

Cambodia

TECHNICAL ANNEX

pursuant to Decision 14/CP.19



Results achieved by the Kingdom of Cambodia from Reducing Emissions from Deforestation, Forest Degradation and Enhancement of Forest Carbon Stock

2020

**FIRST BIENNIAL UPDATE REPORT
OF THE KINGDOM OF CAMBODIA**

TECHNICAL ANNEX PURSUANT TO DECISION 14/CP.19

Progress made [and results achieved] by Cambodia on Reducing Emissions from Deforestation, Forest Degradation and through Enhancements of Forest Carbon Stocks

1 Introduction

This Technical Annex (TA) has been prepared in support of Cambodia first Biennial Update Report (BUR) and Cambodia's upcoming National Communication (NC). The principal objective of the Technical Annex is to report on progress made [and results achieved] by Cambodia on Reducing Emissions from Deforestation, Forest Degradation and through Enhancements of Forest Carbon Stocks over 2015 to 2018 as Cambodia is transitioning from a REDD+ readiness phase to REDD+ demonstration and full implementation. Key objectives of the TA are also to make information available for public, scientific use and other purposes to contribute to our understanding and to improved natural resource use in Cambodia.

In terms of vision for the forest sector the Royal Government of Cambodia (RGC) adopted a long term vision (Sor Chor Nor. # 1211) in 2017 with the aim to reduce greenhouse gas emissions from forestry sector to net zero percent before 2040. This aim is consistent with article 5 of the Paris Agreement [which aims to achieve net zero emissions by 2050]. The RGC aims to achieve this long term vision by implementing three strategic missions:

1. Achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gas emissions from the forestry sector.
2. Improve livelihood opportunities of local communities to reduce their dependence on forest products.
3. Strengthen the production of timber and fuel wood from plantations and protect natural forests.

The TA includes an additional section with results achieved on Reducing Emissions from Deforestation over 2017 to 2018 including aggregated uncertainties around the results achieved (In line with the GCF requirement to provide information on aggregate uncertainties¹, taking into account national capabilities and circumstances.) In addition, as part of the improvements mentioned on the FRL submission, the RGC has worked on including information on accuracy assessment of land use change data for periods of 2006 to 2010 and 2010 to 2014. Moreover, Cambodia is moving forward on estimating aggregate uncertainties, consistent with IPCC's "methods to combine uncertainties"². These results will be used as part of the requirements when applying for Results-Based Payments (RBP) under the GCF RBP Pilot programme. An additional section is included to present the technical advancements made by the RGC and as a

¹ GCF scorecard (Section 2b. REDD-plus Results reporting), concerning uncertainties

² 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 1

commitment to improve transparency and accuracy of its submissions. The technical improvements suggest that emission reductions were only achieved for 2017-2018 and the magnitude of emission reductions is smaller as suggested by the data that is consistent with the technically assessed FRL. Potential Result Based Payments³ over this short, albeit important period, are seen a catalytic to keep momentum and achieve the forest sector long term vision.

2 Summary of information from the assessed FRL

Cambodia's Initial Forest Reference Level (FRL) for reducing emissions from deforestation, forest degradation and enhancement of forest carbon stocks (REDD+), was submitted in November 2016 on a voluntary basis in the context of results-based payments. Cambodia's FRL covers the activities reducing emissions from deforestation, reducing emissions from forest degradation, and enhancement of forest carbon stocks. Cambodia has developed the FRL for the national scale.

Cambodia applied a step-by-step approach to develop the national FRL, in accordance with decision 12/CP.17, paragraph 10, and has presented the FRL with the aim of incorporating other activities as soon as all the relevant data and information will become available as detailed in the 'plan of improvement' section included in the FRL.

2.1 Information used by Cambodia to build the FRL

The FRL covers the historical reference period 2006–2014 and is the annual average of the carbon dioxide (CO₂) emissions associated with deforestation, and net emissions associated with degradation and enhancement, which in this context includes degradation in areas of forest land remaining forest land with changes in forest sub-categories, and removals of CO₂ from the atmosphere through afforestation where other land uses are converted to forest land. The forest definition adopted by Cambodia for REDD+ explicitly excludes rubber plantations, oil palm plantations, and perennial crops.

Activity Data

For the development of Cambodia's FRL historical time series of land-use maps from 2006, 2010, and 2014 were used. Activity data were generated by estimating areas of change from land-use⁴ classes and subclasses from one land use map to the next. Cambodia made efforts to maintain consistency in the calculation of the FRL, including by using data sources with consistent definitions of forest and by undertaking a robust QA/QC processes to minimize misclassifications of activity data. To avoid potential misclassification due to changes in the minimum mapping unit in 2006, 2010 and 2014, Cambodia checked and made corrections using higher-resolution satellite imagery (NDVI time series data, ALOS AVNIR-2 for 2010, and RapidEye and Google Earth high-resolution images for 2014) supplemented by ground-truth surveys. Overall accuracy of the 2006 land use map was 74%, for the 2010 land use map overall accuracy was around 74%, while for the 2014 land use map the overall accuracy was 81%.

Emission Factors

Emission factors were estimated by calculating the carbon stock per unit area before and after land use changes. Carbon stock was assumed to be zero post-deforestation. AGB and BGB pools were included, the

³ Per UNFCCC Decision 14/CP.19

⁴ Land Use/Cover data

FRL excluded the pools litter, deadwood, and soil organic carbon. The information on emission factors was developed from a literature survey and data from various forest inventory surveys implemented in Cambodia and analysed for values of biomass density, as compiled by the UN-REDD Program. For Aboveground Biomass (AGB) in three types of forest (evergreen, semi-evergreen, and deciduous) the average per type estimates were selected for use as country specific estimates. These three forest types make up 90.54% of forest cover in Cambodia. Whereas AGB for four forest types (pine forest, flooded forest, pine plantation, and tree plantation) were drawn from IPCC default values in the 2003 Good Practice Guidance or the Revised 1996 IPCC Guidelines for National GHG Inventories, consistent with Cambodia's Second National Communication. AGB for mangrove, rear mangrove, and forest regrowth were drawn from regionally specific literature sources. Belowground Biomass (BGB) is estimated following application of a ratio recommended for tropical forests (IPCC 2003). The bamboo, rubber plantation, and oil palm plantation land-cover types were assigned a value of zero carbon stock in biomass, effectively treating them as non-forest for the purposes of calculating the FRL.

FRL Construction

To build the FRL, Cambodia followed the methodologies provided by the IPCC in the 2006 Guidelines for National Greenhouse Gas Inventories and 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry. Cambodia took an approach based on historical average of emission and removals from land use change for eight years from 2006 to 2014.

The national historical average emissions of Cambodia for the period 2006-2014 were assessed as **78,953,951 tCO₂e/yr**.

Cambodia submitted its FRL in 2016 for the technical assessment in 2017 and submitted a modified FRL on 22 May 2017. The technical assessment report was published on the UNFCCC website on 29 March 2018. The submitted and modified versions of the Forest Reference Level presented to the UNFCCC and the Technical Assessment Report can be found on the UNFCCC REDD+ web platform⁵.

3 Results in tCO₂e/year

The Conference of the Parties, on the Decision 14/CP.19, paragraph 3 “Decides that the data and information used by Parties in the estimation of anthropogenic forest-related emissions by sources and removals by sinks, forest carbon stocks, and forest carbon stock and forest-area changes, as appropriate to the activities referred to in decision 1/CP.16, paragraph 70, undertaken by Parties, should be transparent, and consistent over time and with the established forest reference emission levels and/or forest reference levels in accordance with decision 1/CP.16, paragraph 71(b) and (c) and chapter II of decision 12/CP.17;”

In this Technical Annex (TA) to the Biennial Update Report (BUR) Cambodia reports the estimations of annual emission reduction over the years 2015 to 2018 (4 years). The emissions over these years were assessed using the same approach and methodologies used to build the FRL (described in section 2) for activity data and emission factors as have been applied by the technically assessed FRL, and hence comparable.

⁵ <https://redd.unfccc.int/submissions.html?country=khm>

Table 1. summarizes annual emissions and removals for the 2006-2010 and 2010-2014 reference periods, and for the 2015-2016 and 2017-2018 reporting periods. To estimate the annual emission reductions, the emissions from the reporting period were subtracted from the reference period.

Table 1 Total Annual CO2 Emissions and Removals (t CO2 /year) for FRL reference period and results period

UNFCCC submission	FRL		BUR-TA	
	2006-2010	2010-2014	2015-2016	2017-2018
Period (year to year)	2006-2010	2010-2014	2015-2016	2017-2018
Annual CO ₂ Removals (t CO ₂ / year)	-7,109,077	-20,138,797	-2,596,085	-2,115,169
Annual CO ₂ Emissions (t CO ₂ / year)	34,111,931	151,043,845	46,304,088	34,731,948
Total Annual CO ₂ Emissions and Removals (t CO ₂ / year)	27,002,854	130,905,048	43,708,003	32,616,779
Average Total Annual CO₂ Emissions and Removals (t CO₂ / year)	78,953,951		43,708,003	32,616,779
Annual Emission Reductions (t CO₂ / year)			35,245,948	46,337,172

The Annual CO₂ Emissions and Removals (tCO₂ / year) are calculated by the following equation:

Equation to calculate Annual CO₂ Emissions and Removals (tCO₂ / year)

$$\begin{aligned}
 & - \Delta C_B = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)} \\
 & - \Delta CO_2 = \Delta C_B \times 44/12
 \end{aligned}$$

Where:

- ΔC_B = annual change in carbon stocks in biomass (the sum of above-ground and below-ground biomass) in land remaining in the same category (e.g., Forest Land Remaining Forest Land), tonnes C yr⁻¹
- C_{t_2} = total carbon in biomass for each land sub-category at time t_2 , tonnes C
- C_{t_1} = total carbon in biomass for each land sub-category at time t_1 , tonnes C
- Ct (Total Emission) = Activity Data (A) × Emission Factor (EF)
- **44/12**: Molecular weight ratio of carbon dioxide to carbon (IPCC, 2006b)

To estimate the annual emission reductions, the emissions from the result period were subtracted from the reference period following these equations:

- Equation to calculate Annual Emission Reductions (Emission REDD+ Results (2015-2016) = FRL – tCO₂ (2015-2016) /2
- Emission REDD+ Results (2017-2018) = FRL – tCO₂(2017-2018) /2

Where:

FRL = Average Total Annual CO2 Emissions and Removals (tCO2 /year) for the FRL period
tCO2 = Annual Emission Reductions for the REDD+ period.

4 Demonstration that the methodologies used to produce the results are consistent with those used to establish the FRL

4.1 Activity data

The methodology, data sources and information to generate the land use/cover map of 2016 and 2018 used in the estimation of results presented in this Technical Annex is the same as described in the FRL submitted by Cambodia and technically assessed by the UNFCCC in 2017. This includes a consistent land use/cover classification.

2016 mapping

The 2016 land use/cover map included the segmentation and classification of all forest and non-forest areas, using the same methodology of the 2014 land use/cover map. The classes of each segment were identified by semiautomatic classification and visual interpretation, using the Landsat images available on the period of November 2015 to April 2016. (see section 6 with necessary information that allows for the reconstruction of the results) and considering the previous classification as part of the classification.

Several ancillary datasets (including boundary of forest plantation, social and economic land concessions and locations of hydropower dams) were utilized during the process of delineation to catch additional valuable information for classification. Directive 001 land (Order 01BorBor⁶ dated 07th May 2012 and SarChorNor 666⁷ dated 26th June 2012) was classified as agricultural land because it was allocated for agricultural use, and Social Land concessions (SLC) holders must abide by conditions that include development of the land through agricultural cultivation. The majority of lands have already been cleared. Therefore, it was assumed that all the Directive 001 land is classified as agricultural area.

2018 mapping

The 2018 land use/cover map included the segmentation and classification of all forest and non-forest areas using the same methodology of the 2014 and 2016 land use/cover map. The classes of each segment were identified by semiautomatic classification and visual interpretation, using the Landsat images available on the period of November 2017 to April 2018 (see necessary information that allows for the reconstruction of the results) and considering the previous classification as part of the classification.

Several ancillary datasets (including boundary of forest plantation, social and economic land concessions and locations of hydropower dams) were utilized during the process of delineation to catch additional valuable information for classification. Directive 001 land was classified as agricultural land because it was allocated for agricultural use, and Social Land concessions (SLC) holders must abide by conditions that

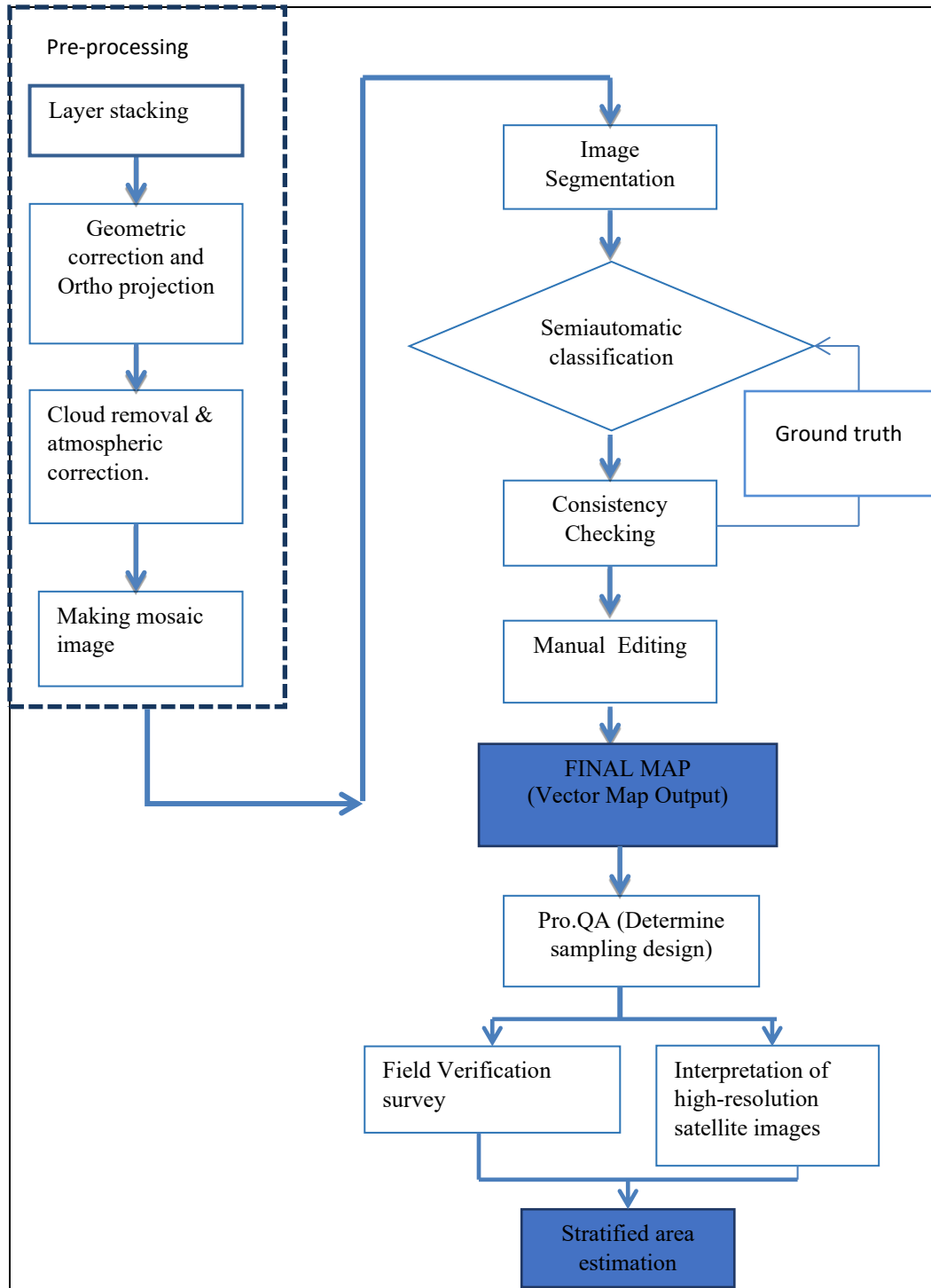
⁶ Order 01 BorBor on “Measures to strengthening and enhancing the effectiveness of management of economic land concessions (ELCs)”

⁷ SarChorNor 666 on “ Case for Principles for Land Registration Work in the Target Area in which the Order 01 BorBor”

include development of the land through agricultural cultivation. The majority of lands have already been cleared. Therefore, it was assumed that all the Directive 001 land is agricultural area.

The procedure to obtain the land use/cover maps for 2016 and 2018 is explained in Figure 1 Procedure for the 2016 and 2018 mapping (and FRL mapping)

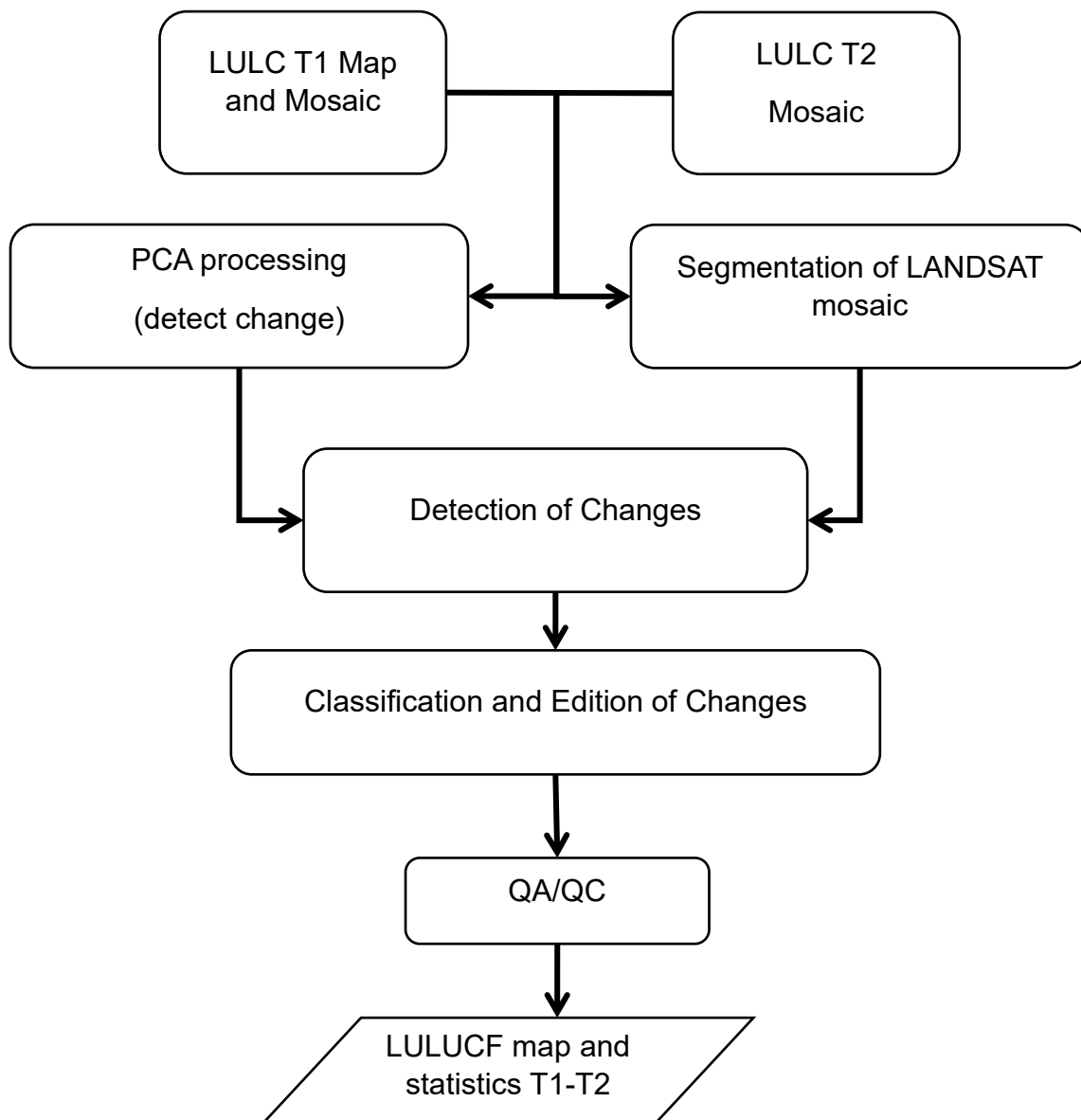
Figure 1 Procedure for the 2016 and 2018 mapping (and FRL mapping)



Estimation of Changes

Cambodia refers to land use/cover change to any change from a forest class to a non-forest class or vice versa (see Table 7). The estimation of land use/cover changes for 2015-2016 and 2017-2018 is obtained by comparing the land use/cover of two points in time, comparing the land use/cover class of each segment in the first point in time with the corresponding segment of the second point in time. To quantify the change of each period, a GIS technique for geo-processing and logical function was applied. The basic 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 is then made with the histograms of change. The procedure for forest land use change is explained in Figure 2.

Figure 2 The procedure for forest land use change



4.2 Emission factors

The results in the TA were calculated using the same emission and removal factors included in the FRL submitted by Cambodia and technically assessed by the UNFCCC in 2017.

Table 2 AGB values used in FRL and BUR-TA

Land use/cover		Recommended AGB (t/ha)	Data source*	References Used for	
Category	Sub-category				
Forest land	Natural forest	Evergreen	163	Country specific	UN-REDD (2014)
		Semi-evergreen	243	Country specific	UN-REDD (2014)
		Deciduous	85	Country specific	UN-REDD (2014)
		Pine forest	100	Country specific	MoE (2003)
		Bamboo	0	-	(Nil)
		Mangrove	150	Country specific	MoE (2003)
		Rear mangrove	165	Regional	Tran (2015)
		Flooded forest	70	Country specific	MoE (2003)
		Forest regrowth	75	Country specific	CFI (2008) cited in Sar (2010)
	Planted Forest	Pine plantation	100	Country specific	MoE (2003)
Tree plantation		100	Country specific	MoE (2003)	
Cropland	Rubber plantation	-	-	-	
	Oil palm plantation	-	-	-	
	Cropland	-	-	-	
	Paddy field	-	-	-	
Grass land	Grass land	-	-	-	
	Wood shrub	-	-	-	
Wetland	Water	-	-	-	
Settlement	Village	-	-	-	
	Built-up area	-	-	-	
Other land	Rock	-	-	-	
	Sand	-	-	-	

* Country specific: based on studies of forest in Cambodia, Regional: based on the study in neighbouring countries in Southeast Asia

Emission factors were estimated by calculating the carbon stock per unit area before and after land use/cover changes. Post-deforestation carbon stock was assumed to be zero. Aboveground biomass (AGB) and belowground biomass (BGB) pools were included; the FRL excluded the pools litter, deadwood, and soil organic carbon. The information on emission factors was developed from a literature survey and data from various forest inventory surveys implemented in Cambodia and analysed for values of biomass density, as compiled by the UN-REDD Program. For Aboveground Biomass (AGB) in three types of forest (evergreen, semi-evergreen, and deciduous) the average estimates were selected, which make up 90.54% of forest cover in Cambodia. AGB values for four forest types (pine forest, flooded forest, pine plantation, and tree plantation) were drawn from IPCC default values in the 2003 Good Practice Guidance or the Revised 1996 IPCC Guidelines for National GHG Inventories, consistent with Cambodia's second national communication. AGB values for mangrove, rear mangrove, and forest regrowth were drawn from regionally specific literature sources. BGB is estimated following application of a ratio recommended for tropical forests (IPCC 2003b). The bamboo, rubber plantation, and oil palm plantation land-cover types

were assigned a value of zero carbon stock in biomass, effectively treating them as non-forest for the purposes of calculating the FRL and results.

4.3 Carbon pools

The carbon pools used in the estimation of results presented in this TA are the same carbon pools included in in the section 4.2.2 of the FRL of Cambodia presented and submitted to UNFCCC in 2017.

Table 3 Carbon pools used in the estimation

Carbon Pool	Included/ Excluded in the FRL	Included/ Excluded in the TA
Above Ground Biomass	Included	Included
Below Ground Biomass	Included	Included
Litter	Excluded	Excluded
Deadwood	Excluded	Excluded
Soil Organic Matter (SOM)	Excluded	Excluded

Future inclusion of the Litter, Deadwood and SOM carbon pools is part an improvement plan; Litter and Deadwood pools are expected to be included in future FRLs through the implementation of Cambodia’s first National Forest Inventory (NFI) if sufficient funds to implement the NFI become available. The SOM pool can be included when more funds for the NFI will be identified.

4.4 REDD+ activities (Deforestation, Degradation (partially), Enhancement)

The REDD+ activities included in this TA are the same as the activities included in section 4.2.1 of the Forest Reference Level presented by Cambodia and submitted to the UNFCCC in December 2017. These activities are deforestation, degradation and enhancement of forest carbon stocks.

- *Box 1: Technical considerations of REDD+ activities proposed in the FRL and the Technical Annex:*

The first FRL is the annual average of the carbon dioxide (CO₂) emissions associated with deforestation, including degradation and the enhancement of carbon stocks in forest land remaining forest land (with only changes in forest subcategories), and removals of CO₂ from the atmosphere through afforestation where other land uses are converted to forest land. For example, the changes from forest land to non-forest land such as plantation or pine plantation are considered as deforestation, and changes from non-forest land to forest land are considered as afforestation. The same approach is used to quantify net emissions from forest degradation and enhancement of forest carbon stocks within forest land remaining forest land (presented as a change in forest subcategory).

5 Description of the National Forest Monitoring System (NFMS) and the institutional roles and responsibilities for Measuring, Reporting and Verifying the results (MRV)

The NFMS of Cambodia is one of the four technical elements of the Warsaw Framework (decision 11/CP.19), that includes to spatially obtaining and quantifying the forests area change and to determine the changes of carbon emissions, estimating anthropogenic forest-related greenhouse gas emissions and removals.

The development of Cambodia's NFMS follows a phased approach according to the national capacities as recommended by the UNFCCC and stipulated by national policy and according to the national capacities and circumstances. Phase 1 (2011-2015) aimed at designing the NFMS and building technical and institutional capacity for major activities; Phase 2 (2016-2020) aims at testing the methodologies designed in phase 1; and Phase 3 (beyond 2020) is the full operational stage.

Description of the SLMS and monitoring system

The Satellite Land Monitoring System (SLMS) is key for the measurement part or MRV function; it also provides frequent information on land use/cover for monitoring purposes. For land use/cover change data, Cambodia produces spatial data and information of land use/cover change every two years, integrating methodologies and techniques to process and analyse spatial information using, mainly, satellite images of medium and high spatial resolution such as Landsat ETM and Sentinel 2.

The monitoring function of the NFMS focuses on the effect of policies and measures (PAM) to address drivers of deforestation and forest degradation, monitoring of forest management. This needs to be done using remote sensing-based technologies and information to be provided by local government and local officers, as well as local communities.

Cambodia is currently working on establishing a monitoring function that will integrate data from different organisations (notably the Ministry of Environment (MOE) and Ministry of Agriculture, Forestry and Fisheries (MAFF) and NGOs to provide field information into a central database to support law enforcement on protected areas, assist to better manage natural resources and conserve biodiversity.

The Monitoring function, based on the SMART platform is use by different NGOs in Cambodia, will enable information collected from the field to automatically upload to a central databases. Moreover, the same platform will be used to verify and transmit forest loss alerts to the field.

Cambodia established a NFMS Webportal (accessible at: <http://cambodia-nfms.org>) for information sharing and transparency purposes (reporting) to the public. The portal contains several types of data related to forest and REDD+ PAMs. The portal is a hub of information that can be used to share relevant information coming from various stakeholders. Information on the portal is regularly updated.

Descriptions of the NFI and temporary use of existing data

Under the NFMS implementation of the future National Forest Inventory is foreseen to obtain precise information on the biomass of different types of forest at different ages, different densities and different locations. The data to be collected will be used to improve emission and removal factors. All the five

carbon pools, namely above-ground biomass (AGB), below-ground biomass (BGB), deadwood, litter, and soil organic matter are targeted.

Cambodia has undertaken several subnational forest inventories, and Cambodia plans to implement a recently designed national forest inventory, which is expected to improve the national emission factors and use the resulting improved national emission factors for future FRL submissions. However, to date, a full-scale national forest inventory has for the moment not been carried out, and EFs were obtained from existing studies. Emission factors were estimated by calculating the carbon stock per unit area before and after land cover changes. The information on emission factors was developed from a literature survey and data from various forest inventory surveys implemented in Cambodia and analysed for values of biomass density, as compiled by the UN-REDD Program.⁸

GHG-I including AFOLU

The purpose of the national GHG inventory of the AFOLU sector is to estimate sources and sinks in order to develop GHG mitigation activities and reporting on the climate change mitigation impact resulting from the implementation of AFOLU activities. The GHG inventory should follow the international guidance following Good Practice Guidance of the Intergovernmental Panel on Climate Change (IPCC); and be reported to the UNFCCC Secretariat on a regular basis.

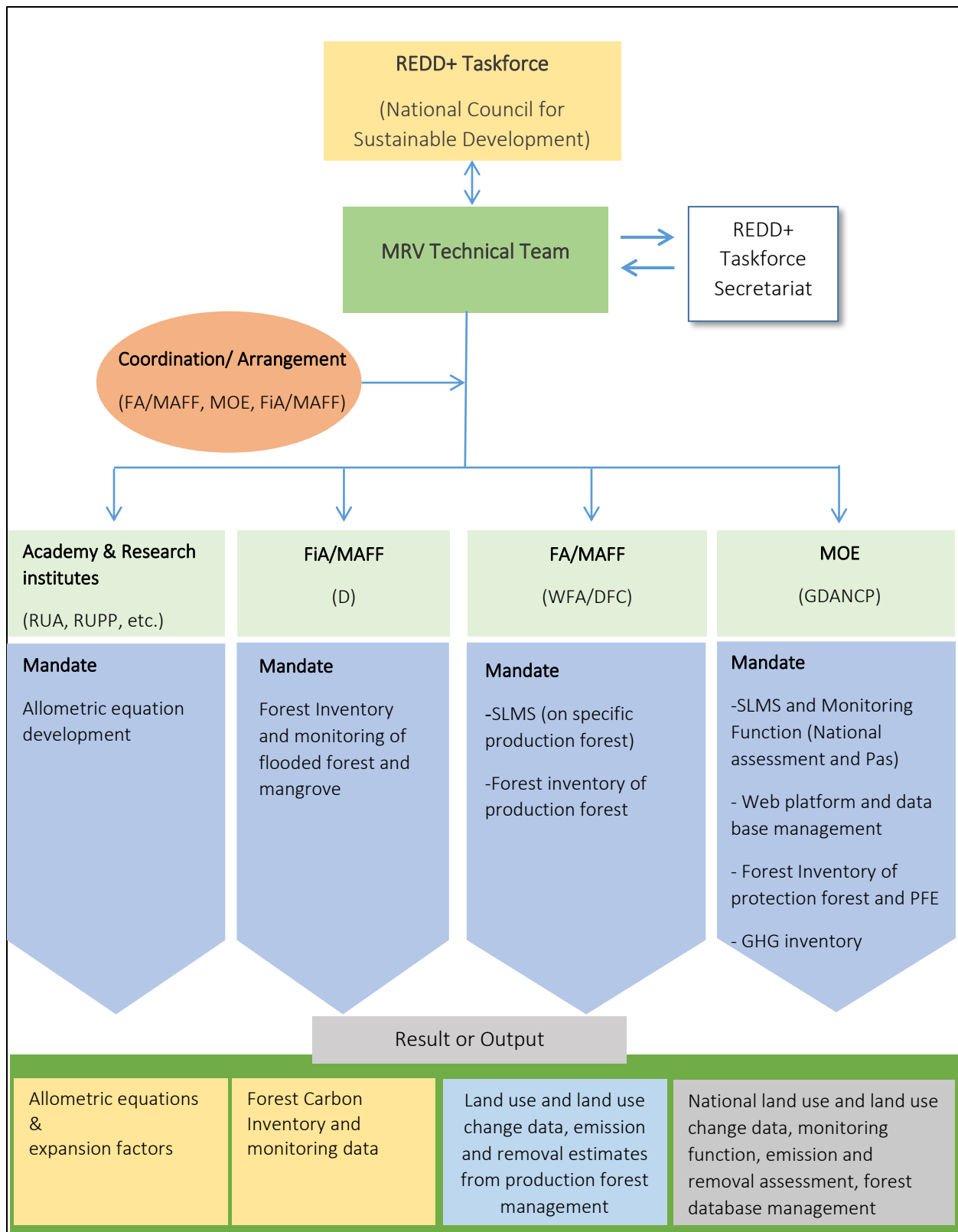
The mitigation results reported in the forest sector will form the basis for results-based payments for REDD+, once the results have undergone a process of verification through International Consultation and Analysis (ICA).

Cambodia has finalized the Third Greenhouse Gas Inventory (GHG inventory) that is presented in the First Biennial Updated Report. To maintain consistency between both reports on the information related to the land use categories, all the data used in the GHG inventory is the same as that used in the FRL.

Roles and responsibilities in each of the components (institutional arrangements)

The NFMS is operated by the MRV technical team, which is composed by three main institutions with a mandate to manage the forest resources in Cambodia, namely the General Department of Administration for Nature Conservation and Protection (GDANCP) of the Ministry of Environment (MOE), the Forestry Administration (FA) and the Fisheries Administration (FiA) of the Ministry of Agriculture Forestry and Fisheries (MAFF), plus academic and research institutions like the Royal University of Phnom Penh (RUPP) and the Royal University of Agriculture (RUA). The roles and responsibilities of each institution is highlighted in the figure below. It is understood that the institutions have shared responsibilities to operate and improve the NFMS.

⁸ Sola G., Vanna S., Vesa L., Van Rijn M., Henry M., 2014. Forest biomass in Cambodia: from field plot to national estimates, UN-REDD Programme, Phnom Penh, Cambodia.



Note: the institutional arrangements might not reflect latest settings and will be updated accordingly

Plans for future NFMS improvements

NFMS improvements foreseen include:

- *Improvement in the Capacities of Monitoring*: such as Near real-time monitoring; using handheld devices for case tracking and to provide feedback information to responsible central government agencies (options community, government use); use of drones of monitoring of land encroachment as well as improvement of AD; monitoring of drivers of deforestation
- *Improved capacities to measure Forest degradation and enhancement*: Such as detection of road disturbance and other disturbances using various tools; classifying different biomass stocks of forests
- *Implementation of Cambodia's first National Forest Inventory*: including with help of mobile handheld devices. Allowing improvement of Emission Factors, and coverage of AGB, BGB, Litre, Deadwood and SOM Carbon Pools
- Development of a nested system and capacity to tracking REDD+ implementation and measures; including implementation arrangement

Further information on Cambodia's NFMS can be obtained in a background document on the NFMS available under: <https://redd.unfccc.int/submissions.html?country=khm>

6 Necessary information that allows for the reconstruction of the results

1. Satellite image: used for construct the land use map 2006-2010-2014-2016-2018 are stored in the NFMS database.
 - Landsat 2006,2010,2014,2016, 2018 in NFMS database or NFMS Web portal: <http://cambodia-nfms.org>
2. Land use map for year 2006-2010-2014-2016-2018 are presented as digital map and stored in the NFMS database.
 - Land use map 2006, 2010 and 2014 presented in Cambodia Forest Cover 2014 booklet (publication : September, 2016)
 - Land use map 2016 presented in Cambodia Forest Cover 2016 Booklet (publication :March, 2018) or https://redd.unfccc.int/uploads/54_3_cambodia_forest_cover_resource_2016_english.pdf
 - Land use map 2018 stored in the NFMS database
3. Land use change 2006-2010, 2010-2014, 2014-2016, 2016-2018 are presented as digital map and stored in the NFMS database
 - Land use change map 2006- 2010 and 2010-2014 presented in Cambodia Forest Cover 2014 booklet (publication: September, 2016)
 - Land use change map 2014-2016 presented in Cambodia Forest Cover 2016 Booklet (publication: March, 2018) or https://redd.unfccc.int/uploads/54_3_cambodia_forest_cover_resource_2016_english.pdf
 - Land use change map 2016-2018 stored in the NFMS database
4. The ground truth data and high resolution imagery to perform the accuracy assessment and area estimation are in digital data and stored in the NFMS database.

Contact person: Mr. Chivin Leng, Cambodia's FRL/MRV Coordinator;
 Ms. Hout Naborey, MRV technical specialist

7 Description of how the elements contained in Decision 4/ CP. 15, para (c) and (d) have been taken into account

7.1 Use of the most recent IPCC guidance and guidelines

Cambodia's FRL and Technical Annex is consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories as a basis for estimating emission and removal resulting from deforestation, forest degradation and enhancement. The IPCC considers the carbon stock in the biomass immediately before and immediately after a conversion. Cambodia applies the product of activity data (in hectares/year) and emission factor (in t CO₂e/ha) for estimating emissions and removals

7.2 Establish, according to national circumstances and capabilities, robust and transparent national forest monitoring system

Development of Cambodia's NFMS follows a phased approach as recommended by the UNFCCC. Phase 1 (2011-2015) aimed at designing the NFMS and build technical and institutional capacity; Phase 2 (2016-2020) aims at testing the methodologies designed in phase 1; and Phase 3 (beyond 2020) is the full operation stage. Cambodia established a NFMS Web portal (accessible at: <http://cambodia-nfms.org>) for information sharing and transparency purposes. The portal contains several types of data related to forest and REDD+ policies and measures. The portal is a hub of information that can be used to share relevant information coming from various stakeholders. Information on the portal will be regularly updated.

The Forest Reference Level of Cambodia is constructed using activity data from the period 2006-2014. For the supporting BUR technical annex, the land use/cover maps 2016 and 2018 were analysed. Cambodia plans to continuously update its Activity Data at two year intervals.

Cambodia plans to implement a recently designed national forest inventory, which is expected to improve the national emission factors and use the resulting improved national emission factors for future FRL submissions and results reporting. However, until a full-scale national forest inventory is carried out, a literature survey and data from various forest inventory surveys have formed the basis for developing the emission factors.

Both the continued updates of activity data and the planned implementation of the NFI are of great importance to the advancement of the forest agenda in Cambodia and instrumental to maintaining and step-by step development of a robust and transparent forest monitoring systems at the national level. Improvements will follow a phased approach, appropriate to national circumstances and capabilities.

8 Annex to technical annex for results by Reducing Emissions from Deforestation over 2017-2018 with aggregated uncertainties

In line with the recent update of the GCF scorecard requesting countries to provide information on aggregate uncertainties⁹ around emissions estimates, this section presents REDD+ results (i.e. emissions reductions) over the 2017-2018 period including aggregated uncertainties around emission estimates. This section is added to the TA since Cambodia's FRL submission did not include information on aggregate uncertainties, as estimating aggregate uncertainties is not an UNFCCC requirement for FREL/FRL, and since the conditions of the GCF pilot programme for RBPs were not known at the time of the FRL submission. However, if aiming to apply for RBPs under the GCF Pilot programme for RBPs, REDD+ Technical Annexes submitted for assessment from 2019 onwards shall present information on aggregate uncertainties. If not, countries will fail the scorecard.

In this section, we present the results and we detail the methodology used to estimate land cover change areas and uncertainties around those estimates following a Stratified Area Estimation (SAE) methodology. This section is also added as it shows technical advancements made and Cambodia's commitment to improve transparency and accuracy of its submissions.

8.1 Results achieved by Reducing Emissions from Deforestation over 2017 to 2018

In light with its strategy to reduce emission from Deforestation and Forest Degradation as well as reverse the trend and reach zero percent before 2040, the RGC has taken important steps to tackle deforestation and forest degradation, and target forest restoration and carbon enhancement.

- In 2012, at the peak of ongoing deforestation, the RGC set in motion a suspension of new Economic Land Concessions (ELC) grants and initiated a review of existing ELCs (order 01BB).
- In 2015, REDD+ was included as key mitigation strategy in Cambodia's intended National Determined Contribution (NDC).
- In 2016, the RGC issued sub-decrees creating of new national parks, such as the Prey Preah Rok and Prey Lang national park and announced moratorium on economic land concession, in total of 411,021 ha of granted ELCs has been revoked and has placed under the National Production Strategic Plan 2018-2032 as an area for forest rehabilitation through public-private-community partnership
- In 2017 the government has set up biodiversity conservation corridors of the area of nearly 1.5M hectares (sub-decree No 07) to ensure the stability and security of the ecosystem and to maintain the environment. At the same time had the RGC decided to degazette Snuol Wildlife Sanctuary (75,000 ha) and Roneam Daun Sam Wildlife (40,000 ha) to focus efforts on the remaining protected areas, resulting in nearly 40% of the land surface under some form of protection.

RGC increased total number of Protected Area (Pas) from 23 PAs (18%) in 1993 to 55 PAs (40%) in 2018. To facilitate this protection process, MoE have also develop several strategic plans and guideline to support PAs protection and management including the National Protected Area Strategic Management Plan and Action Plan 2018-2022 (NPASMP), Technical guideline on PA zoning (2017) and on development of protected area management plan (2018). Several, pilot capacity building is also being tested in serval PAs including Phnom Kulen and Kulen Prumtep National Parks.

⁹ GCF scorecard (Section 2b. REDD-plus Results reporting), concerning uncertainties

While lead-in time is required to see further effects the implementation of such policy reforms (considered as REDD+ policies and measures) have set in motion a decreasing trend of deforestation from its peak in the years 2010-2014. And while Cambodia is committed to maintain this momentum, the RGC considers it just to put forward emissions reductions achieved from REDD+ implementation over the 2017-2018 period.

Table 4 Annual emission estimates (t CO2/yr)

Annual emission estimates (t CO2/yr)		
Period	Cambodia map (pixel count)	Stratified area estimate
2006-2010	27,002,876	41,020,754
2010-2014	130,905,036	87,030,849
FRL (average 06-14)	78,953,956	64,025,801
2014-2016	43,708,003	72,984,049
2016-2018	32,616,779	59,258,364

Table 5 Annual Emission flux (t CO2/yr)

Annual Emission flux (t CO2/yr)		
negative= reduction in deforestation, positive= increase in deforestation		
	Cambodia map (pixel count)	Stratified area estimate
14-16	-35,245,953	9,043,800
16-18	-46,337,177	-4,811,773

8.2 Activity Data – and quantified their uncertainty using stratified estimation in Cambodia

The Royal Government of Cambodia has developed land use maps for the years 2006, 2010, 2014 that were used to build the national forest reference level (FRL). Likewise, developed the maps for 2016 and 2018. All those are wall-to-wall maps for the whole country using available satellite images (Spot, Landsat and Sentinel). Each of those maps were stratified using the same classification system and methodology as follows:

Table 6 Land-use classification

Code	FRL_Classes	FNF	IPCC
E	Evergreen forest	Forest	Forest
Se	Semi-evergreen forest	Forest	Forest
D	Deciduous forest	Forest	Forest
B	Bamboo	Forest	Forest
Ws	Wood shrub	Non-Forest	Grassland
M	Mangrove forest	Forest	Forest

Mr	Rear mangrove	Forest	Forest
Rp	Rubber plantation	Non-Forest	Crop land
Ff	Flooded forest	Forest	Forest
Fr	Forest regrowth	Forest	Forest
P	Pine forest	Forest	Forest
Pp	Pine plantation	Forest	Forest
Po	Oil palm	Non-Forest	Crop land
Tp	Tree plantation	Forest	Forest
Hr	Paddy field	Non-Forest	Crop land
Hc	Various Crop land	Non-Forest	Crop land
G	Grassland	Non-Forest	Grassland
Bu	Built-up area	Non-Forest	Settlements
Bt	Village	Non-Forest	Settlements
R	Rock	Non-Forest	Other
S	Sand	Non-Forest	Other
W	Water	Non-Forest	Wetlands

In order to estimate the area of land-use change, changes of the following periods were considered: 2006-2010 (four years), 2010-2014 (four years), 2014-2016 (two years), 2016-2018 (two years). For each of those periods the classes were aggregated on the forest and non-forest classes

Table 7 aggregated classes

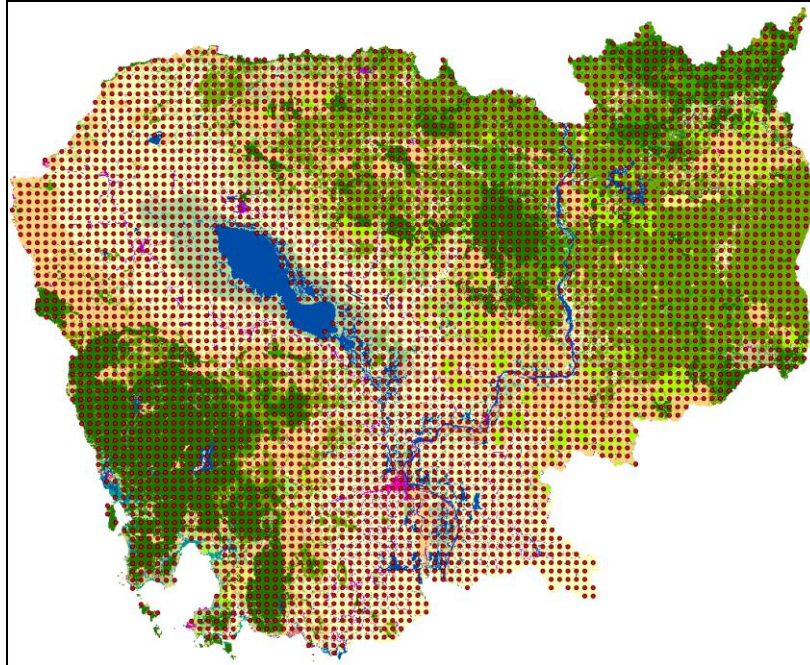
	F	O
F	Stable forest	Forest loss
O	Forest gain	Stable non-forest

Sampling Design and Reference Data

The method implemented to estimate the accuracy and uncertainty of LULUCF maps was based on (Olofsson, Foody, Stehman, & Woodcock, 2013). This method requires to elaborate a sampling design, collect data and analyze the results through an error-matrix to calculate the accuracy, uncertainty and estimate the area of the classification.

In order to improve the data presented on the FRL and have a spatial analysis of drivers of deforestation at multiple jurisdictional scales, a campaign to collect reference data was conducted during the first quarter of 2019. A systematic grid of 6 x 6 km. that match with the national forest inventory (NFI) design was chosen. The total number of plots is 4921, where each plot represents 0,5 ha (following the forest definition).

Figure 3 systematic sampling grid of 6 x 6 km on top of Cambodia



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 (RUPP), UNDP, FAO and SERVIR Mekong.

A survey was designed in Open Foris Collect Earth (<http://www.openforis.org/tools/collect-earth.html>) to collect the land use information of each plot from 2005 to 2019. Using all the very high spatial resolution available on Internet and the tree canopy cover response (<https://glad.umd.edu/cambodia>), the following information was collected for each plot:

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.



LULUC
Element
RS Info

Land Use 2019

Forest

Cropland

Grassland

Settlement

Otherland

Wetland

No data

Land Use 2018- Confidence

Yes

No

Land Use Change

C > C

O > C

F > C

G > C

W > C

S > C

Land Use Change- Confidence

Yes

No

Next

Having a general approach to classify the land-use was a key factor to ensure all interpreters follow the same rules 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 is labelled with this class. If the area is lower, the interpreter look for the class on the list that cover the minimum area required. Following the IPCC good practices, Settlement and Cropland classes are above Forest, because both are anthropogenic land-use.

The threshold of the classes is:

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



For example:

In this case, more than 20% of the plot is covered by a road, then, even if there is more than 70% of trees, this plot is classified as Settlement.

Nevertheless, on the element's window in the survey, the proportion of each class will be registered.

Error-matrix and uncertainty

The accuracy assessment was effectuated independently for each LULUCF map, using the corresponding classification of the 4921 plots – for 06-10 there were 3 plots not included.

Table 8 Error Matrices (2006-2010, 2010-2014, 2014-2016, 2016-2018)

Matrix 0610				
	FF	FO	OF	OO
FF	2551	86	0	243
FO	33	35	0	70
OF	30	0	0	7
OO	247	38	2	1576

Matrix 1416				
	FF	FO	OF	OO
FF	2042	53	0	166
FO	21	36	0	45
OF	12	0	0	2
OO	302	54	1	2187

Matrix 1014				
	FF	FO	OF	OO
FF	2078	66	1	122
FO	202	235	0	212
OF	73	2	0	21
OO	165	43	1	1699

Matrix 1618				
	FF	FO	OF	OO
FF	1965	63	0	177
FO	13	13	0	44
OF	5	0	0	4
OO	280	39	1	2317

Accuracy and Uncertainty estimation of Activity Data

Following (Olofsson et al., 2014), the accuracy and the uncertainty with a 95% of confidence (CI) was calculated. In general, the forest loss uncertainty is relatively low (> 16%). However, the producer accuracy is also low in all cases (around 25%) with the exception of the period 10-14 (around 67%).

SAE 0610									
class	code	P_Acc	W_P_Acc	U_Acc	map_Area_Ha	Area_Esti_Ha	Standard_Error	Conf_Interval	CI_%
FF	FF	89%	88%	89%	10300773	10325196	85925	141346	1.37%
FO	FO	22%	23%	25%	530983	588669	44834	73752	12.53%
OF	OF	0%	0%	0%	151113	7706	5447	8961	116.29%
OO	OO	83%	84%	85%	7177793	7239091	84053	138267	1.91%

SAE 1014									
class	code	P_Acc	W_P_Acc	U_Acc	map_Area_Ha	Area_Esti_Ha	Standard_Error	Conf_Interval	CI_%
FF	FF	83%	82%	92%	8134731	9102738	80702	132754	1.46%
FO	FO	68%	67%	36%	2317154	1248938	58230	95789	7.67%
OF	OF	0%	0%	0%	383346	7428	5255	8645	116.39%
OO	OO	83%	84%	89%	7325429	7801556	79489	130760	1.68%

SAE 1416									
class	code	P_Acc	W_P_Acc	U_Acc	map_Area_Ha	Area_Esti_Ha	Standard_Error	Conf_Interval	CI_%
FF	FF	86%	86%	90%	8154114	8604645	81230	133624	1.55%
FO	FO	25%	25%	35%	363963	523679	41572	68386	13.06%
OF	OF	0%	0%	0%	28067	3779	3779	6217	164.50%
OO	OO	91%	92%	86%	9614516	9028556	81960	134824	1.49%

SAE 1618									
class	code	P_Acc	W_P_Acc	U_Acc	map_Area_Ha	Area_Esti_Ha	Standard_Error	Conf_Interval	CI_%
FF	FF	87%	86%	89%	7901370	8161755	80641	132655	1.63%
FO	FO	11%	12%	19%	280811	425194	38824	63865	15.02%
OF	OF	0%	0%	0%	19405	3777	3777	6213	164.50%
OO	OO	91%	91%	88%	9959075	9569935	79885	131411	1.37%

Presented in a Matrix format, the areas of change and no change are:

SAE 2006-2010						
Activity data (ha)			Confidence intervals (%)			
	F	O		F	O	
F	10325196	588669		F	1.37%	12.53%
O	7706	7239091		O	116.29%	1.91%

SAE 2010-2014						
Activity data (ha)			Confidence intervals (%)			
	F	O		F	O	
F	9102738	1248938		F	1.46%	7.67%
O	7428	7801556		O	116.39%	1.68%

SAE 2014-2016						
Activity data (ha)			Confidence intervals (%)			
	F	O		F	O	
F	8604645	523679		F	1.55%	13.06%
O	3779	9028556		O	164.50%	1.49%

SAE 2016-2018						
Activity data (ha)			Confidence intervals (%)			
	F	O		F	O	
F	8161755	425194		F	1.63%	15.02%
O	3777	9569935		O	164.50%	1.37%

8.3 Emission Factors

To match the information on activity data, emission factors were developed using the same set of forest inventory measurements as the Forest Reference Level, i.e. 1755 plots from a wide range of projects and government initiatives, covering all the major forest types in the country. As the activity data is reduced to forest and non-forest, the carbon stock for forest was calculated based on the 1041 plots covering the three main forest types: Evergreen, Mixed Deciduous and Semi-evergreen Forest.

Across these three main forest types the average aboveground biomass was **137 ton of AGB/ha, equal to 64.18 ton C/ha and 235.33 tCO₂/ha.**

A carbon fraction of 0.47 was used to convert biomass to carbon. The associated belowground biomass was calculated using the formula:

$$\text{BGB} = \text{EXP}(-1.0587 + 0.8836 * \text{LN}(\text{AGB}))$$

Based on Cairns et al (1997).

It resulted in **26.73 ton of BGB/ha, equal to 12.56 ton C/ha and 46.06 tCO₂/ha**

The **confidence interval (CI) of the aboveground biomass was 7%**, calculated as:

$$CI = STDEV(AGB) / \sqrt{n \text{ plots}} * t(0.05, n \text{ plots}).$$

Table 9 Carbon Stock (tCO₂/Ha) and associated confidence intervals (%)

tCO ₂ /ha	F	O		CI (%)	F	O
F	0	281.39		F	0%	7%
O	-281.39	0		O	7%	0%

The calculations include only uncertainty derived from sampling and do not include other error sources (e.g., errors from allometric equation, human errors or others).

8.3 Results with aggregated uncertainties

Activity data and emission factors are combined to calculate the results, with the different steps outlined in the tables below. The combined uncertainty assessment (deforestation) was conducted at tier 1 level according to the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2006).

EQUATION 3.1
COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

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

EQUATION 3.2
COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

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

Table 10 Emissions and removals (tCO₂) 2006-2010, 2010-2014, 2014-2016, 2016-2018

SAE 2006-2010						
Data			Confidence intervals (%)			
	F	O		F	O	
F	0	165639683	F	1.37%	14.35%	
O	-2168314	0	O	116.50%	1.91%	

SAE 2010-2014						
Data			Confidence intervals (%)			
	F	O		F	O	
F	0	351426174	F	1.46%	10.38%	
O	-2090091	0	O	116.60%	1.68%	

SAE 2014-2016						
Data			Confidence intervals (%)			
	F	O		F	O	
F	0	147352797	F	1.55%	14.82%	
O	-1063335	0	O	164.65%	1.49%	

SAE 2016-2018						
Data			Confidence intervals (%)			
	F	O		F	O	
F	0	119641088	F	1.63%	16.57%	
O	-1062772	0	O	164.65%	1.37%	

Table 11 FREL/FRL Annual (tCO₂e/year) (2006-2010, 2010-2014, combined)

SAE 2006-2010						
Data			Confidence intervals (%)			
	F	O		F	O	
F	0	165639683	F	1.37%	14.35%	
O	-2168314	0	O	116.50%	1.91%	

SAE 2010-2014						
Data			Confidence intervals (%)			
	F	O		F	O	
F	0	351426174	F	1.46%	10.38%	
O	-2090091	0	O	116.60%	1.68%	

FREL/FRL Annual (tCO ₂ e/year)						
Data			Confidence intervals (%)			
	F	O		F	O	
F	0	64633232	F	0.00%	8.42%	
O	-532301	0	O	82.43%	0.00%	

FRL	64,100,931 +/-	8.52%
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Table 12 Emission and Removal estimates (tCO₂e/year)

SAE 2014-2016					
Data			Confidence intervals (%)		
	F	O		F	O
F	0	147352797	F	1.55%	14.82%
O	-1063335	0	O	164.65%	1.49%

SAE 2014-2016 (tCO ₂ e/year)					
Data			Confidence intervals (%)		
	F	O		F	O
F	0	73676399	F	1.55%	16.39%
O	-531668	0	O	164.80%	1.49%

SAE 2016-2018					
Data			Confidence intervals (%)		
	F	O		F	O
F	0	119641088	F	1.63%	16.57%
O	-1062772	0	O	164.65%	1.37%

SAE 2016-2018 (tCO ₂ e/year)					
Data			Confidence intervals (%)		
	F	O		F	O
F	0	59820544	F	1.63%	17.99%
O	-531386	0	O	164.80%	1.37%

Table 13 Results (tCO₂e/year)

Results 2014-2016 (tCO ₂ e/year)					
Data			Confidence intervals (%)		
	F	O		F	O
F	0	9043167	F	0.00%	9.58%
O	633	0	O	92.10%	0.00%

RESULTS	9,043,800	+/-	9.58%
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Results 2016-2018 (tCO ₂ e/year)					
Data			Confidence intervals (%)		
	F	O		F	O
F	0	-4812688	F	0.00%	9.69%
O	915	0	O	92.08%	0.00%

RESULTS	-4,811,773	+/-	9.69%
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