Cambodia REDD+ Roadmap:

Development of a Reference Scenario and Design of a Monitoring System

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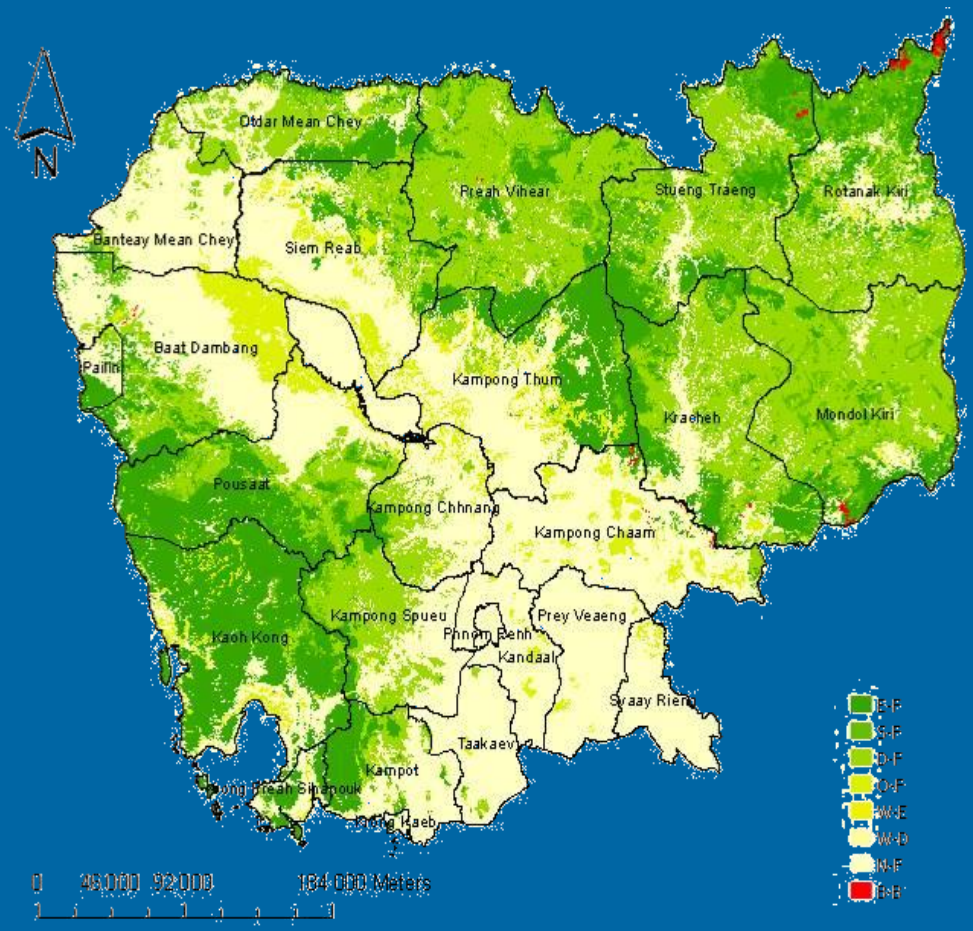

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Background to MRV and REL in Cambodia

Land-use change in Cambodia

Cambodia has one of the highest forest coverage in South East Asia, with approximately 10.7 million hectares or roughly 60% of the national territory[1]. The extent of Cambodian forests are significantly declining[2] (**Error! Reference source not found.**) due to land use change, forest degradation through logging, forest fires, land-grabbing and encroachment of agriculture. The land use change is considered relatively high, with 379,485 hectares of forest cleared between 2002 and 2005/6**Error! Bookmark not defined.**, equivalent to a deforestation rate of 0.8% per year. As a consequence Cambodia can be considered to be a 'high forest cover, high deforestation' country for the purposes of REDD[3].

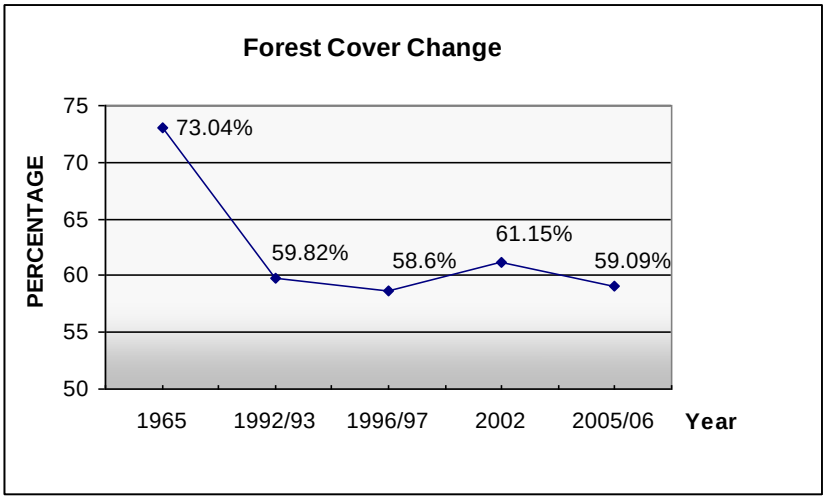

Figure 1 Change in forest cover from 1965-2006 (Source: Forestry Administration (2007))

Figure 1 shows the available data on forest cover from national assessments since 1965. The figure suggests that forest cover has fluctuated between 58 and 61% since 1992/3. However, the differences in the estimates for various years is mainly because of different analysis methods that were used[4]:

- The 1988/1989 dataset, produced by the Mekong Secretariat, is based on visual interpretation of LANDSAT satellite image hardcopies and identified 20 land use clases

[1] Forestry Administration, 2007. Forest Cover Changes in Cambodia, 2002-2006. Paper prepared for the Cambodia Development Cooperation Forum. Forestry Administration, Phnom Penh.

[2] Cambodia's National Forestry Programme. 2009. Strategic Framework Document. 288 pp.

[3] As described in Griscom, B., Shoch, D., Stanley, B., Cortez, R. and Virgilio, N. 2009. Sensitivity of amounts and distribution of tropical forest carbon credits depending on baseline rules. Environmental Science and Policy 12: 897-911.

[4] Brun, S. 2009. Elaboration of Cartographic tools for reforestation, CDM and REDD project activities in Cambodia. ONF International, Paris.

(where 9 classes depict various forest cover) at a scale of 1:250 000, and a minimum mapping unit of 1 km^2 (4 x 4 mm at map scale).

- The 1992/3 and 1996/7 datasets were produced by the Forest Cover Monitoring Project, a Mekong River Commission initiative executed by the GTZ. The two land cover datasets are based on the visual interpretation of 1992/1993 and 1996/1997 LANDSAT satellite image hardcopies, at a scale of 1:250 000 with a minimum mapping unit of 1 km^2. The Land use cover analysis for 1996/1997 results in a classification in 30 land cover classes (with 15 ''forest'' classes).

- The 2002 and 2005/6 analyses were produced by the Forestry Administration's GIS/RS Unit with the support of the Danida. The results of this analysis have been recently published in English and Khmer[5]. These country-wide analyses have been based on manual on-screen visual interpretation of Landsat ETM+ imagery. The digitalization process has been conducted with false colour combinations of bands 2, 3, 4. These two latest land cover datasets are the most accurate: a) the minimum mapping unit of 0.2 km^2 (20 ha), and b) the scale of 1:50 000, allowing a much thinner depiction of the different classes. However, the land cover nomenclature used for the year 2002 and 2005/06 differs from the one related to 1988/89 and 1996/97 databases. For 2006, the nomenclature adopted in 2002, 4 forest classes on a total of 8 land cover classes, has been slightly modified, 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%. In the 2006 nomenclature, finally 5 land cover classes 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.

As a consequence of these differences, whilst the 1992/3 and 1996/7 analyses are comparable, and the 2002 and 2005/6 analyses are also comparable, the 2002 and 2005/6 results cannot be compared to the earlier results from the 1990s.

The forest cover in Cambodia dropped from 11,104,300 ha in 2002 to 10,730,800 ha in 2006[6]. As much as 380,000 ha of forests have been lost in Cambodia between 2002 and 2006, which accounts for a total deforestation of more than 2.0% across the four years, or as much 0.9% forest loss per year (i.e. deforestation rate) (**Error! Reference source not found.**).

[5] Forestry Administration. 2008. Cambodian Forest Cover; Forest cover map change 2002 - 2006.

[6] Forestry Administration. 2007. Final report: Forest cover assessment for year 2005/2006. 14 pp.

Table 1: Forest cover area and change in forest cover from 2002 to 2006

FOREST TYPES	2002		2006		Change 2002-06	
	AREA		AREA		AREA	
	Ha	%	Ha	%	Ha	%
Evergreen Forest	3,720,493	20.49	3,668,902	20.20	-51,591	-0.28
Semi-evergreen forest	1,455,183	8.01	1,362,638	7.50	-92,545	-0.51
Deciduous forest	4,833,887	26.62	4,692,098	25.84	-141,789	-0.78
Others forest	1,094,728	6.03	1,007,143	5.55	-87,585	-0.48
TOTAL	**11 104 291**	**61.15**	**10 730 781**	**59.09**	**-373 510**	**-2.06**

Source: Adapted from the Forestry Administration (2007)

Broadhead and Izquierdo (2010)[7], in their report to the Cambodia REDD+ Roadmap process identify the principle drivers of deforestation shown in Table 2.

Table 2. Drivers of deforestation and forest degradation

	Within the forest sector	Outside the forest sector
Direct	• Logging and especially poor quality logging.	• Clearance for agriculture; • Expansion of settlements; • Infrastructure development; • Fire; • Woodfuel demand.
Indirect	• Low institutional capacity and weak policy implementation; • Weak forest sector governance ○ Weak enforcement and control; ○ Low levels of stakeholder participation and involvement; ○ Corruption, clientelism and nepotism; ○ Lack of transparency and accountability;	• Population increase; • Rising incomes and demands for resources; • Increasing accessibility of forest areas; • Migration; • Land privatisation for cultivation and granting of economic land concessions; • Governance ○ Weak land tenure – tenure is weakest in forests and other areas outside residential or farming zones; ○ Low prioritisation of human rights;[8]

[7] Broadhead, J. and Izquierdo, R. 2010. Assessment of land-use, forest policy and governance in Cambodia. Report prepared by FAO as a contribution to the Cambodia REDD+ readiness process. FAO-Regional Office for Asia and the Pacific, Bangkok.

	• Lack of incentives promoting sustainable management of forests.	○ Overlapping/unclear jurisdictions; ○ Chronic incidence of high-level interministerial and interagency disputes; • Social norms (claiming land through utilisation).

Cambodia Reporting to the UNFCCC and climate change policy

The first National Communication from Cambodia to the UNFCCC occurred in 2002 (for year 1994) and the National Adaptation Programme of Action to Climate Change (NAPA) was approved by the Royal Government in 2006. The second national communication to the UNFCCC (for year 2000) is currently being prepared using a combination of new existing country specific data for Cambodian forests. Implementation of the work proposed in this document will be able to feed into producing an improved national communication in the future.

In 2003 the Ministry of Environment established an Office of Climate Change and in 2006 the Royal Government set up the National Climate Change Committee (NCCC), with representation of 19 Government ministries and agencies. The new Department of Climate Change in the Ministry of Environment, which was upgraded from the old office in 2009, is the Secretariat of the NCCC. The NCCC and the Department of Climate Change have the responsibility to coordinate development of climate change policies, including the planned Cambodia Climate Change Strategy and Action Plan (CCCSAP), and for reporting to the UNFCCC.

UNFCCC Methodological Guidance on REDD+

In order to participate in a national REDD+ system, countries will need to establish national monitoring systems, which include reporting and verification of emissions reductions. This is sometimes referred to MRV: monitoring, reporting and verification. Countries will also need to develop a national-level baseline against which results will be monitored, often referred to as the Reference Scenario or the Reference Level (RL), or the Reference Emissions Level (REL) if only applied to emissions from deforestation and forest degradation. The Reference Level could potentially include both emissions (from deforestation for example) and removals of greenhouse gases (from replanting trees for example).

According to Decision 4 of the UNFCCC Conference of the Parties at COP-15[9], all countries should use the IPCC framework (2003 and 2006[10]) to develop their monitoring systems for REDD+ and to estimate their historic emissions for the activities under REDD+. The IPCC framework is outlined in

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[8] Centre for Justice and Reconciliation 2010. CJR Law Review Issue 01 A, March 2010. http://www.cjr-cambodia.org/pdf/CJR_LawReview_Mar2010_English.pdf

[9] COP15 decision (4/CP.15) recommended that the most recent IPCC guidance and guidelines should be used as a basis for estimating the anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks (Article 1(c)).

[10] Refers to IPCC 2003 Good Practice Guidance for Land Use, Land Use Change and Forestry and the IPCC 2006 GHG Inventory guidelines for the agriculture, forestry and other land use (AFOLU) sector.

Figure 2 and is based on measuring activities (changes in the area of land-use categories over time) and emissions factors (carbon stock changes caused by activities). The following activities under the IPCC are relevant for REDD+: (1) deforestation is covered by "forests converted to other lands"; (2) degradation is covered by "forests remaining as forests"; and (3) enhancement of carbon stocks is covered by both "forests remaining as forests" (improve stocking of existing forests) and by "other lands converted to forests" (afforestation and reforestation).

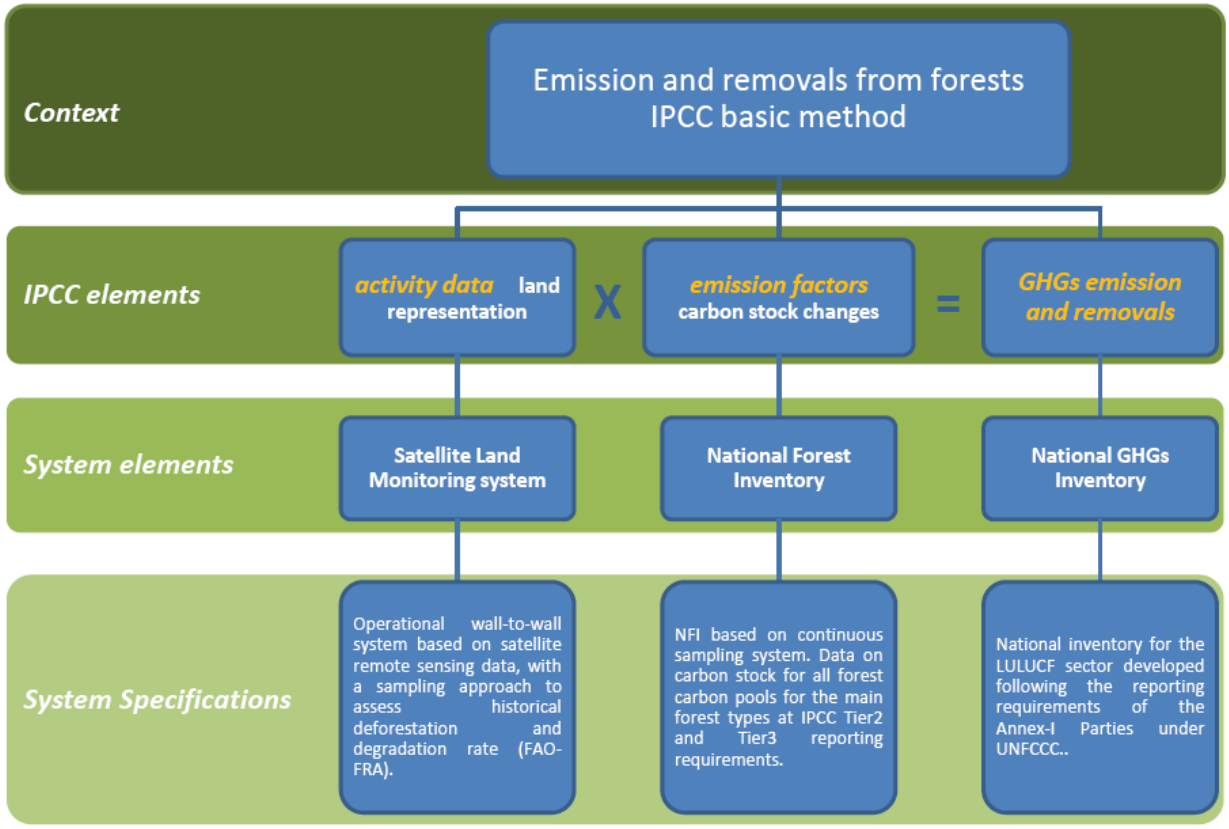

Figure 2. Basic elements of an MRV system under the IPCC (taken from FAO)

At this stage, it is unknown how the modalities for establishing the Reference Scenario (Reference Emissions Level, REL) will be set as policy decisions are ongoing under the UNFCCC. However, it is clear from UNFCCC 15th Conference of the Parties Decision 4/CP.15 that RELs will be based on historical data, adjusted for national circumstances[11]. What is meant by 'adjusted for national circumstances' is not clear in the COP Decision but could include socio-economic factors, drivers of deforestation and the national policy context.

[11] At its 30th session, the SBSTA of the UNFCCC discussed REDD in detail, resulting in a Decision which was adopted by the Conference of the Parites to the UNFCCC at its 15th session in Copenhagen (Decision 4/CP.15)—the relevant text here is in Article 7: Recognizes that developing country Parties in establishing forest reference emission levels and forest reference levels should do so transparently taking into account historic data, and adjust for national circumstances, in accordance with relevant decisions of the Conference of the Parties.

Roadmap Section 5: Development of a Reference Scenario

Objectives

The overall objective of this section is to develop a scenario for the reference level (REL) that projects emissions and removals of CO_2 into the future in the absence of REDD+ incentives. The REL, while based on historical information, will also reflect national circumstances and relevant policies as well as meet international standards and requirements. The REL will be developed in a way so that emissions and removals that are monitored in the future can be compared directly to the emissions and removals in the reference scenario—in other words there will be consistency between the approaches used for the REL and the MRV (Monitoring, Reporting and Verification) system.

Accomplishment of this objective involves two sub-goals:

- Quantification of *historic emissions/removals* from deforestation, degradation and enhancement of carbon stocks for the proposed period between 2000 to 2010 at a national scale, using the IPCC framework, and spatially represented to reflect differences in sub national activities in use and cover of the land; and
- Development of *future trajectories* of emissions/removals over different time periods (e.g. 5 yr and 10 yr periods) and under different economic and development scenarios. This will take into consideration such factors as Cambodia's Rectangular Strategy for Growth, Employment, Equity and Efficiency – Phase II, Cambodia's National Strategic Development Plan Update 2009-2013, the Cambodia Millennium Development Goals[12], and the Cambodia REDD+ Strategies. Other current country indicators will also be taken into consideration, such as: GDP, population growth, agricultural expansion, industry growth, sectoral development plans, specific investment programs, and/or adjustment coefficients otherwise derived from such factors and data.

The National REDD+ Taskforce will need to track the international negotiations process during the implementation stage of the Cambodia REDD+ Roadmap so as to ensure work being done on this topic will meet the policy requirements. However, any process agreed to for setting a reference scenario will be based on the historic emissions as a starting point.

Outline of steps to make REL

An outline of the activities and steps that need to be accomplished to attain the objectives of this Section are presented the outcome chain diagram in Figure . The proposed steps in Figure 3 are essentially the terms of reference that would need to be accomplished to meet the objectives of this Section.

[12] See REDD+ Roadmap Background Report for further details on these three plans.

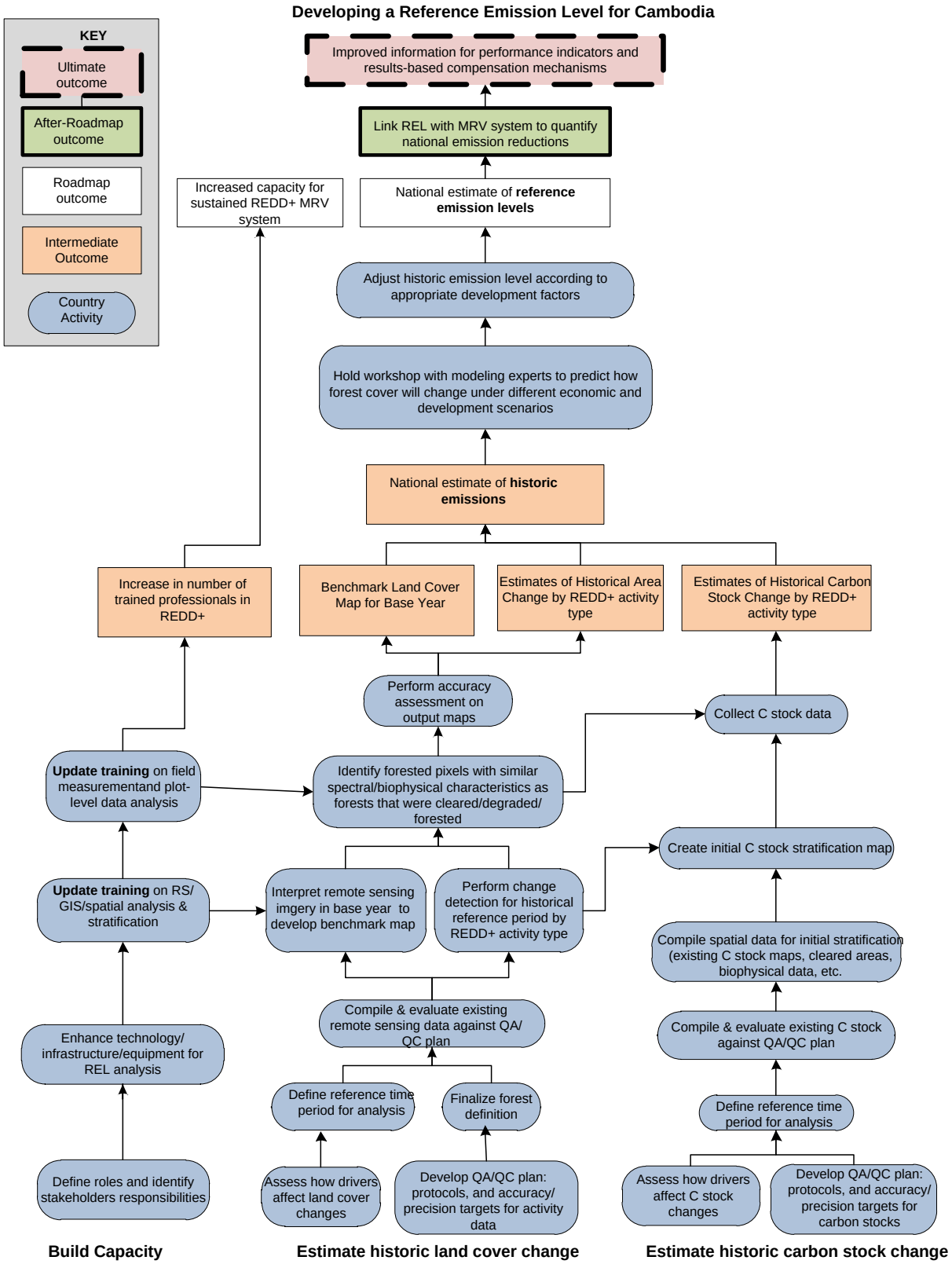

Figure 3 Outcome chain/TORs for developing the REL in Cambodia

5-1 Establish national-level institutions for MRV/REL with adequate capacity

Step 5-1a. Define management roles and responsibilities

The National REDD+ Taskforce will be responsible for the implementation of a REDD+ program in Cambodia (for further details on roles and responsibilities of the relevant government agencies see the Cambodia REDD+ Roadmap). The REDD+ Taskforce will coordinate the Cambodia National REDD+ Readiness process. Its specific roles will include:

- Development of National REDD+ registry
- Development of Guidelines for REDD+ projects in Cambodia, including procedures for Government approval
- Determine benefit-sharing and REDD+ revenue management
- Setting Cambodia's RELs and rules for MRV via the REL/MRV Working Group, including national forest carbon accounting methods (e.g. methods to be used, definitions of forests, etc.)

A management structure for the REL/MRV Working Group will need to be developed and roles and responsibilities of various institutions defined to ensure that groups are working together towards a common goal. A key aspect for this work will be the enhancement and formalization of existing collaboration and cooperation among key agencies and organizations (governmental and non-governmental) leading to improved sharing of data and information relevant to developing the REL and the MRV system.

Step 5-1b. Enhance capacity, staffing and technological capabilities

The Cambodian REDD+ concerned agencies that identified needs for enhanced capacity, both in staffing and technological skills are presented in (Table). Cambodia has a relatively well developed capacity in GIS and Forestry, however human as well as technological capacity needs to be enhanced within relevant groups to develop a REL and build a MRV system (Section 6).

- Expand number of people trained in REDD+ analysis to a minimum of 10-15 in the Forestry Administration and and a further 10-15 in the Ministry of Environment; other agencies may need around 5-10 trained people.
- Upgrade current hardware and software for processing, interpreting and storing data (remote sense and carbon stock data).
- Build capacity in staff on the latest technology and methods used for: interpreting, analyzing and modelling remote sensed data, such as: multi-spectral satellite imagery, LiDAR, Radar, LCM, GEOMOD among other relevant REDD+ analysis methods (e.g. as described in the GOFC-GOLD Sourcebook). This could be accomplished by supporting at least 5 staff from the relevant agencies to attend training workshops or internships overseas.
- Improve computer and internet network architecture including dedicated servers for data storage, back-up and storage of data, fast transfer of large files among relevant stakeholders, and increased access and use of government approved hardware and software (desktop and laptop computers).

In addition, it is important to also build capacity on internationally accepted and credible IPCC approaches and methodologies for estimating GHG emissions and removals at the national scale (e.g. as described in the IPCC 2003 GPG and 2006 AFOLU). Capacity in information management and information technology will also be needed due to large amounts of data that will be generated and managed. Such steps will ensure Cambodia's ownership of the REL process and provide a sustained capacity for future REDD+ monitoring.

Table 3 Overview of Cambodian government institutions participating in the establishment of REDD+ REL and MRV system and expected increased capacity needs

Institutions involved	Scale of operation	Expected role	Capacity needed
RGC	National	• Adoption of REDD+ policies, strategies, new laws and subsidiary regulations	○ Finance ○ Advisory group ○ At least 1-2 technical staff
NCCC	National	• Oversee Climate Changes Programs	○ Finance ○ Technical staff ○ Updated computing and field equipment, infrastructure, etc
REDD+ Taskforce	National	• Implementation for REDD+ activities/ interventions • Following international negotiations on REDD+	○ Support staff (up to 2 persons) ○ Finance expert ○ REDD+ expert staff from MEF ○ Updated computing and equipment, infrastructure, etc
MRV/REL Working Group	National	• Implementation of MRV and REL sections of the Roadmap	○ Lead representatives from FA, MoE, FiA and Department of Geography ○ Training in overall MRV and REL planning ○ Training in Carbon stock assessment (RS/GIS/Field methods) ○ Updated computing and field equipment, infrastructure, etc
MoE	National	• Management of Protected areas • Review environmental impacts assessments • CDM interim designated national authority • Developing and implementing National Protected Areas Strategic Management Plan • Cooperate with relevant institutions to: develop national climate change strategies, and carbon credit policy, manage climate change trust funds	○ REDD+ expert staff ○ Training in Carbon stock assessment (RS/GIS/Field methods) ○ Technical support (equipments, infrastructure, etc)

		• UNFCCC focal point: negotiations, implementing UNFCCC decisions and preparing national GHG inventory reports • coordinating implementation of carbon projects	
FA	National	• Responsible for Permanent Forest Estate • Manager of the Permanent Forest Reserve • Establishing Community Forests • Regulating timber production • Establishing the National Forest Inventory • Undertaking National Forest Cover Assessments	○ 5 REDD+ expert staff (enhanced capacity in steps needed to implement and in ongoing international discussions) ○ 10-15 additional carbon stock inventory staff (could be shared with other institutions) ○ High capacity computer servers and printers/ plotters (about 5-10 systems) ○ MRV Secretariat office facilities and equipments ○ Provide adequate training of trainers to communities on basic inventory skills
Forest Management Units (Protected Areas, Protection Forests, etc.)	Local	• Responsible for managing an area of state public property • Developing area management plans	○ Training in Carbon stock assessment using field methods ○ Sufficient understanding of the natonal REDD+ programme ○ Provide extension services and undertake consultation with local communities
Local Communities	Local	• Coordinate community forest activities • Indigenous Land Titling • Perform MRV in community forested areas • Local oversight of REDD implementation	○ Training in Carbon stock assessment using field methods

5-2 Establish National Definitions for REDD+ Accounting

The MRV/REL Working Group should cooperate with the REDD+ Taskforce and key Ministries (especially MAFF and MoE) to set national definitions that will be used for REDD+. These definitions will include:

Step 5-2a. Define the reference time period

Although Cambodia has imagery collected in 1989, 1992/3, 1996/7, 2002 and 2005/6 and have produced land cover maps, the REL for Cambodia will be based on historic emissions from 2000 until 2010, because older imagery were collected using different techniques, have different scales and resolution, and therefore cannot be directly compared with recent imagery (see above).

Step 5-2b. Set the national forest definition

The definition of forest decided by the Ministry of Agriculture, Forestry and Fisheries (MAFF) that Cambodia has submitted to the UNFCCC[13] is based on the following thresholds: minimum crown cover of 10%, minimum height of 5 m and minimum area of 0.5 ha[14]. However, the identification of forest in remote sensing imagery using lower than a 15% threshold for canopy cover is more difficult because as the threshold for forests is reduced, the accuracy of the remote sensing analysis declines. Under the CDM, the minimum crown cover chosen by Cambodia is 10% to allow all areas with less than that crown cover to potentially participate in CDM. Given that the current definition of forests in Cambodia is based on non-REDD+ programs and the technical issues related to using low canopy cover thresholds, Cambodia will revise its definition of forests to ensure the opportunities for implementing a REDD+ strategy maximizes the sustainable development of its forests while at the same time being able to respond to other reporting needs. Given that the 2002, 2006, and 2010 images were classified using a crown cover of 20%, and that changes to and from forests defined this way practically cover all the likely REDD+ strategies that will be implemented in Cambodia, it is recommended that the canopy cover threshold should be set at 20%, with the other two thresholds maintained the same. This change in canopy cover threshold is different than that registered with the UNFCCC under the CDM. As no CDM AR project is registered for Cambodia and that any AR activities can be captured under the "plus" of REDD+, there are no real implications of changing the forest definition for REDD+. However, any decision to revise the national forest definition will need to be widely consulted on in Cambodia and adopted by MAFF.

Step 5-2c. Decide forest classes to be used

The different land-use assessments have used varying definitions of Cambodia's forest types. A single classification system for REDD+ purposes will need to be developed, and classifications should then use this standard system. To facilitate reporting to the UNFCCC, the classification system will need to be consistent with the IPCC land-use categories. Historical datasets may need to be reclassified based on these revisions.

Step 5-2d. Identify key carbon pools to include in the historic estimate

Cambodia proposes to include aboveground and belowground carbon stock in trees as the main pools in all land cover changes that are related to their REDD+ activities. The addition of supplemental pools can lead to increases in the cost of field measurements and monitoring. Therefore, the MRV/REL Working Group will need to assess which additional pools it wishes to include for the appropriate land cover changes. During this process, it may be appropriate to consider which carbon pools the pilot REDD+ projects are measuring, in order to ensure data consistency. These are:

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[13] Available at: http://cdm.unfccc.int/DNA/ARDNA.html?CID=37

[14] The definitions of forest and woodlands used by Cambodia are required by FAO for their reports. but as stated here the identification of forest in remote sensing imagery using lower than a 15% threshold for canopy cover is more difficult because as the cutoff gets lower, the accuracy of the remote sensing analysis declines.

- Oddar Meanchey: Aboveground biomass, belowground biomass and dead wood biomass
- Seima: Aboveground biomass, belowground biomass and dead wood biomass
- Southern Cardamoms: Aboveground biomass, belowground biomass, dead wood biomass and leaf litter biomass.

Other published studies for Cambodia have measured the following pools:

- Kim Phat et a. 2000 and Top et al. 2004[15]: Aboveground biomass (Kompong Thom province).
- Kiyono et al. 2010[16]: Aboveground biomass, belowground biomass, dead wood biomass and leaf litter biomass (12 plots, several provinces).

None of the pilot projects decided to measure soil carbon, and whether or not to include the social carbon pool for deforestation and forestation will require further investigation. As a first step, a summary of soil carbon data typical of forest soils in Cambodia will be compiled and assessed as well as compared to the global data sets that exist. This will enable the MRV/REL Working Group to assess the cost and benefit of including soil carbon or not.

Tree removals and dead wood for charcoal production, over grazing of understory reducing regeneration, and fire all contribute to forest degradation. However, little data are available in Cambodia on how these degradation activities affect the carbon stocks in which pools. A first step during the REDD+ implementation phase will be to review the literature to determine if there are any studies on related topics in similar environments (including neighboring countries). In addition, field studies will be necessary to determine the effect these activities have on carbon stocks and to assist in determining which additional pools will need to be included. These studies would need to build on existing research reports[17].

In order to ensure that reports of decreases in emissions are not overstated as compared to the reference case, the principle of conservativeness will be used when deciding which pools to include in the REL as well as in the MRV, and except for the dominant tree pool, it allows certain pools to be

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[15] Kim-Phat N, Ouk S, Uozumi Y, Ueki T. 2000. Stand dynamics of dipterocarp trees in Cambodia's evergreen forest and management implications – a case study in Sandan district, Kamong Thom. J Jpn Forest Plann 6:13–23. Top, N., Nobuya Mizoue, and Shigetaka Kai, 2004, Estimating forest biomass increment based on permanent sample plots in relation to woodfuel consumption: a case study in Kampong Thom Province, Cambodia. Journal of Forestry Research, 9:117-123.

[16] Kiyono, Y., Furuya, N, Sum, T., Umemiya, C., Itoh, E., Araki, M. and Matsumoto, M. 2010. Carbon stock estimation by forest measurement contributing to sustainable forest management in Cambodia. Japan Agricultural Research Quarterly. 44 (1), 81 – 92. http://www.jircas.affrc.go.jp.

[17] Including: GERES, 2007. Wood energy in Cambodia – a brief overview; GERES, 2006. Wood energy baseline study for CDM; UNDP, 2008. Residential energy demand in rural Cambodia: An empirical study; GERES, 2009. WISDOM around Phnum Chumriey; Baskoro et al. , 2008 Biomass baseline information study using case studies to compare domestic and regional demand for rubber wood, rice husk and wood chips. GERES Cambodia; Suntra, H. 2009. Project for the Study on the Use and Supply of Timber/Wood in Cambodia. FA/TWGF&E.

omitted. However, it is clear that once established, the REL and subsequent MRV estimations must remain constant and include exactly the same pools.

5-3 Quantify activity data

Cambodia proposes to use Approach 3 under the IPCC for measuring activity data, requiring the collection of spatially explicit information on land use changes and the conversions among land uses. Existing land-use assessments for Cambodia are consistent with Approach 3.

The Landsat program has been the most useful of the many satellite systems designed for land cover monitoring because it is the longest running exercise in the collection of multispectral, digital data of the earth's surface from space. Fifteen Landsat scenes practically cover the whole of Cambodia, and due to long life of the Landsat program, along with the high spatial resolution the extensive archive of freely available data, and the compatibility with previously collected datasets in Cambodia, Landsat data are the ideal choice for mapping historical rates of deforestation at the national scale.

The land cover products available for Cambodia, based on a compilation of the existing remote sensing data, is given in Annex 1. Despite the number of products on land cover, there is a lack of information on how the products were produced and validated and if validated what accuracies were achieved. Without such information, the usefulness and credibility of the products is questionable. Thus a key step under this task will be to further investigate how the map products were produced using data from 2002 and onwards and provide the appropriate documentation including whether supervised or unsupervised classification was used, number and type of land cover classes included, and accuracies attained. Given that additional pre-and post-2006 products will be needed to estimate historic emissions, ground data will need to be collected for the post-2006 products that also can be used to validate earlier products.

In addition to mapping deforestation, remote sensing has also been useful for mapping and monitoring indicators of forest degradation such as logging roads, fire scars, other forest canopy damages, and secondary forest recovery[18], all of which occur in Cambodia. However, the accuracy of mapping changes in forest cover for forests remaining as forests depends on forest stand characteristics, processes of degradation/enhancement, intensity of disturbance, timing of satellite imagery acquisition relative to the events, and spatial resolution of the imagery. Thus remote sensing can play an important role in mapping indicators that can be used to guide a field measurement program to understand the impacts of forest degradation and enhancements of carbon stocks. The MRV/REL Working Group will need to commission or undertake research to investigate how remote-sensing can be used in Cambodia to estimate historic emissions from forest degradation.

The following are the proposed series of sub-steps Cambodia will take for mapping deforestation, forest degradation, carbon stock enhancement, and forestation from 2000 to 2010 to be used for

[18] GOFC-GOLD, 2009, A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report version COP15-1, (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada).

estimating historic emissions/removals. It is expected that advice will be solicited from national and international experts as needed.

Step 5-3a. Perform change detection for historical reference period

Imagery will be compiled and interpreted based on the selected definition of forest to create a land cover map with classes relevant to REDD+ activities and drivers. The years for which satellite data already exist are 2002 and 2006. Data will need to be acquired for 2010 at a minimum, which is already underway by the Forestry Administration, and preferably 2000. A 2000 product will serve as the benchmark map for the historic period against which changes from 2000-2010 will be determined using standard remote sensing protocols for change detection. The 2010 product will be updated resulting in a benchmark map for future monitoring. Land cover change will be mapped over the reference period using the Landsat imagery (2000, 2002, 2006 and 2010+) using standard approaches and the expertise of staff within the Government agencies responsible.

Step 5-3b. Classification quality control and accuracy assessment

All map products will undergo quality control to ensure that the interpretation and classification provides accurate products. As shown in the outcome change (Figure 3), a plan for assuring quality of the mapping products will be developed and then used in this step. The selection of methodologies and algorithms for classification and accuracy assessments for mapping changes in forest cover (gains and losses) will be based on existing experience in remote sensing interpretation coupled with a review of peer-reviewed methodologies and discussions with the international remote sensing community. Visual interpretation of the imagery will be used to evaluate the success/effectiveness of the classification routines.

The accuracy assessment can be conducted by comparing maps of deforestation derived from remote sensing with field observations or high resolution aerial imagery. This will be done in collaboration with new initiatives already being implemented in Cambodia—e.g. the national forest inventory effort. For historical imagery (pre-2010), the use of existing aerial imagery and scattered very high resolution (<5 meters) imagery will be investigated. Standard methods used by the remote sensing community (e.g. described in the GOFC-GOLD 2009 Sourcebook[19]) will be used to assess the overall accuracies of the land cover classification to provide a statistically valid representation of map accuracy.

Based on results from the quality control step, the classification results will be adjusted either manually in the GIS or by adjusting the parameters used to assign Landsat spectral information to the forest and non-forest classes. All image processing methods and evaluation results will be permanently documented and recorded for verification and complete transparency.

[19] GOFC-GOLD, 2009, A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gain and losses of carbon stocks in forests remaining forests, and forestation, GOFC-GOLD Report version COP15-1. Hence forth document referred to as: GOFC-GOLD, 2009

Step 5-3c. Mosaic and stratify classification products

Individual Landsat products will be stitched together (15 Landsat scenes per point in time) to create the final wall-to-wall benchmark and change maps. In addition, these products will be stratified by forest type, ecoregion, etc. to facilitate integration with carbon products and to understand regional differences in rates and patterns of forest cover change. We anticipate that, at a minimum, the following products will be created by: (1) deforestation and (2) forestation maps for 2000 to 2006 and 2006 to 2010+ (to a maximum of 2012). These maps will indicate areas of forest lost and forest gained during each census period for each stratum identified.

Maps of forest degradation and stock enhancement are more difficult to detect using Landsat imagery and require higher resolution imagery. Forest degradation was not taken into account during the preparation of the national land cover maps and therefore forest degradation has not been mapped at the national scale. Large-scale logging during the 1990s in many areas almost certainly has caused considerable forest degradation. Present day deforestation and forest degradation are particularly intensive on the boundary between agricultural and the major forests cover and in the flooded forest. The development of new access roads through isolated forest enables deforestation and degradation of primary forest. Methods for addressing degradation will be developed during the implementation stage of the Cambodia REDD+ Roadmap, and taken into consideration in the planning of the National Forest Inventory plan.
Methods to assist in stratifying into area of degradation and enhancement of stocks have been described in the GOFC-GOLD Sourcebook. These methods use other spatial data layers such as transport networks, bio-geophysical characteristics of the landscape, population centers, already cleared land and the like. Cambodia has abundant spatial data bases covering the bio-geo-physical, economic and transportation sectors present in its territory (

Annex 2 Existing GIS Data in Cambodia).

As a starting point for stratifying the forests into degraded or enhanced classes, a workshop of experts will be convened to plan a strategy for estimating emissions/removals from these activities during the historic time period. The workshop shall gather all REDD+ concerned partitions and define the information, data and preparation gaps that exist in Cambodia, and therefore the action plans to cover them.

5-4 Develop emission and removal factors for REDD+-related activities

Cambodia will aim for at least a Tier 2 level of data for its estimate of historic emissions/removal. The sub-sections below describe the steps we propose to collect Tier 2 level data for emission and removal factors to be pooled with the activity data collected in Section 6.

Step 5-4a. Develop QA/QC plan and protocols for carbon stock change data collection

A data archiving framework and Quality Assurance/Quality Control (QA/QC) plan will be formulated so that field data on carbon stocks measured at various locations and for various attribute combinations will be transparently and accurately mapped and tracked.

Well established, commonly accepted principles of forest inventory, soil sampling, and ecological surveys form the basis for the techniques and methods used for measuring and estimating the carbon stocks of terrestrial carbon pools. There are a number of sources (e.g., IPCC 2003 GPG LULUCF, World Bank's BioCarbon Sourcebook for LULUCF, GOFC-GOLD Sourcebook, etc.) and the Standard Operating Procedures (SOPs) for the REDD voluntary carbon projects under development (including Oddar Meanchey, Seima and the Southern Cardamoms) that provide standard methods for measuring and estimating the carbon stocks of the key carbon pools that will be identified from step 5-2d. After reviewing these sources a set of standard field measurement protocols will be finalized by the MRV/REL Working Group that suite Cambodia's circumstances for each selected pool.

It is likely that the carbon stocks of some forested types will be more variable than others. There is a relationship between the targeted accuracy/precision and the cost to sample that is related to the spatial variability of carbon stocks across the landscape—the more variable the carbon stocks and the higher the targeted precision the more costly it will be to measure in general. Therefore a cost to monitor versus a desired accuracy/precision will be investigated before the final protocols are developed.

A sampling plan and protocols for conducting the national carbon stock inventory will be defined during the implementation of the steps needed to develop a REL. This sampling scheme will describe the technical methods that will be used to conduct the carbon stock assessments, the appropriate stratification of the land area to be monitored according to the real vegetation and stocks present on the ground. Collection of preliminary data using a draft of the sampling design adopted will be required to adjust design to specific needs and finalizing the sampling scheme. With finalized sampling design, the MRV/REL working group will develop the national carbon stock assessment.

Based on the assessment, national values for key parameters will be calculated and a database associating the emission/removal factors will be created to facilitate in the future monitoring.

The sampling plan and protocols will include details on stratification of the wooded lands for measurement, estimation of sampling intensity (number of plots), plot size, and standard operating procedures for collecting measurements for each key carbon pool. Relevant FA, MoE and FiA staff (as appropriate) will be trained on these methods.

Step 5-4b. Inventory all existing historical data and evaluate against accuracy and precision targets.

A number of analyses of Cambodia's forest have been conducted (Table). Some of these studies were conducted for proposed voluntary market carbon projects and therefore measurements cover only specific areas of the country. These studies must be evaluated to determine how such information can be used in creating emission factors. Some data may be able to be used directly to estimate the carbon stocks of a given forest type while other data may inform how such forest types should be stratified during further analysis and data collection. The datasets are fairly comprehensive for most of the major dryland forest types, but very little forest carbon stock data exists for flooded forest types and mangroves.

Table 4 Existing Forest Inventory Data

Name of data	Description	# plots	Species/ forest types included	Min DBH (cm)	Year	Source
Permanent Sample Plots	1st measurement	120	(**)	>7.5	1998*	Field data
	3rd measurement	104	(**)	>7.5	2004*	Field data
	4th measurement	48	(**)	>7.5	2010*	Field data
Regrowth Forest	3rd measurement	15	(**)	>7.5	2010*	Field data
Strategic Forest Management Plan (SFMP)	15 Forest Concessions	2000	Unlogged Evergreen	>Sapling	2002	Field data
		1760	logged Evergreen			
		1460	Unlogged Mixed			
		300	Logged Mixed			
		1360	Unlogged Deciduous			
		60	Logged Deciduous			
Kim-Phat et al. 2000 and	Kompong Thom	60	Evergreen, Mixed, and	>10	1997	Forestry Administration

Top et al. 2004[20]			Deciduous forest			and Miyazaki University, Japan
Tani 2007[21]	Kompong Thom, Kratie and Mondulkiri	34	Semi-evergreen /evergreen and deciduous	>10	2003-5	Kyoto University
Kiyono et al. 2010[22]	Several provinces	12	Evergreen, Deciduous and Secondary forests	>5	2005	Forestry and Forest Products Research Institute, Japan
Seima Carbon Stock Survey	Systematic Random Sample of project area, Mondulkiri province	225	All dryland types	>5	2008	WCS /FA
Preah Vihear Pilot Stock Survey	Systematic Random Sample of trial blocks, Preah Vihear province	72	All dryland types	>5	2010	WCS /FA/MoE
Seima High Value Forest survey	Randomly located plots in fairly small survey area, Mondulkiri province	9	Semi-evergreen /evergreen	>20	2004	WCS/CDRI/FA [23]
Cherndar High Value Forest Survey	Randomly located plots in fairly small survey area, Preah Vihear province	15	Evergreen	>20	2004	WCS/CDRI/FA
Oddar Meanchey Carbon Stock Survey	Systematic Random Sample of project area, Oddar Meanchey province					CFI/TGC/PACT /FA

[20] Kim-Phat N, Ouk S, Uozumi Y, Ueki T. 2000. Stand dynamics of dipterocarp trees in Cambodia's evergreen forest and management implications – a case study in Sandan district, Kamong Thom. J Jpn Forest Plann 6:13–23. Top, N., Nobuya Mizoue, and Shigetaka Kai, 2004, Estimating forest biomass increment based on permanent sample plots in relation to woodfuel consumption: a case study in Kampong Thom Province, Cambodia. Journal of Forestry Research, 9:117-123

[21] Tani, A. 2007. Vegetation analysis of Cambodian forests based on species composition data. Masters thesis. Laboratory of Tropical Forest Resources and Environment, Graduate School of Agriculture, Kyoto University, Japan.

[22] Kiyono, Y., Furuya, N, Sum, T., Umemiya, C., Itoh, E., Araki, M. and Matsumoto, M. 2010. Carbon stock estimation by forest measurement contributing to sustainable forest management in Cambodia. Japan Agricultural Research Quarterly. 44 (1), 81 – 92. http://www.jircas.affrc.go.jp.

[23] CDRI and WCS. 2004. Focusing on Cambodia's High Value Forests: Livelihoods and Management. CDRI, Phnom Penh.

Southern Cardamoms Carbon Stock Survey	Systematic Random sample of project area, Southern Cardamoms	124	All dryland types	>5	2010	ONFI/Wildlife Alliance/FA

(*) Year of measurement and remeasurement. (**) Number of species per forest types be calculated from PSPs and field practice is given per forest type.

Step 5-4c. Identifying lands that underwent change in historic period (linking RS and field data).

There are numerous physical, biological and human factors that affect carbon stocks across a landscape and associating a given area of deforestation, forestation, or forest degradation with a specific carbon stock results in a more accurate and precise estimate of carbon emissions. Furthermore, the cost and time associated with sampling forest carbon stocks across the entire country would be substantial, the information of which may not prove valuable if the forests for which data are collected are under no threat of deforestation or degradation or undergoing small changes in stocks from previous disturbance. In fact, only the data pertaining to carbon stocks of the lands that underwent change or are expected to undergo change in the future is relevant in estimating historic emissions.

- For forests, only the areas that underwent deforestation/degradation/disturbance are relevant;
- For soils, only the soils carbon stocks needed for areas converted to/from annual cultivation.

Cambodia proposes to assess the suitability of the approach in the 2009 GOFC-GOLD Sourcebook that explains how to identify forested areas today whose carbon stocks represent the carbon stock of forests that have changed since the base year. The GOFC-GOD Sourcebook proposes that, the spectral characteristics of forested pixels (e.g. NDVI) in the remote sensing imagery that were changed over the historical reference period can provide information about the remaining forested pixels that share these same attributes when combined with other spatial data layers (such as proximity to roads and rivers, logging infrastructure, elevation, and proximity to population centers, already cleared areas and protected areas). Then, carbon stocks in these remaining forested pixels can be sampled as proxies for the carbon stocks in the pixels that were deforested, degraded or enhanced.

During this phase of the Cambodia REDD+ Roadmap implementation, Cambodia can use the data amassed for the REL to begin investigating the possibility of developing a national carbon stock table under the plans for the National Forest Inventory, which can be further developed during the implementation of the MRV plan[24]. This table will relate change data from remote sensing interpretation to a likely estimate of carbon stocks derived from field data. Steps 5-4a to 5-4c will result in a detailed plan outlining how estimates of carbon stocks of forests that have undergone change will be measured and estimated, including where measurements need to be made.

[24] For example, see Box 2.2.2 in the GOFC-GOLD Sourcebook (2009) that illustrates this approach. Available at: http://unfccc.int/files/methods_science/redd/methodologies/other/application/pdf/sourcebook_version_nov_2009_cop15-1.pdf

Step 5-4d. Carbon stock assessment

The stratification plan, sampling plan, and protocols developed from the prior steps will be implemented and the forest areas to be measured identified on a map. The sampling strategy adopted will ensure that carbon stocks measured in each stratum attain an acceptable level of accuracy and precision as defined in the QA/QC plan and field protocols. Results from the field measurements will be used to estimate emission factors for various land cover changes (deforestation, degradation, forestation, enhancement of carbon stocks) using the IPCC GPG framework, along with the estimated uncertainty around each emission factor.

5-5. Combine activity data with emission factors to develop total historical emissions

The purpose of this step is to estimate the annual historical emissions and removals, based on changes in carbon stocks, for the time periods in the reference time frame. These historic emissions and removals can be produced for any subnational scale such as by province or ecological zone or as well as nationally.

The IPCC framework will be used for this step, applying the stock change approach for deforestation and forestation, meaning that the area of change and the carbon stocks before and after the change event will be combined. In this circumstance the gain loss-approach will most likely be favoured for degradation and enhancement of carbon stocks. Rates of growth would account for carbon stock gains. For losses in carbon stock, data referring to timber harvests, removals of trees for charcoal/ fuel, and transfers to the dead organic matter pool due to disturbances would be used.

For fire, the IPCC AFOLU 2006 report (Chapter 2) provides detailed methods (equations and combustion factors for both CO2 and non-CO2 GHGs) that would be used. This would combine the area burned with the carbon stock before and after a burn along with IPCC default values for combustion and efficiency factors.

5-6. Develop future trajectory under different economic and development scenarios

After estimating historical emissions and removals, international experts in the fields of financial and economic modelling will be required to advise on modelling future reference emission scenarios. The impacts of development policies, global trends in demand and prices for Cambodia's land based commodities, and other economic factors will be included in these models. A workshop will be held in this regard, to consult with national and international modelling experts and Cambodian Ministries related to planning and finance. The outcome of this workshop would be a methodology by which the historic emissions can be projected over different time periods and under different economic and development scenarios, taking into consideration such factors as GDP, population growth, past and present agricultural expansion, forest industry growth, sectoral development plans, subnational development plans, specific investment programs, and/or adjustment coefficients otherwise derived from such factors and data.

Work on this activity will require coordination and inputs from other government departments. In addition to REDD+ Taskforce and MRV/REL working group members, national experts and university staff/researchers will be engaged and consulted with for their assistance in developing the data

bases and models to derive adjustment coefficients to modify the historical emission levels for developing future trajectories.

Developing future trajectories will include such activities as:

- Organization by REDD+ Taskforce and MRV/REL working group of an initial workshop to include staff from the relevant government departments, experts from national universities, and international experts to discuss the current thinking and methodologies for modelling future emissions scenarios based on historic emissions
- Convene a small focused national subgroup of experts from government, universities, and private sector in REDD+ and provide support as needed for them to design potential methodologies for modelling future projections (expected to develop at least 2-3 different methodologies to test appropriateness for Cambodia's situation)
- Obtain and collate the required data bases to implement the methodologies, test methodologies, share results with REDD+ Taskforce, and decide on a plan to move forward.
- Stay abreast of the international discussions and decisions on how reference scenarios for REDD+ are to be established.

Table 5 Summary of Reference Emission Level Activities and Budget

	Estimated Cost			
Activity	2011	2012	2013	Total
5.1 Establish national-level institutions for MRV/REL with adequate capacity				
5.2 Establish National Definitions for REDD+ Accounting				
5.3 Quantify activity data				
5.4 Develop emission and removal factors for REDD+ related activities				
5.5 Combine activity data with emission factors to develop total historical emissions				
5.6 Develop future trajectory under different economic and development scenarios				
Total				

Roadmap Section 6: Design a Monitoring System

6a. Monitoring of Emissions and Removals

Objective for Section 6a

The overall objective of Section 6a is to develop a monitoring, reporting and verification (MRV) system that allows for transparent and conservative accounting of emissions and removals of CO_2 through time that can be compared against the projected reference scenario. An important question to answer before designing a REDD+ MRV system is: "what should be monitored?" If the objective of the MRV system is to evaluate the degree to which Cambodia's candidate REDD+ strategies have or have not been effective in reducing GHG emissions and/or increasing removals, it is logical to think that monitoring indicators should be linked to each candidate REDD+ strategy. However, the implementation of an individual REDD+ strategy may have indirect rather than direct impacts on emission reductions. For example, an improvement in forest governance may have profound impacts on how forests are managed in Cambodia, yet developing a specific indicator to ascribe the impact of this action to reducing emissions or enhancing removals of CO_2 would be difficult. Examples of monitoring indictors related to candidate REDD+ strategies are presented in the main text that will be taken into consideration during the design of the MRV system.

The MRV section is composed of two phases — a MRV development phase and a MRV implementation phase. The outcome of the implementation of this section will be a functional MRV system for evaluating the performance of REDD+ interventions in Cambodia. The exact details of the MRV system will be adapted and finalized during the Cambodia REDD+ Roadmap implementation phase as it is tested at demonstration sites, but key features of the system design are presented as a starting point for further development. The design of the MRV system will build upon the framework already established for estimating historical emissions in Section 5, as the methods for estimating emissions and removals during the monitoring period will need to be comparable to those used for estimating historical emissions, so that the performance of REDD+ interventions can be measured. Thus many of the steps outlined in Section 5 will carry over into Section 6a.

Linkages between REDD+ strategies and monitoring Sections

Broadly, the REDD+ strategies proposed to Cambodia are based on existing policy frameworks, laws and subsidiary regulations, such as: (i) the National Forestry Programme (NFP) for the Permanent Forest Estate, including community forestry, protection forests, concession forests, etc., (ii) the National Protected Areas Strategic Management Plan for Protected Areas (under development) and, (iii) the Strategic Planning Framework for Fisheries for flooded forests and mangroves outside of protected areas.

Although REDD+ strategies are still under discussion and agreements, Table 6 below indicates the main lines on the ongoing discussion and methods and indicators that will be taken into account to monitor the particular needs of candidate REDD+ intervention strategies going forward. We propose that the essence of the MRV system will be to determine the degree to which the sum total of all

REDD+ strategies implemented across Cambodia have or have not resulted in a reduction in emissions from the land use sector at the national scale. Therefore, the data to be monitored as part of Section 6a include changes in the area of each REDD+ activity class (deforestation, forestation, forest degradation, sustainable forest management, enhancement of forest carbon stocks) and the resulting changes in carbon stocks. Emission reductions will be verified at the national scale, but monitoring and reporting may be implemented at sub-national and local scales. Data collected at subnational scales will be integrated into the national accounting structure via a national data clearinghouse, where additional quality assurance/quality control measures are undertaken to ensure against double counting.

Table 6 Proposed methods to monitor change in area and carbon stocks of lands targeted for REDD+ strategies

Candidate REDD+ strategies	Methods to implement strategy	Methods to monitor effectiveness of strategy
Implementation of the National Forestry Programme	- Forest law enforcement and governance - Community forestry Programme - Forest demarcation, classification and registration - Forest resource management and conservation, including forest certification, production forest management, and reforestation/afforestation	Forestry Administration will manage use of remote sensing and GIS techniques, and perform field carbon stock assessments (section 5-4) Community forest carbon monitoring in community-managed areas
Implementation of the National Protected Areas Strategic Management Plan	- Improved Protected area management - Community Protected Areas	Monitor forest cover change with remote sensing imagery over protected areas Community forest carbon monitoring in community-managed areas
Sustainable management of flooded forest and mangrove resources	- Community fisheries - Fisheries conservation areas - Sustainable management of habitat in fishing lots	Monitor area with remote sensing imagery Community forest carbon monitoring in community-managed areas
Develop payment for environmental services programs	- Establish program in cooperation with local communities for: watershed protection, reforestation, ecotourism, wildlife observation, etc.	Develop cooperative partnership with local and indigenous communities to perform on the ground surveys of carbon stock changes to be used by the national RS team in the FA or MoE
Improved management of fuelwood	- Forest law enforcement and improved governance - Encourage systems of certification of managed forests	Monitor fuelwood use—quantity and source Partner with concessionaires to obtain data on timber

	-Woodlots	removal, and combine with FA collected data on expected damage and estimated regrowth
Conservation Concessions	Set aside large tracts of forest for conservational purposes	Monitor with remote sensing imagery development encroachment and regulate accessibility to concessions
Integrating REDD+ into subnational land-use planning	- Implement REDD+ using nested approach - Integrate REDD+ into provincial and communal level land-use plans	Report national monitoring results of emissions/removals by subnational level and compare to reference scenario

Summary of Activities under Section 6a

An outline of the activities and steps that need to be accomplished to attain the objectives of Section 6a are presented in the outcome-chain (Figure 4). The proposed steps also can serve as the terms of reference that would need to be accomplished to meet the objectives of this Section.

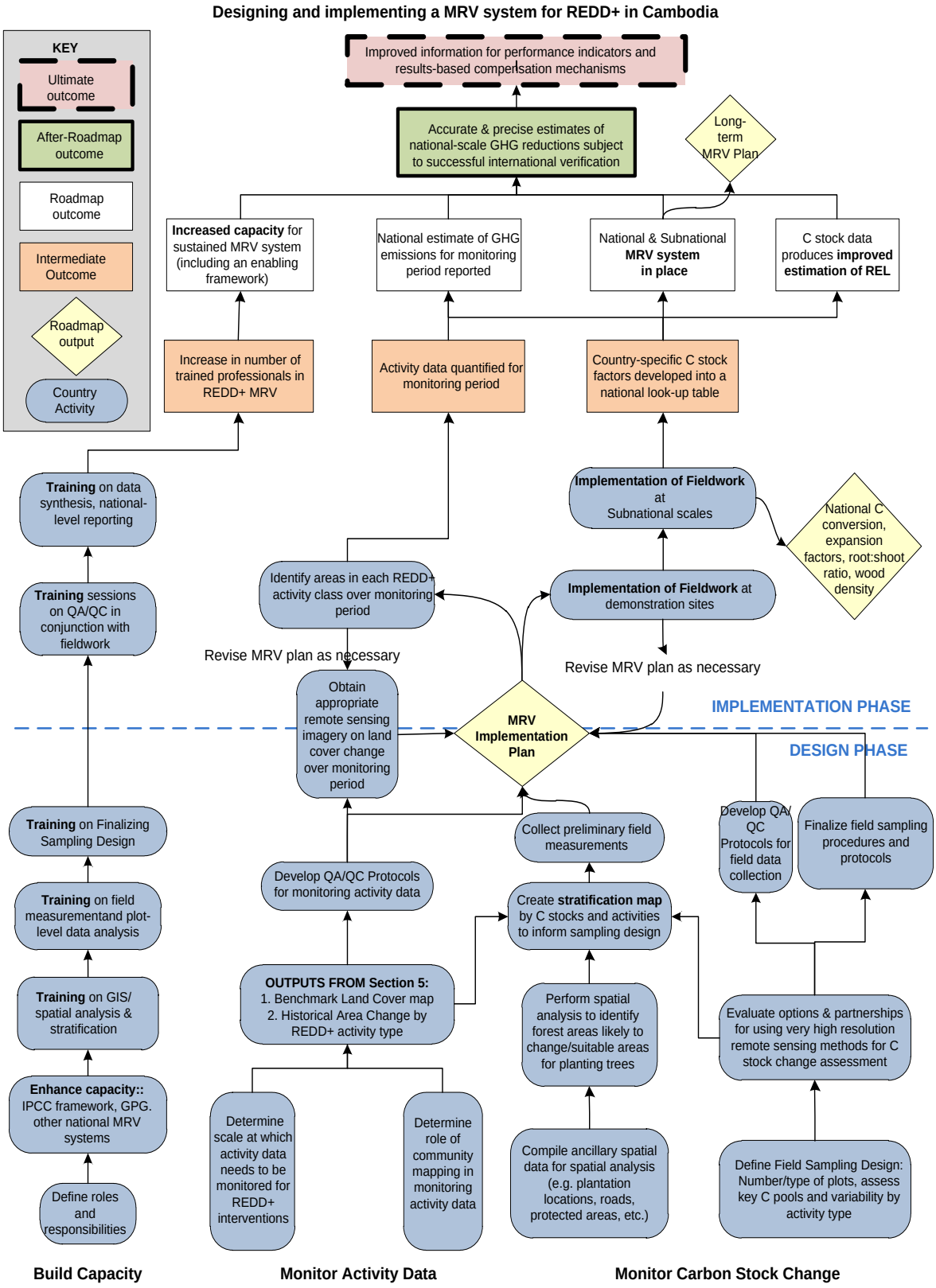

Figure 4 Outcome chain for designing and implementing a MRV system for REDD+ in Cambodia

Description of Activities

Activity 6a-1. Define roles and responsibilities of various institutions in designing and implementing the MRV system and develop a system for collaboration.

The roles and responsibilities for Section 6a are likely to be similar to those established in Section 5. However, the role of local communities and local management authorities (protected areas, forestry units, etc.) is likely to be more significant in Section 6a, because new data will need to be collected going forward and therefore these stakeholders will be important for collecting information on both area changes and carbon stock changes that are not detectable using remote sensing imagery, such as activities related to reductions in the extent of degradation, improvements in use and management of protected areas and protection forests, production forest areas, community forests (CFs), community protected areas (CPAs), community fisheries (CFis), fishing lots, tree planting activities outside forests, etc. The MRV/REL working group, especially FA, MoE and FiA representatives, will need to compile the data collected at the local level and across the communities. The identification of technologies commonly and widely used across the communities to improve compilation and storing of this data must be assessed. For instance, the use of mobile phones may be a form of collaboration among institutions and allow, by using a set of standard operating procedures for data input, that information collected at the local level to be sent via text message and be compiled and archived automatically using simple computer programming scripts. This would automate and streamline the data collection process and provide a linkage between data collected at project/sub-national scales and data compiled for the national monitoring system.

Activity 6a-2. Enhance capacity and training for various stakeholders involved in monitoring.

Once roles and responsibilities are established by the REDD+ Taskforce, stakeholders engaged in monitoring efforts will be trained in relevant methods for monitoring land cover changes and carbon stock changes. Training will build on that gained during implementation of the steps to develop the ReL and occur at multiple levels:

- REDD+ Taskforce and REL/MRV working group: Engage with international experts to become more familiar with other national MRV systems already in place. Through this process, Cambodia will be able to apply lessons learned when developing and implementing an MRV system. Carbon stock measurement teams will be formed at subntational level and will be further trained (building on expertise attained during work on the REL Section) by experts in plot-level measurement and data analysis. The FA, and MoE and FiA as appropriate, should have high end capacity on RS/GIS in order to efficiently manage the MRV data achieve and registry.

- FA, MoE, FiA, Management Authorities for forested areas, and Department of Geography: Staff will receive training on GIS/spatial analysis relevant to monitoring REDD+ activities, including how to apply various land change models (e.g., GEOMOD, LCM, others) and how to develop a field sampling design within a GIS.

- Local communities (CFs, CFis, CPAs, indigenous communities): Will need training carbon stock measurement and monitoring methods, including field plot measurement techniques

and collecting land cover data, especially for forests remaining as forests that are more difficult to monitor remotely.

Table 7 Overview of Cambodian government institutions that will receive training in MRV latest techniques

Agency	Responsible for implementing training	Type of training
Ministries	REDD+ Taskforce	- Overall implementation of REDD+ activities - RS/GS/Spatial modelling & stratification
FA	REDD+ Taskforce	- Overall implementation of REDD+ activities - RS/GS/Spatial modelling & stratification - Field sampling procedures and protocols
MoE	REDD+ Taskforce	- Overall implementation of REDD+ activities - RS/GS/Spatial modelling & stratification - Field sampling procedures and protocols
FiA	REDD+ Taskforce	- Overall implementation of REDD+ activities - RS/GS/Spatial modelling & stratification - Field sampling procedures and protocols
Department of Geography, MLMUPC	REDD+ Taskforce	- RS/GS/Spatial modelling & stratification
Local communities	REDD+ Taskforce	- RS/GS/Spatial modelling & stratification - Field sampling procedures and protocols

Activity 6a-3. Design and implement MRV plan for monitoring activity data

Step 6a-3a. Determine scale at which activity data can be monitored using remote sensing imagery

Deforestation and afforestation/reforestation can be readily monitored with medium-resolution remote sensing data (e.g. Landsat, SPOT), but other REDD+ interventions that occur at smaller spatial scales or that do not result in a change in land cover (e.g. forest degradation, enhancement of forest carbon stocks) may be more difficult or even impossible to monitor remotely. High resolution satellite imagery and aerial photography are other options for monitoring small scale changes in land cover and forest condition. The Geography Department, the Forestry Administration and several Development Partners have significant amount of high resolution imagery data (Aerial photos, Ikonos, SPOT, etc) for various provinces of Cambodia. The possibility of using both, high resolution imagery and freely available RS data will be evaluated and a draft monitoring framework will be developed to identify gaps.

Step 6a-3b. Determine role of community mapping and local forest management units in monitoring activity data

For REDD+ interventions that cannot be monitored cost-effectively from satellite or other remote sensing imagery (e.g., monitoring trees outside forests), options will be investigated for incorporating mapping by communities and local forest management units (e.g. Protected Areas,

Protected Forests) into the monitoring framework. For local mapping activities a sampling methodology, sampling design and QA/QC protocols will need to be developed during the design phase and incorporated into the final MRV Implementation Plan.

Step 6a-3c. Decide on scale for remote-sensing based area change based on cost-benefit analysis

Some area changes are easy to measure and result in large changes in carbon stocks (e.g., deforestation) while others involve much more intensive measurement and may not result in large emissions (or emission reductions). Prior to finalizing methods for monitoring land cover change at various scales, pilot areas will be monitored to evaluate the costs of monitoring small changes and a cost-benefit analysis (costs of monitoring vs. carbon benefits generated) will be conducted. Based on the analysis of these pilot projects, a detailed description on how to perform MRV in different scales will be formulated.

Step 6a-3d. Develop QA/QC procedures for monitoring activity data, test draft MRV plan at demonstration sites and revise MRV plan as necessary

QA/QC procedures for monitoring area change will be developed including recommendations on expected standards and methodologies for mapping rates of land cover change, as will methods for addressing the use of different data sources through time for quantifying activity data. A description of all decisions made and methods developed in steps 6-3a through d will be compiled into an initial MRV implementation plan. (This plan will also include descriptions on carbon stock changes, summarized in Activity 6a-4 below). The plan will be tested at demonstration sites and revised as necessary to ensure that the finalized MRV plan is functional and high quality.

During future monitoring periods, an assessment will be made during this step of opportunities for using the most up-to-date satellite-based or airborne-based methodologies for improved monitoring of performance of REDD+ activities at the national to regional scales and the MRV plan will be revised as necessary.

Step 6a-3e. Obtain appropriate data on area change over monitoring period

The MRV implementation plan, including collection of activity data and data on carbon stock changes, will be tested in demonstration sites and modified to adjust the plan as necessary to account for lessons learned. After this initial testing phase, appropriate data (including remote sensing data as well as other data collected by local communities as applicable) will be collected during each monitoring period.

Step 6a-3f. Divide activity data by each REDD+ activity class over monitoring period

Once activity data have been collected for the monitoring period, these data will be analyzed and broken down by the areas in each REDD+ activity class (deforestation, forest degradation, afforestation/reforestation, sustainable forest management, enhancement of forest carbon stocks) so that the area data can be combined with emission/removal factors developed in Activity 6a-4 below.

Activity 6a-4. Design and implement MRV plan for monitoring carbon stock changes.

Step 6a-4a. Stratification of land area to be monitored

Although national forest inventories are useful for many purposes, it is proposed that not all lands need to be monitored as part of an MRV system for REDD+, because monitoring lands that do not undergo changes in land cover and/or changes in carbon stocks over the monitoring period – and therefore do not generate carbon benefits – would be resources poorly spent. Instead, it is proposed to stratify the land area to be monitored by potential REDD+ activity and potential change in carbon stocks.

Outputs from Section 5 (benchmark land cover map and historical area change by REDD+ activity type) will be needed to inform this stratification process. Combining historical area changes (deforestation, afforestation/reforestation, forest degradation, improved forest management, areas undergoing carbon stock enhancement) with other ancillary data that provide information about the likelihood of future changes will allow the identification of currently forested areas that are under threat of deforestation and forest degradation or that could undergo sustainable forest management or carbon stock enhancement, as well as the identification of currently non-forested areas that that are suitable for supporting tree cover. Such ancillary data could include, but are not limited to, biophysical data such as elevation, rainfall, slope, soil type, etc. as well as data related to how people use lands, such as locations of existing forest plantations, charcoal-producing regions, roads, protected areas, previously burned areas, forest communities, areas under agricultural production, etc. It is planned to use geospatial analysis and geospatial modelling to combine these data layers together to identify which areas within Cambodia are most suitable for each proposed REDD+ intervention. Monitoring intensity and type will strongly depend on the deforestation threat and type of REDD+ intervention.

Step 6a-4b. Develop draft field sampling design

The stratification map will be used to inform the sampling design for carbon stock assessment. This will be based on the protocols and sampling design used in Section 5 for the historic emissions. Additional design considerations (additional to historic emissions work) will include the timing and frequency of different types of measurements (e.g., which measurements must occur up front vs. through time and which measurements must be collected once vs. once per monitoring period vs. once per year, etc.), Standard operating procedures developed for the historic emissions work (section 5) for all field measurements will be revised as needed and incorporated into the MRV Implementation Plan.

Step 6a-4c. Evaluate options and partnerships for using very high resolution remote sensing methods for carbon stock change assessment

High resolution remote sensing methods have emerged recently to map and monitor indicators of forest degradation such as logging roads, fire scars and other forest canopy damages, and secondary forest recovery. In addition, high resolution, airborne imagery has been used in combination with

satellite imagery to estimate forest carbon stock changes over large areas[25]. The approach enables high resolution monitoring of forest cover and disturbance to estimate carbon emissions. This option for using state-of-the art methods for assessing carbon stock changes will be evaluated by the REL/MRV Working Group when making final decisions on sampling design.

Step 6a-4d. Collect preliminary field measurements, finalize sampling plan and incorporate into draft MRV Implementation Plan

Preliminary field measurements will be collected in each stratum to determine the number of plots that will likely be necessary to achieve desired accuracy and precision targets for measuring carbon stock changes. A description of all decisions made and methods developed in steps 6-4 a through c will be compiled into an initial MRV implementation plan.

Step 6a-4e. Test draft MRV Implementation plan at demonstration sites and revise MRV plan as necessary

The full MRV plan (that includes monitoring activity data and carbon stock changes) will be tested at demonstration sites (locations to be determined after REDD+ interventions are implemented) and revised as necessary to ensure that the finalized MRV plan is functional and of high quality. The monitoring system will ultimately allow for national-scale, (but reportable at sub-national scales), annual to bi-annual reporting of GHG reductions achieved as compared to the reference scenario. During future monitoring periods, an assessment will be made during this step of opportunities for using the most up-to-date methodologies for improved monitoring of performance of REDD+ activities at the national to regional scales and the MRV plan will be revised as necessary. After this initial testing phase, appropriate carbon stock data will be collected during each monitoring period at sub-national scales.

Select members of line agencies, Cambodian forest communities (CFs, CPAs, CFis, indigenous communities, etc.), local forest management units (Protected Areas, Protected Forests, etc.) and relevant private sector companies will be trained and engaged in future monitoring as appropriate. These stakeholders will be identified early on by the REL/MRV Working Group in the MRV design process so that they will be engaged from the outset.

Step 6a-4f. Develop national values for key default parameters

Once carbon stock data have been collected at sub-national scales, the data will be used to develop sub-national and/or national-level values such as carbon conversion factors, biomass expansion factors (if applicable), allometric equations for biomass estimation, root:shoot ratios, wood density, etc. These values will be compiled into one table so that calculations associated with monitoring will be able to be performed transparently, quickly and efficiently.

[25] Asner, GP. 2009. Tropical forest carbon assessment: integrating satellite and airborne mapping approaches. *Environmental Research Letters* 4: 034009.

Step 6a-4g. Compile sub-national database of emission/removal factors

Activity data for each REDD+ activity class (deforestation, forest degradation, afforestation and reforestation, sustainable forest management, enhancement of carbon stocks) must be paired with a corresponding emission or removal factor to calculate total emissions or removals. Therefore, the carbon stock data collected within each stratum will be compiled into a sub-national database ("lookup table") of emission and removal factors (t CO_2/ha) by REDD+ activity class that can be used with activity data to quickly estimate emissions or removals across all REDD+ activity types.

Activity 6a-5. Report national estimate of GHG emissions during monitoring period and subject this estimate to international verification

In this activity, the outcome of the monitoring system will be synthesized and compared against the reference scenario to provide timely reporting of emissions/removals for REDD+ activities. The MRV implementation plan will be developed to allow for complete transparency so as to be open for verification and peer review.

6b. Monitoring of Other Benefits and Impacts

Background

Section 6b outlines a monitoring and reporting system for social, environment and other impacts of increased forest cover resulting from implementation of REDD+ activities. Increased forest cover will also protect soils from erosion, increase biodiversity, and provide timber and fuel for local communities.

REDD+ strategies to reduce deforestation and degradation will have substantial social and environmental impacts beyond climate change and carbon accumulation. Those impacts will be felt at the national level (for example through improved water supply, quality and electricity) and at local levels (for example through maintenance of forest areas and the resources they provide) and at various levels in between through other benefits such as jobs related to the forest industry, forest based tourism, etc. Some individuals or groups may be negatively impacted by the proposed REDD+ strategies and these impacts must also be identified and mitigated. For example, stopping agricultural encroachment and expanding the forest area will leave less land available for food crop production, while addressing unsustainable use of forests will reduce the quantities of forest products available for harvest in the short term. These social and environmental and other impacts of the REDD+ strategies will be monitored.

Section 6b builds on the Strategic Environmental and Social Assessment (SESA) prepared in the Roadmap Implementation Framework (Roadmap Section 4). It will put into place a monitoring methodology framework for environmental, socio-economic and governance components.

Activity 6b-1. Environmental Monitoring

The outputs of the SESA will be used to gather the relevant data. This will include defining biodiversity indicators, and creating a biodiversity monitoring system using indicators of a recognized standard, e.g. IUCN RED List. The monitoring system will use existing site-based biodiversity and species monitoring programs established in protected areas and other forest

management units by conservation projects throughout Cambodia. The stakeholders responsible for such monitoring will be identified by the REL/MRV Working Group, and the existing capacities and resources will be examined and the capacity and resource needs established.

Activity 6b-2. Socio-economic Monitoring

The socio-economic impact of the REDD+ Strategy on local forest-dependent and rural communities on employment, poverty reduction, health, education, gender, and food security according to existing indices (e.g. Human Development Index) will be monitored. The monitoring system developed will assess the distribution of costs and benefits for implementation of REDD+ activities. The stakeholders responsible for such monitoring will be identified. The existing capacities and resources will be examined and the capacity and resource needs established.

Activity 6b-3. Governance Monitoring

Limited institutional capacity, scarcity of resource, illegal forest logging, and forestland clearing were identified as the major drivers of deforestation and degradation and a number of candidate strategies are proposed to address this. Improved governance measures to enforce local regulations and support programs are considered essential to ensure the other measures have a lasting impact. Monitoring the impact of governance measures requires assessment of the governance measures and an assessment of their impact on carbon accumulation.

The performance of implementation of REDD-specific governance bodies will be monitored along with the enforcement of laws relating to forest governance in respect of transparency and accountability, quality of and respect for procedures and preventive measures against corruption. The methods used to ensure free prior and informed consent will be assessed and indicators developed including meeting minutes, meeting attendance list of various stakeholders, resolutions, work plans and activity reports.

Table 2 Summary of Monitoring Activities and Budget

Activity	Estimated Cost			
	2011	2012	2013	Total
Design the M&E plan for other benefits and impacts				
Assess capacities and resources and build capacity				
Select indicators and collect baseline data				
Total				

ANNEXES

Annex 1 Existing remote sensing data held by Cambodia

Name of the Satellite/Sensor	Spatial resolution	Temporal resolution (years)	Coverage (national/only for 1 province, etc.)	Source (organization/ Dept., etc.)
Digital orthophos, B/W	0.5 m	1992-1996	LMAP Areas (14 provinces)	Department of Geography, MLMUPC
Digital ortho image (IKONOS)	0.6 m	2004	Phnom Penh	Department of Geography, MLMUPC
Digital orthophotos (1:40k AP), B/W	1 m	2001-2005	80% of whole Cambodia	Department of Geography, MLMUPC
Aerial photos	various	2005	Tonle Sap	TSEMP
	various	various	Preah Vihear ,small areas	Department of Geography, MLMUPC
	1 m		Target area	Private sector
Quick bird	2,5 m	2006	Preah Vihear, Battambang and Pailin provinces.	WFLMO, Forestry Administration
	2,5 m	2007	Oddar Meanchey province	WFLMO, Forestry Administration
SPOT	10 m	1998-2003	National	Department of Geography, MLMUPC
	5 m	2004	1 scene	WCS
	5 m	2008	Kratie province	Forestry Administration
	5 m	2009	Kratie province	Forestry Administration
Alos AVNIR-2	10m	2007	Kratie province	Forestry Administration
Alos AVNIR-2	10m	2008	Mondulkiri province	Forestry Administration
Aster	<10 m			Private Sector
	15 m	2001-2007 (patchy)	Mondulkiri, Kratie, Preah Vihear, Kompong Thom and Siem Reap provinces	WCS
LISS IV	5.6 m	2007	Mondulkiri, Kratie, Ratankiri provinces	WCS
LISS	23 m	2006	Preah Vihear, Stung Treng, Kompong Cham, Kompong	Forestry Administration

			Chnang, Kompong Speu, Kandal, Prey Veng, Ratanakiri, Kratie, Phnom Penh	
LISSIII	23 m	2007	Mondulkiri, Kratie, Ratankiri provinces	WCS
JERS	20 m	2004	National	Department of Geography, MLMUPC
Landsat ETM+	30 m	2002	National	Forestry Administration
	30 m	2005	National	Forestry Administration
Landsat 7	30 m	2003	National	Department of Geography, MLMUPC
Landsat TM	30 m	2002-2005	National	Dept. D, Ministry of Environment
Landsat	30m	2002	National	Department of Geography, MLMUPC
MODIS	250m	2006	National	Department of Geography, MLMUPC

Annex 2 Existing GIS Data in Cambodia

Name of the spatial dataset	Spatial extent	Coordinate system	Metadata available	Temporal Resolution	Accuracy assessment	Source
Administrative level 1 (province)		Indian 1960 48n	Available	2001/ 2002/ 2008		Forestry Administration, Dept. D / Ministry of Environment, Department of Geography, MLMUPC
Administrative level 2 (districts)		Indian 1960 48n	Available	2001/ 2002/ 2008		Forestry Administration, Dept. D / Ministry of Environment, Department of Geography, MLMUPC
Administrative level3 (villages)		Indian 1960 48n	Available	2001/ 2002/ 2008		Forestry Administration, Dept. D / Ministry of Environment, Department of Geography, MLMUPC
Administrative boundaries (Province, District, Commune)	ESRI format	UTM Zone 48			Acceptable	
National Roads		Indian 1960 48n/ Projected, UTM	Available	2001/ 2002/ 2003/ 2005		Forestry Administration, Dept. D / Ministry of Environment, Department of Geography, MLMUPC
Province Road		Indian 1960 48n	Available	2001/ 2002/ 2005		Forestry Administration, Dept. D / Ministry of Environment, Department of Geography, MLMUPC
Road Network (National, Provincial, Rural)	Shapefile	UTM Zone 48			Acceptable	Department of Geography, MLMUPC, Ministry of

River Data	Shapefile	UTM Zone 48/ Indian 1960 48n	Available	2001 -02	Definitive	Public Works and Transport Forestry Administration, Department of Geography, MLMUPC
River Network	Shapefile	UTM Zone 48/ Indian 60	Yes	2002		Department of Geography, MLMUPC
Lake	Shapefile	UTM Zone 48/ Indian 60	Yes	2002		Department of Geography, MLMUPC
Pond	Shapefile	UTM Zone 48/ Indian 60	Yes	2002		Department of Geography, MLMUPC
Forest cover 2002		Indian 1960 48n	Available	2001/ 2002		Forestry Administration, Department of Geography, MLMUPC
Forest cover 2005 -06		Indian 1960 48n	Available	2005/ 2006	74%	Forestry Administration, Department of Geography, MLMUPC
LandUse2000 (MMU≈1ha)	National	Projected, UTM	Yes	2000 -2003		Ministry of Public Works and Transport, JICA
LandUse2002 (MMU≈1ha)	National	Projected, UTM	Yes	2002		Forestry Administration
LandUse 1996/97	National	Projected, UTM	Yes	1996 -97		Forestry Administration
LandUse 1992/93	National	Projected, UTM	Yes	1992-3	Acceptable	Forestry Administration, Department of Geography, MLMUPC
LandUse 1989	National	Projected, UTM	Yes	1989		Forestry Administration
Scanned Topographic map 1:50k in 1960 -70s	ESRI Format				Acceptable	Forestry Administration, Department of Geography, MLMUPC
Topographic map 1:100k (1996 -2003)	ESRI format/ Illustrator file				Acceptable	Forestry Administration, Department of Geography, MLMUPC
Forest Concessions	National	Projected, UTM		2002		Forestry Administration

Protected Forests	*Protected Areas managed by FA/MAFF*	Projected, UTM		Current	Forestry Administration
Protected Areas	*Protected Areas managed by MoE*	Projected, UTM		Current	Ministry of Environment
Digital Elevation Model					Department of Geography, MLMUPC
Population Census	National			Census 1998	National Institute of Statistics
Population census			Available	2008	National Institute of Statistics
Biodiversity data			Available	Not known	Forestry Administration, Ministry of Environment, conservation projects
Rainfall	National				N/A
Mining Data			Available	Current status	Ministry of Industry and Mines
Land Concessions					Ministry of Agriculture, Forestry and Fisheries
Community Forests, Community Fisheries and Community Protected Areas			Available	Current status	Forestry Administration, Fisheries Administration, Ministry of Environment
Fishing Lots					Fisheries Administration