

Land cover and forest classification systems of Cambodia

Cambodia, 2013



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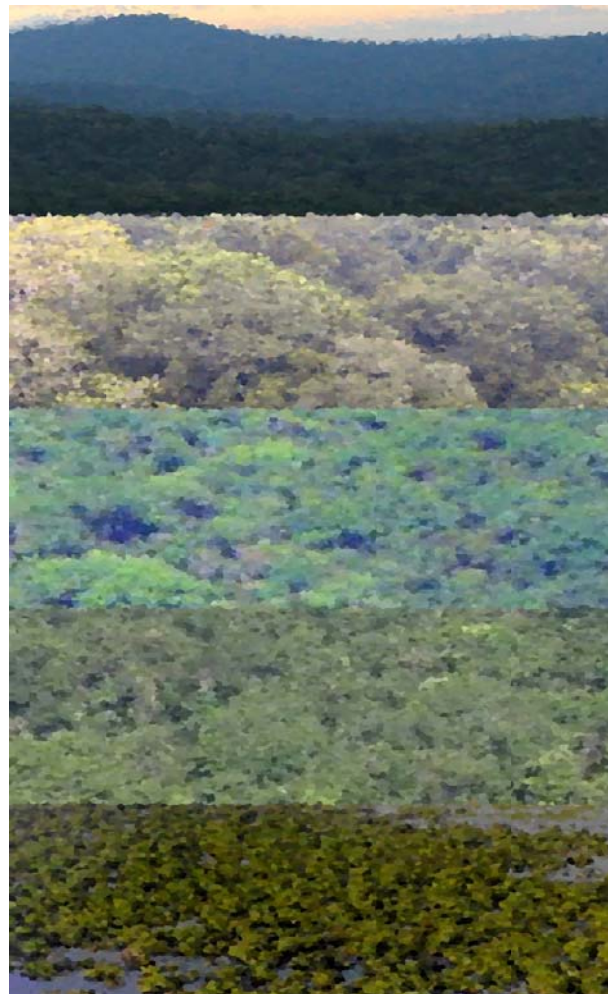
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Phnom Penh, Cambodia



The UN-REDD Programme, implemented by FAO, UNDP and UNEP, has two components: (i) assisting developing countries prepare and implement national REDD strategies and mechanisms; (ii) supporting the development of normative solutions and standardized approaches based on sound science for a REDD instrument linked with the UNFCCC. The programme helps empower countries to manage their REDD processes and will facilitate access to financial and technical assistance tailored to the specific needs of the countries.

The application of UNDP, UNEP and FAO rights-based and participatory approaches will also help ensure the rights of indigenous and forest-dwelling people are protected and the active involvement of local communities and relevant stakeholders and institutions in the design and implementation of REDD plans.

The programme is implemented through the UN Joint Programmes modalities, enabling rapid initiation of programme implementation and channeling of funds for REDD efforts, building on the in-country presence of UN agencies as a crucial support structure for countries. The UN-REDD Programme encourage coordinated and collaborative UN support to countries, thus maximizing efficiencies and effectiveness of the organizations' collective input, consistent with the "One UN" approach advocated by UN members.

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Acronyms

AHTEG	Ad Hoc Technical Expert Group
CBD	Convention on Biological Diversity
CCD	Climate Change Department
CDM	Clean Development Mechanism
CTSP	Cambodia Tree Seed Project
DANIDA	Danish International Development Agency
DED	German Development Service
DFW	Department of Forestry and Wildlife
FA	Forestry Administration
FAO	Food and Agriculture Organization
FCMP	Forest Cover Monitoring Project
FCPF	Forest Carbon Partnership Facility
FFI	Fauna Flora International
FIA	Fisheries Administration
FRA	Forest Resources Assessment
FREI	Forest Research and Education Institute
GDANCP	General Dept. for Administration of Nature Conservation & Protection
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
ITTO	International Tropical Timber Organization
JAFTA	Japan Forest Technical Association
JICA	Japan International Cooperation Agency
MAFF	Ministry of Agriculture, Forestry and Fisheries
MMU	Minimum Mapping Unit
MOE	Ministry of Environment
MPWT	Ministry of Public Work and Transportation
MRC	Mekong River Commission
MRV	Measurement, Reporting and Verification
NFI	National Forest Inventory
NFP	National Forest Programme
REDD+	Reducing Emissions from Deforestation and forest Degradation
RGC	Royal Government of Cambodia
RL	Reference Level
REL	Reference Emission Level
UNEP	United Nation Environment Programme
UNFCCC	United Nation Framework Convention on Climate Change
WCMC	World Conservation Monitoring Centre
WCS	Wildlife Conservation Society
WWF	World Wildlife Fund

Summary

National forest definition and forest classification system are essential for calculating emissions and carbon stocks in the context of REDD+. The overall objective of this report is to provide recommendations for the adoption of a new national forest classification system taking into account the requirements under international conventions such as the UNFCCC. Forest definition and forest classification systems used in Cambodia contribute to the preparation of the design of the national forest measurement, reporting and verification system which includes the design of the multipurpose national forest inventory and the national satellite forest monitoring system.

The review presented in this report clearly suggests that due to their high level of inconsistency, the various national forest cover assessments can't respond to the needs of implementation of a national satellite forest monitoring system without harmonization or re-interpretation. Recommendations are provided for a possible revision of the Cambodian forest definition and for the development of the national forest monitoring system. Institutional arrangements are also discussed as the different agencies working on forest and land management issues have to strengthen their cooperation for implementing the mitigation options for Cambodia. Finally, the adoption of a new land cover classification system is recommended in order to improve the accuracy of the greenhouse gas emissions estimates for the forestry sector.

1. Introduction

Evaluation of the forest resources is capital for improving forest management in Cambodia. The development of a national forest monitoring system for Reducing Emissions from Deforestation and forest Degradation (REDD+)¹ will require a clear forest definition compliant with international standards and a unique and functional forest classification system.

Within the framework of REDD+, country parties are requested to use the most recent Intergovernmental Panel on Climate Change guidance and guidelines as a basis for estimating anthropogenic forest-related greenhouse gas (GHG) emissions by sources and removals by sinks, forest carbon stocks and forest area changes to ensure that this assessment of the forest resource and particularly emission reductions are as far as possible accurate, consistent, transparent, complete and comparable². According to the Intergovernmental Panel on Climate Change (IPCC), the forest land is defined as follow: *"all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, sub-divided into managed and unmanaged, and also by ecosystem type as specified in the Revised 1996 IPCC Guidelines. Also includes systems with vegetation that fall below, but are expected to exceed, the threshold of the forest land category"*³.

At current status, Cambodian institutions are using different forest definitions and forest classification systems. While Cambodia desires to report all forest lands to international conventions and organizations, the different institutions: Ministry of Environment (MoE) and the Ministry of Agriculture, Forestry and Fisheries (MAFF) will have to adopt a common definition and forest classification system. The creation of a standard forest definition applicable at multiple scales, from local to national, sub-national to international, is a critical issue for the measurement, reporting and verification (MRV) of GHG emissions reductions for the forestry sector in particular.

Therefore, the choice of the threshold criteria used for the national forest definition (tree height, crown cover and minimum area) and the forest classification system are essential for calculating emissions and carbon stocks in the context of deforestation and forest degradation⁴.

1.1. Status of forest cover assessment in Cambodia

The geographic information system (GIS) unit of the Forestry Administration's Watershed Management and Forest Cover Assessment Office, since its creation in 2003, is responsible for assessing the forest cover of Cambodia. Recently, the forest cover 2010 has been

¹ Based on decision 4 of the UNFCCC Conference of the Parties at the fifteenth Conference of the Parties (4/CP.15), REDD+ is defined as: *"Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries"*

² Decision 4/CP.15, *Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries*, UNFCCC, 2010.

³ IPCC (2006)

⁴ FFPRI (2012)

published with the support from DANIDA and ITTO⁵. The results have been verified independently by GRAS A/S (University of Copenhagen) who was previously involved in capacity building and accuracy assessment for the 2005/2006 forest cover assessment.

The 2010 forest cover map (fig. 1) is based on relatively high resolution Landsat 5 TM images which allows delineation of forest cover with a 30 m pixel (0.09 ha). These images have been preferred to the free Landsat 7 ETM+ images cause they are not affected by any artifacts. The data have been obtained and purchased from the local ground receiving station in Bangkok, Thailand.

The methodology followed for the 2010 forest cover map is similar to the 2005/06 one with some minor modifications in the forest definition and forest classification system. The same methodology that have been previously used for the 1992/93-1996/97 Forest Cover Monitoring Project (FCMP) of the Mekong River Commission (MRC) has been applied in 2010: the **dependent interpretation**⁶. This means that the interpreters based their interpretation of the most recent year on the results produced for the previous period. In this process, corrections are applied wherever interpretation errors from the earliest period are found.

The classification procedure which consists in an update of the 2005/06 forest cover map is based on visual interpretation of the Landsat associated with manual, on-screen digitization with a minimum mapping unit set to 0.2 km². This update process ensure consistency in the time even if previous interpretation errors in the 2005/06 map can be reported to the 2010 map⁷.

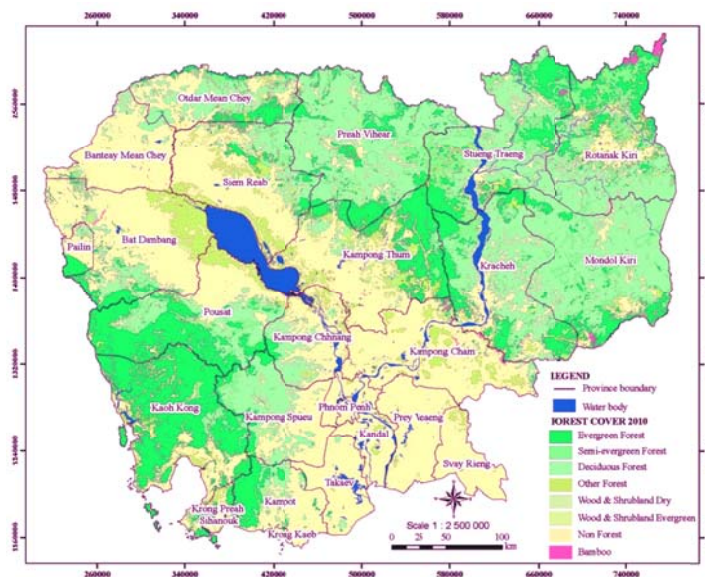


Figure 1: Cambodian forest cover map 2010 (FA, 2011)

⁵ FA (2011)

⁶ Malyvanh M., Feldkotter C. (1999)

⁷ GRAS A/S. (2010)

According to the 2010 forest cover assessment, Cambodia, with approximately 10.3 million hectare of forest on 57% of the whole country area, is one of the most forested country in southeast Asia. Detailed estimates for the four forest types are presented in the table 1.

No	Forest Types	Area	
		Ha	%
1	Evergreen Forest	3,499,185	19.27
2	Semi-evergreen Forest	1,274,789	7.02
3	Deciduous Forest	4,481,214	24.68
4	Others Forest	1,108,600	6.1
Total Forest Land		10,363,789	57.07
5	Non-Forest	7,796,885	42.93
TOTAL AREA		18,160,674	100

Table 1: Results of the 2010 Forest cover assessment (FA, 2011)

1.2. REDD+ and forest-based climate change mitigation potential in Cambodia

Mitigating the effects of climate change on forest-based livelihoods is a strategic objective of the National Forest Program (NFP)⁸. With the last 2010 forest cover assessment it is possible to monitor the evolution of the forest cover on a 45 years period since the first estimates have been published in 1965 (fig. 2). However, the adopted definitions and classification systems should be borne in mind when comparing these national forest cover estimates provided by different institutions with different objectives.

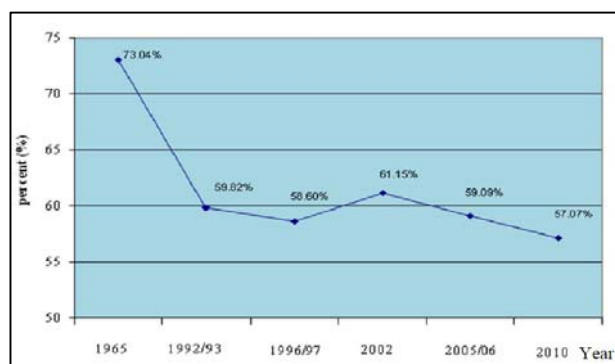


Figure 2: Forest cover of Cambodia from 1965 till 2010⁹ (FA, 2011)

Forest cover changes have been analyzed by the GIS Unit of the Forestry Administration (FA) between 2002, 2006 and 2010 and the large areas of deforestation reveal an important potential for REDD+ in Cambodia (fig. 3). Comparison between the 2002 and 2010 forest cover assessment indicates that forest cover declined from 61.15% to 57.07%, representing a decrease of 4.08% on a 8 years period (annual rate of 0.51%). Deciduous forests (0.25% per year) and Evergreen forests (0.15% per year) are the most affected by deforestation.

⁸ Blaser, J., Sarre, A., Poore, D. & Johnson, S. (2011)

⁹ Estimates for the year 1965 are published in Pan Leang Cheav, 1972

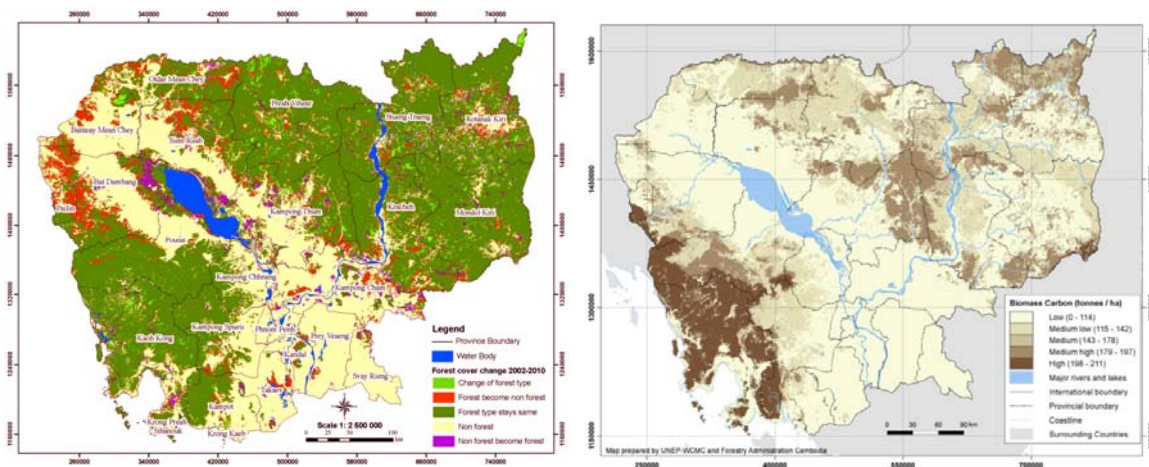


Figure 3: Left, Forest cover changes between 2002 and 2010 (FA, 2010). Right, Distribution of biomass carbon in Cambodia (UNEP-WCMC, 2010)

Agriculture expansion, illegal logging, expansion of settlements, road network extension, wood fuel demand, mining explorations, hydropower development are some of the driving forces behind the conversion of forested areas¹⁰.

As shown on the map of forest cover change the most significant loss of forests occurred in the northwestern provinces while smaller patches of deforestation are observed in the northeastern part of the country.

The UNEP-WCMC carbon map of terrestrial carbon stock has been generated in 2010, based on the FA 2006 forest cover and the JICA 2002 topographic map. According to the map, 2.97 Gt of carbon is stored in the biomass and soils of Cambodia's terrestrial ecosystem. One third of this carbon is stored in the evergreen forest (mainly located in the south western part of the country)¹¹.

"The extent of forests are significantly declining due to land use change, forest degradation through logging, forest fires, land grabbing and encroachment of agriculture"¹². Cambodia with a relative high forest cover associated with significant deforestation rates offers great potential for REDD+ activities¹³.

1.3. Defining the forest, three widely accepted definitions of forest

The most common international definition has been developed within the framework of the Clean Development Mechanism (CDM) of the Kyoto protocol. The **Marrakech Accords** (7th Conference of the Parties) determined the Parties should select a single value of crown area (fig. 4), tree height and area to define forests within their national boundaries (table 2)¹⁴.

¹⁰ MOE (2003)

¹¹ Kapos, V., Ravilious, C., Leng, C., Bertzky, M., Osti, M., Clements, T., Dickson, B. (2010)

¹² Cambodia interim REDD+ taskforce (2011)

¹³ Bradley, A. (2011)

¹⁴ Schoene, D., Killmann, W., Von Lupke, H., Loyche Wilkie, M. (2007)

Country	Tree Height	Crown cover	Land Area (ha)
Cambodia	5	10	0.5
Indonesia	5	30	0.25
Lao PDR	5	20	0.5
Myanmar	2	10	0.1
Philippines	5	10	0.5
Thailand	3	30	0.16
Vietnam	3	30	0.5

Table 2: Comparison of the threshold values adopted for defining forest under the CDM in various neighbouring ASEAN countries (Source: <http://cdm.unfccc.int/DNA/index.html>)

Selection must be within the following ranges, with the understanding that young stands that have not yet reached the necessary cover or height are included as forest.

"Forest is a minimum area of land of **0.05 - 1.0 ha** with tree crown cover (or equivalent stocking level) of more than **10-30 %** with trees with the potential to reach a minimum height of **2 - 5 m** at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes, but which are expected to revert to forest."

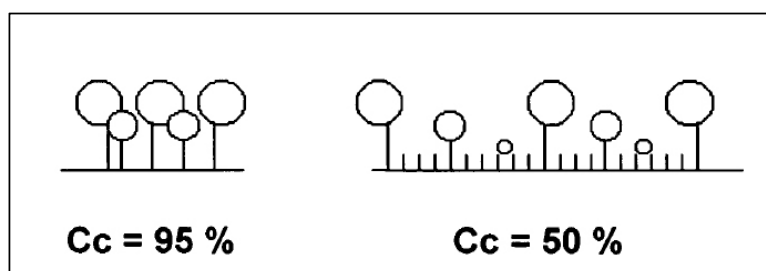


Figure 4: Illustration of two canopy or crown cover thresholds, percentage of ground area shaded by the crowns. Source: Forster, A. (2007)

When the Royal Government of Cambodia (RGC) intended to participate to the CDM of the Kyoto protocol, the following parameters for the forest definition have been retained¹⁵:

Tree Crown Cover: >10 %, Land Area: 0.5 ha min., Tree Height: >5 m

The criteria thresholds specified in this definition are similar to the ones mentioned in the forest definition included in the Cambodia National Forest Programme 2010-2029:

¹⁵ Letter ref. No. 4580 MAFF dated 02 September 2008

"Forest is the unit of the natural ecosystem or plantation in the forms of wetland, low land and dry land which covers by natural stands or plantation trees with a height from **5 meters** on an area last least **0.5 hectares** with a canopy of more than **10 per cent**. The plantations such as rubber, oil palm, teak, acacia and eucalyptus and other kinds of trees which fall under the above criteria will also be classified as forests."¹⁶

The Ad Hoc Technical Expert Group (AHTEG) on Forest Biological Diversity of the **Convention on Biological Diversity (CBD)** provides a second definition of forest.

"Forest is a land area of more than **0.5 ha**, with tree canopy cover of more than **10%**, which is not primarily under agriculture or other specific non-forest land use. In the case of young forests or regions where tree growth is climatically suppressed, the trees should be capable of reaching a height of **5 m** in situ, and of meeting the canopy cover requirement."

The CBD also provide a definition of the forest ecosystem: "A forest ecosystem can be defined at a range of scales. It is a dynamic complex of plant, animal and micro-organism communities and their abiotic environment interacting as a functional unit, where trees are a key component of the system. Humans, with their cultural, economic and environmental needs are an integral part of many forest ecosystems" but this kind of definition is too ambiguous. Even if in ecological terms they not capture all the elements of the state and change of forest, forest types are more robust to serve as a basis for forest classification.

Parameters	UNFCCC COP7/Marrakech Accord	UNEP/Convention on biological diversity	FAO/FRA
Young stands			
Temporarily unstocked areas			
Forestry land use			
Min. area (ha)	0.05 - 1	0.5	0.5
Min height (m)	2 - 5	5	5
Crown cover (%)	10 - 30	10	10
Strip width (m)			20

Table 3: Attributes and thresholds values of three forest definitions (Schoene, D. et al., 2007)

One commonly agreed definition is the one applied by the United Nations Food and Agriculture Organization (FAO) for the Forest Ressource Assessment (FRA) country reports.

The **FAO definition** covers ecosystems that are dominated by trees (defined as perennial woody plants taller than **5 m** at maturity), where the tree crown cover (or equivalent stocking level) exceeds **10%** and the area is larger than **0.5 ha** (FAO 2000, 2001b, 2001c). The term includes forests used for production, protection, multiple use, or conservation, as well as forest stands on agricultural land (such as windbreaks and shelterbelts of trees with a width of more than **20 m**) and plantations of different types. It also includes both naturally regenerating and planted forests. The term excludes stands of trees established primarily for agricultural production, such as fruit tree plantations, and trees planted in agroforestry

¹⁶ Forestry Administration (2010)

systems (but rubber plantations are included).

This definition is the one retained by the Forestry Administration for reporting to the FAO Global Forest Cover Assessment¹⁷. According to the comparison of the 3 definitions presented in the table 3, the FAO definition can be considered as the most complete by including all type of parameters.

2. Objectives

In 2002, The RGC presented its first National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) for the year 1994. The preparation of the second National Communication by the Department of Climate Change of the MoE is ongoing and new existing country specific data should be considered.

The overall objective of this report is to provide recommendations for the adoption of a new national forest classification system taking into account the requirements under international conventions such as the UNFCCC.

Analysis of various forest cover assessments in Cambodia constitute the first step of the design of a Forest Monitoring System "*expected to provide timely and accurate data on the forest cover changes in order to:*

- *Guide the implementation of the forest policies and measures including the REDD+ activities (for this function frequent data are needed); and;*
- *Quantify the impact of REDD+ activities on the GHG balance of the national land territory (for this function accuracy of data is the goal)."*¹⁸

This analysis aim to compare and analyze:

- **The spatial imagery used for the mapping:**
Type of sensor, spatial resolution, spectral resolution.
- **The methodology/classification techniques used for the forest cover assessment:**
Software used for the mapping, visual interpretation, (semi-)automatic classification, image segmentation, accuracy assessment and field verification techniques.
- **The forest classification retained for the mapping:**
Forest classes discriminated, according to the image resolution used for the assessment and according to the classification technique. Minimum mapping unit.

¹⁷ FAO (2010)

¹⁸ Federici, S. (2012)

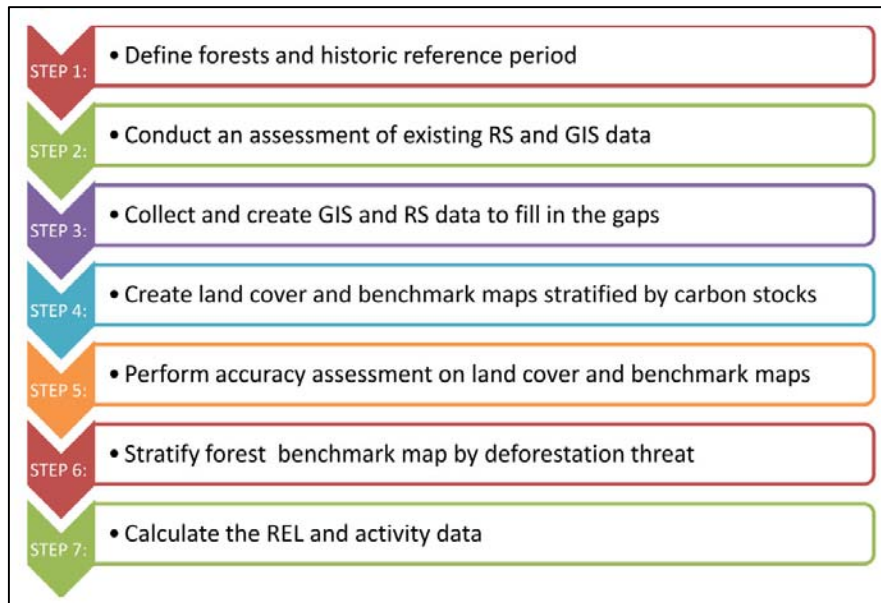


Figure 5: Flowchart of steps for developing activity data under REDD+ REL scenario (Source: Petrova, S.H. et al., 2010)

Forest stratification is crucial for developing Reference Level (RL) and Reference Emission Level (REL) (fig. 5 & 6) and for the implementation of a MRV system for REDD+ in Cambodia.

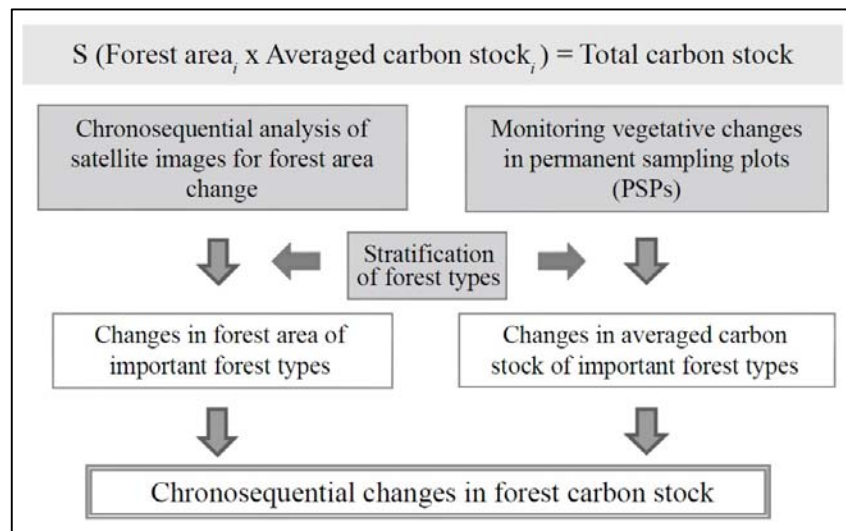


Figure 6: Forest stratification is essential for estimating changes in forest carbon stock (Source: Samreth, V., et al., 2012)

"Stratification refers to the division of any heterogeneous landscape into distinct sub-sections (or strata) based on some common grouping factor. [...] If multiple forest types are present across a country, stratification is the first step in a well-designed sampling scheme for estimating carbon emissions associated with deforestation and degradation"¹⁹.

¹⁹ GOF-C-GOLD (2012)

The recommendations on the forest definition and classification system to adopt will also contribute to the preparation of the design of the national forest MRV system which includes the design of the multipurpose National Forest Inventory (NFI) and the national Satellite Forest Monitoring System (NSFMS).

3. Ecology of forests in Cambodia

3.1. Territorial zoning in Cambodia

Existing zoning and additional biophysical data (geology, elevation) can serve as a basis for refining the actual forest classification system used in Cambodia. The ecoregion approach is a good starting point to understand the ecology of the forests in Cambodia as climatic, edaphic and elevation variations are influencing largely the spatial distribution of the forest types.

While the FAO Global Ecological Zoning identify 3 regions in the country: the **tropical dry forest**, the **tropical moist deciduous forest** and the **tropical rainforest**, others approaches of zoning provide more detailed stratifications of the country which can participate to improve the actual broad classification system used for the forest cover assessments.

The **ecoregions approach of Wikramanayake**²⁰ recognized 6 ecoregions in Cambodia:

- Southern Indochina Dry evergreen forest;
- Central Indochina dry forest;
- Cardamom Mountains Rain forest;
- Southern Annamites Montane forest;
- Tonle Sap Freshwater Swamp forest;
- Tonle Sap Mekong Peat swamp forest.

Within the **terrestrial ecoregions identified by the WWF**²¹, 10 ecoregions describe the ecological context of the forests of Cambodia (fig. 7):

- The Bolovens-Kan Tum montane forests;
- The Cardamom mountains moist forests;
- The Central Indochina dry forests;
- The Central Indochina moist forests;
- The Da Lat-Phnom Lyr montane forests;
- The Gulf of Thailand mangroves;
- The Tenasserim-South Thailand semievergreen moist forests;
- The Tonle Sap fresh water swamp forests;
- The Tonle Sap-Mekong peat swamp forests.

²⁰ Wikramanayake, E. et al (2001)

²¹ Olson, D.M., et al (2001)

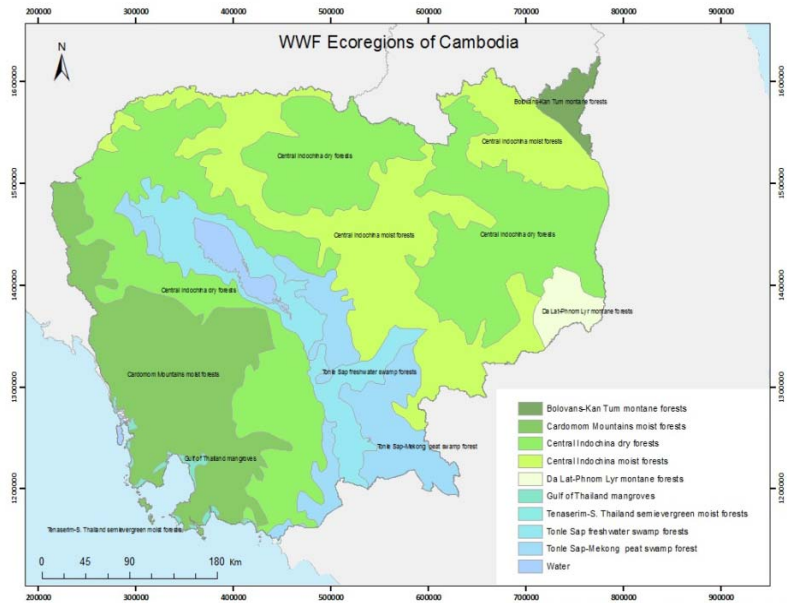


Figure 7: Map of the Ten WWF ecoregions identified in Cambodia (Olson, D.M., et al.,2001)

With the support of Danida in cooperation with the Forestry Administration and the German Development Service (DED), the Cambodia Tree Seed Project (CTSP) has developed a database and geographical model to describe and predict natural genetic variation in Cambodia’s important timber-tree species (fig. 8): the **Gene-Ecological Zonation**²².

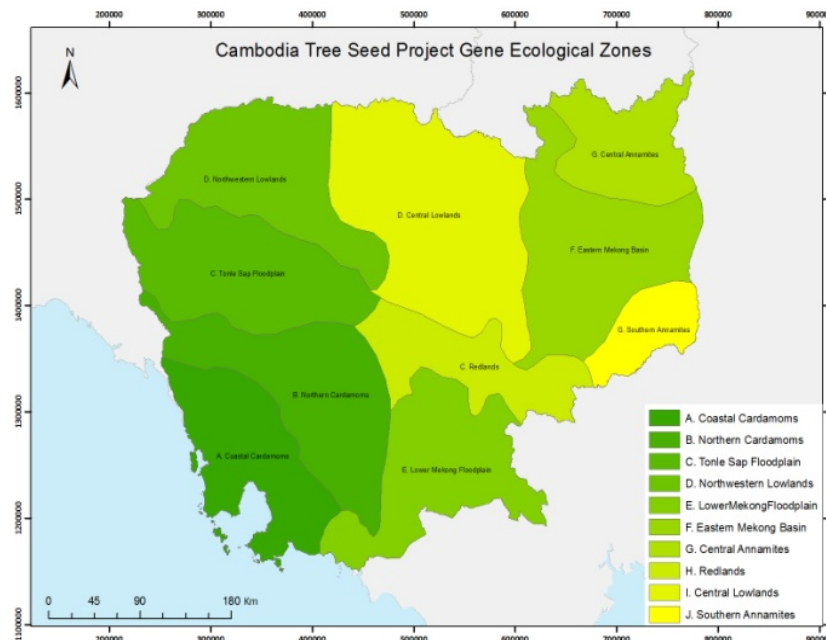


Figure 8: The 10 Gene-ecological zones of Cambodia (FA, 2003)

²² Forestry Administration (2003)

Seven distinctive gene-ecological zones and three sub zones have been described with information related to geographical, geological, climatic, and biological character of each region:

- Coastal cardamoms;
- Northern cardamoms;
- Tonle Sap floodplain;
- Redlands;
- Northwestern lowlands;
- Central lowlands;
- Lower Mekong floodplain;
- Eastern Mekong basin;
- Central Annamites;
- Southern Annamites.

The description of the physiographic zones of Cambodia (fig. 9) have been provided by Wharton²³. The zoning is quite similar than the previous one, the following ten region have been identified:

- Northern Plains: Flat sandstone plains or rolling terrain interrupted by occasional flat-topped hills or scarps, and rounded hills of Andesite and Basalt;
- Dang Rek Scarp: Steep escarpment forms the northern rim of the northern plains and delineates Cambodia from similar sandstone sediments in north-eastern Thailand;
- Northeastern Mountains: Represent an extent of metamorphic and sedimentary rocks of the Kontum Plateau within the Annamese mountain chain of Laos and Vietnam;
- Chhlong Plateau: Bokeo (Rattanakiri) and Chhlong Plateaus of basalt situated on Cambodia's north eastern borders and extending towards the Annamese mountain chain of Vietnam;
- Red land hills: basaltic areas in the vicinity of Kampong Cham province;
- Coastal Ranges: Cardamom and Elephant mountains, including Phnom Aural and Phnom Samkos, which attain elevations of 1771 and 1717 meters respectively;
- Sandy colluvial plain: colluvial slopes along the Northern and Eastern edges of the Cardamom and Elephant Ranges;
- Mekong alluvial plain: alluvial soils of the upper portion of the Mekong Plain;
- Tonle Sap alluvial plain: bordering the Mekong river and Tonle Sap wetlands system at elevations 5 - 30 meters, much of this area receives an annual increment of alluvial silt;
- Battambang Plain: fertile soils.

²³ Wharton, C.H. (1968)

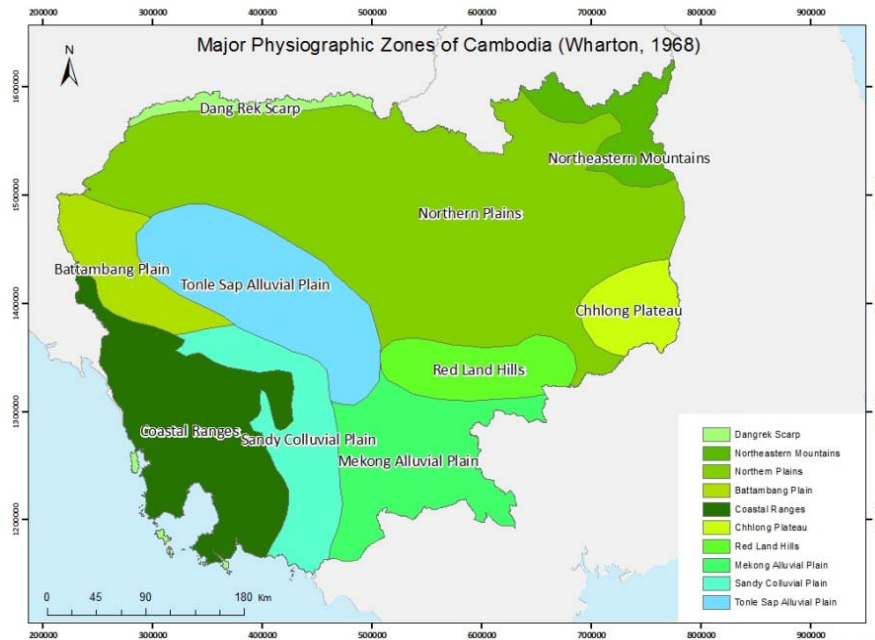


Figure 9: Physiographic zoning of Cambodia (Wharton, C.H., 1968)

Finally, elevation pattern have often been used to subdivide a given forest type. The common practice consist in the separation between the sub-montane forest land (>600-700m) and the lowland forest land (<600-700m). Another stratification could be more relevant using soil data available for Cambodia²⁴, unfortunately this map is relatively outdated.

These variations in term of ecological condition will explain the spatial distribution of different types of forest. Forest types of Cambodia have been described by many authors the fact remains that *"defining forest types is a somewhat arbitrary process in Cambodia since in there often a continuum without sharp boundaries, and many intermediates can be found"*.²⁵

3.2. Forest types of Cambodia

One of the most common ecological criteria used for discriminating major forest types in Cambodia is the leaf phenology, distinguishing deciduous from evergreen forests. The main reason of employing this criteria is that these two forest types can be discriminated using remote sensing. However, *"Evergreen, semi-evergreen and deciduous forest encompass a number of forest complexes and wide range of floristic plant communities associated with varying geological substrates, soils, climate, fire and disturbance regimes"*.²⁶

The following review, based on the ecological descriptions of forest types identified by the french botanists²⁷, Williams L.²⁸, Rundel P.W.²⁹ and Kim Phat N.³⁰, aims to complete the

²⁴ Crocker, C.D. (1962)

²⁵ WCS (2011)

²⁶ USAID (2011)

²⁷ Legris, P., Blasco, F. (1972)

²⁸ Williams, L. (1965)

definitions provided by FA GIS unit³¹.

- **Lower montane forests, the hill evergreen forest**

Syn. Tropical Broad-leaved Evergreen forest, Tropical rainforest, Forêt dense, Forêt dense humide.

At altitudes beyond 600-800 m., Dipterocarpaceae are absent, dominant species of this forest type are representatives from families such as Fagaceae (*Lithocarpus sp.*, *Quercus sp.*, *Castanopsis sp.*) Lauraceae (*Cinnanomum sp.*), Myrtaceae.

The structure is simplified with a relatively low stratum (20 m.) with an open canopy structure, due to frequent fires and cutting, dominating an dense understory of small trees with a well developed epiphytic flora. These forests may be divided into those located in the coastal ranges and those in northern uplands.

- **Wet evergreen forest, the lowland tropical rainforest**

Syn. Moist evergreen forest.

This forest type correspond to a multistoried forest with an irregular canopy at an average height of 30m where trees keep their leaves during the whole year (fig. 10).

Dominant trees are *Dipterocarpus costatus* (Chheuteal Bangkuoy), *Anisoptera costata* (Pdeak), *Hopea odorata* (Korki Msav), *Shorea hypocra* (Korki Pnong) associated with *Herrietiarra javonica* (Khley), *Swintonia pierrei* (Svay Kandol) and *Palaquium obovatum* (Chur Ni).

In the poorly drained depressions this forest type becomes a **Dwarf evergreen forest** where the Gymnosperm abundance increase (*Dacrydium pierrei*, *Podocarpus neriifolius*, *P. imbricatus*) in association with small to medium sized Dipterocarps (*Hopea odorata* and *Hopea pierrei*). The average height of the trees is only 10 m.

- **Dry evergreen forest, an evergreen type rich in deciduous trees**

Syn. Semi evergreen forest, Forêt dense semi-decidue (Legris).

The term evergreen is a misleading name as this type of forest contains a large number of "partially" deciduous trees (sometime half or more), however this forest type (fig. 11) never appear leafless³². Others have been qualifying this forest type as follow: seasonal evergreen forest, tropical semi-evergreen forest or semi-deciduous forest. This type also correspond to the "forêt dense" of the coastal ranges and "forêt dense hemiombrophile" of the northern uplands .

²⁹ Rundel, P.W. (2009)

³⁰ in MoE (2003)

³¹ FA (2008)

³² Rundel, P.W. (2009)



Figure 10: Wet evergreen forest of the Phnom Samkos wildlife sanctuary, Cardamoms. ©C. Webb/FFI Cambodia



Figure 11: Dry evergreen or Semi evergreen forest in Siem Pang (North-eastern Cambodia). ©Jonathan C Eames/Birdlife

The variation of the terms used to describe this forest type illustrate its high level of heterogeneity in term of physiognomy and composition. When the soil is getting drier the Dry evergreen forest is replaced by the deciduous dipterocarp forest³³. The multilayered canopy (multistoried) recall the structure of Evergreen type (with a lower species richness and a more open canopy). This forest type is intolerant to fire and drought sensitive.

At the height of 40-50 m., the dominant tree species are represented by *Ficus sp.*, *Heritiera javanica*, *Dipterocarpus alatus* (Chheuteal Toek), *Shorea vulgaris* (Chor Chong), *Anisoptera cochinchinensis*, *Tetrameles nudiflora*. This discontinuous stratum dominate a second continuous and very heterogeneous stratum around 20-30 m. high where evergreen trees from *Guttifera sp.* are well represented in association with the partially deciduous trees: *Ficus sp.*, *Irvingia malayana* (Cham Bak), *Sindora cochinchinensis*, *Pterocarpus pedatus* and *Pahudia cochinchinensis* (Beng).

The distribution of the dry evergreen forest or semi-evergreen forest is largely influenced by soil-moisture availability. This type of forest often occurs on deep soil profile with a good capacity for soil-moisture.

- **Mixed deciduous forest**, a deciduous type of the semi evergreen forest
an intermediate type dominated by deciduous species:

Syn. Monsoon forest or nearly deciduous forest.

Strong seasonality with frequent fires. Closed canopy with tree height around 30m. Beneath, the understory is relatively open. Dominated by Fabaceae, Lythraceae (*Lagerstroemia sp.* not favored by loggers) and Rubiaceae together with a low occurrence or absence of Dipterocarpaceae.

Dominant species include *Xylocarpus xylocarpa*, *Pterocarpus macrocarpus*, *Azadirachta xylocarpa* and *Dalbergia spp.*, *Terminalia spp.* (Combretaceae).

Phenology of canopy trees show a nearly 5 months leafless period which begin around 1-2 months after the beginning of the dry season.

Deciduous tree, Lagerstroemia is also a dominant specie of semi-evergreen forest, this forest type is often classified as mixed deciduous forest instead of a deciduous type of the semievergreen forest (fig. 12).

The mixed deciduous forest can also be interpreted as a degraded type of the Dry evergreen forest. This forest type is an intermediate type between a moister semievergreen forest and a dryer deciduous dipterocarp forest³⁴.

- **Deciduous dipterocarp forest**, a low and open type of forest adapted to fire

Syn. Deciduous dipterocarp woodland, dry dipterocarp forest, tropical savanna-woodland,

³³ Op. cit.

³⁴ Op. cit.

Savannah-like deciduous dipterocarps forest, Dwarf dipterocarp forest, forêts claires (decidues à diptérocarpacées)

One stratum of small to medium sized deciduous trees (5-15m) dominate an open understory dominated by grasses. This forest type (fig. 12) present a moderate species richness.

Deciduous species of Dipterocarpaceae are the dominant elements. Deciduous dipterocarps trees (6 of the 550 known dipterocarps species) are represented in this forest type: ***Shorea siamensis*** (Meranti), ***Shorea obtusa*** (Phchek), ***Dipterocarpus obtusifolius*** (Thbaèng) and ***Dipterocarpus tuberculatus*** (Khlóng). ***Dipterocarpus intricatus*** can appear on the better soils. ***Pinus merkusii*** may be codominant in these formations. Other tree species in this forest include *Pinus merkusii* (sral sleuk pi), *Pentacme siamensis* (re`ang). *Corypha lecomtei* (a palm), *Memecylon edule*.

Fires constitute a frequent disturbance in this forest type, most of the species are tolerant, the formation is also qualified as a fire adapted forest ("fire-climax"). According to Williams and Rundell, it is also the most extensive forest type in Cambodia (Rundell, Williams).

This forest type can also occur in higher rainfall areas when edaphic conditions are dry.

- ***Pine woodland***, an extension of the dry dipterocarp woodland

Syn. coniferous forest, forêt claire, pinède à Pinus merkusii

Pinus merkusii is the most common representant of this formation (***Pinus kesiya*** has also been found in the Cardamom mountains), often mixed with *Dipterocarpus obtusifolius* and other species of the dry dipterocarp woodland.

- ***Flooded forest and gallery forest***

Syn. Inundated forest, Swamp forest, peat swamp forest, riverine forest, forêt inondée.

The *flooded forest* is typical from the floodplain of the Tonle Sap and the Mekong (fig. 13). This forest type is subject to seasonal flooding (6-8 months). Strong seasonality of flooding explain the dominance of deciduous species which lose their leaves during the flooded season (instead of the dry season). During the recession, new leaves are produced rapidly³⁵.

This flooded forest is dominated by 2-3 characteristic species ***Barringtonia acutangula***, ***Coccoreas anisopodum*** and ***Diospyros cambodiana***. The canopy never exceed 7-15 m in height. A short tree-shrubland (2-4 m) with species that can reach tree size in the proper swamp forest. This shrubland can take the form of dense thickets of the invasive *Mimosa pigra* who tend to eliminate all the other species.

³⁵ Araki, Y., Hirabuki, Y., and Powkhy, D. (2007)



Figure 12: Deciduous dipterocarp forest, surrounding a patch of mixed deciduous forest in the Cardamoms. ©C. Webb/FFI Cambodia



Figure 13: The flooded forest of the Mekong River in Kratie Province, Cambodia. ©Mark Bezuijen/WWF.

The flooded forest type is also present on the floodplains of the major rivers to form an **Evergreen gallery forest**. These riparian forests are encountered on alluvial soils, dominant tree species are typically dipterocarps trees, **Dipterocarpus alatus**, **Dipterocarpus dyeri**, **Hopea odorata**, characteristics from an evergreen forest type, in association with riverine tree species. The floristic affinities with the wet evergreen forest of the southwestern cardamom range suggest that these gallery forests may "have served in the past as migration corridors between these ranges and the Annamite range to the east"³⁶.

- **Mangrove and associated rear mangrove forest**

The distribution of the mangrove forests is limited to the coastline of Cambodia. The trees height generally does not exceed 10 meters. Some formation of **Rhizophora conjugata** can reach 15-20 meters. Other Rhizophoraceae dominant species are represented by **Rhizophora mucronata**, **Bruguiera sp.**, **Ceriops sp.**

Other tree species such as **Melaleuca leucadendron** (syn. **Melaleuca cajuputi**) tend to dominate in the hinterland of the mangrove forest to form the rear mangrove forest in areas less affected by salted water.

4. Forest definitions and classifications

Numerous forest cover assessments have been carried out at various scales using different techniques as well as different methodologies. Depending of the purpose of the forest resource assessment and depending of the scale of the spatial analysis, results considerably differ in term of forest type classifications. Finally, the classification system to adopt is selected according to the capability of the sensor to detect the objects on the earth's surface and their practical significance in the real world.

4.1. Forest classification and definition used for national forest cover assessments

The first figures available for the country are given by the **1965 forest cover assessment of Cambodia** (fig. 14) have been published with a vegetation map by Pan Leang Cheav³⁷.

We assume that estimations refer to a first forest inventory implemented by the Forest Research and Education Institute³⁸ based on interpretation of aerial photography³⁹. Information about the methodology used for producing this vegetation map is not available. The accuracy of such small scale map is questionable. However, estimation on forest cover extent, 13,227,100 ha or 73.04% of the country, are provided for a total number of 9 forest types.

³⁶ Rundel, P.W. (2009)

³⁷ Pan Leang Cheav. (1972)

³⁸ FAO (2004)

³⁹ Gentile, J. and al. (1996)

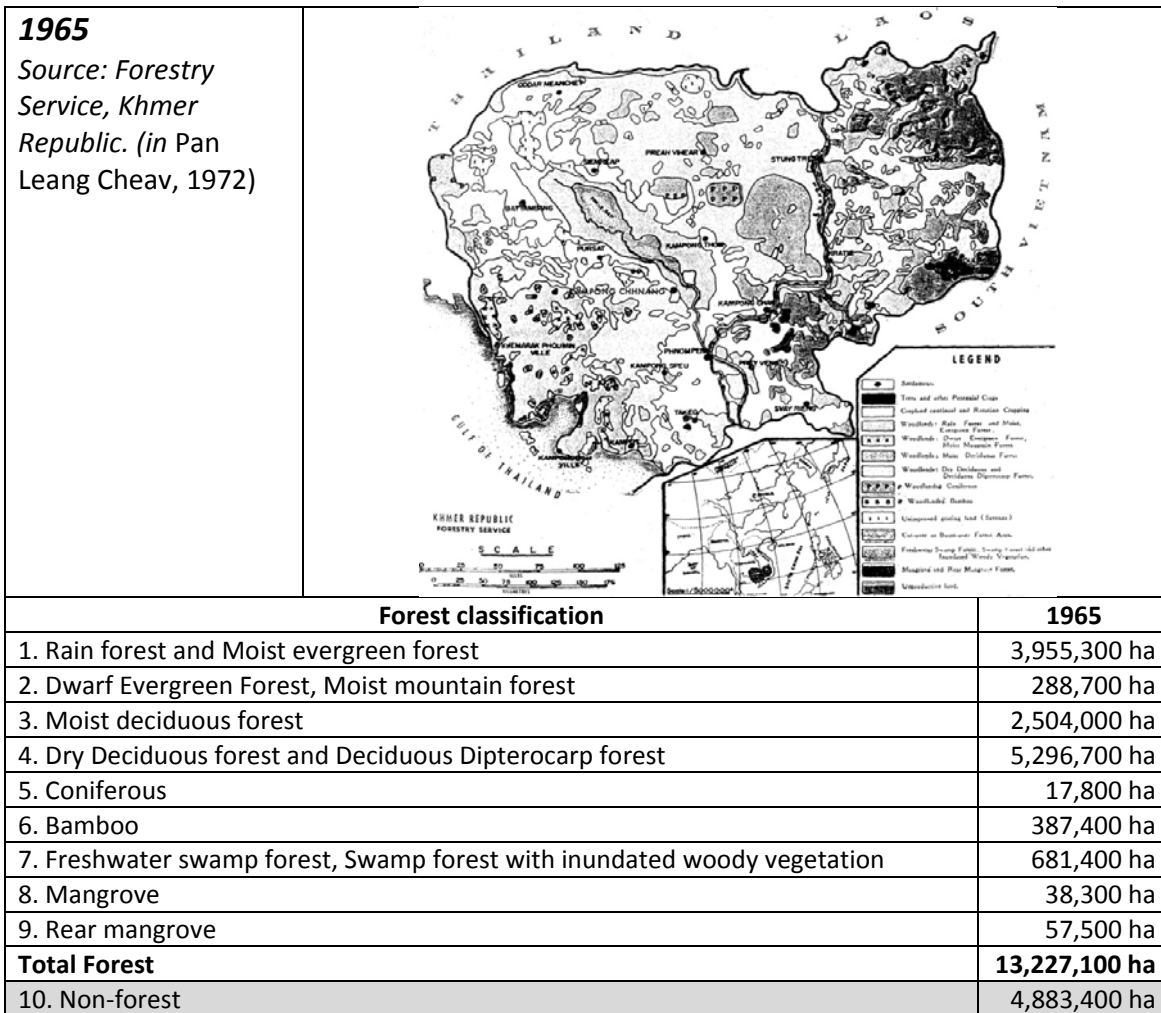


Figure 14: The 1965 forest cover assessment of Cambodia (FREI)

The **1988/1989 Reconnaissance Land Use Maps of Cambodia**, LUKAM dataset (fig. 15), produced by the Remote sensing and Mapping Unit of the Mekong Secretariat, can be imported in any GIS software.

This visual interpretation of LANDSAT satellite image hardcopies results in a classification of the country in 20 land use classes (where 9 classes depict various forest cover) at a scale of 1:500 000, and a minimum mapping unit of 1 km² (4 x 4 mm at map scale). Canopy cover threshold adopted for the forest definition is the one corresponding to the actual FAO forest definition (10%).

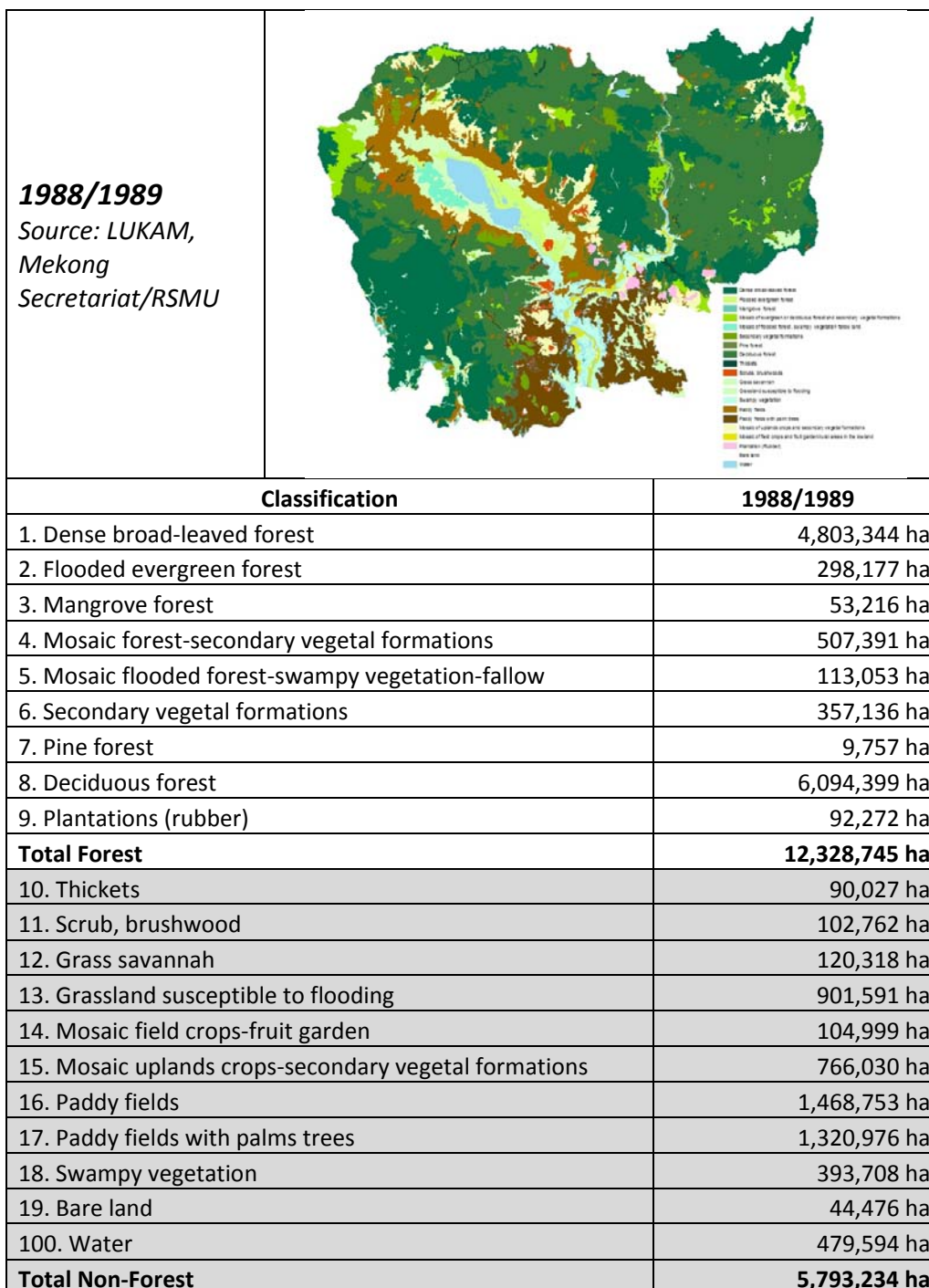


Figure 15: 1988/1989 Reconnaissance Land Use Maps of Cambodia published in 1991 by the Mekong Secretariat.

The Cambodia Land Cover Atlas, published in 1994, with support from FAO/UNDP.

Changes in forest cover that have occurred over twenty years have been estimated for the purpose of the FAO/UNDP/MRC Cambodia land cover Atlas (fig. 16). Lands with more than

estimated **10% canopy cover** (based on Landsat interpretation) were considered as forest⁴⁰.

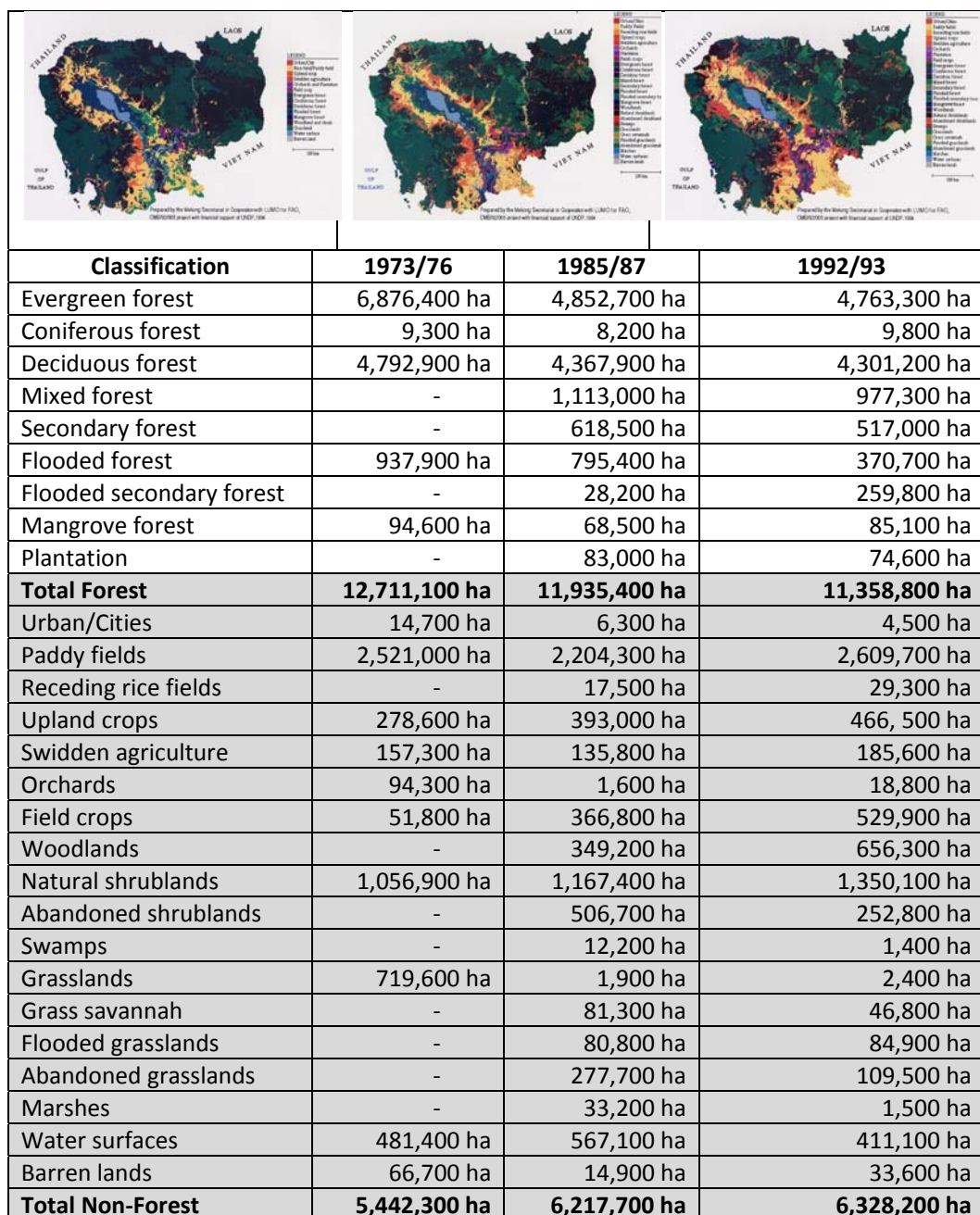
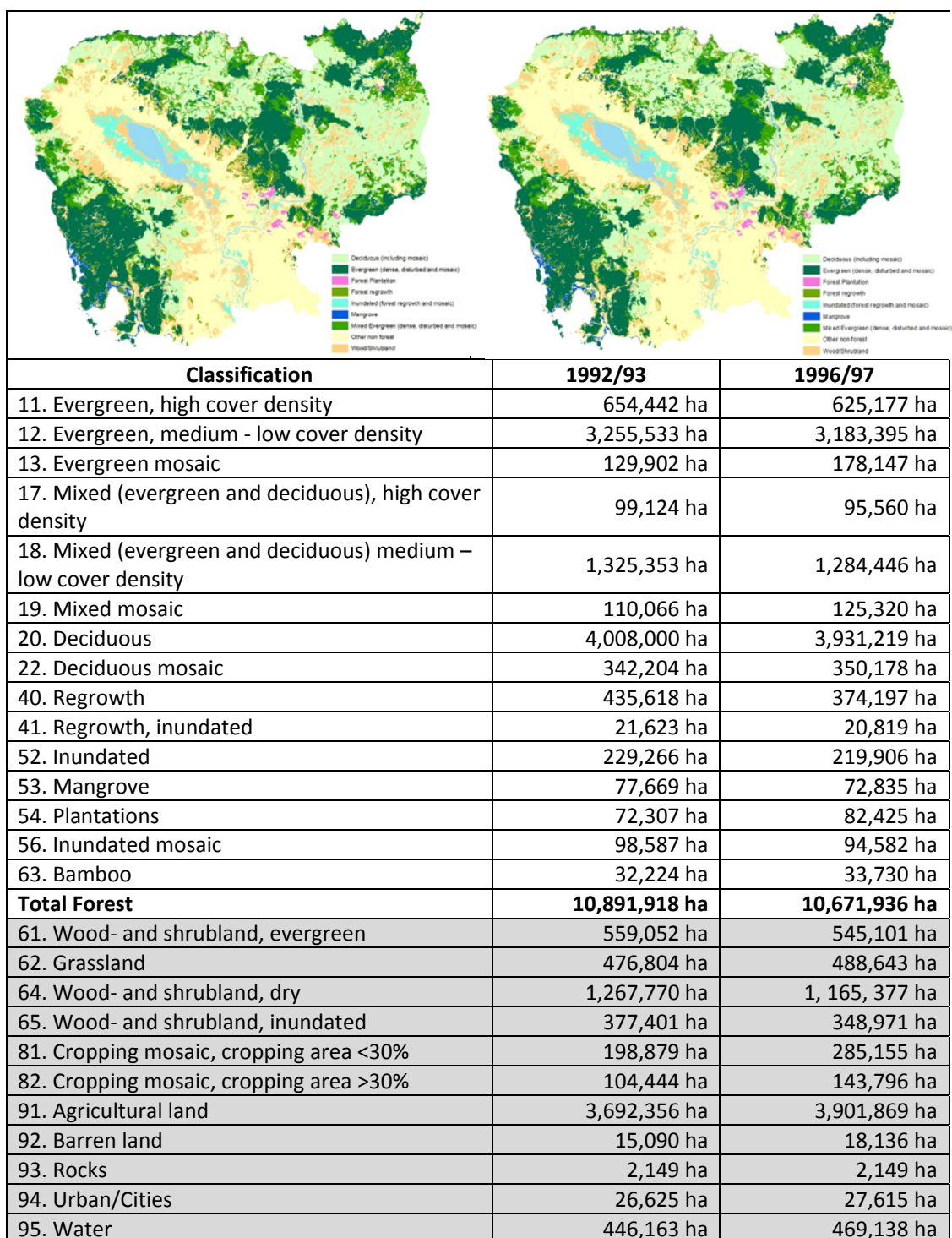


Figure 16: The Cambodia Land Cover Atlas, published in 1994, with support from FAO/UNDP.

Forest Cover Monitoring Project (FCMP) 1992/93-1996/97, a MRC initiative executed by the GTZ (fig. 17). Forest types have been mapped with a high degree of detail by visual interpretation of Landsat hardcopies. Several major forest types have been differentiated. Every major forest type has been sub-divided into density classes, where appropriate. Forest were defined as land with tree cover where the **crown cover was more than 20%** and tree height was at least **10 m**. The minimum mapping unit (MMU) was defined as the smallest

⁴⁰ Mekong Secretariat (1994)

unit to be mapped by the interpreter. "The FCMP used a 2 x 4 mm MMU which is equivalent to 0.5 km² (assuming a scale of 1:250,000)"⁴¹. The 20% Crown cover threshold was chosen in view of the abundance of the Dry Dipterocarp Forest in the Lower Mekong Basin region and by nature quite open⁴².



⁴¹ Forster, A. (2007)

⁴² Malyvanh M., Feldkötter C. (1999)

55. Other	1,756 ha	1,756 ha
97. Wetland	91,079 ha	83,340 ha
99. Clouds	1,497 ha	-
Total Non-Forest	7,261,065 ha	6,315,669 ha

Figure 17: The Forest Cover Monitoring Project 1992/93-1996/97, MRC-GTZ

Other (non-forest) land cover types have been mapped with a lesser degree of detail, e.g. there is only 1 class of permanent agriculture, which contains rice fields as well as agricultural plantations. Small patches of forest have not been detected due to the resolution of the satellite images⁴³.

Qualitative changes in canopy density resulting from human activities such as logging, shifting cultivation, agriculture extension, etc... have been considered. Three Crown Cover Classes as seen on satellite images were distinguished: 0 – 19 % (Low), 20 – 69 % (Medium) and 70 – 100 % (High).

An additional classification criteria, the canopy density corresponding to a combination of crown cover and forest cover, has been adopted after the visual interpretation (fig. 18 & 19). To be classified as Forest, a MMU must have a forest cover of at least 40% (Forest cover is the percentage of areas within a MMU where the crown cover is at least 20%).

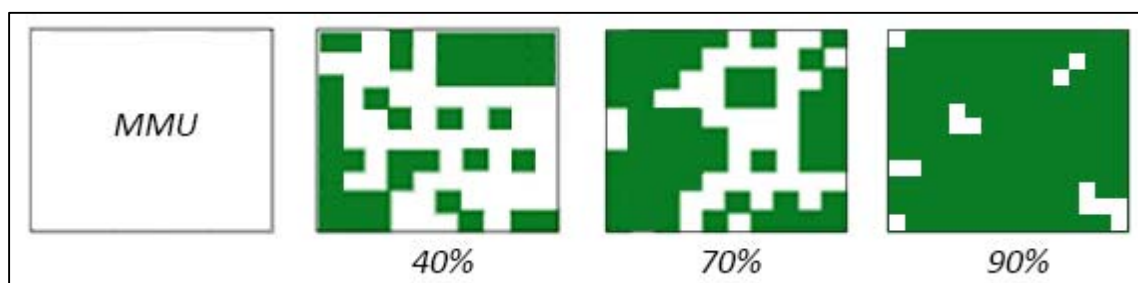


Figure 18: The forest cover (%) defined by the FCMP as the percentage of the area within the MMU where the crown cover is higher than 20%

Forest land has been later classified into three classes according to forest cover and crown cover values:

Forest category	Forest Cover		Crown Cover
High cover density	>90%	and	>70%
Medium-low cover density	70-89%	and/or	20-69%
Mosaic	40-69%	and	>20%

Figure 19: Classification of the MMU using forest cover and crown cover threshold (Malyvanh M., Feldkotter C., 1999).

The Whole of Cambodia Forest Register 1995, JAFTA

The forest cover map carried out by the Japan Forest Technical Association (JAFTA) (fig. 20)

⁴³ Op. cit.

is the first national forest cover assessment done using automatic classification techniques⁴⁴. The Landsat images used for the mapping are dated from 1990 to 1995. The final classification system retained for the mapping (8 forest types including "Rubber plantation") is the following:

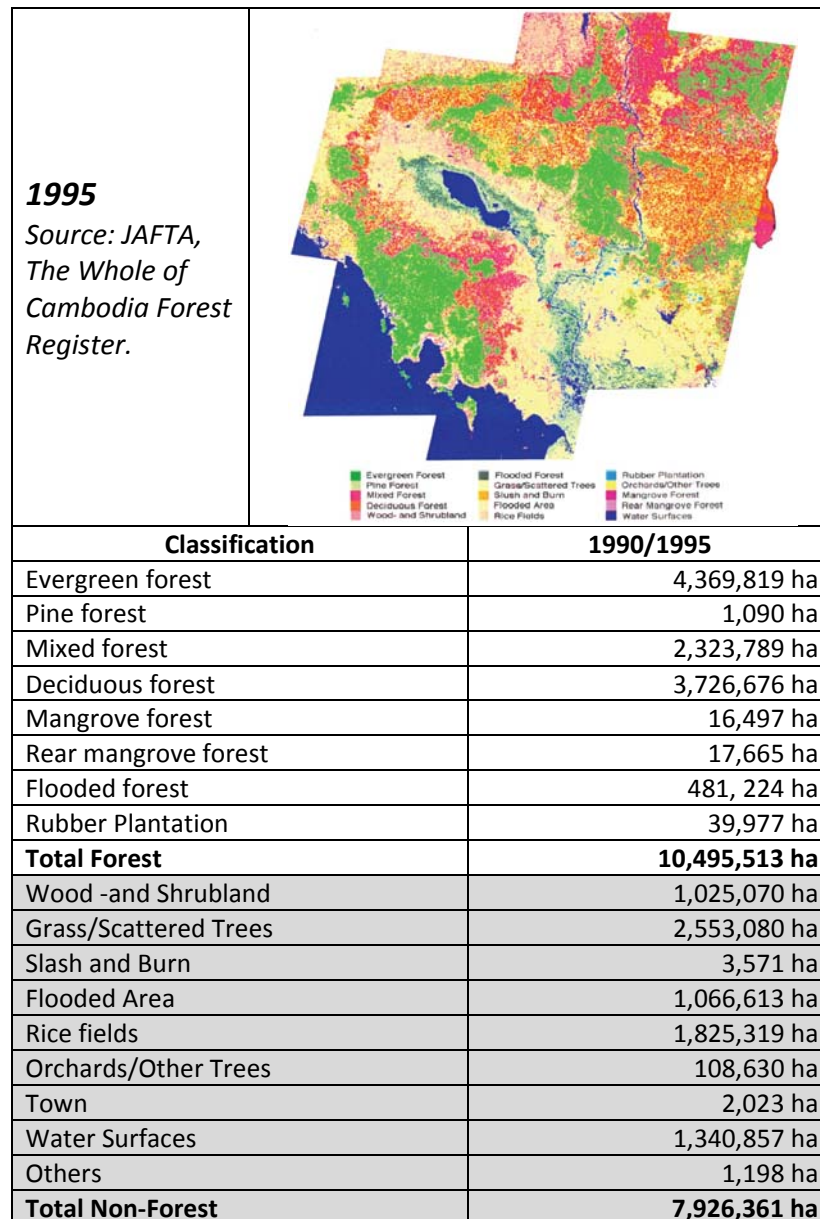


Figure 20: The whole of Cambodia forest register, JAFTA

The **Forest Concession Management and Control pilot project**, the consortium FRM/INDUFOR/SGS⁴⁵ conducted a remote sensing study of Cambodia's forest cover (fig. 21). A detailed map has been produced in collaboration with the GIS and remote sensing unit of the Department of Forestry and Wildlife (DoFW, MAFF). This country-wide analysis has been based on manual on-screen visual interpretation of Landsat ETM+ imagery. The retained

⁴⁴ Japan Forest Technology Association (1995)

⁴⁵ FRM (2003)

MMU is the same than the one used for the 1996/97 to allow comparability while the interpretation has been conducted at a much more precise scale (1/50 000). The classification system retained for the mapping consist in a merge version of the existing 1996/97 (FCMP,MRC/GTZ) forest cover assessment:

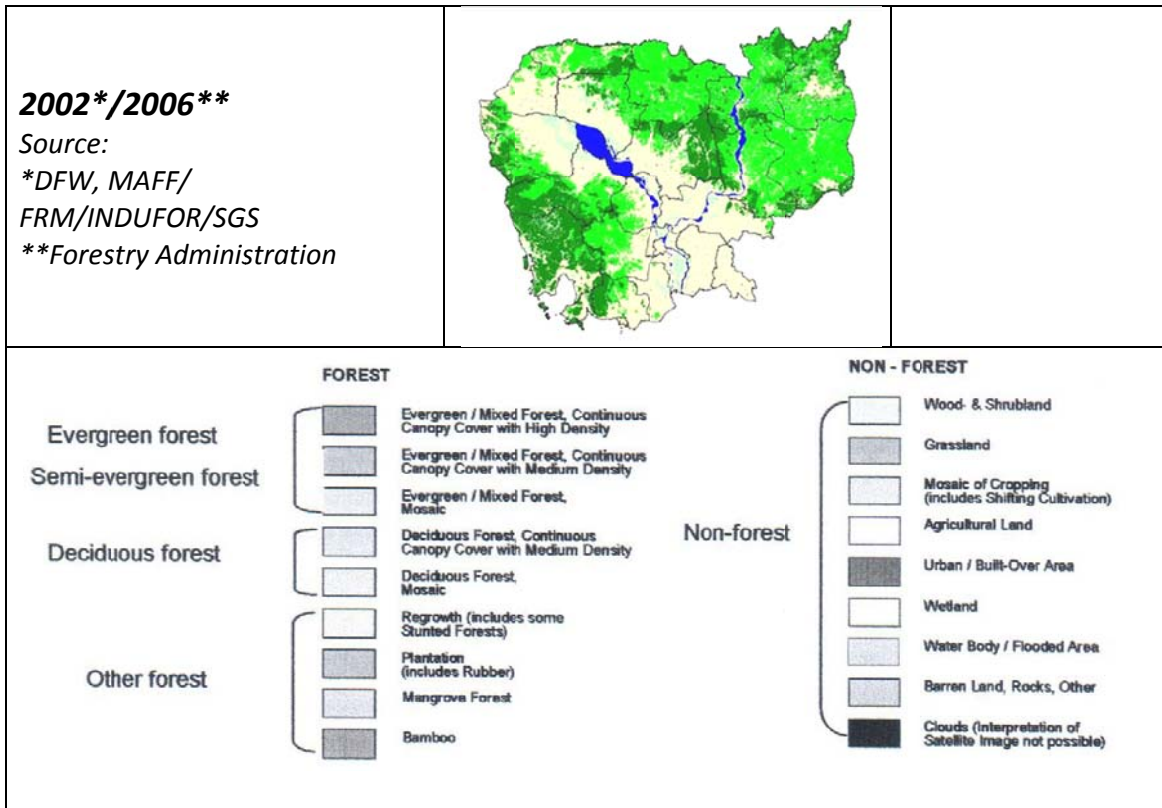


Figure 21: The broad classification system adopted by the Forestry Administration in 2002 after aggregation of the classes adopted for the 1993/1997 forest cover assessment FCMP, MRC-GTZ. Source: DFW/FRM

The **2010 Forestry Administration's Cambodia's Forest Cover** (fig. 22) updated the previous forest cover assessment. The methodology followed for the 2006 map as well as the forest definition stayed unchanged while the nomenclature adopted in 2002 has been slightly modified in 2006 (4 forest classes on a total of 8 land cover classes). However, as recommended by the GRAS A/S accuracy assessment report, due to their low accuracy, the smaller classes have been merged with others increasing the accuracy from 71% to 74%. Finally, in the 2006 nomenclature, the same 5 land cover classes of 2002 have been retained, the class "bamboo" has been included in the "other forest" class, while the classes "wood & shrubland dry" and "wood & shrubland evergreen" have been merged within the "non-forest" class.

In the latest forest cover assessment (2009/10) the main difference deals with the forest definition even if some modifications have been introduced in the classification system.

While for 2005/06 Forest cover map, a forest was defined with a Minimum Crown cover threshold of 20%, in 2010, the national forest cover map is based on the definition of forest as defines in the FAO's Global Forest Resources Assessment (0.5 ha, 5 m., 10%).

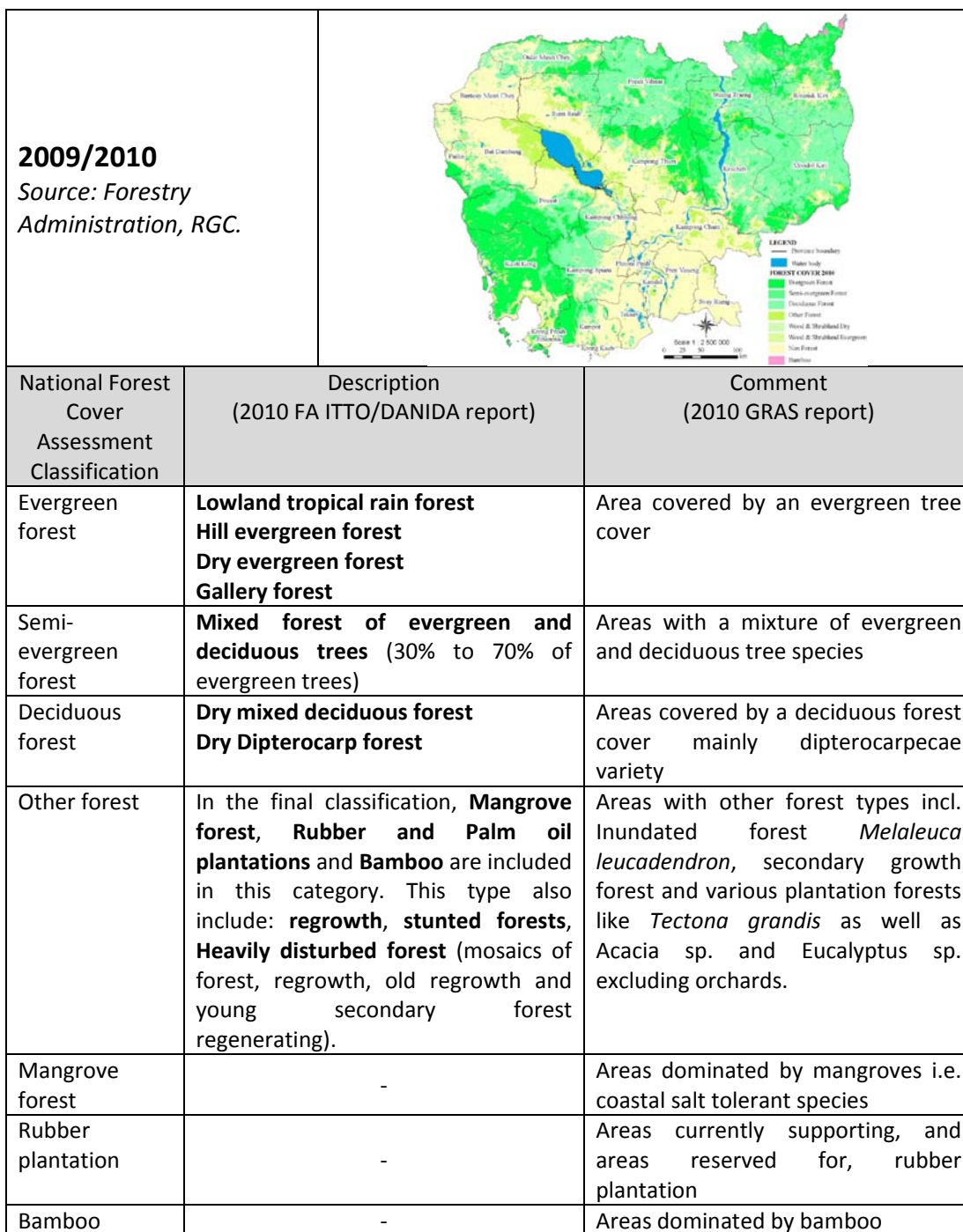


Figure 22: 2009/2010 Forest cover assessment (FA/MAFF, 2011)

For the 2010 forest cover assessment, the classification scheme has been broadened, containing 2 more classes absent of the classification since the 2002 (*Mangrove forests* and *Rubber plantation*) to the 8 classes of the 2005/06 forest cover classification. After recommendations by FAO, for reporting to the Global Forest Resource Assessment, these two newly added forest types, mapped with "high individual accuracies" (fig. 23), have been

merged in the "Other forest" class in the final map, like in the 2005/06 map⁴⁶.

		Combined sample											
		E-F	S-F	D-F	O-F	W-D	W-E	N-F	B-B	M-F	R-P	Sum	User Acc.
Classified	E-F	50	2									52	96%
	S-F	2	25	2				2				31	81%
	D-F		5	64				1	1			71	90%
	O-F	1			26			3				30	87%
	W-D			4	2	7		1				14	50%
	W-E			3	1		15					19	79%
	N-F	3		3	1			26		2		35	74%
	B-B		1					1	17			19	89%
	M-F				1			1		13		15	87%
	R-P				1			2			15	18	83%
Sum		56	33	76	32	7	16	37	17	15	304		
Prod. Acc.		89%	76%	84%	81%	100%	94%	70%	100%	87%	100%		

Overall acc. = 85%

Figure 23: Confusion matrix between the 2010 forest cover map and the combined use of field and Landsat samples. Evergreen forest (E-F), Semi-evergreen forest (S-E), Deciduous forest (D-F), Other forest (O-F), Wood shrub evergreen (W-D), Wood shrub dry (W-E), Bamboo (B-B), Non-forest (N-F), Mangrove forest (M-F) and Rubber plantation (R-P). (Source: GRAS, 2010)

Land use data are also available from the **Cambodia Reconnaissance Survey** conducted in 2003 by the ministry of Public Works and Transportation (MPWT) with the support from JICA. The Land use map, at a scale of 1:100 000, is based on Landsat TM Imagery interpretation.

Among a total of 40 classes, 12 forest types have been considered (table 4). According to the legend of the map, forest are defined with a minimum crown cover of 10% (which is consistent with the 2010 Forest Cover assessment).

Code	Classification	Area
Fe	Evergreen broad leaved forest	3922638.39 ha
Fc	Coniferous forest	7145.17 ha
Fd	Deciduous forest	3549993.34 ha
Fdo	Dry Deciduous (open) forest	248806.04 ha
Fx	Mixed forest from evergreen and deciduous species	1429007.43 ha
Fr	Riparian forest	384923.59 ha
Fs	Bamboo and secondary forests	772234.87 ha
Ff	Flooded forest	20644.32 ha
Fp	Forest plantation	3773.30 ha
Fm	Mangrove forest	34710.08 ha
Fmd	Degraded mangrove forest	36293.56 ha
Fp	Forest plantation	3773.30 ha

Table 4: The 12 forest classes identified in the 2003 JICA Land Cover map.

The updated version of the **Vegetation map of Cambodia** (French Institute of Pondicherry,

⁴⁶ GRAS A/S (2010)

P. Legris et F. Blasco, 1970) published in 1996 offers a more ecological approach for mapping the forest types of Cambodia. This map has later been integrated in a "third update": the **Terrestrial Vegetation and Landuse patterns** map (fig. 24).

Published by the MoE, Biodiversity and Protected Area Management Plan (BPAMP), in 2007, it integrates two existing classification systems.

The JICA Land reconnaissance survey has been adapted and the initial relative broad forest categories have been reclassified taking into consideration the elevation (650 m has been used as a boundary between lowland and sub-montane vegetation types) and other bioclimatic criteria (mainly the humid coastal ranges and hinterlands opposed to the less humid forest of the inlands).

This map is very similar to the one published by P. Legris et F. Blasco in 1970, updated by F. Blasco, M.F. Bellan et D. Lacaze in 1996 where stratification of the forest types has been based on elevation (submontane/lowland), bioclimatic (very humid, humid, sub-humid) and edaphic criteria (table 5). *"This classification developed by Cambodian and French botanists and foresters prior to the war remains the most comprehensive and useful typology to date [...] the resulting map was "ground-truthed" through an extensive series of aerial surveys with a light aircraft in which over 10,000 aerial photos".*⁴⁷

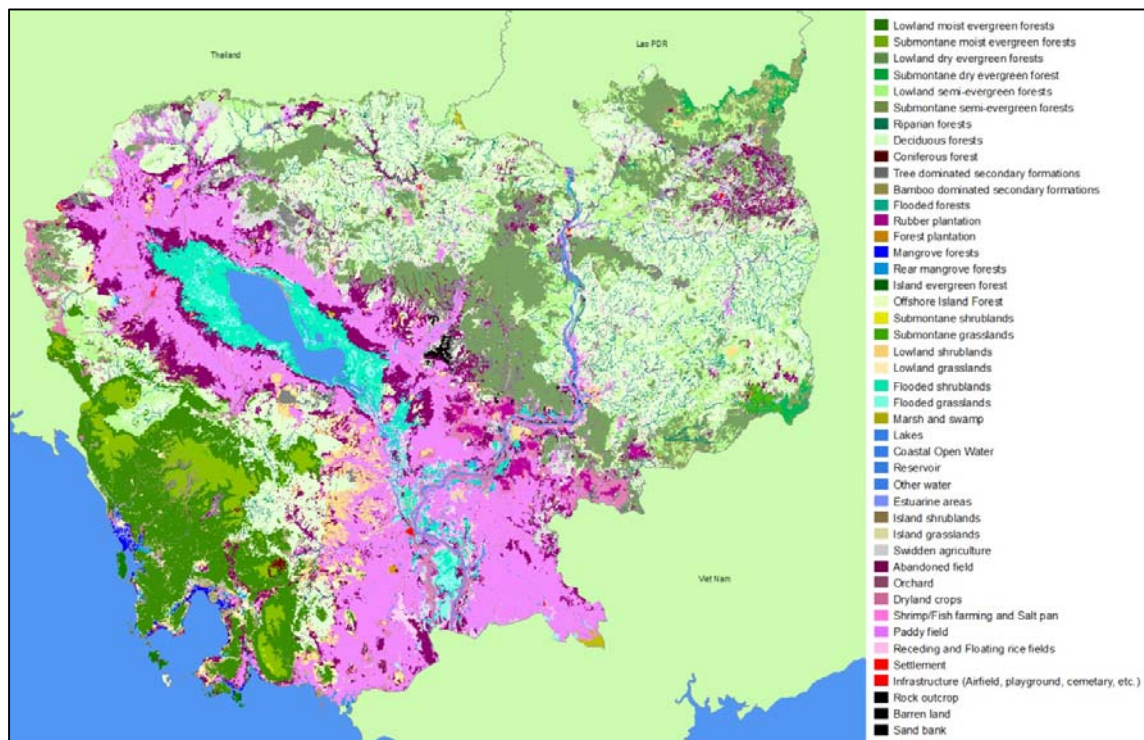


Figure 24: Terrestrial vegetation and landuse patterns (BPAMP/MoE, 2007).

⁴⁷ USAID (2011)

Final Classification	Area
Sub-montane moist evergreen forest	373843.43 ha
Sub-montane dry evergreen forest	84624.87 ha
Sub-montane semi-evergreen forest	21312.97 ha
Lowland moist evergreen forest	1370648.46 ha
Lowland dry evergreen forest	1956437.24 ha
Lowland semi-evergreen forest	1339974.79 ha
Riparian forest	382358.07 ha
Deciduous forest and woodland	4024057.57 ha
Coniferous forest	8645.25 ha
Tree dominated secondary formations	621150.05 ha
Bamboo dominated secondary formations	236218.34 ha
Flooded forest	20644.32 ha
Rubber plantation	84536.57 ha
Forest plantation	3773.30 ha
Mangrove forest	34154.77 ha
Rear Mangrove forest	31938.80 ha
Island evergreen forest	21346.49 ha
Offshore island forest	2435.45 ha
Non Forest	7557861.62 ha

Table 5: Classification used for the Terrestrial Vegetation and Landuse patterns map.

4.2.A global classification system for Cambodia, the FAO GLCN/LCCS

The main objective of the GLCN/LCCS is to respond to the need for standardization or harmonized collection of data and to develop a common integrated approach to all aspects of land cover. Such harmonized nomenclature will improve the comparability of GHG emission estimations at regional or international level⁴⁸. "Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers"⁴⁹. In the case of the Cambodian study, the following set of classifiers (table 6) have been used for the forest:

Code	Classifiers	Type of classifiers
A3	Trees (Main layer)	Life Form
A10	Closed > 70-60 %	Cover
A11	Open General <70-60% and >20-10%	Cover
A12	Closed > 70-60 %	Cover
A20	Closed to Open 100-15%	Cover
B2	> 30 - 3 m (Tree Height Main Layer)	Height
C1	On Permanently Flooded Land	Water seasonality
D1	Broadleaved	Leaf Type
D2	Needleleaved	Leaf Type
E1	Evergreen	Leaf Phenology
E2	Deciduous	Leaf Phenology

Table 6: Set of classifiers used for the Cambodian LCCS.

The classification system is said hierarchical starting with 8 mutually exclusive broad classes

⁴⁸ Di Gregorio, A., Jansen, L.J.M. (2005)

⁴⁹ Op. cit.

such as Cultivated and Managed Terrestrial Areas or Natural and Semi-Natural Terrestrial Vegetation to be subdivided into more detailed sub-classes at the lower levels (fig. 25).

<i>Pure Land Cover Classifiers</i>	Life Form and Cover		Height	
	Leaf Type		Leaf Phenology	
	Stratification			
<i>Environmental Attributes</i>	Land Form		Lithology/Soils	
	Climate	Altitude		Erosion
<i>Specific Technical Attributes</i>	Floristic Aspect			

Decreasing
Mapability
↓

Figure 25: High level of vegetation classification and mapability (Source: Di Gregorio, A., Jansen, L.J.M., 2005).

About life forms distinction, in the LCCS, woody plants higher than 5 m. are classified as "Trees" with the following exception that plants essentially herbaceous but with a woody appearance (such as bamboo) are classified as Trees if the height is more than 5m, and as shrubs is the height is less than 5m (fig. 26).

LEVEL I	A. LIFE FORM OF MAIN LAYER						D. LEAF TYPE			LEVEL II			
	WOODY			HERBACEOUS			BROADLEAVED		NEEDLELEAVED		APHYLLOUS		
	TREES	SHRUBS	FORBS	GRAMINOIDS	LICHENS	MOSESSES	D. LEAF PHENOLOGY						
	A. COVER OF MAIN LAYER						EVERGREEN						
							DECIDUOUS				MIXED (FOR FORBS & GRAMINOIDS)		
							MIXED (BROADLEAVED DECIDUOUS WITH NEEDLELEAVED EVERGREEN)						
	CLOSED > (70-60) %			OPEN (70-60) - (20-10) %			SEMI-DECIDUOUS OR SEMI-EVERGREEN (BROADLEAVED EVERGREEN & DECIDUOUS)				PERENNIALS		
	(70-60) - 40 %			40 - (20-10) %			F. STRATIFICATION				ANNUALS		
	SPARSE (20-10) 1 %										SECOND LAYER AND/OR THIRD LAYER:		PRESENT
	SPARSE (20-10) - 4 %			SCATTERED 4-1 %			WOODY		HERBACEOUS				
B. HEIGHT						F. COVER							
7 - 2 m (only for WOODY)			3 - 0.03 m							CLOSED TO OPEN			
> 30 - 3 m			5 - 0.3 m							CLOSED (> 70 - 60) %			
> 14 m			5 - 0.5 m							OPEN (70 - 60) - (20 - 10) %			
14 - 7 m			5 - 3 m							SPARSE (20-10) - 5 %			
C. SPATIAL DISTRIBUTION - MACROPATTERN						G. HEIGHT							
CONTINUOUS		FRAGMENTED		PARKLIKE PATCHES		> 30 - 0.3 m (only for WOODY)			3 - 0.03 m				
		STRIPE		CELLULAR		> 30 - 3 m		5 - 0.3 m					
						> 14 m		5 - 3 m					
						14 - 7 m		3 - 0.5 m					
						7 - 3 m		< 0.5 m					
								0.3 - 0.03 m					

Figure 26: Three level of classification for the Natural and Semi-Natural Vegetation (code A12 of the LCCS). For the LCCS prepared for Cambodia, only criteria from level 1 and level 2 have been considered. (Source: Di Gregorio, A., Jansen, L.J.M., 2005).

For the (canopy) cover criteria, distinction is made between Closed (>60 - 70) percent), Open (between (60 - 70) and (10 - 20) percent) and Sparse (below (10 - 20) percent but >1 percent).

In 2010, the Land Cover Classification System produced by FAO has been used to generate a land cover map of Cambodia (reference year 2005), at the scale of 1:100,000. A Land cover change map has also been produced after aggregation of the initial 35 LCCS classes⁵⁰.

Existing classifications and legends have been converted into the reference system, thus facilitating the use of existing historical materials. Existing data of the Cambodia Land Cover Atlas 1985/1987-1992/93 have been translated into LCCS standardized classes. Thirty five classes have been identified to characterize the land cover types of Cambodia after interpretation of 2004/2005 Landsat ETM images (table 7 & fig. 27).

	Class Name	LCCS Class Name
2TCne	Needleleaved Evergreen Trees	Closed (65-100%) Needleleaved Evergreen Forest
2TCbe	Broadleaved Evergreen Trees	Closed (65-100%) Broadleaved Evergreen Trees
2TObe	Broadleaved Evergreen Woodland	Open (15-65%) Broadleaved Evergreen Trees
2TCOd	Broadleaved Deciduous Closed to Open Trees, With Shrubs	Closed to Open (15-100%) Deciduous Trees with Closed to Open (15-100%) Shrubs
2TCm	Mixed Trees	Closed (65 - 100%) Trees. Deciduous > 50%
2TOm	Mixed Woodland	Open (15-65%) Trees. Deciduous > 50% Woodland
4TOFF	Woodland On Permanently Flooded Land	Open (15-100%) Trees Permanently (> 4 months) Flooded
4TCFF	Trees On Permanently Flooded Land	Closed (65-100%) Trees Permanently (> 4 months) Flooded
4MC	Broadleaved Evergreen Trees On Permanently Flooded Land (With Daily Variations)	Closed (65 - 100%) Broadleaved Evergreen Trees permanently (> 4 months) flooded. Mangrove forest
1TP	Tree Plantation	Rainfed Tree Crop(s)

Table 7: Among the 35 classes of the classification system, 10 classes are describing the forest cover.

The 10 LCCS classes identified representing forested land are also described as follow:

- **Evergreen Forest**
2TCbe, 2TObe: respectively closed (65-100% of coverage) and open (15-65%) broadleaves evergreen forest.
2TCne: needle leaved evergreen forest. The coverage exceeds 70%. This class refers to pine forests in the Kirirom region.
- **Deciduous Forest**
2TCm, 2Tom: respectively closed (65-100% of coverage) and open (15-65%) mixed forest. Deciduous species represent more than 50%.
2TCOd: closed to open (15-100% of coverage) deciduous forest. Deciduous species exceed 80%.
- **Plantation**
1TP: monoculture tree plantation. This class includes mainly rubber plantations, some palm plantations in the south of the nation and tree plantations for afforestation.

⁵⁰ GLCN-FAO (2010)

- Flooded forests:**
 4MC: closed (>65%) mangrove forests.
 4TCFF, 4TOFF: respectively closed (> 65%) and open (15-65%) broadleaved trees on permanently (> 4 months) flooded areas.

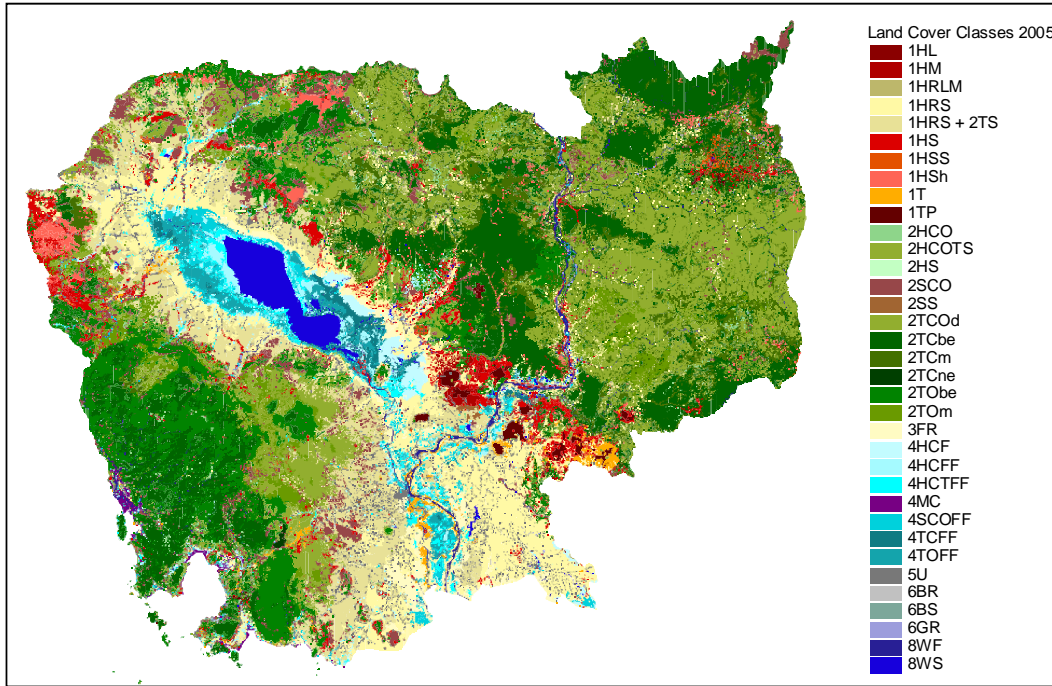


Figure 27: 2005 Land Cover map for Cambodia showing single LCCS classes. The final shapefile derived from the 2000/2002 Landsat images has been updated by overlaying the shapefile of changes (see below) for the year 2004/2006 (FAO, 2010).

In order to represent the land cover changes between 1995 and 2005, the 35 initial LCCS classes have been aggregated in 12 final classes as follow (table 8 & fig. 28):

Legend	LCCS Class Code
Evergreen forest	2TCbe, 2TObe, 2TCne
Deciduous forest	2TCm, 2TCOd, 2TOm
Plantation	1TP
Mangrove	4MC
Natural flooded areas	4HCF, 4HCFF, 4HCTFF, 4SCOFF, 4TCFF, 4TOFF
Waterbodies	8WF, 8WS
Shrubs	2SCO, 2SS
Rice	1HRLM, 1HRS, 1HRS+2TS, 3FR
Herbaceous closed to open	2HCO, 2HCOTS, 2HS
Urban	5U
Agriculture	1HL, 1HM, 1HS, 1HSh, 1HSS, 1T
Bare	6BR, 6BS, 6GR

Table 8: Aggregated classification retained for the change in land cover analysis.

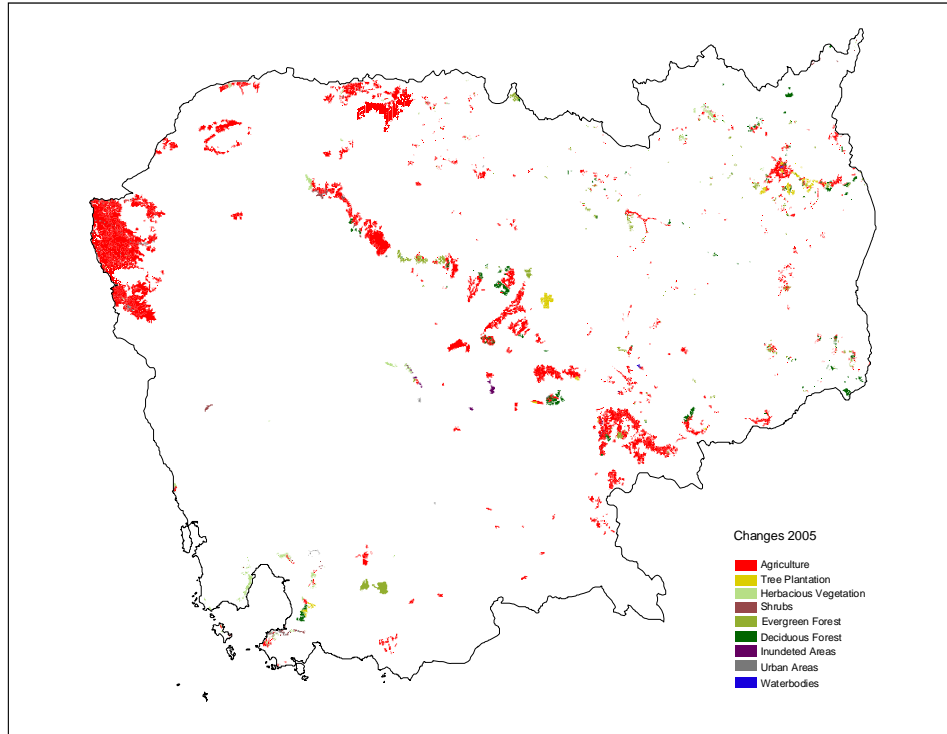


Figure 28: Land cover changes from 1975 to 2005 after LCCS classes aggregation.

4.3. Forest classification and definition used for sub-national activities

Two example of classification schemes adopted by the French botanists for forest inventories purpose.

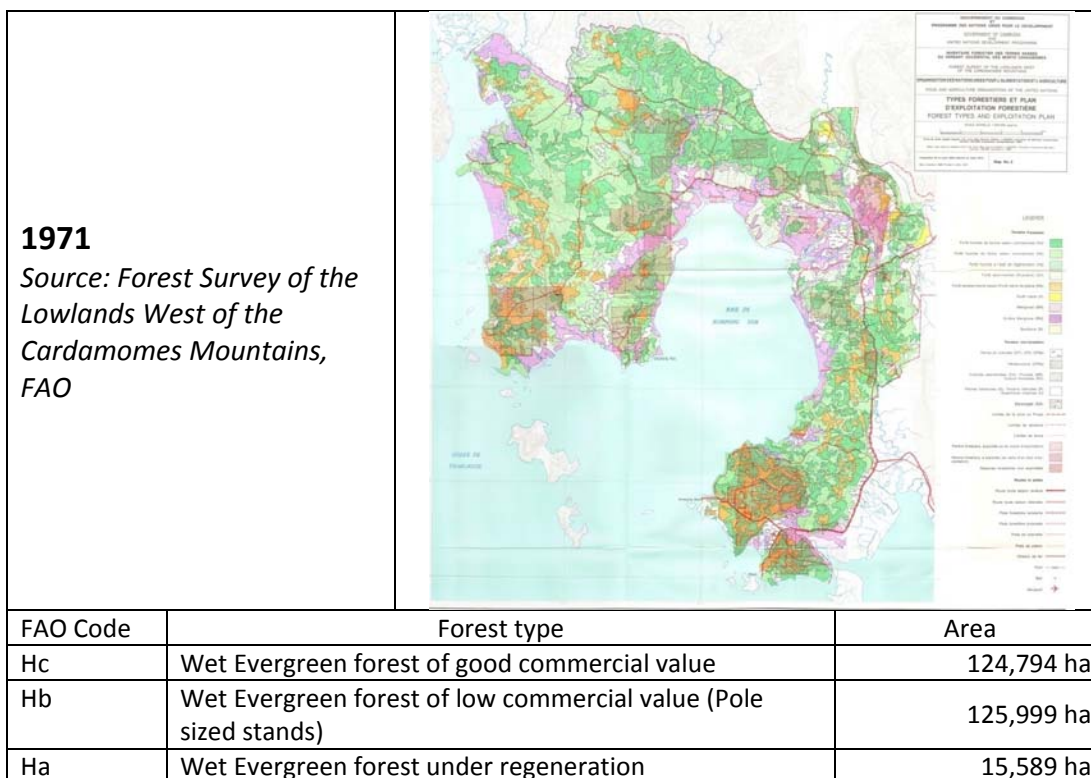
<p>1962 Source: Forestry Inventory in East Mekong, FAO</p>		
<p>French Classification Forêts denses (toujours vertes)</p>	<p>English translation Dense forests (Wet evergreen forest), Syn.</p>	<p>Area (km2) 6,225</p>

	Lowland tropical rain forest	
Forêts secondaires (forêts sèches à dipterocarpacees de deuxième génération)	Secondary forests (dipterocarpus obtusifolius, dipterocarpus intricatus)	7,706
Forêts semi-denses à Lagerstroemia sp. (& Xylia sp.)	Semi-dense forest of Lagerstroemia (mixed deciduous forest , semievergreen forest)	3,607
Forêts intermédiaires	Mixed (intermediary) forest (<i>Terminalia tomentosa</i> , <i>Xylia dolabriformis</i>) between mixed deciduous and dry dypterocarp forest.	1,826
Forêts claires	Open forests (Shorea obtusa, Dipterocarpus tuberculatus, Terminalia tomentosa) Dry dipterocarps forest	19,386

Figure 29: Forest classification used for the Forestry Inventory in East Mekong (FAO, 1962).

The map from Rollet (fig. 29) is based on visual interpretation of 1:40,000 panchromatic aerial photo coverage dated 1953 provided by the French National Geographic Institute and additional aerial photography dated 1959 provided by USAID⁵¹.

The forest types have been classified in 5 broad classes, no clear definition of these forest classes is proposed and sometime the english translation of the french terms is not obvious. On the 5 classes, 3 forest types describe degraded stage of forest: the "Secondary forest", the "Mixed forest" and the "Open forest" classes reflect the human influence (woodfuel extraction, shifting cultivation).



⁵¹ Rollet, B. (1962)

SH	Moist Deciduous forest (Riparian)	2,505 ha
Mb	Dwarf Evergreen forest (Heath forest)	47,250 ha
D	Dry Deciduous forest	3,301 ha
SM	Shore Mangrove	13,421 ha
RM	Rear Mangrove	39,066 ha
B	Bamboo	5,407 ha
Non Forest	Including Rubber plantation (CP3a)	59,777 ha
Water	Rivers, Open water, Swamps	4,711 ha

Figure 30: Forest survey of the lowlands west of the Cardamomes mountains (FAO, 1971).

Forest types of this coastal hinterland have been surveyed on 487,000 ha in 1968⁵² (fig. 30). Aerial photography have been used for the mapping. The classification system adopted is based on the structure and physiognomy of the forest types rather than on floristic composition⁵³.

A total of 10 forest types (including rubber plantation) have been considered. The classification system retained for this inventory is based on structural and physiognomic aspects of the vegetation. The project area was mainly covered by stocked dense wet lowland evergreen forests (Hc), pole stands of dense wet lowland evergreen forest (Hb), Heath forest (Mb) and *Melaleuca* woodlands (RM).

Finally, an interesting comparison with other existing forest classification systems (table 9) has been developed in order to link similar forest types defined differently⁵⁴.

Code	Forest Inventory 1962	Champion modified by Puri (1)	FAO	Other classifications
D	Dry Deciduous forest	Tropical dry deciduous forest	Dry deciduous forest	-
P	Pine forest	Subtropical pine forest	Coniferous forest	-
H	Wet evergreen forest	Tropical evergreen forest with Dipterocarps	Moist evergreen forest	Evergreen dipterocarp forest (2), Montane oak forest (3)
SH	Moist Deciduous forest	Tropical moist deciduous forest	Moist deciduous forest	-
M	Dwarf evergreen forest	Moist tropical hill forest	-	Heath forest (4) Montane oak forest
B	Bamboo	Moist bamboo brakes	-	-
SM	Shore mangrove	Beach forest, Tree mangrove forest	-	-
RM	Rear Mangrove	Freshwater swamp forest and riverain forest		

(1) from Puri, G.S. 1960. *Indian Forest Ecology*, Calcutta. (2) Ashton, P.A. 1967. *J. Ecol.* 55. 67 p. (3) Symington, C.F. 1943. *Malayan For. Rec.* 16. (4) Richards, P.W. *The tropical Rain Forest*.

Table 9: Comparison of forest types classifications (from Ashton 1970, modified)

A more detailed classification has been elaborated for the wet evergreen forest (class H) taking in consideration the productivity of the stands (sub-classes Ha, Hb, Hc).

⁵² Marcotte, M. (1971)

⁵³ Ashton, P.A. (1970)

⁵⁴ Op. cit

Forest cover assessments realized at the project scale can provide more detailed information related to the forest types encountered in the country (fig. 31).

After a review of the existing available data among the Government agencies and the NGO's, it appears that most of the sub-national activities are using the Forestry Administration maps and classification system or broad classification system of forest types. The "mapability" of the forest types is the main reason for retaining these broad forest classes. Other subnational forest cover assessment, for the purpose of REDD+, have been focusing on deforestation estimates and on a simple forest/non forest classification, however they provide valuable information in term of floristic composition and dynamic of the forest types.

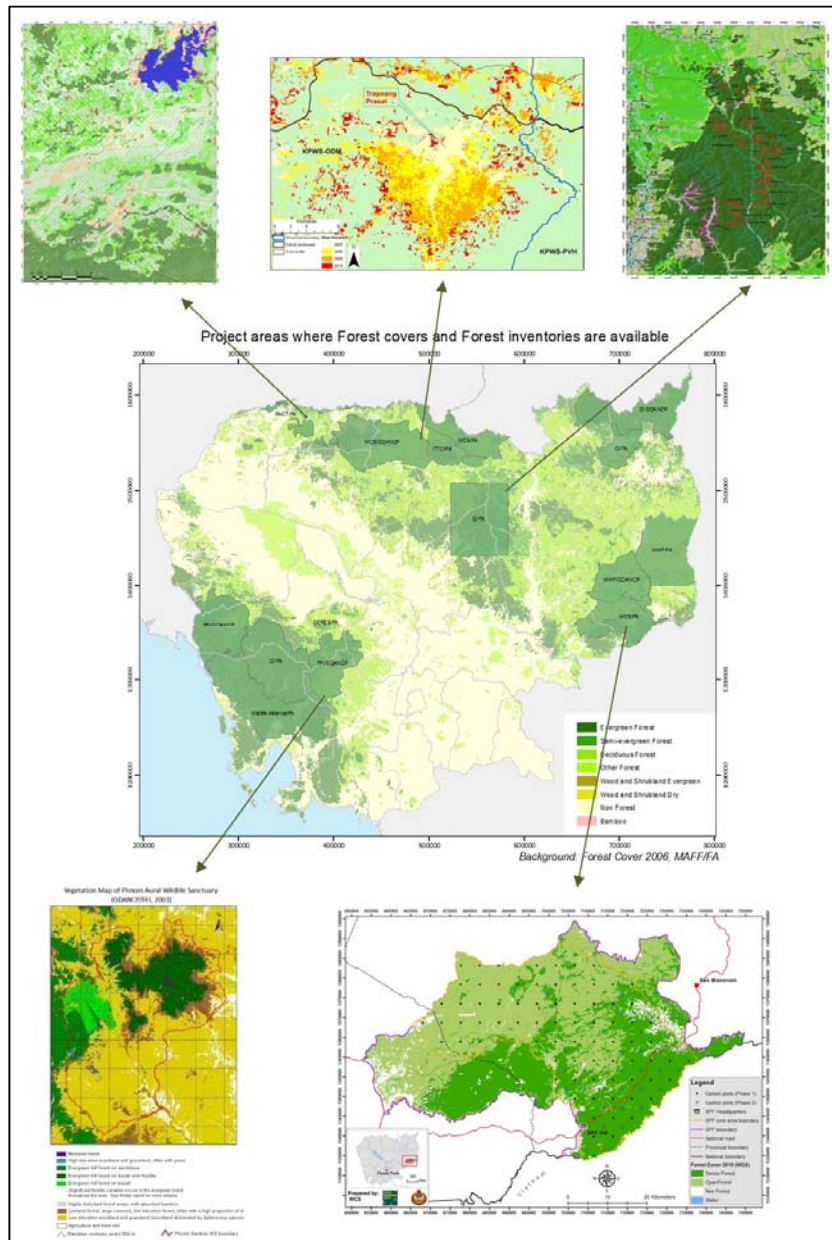


Figure 31: Project areas where forest covers and forest inventories data are available: This illustration shows various forest cover assessment done at the project scale, referring to different forest classification systems.

Forest types of the northern drylands, the Oddar Meanchey REDD+ project (PACT)

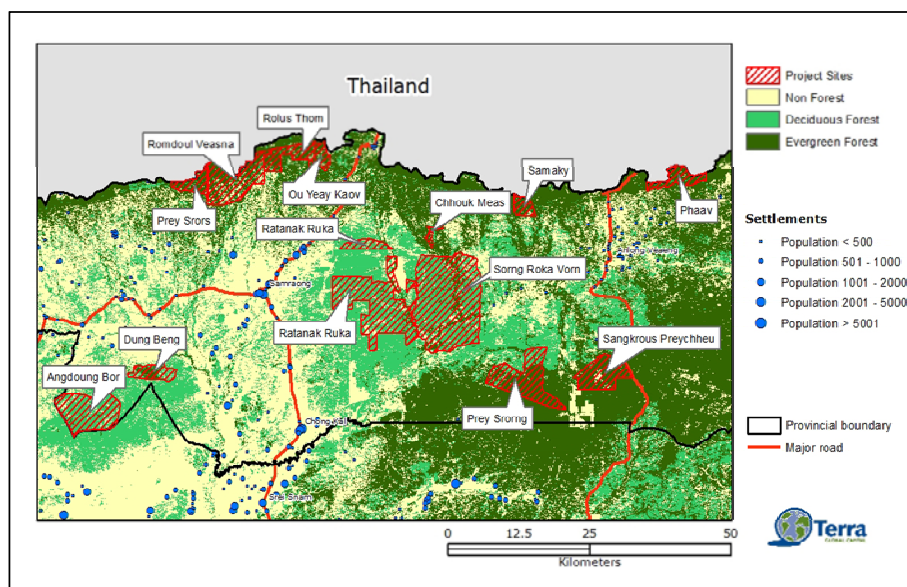


Figure 32: Forest cover map of the Oddar Meanchey REDD+ project area (PACT-TGC, 2009).

"The forest definition applied for the demonstration of eligibility was at least 10% canopy cover, a tree height of 2 m, and a minimal area of 1 ha, while the UNFCCC forest definition of Cambodia is at least 10% canopy cover, a tree height of 5m, and a minimal area of 0.5 ha."⁵⁵

Two forest types have been discriminated: Evergreen and Mixed/Deciduous forests (fig. 32). Deciduous forests contain almost exclusively deciduous tree species (>90%). Mixed forests contain both deciduous and evergreen tree species, where deciduous species represent more than 50 % of the stand. Evergreen forests are dominated by evergreen tree species. Due to the difficulties to distinguish between mixed and deciduous forest types in the forests of the Oddar Meanchey Province, for estimating carbon stocks, any dry-land forest system of which more than 50% of the trees are deciduous are part of a combined "mixed and deciduous" forest class. According to the Verified Carbon Standard project document: "further subdivision of the evergreen (EVG) and deciduous and mixed (DCD) forest classes was not possible"⁵⁶.

- Evergreen forest contains more than 70% of evergreen tree species.
- Mixed and Deciduous forest correspond to a mixed forest with more than 30% of deciduous tree species. This open forest present a single tree stratum and the species composition is usually poor. Dipterocarps are dominant in association with Lagerstroemia spp. and Xylia dolabriformis. This forest type is particularly subject to fires during the dry season which explain the presence of a very sparse understory dominated by grasses.

The final classification (table 10) in sub-types according to the density of the forest cover has

⁵⁵ PACT (2012)

⁵⁶ Op. cit.

been adopted:

CODE	Forest Classification	Criteria & thresholds
EG1	Evergreen Low stocked/Medium to low density Evergreen forest	Canopy Closure: 10-70% Tree Height: 5-20 m Tree Diameter: 10-75 cm
EG2	Evergreen well stocked/Mature evergreen forest	Canopy Closure: 70-100% Tree Height: > 20 m Tree Diameter: 10-175 cm
MX1	Mixed and deciduous low stocked/low density mixed deciduous forest	Canopy Closure: 10-30% Tree Height: 2-5 m Tree Diameter: 10-25 cm
MX2	Mixed and deciduous medium stocked/Medium density mixed deciduous forest	Canopy Closure: 30-50% Tree Height: 5-10 m Tree Diameter: 10-50 cm
MX3	Mixed and deciduous well stocked/Mature mixed deciduous forest	Canopy Closure: 50-70% Tree Height: 10-20 m Tree Diameter: 10-75 cm

Source: PDD Oddar Meanchey

Table 10: Forest classification retained for the Oddar Meanchey project

Forest types described in the eastern plains, SEIMA, WCS project.

The Seima Biodiversity Conservation Area (SBCA) "contains an unusually high diversity of forest types"⁵⁷, evergreen forest, deciduous forest and the transition between these forest types are represented. The Forest types form a very complex mosaic and cover four of the broad categories defined by the Forestry Administration.

The distinction between these two types is often delicate considering their degree of disturbance⁵⁸. The upper canopy (40-55 m. high) of the **evergreen forest**, found on the hilly parts of the SBCA, is often affected, reduced, opened or removed (Secondary/low stature evergreen forest).

Present on a more extensive area, the **semi evergreen** type (which include mixed deciduous forest) is more heterogeneous in term of structure and composition. Evergreen and deciduous tree stands dominate a pure evergreen understorey of lianas, rattan and palms which tracts with a more open understorey with an high density of saplings. This forest type is well distributed in the whole area, it is also found inside the deciduous dipterocarp forest along the rivers to form the gallery forest.

The semi evergreen type grade into forest areas dominated by deciduous trees, *Lagerstroemia calyculata* (the Indochinese mixed deciduous forest). This **mixed deciduous forest** type, qualified as a "*depauperate version of the semi-evergreen forest*" in term of floristic composition, certainly result of evergreen tree (*Dipterocarpus alatus*) selective logging of the previous type. Below the *Lagerstroemia calyculata* canopy, the understorey is often sparse and frequently burnt. With the diminution of fire occurrence, bamboo and rattan stands can dominate the vegetation below the Lagerstroemia sp.

⁵⁷ WCS (2009)

⁵⁸ WCS (2011)

The **Dry deciduous dipterocarp forest**, this type vary in term of tree density which dominate an understorey of bamboo grading to more open tree savannah like or even a grassland with scattered trees. A relatively rich deciduous dipterocarp forest type in term of tree composition (2-3 species) present a crown cover of 20-40% at 20-35 m. high, which dominate a middle storey (only along the drainage lines) and a ground storey of sparse vegetation occur in close proximity of a least diverse type, which appear in patches and seems to result of frequent burning (fire-climax).

A classification system for the establishment of a NFI in the Sandan district, Kampong Thom province

Aerial photography interpretation and forest mapping in the district of Sandan, Kampong Thom province, has been realized in 1996 for the purpose of the "**establishment of a Forest Ressources Inventory process in Cambodia**"⁵⁹. A total of 612 aerial photographs have been interpreted. The classification system adopted for the mapping in Sandan is presented in the table 11:

Class Name	Definition
Evergreen Forest	<i>The canopy remains green throughout the year though a few individual trees may be leafless for a few weeks.</i>
Mixed/Semi deciduous Forest	<i>Most of the upper canopy is constituted of deciduous trees, many of the understorey trees and shrubs are evergreen and more or less sclerophyllous. However evergreen and deciduous woody plants are not always separated by layer. They may occur mixed within the same layers or shrubs may be primarily deciduous and trees evergreen.</i>
Deciduous Forest	<i>Majority of trees and shrubs shed their foliage simultaneously during unfavorable season which may be dry or cold. The trees and shrubs loose all their leaves and become temporarily bare-stemmed</i>
Pine Forest	<i>Forest consisting mainly of trees belonging to the genus Pinus.</i>
Riparian Forest	<i>Occurs along the banks of large streams and forms generally a fringe along the stream mainly dominated by fast growing trees.</i>
Bamboo Forest	<i>Usually consists of individual clumps or culms of bamboo. Taxonomically speaking, bamboo are grasses but because they are woody stemmed and because of their peculiar growth forms they have been considered s constituent of forest.</i>
Forest Plantation	<i>Forest raised by artificial means by planting seedlings, stumps or by direct sowing. All stages, from seedlings to poles included.</i>
Flooded Forest	<i>Forest in which rain water accumulates during raining season</i>
Mangroves	<i>Composed almost entirely of evergreen sclerophyllous broad-leaved trees and or shrubs with either stilt roots or pneumatophores.</i>
Nypa Stand	<i>Aggregation of Nypa fruticans generally on the brackish water sediment.</i>
Scrub Forest	<i>Mainly composed of woody plants, 0.5 to 5 m tall.</i>
Shifting Cultivation	<i>Cultivation by nomadic people for a few years until the soil becomes exhausted, the group than moves and clears a fresh piece of forest land, usually by burning the vegetation and digging in the ashes, leaving the old area to become overgrown.</i>
Abandoned shifting cultivation	<i>Coppice growth, grasses and at places bamboo's may be commonly seen and can be easily distinguished from natural and man made forests</i>

⁵⁹ FAO (1998)

Savannah	Tall grass land with tree synusia covering 10 - 40% with or without shrubs but with a more or less continuous ground cover (over 50%)
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Table 11: Forest definitions in the district of Sandan (FAO, 1998)

Three forest canopy height classes (5-20 m, 21-30 m, >30 m) and four crown density classes (10-20%, 21-40%, 41-70%, >70%). Rubber plantation (*piece of land covered and maintained under rubber crop includes crops of all age classes/groups, from very young to mature*) have been included in the Non forested land. Following the forest cover mapping, the forested area has been stratified in three strata (Evergreen, Mixed/Semi-deciduous, Deciduous) for the forest inventory in the field.

Forest classification system suggested for the northern Cardamoms mountains, FFI

An interesting classification system of the vegetation of the two wildlife sanctuaries of the northern Cardamom mountains has been developed by Fauna Flora International⁶⁰. The classification scheme illustrates the difference between "mapable" units of vegetation and forest types observed in the field (fig. 33). Subtypes of broad classes such as Evergreen forest or Deciduous forest have been obtained using additional classifiers (mainly geological and elevation criteria).

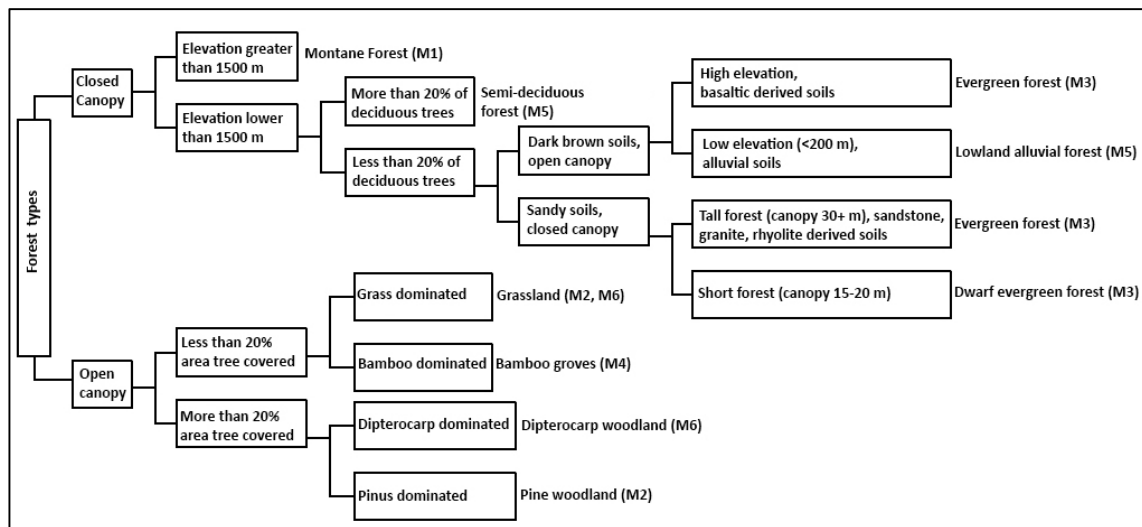


Figure 33: Vegetation classification system proposed for the Phnom Samkos and Phnom Aural Wildlife sanctuaries (FFI, 2004, modified)

MMU	Vegetation Class	Final Classification
M1	-Montane forest	<ul style="list-style-type: none"> Montane forest (> 1500-1600 m.) High elevation (>500 m.) woodland and grassland, often with Pinus sp.
M2	-High elevation woodland and grassland, often with Pinus sp.	
M3	-Evergreen Hill Forest (on Sandstone, Rhyolite, Granite) -Basalt Evergreen Hill Forest -Dwarf Evergreen Hill Forest (on Sandstone)	<ul style="list-style-type: none"> Evergreen Hill Forest on sandstone Evergreen Hill Forest on dacite and rhyolite Evergreen Hill Forest on basalt
M4	-Bamboo groves	<ul style="list-style-type: none"> Highly disturbed forest areas, with

⁶⁰ Webb, C.O. (2004)

		abundant Bamboo
M5	-Lowland alluvial evergreen forest	<ul style="list-style-type: none"> • Lowland forest (on Alluvial soils)
	-Deciduous forest and gallery forest	
M6	-Dipterocarp Woodland	<ul style="list-style-type: none"> • Low elevation (<500 m.) woodland and grassland (dominated by Dipterocarpaceae)
	-Grassland	
		<ul style="list-style-type: none"> • Agriculture and Bare soil

Table 12: Final classification retained for the mapping of the two wildlife sanctuaries (FFI, 2004)

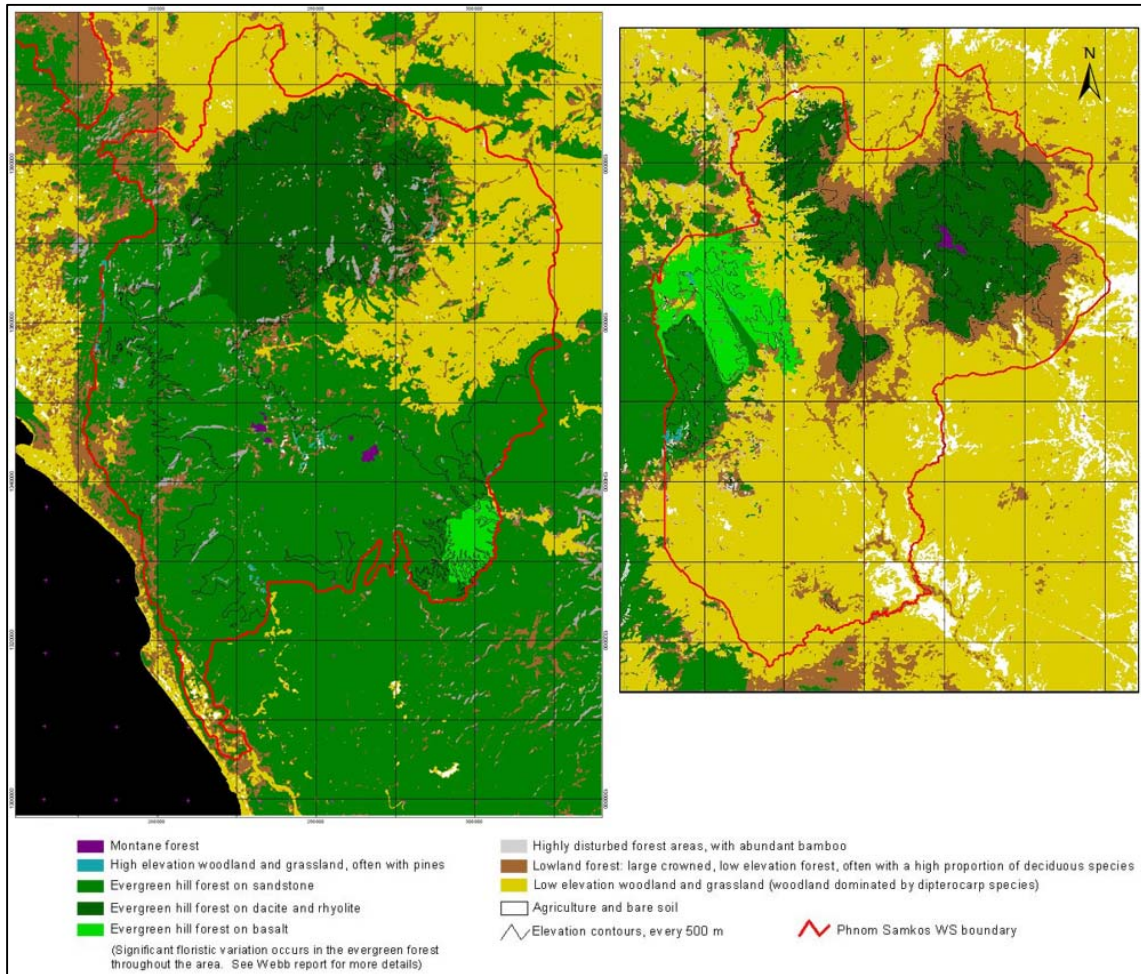


Figure 34: The two vegetation maps produced in Phnom Samkos (left) and Phnom Aural (right) Wildlife Sanctuaries for the purpose of establish a zoning of these two national parks (FFI/GDANCP, 2003).

The table 12 shows the comparison between a vegetation classification system based on ecological criteria (elevation, soil, phenology) and what have been possible to discriminate using Remote sensing data (Landsat 7 ETM+ Image supervised classification). GIS layers (Geological maps and Digital Elevation model) have been used to refine broad classes obtain after image classification such as Evergreen Forest and Grassland/Dipterocarp woodland (fig. 34).

5. Technical issues related to different forest definitions

5.1. Consistency over space and time and comparability of the estimates

"Since classification based on the interpretation of satellite and radar imagery has been made possible, a new generation of vegetation classifications and maps has emerged. Classification systems as well as forest definitions differ widely not only from one country to another but also within the same country."

The review presented in this report clearly suggests that due to their high level of inconsistency, the various national forest cover assessments can't respond to the needs of implementation of a national satellite forest monitoring system without harmonization or re-interpretation (table 13).

An interesting comparison⁶¹ between the BPAMP/MoE classification and the actual FA classification systems (fig. 35) highlight a very low level of comparability.

Source: FA (2003), Blasco F., Bellan M.F. & Lacaze D. (1996) from USAID (2011)

BPAMP 2007		FA 2002, 2006 & 2010				
GENERAL ECOLOGY	VEGETATION FORMATION	EF	SEF	DF	OF	NF
VERY HUMID	Low Elevation					
	Medium Elevation					
HUMID	Low Elevation	Dense semi-deciduous Forest				
		Dense forest/secondary vegetation mosaic (dense forest predominant)				
		Dense forest/secondary vegetation mosaic (secondary vegetation predominant)				
	Medium Elevation	Dense semi-deciduous Forest				
SUB-HUMID FORMATIONS	Mixed Deciduous Forest					
	Woodland with <i>Dipterocarpaceae</i>					
	Degraded Woodland with crops					
	Dense Thicket					
EDAPHIC FORMATIONS	Swampy degraded plant communities (flooded forests)					
	Herbaceous hydromorphic types					
OTHER FORMATIONS	Mosaic of crops and degraded vegetation					
	Paddy fields					
	Paddy fields with <i>Borassus flabellifer</i>					

Figure 35: A difficult comparison between the BPAMP (MoE) and the FA classification systems. (EF: Evergreen forest, SEF: Semi-evergreen forest, DF: Deciduous forest, OF: Other forest, NF: Non-forest)

⁶¹ USAID (2011)

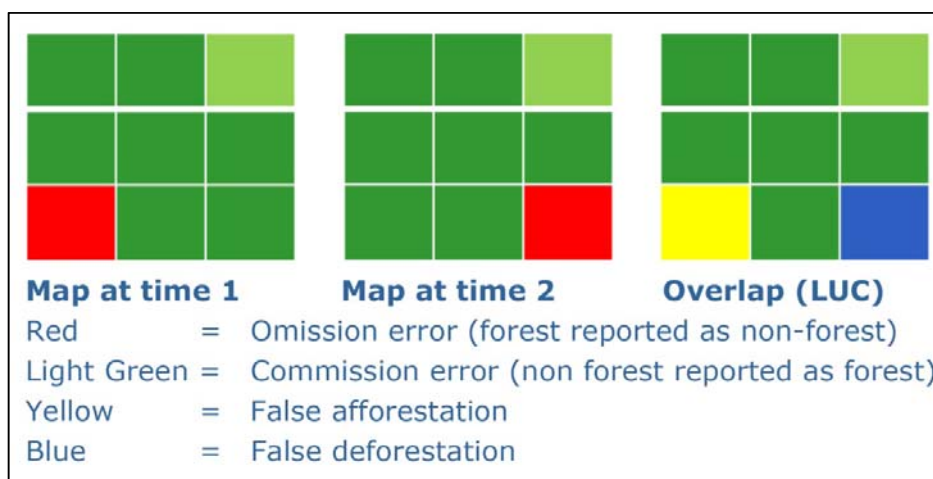
Year	Institution	# Classes	Forest definition	Interpretation	MMU	Scale	Source imagery	Imagery provider	Additional imagery	Ground truthing
1965	U.S. Army Map Service	15 classes (9 F)		Visual on hardcopies		1/50,000	Aerial photographs			No
1973/1976*	FAO/UNDP/MRC Land Cover Atlas LUMO	27 classes (9 F)	Crown cover >10%	Landsat Interpreted and digitized data	0.25 km ²	1/250,000	Landsat TM	RSMU/LUMO		
1985/1987*	FAO/UNDP/MRC Land Cover Atlas LUMO	27 classes (9 F)	Crown cover >10%	Landsat Interpreted and digitized data	0.25 km ²	1/250,000	Landsat TM	RSMU/LUMO		
1988/1989	Reconnaissance landuse map/Mekong Secretariat	20 classes (9 F)	Crown cover >10%	Visual on hardcopies	1 km ²	1/500,000	Landsat TM	RSMU	Aerial photographs	No
1992/1993*	FAO/UNDP/MRC Land Cover Atlas LUMO	27 classes (9 F)	Crown cover >10%	Landsat Interpreted and digitized data	0.25 km ²	1/250,000	Landsat TM	RSMU/LUMO		
1992/1993**	Mekong River Commission/GTZ FCMP	29 classes (15 F)	Crown cover >20%	Visual on hardcopies	0.5 km ²	1/250,000	Landsat TM	FCMP/DFW	SPOT and Aerial photographs	Field Verification
1993/1995	JAFTA Wide Area Tropical Forest Resources Survey	17 classes (8 F)	Crown cover >10%	Digital processing		1/250,000	Landsat TM	JAFTA	Aerial photographs	
1996/1997**	Mekong River Commission/GTZ FCMP	29 classes (15 F)	Crown cover >20%	Visual on hardcopies	0.5 km ²	1/250,000	Landsat TM	FCMP/DFW	SPOT and Aerial photographs	Field Verification
2002	Department of Forestry and Wildlife, MAFF/FRM	8 classes (5 F)	Crown cover >20%	Visual on screen	0.5 km ²	1/50,000	Landsat ETM+	FCMP/DFW	Landsat TM	88 samples
2005/2006	Forestry Administration	8 classes (5 F)	Crown cover >20%	Visual on screen	0.2 km ²	1/50,000	Landsat ETM+ gap-filled	FA's GIS/RS Unit	Landsat TM, Quickbird	100 samples
2009/2010	Forestry Administration	10 classes (7 F)	Crown cover >10%	Visual on screen	0.2 km ²	1/50,000	Landsat TM	FA's GIS/RS Unit		104 points

Existing national forest cover products available for Cambodia

One forest type described in the FA classification correspond in reality to a large scope of forest considering elevation and climatic variations. The same remark can be done for the semi-evergreen forest class of the FA system which is corresponding to numerous deciduous forest types in the BPAMP classification.

When integrating different sources of data coming from different actors a fundamental guiding principle has to be the consistency to avoid that any detected change result from differences in data quality and in methodologies instead of real differences in land cover changes along a reference period. IPCC methodological guidance provide means to ensure consistency when different data sources need to be integrated, it is recommended that consistency in definitions and geographical boundaries be achieved through harmonization of methods applied for collecting information⁶².

In the illustration presented below (fig. 36), the absence of comparability (due to different forest definitions and the classification systems adopted) will result in accounting false deforestation or afforestation.



Source: Federici, S., Grassi, G. (2012)

Figure 36: When overlapping different maps on a specific time period, false changes can be counted

5.2. Problem related to the accuracy and completeness of the estimates

The Forest Cover Assessment done by the Department of Forestry and Wildlife was done up to district level⁶³. However, in developing the National Greenhouse Gas Inventory, the data used were national level data. In addition, forest types considered in the analysis only included the major category and there was also no separation between undisturbed (*climax forest*) and disturbed forests. All forests are assumed to sequester the same amount of carbon.

In fact, forests that reach *climax stage* may not sequester carbon any longer as rate of photosynthesis may be the same as the rate of respiration. Therefore, separation between undisturbed and disturbed forest in the analysis is very important for reducing the uncertainty.

⁶² Federici, S. (2012)

⁶³ MOE (2003)

Accurate estimates of carbon stored in secondary, logged or other non-primary forests are needed to estimate emissions from degradation and deforestation as the amount of carbon stored and subsequently emitted to the atmosphere varies greatly depending on forest condition⁶⁴.

Different forest types represent different carbon stocks. Even within one forest type, the stock will vary according to the location (elevation, rainfall and soil type will mainly affect the carbon stock of a specific type of forest). Problems linked to the discrimination between different forest types using remote sensing will not allow the differentiation between carbon stocks. However, the stratification of forest into *"relatively homogeneous forest cover units with respect to their carbon stocks can result in a more cost effective field sampling design and more precise and accurate estimates of carbon stocks across a landscape"*⁶⁵.

Considering the UNEP/WCMC map showing the spatial distribution of carbon stocks in Cambodia's terrestrial ecosystems (presented in part 1.2) several remarks have been observed regarding the accuracy of the estimates. The fact is that the map is based on the broad forest classification system which cannot capture the variations of carbon stock within a given forest type: *"there is some concern that the mapping of the medium and high carbon areas are not adequately mapped [...] pre-war biomass estimates suggest that sub-montane forests in the areas of the south-West Cambodia above 600 meters asl are quite low (67 t/ha) while those of the dry evergreen forests in the north-central Cambodia, such as in Prey Lang, are generally over 200 t/ha"*⁶⁶.

Only broad forest types have been considered for estimating the associated carbon stock. Mangrove forests should be part of the classification system even if they are relatively limited in term of distribution over the country compared with other forest types. Mangroves forests are among the most carbon-rich forests in the tropics, 10% of global emissions from deforestation are due to mangrove deforestation, while this type of forest is representing only 0.7% of the tropical forest area⁶⁷, *"moreover, the anoxic conditions of the muddy intertidal substrates allows for some of this carbon to be sequestered as part of long-term carbon pool [...] this has raised interest in the conservation of mangrove swamps as a means to mitigate the impact of climate change"*⁶⁸. Some others particular forest types actually not represented in the classification system can participate to increase the reliability of the estimations, this is the case of the Southeast Asian's peat-swamp forests where soils after deforestation are releasing non negligible amounts of carbon⁶⁹. Flooded forests associated with the Tonle Sap inundation zone should also be considered, many species have similarities to Mangrove forests.

Finally, with the adoption of a new forest definition for the 2010 forest cover assessment (decrease of the crown cover threshold), the deforestation rate might be under-estimated (especially in the case of the open forest land such as deciduous forest) as areas considered

⁶⁴ Gibbs, H.K. et al (2007)

⁶⁵ GOF-C-GOLD (2012)

⁶⁶ USAID (2011)

⁶⁷ Donato, D.C. et al (2011)

⁶⁸ Killeen. T.J. (2012)

⁶⁹ MRC (2003)

as non-forest in 2002 have been interpreted as forest in 2010.

Another issue is related to the accuracy assessment. While for the 2006 forest cover accuracy assessment additional high-resolution QuickBird images have been used for the verifications, in 2010, it seems like verifications have been based on re-interpretation of the same landsat data used for the mapping when the ground control points were not accessible: *"time and budget limitations prevented the completion of a full scale accuracy assessment based on samples all being verified in the field. Thus, other means of sample verification had to be used and with the only feasible being a re-interpretation of the land cover at selected sites in the Landsat image"*⁷⁰.

6. Recommendations

6.1. Forest definition

Possible revision of the actual national forest definition have emerged from different report. The Readiness Preparation Proposal to the forest carbon partnership facility (FCPF)⁷¹ mention a modification of the actual definition by increasing of the crown cover threshold from 10% to 20%.

The Cambodia REDD+ Road Map published by Winrock International recommends the same revision of the canopy cover threshold (from 10% to 20%) *"given that the 2002, 2006 and 2010 images were classified using a crown cover of 20%"* concluding that *"there is no real implications of changing the forest definition for REDD+"*⁷². Actually, the 2010 national forest cover map is based on the FAO forest definition considering the 10% canopy cover threshold (GRAS, 2010) but with the resolution of the images used for the mapping, it is quite impossible to discriminate such variations in the canopy cover threshold. As single trees can't be detected on Landsat images, the precise crown cover as well as the variations in tree height can't be measured using such mid-resolution images.

If new forest types are adopted in the national classification system, they will have to be clearly defined. It is especially the case of the wood/shrub actually defined as non-forest due to low accuracy but also defined as *"a mixture of shrubs, grass and trees, the trees cover however remaining below 20 percent. This forest type can be found mainly on shallow soils, on the top of mountains under climax conditions or as a result of non sustainable land use. Theoretically there is a chance of becoming forest again"*⁷³. This class could be defined as forest (as the canopy cover has not yet reached the 10% threshold) or *"unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate"*⁷⁴.

The fact remains that defining a new canopy cover threshold for the forest land will mostly affect the possibilities of afforestation/reforestation, the + of the REDD+, as the land eligible

⁷⁰ GRAS A/S (2010)

⁷¹<https://www.forestcarbonpartnership.org/sites/forestcarbonpartnership.org/files/Documents/PDF/Mar2011/Cambodia%20R-PP-Final%20Clean%20Version-%20March%205,%202011.pdf>

⁷² Walker, S.M., Casarim, F., Harris, N. and Brown, S. (2010)

⁷³ FA (2011)

⁷⁴ FAO (2010)

for these enhancement of carbon stock related activities will increase with the threshold. In other words, Setting the forest cover threshold too low will limit the country's ability to offer A&R projects. If a too high forest cover threshold is defined for Cambodia, afforestation measures may result in the replacement of natural forests systems (falling below the crown cover threshold) by simplified forests such as industrial plantations.

In one hand, the 10% threshold retained for the national forest cover assessment in Cambodia (FAO definition) *"has been developed in view of the very open African Woodlands and appear to be rather low for some forest type of the region"*⁷⁵. On the other hand, with the rather low threshold of 20%, area considered as forest can include Dry dipterocarp forest as well as a large amount of degraded forest area. For evergreen and mixed forests a 30% threshold could even seem more appropriate but it would result in the exclusion of the specific types of forest such as the open dry dipterocarp forests.

The use of dry season cloudless images constitutes a problem in term of crown cover variation within a specific forest type, canopy cover classes of Deciduous forest cant interpreted reliably. Additional wet season images should be used as often as possible in order to improve the forest cover assessment accuracy. Higher resolution images or Aerial photography could also contribute to improve the accuracy of the mapping.

Finally, it is suggested to look at the definitions adopted in the neighboring countries as ecological conditions as well as forest types present important similarities.

6.2. Contribution to the national forest monitoring system

The adoption of a national forest definition and classification system will serve as a basis for the forest monitoring system and the preparation of the GHG inventory. Any percentages and thresholds discussed in this report used to distinguish forest classes and to define their boundaries were provided as guidance for visual interpretation and have to be considered approximate. Precise measurements of the forest definition criteria are not possible on Landsat satellite images but would require aerial photos or High resolution satellite images⁷⁶. Tree height and percent crown cover are quantitative thresholds widely used for defining and classifying the forest. Till now, these parameters are determined based on a relative subjective judgment, especially when using coarse or even medium resolution remote sensing data. As a consequence, monitoring forest degradation is limited by *"technical capacity to sense and record the change in canopy cover because small changes will likely not be apparent"*⁷⁷.

Forest types identified on the ground might be impossible to discriminate accurately with specific remote sensing data or software, the *"accuracy of the classification results is inversely proportional to the number of classes used"*⁷⁸.

The national forest monitoring system could also integrate more than one methodology taking into consideration the spatial distribution of various forest types. Specific

⁷⁵ Malyvanh M., Feldkotter C. (1999)

⁷⁶ Malyvanh M., Feldkotter C. (1999)

⁷⁷ GOF-C-GOLD (2012)

⁷⁸ Giri, C., Shrestha S. (1995)

routines/methodologies could be more adapted for the monitoring of particular forest types (such as the hardly "mapable" Deciduous dipterocarp forest) using high resolution imagery and/or aerial photography that can't be used for the whole country considering financial limitations. The harmonization process might be source of error but the overall accuracy for mapping specific forest types would be increased.

The IPCC Guidelines for National Greenhouse Gas Inventory even recommend to proceed to a "Re-classification of forest types according to updated remote sensing technologies"⁷⁹. It is also recommended to use different remote sensing data than Landsat images which offer low possibilities of discrimination between forest types. Radar imagery could help to improve the classification system by facilitate the mapping of the deciduous forest during the rainy season when other cloud free images are hardly available. This is a financial issue as national cover of high resolution images will be extremely costly.

Finally, it is important to keep in mind that more research is needed to correlate the classes identified in remote sensing data with the one retained for the classification system. The classification system to adopt will be a compromise between what can be discernible with the remote sensing data used for assessing the forest cover and what is observed on the ground. Objects "in-distinguishable with satellite data"⁸⁰ will never be part of the legend of a newly adopted national classification system.

6.3. The REDD+ national policy, a step toward institutional arrangements

"Effective management of forests in Cambodia is complicated by an institutional framework whereby several government agencies divide responsibilities"⁸¹.

Two key ministries are responsible for the management of the forest land in Cambodia: the Ministry of Environment and the Ministry of Agriculture, Forestry and Fisheries.

The management of the protected area system (about 25-30% of the total forest land) falls under the General Department of Administration for Nature, Conservation and Protection (GDANCP) of the MoE.

Two main departments of the MAFF have a significant stake in the management of the forested areas: the Forestry Administration (FA, former Department of Forestry and Wildlife, DFW) and the Fisheries Administration (FiA). The FA is responsible for regulating forest and forest product use on state public lands, including production forest and protection forests as well as other public or private forests associated with indigenous minorities, private individuals, and others. MAFF is also responsible for forest areas allocated for conversion as economic land concessions.

Since 1978, the department of fisheries of the MAFF, actual FiA, is responsible for the management of a smaller area of state public land which include the flooded forests, the coastal mangroves (at the exception of the ones located in protected areas under jurisdiction of the MoE) and the other wetlands.

⁷⁹ IPCC (2006)

⁸⁰ Giri, C., Shrestha S. (1995)

⁸¹ Bradley, A. (2011)

With the recent engagement of Cambodia in developing a national strategy on REDD+, the different agencies working on forest and land management issues will have to strengthen their cooperation. A clear legal framework for implementing any REDD+ national policy will require clarification and/or definition of the roles and responsibilities of these different agencies. Strengthening institutional cooperation among the relevant ministries is a priority for implementing mitigation options for Cambodia. Partnership, Institutional arrangements, Memoranda of Understanding or Inter-ministerial agreements between MoE, MAFF and/or any relevant actor is therefore essential for reaching the long term objectives of the national REDD+ roadmap. In 2003, Royal Government of Cambodia established a Climate Change Office later promoted to the Climate Change Department (CCD) in 2009 within the MoE. This "arm" of the GDANCP doesn't seem to be represented in the National REDD+ taskforce. Nevertheless, the Cambodian REDD+ Taskforce (formalized at the end of the year 2011), chaired by the FA of the MAFF and co-chaired by the GDANCP of the MoE is a coherent framework for the establishment of an inter-ministerial agreement.

Inter-ministerial agreements will also be needed in order to harmonize and disseminate all data required for the GHG inventory reporting. Limited existing data for preparation of the GHG inventory is also a important constraint to evaluate and implement any mitigation options. Remote sensing data and ground field measurements are constituting the basis for forest cover assessment. Numerous data are available for historical analysis however these data when available through multi-user licensing are not centralized or cannot be used due to the lack of agreement between the different government agencies. Government agencies as well as NGOs can provide very relevant data at a sub-national level. (MOE-MIS unit own full aerial photography coverage of Cardamom Wildlife sanctuaries). Data sharing can also be facilitated by commercialization of products. A common pricing framework could be implemented. Each agencies responsible for specific data collection could give access to their data for a specific (symbolic ?) fee.

"The incoming deadline for the first submission of Biennial Update Report from developing countries, December 2014, is a great opportunity for those countries to start the process of setting institutional arrangements for GHG reporting and for preparing their first GHG inventory exclusively based on domestic expertise and available data"⁸².

6.4. National forest and land cover classification system

In 1999, the Department of Forestry and Wildlife (Actual Forestry Administration of the MAFF) adopted a classification system (fig. 37) to divide the Cambodian forest into 11 forest types⁸³.

The classification system proposed in 1999 is much more detailed than the actual one and should be reconsidered as a basis for the stratification of the country's forest.

⁸² Federici, S. (2012)

⁸³ MOE (2003)

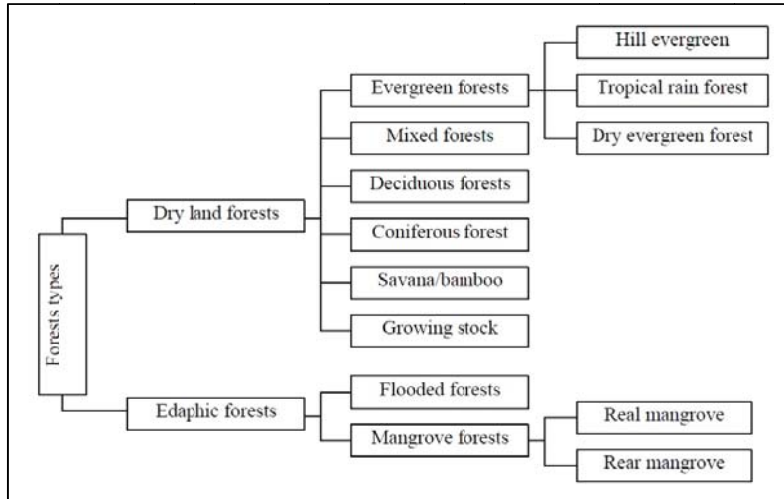


Figure 37: Forest Classification of Cambodia (from Kim-Phat N., undated) In MoE 2003

It is a good example of a relatively simple stratification that could be used in order to improve the accuracy of the forest related carbon stocks estimates.

Other classification systems (fig. 38) have been proposed in Cambodia based on land ownership or forest cover/land cover⁸⁴. As forest management (Conservation, Sustainable forest management, production or restoration) will be largely influenced by the forest land ownership and the corresponding forest policy, such stratification could improve the estimation of the forest carbon stock. The classification system presented illustrate the numerous possibilities of classifying the forest in Cambodia according to various objectives.

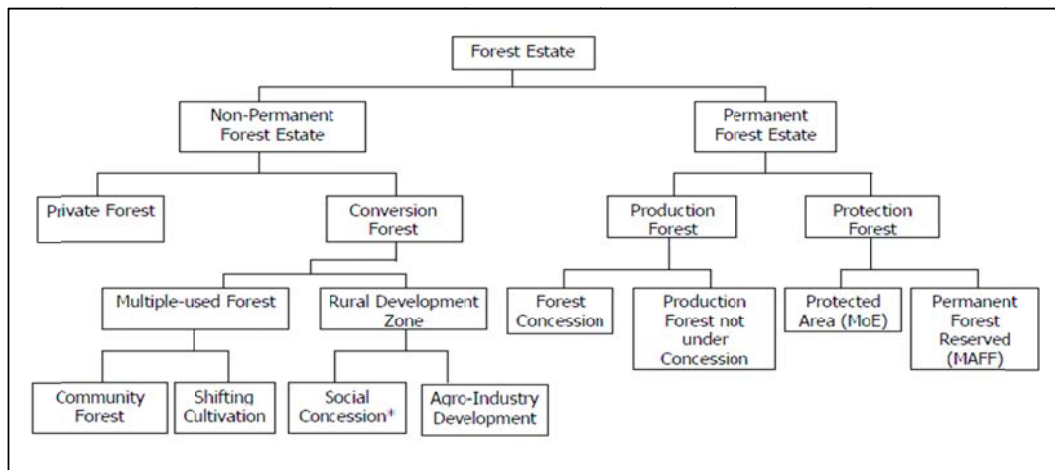


Figure 38: Forest classification system based on land ownership (Source: Mak Visal, 2005)

Specific matrices can also be developed. In this case, emissions from forest degradation could be quantified by comparing estimates of carbon storage under different forest conditions. Such country specific stratification matrix (fig. 39) can be developed using broad forest types, forest conditions such as drainage (flooded or dry), elevation (mountainous,

⁸⁴ Mak V. (2005)

lowland), level of degradation and age (see example below)⁸⁵.

Forest Condition →

<i>Forest Type</i> ↓		Mature	Logged	Secondary (young)	Secondary (med. aged)	Burnt
	Moist					
	Dry					
	Seasonal					

Source: Gibbs, H.K. et al. (2007)

Figure 39: Example of a stratification matrix that uses seasonality and management practice to capture the major variation in forest carbon stocks.

Specific attention should be paid for the secondary forests. The secondary forests can be defined as "forests regenerating largely through natural processes after significant human disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites". In the lower Mekong countries, secondary vegetation types from early regenerated forests to open canopy forests have replaced the primary forests so that "most forest cover in Cambodia may be secondary [...] timber extraction and conversion of forest land to agriculture are the two principal causes of forest degradation in the region"⁸⁶.

Finally, the development of a new national classification system based on the LCCS version 3 software constitute an opportunity for the country to improve the transparency, consistency, completeness, accuracy and comparability of the GHG emissions estimates. Such national legend will have to be enough flexible to respond to the needs of the different government agencies and institutions involved in the management of the forest resource.

⁸⁵ Gibbs, H.K. et al (2007)

⁸⁶ Mittelman, A. (2001)

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