Initial Forest Reference Level for Cambodia under the UNFCCC Framework

July 22, 2016

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ABBREVIATIONS

ACRONYM	FULL WORD
AGB	Aboveground Biomass
BGB	Belowground Biomass
EF	Emission Factor
ELCs	Economic Land Concession
FA	Forestry Administration
FAO	Food and Agriculture Organization of the United Nations
FiA	Fisheries Administration
FLR	
FREL	Forest Reference Emission levels
FRL	Forest Reference Level
GDANCP	General Department of Administration for Nature Conservation and Protection
INDC	Intended Nationally Determined Contribution
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
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NPASMP	National Protected Areas Strategic Management Plan
NRS	
NSDP	National Strategic Development Plan
ODA	
PA	Protected Area
PFE	Permanent Forest Estate
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 Concession
SOM	

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 on a voluntary basis for consideration by the UNFCCC its initial Forest Reference Level (FRL).

In this report, we provide an overview of the data and methodologies used to develop Cambodia's initial 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). The submission of a FRL is exclusively for the purpose of obtaining and receiving payments for results from Cambodia's REDD+ program implementation.

Cambodia has high levels of deforestation and forest degradation but limited capacity and finance and expects to face continuing challenges to reduce emissions. The Cambodia REDD+ strategy outlines the policies and measures intended to reduce emission from deforestation and forest degradation. As these policies and measures are shaped they are expected to introduce long-term effects.

1.2. Cambodia's forest sector

Cambodia covers a total area of 181,035 km2. Cambodia is categorized as a least developed, low-income country. Relative peace and stability over the past decade has 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.

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 Department 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 (Source: 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 Department of Administration for Nature Conservation and Protection (GDANCP) of the Ministry of Environment (MoE) under the 2008 Protected Areas Law. Cambodia's 23 PAs covering about 3.2 million ha, or 18% 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),[1] set out in the Strategic Planning Framework for Fisheries 2010-2019.

More general 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 are being developed. The National Council for Sustainable Development 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 implementation of activities. The REDD+ Taskforce and Taskforce Secretariat have been established. 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.

2. Application of UNFCCC Modalities

2.1. UNFCCC modalities

The presented Initial Forest Reference Level (FRL) is consistent with the following UNFCCC decisions, among others:

1. Decision 4/CP.15: recognizing that developing country Parties in establishing forest reference emission levels and forest reference levels should do so transparently taking into account historic data, and adjust for national circumstances, in accordance with relevant decisions of the Conference of the Parties,
2. Decision 1/CP.16, paragraph 71: include forest reference emission levels as one of the four key elements to be developed for REDD+ in accordance with national circumstances and respective capabilities[1]
3. Decision 12/CP.17: modalities relating to forest reference emission levels and forest:
    - expressed in tonnes of carbon dioxide equivalent per year and serve as benchmarks for assessing the country's performance in implementing the activities referred to in decision 1/CP.16, paragraph 70
    - maintaining consistency with anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks as contained in the country's greenhouse gas inventories
    - a step-wise approach to national forest reference emission level and/or forest reference level development, enabling Parties to improve the forest reference emission level and/or forest reference level by incorporating better data, improved methodologies and, where appropriate, additional pools
    - allowing updates periodically as appropriate, taking into account new knowledge, new trends and any modification of scope and methodologies
4. Decision 13/CP.19: Guidelines and procedures for the technical assessment of submissions from Parties on proposed forest reference emission levels FREL/FRL:
    - submission shall be subject to a technical assessment

[1] According to Decision 12/CP.17, countries can submit rational on the development of FRL including details of national circumstances and if adjusted include details on How the national circumstances were considered, in accordance with the guidelines.

- developing countries may, on a voluntary basis and when deemed appropriate, submit a proposed forest reference emission level and/or forest reference level
- proposed forest reference emission levels and/or forest reference levels might be technically assessed in the context of results-based payments

2.2 Consistency with National GHG reporting

Cambodia's initial FRL uses the most recent Intergovernmental Panel on Climate Change guidance and guidelines (IPCC 2003 GPG and 2006 guidelines) to estimate emissions. The period covered does not overlap with the earlier GHG inventories. Planned GHG inventories are set to use IPCC GPG 2003/2006 guidelines consistent with the FRL and the updated data used for the development of the FRL, reflecting improvements in methodologies and capacities to assess activity data, emission factors and emission/removal estimates.

3. Proposed Forest Reference Level

The Initial Forest Reference Level is assessed at **79,245,643 tCO_2/year** in Cambodia based on the historical average net emission levels from 2006 to 2014.

The average (AVG) net total annual CO2 emissions and removals (tCO2/year) are calculated following this equation;

$$\text{Average} = \frac{C_{def_{y1}} + C_{def_{y2}}}{n_{y1+y2}}$$

Where:

$\boldsymbol{C_{defy}}$: The sum of emissions from deforestation over the "y" years of emissions over the time of observation. In case of removal, the sum of removal over the "y" years of removal over the time of observation.

Table 3-1: Total Annual CO2 Emissions and Removals (t CO2 / year) FRL reference period

Period (year to year)	2006-2010	2010-2014
Annual CO_2 Removals (t CO_2 / year)	-6,626,046	-20,298,825
AVG Annual CO_2 Removals (t CO_2/year)	-13,462,436	
Annual CO_2 Emissions (t CO_2 / year)	34,148,629	151,267,528
AVG Annual CO_2 Emission (t CO_2/year)	92,708,079	
Net Total Annual CO_2 Emissions and Removals (t CO_2 / year)	27,522,583	130,968,703
AVG Net Total Annual CO_2 Emissions and Removals (t CO_2 / year)	79,245,643	

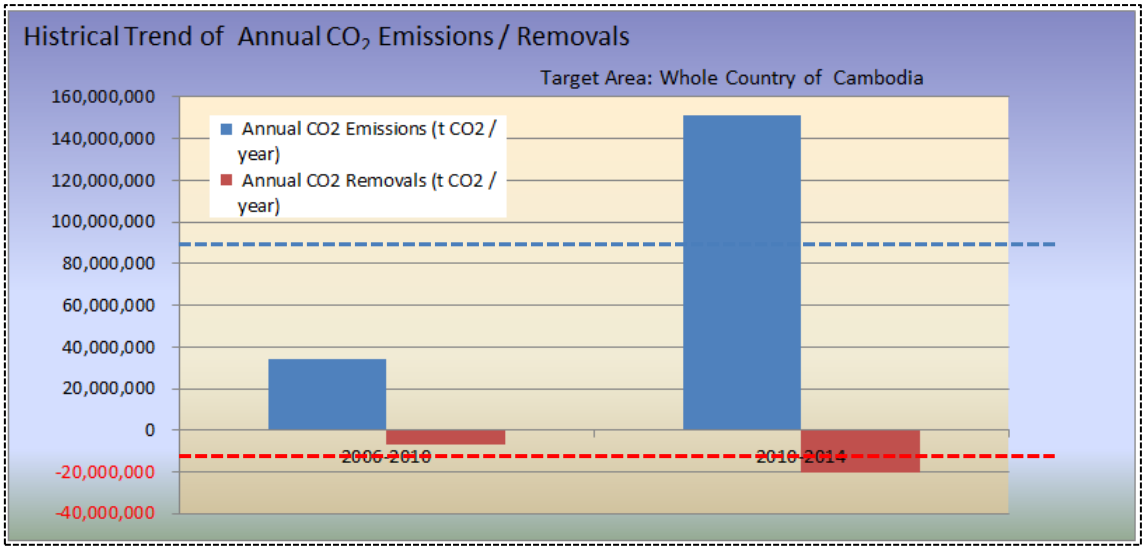

Figure 3-1: Histrical Trend of Annual CO_2 Emissions / Removals

Red dotted line is the Average annual CO_2 removal

Blue dotted line is the Average annual CO_2 emission

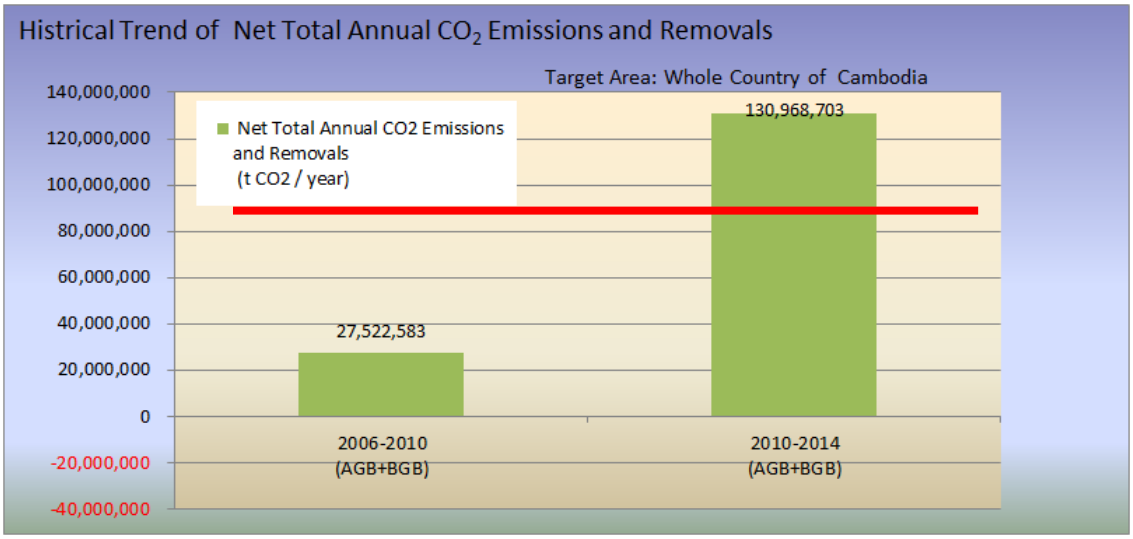

Figure 3-2: Historical Trend of Net Total Annual CO_2 Emissions

4. Information used for development of forest reference level

4.1. Scale

The FRL area encompasses Cambodia's Nation. The national scale is chosen to include considerations such as inter-institutional collaborations, with the responsibility of the forest estate under three institutions and linkages to national policies to implement REDD+. The national scale was possible due to the establishment of the National Forest Monitoring System (NFMS), availability of data and capacities.

It is however noted that REDD+ implementation could focus on specific areas before reaching the maturity of implementation at the national scale.

4.2. Scope

4.2.1. Scope of activity

Deforestation (forest land converted to other land types), degradation and enhancements (forest land remaining forest land with changes in forest sub-categories), and removal of CO_2 from the atmosphere through afforestation (other land uses converted to forest land) are included in the initial FRL.

Degradation and enhancement (through biomass stock changes within forest land without changes in forest sub-categories) are believed to be a significant contribution to emission or removals, however the information to monitor these type of degradation and enhancement (though biomass stock changes within forest land without changes in forest sub-categories) is for the moment not robust and reliable enough to be included in this FRL submission.

4.2.2. Scope of pools

Out of five carbon pools as described per IPCC guidelines, two pools, above ground biomass and below ground biomass, are included for the initial FRL establishment in Cambodia, which is consistent with LULUCF section in the national GHG inventory, and believed to be conservative while limited information exist on the litter, deadwood, and SOM pools. Information of these pools is expected after implementation of Cambodia's first National Forest Inventory (NFI).

Table 4-1: Carbon pools included in Initial FRL

Carbon Pool	Included/Excluded	Justification/ Explanation of Choice
Above Ground Biomass	Included	Major carbon pool affected by selected activity
Below Ground Biomass	Included	Major carbon pool affected by selected activity
Litter	Excluded	Stock change expected to be minor by selected activity and no data available.
Deadwood	Excluded	Stock change expected to be minor by selected activity and no data available.
Soil Organic Matter	Excluded	Stock change expected to be minor by selected activity and no data available.

4.2.3. Scope of Gas

Only CO_2 is included because in Cambodia emissions of other gases from land use and land use change are considered to be minor, and considered conservative while limited information exist on other gases. The Global Forest Resources Assessment (FAO, 2015) has recently released tables on forest fires; these figures are not used in the initial FRL to be conservative. Cambodia intends to monitor and explore inclusion of other gasses in its future submissions.

4.3. Definition of forest and land use classes

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. In order to implement the Cambodia REDD+ programme, forests have 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 metres 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.

The forest definition adopted by Cambodia for REDD+ has been formed taking into consideration Decision 1/CP.16 Appendix 1E (safeguard natural forest), for countries seeking result based payments, the conversion of natural forest to plantations is not eligible for result based payments.

The following Table highlights the hierarchical structure of IPCC land use categories and National Land use/cover classes adapted for REDD+ purpose in Cambodia. Detailed description of the national land use/cover classes is provided in annex 2.

Table 4-2: land use types hierarchy:

No	Forest/Non-Forest	IPCC land use Category	No	National Land Use/Cover Categories	FRL Classes (Initial FRL)
1	Forest	Forest	1	Evergreen forest	Evergreen forest
			2	Semi-evergreen forest	Semi-evergreen forest
			3	Deciduous forest	Deciduous forest
			4	Pine trees	Pine forest
			5	Pine plantation	Pine plantation
			6	Tree plantation	Tree plantation
			7	Mangrove forest	Mangrove
			8	Rear mangrove	Rear Mangrove
			9	Forest regrowth	Forest regrowth
			10	Flooded forest	Flooded forest
			11	Bamboo	Bamboo
2	Non-Forest	Crop land	12	Rubber plantation	Non-forest
			13	Oil palm	
			14	Paddy field	
			15	Crop Land	
3		Grassland	16	Grassland	
			17	Wood shrub	
4		Wetlands	18	Water	
5		Settlements	19	Built-up area	
			20	Village	
6		Other	21	Rock	
			22	Sand	

4.4. Historical period

The UNFCCC requires historical data to be taken into account for the construction of a FRL but does not specify the length of reference periods. In Cambodia, there is a continuing trend of rapid deforestation in recent years. Therefore the emissions from a recent period are expected to better reflect future emissions from deforestation in absence of REDD+. For this moment reliable and consistent historical activity data is only available from 2006 to 2014. Cambodia chose the years from 2006 to 2014 as historical period for initial FRL construction because of data availability and because Cambodia believes the recent data form a better approximation of deforestation rates in the near future in the absence of REDD+ implementation.

The choice of the reference period and use of historical average is based on a review of national circumstances. The average of historical emissions from the data available is conservative choice for approaching FRL construction, as explained in Section 4.5. However, there is a high degree of uncertainty regarding the impact of current circumstances in socioeconomic development, including policies and growth patterns, on the level of future emissions arising from forestland conversion.

4.5. National circumstances during historical period under review for FRL development

As part of the development of the FRL the national circumstances have been thoroughly reviewed. This section begins by describing an outline of the development of the legal and policy context for environmental conservation between 2006 and 2014. A qualitative analysis of the drivers of deforestation and forest degradation is then presented, as is an overview of the expected implications of Cambodia's for future emissions based on consideration of the national circumstances.

4.5.1. Legend and policy context during the reference period

The 2001 Land Law, 2002 Forestry Law, 2006 Law on Fisheries and the 2008 Protected Areas Law established the legal framework governing forest use in Cambodia. A series of sub-decrees elaborated on forestland management prescriptions, including a 2003 Sub-Decree (SD) on Community Forestry Management, 2003 SD on Social Land Concessions (SLCs), 2005 SD on Economic Land concessions (ELCs), and 2009 SD on Registration of Land of Indigenous Communities.

The National Strategic Development Plan (NSDP) contains the overarching goals and

action plans for harmonizing and maximizing effectiveness of development efforts. It seeks to implement RGC's "Rectangular Strategy", focusing on growth, employment, equity and efficiency. Starting in 2006, the NSDP has emphasized natural resource management throughout its existence. Currently in its third phase, NSDP 2014-2018 aims to balance the demands for economic development and needs for conservation via a series of land and forestry reforms. Forest management is strengthened through the National Forest Programme (NFP) 2010-2029 for improved management forests in the PFR, while the National Strategic Plan on Green Growth and Development 2013-2030 seeks to develop regulatory frameworks and mechanisms for carbon trading and strengthening the capability, preparation and implementation of climate change adaptation measures, among other things. The NFP 2010-2029 defines the policy and implementation strategies for the sustainable management of the nation's forestry sector under a series of programmes, including forest demarcation, classification and registration; Conservation and development of forest resource and biodiversity; forest law enforcement and governance; community forestry programme; capacity and research development; and sustainable forest financing.

4.5.2. Drivers of forest cover change

The drivers of deforestation and forest degradation in Cambodia are the result of a complex set of interrelated factors related to a pattern of economic development and resulting land-use change in a context where state institutions still have limited capacity to enforce the existing regulatory frameworks, exacerbated by incomplete land management systems and lack of inter-ministerial coordination (Broadhead & Izquierdo, 2010). The REDD+ Roadmap identified a series of direct drivers, including clearance for agriculture, settlement expansion, infrastructure development, illegal logging, and unsustainable harvesting wood fuel, alongside a large set of indirect factors related to the socioeconomic environment and governance conditions both within and outside the forestry sector (Forestry Administration, 2010). Since then, a number of reports have sought to quantify these drivers, and have pointed to the relevance of SLCs, mining, large-scale infrastructure development, and unsustainable fuelwood collection and charcoal production, and an incomplete and often overlapping land management system (see Aruna Technology ltd, 2015; Delux & Van Rijn, 2015; GERES, 2015). Lack of up to date and reliable primary data is a common concern across all studies, limiting the ability to accurately assess the identified drivers. While rates of deforestation can relatively accurately be measured using Remote Sensing (RS) attributing observations support to specific agents and underlying causes requires information that is often absent. Nonetheless, findings from the various studies indicate that the dominant driver of deforestation has been the conversion of forestland to large-scale agro-industrial plantations by private investors under Economic Land

Concessions (ELCs) (Banks, Sloth, Garcia, & Ra, 2014; Forests Trends, 2015; Lawson et al., 2014). The dramatic increase in emissions resulting from deforestation since 2010 is likely a consequence of an increase in forestland conversion and timber harvesting within sites allocated for ELCs and agricultural expansion for cash crops. Forest disturbance resulting from the expansion of monoculture plantations for rubber has been statistically linked to international market price fluctuations, with the past few years seeing higher market prices , and exceptionally high disturbance rates (Grogan, Pflugmacher, Hostert, Kennedy, & Fensholt, 2015).

Both MoE and MAFF have the authority to issue ELCs.[2] [Between 1996 and 2012, MAFF and MoE allocated ELCs covering 1,55 mill. ha (Source: MAFF on 21 Jul 2016) and 470,000 ha of Cambodia's approximately (Source: MoE reported on 15 Sept 2015). The allocation of land to ELCs halted with the implementation of Directive01 in 2012, although some forests within existing ELCs are still largely intact, and conversion to inside these ELCs is expected to remain for the coming years.

SLCs are a legal mechanism for redistributing land to for socioeconomic development. There are two categories of beneficiaries of SLCs: (a) poor and landless families or families of former military personnel, (b) communities requiring land for local development projects such as physical infrastructure, for future population increase, and (c) issued land title to local people (RGC, directive01). Although the procedural requirements for the granting and distribution of SLCs have been in place since the 2003[3], the mechanism was not fully utilized until 2010. [Between 2009 and 2013, government land allocated for SLCs 2,450,000 ha (Source: MLMUPC declaration dated on 25 Jan, 2016)]. Due to an increasing scarcity of available land, combined with an incomplete forest demarcation, SLCs often encroach on forestland and have been linked to deforestation and forest degradation, although the aggregate impact is unknown. Nevertheless, monitoring of both ELCs and SLCs are being conducted by RGC to ensure alignment with laws and regulations. The National REDD+ strategy is envisioned to strengthen this monitoring.

Under Directive01, RGC has accelerated land titling through the sporadic and systematic land registration systems, in addition to implementing an "old policy, new action" initiative. A total of around 1.2 mill.ha of land titles have been distributed so far. The land registration

[2] Under the 2008 Protected Area Law and 2001 Land Law, respectively

[3] 2003 Sub-decree on Social Land Concessions

system and SLC programmes are embedded with incentives for land clearance. Claimants must prove occupation of land parcel for a minimum of five years, and SLC holders must abide by conditions that include development of the land through agricultural cultivation.

4.5.3. Future

A number of trends in the national context point to continued high emission levels arising from the land use and forestry sectors in the future. Strong economic growth is expected to continue, and is likely to continue relying on extractive economic institutions in the land-use sectors for the immediate future. Expansion of monoculture cropping is expected to grow as the Cambodian government invests in strengthening commercialization for small-scale farmers and enhancing linkages between large-scale agro-industrial plantations and surrounding smallholders. Examples of relevant policies include the policy on "Promotion of Paddy Rice Production and Milled Rice Export" and the "National Rubber Development Strategy 2011-2020."

Although the sector is currently underdeveloped, mining is expected to grow extensively in the future with increased foreign investment and improved technology, with uncertain implications for forests. An unknown area has been granted by MME for mining and mineral exploration. Moreover, Investment in the construction of hydropower dams to supply the population's growing energy needs is growing, with numerous projects at varying stages of development. These large-scale projects are regulated by the 2007 Concessions Law, without effective mechanisms for ensuring of environmental and social safeguards, there is a risk that logging and other illegitimate extractive practices will occur.

Many of the issues illustrated above illustrate the need for a well-functioning and effective governance of the forestry sectors and coherent approach to policies within the land-use sectors. Today, government reforms to align development priorities with conservation efforts and inculcate coherence in land use are well underway. RGC's submission of its Intended Nationally Determined Contribution (INDC) in 2015 outlines Cambodia's efforts at reducing greenhouse gas emissions by sector. There is thus a growing recognition of the need for enhanced efforts at climate change mitigation and adaptation.

As Cambodia graduates to Lower-Middle Income Country status in the near future (RGC, 2014), donor funding will dissipate and RGC will have to seek funding from other sources. Already by 2013, a larger share of Overseas Development Assistance took the form of

concessional loans compared to ODA grants (CDC, 2014). In 2012, of a total of USD 1.50 billion around USD 14 million and USD 7 million of a total of 1.5 billion USD for ODA were committed to environment and conservation, and climate change, respectively.

Cambodia will continue to integrate into regional and global markets, with uncertain implications for environmental conservation. As the ASEAN Economic Community is consolidated, Cambodia's forests could become increasingly threatened as economic hubs become increasingly connected. On the other hand, further integration might be accompanied by pressures for strengthened state regulations of the flow of goods across borders.

For these reasons and acknowledging the uncertainty of future impacts on emissions within these sectors, averaging historical emissions over 2006-2014 represents a conservative approach to FRL development.

4.6. Approach for FRL establishment

Cambodia takes an approach based on historical average of net emission from deforestation[4] for eight years from 2006 to 2014. The reason for the choice of this methodology is due to the national circumstances outlined above and the fact that there are only three points in time for activity data. Three data points (for two change assessments) are considered insufficient to create a regression line for the predication of future trends.

4.7. Methodology

Historical emission estimates are developed based on the activity data from 2006 to 2014. Annual CO^2 Emissions and Removals (tCO_2 / year) are calculated by the following equation;

$$\Delta C_B = \frac{(Ct_2 - Ct_1)}{(t_2 - t_1)}$$

$$\Delta CO_2 = \Delta C_B \times 44/12$$

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)

4.8. Activity Data

Activity data explains the extent of human activities, in this case expressed in land use and land use change maps. There are several historical forest cover maps in Cambodia; made in 1989, 1993, 1997, 2002, 2006, 2010 and 2014. However, there are inconsistencies in the definition of forests and the forest classification before the 2006 data. Therefore, Cambodia development of FRL, only the maps in 2006, 2010 and 2014 were used.

"Forest" and "Non Forest" classes were stratified according to newly defined land use/cover classes by using the same LANDSAT images used in the original mapping. Land use/cover class of each segment (polygon) was identified by visual interpretation of LANDSAT images. Information such as maps made by FAO and Mekong River Commission and images of

[4] Net emissions from deforestation in this context includes degradation and enhancements in areas of forest land remaining forest land but with changes in forest sub-categories, and removal of CO2 from the atmosphere through afforestation where other land uses are converted to forest land

Google Earth were also used as reference. The minimum mapping unit (MMU) of the Land use/cover classes was 5ha.

For consistency of the mapping procedure, LANDSAT 8 images were used to develop 2014 map. The segmentation technique was used in automatic polygon generation and then land use/cover class of each segment (polygon) was identified by visual interpretation of LANDSAT images. Google Earth images were also used as a reference.

Note: The detailed methodology to develop the activity data is described in Annex 3.

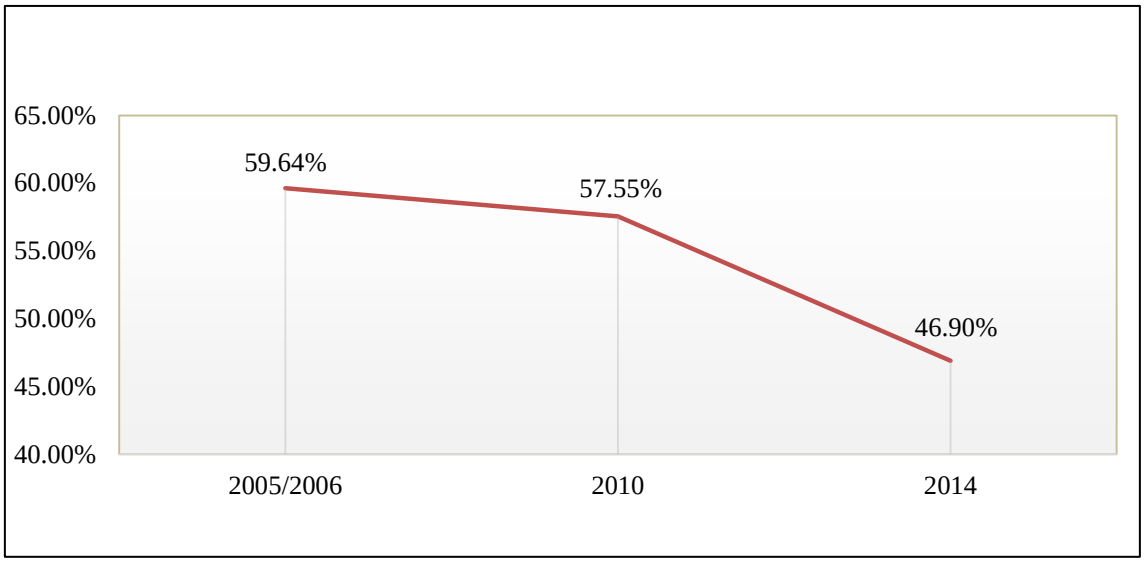

Figure 4-1: Change of forest cover from 2006 to 2014 excluding rubber and oil palm plantation as in the definition for REDD+

Table 4-3: Forest Cover and land use statistics in 2006, 2010 and 2014

Classification	2006		2010		2014	
	Ha	%	Ha	%	Ha	%
Evergreen Forest	3,710,271	20.43%	3,573,925	19.68%	2,973,903	16.38%
Semi-evergreen forest	1,453,441	8.00%	1,391,117	7.66%	1,108,320	6.10%
Deciduous Forest	4,613,417	25.40%	4,498,397	24.77%	3,480,532	19.17%
Flooded Forest	597,355	3.29%	524,005	2.89%	481,078	2.65%
Forest Regrowth	216,123	1.19%	249,341	1.37%	228,560	1.26%
Bamboo	129,837	0.71%	130,930	0.72%	130,678	0.72%
Mangrove	32,060	0.18%	31,443	0.17%	33,002	0.18%
Classification	**2006**		**2010**		**2014**	
	Ha	**%**	**Ha**	**%**	**Ha**	**%**
Rear Mangrove	27,519	0.15%	27,371	0.15%	25,906	0.14%
Pine Forest	8,157	0.04%	8,157	0.04%	8,196	0.05%
Pine Plantation	0	0.00%	11	0.00%	3,709	0.02%
Tree Plantation	43,547	0.24%	17,214	0.09%	44,289	0.24%
Forest Area	**10,837,260**	**59.64%**	**10,451,911**	**57.55%**	**8,518,173**	**46.90%**
Oil Palm Plantation	35	0.00%	5,055	0.03%	36,311	0.20%
Rubber Plantation	78,148	0.43%	137,307	0.76%	484,316	2.67%
Grassland	600,006	3.30%	473,281	2.61%	351,337	1.93%
Agriculture	1,000,634	5.51%	1,275,444	7.02%	2,787,413	15.35%
Paddy Filed	3,668,981	20.20%	3,859,452	21.25%	4,133,474	22.76%
Rock	219	0.00%	668	0.00%	2,054	0.01%
Sand	8,304	0.05%	10,459	0.06%	40,581	0.22%
Built up area	37,435	0.21%	43,800	0.24%	328,820	1.81%
Village	248,126	1.37%	296,513	1.63%	42,166	0.23%
Water	438,410	2.41%	458,658	2.53%	813,839	4.48%
Wood shrub	1,248,649	6.88%	1,148,126	6.32%	622,190	3.43%
Non Forest	**7,328,947**	**40.36%**	**7,708,763**	**42.45%**	**9,642,501**	**53.10%**
Total Area	**18,160,674**	**100.00%**	**18,160,674**	**100.00%**	**18,160,674**	**100.00%**

4.9. Emission Factor

Emission factors (EF) are defined as CO2 emission per unit area induced by human activities. Emissions are estimated by calculating the change of carbon stock per unit area between two points in time. In FRL calculation, post-deforestation carbon stock is assumed to be zero. Emission factors for Aboveground Biomass (AGB) changes between forest types and changes between land use types are derived from the table below. Whereas Belowground Biomass (BGB) is estimated following application of a ratio recommended for tropical forests (IPCC 2003b).

Cambodia has never conducted a National Forest Inventory (NFI). Cambodia has recently designed a NFI. When implemented, the NFI is expected to improve the national emission factors. The post-deforestation carbon stock per unit of area is assumed zero because there is no reliable data on the replacing land-use and regrowth at the moment.

Based on existing references, Cambodia selected following AGB for FRL establishment. Detailed methodology is described in Annex 4.

Table 4-4: Estimation of above ground biomass (ton ha-1) by forest types in Cambodia

Forest type	AGB ton ha-1	C ton ha-1*	CO^2 ton ha-1**
Evergreen forest	163	76.6	280.90
Semi-evergreen	243	114.21	418.77
Deciduous	85	39.95	146.48
Forest regrowth	75	35.25	129.25
Flooded	70	32.90	120.6
Plantation	100	47.00	172.33
Pine plantation	100	47.00	172.33
Mangrove	150	70.50	258.50
Rear Mangrove	165	77.55	284.35
Bamboo***	0	0.0	0

*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.

References: CCEAP (2003), CFI (2008), IPCC (2006b), JICA TAT (2015), Sasaki *et.al*. (2013), Sola *et al*. (2014), Tran (2015)

***Bamboo=0, mean that area land cover represented bamboo class are very small

Above ground biomass values for Evergreen, Semi-evergreen and Deciduous forests were

estimated based on the estimation by Sola *et al*. (2014). Chave *et al*. (2005) equations were used for the calculation.

-Dry zone (Annual rain < 1500 mm):

$AGB=WD\times(-2.187+0.916\times\ln(WD\times DBH^2\times H)$

- Moist zone (1500 mm ≤ Annual rain ≤ 3500 mm):

$AGB=WD\times(-(DB0$ mm):$\times DBH^2\times H)$

- Wet zone (Annual rain > 3500 mm):

$AGB=WD\times(-2.557+0.940\times\ln(WD\times DBH^2\times H)$

Where

AGB: Above ground biomass of trees

DBH: Diameter at breast height

WD: Wood density

H: Tree height

- Tree height was estimated with the local H-DBH model for trees (Sola *et al*., 2014)

$$H=1.3+9.303525\times DBH^{0.24991}$$

-BGB was calculated from AGB using the following equation.

UBGB (ton/ha of dry matter) = exp[-1.0587 + 0.8836 • ln (UAGB)]

Variable: UAGB (Unit Above Ground biomass) (ton / ha of dry matter)

Application: tropical forests

(Reference: IPCC (2003b))

5. Transparency, completeness, consistency and uncertainty of information

Per decision 12/CP17 Guidelines for submissions of information on reference levels, information provided in the FRL submission should include information that is Transparent, Complete, Consistent and Accurate, for the purpose of allowing a technical assessment of the data. The following information supports this.

5.1. Transparency

Decision 12/CP.17 requires transparent and consistent information should be provided, that is, information should be accessible by all relevant stakeholders and updated on a regular basis. The data used for calculation of emission factors of the FRL will be published after completion of the technical assessment. Also, the results of FRL are accessible by all relevant stakeholders through developed web interface which will be updated when FRL is updated. This report will also be open for public access. Key information is publically accessible on *www.cambodia-redd.org.*

5.2. Completeness

Completeness in Decision 12/CP.17 means whether the provision of information allows for the reconstruction of the FRL. Methods used are clearly described in the previous section and in the annexes. Therefore, the FRL can be reconstructed. The data provided in the FRL is complete to the extent possible and intentions to improvements are outlined in the separate section and in chapter 7 Plan for FRL improvement. Raw data for emission factors and activity data are available upon request from the REDD+ secretariat, Cambodia.

5.3. Consistency

Decision 12/CP.17 requires that the forest reference levels shall maintain consistency with anthropogenic forest related greenhouse gas emissions by sources and removals by sinks as contained in the country's national greenhouse gas inventory (GHG inventory). As described in chapter 1.2 Cambodia's initial FRL development reflecting improvements in methodologies and capacities to assess activity data, emission factors and emission/removal estimates. The FRL historical period covered does not overlap with the earlier GHG inventories, future planned GHG inventories are set to be consistent with the improvements reflected in the FRL.

5.4. Accuracy

5.4.1. Accuracy of Emission factors

In Cambodia, no nationwide forest inventory has been conducted. Although localities were limited, 39 PSP and above 474 REDD+ related project and 528 community forest survey data were collected for calculation of emission factors for main forest types, Evergreen,

Semi-evergreen and Deciduous forest. Coefficient of variation (CV) for those forest inventory data ranges from 0.99 % to 1.47%. These relatively high values of CV are expected to decrease by conducting the National Forest Inventory (NFI) in the future. For other forest types, emission factors will also be improved through the NFI.

5.4.2. Accuracy of Activity Data

Accuracy assessment of the original 2006 and 2010 forest assessment map was performed by Geographic Resource Analysis & Science A/S (GRAS). The report was compiled as Accuracy Assessment Report (draft final). Overall accuracy of the five classes – Evergreen Forest, Semi-evergreen forest, Deciduous Forest, Other Forest and Non-Forest, was 74% of 2006 map and 85% of 2010 map.

New accuracy assessment of the upgraded 2006 map and 2010 map was performed after the completion of the initial classification edit. The accuracy assessment of 2014 map, total number of accuracy assessment points was calculated by using the same Congalton & Green formula and distributed for each class in proportion to the area of each class. Overall accuracy of the 22 classes was 81.23% with kappa 79.49% (Annex 3).

Furthermore, Cambodia is currently undertaking an accuracy assessment of change of land use change data between 2006 and 2010, and between 2010 and 2014. The results are expected to be made available to the technical assessment team and part of future FRL submissions once available.

6. Plan of FRL improvement

The FRL submission presented in this report is thought to best reflect current methodologies, data and capacities to assess activity data, emission factors and emission/removal estimates, with an intention to im/.prove future FRL submission.

The initial FRL is based on activity data between 2006 and 2014; it is envisioned that future FRL submissions include updates of the land use/cover data. It is planned to produce land use/cover map every two years from 2016.

Accuracy of data in the initial FLR based on activity assessment performed for individual maps it is envisioned that an assessment of the accuracy of land use changes will be performed in the future.

Improvements in both emission factors and activity data are expected through implementation of Cambodia's first NFI. The data in Sola *et al*. (2014) used assessing the AGB of Evergreen, Semi-evergreen and Deciduous forest are based on a collection of data from several locations, but do not represent a systematical assessment of forest in Cambodia.

An allometric equation is used to calculate dry weight, above ground biomass of a tree from easier-to-measure characteristics such as tree diameter or height. For the initial FRL development, general allometric equations were used. However, tree forms differ from one species to another, and therefore so would tree biomass and allometric equations. Country specific allometric equations will be developed to increase reliability

Recent studies show that wood density is an important predictor of tree biomass (Chave *et al*., 2014). Available methodologies and associated cost for measuring it in forest inventories are huge constraints but average wood density at tree species level can be used without creating bias (Fayolle *et al*., 2013). Therefore, developing a table of wood density values at species level would improve biomass estimates (Sola *et al*., 2014).

Overall consistency between FRL submissions and National GHG reporting is strengthened by the establishment of a REDD+ database. All information and subsequent updates in information are stored in the database, allowing for improvement of consistency between various submission reports.

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Annex 1 Emission/Removal Calculation Tables

Table 1: Forest Living Aboveground Biomass CO2 Emission / Removal Matrix between 2006 and 2010

Target Area: Whole Country of the Kingdom of Cambodia

Unit: t CO_2

Forest Type		Year 2010												Total	
		E	Se	D	B	Ff	Fr	M	Mr	P	Pp	Tp	NF		
Year 2006	E	0	0	0	5,662	0	699,168	0	0	0	0	114,634	40,596,497	41,415,961	44.9%
	Se	23,663	0	3,419	0	0	951,150	0	0	0	0	10,385	27,527,183	28,515,800	30.9%
	D	0	0	0	1,426	0	19,208	0	-1,153	0	0	-58,825	19,427,761	19,388,418	21.0%
	B	0	0	0	0	0	-1,478	0	0	0	0	0	0	-1,478	0.0%
	Ff	0	0	0	0	0	-5,103	0	0	0	0	0	15,069,620	15,064,517	16.3%
	Fr	-26,521	-1,713	-1,434	0	175	0	0	-1,689	0	0	-11,953	3,252,497	3,209,362	3.5%
	M	-3,216	-8,840	0	0	0	0	0	-1,038	0	0	0	204,085	190,991	0.2%
	Mr	0	-10,441	0	0	0	6,701	2,347	0	0	0	0	234,505	233,112	0.3%
	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	Pp	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	Tp	0	-4,113	674	0	389	6,959	0	0	0	0	0	6,087,045	6,090,955	6.6%
	NF	-2,064,725	-2,833,341	-3,060,632	0	-6,289,256	-6,350,958	-82,896	-235,594	0	-1,882	-956,308	0	-21,875,594	-23.7%
Total		-2,070,799	-2,858,447	-3,057,973	7,088	-6,288,691	-4,674,352	-80,549	-239,474	0	-1,882	-902,067	112,399,193	92,232,045	100.0%
		-2.2%	-3.1%	-3.3%	0.0%	-6.8%	-5.1%	-0.1%	-0.3%	0.0%	0.0%	-1.0%	121.9%	100.0%	

CO_2 Emission for 4 years from 2006 to 2010	114,245,155	t CO_2
CO_2 Removal for 4 years from 2006 to 2010	-22,013,109	t CO_2
CO_2 Emission / Removal for 4 years from 2006 to 2010	92,232,045	t CO_2
Annual CO_2 Emission from 2006 to 2010	28,561,289	t CO_2/yr
Annual CO_2 Removal from 2006 to 2010	-5,503,277	t CO_2/yr
Annual CO_2 Emission / Removal from 2006 to 2010	23,058,011	t CO_2/yr

Table 2: Forest Living Belowground Biomass CO2 Emission / Removal Matrix between 2006 and 2010

Target Area: Whole Country of the Kingdom of Cambodia

Unit: t CO_2

Forest Type		Year 2010												Total	
		E	Se	D	B	Ff	Fr	M	Mr	P	Pp	Tp	NF		
Year 2006	E	0	0	0	1,086	0	123,233	0	0	0	0	19,938	7,784,395	7,928,653	44.4%
	Se	3,908	0	582	0	0	162,621	0	0	0	0	1,755	5,037,371	5,206,237	29.2%
	D	0	0	0	295	0	3,515	0	-202	0	0	-10,680	4,016,854	4,009,781	22.5%
	B	0	0	0	0	0	-310	0	0	0	0	0	0	-310	0.0%
	Ff	0	0	0	0	0	-955	0	0	0	0	0	3,187,980	3,187,025	17.8%
	Fr	-4,675	-293	-262	0	33	0	0	-297	0	0	-2,177	682,794	675,122	3.8%
	M	-547	-1,466	0	0	0	0	0	-177	0	0	0	39,514	37,324	0.2%
	Mr	0	-1,723	0	0	0	1,180	400	0	0	0	0	44,905	44,762	0.3%
	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	Pp	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	Tp	0	-695	122	0	71	1,267	0	0	0	0	0	1,235,541	1,236,307	6.9%
	NF	-395,912	-518,491	-632,812	0	-1,330,493	-1,333,251	-16,050	-45,114	0	-382	-194,110	0	-4,466,614	-25.0%
Total		-397,226	-522,668	-632,370	1,381	-1,330,389	-1,042,700	-15,651	-45,790	0	-382	-185,274	22,029,354	17,858,286	100.0%
		-2.2%	-2.9%	-3.5%	0.0%	-7.4%	-5.8%	-0.1%	-0.3%	0.0%	0.0%	-1.0%	123.4%	100.0%	

CO_2 Emission for 4 years from 2006 to 2010	22,349,361	t CO_2
CO_2 Removal for 4 years from 2006 to 2010	-4,491,075	t CO_2
CO_2 Emission / Removal for 4 years from 2006 to 2010	17,858,286	t CO_2
Annual CO_2 Emission from 2006 to 2010	5,587,340	t CO_2/yr
Annual CO_2 Removal from 2006 to 2010	-1,122,769	t CO_2/yr
Annual CO_2 Emission / Removal from 2006 to 2010	4,464,571	t CO_2/yr

Table 3: Forest Living Aboveground Biomass CO2 Emission / Removal Matrix between 2010 and 2014

Target Area: Whole Country of the Kingdom of Cambodia

Unit: t CO_2

Forest Type		Year 2014												Total	
		E	Se	D	B	Ff	Fr	M	Mr	P	Pp	Tp	NF		
Year 2010	E	0	-11,571	81,236	0	0	6,815,422	468	-155	0	6,066	351,314	167,316,879	174,559,660	39.8%
	Se	0	0	0	34,501	0	4,710,453	0	0	0	22,604	395,420	122,854,383	128,017,361	29.2%
	D	-2,785	0	0	986	0	208,821	0	0	0	-1,610	-325,368	166,838,171	166,718,214	38.0%
	B	0	0	0	0	0	-77,525	0	0	0	0	0	0	-77,525	0.0%
	Ff	0	0	0	0	0	-15,404	0	0	0	0	0	14,119,502	14,104,098	3.2%
	Fr	-796,848	-951,553	-25,121	32,337	5,643	0	-3,851	-20,697	0	-306	-91,936	18,477,538	16,625,207	3.8%
	M	0	0	0	0	0	0	0	-2,305	0	0	0	459,803	457,498	0.1%
	Mr	185	0	0	8,895	0	99,412	10,690	0	0	0	10,191	2,378,061	2,507,435	0.6%
	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	Pp	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	Tp	-1,201	-4,061	132	0	0	10,119	0	0	0	0	0	930,448	935,438	0.2%
	NF	-11,166,290	-10,567,116	-21,066,979	0	-9,077,730	-7,599,210	-765,951	-2,235,465	-6,834	-605,753	-2,255,661	0	-65,346,989	-14.9%
Total		-11,966,939	-11,534,301	-21,010,731	76,719	-9,072,087	4,152,089	-758,643	-2,258,622	-6,834	-578,999	-1,916,040	493,374,785	438,500,397	100.0%
		-2.7%	-2.6%	-4.8%	0.0%	-2.1%	0.9%	-0.2%	-0.5%	0.0%	-0.1%	-0.4%	112.5%	100.0%	

CO_2 Emission for 4 years from 2010 to 2014	506,179,682	t CO_2
CO_2 Removal for 4 years from 2010 to 2014	-67,679,285	t CO_2
CO_2 Emission / Removal for 4 years from 2010 to 2014	438,500,397	t CO_2
Annual CO_2 Emission from 2010 to 2014	126,544,920	t CO_2/yr
Annual CO_2 Removal from 2010 to 2014	-16,919,821	t CO_2/yr
Annual CO_2 Emission / Removal from 2010 to 2014	109,625,099	t CO_2/yr

Table 4: Forest Living Belowground Biomass CO2 Emission / Removal Matrix between 2010 and 2014

Target Area: Whole Country of the Kingdom of Cambodia

Unit: t CO_2

Forest Type		Year 2014												Total	
		E	Se	D	B	Ff	Fr	M	Mr	P	Pp	Tp	NF		
Year 2010	E	0	-1,911	14,248	0	0	1,201,268	80	-26	0	1,055	61,103	32,083,082	33,358,899	39.1%
	Se	0	0	0	6,313	0	805,359	0	0	0	3,821	66,835	22,481,890	23,364,217	27.4%
	D	-489	0	0	204	0	38,210	0	0	0	-292	-59,074	34,495,201	34,473,760	40.4%
	B	0	0	0	0	0	-16,275	0	0	0	0	0	0	-16,275	0.0%
	Ff	0	0	0	0	0	-2,884	0	0	0	0	0	2,986,983	2,984,099	3.5%
	Fr	-140,450	-162,690	-4,597	6,789	1,057	0	-683	-3,645	0	-56	-16,744	3,878,973	3,557,954	4.2%
	M	0	0	0	0	0	0	0	-392	0	0	0	89,026	88,633	0.1%
	Mr	31	0	0	1,703	0	17,509	1,820	0	0	0	1,771	455,373	478,208	0.6%
	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	Pp	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
	Tp	-209	-686	24	0	0	1,843	0	0	0	0	0	188,861	189,833	0.2%
	NF	-2,141,141	-1,933,743	-4,355,776	0	-1,920,395	-1,595,295	-148,301	-428,068	-1,387	-122,955	-457,851	0	-13,104,912	-15.3%
Total		-2,282,257	-2,099,030	-4,346,100	15,009	-1,919,339	449,734	-147,085	-432,132	-1,387	-118,427	-403,960	96,659,389	85,374,416	100.0%
		-2.7%	-2.5%	-5.1%	0.0%	-2.2%	0.5%	-0.2%	-0.5%	0.0%	-0.1%	-0.5%	113.2%	100.0%	

CO_2 Emission for 4 years from 2010 to 2014	98,890,431	t CO_2
CO_2 Removal for 4 years from 2010 to 2014	-13,516,014	t CO_2
CO_2 Emission / Removal for 4 years from 2010 to 2014	85,374,416	t CO_2
Annual CO_2 Emission from 2010 to 2014	24,722,608	t CO_2/yr
Annual CO_2 Removal from 2010 to 2014	-3,379,004	t CO_2/yr
Annual CO_2 Emission / Removal from 2010 to 2014	21,343,604	t CO_2/yr

Annex 2 Description of land use/cover types

No	Land cover class	ID	Description
1	Evergreen forest	E	Areas covered by trees maintaining their leaves during the whole year.
2	Semi-evergreen forest	Se	Contain variable percentages of evergreen and deciduous trees.
3	Deciduous forest	D	Comprised of dry mixed deciduous forest and dry Dipterocarp forests
4	Bamboo	B	Areas dominated by bamboo
5	Wood shrub	Ws	Areas dominated by evergreen and deciduous woodland with a height less than 5 meters
6	Mangrove forest	M	Areas dominated by Mangroves i.e. coastal salt tolerant species
7	Rear Mangrove	Mr	Mostly growing in coastal zone after mangrove spp. Salt tolerant species but only infrequent floods
8	Rubber plantation	Rp	Areas currently supporting, and areas reserved for, rubber plantation
9	Flooded Forest	Ff	This forest type is found in Tonle Sap Lake. Most of the forests are low and disturbed. In many cases, there is only a mosaic remaining
10	Forest Regrowth	Fr	Areas of naturally regenerated forest where there are clearly visible indication of human activities such as selective logging, areas regenerating following agricultural land use, areas recovering from human induced fire, etc. • Include forest where it is not possible to distinguish whether planted or naturally regeneration. • Include forests with mix of naturally regenerated trees and planted/seeded trees, and where the naturally regenerated trees are expected to constitute more than 50 percent of the growing stock at stand maturity. • Include abandoned forest land and bare land which will regrow into forest within ten years
11	Pine Tree	P	The area dominated by coniferous trees
12	Pine plantation	Pp	The area domunated by pine tree plantation
13	Oil palm	Po	The area dominated by oil palm tree.
14	Tree plantation	Tp	This class includes the following type: teak, eucalyptus, acacia, jatropha and others.
15	Paddy Field	Hr	Paddy field is a flooded parcel of arable land used for growing semiaquatic rice.
16	Crop Land	Hc	This category includes arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category
17	Grassland	G	Grasslands are characterized as lands dominated by grasses rather than large shrubs or trees. It is crucial that the rainfall is concentrated in six or eight months of the year, followed by a long period of drought when fires can occur.
18	Built-up area	Bu	The patch of land with building and construction
19	Village	Bt	The patch of land with houses and garden surrounding house.
20	Rock	R	Land of naturally exposed rocks or strip mines, quarries and gravel pits.
21	Sand	S	In general, land of sand having thin soil or sand including deserts, dry salt flats, beaches, sand dunes.
22	Water	W	Area of fresh and sea water

Annex 3 Detailed methodology for acquiring activity data

1. Preparation of maps for FRL calculation

As of 2011 when Cambodia started its REDD+ readiness activities, maps showing forest cover of Cambodia were available for the year 1965, 1993, 1997, 2002, 2006 and 2010. Historically, the maps were made by interpreting satellite images printed on paper. From the 2002 map production, on-screen digitizing method using GIS software was introduced. The classification system and forest definition thresholds were not consistent for these maps (Brun, 2013)

Cambodia planned to establish its initial Forest Reference Level (FRL) by around September 2015 and in order to achieve this goal, development of a 2014 base map was initiated. For historical data existing maps were envisioned to be used as long as consistency could be warranted. These historical maps had the following issues as base for activity data for FRL establishment:

- The historical maps used various classification systems
- Before (2002) the forest cover threshold was 20% whereas the FRL forest definition is using a 10% threshold.
- Accuracy assessment was performed for the 2006 and 2010 maps only. That is, only these maps are suitable to be used in FRL establishment.
- Rubber and oil palm plantations, which are excluded from the Cambodia's forest definition for REDD+, were included in Other Forest class and were not separated in most historical data.
- Non-forest area is not stratified

To deal with these issues, the following measures were taken:

- Comparison of the classification and forest definitions used in historical maps and those used for FRL establishments
- Review land use/cover classes of 2006 and 2010 maps to make them consistent with six land use/cover categories defined by IPCC.
- Stratify Other Forest and Non-Forest classes of the 2006 and 2010 maps according to the new land use/cover classes and also exclude rubber and oil palm plantation classes from forest category.

2 Forest Definition for REDD+

The forest definition for REDD+ follows the definition of the National Forest Programme while rubber and oil palm plantation classes are excluded from the definition of forest. 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%. Area also included in the REDD+ programme are forest regrowth.

The land cover/use classification of Cambodia presents in 22 classes, including 9 classes of natural forests, 2 classes of plantation forest, 11 classes of non-forest, covering all 6 IPCC land use categories. Name of the 22 classes and description are in Annex 2 and the comparison of the land use class with the class of IPCCC category are show in the Table 1..

Table 1. Comparison of land use/cover classes

	Old (2006/2010) class		New class	IPCC guideline classification
1	Evergreen forest	1	Evergreen forest	Forest land
2	Semi-evergreen forest	2	Semi-evergreen forest	
3	Deciduous forest	3	Deciduous forest	
4	Bamboo	4	Bamboo	
5	Wood shrub dry	5	Wood shrub	Other land
6	Wood shrub evergreen			
7	Other forest	6	Mangrove forest	Forest land
		7	Rear mangrove	
		8	Rubber plantation	Cropland
		9	Flooded forest	Forest land
		10	Forest regrowth	
		11	Pine tree	
		12	Pine plantation	
		13	Oil palm	Crop land
		14	Tree plantation	Forest land
8	Non-forest	15	Paddy field	Cropland
		16	Crop Land	
		17	Grassland	Grassland
		18	Built-up area	Settlement
		19	Village	
		20	Rock	Other land
		21	Sand	
		22	Water	Wetland

The 22 land cover classes are based on physiognomy or biophysical appearance that are sensed by remote sensing data used (Landsat at 30m) and LCCS3 was used as a guiding tool to develop the classification.

3. Map production method

a. 2014 mapping

Unlike 2006 and 2010 mapping, all of the forest and non-forest areas were segmented for the 2014 mapping. The land use/cover classes of polygons generated by the segmentation process were identified by visual interpretation of LANDSAT images.

Several ancillary datasets (including boundary of forest plantation, Social Land concession, Economic land concession, and location of hydropower dams) were utilized during

the process of delineation, to catch additional information valuable for classification. Directive 001 land was classified as agricultural land because it was allocated for agricultural use, and SLC holders must abide by conditions that include development of the land through agricultural cultivation. The majority of lands have already been cleared, and it is reasonable to assume that all the Directive 001 land is converted to agricultural area in a very short period.

The procedure for the 2014 mapping is explained in Figure 1.

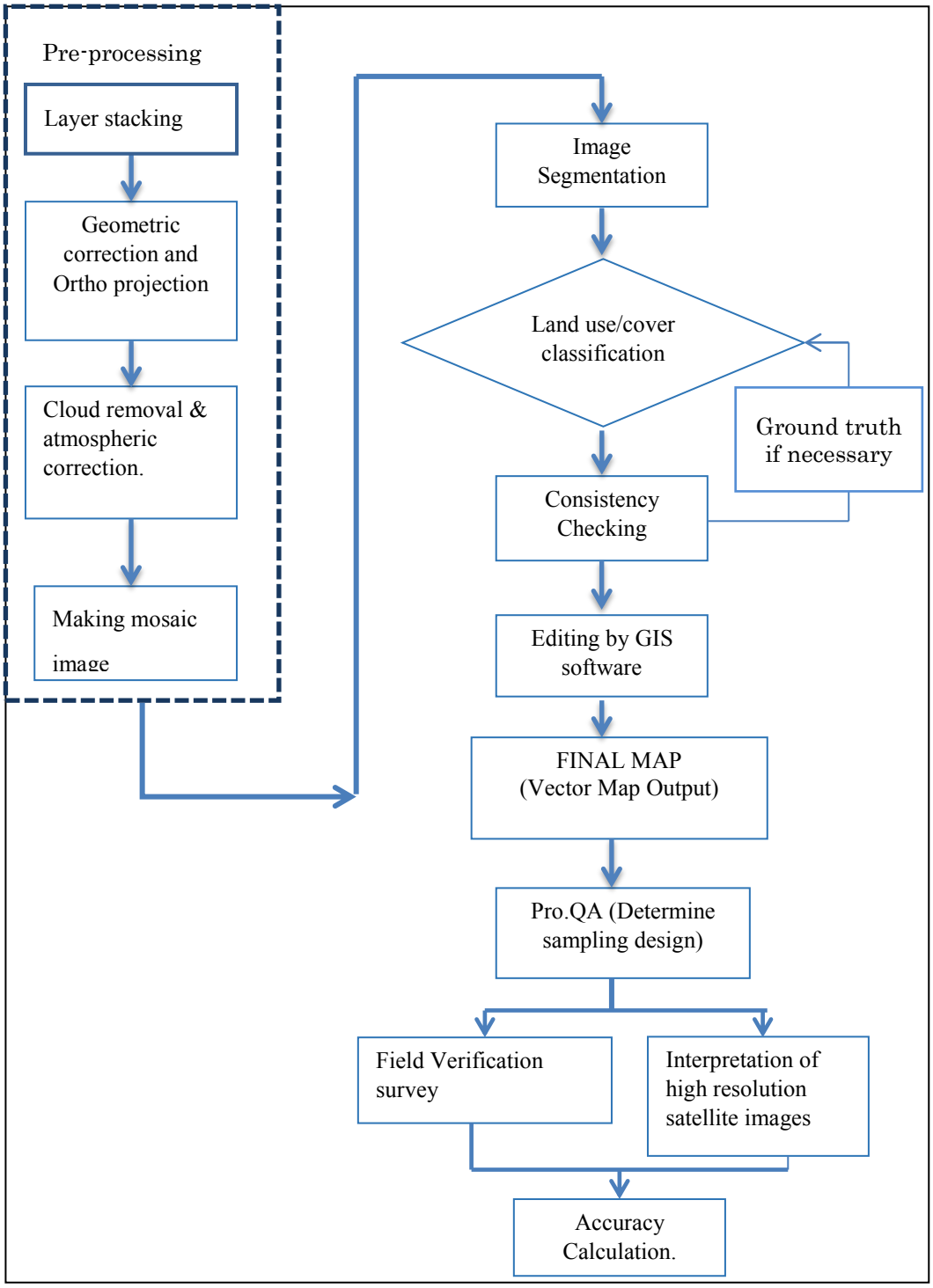

Figure 1: Procedure for develop Land Use/Cover 2014 Mapping

b. 2006 and 2010 map upgrading

"Other Forest" and "Non Forest" classes of original 2006 and 2010 maps were stratified according to newly defined land use/cover classes (Table 1) by using the same LANDSAT images used in the original mapping. In the stratification, segmentation technique was used. Land use/cover class of each segment (polygon) was identified by visual interpretation of LANDSAT images. Information such as map made by FAO and Mekong River Commission and images of GoogleEarth were also used as reference. Land use/cover class of minimum mapping unit (MMU) of Other Forest and Non Forest classes was 5ha while forest area data with a MMU of 25Ha was checked during correction stage to minimize inconsistency (See quality assurance and consistency).

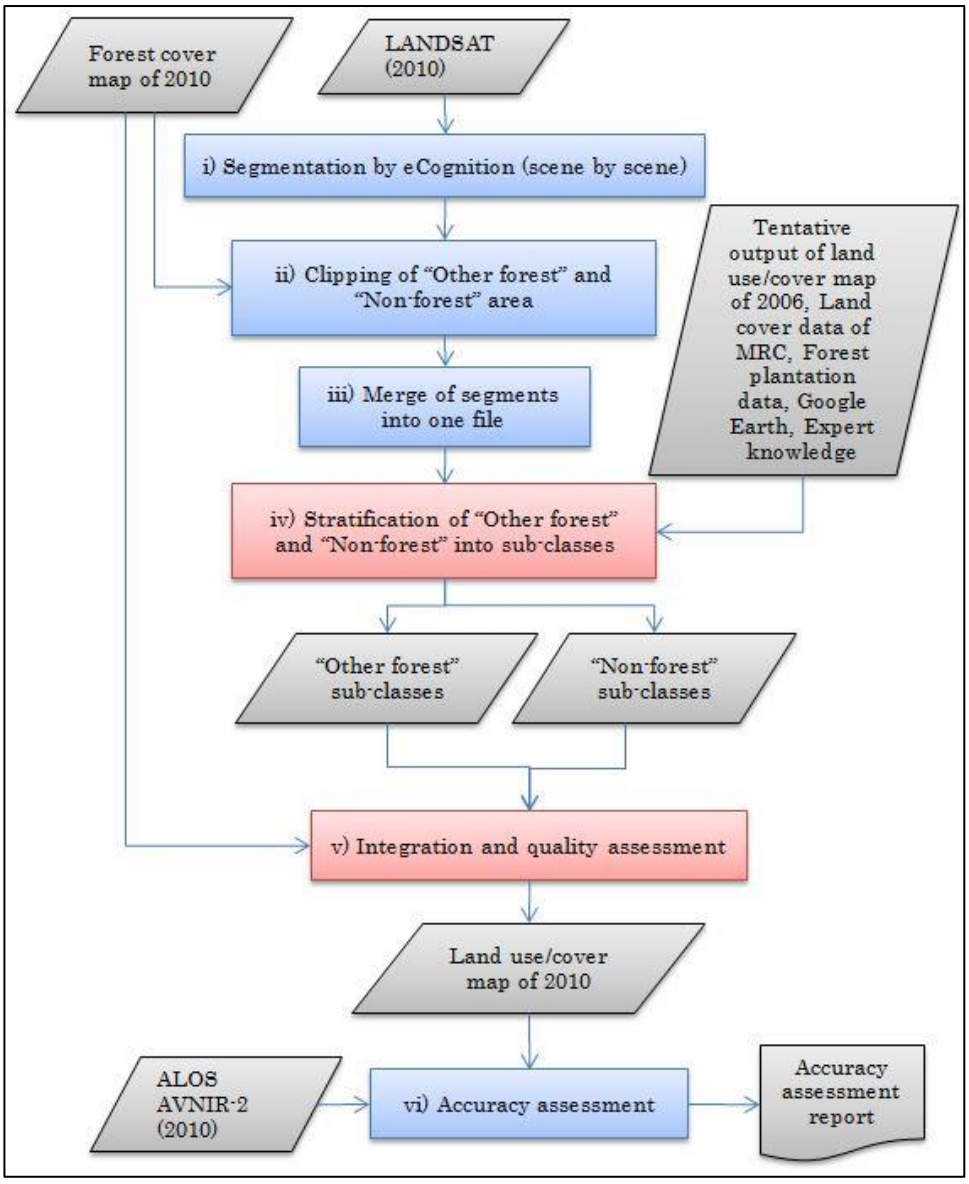

Figure 2: Procedure for upgrading Land Use/Cover 2010 Map

c. Quality assurance and consistency

New map of 2014 and upgraded maps of 2006 and 2010 were prepared for the purpose of obtaining land use/cover change information between 2006-2010 and 2010-2014. While the accuracy of each of the three maps is important, it is also important that land use/cover change information derived from the three maps is accurate.

To eliminate miss interpretation completely, thorough inspection of generated polygons is required. However, it is not practical to do this. Alternative method for checking is to identify land use/cover change patterns which are considered not likely and inspect land use/cover class of identified polygons. Process of land use/cover change pattern inspection is divided into three steps as shown in Figure 3.

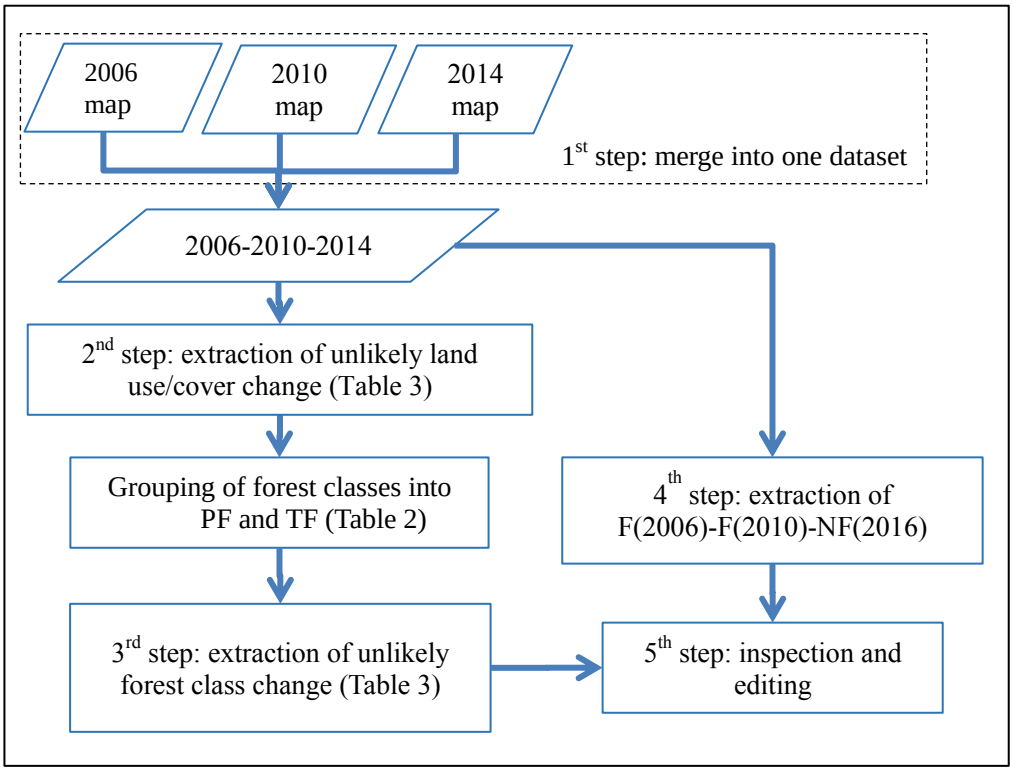

Figure 3: Procedure of quality assurance

In the 1st Step, map data of 2006, 2010 and 2014 were merged (intersected) into one file by using GIS.

In the 2nd Step, polygons with one of the following two land use/cover change pattern were selected.

F(2006)-NF(2010)-F(2014)
NF(2006)-F(2010)-NF(2014)

These two patterns were selected because it is unlikely that NF changes to F within a short period

of time such as 4 years. However, if F is actually Forest Regrowth, NF to F change could be possible. So, for further inspection of land use/cover change, land use/cover classes belonging to Forest are divided into two groups as shown on Table 2.

Table 2. Grouping of forest classes into PF and TF

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)	

For the purpose of above grouping, Permanent Forest class is defined as those forests where their conditions continue for a long time if there are no anthropogenic or natural disturbances. Temporary Forest class is defined as those forests where their conditions change in relatively short period such as a few years to a few decades.

Then, as shown on Table 3, F-NF-F and NF-F-NF patterns were divided into 6 sub-patters. And among the 6 land use/cover change patterns, 3 patterns were considered as unlikely change.

Table 3. Pattern of unlikely land use/cover change

Forest (F)/ Non-forest (NF) change	Forest type change	Unlikeliness
F(2006)-NF(2010)-F(2014)	PF(2006)-NF(2010)-PF(2014)	Unlikely
	TF(2006)-NF(2010)-PF(2014)	Unlikely
	TF(2006)-NF(2010)-TF(2014)	Likely
	PF(2006)-NF(2010)-TF(2014)	Likely
NF(2006)-F(2010)-NF(2014)	NF(2006)-PF(2010)-NF(2014)	Unlikely
	NF(2006)-TF(2010)-NF(2014)	Likely

In the 3rd step, change patterns F(2006) – F(2010) – F(2014) were divided into 8 sub-patterns and 4 of them were labeled as unlikely change as shown in Table 4. And, polygons which belong to one of these four patterns were extracted.

Table 4. Pattern of unlikely change among forests

Forest (F)/Temporary forest classes (TF) change	Forest type change	Unlikeliness
F(2006)-F(2010)-F(2014)	PF(2006)-TF(2010)-PF(2014)	Unlikely
	TF(2006)-TF(2010)-PF(2014)	Unlikely
	TF(2006)-PF(2010)-PF(2014)	Unlikely
	TF(2006)-PF(2010)-TF(2014)	Unlikely
	PF(2006)-PF(2010)-TF(2014)	Likely
	PF(2006)-TF(2010)-TF(2014)	Likely
	TF(2006)-TF(2010)-TF(2014)	Likely
	PF(2006)-PF(2010)-PF(2014)	Likely

As shown on Table 3 and 4, changes between Forest classes and Non-Forest, and changes between Permanent forest classes and Temporary forest classes were inspected. Inconsistency among non-forest classes was not checked because, for the calculation of initial FRL of Cambodia, carbon stock of non-forest classes was considered as zero.

There are two possible reasons for unlikely changes. One is miss interpretation of satellite images. The other is caused by different Minimum Mapping Units (MMU) used in new 2014 map and those used in upgraded 2006 and 2010 maps. MMU of the 2014 map is 5ha while the MMU of 2006 and 2010 map for forest land was 25ha. As shown in Figure 4, a small patch of land which is less than 25ha and larger than 5ha could not be captured in 2006 and 2010 maps but captured in 2014 map. In the inspection and correction stage the use of different MMU was considered as a potential cause of unlikely change.

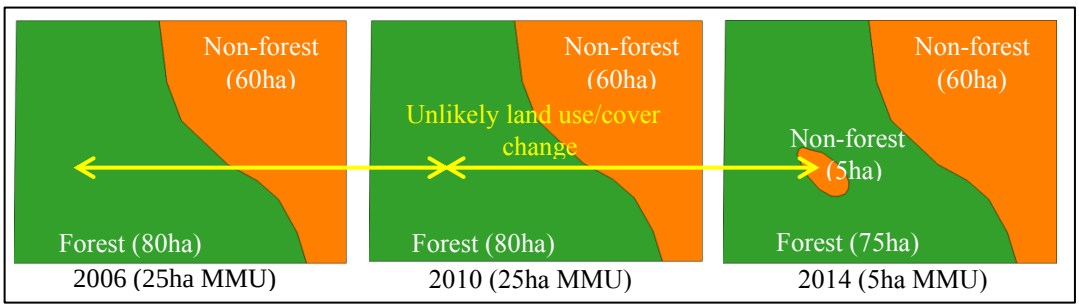

Figure 4. Unlikely land use/cover change caused by inconsistent MMU

In the 4th Step, target of inspection was F(2006)-F(2010)-NF(2014) change pattern. This is because there was possibility that small openings (non-forest areas) within forest class were not identified on 2006 and 2010 maps because of larger MMU.

First, Non-Forest areas on 2014 map were selected. Then, the selected Non-Forest areas which

were classified as Forest on 2006 and 2010 maps were extracted. And among the extracted areas, areas which could be Non-Forest were identified by using Normalized Difference Vegetation Index (NDVI). And finally, 2006 and 2010 land use/cover class of the identified areas was determined by interpreting LANDSAT images.

Note: If identified land is more than 5ha, then, LANDSAT images of 2006, 2010 and 2014 were checked and correction of land use/cover class was made if necessary. If the size of the identified land is less than 5ha, they were corrected automatically based on logics set for each land use/cover change pattern.

4. Accuracy Assessment

a. 2006 map

Accuracy assessment of the original 2006 forest assessment map was performed by Geographic Resource Analysis & Science A/S (GRAS). The report was compiled as Accuracy Assessment Report (draft final) (2007). Overall accuracy of the five classes – Evergreen Forest, Semi-evergreen forest, Deciduous Forest, Other Forest and Non-Forest, was 74%.

b. 2010 map

Accuracy assessment of the original 2010 forest assessment map was performed by GRAS. Overall accuracy was around 85%. After upgrading of the 2010 map and initial editing the Forestry Administration continued to check consistency among the three maps – 2006, 2010 and 2014 – and made necessary correction. The accuracy assessment was performed after the completion of consistency check and editing.

Number of accuracy assessment points was calculated by using a formula of Congalton & Green (Congalton, R. G. and Green, K., 2009) presented below.

$$n = B/4b^{\wedge}2$$

where

Confidence level (95%)	α	0.05
Number of class	κ	22
upper (α/κ) x 100th percentile of the $\chi 2$ distribution with 1 degree of freedom	B	9.3151
Desired precision	b	5% (0.05)

hence

$$n = B/4b^{\wedge}2 = 9.3151 / 4 \times (0.05)^{\wedge}2 = 932$$

While the calculated total number of the point was 932 minimum 50 points were assigned for each class where possible.

First, total 932 points were distributed to each land use/cover class in proportion to the area of each class. And minimum number of the assessment points was set as 50. If calculated number of the assessment point was less than 50, it was replaced by 50 to determine temporary number of the points.

On the other hand, Forestry Administration decided that accuracy assessment points should be selected among from national forest inventory (NFI) points, which cover Cambodia in a systematic way with a fixed distance. Based on this condition, number of NFI points included in each land use/cover class was calculated and compared with the temporary number of the points.

If the number of NFI point is less than the temporary assigned number, it was replaced by the number of NFI points. Table 4 shows the number of the calculated accuracy assessment points. As the result of the adjustment described above, total number of the accuracy assessment point was 1233.

Table 4 Accuracy assessment points for each land use/cover class for 2010 map

Class	Area (km2)	%	Calculated Number of points	Temporary number	NFI Point included in polygon	Final Number of points
Bamboo	1,280.99	0.71%	7	50	40	40
Village	2,948.46	1.62%	15	50	108	50
Built up area	437.03	0.24%	2	50	14	14
Deciduous	45,115.69	24.84%	232	232	1234	230
Evergreen	36,512.05	20.11%	187	187	1018	183
Flooded forest	5,126.93	2.82%	26	50	306	50
Forest regrowth	2,534.33	1.40%	13	50	70	50
Grass land	5,132.26	2.83%	26	50	238	50
Agriculture	11,824.51	6.51%	61	61	379	65
Paddy field	38,466.57	21.18%	197	197	1530	198
Mangrove	314.43	0.17%	2	50	34	40
Rear Mangrove	274.36	0.15%	1	50	30	29
Pine forest	81.29	0.04%	0	50	2	2
Oil palm	50.35	0.03%	0	50	3	3
Rock	6.92	0.00%	0	50	0	
Rubber	1,117.87	0.62%	6	50	32	36
Sand	100.04	0.06%	1	50	4	4
Semi-evergreen	14,132.79	7.78%	73	73	398	71
Tree plantation	170.61	0.09%	1	50	7	5
Water	4,561.38	2.51%	23	50	236	50
Wood shrub	11,392.86	6.27%	58	58	426	58
	181,590.57	100.00%	932		6105	1,233

For the selected accuracy assessment points, their land use/cover class was interpreted on AVNIR2 images of ALOS satellite. Then, the result of the interpretation was compared to the land use/cover class of the upgraded 2010 map. The overall accuracy assessment of upgraded 2010 map is 73.97% with the kappa accuracy is 70.98%. The result of the accuracy assessment is summarized as a confusion matrix as presented in Table 5.

Table 5 Confusion matrix of upgraded 2010 map

Land use/cover classes		Verificaiton Result																				
		E	Se	P	D	Fr	B	M	Mr	Ff	Tp	Rp	Po	Hc	Hr	G	Ws	W	Bu	Bt	S	Sum	User Acc.
Classification on Map	E	165	8		1	1						1		4		1	2					183	90.16%
	Se	15	34		12	1								7		1				1		71	47.89%
	P			2																		2	100.00%
	D	8	31		169									13	1	2	5			1		230	73.48%
	Fr	3				29								5	2	1	10					50	58.00%
	B	12	1			5	15							1	1	1	9					45	33.33%
	M							36							1		1	2				40	90.00%
	Mr					1		4	20						1	1		2				29	68.97%
	Ff									39					1	5	5					50	78.00%
	Tp										5											5	100.00%
	Rp					1						33		1						1		36	91.67%
	Po												2	1								3	66.67%
	Hc				2							1		50	6		4			2		65	76.92%
	Hr				1	1								7	169		3	2		15		198	85.35%
	G	2	1							1				5	4	30	2	5				50	60.00%
	Ws	1			5	1				2				12	8	3	25			1		58	43.10%
	W									1					2		2	45				50	90.00%
	Bu													1	1	1			11			14	78.57%
	Bt					1								1	16		2			30		50	60.00%
	S					1															3	4	75.00%
	Sum	206	75	2	190	42	15	40	20	43	5	35	2	108	213	46	70	56	11	51	3	1233	16.71%
	Prod.Acc.	80%	45%	100%	89%	69%	100%	90%	100%	91%	100%	94%	100%	46%	79%	65%	36%	80%	100%	59%	100%		

c. 2014 map

Just like the accuracy assessment of the upgraded 2010 map, total number of accuracy assessment points was calculated by using the same Congalton & Green formula and then they were distributed for each class in proportion to the area of each class. Then, actual number of the points was adjusted in the same manner with the 2010 map accuracy assessment. Total number is 1252. Their location is shown in Figure 4.

All procedures in the sampling strategy follow the methodology described by Congalton & Green (1999, 2009), which is the most commonly used procedure for accuracy assessment of maps derived from remote sensing.

A summary table of the sample selection has shown in Table 6.

212 of the 1252 points were visited in the field. Remaining 527 points were checked on satellite images – 165 on Rapid Eye images, 527 using Google Earth high resolution images and 348 by careful visual interpretation of LANDSAT8 images.

Table 6: Summary of samples used in the accuracy assessment of the 2014 land use and land cover assessment

ID	Class LU/LC	Area		Number of sample				
		Ha	**%**	**Field Collection**	**Google earth**	**Rapid eye**	**Landsat 8**	**Total**
1	Evergreen Forest	3018031	16.62%	1	36	43	73	153
2	Semi Evergreen forest	1146937	6.32%	2	23	10	24	59
3	Deciduous Forest	3662553	20.17%	14	65	32	80	191
4	Pine Forest	8161	0.04%			2		2
5	Flooded Forest	478768	2.64%	6	29	7	5	47
6	Bamboo	137852	0.76%	4	15	4	17	40
7	Forest Regrowth	245348	1.35%	8	26	1	11	46
8	Mangrove	32898	0.18%	2	14	15	5	36
9	Rear mangrove	27072	0.15%	1	7	14	3	25
10	Pine Plantation	3751	0.02%	1	1		1	3
11	Tree Plantation	49237	0.27%	10	2		4	16
12	Oil Palm Plantation	34107	0.19%		2	1	9	12
13	Rubber Plantation	482822	2.66%	15	10	7	18	50
14	Paddy field	4122259	22.70%	72	120	4	20	216
15	Agriculture	2538572	13.98%	24	60	11	38	133
16	Wood shrub	629303	3.47%	12	19	5	9	45
17	Village	339941	1.87%	20	24	1	2	47
18	Built up area	42864	0.24%	11	3		0	14
19	Grassland	345826	1.90%	5	22	4	15	46
20	Rock	2141	0.01%				1	1
21	Sand	44311	0.24%	2	9	2	3	16
22	Water	767932	4.23%	2	40	2	10	54
	Total area	**18160684**	**100%**	**212**	**527**	**165**	**348**	**1252**

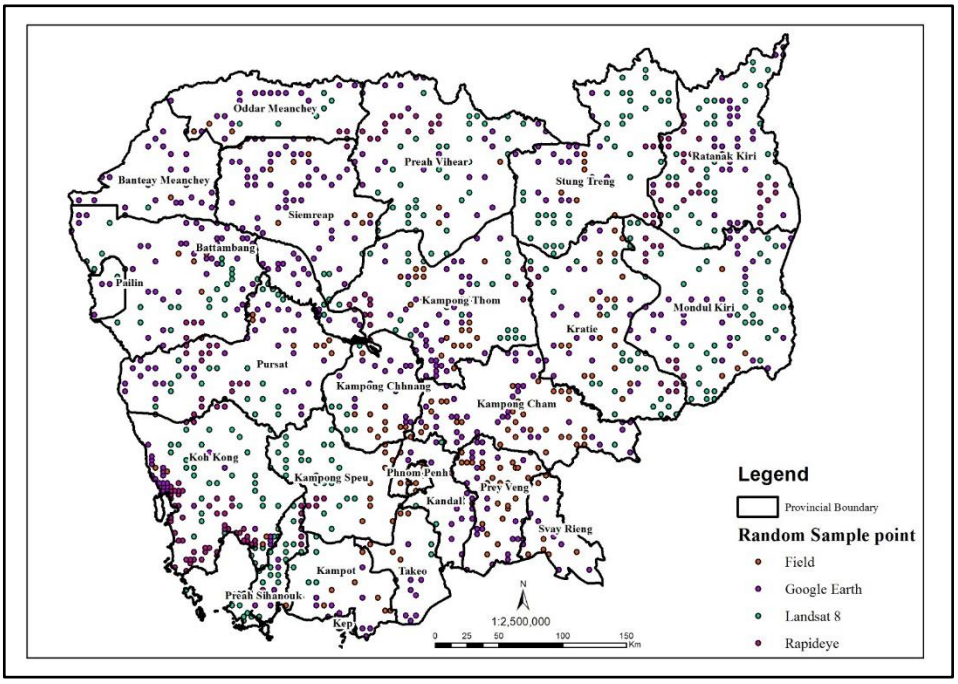

Figure4: Map of random sample 1252 points for accuracy check land use /land cover 2014

In total, 201 of the planned 212 points were visited in the field. The reason for the visited points being lower than the planned points was due to restricted access (9 cases), Seven of these points were situated in the flooded forest area which could not be reached due to extended dry season which prevented access by boat and two points were situated in prohibited area (Military station and economic land concession). The distribution of the field samples covered 22 provinces out of 24 (Table 7).

Table7: Summary of random sample point assess by province

No	Province	Point	Assess point
1	Kampong Spueu	10	9
2	Kaoh Kong	4	4
3	Krong Preah Sihanouk	1	1
4	Krong Kaeb	1	1
5	Kampot	7	7
6	Takaev	5	5
7	Kandal	8	8
8	Bat Dambang	5	4
9	Pousat	14	9
10	Kampong Chhnang	14	12
11	Phnom Penh	8	8
12	Kampong Cham	31	9
13	Kampong Thom	20	19
14	Preah Vihear	3	3
15	Otdar Mean Chey	3	3
16	Banteay Mean Chey	2	2
17	Siem Reap	9	9
18	Stueng Traeng	6	6
19	Kratie	22	21
20	Mondol Kiri	4	4
21	Prey Veaeng	28	28
22	Svay Rieng	7	7
TOTAL		212	201

Assessment of land use/cover consistency between field verification data collected in 2015 and Landsat image of 2014

1 year had elapsed between satellite image acquisition and field survey. So, it was necessary to check whether the site had changed during the one year period in order to verify the result of field survey for accuracy assessment.

For the purpose of this verification, Landsat 8 images of the year 2014 and 2015 were compared as shown in Figure 5. In Figure 5, the land cover class observed during field survey differed from the land cover class interpreted on 2014 satellite image. Therefore, this field verification data was excluded from the samples of accuracy assessment.

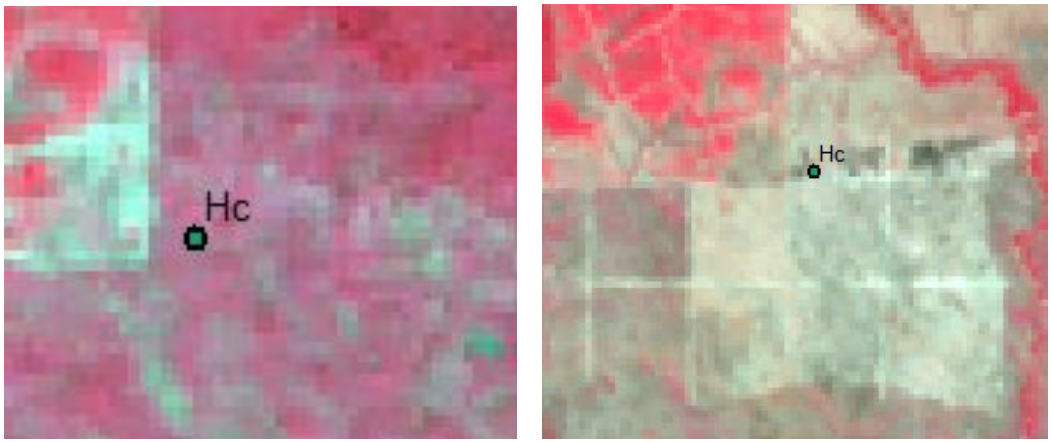

Figure5: Landsat image 2014 Landsat image 2015

The result of the accuracy assessment on land use and land cover 2014 is shown in Table 8.

Table 8 Confusion Matrix of 2014 map

LU/LC classes		Field sample																							
		BB	Bt	Bu	D	E	Ff	Fr	G	Hc	Hr	M	Mr	P	Po	Pp	R	Rp	S	Se	Tp	W	Ws	Sum	User acc.
Classified	BB	25				8				3										3			1	40	62.5%
	Bt		42							2	3													47	89.4%
	Bu		1	8															3				2	14	57.1%
	D	3			147			2	3	3	2									22			9	191	77.0%
	E				4	139		1	1	2										5			1	153	90.8%
	Ff						46															1		47	97.9%
	Fr		1				2	37	1	3	1												1	46	80.4%
	G				1		1		32	3	3								1			1	4	46	69.6%
	Hc		1		6			2	2	102	4		1					3	1			3	8	133	76.7%
	Hr	1	7	1	1				1	2	196								1			3	2	216	90.7%
	M										1	29	4									1	1	36	80.6%
	Mr											5	19									1		25	76.0%
	P													2										2	100.0%
	Po											1			11									12	91.7%
	Pp								1							2								3	66.7%
	R																1							1	100.0%
	Rp								2	4								44						50	88.0%
	S								1	1	1								10			2	1	16	62.5%
	Se	1			5					2	1									45		1	4	59	76.3%
	Hc				1					3											11		1	16	68.8%
	W		1	1			2		1		3											46		54	85.2%
	Ws		1		4	2	1	3	4	2	1	1									1	2	23	45	51.1%
	Sum	30	54	10	169	149	52	45	49	132	216	36	24	2	11	2	1	47	16	75	12	61	58	1252	
	Sum Prod. Acc	83.33%	77.78%	80.00%	86.98%	93.29%	88.46%	82.22%	65.31%	77.27%	90.74%	80.56%	79.17%	100.00%	100.00%	100.00%	100.00%	93.62%	62.50%	60.00%	91.67%	75.41%	39.66%		

The overall accuracy with respect to the combination of field verification and high resolution images is 81.23% with user's accuracy is 78.70, producer's accuracy is 82.17% and Kapa accuracy is 79.49%. The accuracy showed lowest results in the Wood shrub and grass land classes. Some of these errors are inevitable given the difficulties of separating certain classes, e.g. deciduous forest from wood shrub.

References:

Congalton, R.G. and Green, K. 2009. Assessing the Accuracy of Remotely Sensed Data Principles and Practices

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Annex 4 Detailed methodology for acquiring AGB values for emission factors

Introduction

For the purpose of compiling a national Greenhouse Gas inventory for the forestry sector and also of establishing a national forest reference level (FRL)[5] for REDD+, volume of carbon sequestrated in five carbon pools in the forest need to be estimated. In Cambodia, various forest inventory surveys have been carried out. However, nationwide systematic forest inventory survey has not yet been implemented.

In the absence of nationwide data on forest carbon, carbon stock for each forest type of Cambodia need to be estimated based on available data sources. First, JICA Technical Assistants Team carried out a literature survey to identify value of biomass density of each forest type of Cambodia. On the other hand, under UN-REDD program FAO collected raw data of various forest inventory surveys implemented in Cambodia and analyzed values of biomass density (Sola et al., 2014).

Based on these works, values of forest biomass density to be used in GHG inventory and FRL establishment for Cambodia were selected. Additional literature survey was conducted for searching regional data if suitable country specific values were not found in the two works mentioned above. This paper explains the process of the selection and selected values. Since the data other than Above Ground Biomass (AGB) are rather limited for Cambodia, this paper focuses only on AGB.

1 Recommended AGB values for Emission Factors

Recommended values of AGB for each forest type are summarized in

[5] Forest Reference Level is a benchmark for assessing each country's performance in implementing REDD+ activities which is expressed in tons of carbon dioxide (CO2) per year. Forest biomass can be converted to carbon volume and then to the CO2 volume by using existing formulas.

Table 1. All land use/cover types other than forest category used in present land use/cover mapping by Forestry Administration are also shown. The area and ratio of major forest types of Cambodia as of 2010 is summarized in Table 2. As Table 2 shows, three principal forest types, i.e. Evergreen, Semi-evergreen and Deciduous forests, occupy 90.54% of entire forest land of Cambodia. Since AGB values of these three forest types are country specific, emission factors of Cambodia's forest could be substantially considered as Tier 2 level.

Table 1 Recommended unit AGB values

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	IPCC Default	IPCC (2003), MoE/UNDP (2003)
		Bamboo	0	-	(Nil)
		Mangrove	150	Regional	MoE/UNDP (2003)
		Rear mangrove	165	Regional	Tran (2015)
		Flooded forest	70	IPCC Default	MoE, 2002, MoE/UNDP (2003)
		Forest regrowth	75	Country specific	CFI (2008) cited in Sar (2010)
	Planted Forest	Pine plantation	100	IPCC Default	IPCC (2003), MoE/UNDP (2003)
		Tree plantation	100	IPCC Default	IPCC (2003), MoE/UNDP (2003)
Cropland		Rubber plantation	43**	Country specific	Toriyama et.al. (2011)
		Oil palm plantation	42**	Regional	Kotowska et.al (2015)
		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 neighbor countries in Southeast Asia

** These figures of Rubber plantation and Oil palm plantation were not used in the initial FRL calculation.

Table 2 Forest cover in Cambodia (2010)

Forest Type	Area (ha)	Ratio (%)
Evergreen forest	3,573,437	34.19
Semi-evergreen forest	1,391,117	13.31
Deciduous forest	4,498,397	43.04
Other forest	988,472	9.46
Total forest land	10,451,423	100.00

90.54% of total forest land

Source: Cambodia Forest Cover 2010 (Kingdom of Cambodia, 2011)

2 Selection of an AGB value for each forest type

First of all, in Cambodia, forest is classified into 11 types as shown in Table 1. In this chapter, the reasons for the selection of an AGB value for each forest type are explained. Section 2.1 is dedicated to Evergreen, Semi-evergreen, and deciduous Forests, Section 2.2 is for the other forest types, and Section 2.3 is for rubber and oil palm plantations.

2.1 Above Ground Biomass for Evergreen, Semi-evergreen, and deciduous Forests

2.1.1 Data source examined for selecting the values

1) Initial National Communication (INC) of Cambodia (MoE, 2002)

This is the official document of Cambodia submitted to UNFCCC in 2002. The document used default AGB values provided in the Revised 1996 Guidelines for National GHG Inventories (IPCC, 1997).

2) CCEAP Phase 2, final report (MoE/ UNDP, 2003)

Cambodia Climate Change Enabling Activity Project (CCEAP) was carried out to assist Cambodia to prepare an initial National Communication. One of the objectives of Phase 2 of the project was to improve activity data and emission factors used in the INC so that better figures would be used in the future National Communications. Activity data and emission factors identified in the report were used in the second National Communication which is planned to be submitted to UNFCCC in the near future.

In this report, AGB values were collected from two sources. One is a field survey carried out by the CCEAP project in 14 sample plots in seven sites. The other is the results of forest biomass studies conducted in the past in the region of South East Asia.

3) Forest biomass in Cambodia (Sola et al., 2014)

In the past, Cambodian government carried out forest inventory surveys at various locations in collaboration with different institutions. Under UN-REDD program, FAO collected part of the raw data of these forest surveys - 40 permanent sample plots (PSP), 668 plots of REDD+ related projects, and 1,047 plots in Community forests - and harmonized them to create allometric equations and estimate unit AGB values for different forest types (UN-REDD, 2014, unpublished). The location of each plot is shown in in Figure 1.

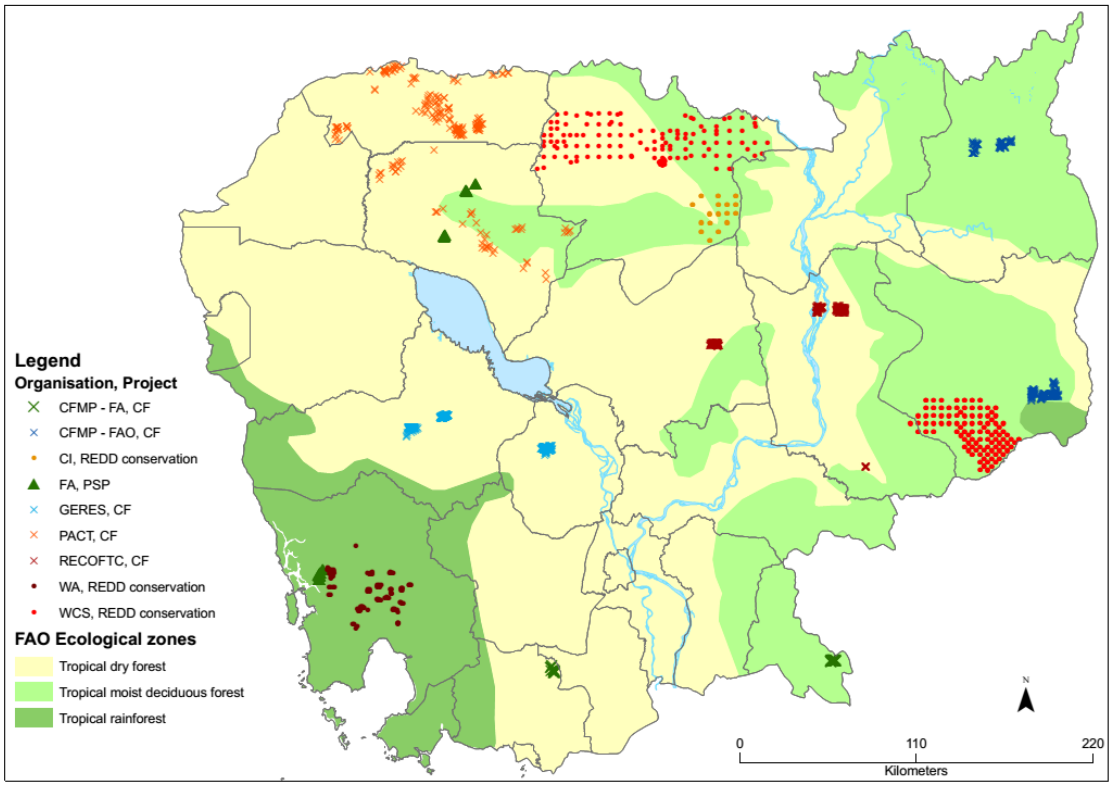

Figure 1: Location of forest inventories used in UN-REDD (2014) (Cited from Sola et al. 2014)

Under those efforts, the values of AGB for Evergreen, Semi-evergreen, and deciduous Forests are calculated by using the data of 39 permanent sample plots (PSP), 474 plots of REDD+ related projects, and 528 plots in Community forests for which the authors of this UN-REDD paper judged that those data were collected in those three forest types. The results are not explicitly shown in the paper. Therefore the values were re-calculated using the back data of this paper of UN-REDD which were offered by one of the authors with his courtesy. Table 3 is the result if the re-calculation.

In Table 3, values in the column of "Average AGB value in each study" are those calculated for each of PSP, REDD+ project plots and community forestry plots (columns (a), (b), and (c)). "n" means the number of plot used for the calculation. Columns (d) and (e) are the average of AGB values of PSP, REDD+ project plots and Community Forestry plots by different combination.

Table 3 Summary of AGB values identified in UN-REDD (2014)

Forest type	Average AGB value in each study*			**(d)** Average of (a) + (b)	**(e)** Average of (a)+(b)+(c)
	(a) PSP (n=39)	**(b)** REDD (n=474)	**(c)** CF (n=528)		
Evergreen	325 t/ha (n= 35)	232 t/ha (n= 270)	47 t/ha (n= 210)	243 t/ha (n= 305)	163 t/ha (n= 515)
Semi-evergreen	- -	356 t/ha (n= 54)	51 t/ha (n= 32)	356 t/ha (n= 54)	243 t/ha (n= 86)
Deciduous	100 t/ha (n= 4)	193 t/ha (n= 150)	29 t/ha (n= 286)	190 t/ha (n= 154)	85 t/ha (n= 440)

* PSP: permanent sample plots, REDD: REDD+ related projects, CF: Community forests.

** The values are calculated from back data of UN-REDD (2014)

*** Only the values of (c) and (d) are shown in UN-REDD (2014). Moreover, the values are slightly different from those calculated from back data. This is the reasons why the value was re-calculated from the back data.

2.1.2 Selection of the values of unit AGB

In order to select recommendable values of unit AGB, those used in the INC of Cambodia (MoE, 2002), those identified in CCEAP (MoE/ UNDP, 2003), and those from UN-REDD (2004) were shown in Table 4.

Table 4: Comparison of AGB values of three main forest types (ton/ha)

Forest type	INC (MoE, 2002)	CCEAP (MoE/UNDP, 2003)	UN-REDD (2014)	
			Average of PSP and REDD	Average of PSP, REDD and CF
Evergreen	295	200	243	163
Semi-evergreen	370	250	356	243
Deciduous	120	100	190	85

The data sets of UN-REDD (2014) are acquired from raw data of forest inventory survey. Therefore, traceability and transparency of the data for acquiring those values are much higher than the other two. Moreover, the values in UN-REDD (2014) are suitable for Tier 2 level GHG inventory because all of the data used are acquired by field survey conducted in Cambodia.

Among two datasets of UN-REDD (2014), the values of "average of PSP and REDD+ related project" is higher than those of CCEAP (MoE/UNDP, 2003) for all of the three forest types. As a figure in Annex I shows, most of PSP and REDD+ related project plots are located in protected areas or protected forests with high biomass density forest. Therefore, the average of only PSP and REDD+ related project plots might result in the overestimation for a national scale AGB.

In the sense of avoiding overestimation, the averaged AGB using all available data of PSP, REDD+ related project plots and community forest plots is more recommendable, although it might result in underestimation of AGB to the contrary because quantity of data collected from Community forest plots was larger than those collected from PSP and plots of REDD+ related projects. This is considered as being conservative.

As a result, selected AGB values of Evergreen forest, Semi-evergreen forest and Deciduous forest are 163 t/ha, 243 t/ha and 85 t/ha, respectively.

2.2 Above Ground Biomass for other forest types

There are eight other forest types in the land use/cover classification of Cambodia REDD+. Those are Pine Forest, Bamboo, Mangrove, Rear Mangrove, Flooded Forest, Forest regrowth, Pine plantation and Tree plantation.

2.2.1 Pine forest

For Pine forest AGB, only one data source was found. CCEAP (MoE/UNDR, 2003) conducted a field study at two plots in Cambodia, and the ABG is calculated as 57 t/ha and 102 t/ha respectively, which average is 80t/ha. Any other studies in South East Asia on Pine forest AGB have not been found. Since only two data are not sufficient to estimate appropriate value of Pine forest AGB, 100 t/ha, the value selected for Pine plantation is substituted for Pine forest AGB.

2.2.2 Bamboo

The distribution of bamboo is very limited in Cambodia, hence, it is not significant sink/source of carbon. No value of bamboo is presented neither in INC (MoE, 2002) nor CCEAP (MoE/UNDP, 2003). Any country specific Bamboo AGB is not found by us except one data from uncertain source, which presents 77 t/ha. Some regional data was found, however, it is rather difficult to justify that those regional values are appropriate for Bamboo AGB of Cambodia. Considering this information Bamboo AGB is set to zero.

2.2.3 Mangrove

Mangrove AGB used in INC (MoE, 2002) and selected in CCEAP (MoE/UNDP, 2003) are 175 and 150 t/ha, respectively. CCEAP (Moe/UNDP, 2003) also shows the result of a field study on Mangrove biomass conducted at two plots in Cambodia, and the ABG is calculated as 89 t/ha and 198 t/ha respectively, which average is 144t/ha.

According to JICA Technical Assistants Team (2015), the range of Mangrove AGB from eight studies conducted in neighbor countries varies from 92 t/ha to 299 t/ha.

Under the circumstances of limited information of country specific data, it is considered to be reasonable to use the same value identified in CCEAP (Moe/UNDP, 2003) for Mangrove forest, that is 150 t/ha.

The Fisheries Administration (FiA) under Ministry of Agriculture, Forestry and Fisheries (MAFF) of Cambodia has implemented field survey of mangrove forest in 2015 with the assistance of USAID. The Mangrove AGB could be updated based on that result when it comes out.

2.2.4 Rear mangrove

Rear Mangrove forest is mainly composed of *Melaleuca leucadendron* in Cambodia (Theilade et al., 2011). No value of Rear mangrove is presented neither in INC (MoE, 2002) nor CCEAP

(MoE/UNDP, 2003).

Only one study found for Rear mangrove of Cambodia is Hozumi et.al. (1969). AGB shown in the study is 13 t/ha. Since only one plot was surveyed in Hozumi et.al. (1969) and this value seems to be very low, it is rather hesitated to select this value as Rear mangrove AGB of Cambodia, although this value is country specific.

Another study found for Melaleuca biomass in the region is Tran, D.B., (2015). This study was conducted for M. cajuputi forest in Phu Quoc National Park along the coast of Vietnam close to Cambodia. As it is a study for a taxonomically very close species and the growing environment is assumed to be similar to that of Cambodia, the value in Tran, D.B. (2015), 165 t/ha (the range is 48 – 235 t/ha), is recommended to be used for Rear Mangrove AGB.

2.2.5 Flooded forest

Flooded forest AGB both used in INC (MoE, 2002) and selected in CCEAP (MoE/UNDP, 2003) is 70 t/ha.

CCEAP (MoE/UNDP, 2003) also presents AGB values as a result of two plot surveys conducted in Cambodia, which are 39 t/ha and 60 t/ha. Three other studies mentioned to Flooded forest AGB of Cambodia were found, and those values are 160, 170, and 175 t/ha, respectively (JICA Technical Assistants Team, 2015).

CCEAP (MoE/UNDP, 2003) also shows the result of two past studies in the region whose range is between 15 t/ha and 342 t/ha.

Since only limited field survey data are available for Flooded forest of Cambodia and the values vary among them, 70 t/ha in INC (MoE, 2002) and CCEAP (MoE/UNDP, 2003) is considered to be appropriate as AGB value for flooded forest until more reliable country specific data becomes available.

Fisheries Administration (FiA) of MAFF has implemented forest survey of flooded forest in Kampong Chhnang and Batambang in 2015 under the technical and financial assistance of FAO. Flooded forest AGB can be updated based on the result of this survey of FiA when it is available.

2.2.6 Forest regrowth

Forest regrowth AGB used in INC (MoE, 2002) and selected in CCEAP (MoE/UNDP, 2003) are 190 t/ha and 120 t/ha, respectively.

CCEAP (MoE/UNDP, 2003) also presents 41 t/ha and 53 t/ha estimated from two plot survey in Cambodia. On the other hand, 6 studies on forest regrowth AGB in Cambodia were found whose range is between 39 t/ha and 75 t/ha, although some caution is required for citing them because the definition for forest regrowth could be different among studies (JICA Technical Assistants Team, 2015).

The range of the regional AGB values for forest regrowth cited in CCEAP (2003) is 32 - 230 t/ha. The reason for the big differences among those figures is probably the large variance in the growing stage of this forest type.

Since all the country specific values mentioned above are smaller than that of INC (MoE, 2003) and CCEAP (MoE/UNDP, 2003) and there is no more material for justifying these figures, 75 ton/ha (CFI (2008) cited in Sar (2010)), which is the maximum value found in the past studies in Cambodia and could avoid possible overestimation, is recommended until more reliable data becomes available.

2.2.7 Pine plantation and Tree plantation

Plantation AGB used in INC (MoE, 2002) and selected in CCEAP (MoE/UNDP, 2003) are 80 and 100 t/ha, respectively.

Forest plantation species in Cambodia are mainly Pine, Acacia and Eucalyptus. However, country specific values of AGB in Cambodia for those plantations were not found, but some regional data are only available.

The range of acacia plantation AGB which are found in some literatures in various countries from Asia to South Pacific regions is between 56 t/ha and 245 t/ha (see Annex II). Eucalyptus plantation AGB found in some past studies in the same region also varies from 62 t/ha to 275 ton/ha (see Annex II). Pine plantation AGB value could not be found even in the region. CCEAP (MoE/UNDP, 2003) also shows the range of 60-153 t/ha as AGB cited from past studies of the region, however the planted species is not clear.

Plantation AGB must be largely influenced by the growing stage, or years after planting. However, it is difficult to collect the information on the age of each forest plantation from all over the country for the moment. Under these circumstances, it is appropriate to choose the value 100 t/ha for both Pine plantation ABG and Tree plantation AGB, which is selected in CCEAP (MoE/UNDP, 2003). This value is also provided in Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003) as a default AGB value of forest plantation (other species) in "Moist with short dry season in Asia.

2.3 Rubber and oil palm plantation

Although rubber and oil palm plantations are not included in forest category under the forest definition for Cambodia' s REDD+, examining unit AGB for these plantations is useful when the simulation of actual biomass emission/removal including non-forest areas is required.

2.3.1 Rubber plantation

Two studies were found on Rubber plantation biomass in Cambodia, those are Khun et.al. (2008) and Toriyama et.al. (2011).

In Khun et.al. (2008), the volumes of stems (m3/ha) of rubber trees which were collected at 15 plots of 6 to 48 years old plantations are presented. 11 plots out of 15 are from 37 years old and older plantations. The values of stem volume were converted to the values of AGB by JICA Technical Assistants Team (JICA Technical Assistants Team, 2015). The range of values of AGB is 42 - 331 t/ha (the average is 218 t/ha).

The range of values in Toriyama et.al. (2011) is 0.9 – 81 t/ha (the average is 43 t/ha) which were collected at eight plots from 1 to 9 years old plantations. CCEAP (MoE/UNDP, 2003) also conducted two plot survey of rubber plantation in Cambodia and the estimated AGB is 88 and 113t/ha, respectively.

The values are also found in some studies in the region which vary from 8 to 191 t/ha (see Annex II)).

The values vary depending on the age class and probably on growing environment. Considering the available information on the values, the average biomass density estimated in Toriyama et.al., (2011), that is 43 t/ha, is recommended for Rubber plantation AGB for the moment. Although the age class of the plots in Toriyama et.al., (2011) tends to be young (up to 9 years old), this can fit to the situation of rubber plantation in Cambodia most of which are newly established.

2.3.2 Oil palm plantation

Country specific value for AGB of oil palm plantation has not been found. Then, Kotowska et al. (2015) conducted in Indonesia is referred. According to this study, average biomass of oil palm plantation is 42 t/ha (the figures of 2 sites are 37 t/ha and 47 t/ha respectively, each of which consists of 8 plots). Since this is the only figures found for the moment, this figure is suggested to be used for Oil palm AGB.

3 Summary of recommended unit AGB

In Table 5, the recommended values of AGB (t/ha) for each forest type in Cambodia are listed and compared with the other datasets of INC (MoE, 2002), CCEAP (MoE/UNDP, 2003) and other studies. Values in other studies were identified either by JICA Technical Assistants Team (2015), CCEAP (MoE, 2003) or in the literature review in this working paper.

As Table 5 shows, most of the recommended values are more or less at the midst of the ranges of the values in other studies, which might imply the recommended values are appropriately selected.

Table 5 Comparison of the AGB values (t/ha)

Land use/cover			INC	CCEAP	Range of values in other studies (Value is country specific)	Recommended AGB
Category		Sub-category				
Forest	Natural forest	Evergreen	295	200	96 - 380 (*1)	163
		Semi-evergreen	370	250	164 - 382 (*1)	243
		Deciduous	120	100	70 - 245 (*1)	85
		Pine forest	n.a.	n.a.	57, 102 (*2)	100
		Bamboo	n.a.	n.a.	45 - 242 (*3)	0
		Mangrove	175	150	89, 198 (*2) 92 - 299 (*1)	150
		Rear mangrove	n.a.	n.a.	48 - 235 (*3)	165
		Flooded forest	70	70	160, 170, 175 (*1) 39, 60 (*2) 15 - 342 (*2)	70
		Forest regrowth	190	120	39 - 75 (*1) 41, 53 (*2) 32 - 230 (*2)	75
		Pine plantation	80	100	n.a.	100
		Other plantation	80	100	56 - 245 (Acacia,*3) 62 - 275 (Eucalyptus,*3) 60 - 153 (*2)	100
Cropland		Rubber	n.a.	n.a.	0.9 - 81 (*1) 42—331 (*1) 88, 113 (*2) 8 - 191 (*3)	43
		Oil palm	n.a.	n.a.	37, 47 (*3)	42

References* 1: JICA TA Team (2015), 2: MoE/UNDP (2003), 3: Annex II of this Working Paper #14.

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