,056	31.9%	151.44	25.0%	3,794,494	40.5%	2.1%
Deforestation	313,773	7.4%		8.2%	71,840,311		9.4%
Enhancement of Forest Carbon Stock	2,313	94.4%	-151.44	25.0%	-350,231	97.6%	97.6%
TOTAL EMISSIONS					**71,490,080**		9.4%

PERIOD 2014-16	AD ha year-1	Û AD %	EF CO2e ha -1	Û EF %	EMISSIONS CO2e year -1	Û combined %	Û comb/em %
Deforestation Evergreen forest	70,249	15.9%	314.30	5.0%	22,079,389	16.6%	6.5%
Deforestation Semievergreen forest	40,547	24.3%	341.70	19.0%	13,855,060	30.9%	7.5%
Deforestation Decidious forest	124,831	17.6%	146.55	10.0%	18,294,298	20.3%	6.5%
Deforestation Other forest	17,100	48.8%	151.44	25.0%	2,589,605	54.8%	2.5%
Deforestation	252,727	11.0%	-	8.2%	56,818,352		12.1%
Enhancement of Forest Carbon Stock	2,339	165.0%	-151.44	25.0%	-354,265	166.9%	166.9%
TOTAL EMISSIONS			-		**56,464,087**		12.1%

PERIOD 2016-18	AD ha year-1	Û AD %	EF CO2e ha -1	Û EF %	EMISSIONS CO2e year -1	Û combined %	Û comb/em %
Deforestation Evergreen forest	45,840	26.6%	314.30	5.0%	14,407,732	27.1%	9.6%
Deforestation Semievergreen forest	21,229	37.7%	341.70	19.0%	7,254,041	42.2%	7.6%
Deforestation Decidious forest	101,333	19.9%	146.55	10.0%	14,850,604	22.3%	8.2%
Deforestation Other forest	26,536	42.8%	151.44	25.0%	4,018,652	49.6%	4.9%
Deforestation	194,939	14.0%	-	8.2%	40,531,030		15.5%
Enhancement of Forest Carbon Stock	907	141.5 %	-151.44	25.0%	-137,313	143.6%	143.6%
TOTAL EMISSIONS			-		**40,393,717**		15.5%

7 SUMARY RESULTS

MAIN FEATURES OF THE FRL	
Proposed FRL	**59,959,491** tCO_2eq/year
Period	2010 - 2018
Uncertainty (%)	6,79%
Type and duration of FRL	FRL based on historical average emissions from 2010 to 2018
Adjustment for national circumstances	No
Scope	National FRL for the entire national territory
Activities included	Deforestation and enhancement of forest carbon stocks
Pools included	Above-ground biomass (AGB) and below -ground biomass (BGB). *Litter, deadwood and soil organic carbon are excluded due to the lack of data*.
Gases included	CO_2
Activity Data	Stratify Area Estimator method is applied.
Emission Factors	Estimated by several existing forest inventories in the country. EF by forest types were: • Evergreen forest: 314.30 • Semi-evergreen forest: 341.70 • Deciduous forest: 146.55 • Other forests: 151.43

8 AREAS OF IMPROVEMENT

Current existing information sources in Cambodia allow to improve the methods, and the report of the national FRL submitted in 2017.

Updating the FRL allows the country to have reliable information about the forest sector in the country today.

The Updated National FRL include several improvements regarding the previous submission:

- The activity data method has been modified to include in the report the best existing information in the country and to provide the information required to timely report uncertainty.
- EF´s have been refined and analyzed with greater rigour to avoid, as far as possible, the over or underestimation of emissions.
- Uncertainty analysis, including the uncertainty propagation and the description of sources of systematic error, has been included.

However, some areas for further technical improvement identified in the FRL Technical Assessment Report from 2017 has not been addressed yet:

- The country has not implemented the NFI to improve the national EFs.
- The country needs to collect data of litter, deadwood, and soil organic carbon pools to be included in the next FRL.
- Non-CO_2 gases have not been included in the Second FRL.

Results demonstrate that deforestation is decreasing in the country since the peak occurred in the period 2010-2014. Increase the accuracy and improve the national data, both to update AD and EF, would allow the country to develop focused policies and strategies to maintain this trend over time.

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Annex 1. Error matrix, proportion matrix and variance matrix.

Table 15. 2010-2014 error matrix, proportion matrix and variance matrix.

ERROR MATRIX 2010-2014

REFERENCE DATA

MAP DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>F	NF > NF	TOTAL	UA
F > F 0	**1,564**	1	1	8	1	-	55	**1,630**	96.0%
F > F 1	**1,816**	54	22	108	8	3	206	**2,217**	81.9%
F > F 2	**622**	27	17	63	4	-	138	**871**	71.4%
E>NF 0	33	**39**	11	3	3	-	20	**109**	35.8%
E>NF 1	64	**138**	33	11	6	-	38	**290**	47.6%
E>NF 2	-	**-**	-	-	-	-	-	**-**	0.0%
Se>NF 0	14	6	**6**	3	3	-	17	**49**	12.2%
Se>NF 1	42	23	**17**	15	3	-	26	**126**	13.5%
Se>NF 2	-	-	**-**	-	-	-	-	**-**	0.0%
D>NF 0	55	1	5	**48**	3	-	85	**197**	24.4%
D>NF 1	136	7	20	**120**	5	1	212	**501**	24.0%
D>NF 2	-	-	-	**-**	-	-	-	**-**	0.0%
Of>NF 0	26	-	-	1	**4**	-	18	**49**	8.2%
Of>NF 1	56	14	4	4	**7**	1	36	**122**	5.7%
Of>NF 2	-	-	-	-	**-**	-	-	**-**	0.0%
NF>F 0	42	-	-	-	-	**-**	10	**52**	0.0%
NF>F 1	133	-	-	5	2	**-**	50	**190**	0.0%
NF>F 2	25	-	-	2	-	**2**	9	**38**	5.3%
NF > NF 0	124	6	1	17	4	1	**1,577**	**1,730**	91.2%
NF > NF 1	168	16	4	31	8	-	**519**	**746**	69.6%
NF > NF 2	-	-	-	-	-	-	**-**	**-**	0.0%
TOTAL	**4,920**	**332**	**141**	**439**	**61**	**8**	**3,016**	**8,917**	
PA	81.3%	53.3%	16.3%	38.3%	18.0%	25.0%	69.5%		**Overall Acc.:**
PA_ADJ	82.3%	60.7%	21.3%	48.7%	21.5%	11.6%	82.9%		**72.7%**

PROPORTION MATRIX

REFERENCE DATA

MAP DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>E	NF > NF	TOTAL
F > F 0	**31.18%**	0.02%	0.02%	0.16%	0.02%	0.00%	1.10%	**32.49%**
F > F 1	**8.91%**	0.26%	0.11%	0.53%	0.04%	0.01%	1.01%	**10.88%**
F > F 2	**1.02%**	0.04%	0.03%	0.10%	0.01%	0.00%	0.23%	**1.42%**
E>NF 0	0.51%	**0.60%**	0.17%	0.05%	0.05%	0.00%	0.31%	**1.68%**
E>NF 1	0.35%	**0.76%**	0.18%	0.06%	0.03%	0.00%	0.21%	**1.60%**
E>NF 2	0.00%	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	**0.00%**
Se>NF 0	0.27%	0.11%	**0.11%**	0.06%	0.06%	0.00%	0.32%	**0.93%**
Se>NF 1	0.23%	0.12%	**0.09%**	0.08%	0.02%	0.00%	0.14%	**0.68%**
Se>NF 2	0.00%	0.00%	**0.00%**	0.00%	0.00%	0.00%	0.00%	**0.00%**
D>NF 0	1.04%	0.02%	0.09%	**0.90%**	0.06%	0.00%	1.60%	**3.71%**
D>NF 1	0.70%	0.04%	0.10%	**0.61%**	0.03%	0.01%	1.08%	**2.56%**
D>NF 2	0.00%	0.00%	0.00%	**0.00%**	0.00%	0.00%	0.00%	**0.00%**
Of>NF 0	0.57%	0.00%	0.00%	0.02%	**0.09%**	0.00%	0.39%	**1.08%**
Of>NF 1	0.24%	0.06%	0.02%	0.02%	**0.03%**	0.00%	0.15%	**0.52%**
Of>NF 2	0.00%	0.00%	0.00%	0.00%	**0.00%**	0.00%	0.00%	**0.00%**
NF>F 0	0.97%	0.00%	0.00%	0.00%	0.00%	**0.00%**	0.23%	**1.20%**
NF>F 1	0.56%	0.00%	0.00%	0.02%	0.01%	**0.00%**	0.21%	**0.80%**
NF>F 2	0.07%	0.00%	0.00%	0.01%	0.00%	**0.01%**	0.03%	**0.11%**
NF > NF 0	2.62%	0.13%	0.02%	0.36%	0.08%	0.02%	**33.28%**	**36.51%**
NF > NF 1	0.86%	0.08%	0.02%	0.16%	0.04%	0.00%	**2.66%**	**3.82%**
NF > NF 2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	**0.00%**	**0.00%**
	50.08%	**2.25%**	**0.97%**	**3.14%**	**0.55%**	**0.05%**	**42.96%**	**100.00%**
Area adj.	9,094,587	409,011	175,883	569,972	100,224	9,251	7,801,746	

VARIANCE MATRIX

REFERENCE DATA

MAP DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>E	NF > NF
F > F 0	**0.0003%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0002%
F > F 1	**0.0001%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
F > F 2	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
E>NF 0	0.0001%	**0.0001%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
E>NF 1	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
E>NF 2	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
Se>NF 0	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%
Se>NF 1	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%
Se>NF 2	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%
D>NF 0	0.0001%	0.0000%	0.0000%	**0.0001%**	0.0000%	0.0000%	0.0002%
D>NF 1	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%
D>NF 2	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%
Of>NF 0	0.0001%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0001%
Of>NF 1	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%
Of>NF 2	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%
NF>F 0	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%
NF>F 1	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%
NF>F 2	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%
NF > NF 0	0.0005%	0.0000%	0.0000%	0.0001%	0.0000%	0.0000%	**0.0006%**
NF > NF 1	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**
NF > NF 2	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**
TOTAL	**0.36%**	**0.13%**	**0.10%**	**0.18%**	**0.09%**	**0.02%**	**0.37%**
CI (ha)	130,123	46,391	35,376	65,506	31,962	8,731	132,721

Table 16. 2014-2016 error matrix, proportion matrix and variance matrix..

ERROR MATRIX 2014-2016

REFERENCE DATA

MAP DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>F	NF > NF	TOTAL	UA
F > F 0	**1,594**	-	1	10	1	-	76	**1,682**	94.8%
F > F 1	**1,637**	25	18	49	5	-	268	**2,002**	81.8%
F > F 2	**401**	86	33	113	16	-	260	**909**	44.1%
E>NF 0	-	**-**	-	-	-	-	-	**-**	0.0%
E>NF 1	21	**49**	8	4	-	-	39	**121**	40.5%
E>NF 2	-	**-**	-	-	-	-	-	**-**	0.0%
Se>NF 0	-	-	**-**	-	-	-	-	**-**	0.0%
Se>NF 1	10	7	**5**	4	1	-	16	**43**	11.6%
Se>NF 2	-	-	**-**	-	-	-	-	**-**	0.0%
D>NF 0	-	-	-	**-**	-	-	-	**-**	0.0%
D>NF 1	26	2	5	**33**	1	-	101	**168**	19.6%
D>NF 2	-	-	-	**-**	-	-	-	**-**	0.0%
Of>NF 0	-	-	-	-	**-**	-	-	**-**	0.0%
Of>NF 1	27	8	2	2	**3**	-	31	**73**	4.1%
Of>NF 2	-	-	-	-	**-**	-	-	**-**	0.0%
NF>F 0	9	-	-	-	-	**-**	1	**10**	0.0%
NF>F 1	4	-	-	1	-	**-**	2	**7**	0.0%
NF>F 2	-	-	-	-	-	**-**	-	**-**	0.0%
NF > NF 0	218	3	2	18	3	1	**1,879**	**2,124**	88.5%
NF > NF 1	376	22	28	31	6	1	**1,314**	**1,778**	73.9%
NF > NF 2	-	-	-	-	-	-	**-**	**-**	0.0%
TOTAL	**4,323**	**202**	**102**	**265**	**36**	**2**	**3,987**	**8,917**	
PA	84.0%	24.3%	4.9%	12.5%	8.3%	0.0%	80.1%	**Overall Acc.:**	
PA_ADJ	85.7%	32.5%	5.3%	11.9%	8.0%	0.0%	91.2%		**77.5%**

PROPORTION MATRIX

REFERENCE DATA

MAP DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>E	NF > NF	TOTAL
F > F 0	**31.93%**	0.00%	0.02%	0.20%	0.02%	0.00%	1.52%	**33.69%**
F > F 1	**7.91%**	0.12%	0.09%	0.24%	0.02%	0.00%	1.30%	**9.68%**
F > F 2	**0.68%**	0.15%	0.06%	0.19%	0.03%	0.00%	0.44%	**1.53%**
E>NF 0	0.00%	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	**0.00%**
E>NF 1	0.11%	**0.25%**	0.04%	0.02%	0.00%	0.00%	0.20%	**0.62%**
E>NF 2	0.00%	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	**0.00%**
Se>NF 0	0.00%	0.00%	**0.00%**	0.00%	0.00%	0.00%	0.00%	**0.00%**
Se>NF 1	0.05%	0.03%	**0.02%**	0.02%	0.00%	0.00%	0.08%	**0.20%**
Se>NF 2	0.00%	0.00%	**0.00%**	0.00%	0.00%	0.00%	0.00%	**0.00%**
D>NF 0	0.00%	0.00%	0.00%	**0.00%**	0.00%	0.00%	0.00%	**0.00%**
D>NF 1	0.13%	0.01%	0.02%	**0.16%**	0.00%	0.00%	0.49%	**0.82%**
D>NF 2	0.00%	0.00%	0.00%	**0.00%**	0.00%	0.00%	0.00%	**0.00%**
Of>NF 0	0.00%	0.00%	0.00%	0.00%	**0.00%**	0.00%	0.00%	**0.00%**
Of>NF 1	0.13%	0.04%	0.01%	0.01%	**0.01%**	0.00%	0.15%	**0.36%**
Of>NF 2	0.00%	0.00%	0.00%	0.00%	**0.00%**	0.00%	0.00%	**0.00%**
NF>F 0	0.10%	0.00%	0.00%	0.00%	0.00%	**0.00%**	0.01%	**0.11%**
NF>F 1	0.02%	0.00%	0.00%	0.01%	0.00%	**0.00%**	0.01%	**0.04%**
NF>F 2	0.00%	0.00%	0.00%	0.00%	0.00%	**0.00%**	0.00%	**0.00%**
NF > NF 0	4.50%	0.06%	0.04%	0.37%	0.06%	0.02%	**38.75%**	**43.81%**
NF > NF 1	1.93%	0.11%	0.14%	0.16%	0.03%	0.01%	**6.75%**	**9.14%**
NF > NF 2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	**0.00%**	**0.00%**
	47.48%	**0.77%**	**0.45%**	**1.37%**	**0.19%**	**0.03%**	**49.71%**	**100.00%**
Area adj.	8,623,465	140,498	81,094	249,662	34,200	4,679	9,026,848	

VARIANCE MATRIX

MAP DATA / REFERENCE DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>E	NF > NF
F > F 0	**0.00033%**	0.00000%	0.00000%	0.00004%	0.00000%	0.00000%	0.00029%
F > F 1	**0.00007%**	0.00001%	0.00000%	0.00001%	0.00000%	0.00000%	0.00005%
F > F 2	**0.00001%**	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	0.00001%
E>NF 0	0.00000%	**0.00000%**	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%
E>NF 1	0.00000%	**0.00001%**	0.00000%	0.00000%	0.00000%	0.00000%	0.00001%
E>NF 2	0.00000%	**0.00000%**	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%
Se>NF 0	0.00000%	0.00000%	**0.00000%**	0.00000%	0.00000%	0.00000%	0.00000%
Se>NF 1	0.00000%	0.00000%	**0.00000%**	0.00000%	0.00000%	0.00000%	0.00000%
Se>NF 2	0.00000%	0.00000%	**0.00000%**	0.00000%	0.00000%	0.00000%	0.00000%
D>NF 0	0.00000%	0.00000%	0.00000%	**0.00000%**	0.00000%	0.00000%	0.00000%
D>NF 1	0.00001%	0.00000%	0.00000%	**0.00001%**	0.00000%	0.00000%	0.00001%
D>NF 2	0.00000%	0.00000%	0.00000%	**0.00000%**	0.00000%	0.00000%	0.00000%
Of>NF 0	0.00000%	0.00000%	0.00000%	0.00000%	**0.00000%**	0.00000%	0.00000%
Of>NF 1	0.00000%	0.00000%	0.00000%	0.00000%	**0.00000%**	0.00000%	0.00000%
Of>NF 2	0.00000%	0.00000%	0.00000%	0.00000%	**0.00000%**	0.00000%	0.00000%
NF>F 0	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	**0.00000%**	0.00000%
NF>F 1	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	**0.00000%**	0.00000%
NF>F 2	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	**0.00000%**	0.00000%
NF > NF 0	0.00083%	0.00001%	0.00001%	0.00008%	0.00001%	0.00000%	**0.00092%**
NF > NF 1	0.00008%	0.00001%	0.00001%	0.00001%	0.00000%	0.00000%	**0.00009%**
NF > NF 2	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	0.00000%	**0.00000%**
TOTAL	**0.37%**	**0.06%**	**0.05%**	**0.12%**	**0.05%**	**0.02%**	**0.37%**
CI (ha)	132,935	22,311	19,723	44,031	16,695	7,720	135,366

Table 17. 2016-2018 error matrix, proportion matrix and variance matrix.

ERROR MATRIX 2016-18

REFERENCE DATA

MAP DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>F	NF > NF	TOTAL	UA
F > F 0	1,581	4	1	16	1	-	89	1,692	93.4%
F > F 1	1,504	30	16	73	11	1	356	1,991	75.5%
F > F 2	-	-	-	-	-	-	-	-	0.0%
E>NF 0	-	-	-	-	-	-	-	-	0.0%
E>NF 1	-	-	-	-	-	-	-	-	0.0%
E>NF 2	53	52	6	5	2	-	94	212	24.5%
Se>NF 0	-	-	-	-	-	-	-	-	0.0%
Se>NF 1	-	-	-	-	-	-	3	3	0.0%
Se>NF 2	19	12	7	5	1	-	53	97	7.2%
D>NF 0	-	-	-	-	-	-	-	-	0.0%
D>NF 1	1	-	-	2	-	-	3	6	33.3%
D>NF 2	85	4	15	71	3	-	285	463	15.3%
Of>NF 0	-	-	-	-	-	-	-	-	0.0%
Of>NF 1	3	-	-	-	1	-	5	9	11.1%
Of>NF 2	43	7	1	1	9	-	76	137	6.6%
NF>F 0	4	-	-	-	-	-	2	6	0.0%
NF>F 1	2	-	-	-	-	-	3	5	0.0%
NF>F 2	-	-	-	-	-	-	-	-	0.0%
NF > NF 0	194	4	2	8	7	-	1,903	2,118	89.8%
NF > NF 1	400	13	9	28	9	1	1,718	2,178	78.9%
NF > NF 2	-	-	-	-	-	-	-	-	0.0%
TOTAL	3,889	126	57	209	44	2	4,590	8,917	
PA	79.3%	41.3%	12.3%	34.9%	22.7%	0.0%	78.9%	Overall Acc:	
PA_ADJ	86.1%	17.5%	5.6%	10.2%	6.4%	0.0%	91.3%		76.8%

PROPORTION MATRIX

REFERENCE DATA

MAP DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>E	NF > NF	TOTAL
F > F 0	31.58%	0.08%	0.02%	0.32%	0.02%	0.00%	1.78%	33.80%
F > F 1	7.34%	0.15%	0.08%	0.36%	0.05%	0.00%	1.74%	9.71%
F > F 2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
E>NF 0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
E>NF 1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
E>NF 2	0.09%	0.09%	0.01%	0.01%	0.00%	0.00%	0.16%	0.36%
Se>NF 0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Se>NF 1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Se>NF 2	0.04%	0.02%	0.01%	0.01%	0.00%	0.00%	0.10%	0.18%
D>NF 0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
D>NF 1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
D>NF 2	0.13%	0.01%	0.02%	0.11%	0.00%	0.00%	0.45%	0.73%
Of>NF 0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Of>NF 1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Of>NF 2	0.08%	0.01%	0.00%	0.00%	0.02%	0.00%	0.15%	0.27%
NF>F 0	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%
NF>F 1	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%
NF>F 2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NF > NF 0	4.00%	0.08%	0.04%	0.17%	0.14%	0.00%	39.28%	43.71%
NF > NF 1	2.04%	0.07%	0.05%	0.14%	0.05%	0.01%	8.78%	11.13%
NF > NF 2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	45.37%	0.50%	0.23%	1.12%	0.29%	0.01%	52.46%	99.99%
Area adj.	8,240,267	91,681	42,458	202,666	53,073	1,813	9,527,735	

VARIANCE MATRIX

REFERENCE DATA

MAP DATA

	F > F	E>NF	Se>NF	D>NF	Of>NF	NF>E	NF > NF
F > F 0	**0.0004%**	0.0000%	0.0000%	0.0001%	0.0000%	0.0000%	0.0003%
F > F 1	**0.0001%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0001%
F > F 2	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
E>NF 0	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
E>NF 1	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
E>NF 2	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
Se>NF 0	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%
Se>NF 1	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%
Se>NF 2	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%	0.0000%
D>NF 0	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%
D>NF 1	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%
D>NF 2	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%	0.0000%
Of>NF 0	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%
Of>NF 1	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%
Of>NF 2	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%	0.0000%
NF>F 0	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%
NF>F 1	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%
NF>F 2	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**	0.0000%
NF > NF 0	0.0008%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0008%**
NF > NF 1	0.0001%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0001%**
NF > NF 2	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	**0.0000%**
TOTAL	**0.37%**	**0.07%**	**0.04%**	**0.11%**	**0.06%**	**0.01%**	**0.37%**
CI (ha)	133,267	24,414	16,001	40,284	22,729	2,565	132,677

Annex 2. Detailed methodology for acquiring activity data.

1. Land Use/ Cover 2016 map

The LULC 2016 map was prepared by MRV team of the General Directorate Administration for Nature Conservation and Protection (GDANCP / MOE) corporately with Forest Administration (FA), using Landsat imagery. The process included segmentation based on the LULC 2014 map and PCA from both 2014 and 2016 imagery to extract potential areas of change. This resulted in consistent polygons through time. The polygons were subsequently visually classified for the areas of change. Land use and Land cover 2016 were generated within 22 categories, in which forest classes fallen under 13 categories and non-forest were in 9 categories with minimum mapping 5ha. The procedure for 2016 mapping is explained in the Figure1.

In the mosaicking of LANDSAT images, all LANDSAT images were masked to remove cloud and haze covered and these masked images were mosaicked together. In case of 2016, a total of 52 LANDSAT surface reflectance images were masked and these masked images were mosaicked to create 2016 LNADSAT mosaic.

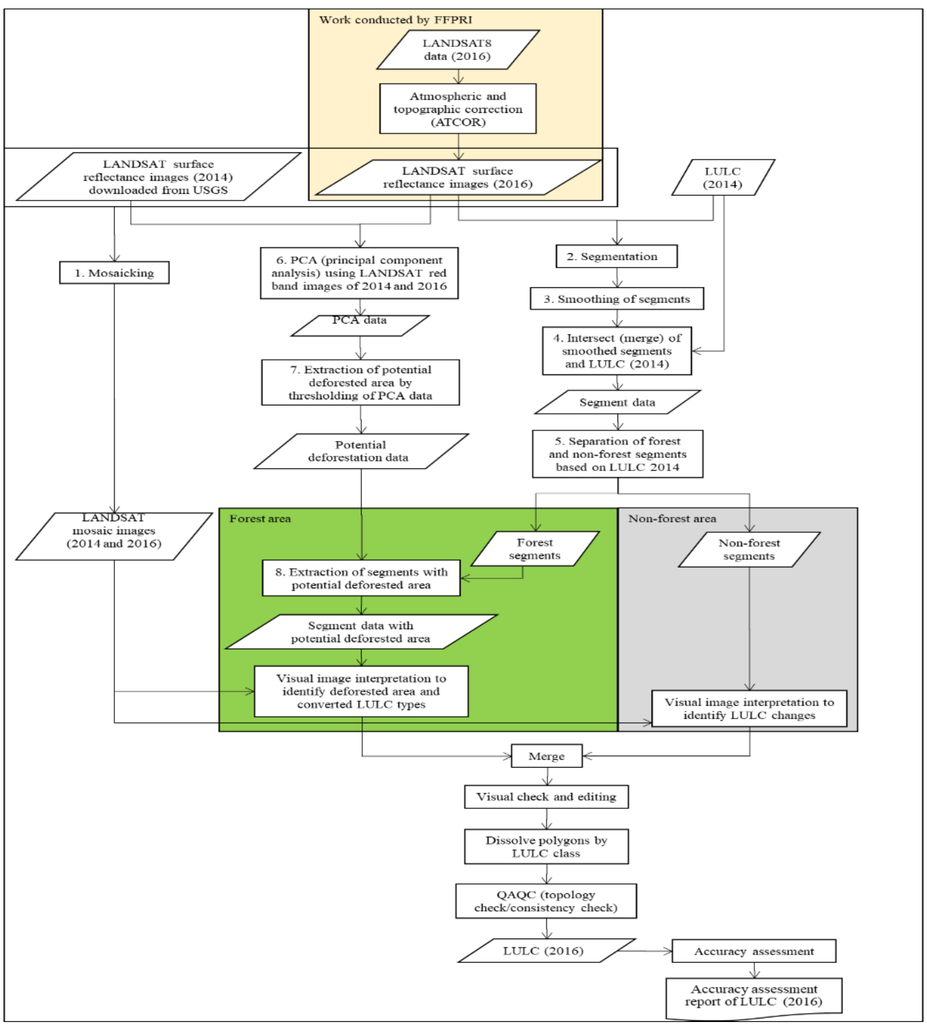


Figure 11 The procedure for LULC 2016 map

Quality assurance and Quality Control (QA/QC)

QA (Quality Assurance)/QC (Quality Control) work was conducted to extract and check potential classification errors. First both 2014 and 2016 forest classes were grouped into permanent and temporary forest classes. Then, unlikely land use/cover conversions between 2014 and 2016 were extracted. All the extracted polygons were manually inspected by the expert image interpreters.

Grouping of 2014 and 2016 forest classes into permanent and temporary forest classes

Permanent forest classes (PF)	Temporary forest classes (TF)
Evergreen forest (E)	Forest regrowth (Fr)
Semi-evergreen forest (Se)	Tree plantation (Tp)
Pine forest (P)	Rubber plantation (Rp)
Deciduous forest (D)	Oil palm plantation (Po)
Mangrove (M)	Pine plantation (pp)
Rear Mangrove(Mr)	
Flooded forest (Ff)	
Bamboo (B)	

Extraction of unlikely land use/cover conversions

2014	2016	Unlikeliness	No. of polygon
NF	PF	Unlikely	1070
TF	PF	Unlikely	15
PF	TF	Likely but rare	2719
PF	PF	Check only forest types in 2014 and 2016 are different	158

All the extracted polygons were checked and corrected (if necessary) by re-interpretation of LANDSAT images by expert image interpreters.

Accuracy assessment and Area Estimation

Accuracy assessment of 2016 LULC was conducted using FAO SEPAL system. Reference sample for accuracy assessment were generated by using SEPAL's stratified area estimation tool.

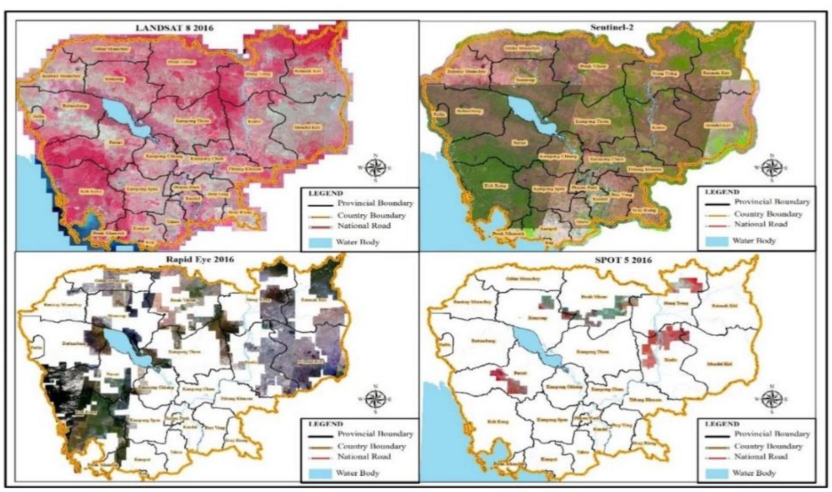


Figure 12. Satellite imageries used for classification and accuracy assessment of forest cover 2016

The accuracy assessment of land use/cover data was carried out into two separate steps through ground truth and verification of data from RapidEye, SPOT5, and Sentinel-2 and images from Google Earth for verification of land use/cover classification with 1651 verified points covering 25 capital-provinces nationwide.

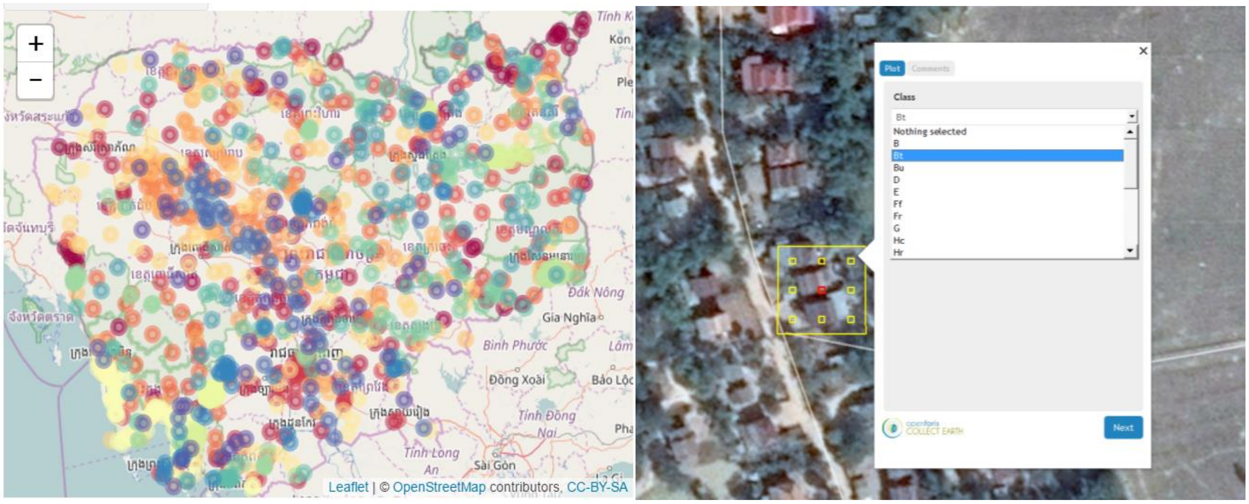
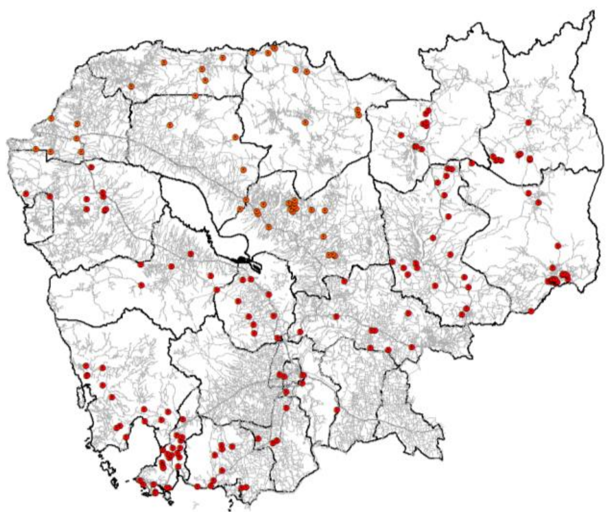


Figure 13. Location of verification points for the accuracy assessment of LULC 2016 and verification based on Google Earth interpretation



No	Province	Assess point
1	Rotanakiri	9
2	Kaoh Kong	18
3	Krong Preah Sihanouk	18
4	Tbong Khum	6
5	Kampot	10
6	Takaev	4
7	Kandal	7
8	Bat Dambang	9
9	Pousat	6
10	Kampong Chhnang	9
11	Kampong Cham	3
12	Kampong Thom	18
13	Preah Vihear	9
14	Otdar Mean Chey	5
15	Banteay Mean Chey	6
16	Siem Reap	6
17	Stueng Traeng	9
18	Kratie	18
19	Mondol Kiri	24
	TOTAL	**194**

Figure 14. Summary of random sample point assess by province

Table 18. Confusion matrix of 2016map

	E	Se	D	B	Ff	Fr	M	Mr	P	Pp	Tp	Po	Rp	Bt	Bu	G	Hc	Hr	R	S	W	Ws	Total	UA
E	155	1	2			1											2						161	96.3%
Se		52	2	2													2			1		2	61	85.2%
D		6	174													2	2	2				1	187	93.0%
B	8	2		30		1							1			1							43	69.8%
Ff					50											1		1		1	1		54	92.6%
Fr	1	2	2			42		1									4						52	80.8%
M	1						39	3													2	1	46	84.8%
Mr	2					1	2	33								3		3				2	46	71.7%
P									45							2							47	95.7%
Pp				1						40						7							48	83.3%
Tp	1							1			38		1							1		2	44	86.4%
Po												40					1					1	42	95.2%
Rp	1		1										49			1	2					1	55	89.1%
Bt														52	3		2	1			1	2	61	85.2%
Bu														1	44	1	2	1		1		2	52	84.6%
G	1		3		2	1										35	5	2			2	2	53	66.0%
Hc			4	1		3					1		4	2		6	133	8			1	11	174	76.4%
Hr			2											1		1	3	213		1	1	5	227	93.8%
R	2		1	1		1								3			1	1	36	1		1	48	75.0%
S			6		1						1		1	1	1	1	1	3	2	38			56	67.9%
W	1			1	2											2		3			39	1	49	79.6%
Ws	2	1	3		2	1		2								1	6	1			1	25	45	55.6%
Total	175	64	200	36	57	51	41	40	45	40	40	40	56	60	48	64	166	239	38	44	48	59	**1651**	
PA	88.6%	81.3%	87.0%	83.3%	87.7%	82.4%	95.1%	82.5%	100.0%	100.0%	95.0%	100.0%	87.5%	86.7%	91.7%	54.7%	80.1%	89.1%	94.7%	86.4%	81.3%	42.4%		
PA_adj	96.9%	85.7%	92.3%	56.4%	86.1%	63.0%	95.9%	35.2%	100.0%	100.0%	67.3%	100.0%	86.0%	84.6%	66.7%	49.7%	87.6%	93.7%	35.9%	37.4%	88.3%	46.6%		

Accuracy Assessment was done in collaboration with national and international experts including from FAO-UNREDD, JICA-CAMREDD and international universities with the Overall Accuracy of LULC map is 84.92 % and the overall accuracy adjusted (to the proportion of area for each class) increase up to 87.48%.

2. Land Use/ cover 2018 map

The LULC 2018 map was prepared by MRV team of the General Directorate Administration for Nature Conservation and Protection (GDANCP / MOE) corporately with Forest Administration (FA), using Landsat imagery. The process includes LULC 2016 created based on segmentation method, PCA automatic change detection method using 2016 and 2018 Landsat mosaics to extract potential areas of change, and GLAD forest cover loss to identify the degree of deforestation potential. The procedure for 2018 mapping is explained in the next figure.

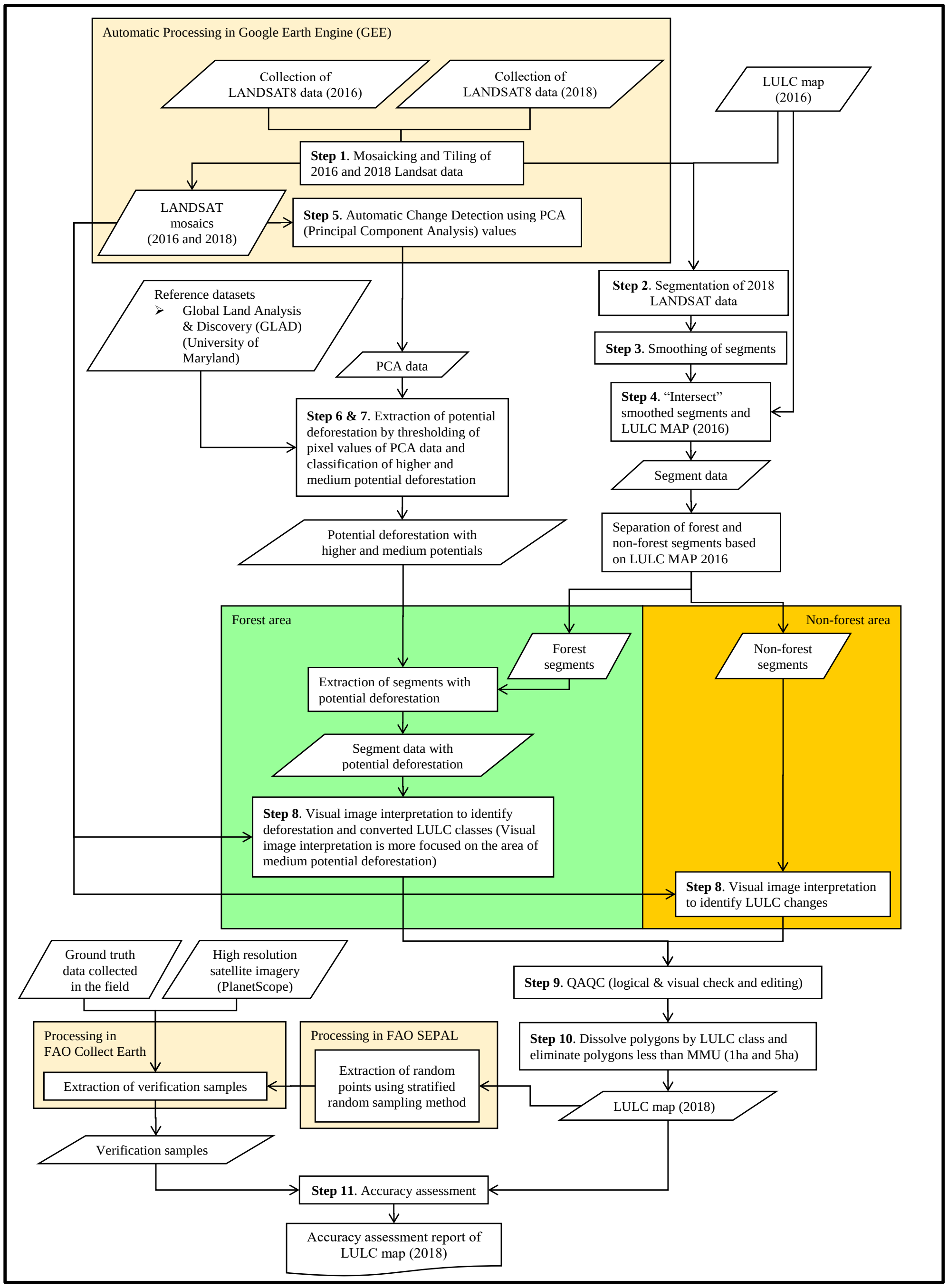


Figure 15. The procedure for LULC 2018 map

Quality Assurance and Quality Control (QA/QC)

QA (Quality Assurance)/QC (Quality Control) work was conducted to extract and check potential classification errors. First 2014, 2016 and 2018 LULC classes were grouped into permanent forest (PF), temporary forest (TF) and non-forest classes. Then, unlikely LULC changes between 2014 -2016 and 2016-2018 were extracted. All the extracted polygons were manually inspected by the expert image interpreters.

Grouping of 2014, 2016 and 2018 LULC classes into permanent and temporary forest classes and non-forest classes

Permanent Forest (PF)	Temporary Forest (TF)	Non-forest (NF)
Evergreen forest (E)	Forest regrowth (Fr)	Crop land (Hc)
Semi-evergreen forest (Se)	Tree plantation (Tp)	Paddy field (Hr)
Pine forest (P)	Rubber plantation (Rp)	Grassland (G)
Deciduous forest (D)	Oil palm plantation (Po)*	Wood shrub (Ws)
Mangrove (M)	Pine plantation (Pp)*	Water (W)
Rear mangrove (Mr)		Built-up area (Bu)
Flooded forest (Ff)		Village (Bt)
Bamboo (B)		Rock (R)
		Sand (S)

* It should be noted that in the national LULC class of Cambodia, Oil Palm Plantation (Po) and Pine Plantation (Pp) are grouped into NF, but these were grouped into TF in QA/QC because these two also appears as forest on satellite imagery.

Extraction of unlikely LULC changes

2014	2016	2018	Unlikeliness
PF	NF	PF	Unlikely
TF	NF	PF	Unlikely
NF	PF	NF	Unlikely
NF	NF	PF	Unlikely
NF	PF	PF	Unlikely
NF	PF	TF	Unlikely
PF	TF	PF	Unlikely
TF	TF	PF	Unlikely
TF	PF	PF	Unlikely
TF	PF	TF	Unlikely
PF	PF	TF	Likely but rare
PF	PF	PF	Check the inconsistent forest classes of 2014, 2016 and 2018.

All the extracted polygons were inspected and corrected (if necessary) by re-interpretation of LANDSAT images by expert image interpreters.

Extraction of unlikely land use/cover conversions

2014	2016	2018	Unlikeliness	No. of polygon
PF	NF	PF	Unlikely	88
TF	NF	PF	Unlikely	3
NF	PF	NF	Unlikely	75
NF	NF	PF	Unlikely	201
NF	PF	TF	Unlikely	5
PF	TF	PF	Unlikely	1
TF	TF	PF	Unlikely	9
TF	PF	TF	Unlikely	5
PF	PF	TF	Likely but rare	149
PF	PF	PF	Check only forest types in 2014, 2016 and 2018 are different	87

All the extracted polygons were checked and corrected (if necessary) by re-interpretation of LANDSAT images by expert image interpreters.

Accuracy assessment and Area Estimation

The accuracy assessment and area estimation of 2018 LULC was conducted using the same procedure as LULC 2016. The total of 1055 points were distributed among 6 operators from the MRV team and international consultant AAS for visual interpretation using Very High-Resolution imagery present in Google Earth and time series of Landsat, Sentinel-II.

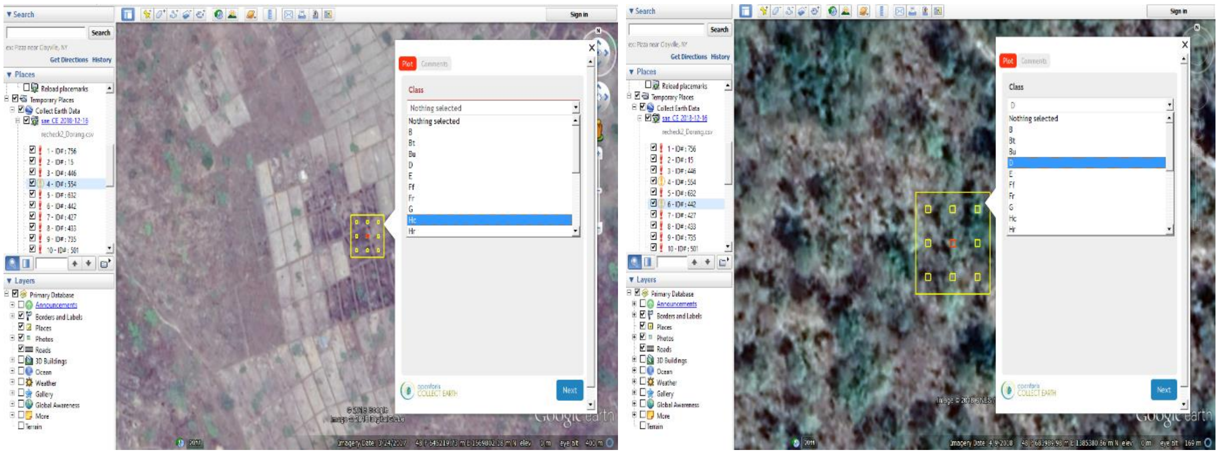


Figure 16. Interpretation of randome point in Google Earth

The team for field check was divided in four teams: First team responsible for 133 sample points that covered the 6 provinces, Second team was responsible for 131 sample points in 6 provinces, Third team was in charge of 137 sample points in 7 provinces and the Fourth team was responsible of 137 sample points in 4 provinces. To cover all the sample points, the teams spent approximately 12 days in the field.

Summary of random sample point assess by province

No	Province	No.Point	No	Province	No.Point
1	Kampong Spueu	16	13	Kampong Thom	32
2	Kaoh Kong	27	14	Preah Vihear	32
3	Krong Preah Sihanouk	8	15	Otdar Mean Chey	18
4	Palin	8	16	Banteay Mean Chey	28
5	Kampot	7	17	Siem Reap	34
6	Takaev	8	18	Stueng Traeng	17
7	Kandal	15	19	Kratie	24
8	Bat Dambang	31	20	Mondol Kiri	20
9	Pousat	27	21	Rotanakiri	20
10	Kampong Chhnang	11	22	Prey Veaeng	35
11	Phnom Penh	18	23	Svay Rieng	21
12	Kampong Cham	33	**TOTAL**		**212**

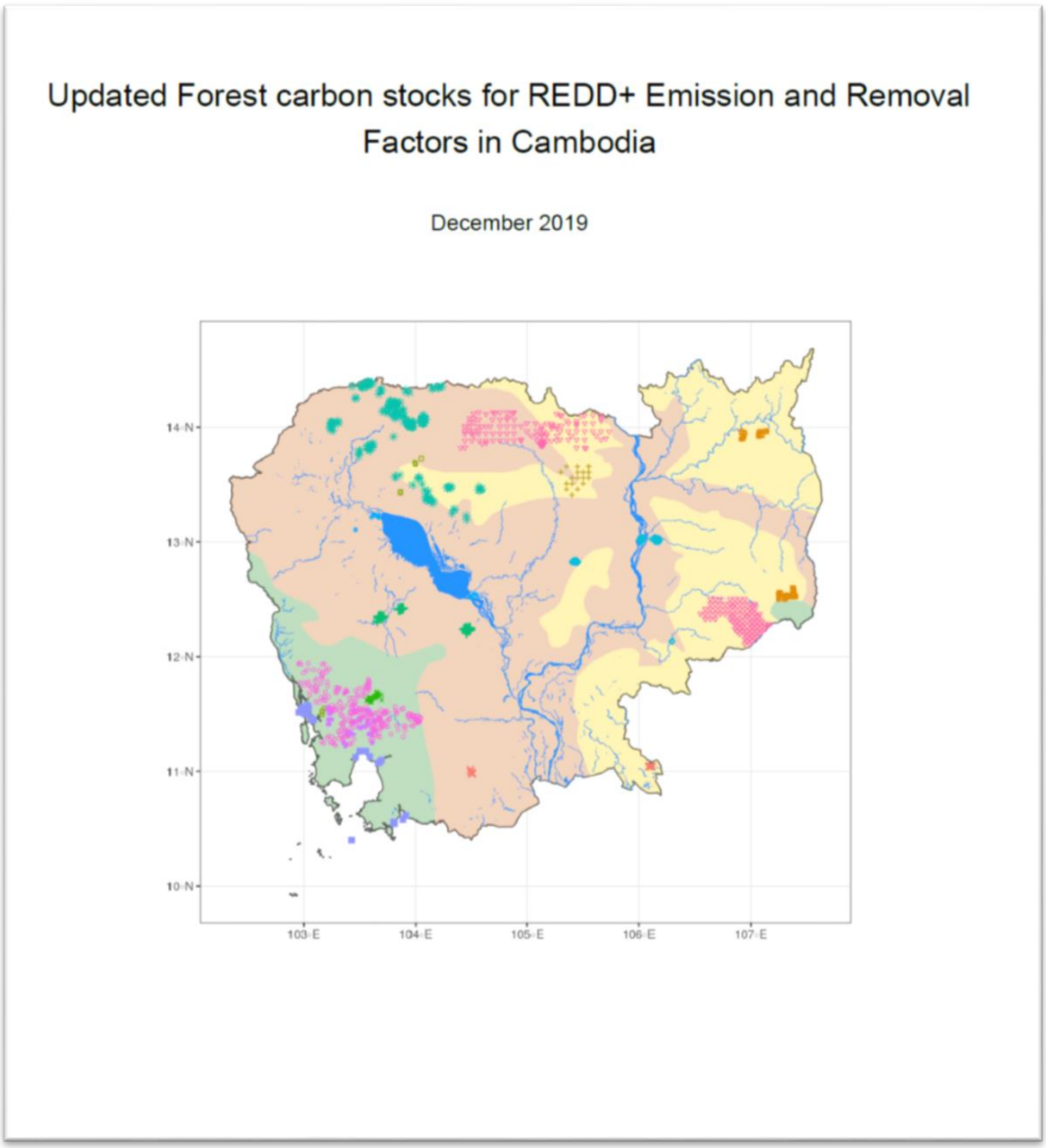
Table 19. Confusion matrix of 2018 map

	E	Se	D	B	Ff	Fr	M	Mr	P	Pp	Tp	Po	Rp	Bt	Bu	G	Hc	Hr	R	S	W	Ws	Total	UA
E	99		1	2													4						**106**	93.4%
Se		27	2	1													3						**33**	81.8%
D		2	107													1	3	1				1	**115**	93.0%
B	1		1	33																		1	**36**	91.7%
Ff					26																3	1	**30**	86.7%
Fr			1			20											2					2	**25**	80.0%
M							29													1	1		**31**	93.5%
Mr							2	28									2	1				1	**34**	82.4%
P		1							31														**32**	96.9%
Pp		2								23			1			1							**27**	85.2%
Tp			2								24						1						**27**	88.9%
Po												30					1						**31**	96.8%
Rp													26				1						**27**	96.3%
Bt														25	1		1						**27**	92.6%
Bu			1											5	23			1					**30**	76.7%
G		1			2									1		25	2	2			1	1	**35**	71.4%
Hc	1	1	2		1	3							4	1		3	95	2	1	2	3	4	**123**	77.2%
Hr			1											2			3	146		1		7	**160**	91.3%
R	1													1	1				33	1			**37**	89.2%
S				1	1							1		1	1			1		15		1	**22**	68.2%
W	1		1		1													2		1	26		**32**	81.3%
Ws			1	1	4											1		2				26	**35**	74.3%
Total	**103**	**34**	**120**	**38**	**35**	**23**	**31**	**28**	**31**	**23**	**24**	**31**	**31**	**36**	**26**	**31**	**118**	**158**	**34**	**21**	**34**	**45**	**1055**	
PA	96.1%	79.4%	89.2%	86.8%	74.3%	87.0%	93.5%	100%	100%	100%	100%	96.8%	83.9%	69.4%	88.5%	80.6%	80.5%	92.4%	97.1%	71.4%	76.5%	57.8%		
PA_adj	98.0%	90.3%	93%	52.1%	74.8%	64.1%	95.1%	100%	100%	100%	100%	96.4%	83.1%	77.5%	68.5%	64.8%	85.2%	95.5%	7.3%	21.4%	81.9%	54.7%		

Accuracy Assessment was done in collaboration with national and international experts including from FAO-UNREDD, JICA-CAMREDD and international universities with the Overall Accuracy of LULC map is 86.92 % and the overall accuracy adjusted (to the proportion of area for each class) increase up to 87.40%.

Annex 3. Updated Forest carbon stocks for REDD+ Emission and Removal Factors in Cambodia.

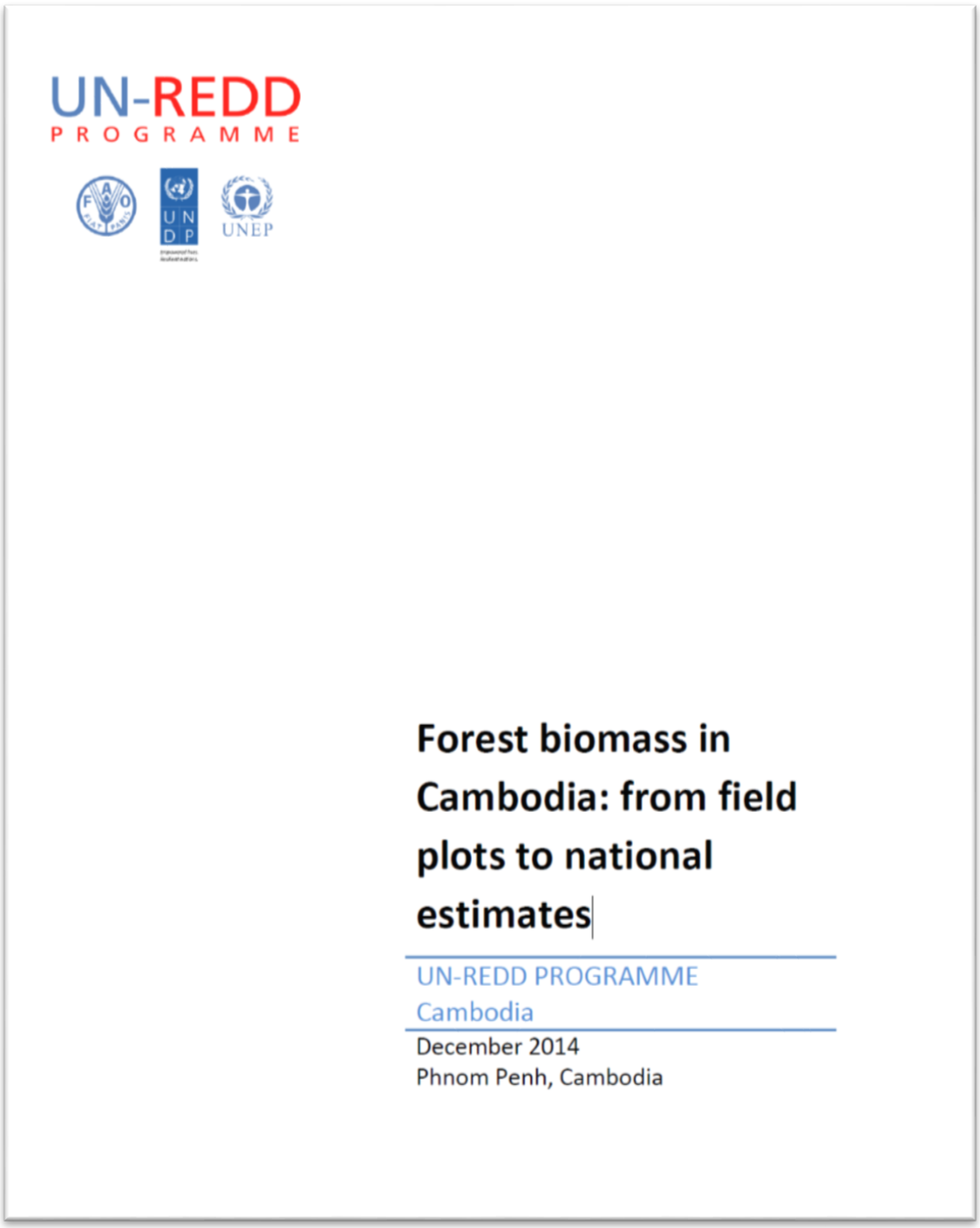
Available in http://cambodia-redd.org/wp-content/uploads/2021/01/Annex3-Updated_REDD_Emission_Factors_Cambodia.pdf


Updated Forest carbon stocks for REDD+ Emission and Removal Factors in Cambodia

December 2019

Annex 4. Forest biomass in Cambodia: from field plots to national estimates.

Available in http://cambodia-redd.org/wp-content/uploads/2021/01/Annex4-Forest-biomass-in-Cambodia-from-field-plots-to-national-estimates.pdf


UN-REDD PROGRAMME

FAO UNDP UNEP

Forest biomass in Cambodia: from field plots to national estimates

UN-REDD PROGRAMME Cambodia

December 2014

Phnom Penh, Cambodia