(A)

2012  2014

**Methods for Estimating Carbon Emissions from Deforestation and Forest Degradation**

**SASAKI, NOPHEA**

13,900,000

REDD+                                                          FREL

(FREL)

2002  2006                                                          30

FREL    4260                                            2830

        Developing countries are required to establish the forest reference emission
level (FREL) before they can participate in the implementation of the REDD+ scheme of the UNFCCC. This
project was designed to estimate forest carbon stock changes, FREL and emission reductions that are
useful for developing monitoring, reporting and verification system.
Forest cover data in all communes in Cambodia in 2002 and 2006 were based to establish the past trend of
forest cover change. Seven categories of forest were classified while primary and secondary data of
forest inventory along with allometric equations were used to derive carbon stocks for all
seven categories. Accordingly, FRELs were estimated at subnational and national levels in Cambodia. Over
a 30-year cycle, national FREL was estimated to be 42.6 million $tCO_2$ per year. Introducing effective
policy interventions to reduce drivers could reduce about 28.3 million $tCO_2$ per year over the same
period.

REDD+

Since the adoption of the Bali Action Plan in 2007, discussions on the inclusion of reducing emissions from deforestation and forest degradation Plus forest conservation, sustainable management of forests, and enhancement of forest carbon stocks (REDD+) have been intensified. The adoption of the Copenhagen Accord in 2009 and the Cancun Accord in 2010 strengthens the recognition of the REDD+ scheme and its ability to reducing emissions while achieving sustainable development in the developing countries. Although the REDD+ scheme is cost effective (Kindermann et al. 2008, Sasaki and Yoshimoto 2010), it is a result-based compensation scheme requiring the known amount of emission reductions through the establishment of forest reference emission level (FREL) and policy interventions introduced to lower the emissions below the FREL. In addition to FREL, Measuring, Reporting, and Verifying (MRV) system is also needed to verify and report the performance.

Despite increasing interests and discussions on the FREL and appropriate policy interventions, no approach was agreed until recently. It is critically urgent to establish FREL and MRV system for tropical forests. This project was aimed to 1) discuss and propose the approaches to estimating forest carbon stocks, FREL and emission reductions; and 2) to propose MRV for forests in Cambodia.

To achieve the project objectives, the following methods were undertaken:
(1) Forest Cover Change: Change of forest area in seven categories was analyzed up to commune level using forest cover statistics in 2002 and 2006. Trend of past change or retrospective approach was used to predict future deforestation, which was based for setting the FREL at subnational and national levels in Cambodia.
(2) Determination of Carbon Pools: Four carbon pools were considered in evergreen, semi-evergreen and deciduous forests, wood shrub dry, wood shrub evergreen, bamboo, and other forest. Other forest includes mangrove, flooded, and plantation forests. Forest inventory data from evergreen, semi-evergreen, deciduous, and other forests throughout Cambodia were analyzed to obtain standing stocks of respective forests. Biomass expansion

factor (BEF) and wood density (WD) were obtained by analyzing the samples of the felled trees. With BEF, WD, inventory data, and allometric equations, carbon stocks in four carbon pools were obtained and used for estimating FREL. Where data were not available, assumptions were based on literatures.
(3) Model Development: Using retrospective approach (trend of area change between 2002 and 2006), models were developed to predict forest area and carbon stock changes for a 30-year timeframe. Accordingly, FREL and removals by forest category at provincial and country levels could be estimated.
(4) Identification of Drivers of Deforestation and Forest Degradation: Socio-economic surveys were carried out mainly in Kampong Thom and Preah Vihear provinces to identify the drivers. Policy interventions were then proposed to address these drivers.

Analysis of forest cover change in 1618 communes (30,021 data points for all seven categories) suggests that forest cover in Cambodia declined 1.2% annually between 2002 and 2006. Banteay Meanchey and Pailin provinces had highest rates of deforestation, suggesting that land clearing along the western and north-western border was intensified.

Figure 1 shows carbon stocks in four pools by seven categories of forests in Cambodia. These stocks were used for estimating C stocks changes, emissions, FRELs, and removals.
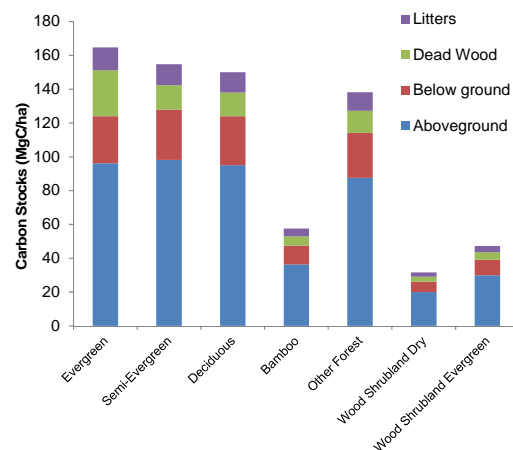


Fig. 1 Forest carbon stocks in four carbon pools by forest category in Cambodia

Deforestation between 2002 and 2006 was responsible for carbon emissions of about 77.6 TgCO$_2$ yr$^{-1}$ but increase in forest area

in some provinces sequestered about 20.5 $TgCO_2 \cdot yr^{-1}$. Further analysis by forest category at provincial level was performed to obtain the trend parameters, which were used to estimate FREL and carbon removals. The latter was due to increase in forest area. Subnational FREL (provincial) was analyzed and adjusted every five-year interval (0-5, 6-10, 11-15, 16-20, and 26-30). The FRELs by interval allow necessary adjustment of FREL every 5 to 10 years to reflect the change in government policies and availability of forest area.

Figure 2 shows subnational FREL in all provinces in Cambodia. Battambang, Odor Meanchey, Preah Vihear, Siem Reap, and Banteay Meanchey provinces have higher FREL, suggesting that more reductions may be achieved if appropriate policies are introduced to address the drivers of deforestation such as unplanned clearing of forests and land economy concessions.
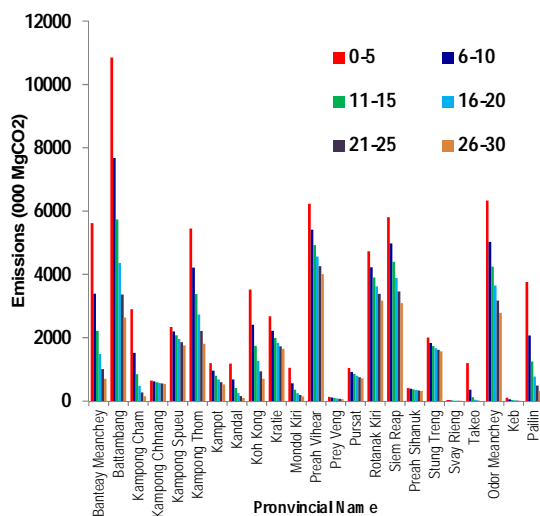


Fig. 2 Subnational FRELs over a 30-year timeframe in Cambodia

National FRELs were estimated at 69.2, 51.9, 42.1, 35.4, 30.5, and 26.8 $TgCO_2 \cdot yr^{-1}$ for 0-5, 6-10, 11-15, 16-20, 21-25, and 26-30 year intervals, respectively.

Removals (carbon sequestration) due to increase in forest area varied depending on the assumed harvesting of the newly established forests. Using a clear-cut and re-planting of 10-year interval, total removals in all forests ranged from 16.1 $TgCO_2$ in the first year and increased to 58.3 $TgCO_2$ in the $30^{th}$ year of the timeframe (Figure 3). If the current rate of forest increase is maintained, future carbon emissions can be compensated by carbon sequestration.
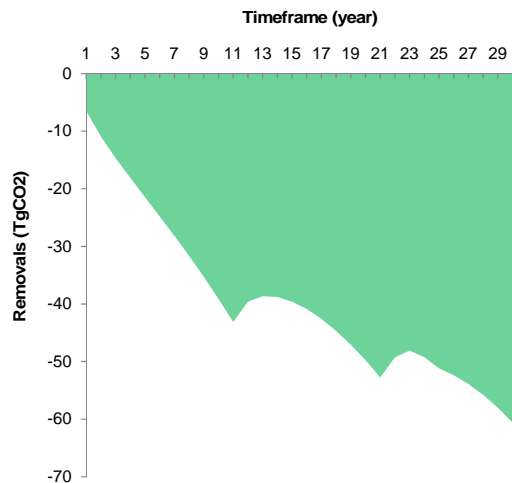


Fig. 3 Carbon removals due to increase of forest area over a 30-yr timeframe

Although understanding FREL and removal can provide a basis for implementing the REDD+ projects, identification of drivers of deforestation and forest degradation allow appropriate introduction of effective policy interventions that will lower emissions below the FREL (subnational and national level). The more emission reductions are achieved, the more financial compensation is provided to developing countries.

Based on analysis of socio-economic data, the following drivers were identified, namely the uncontrolled practices of land concession, forest clearing for agricultural plantation and settlement, illegal logging, wood collection for commercial purposes such as charcoal producing and household woodfuel consumption. Depending on effectiveness of policy interventions introduced to reduce drivers, emission reductions for all forest categories were estimated to be 17.5, 43.1, 35.6, 29.1, 24.0, and 20.3 $TgCO_2 \cdot yr^{-1}$, for 0-5, 6-10, 11-15, 16-20, 21-25, and 26-30 year intervals, respectively.

This project provides useful information such as change in forest cover, carbon stocks, FREL, removals, and drivers of deforestation and forest degradation for development of MRV system for tropical countries. Creating publicly accessible platform for the purpose of MRV of the implementation and result-based performance can ensure transparency of the REDD+ projects.

Deciding FREL for any country needs to be carefully made taking into consideration data availability, economic

and population growth and with support of scientific research because failing to lower emissions below the FREL will disqualified the concerned country from receiving financial compensation. In worse case, that country would be fined for their failure. Recent data on forest cover change is important for retrospective approach because deciding FREL is affected by the past trend of forest cover.

Kindermann, G., et al. (2008) Global cost estimates of reducing carbon emission through avoided deforestation. *PNAS USA*, 105, 10302-10307.

Sasaki, N & Yoshimoto, A (2010) Benefits of tropical forest management under the new climate change agreement—a case study in Cambodia. *Environmental Science and Policy* 13, 384-392.


9

Chan, S. and Sasaki, N (2014) Assessment of drivers of deforestation and forest degradation in Phnom Tbeng forest based on socio-economic surveys. *Journal of Environmental Protection* 5, 1641-1653. . DOI: 10.4236/jep.2014.517155

Aye, Y.Y., Pampasit, S., Unponstira C, Thanacharoenchanaphas, K, Sasaki N (2014) Estimation of carbon emission reductions by managing dry mixed deciduous forest: case study in Popa Mountain Park. *Low Carbon Economy* 5, 80-93. DOI: 10.4236/lce.2014.52009

Sasaki, N, Abe, I., Khun, V., Chan, S., Ninomiya, H, Chheng, K (2013) Reducing carbon emissions through improved forest management in Cambodia. *Low Carbon Economy* 4, 55-67. DOI: 10.4236/lce.2013.44A006

Chan, S., Sasaki N (2013) Reducing deforestation and forest degradation in Phnom Tbeng forests. *International Journal of Environmental and Rural Development* 4-1, 19-24

Koy, R, Sasaki, N (2013) Assessment of local livelihood of forest-dependent communities in Cambodia. *International Journal of Environmental and Rural Development* 4-1, 63-68

Sasaki, N, Chheng, K, Ty, S. (2012)

Managing production forests for timber production and carbon emission reductions under the REDD+ scheme. *Environmental Science & Policy* 23, 35-44
DOI: 10.1016/j.envsci.2012.06.009


19

Sasaki, N Accounting for Forest Carbon Stocks and Emission Reductions or Removals. Training Workshop 2015: Capacity Building on Climate Change Mitigation and Benefits in Forest Sector. 8-15 January 2015

Sasaki, N and Long, K Carbon Emission Reductions in a REDD+ Pilot Project in Oddar Meanchey. Training Workshop 2015: Capacity Building on Climate Change Mitigation and Benefits in Forest Sector. 8-15 January 2015

Sasaki, N Carbon Emission Reductions and Removals in Cambodia under the REDD+ Scheme. 17th FEFCO Seminar on 22 January 2015.

Sasaki, N Accounting for Carbon Emission Reductions and Removals in Selectively Logged Forests: Implications for Timber and Carbon Management. REDD+ Symposium Carbon Emission Reductions and Removals in Tropical Forests, 22-23 February 2014,

Chan, S., Sasaki, N and Ninomiya, H Socio-economic Values of Phnom Tbeng Forests: Assessment and Implications for Safeguarding. REDD+ Symposium Carbon Emission Reductions and Removals in Tropical Forests, 22-23 February 2014,

Khun, V. Sasaki, N and Ninomiya, H Carbon Stocks and Tree Diversity in Seima's Deciduous Forest. REDD+ Symposium Carbon Emission Reductions and Removals in Tropical Forests, 22-23 February 2014,

San, V. and Sasaki, N Fuelwood Consumption Rate for Producing Charcoal and Palm Sugar in Chumriey Mountain Area in South western Kampong Chhnang Province, Cambodia. REDD+ Symposium Carbon Emission Reductions and Removals in Tropical Forests, 22-23 February 2014,

Sasaki N and Chheng, K, Sokh, H,

Khun, V., Mizoue, N Carbon Emission Reductions and Removals in Cambodia under the REDD+ Scheme. Asia Forest Workshop 2013: Interdisciplinary Discussion on Multiple Impacts of Forestry and Land use Change in Tropical Asia. 3-4 December 2013,

Sasaki, N Understanding the "Sustainable Management of Forests" Element of the United Nations REDD+. 27 September 2013

Khun, V., Sasaki, N Estimation of biomass expansion factors for deciduous forest in Cambodia. Asia Forest Workshop 2013: Interdisciplinary Discussion on Multiple Impacts of Forestry and Land use Change in Tropical Asia. 3-4 December 2013,

Koy, R., Sasaki, N Assessment of local livelihood of forest-dependent communities in Cambodia. The 4th ICERD-International Conference on Environmental and Rural Development. 19-20 January 2013,

Chan, S., Sasaki, N Reducing deforestation and forest degradation in Phnom Tbeng forests. The 4th ICERD-International Conference on Environmental and Rural Development. 19-20 January 2013,

Sasaki, N, Kimsun, C, Mizoue, N Carbon and biodiversity loss due to forest degradation - a Cambodian Case Study. Invited talk at the Synthesis Workshop on Options for Monitoring Forest Degradation at Sub-national Levels in the Mekong organized by USAID-LEAF. 13-14 November 2012,

Sasaki, N Managing tropical forests for timber, carbon, and biodiversity conservation. Invited talk at the International Symposium on Southeast Asian Tropical Rain Forest Research related with Climate Change and Biodiversity. 25-26 September 2012

Sasaki, N (2015, Academic Editor) Carbon Emission Reductions and Removals in Tropical Forests". A special issue of *Land* (ISSN 2073-445X).

MDPI, Zurich. http://goo.gl/5dOUgd
117

(1)
SASAKI, Nophea

90382275

(2)
NINOMIYA, Hiroshi

10140740