Methodologies of tropical forest carbon monitoring: Development and state-of-the-art for REDD+

International Symposium on Southeast Asian Tropical Rain Forest Research related with Climate Change and Biodiversity, 25th-26th Sep. 2012, Tokyo

Kiyono Yoshiyuki

FFPRI

Forestry and Forest Products Research Institute (FFPRI), Japan

Contents

- Introduction
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How to measure and monitor forest carbon


What will we do by REDD+?

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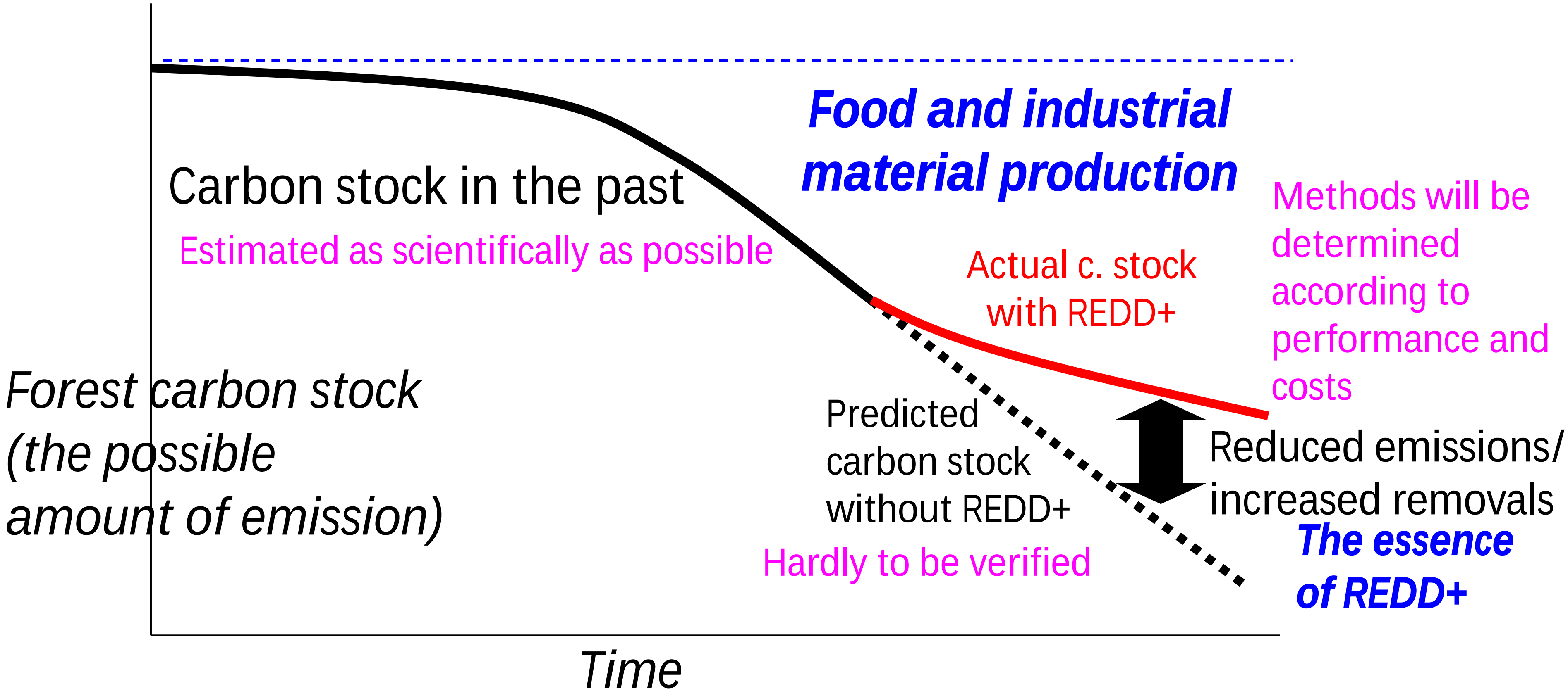
Reducing Emissions from Deforestation in Developing countries and REDD-plus are new mechanisms…..



….to foster reduction of "deforestation and forest degradation (DD)" by inputting international support funds using market mechanisms etc. into developing countries under DD. The UN-rules are not yet determined. However, the trend in amount of anthropogenic GHG emissions from DD will be needed to be predicted, reduced by anthropogenic effort, and monitored with MRV. International support funds will be provided based on the emission reduction.

What will we do by REDD+?

As a conclusion,
REDD+ does not only control vegetation,
but also replace people's present land-use.

<u>The balance of nature (incl. anthropogenic activities) is a key to REDD+.</u>

The success of REDD+ also depends on whether it is managed and run properly in collaboration with local people, who are supposed to play the primary role.

Requirements for forest c. monitoring methods for REDD+

- Accuracy
  - Less errors in each element
  - Covering all important elements

Biomass, CH_4, soil・・・・.

- Large-scale
- High frequency (semi-real time)
- Choices
  - Cause of DD, data availability, cost, etc.

Important assessment in the 2 different ecosystems

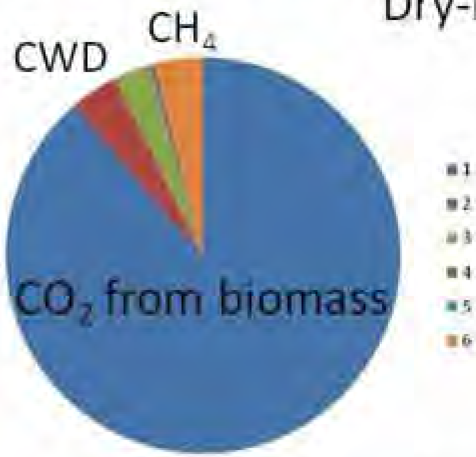
Dry land forests

Drained peat swamp forest

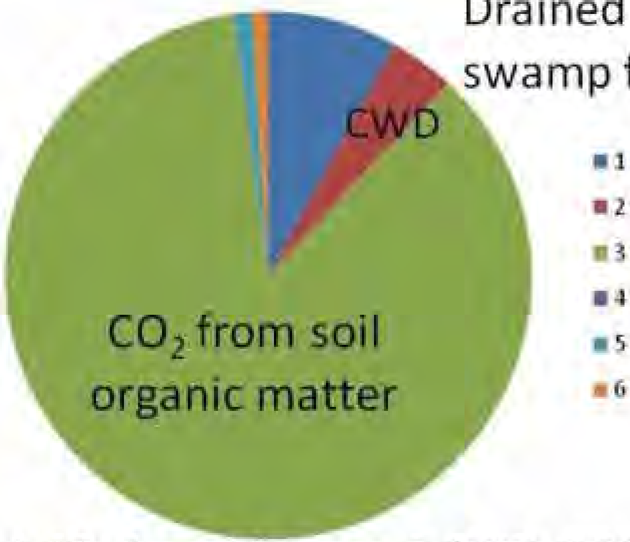
Importance assessment

Modified from Kiyono et al. (2011)

Dry-land forest



Drained peat swamp forest



1:CO_2 from biomass, 2:CWD, 3:SOM, 4:N_2O biomass burning, 5:SOM mineralization, 6:CH_4 biomass burning

	Subcategory	Estimates with the project data (Mg-CO_2 ha^{-1} 10 y^{-1})	Importance
Dry land forest in the test-site in Cambodia			
CO_2	Biomass (aboveground and belowground)	377 (108-517)	89%
	Deadwood, litter	16 (0-19)	4%
	SOM	13 (5-22)	3%
N_2O	Fire	2 (0.3-3)	0.4%
	SOM mineralization	0	0%
CH_4	Fire	17 (3-31)	4%
	Total	425 (116-592)	100%
Drained peat swamp forest in the test-site in Indonesia			
CO_2	Biomass (aboveground and belowground)	60 (39-83)	8%
	Deadwood, litter	37 (29-43)	4%
	SOM	762	86%
N_2O	Fire	1 (1-1)	0.1%
	SOM mineralization	9 (0-37)	1%
CH_4	Fire	9 (7-11)	1%
	Total	878 (838-937)	100%

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A flow for estimating GHG emissions/removals in forest and REDD+ effects

Forest carbon stock = Forest area x Averaged carbon stock per land area

Base map ← Ground truth

Semi- automatic classification

The present challenges

↓

Series of remote sensing images

Simplified/accurate methodologies

↓

DD areas detection by monitoring forest land

↓ ← **Carbon stock per land area for main forest types**

Estimates of carbon stock change (GHG emissions/removals)

↓ ← **Scenarios emissions/removals without REDD+**

Estimates of REDD+ effects (GHG emission reduction)

A matrix for choices of methods (Revised from Kiyono et al. 2011 http://www.jircas.affrc.go.jp/english/publication/jarq/45-2/45-02-14.pdf)

Objective variables	Approaches		Requirements	Costs	Getting data in a large land area	Technical difficulties	Applicability of the method in estimating anthropogenic GHG emissions by each activity						Inprovement in accuracy expected by local people participating in the monitoring
							Conversion to crop land	Reducing fallow period of slash-and-burn agriculture	Logging	Fuel wood collection	Fire	Woody perennial plantation	
Forest area	Land cover classification		Optical spaceborne remote sensor with medium or higher resolution	Medium	Easy	・Not applicable when clouded	Partly possible	Partly possible	Partially possible	Partially possible	Partly possible	Partly possible	Low
			SAR with microwaves longer than L-band	Medium	Easy	・Not applicable to areas with steep slopes	Partly possible	Partly possible	?	?	Partly possible	Partly possible	Low
			Airborne LiDAR, Aerial photograph	High	Medium	・Nothing in particular	Possible	Possible	Partially possible	Partially possible	Possible	Possible	Low
Carbon stocks and GHG fluxes per unit land area	Gain-loss method	Growth rate, removal rate	Measurement on the ground	?	Difficult	・Methods are not tested	?	?	?	?	?	?	High
	Stock difference method	PSP data	Measurement on the ground	High	Difficult	・Limitation in representativeness and secretness of plot	Possible	Possible	Possible	Possible	Possible	Possible	High
		Community age	Remote sensor with medium or higher resolution	Medium	Easy	・Applicable to land use with periodical naked land stages e.g. slash-and-burn farming	Impossible	Possible	Impossible	Impossible	Impossible	Possible	Low
		Crown diameter	Remote sensor with high resolution Aerial photograph	High	Medium	・Not applicable when clouded ・Crowns are hardly recognized in some forests	Partly possible	Impossible	Partly possible	Impossible	Impossible	Impossible	Low
		Overstory height	Multi-polarization SAR	Low	Medium	・Methods are not tested ・Applicable to small parts of globe	?	?	?	Impossible	?	?	Low
			Airborne LiDAR	High	Difficult	・Nothing in particular	Possible	Possible	Possible	Impossible	Possible	Possible	Low
			Stereo mapping remote sensor (DSM)	Medium	Easy	・Not applicable when clouded ・Methods are not tested	?	?	?	Impossible	?	?	Low
			Measurement on the ground	?	Difficult	・Methods are not tested	Possible	Possible	Possible	Impossible	Possible	Possible	High
		Backscattering-coefficients	SAR with microwaves longer than L-band	Low	Medium	・Not applicable to areas with steep slopes ・Not applicable to high biomass	Partly possible	Partly possible	Impossible	Impossible	Partly possible	Partly possible	Low

3 approaches are available for monitoring forest area

1) Spaceborne optical sensors	Pa: cloud problem
2) Spaceborne microwave sensors	Pa: topog. problem
3) Airborne media (e.g. LiDAR)	Expensive

5 approaches for monitor. carbon stock per land area,

1) Permanent sampling plots (PSPs)	Practical
2) Plant community-age	Pa
3) Crown diameter	Pa
4) Overstory height	Under test
5) Backscattering coefficients of PALSAR	Pa

Pa: partly or partially available.

A case study for estimating nationwide forest biomass carbon stock in Cambodia

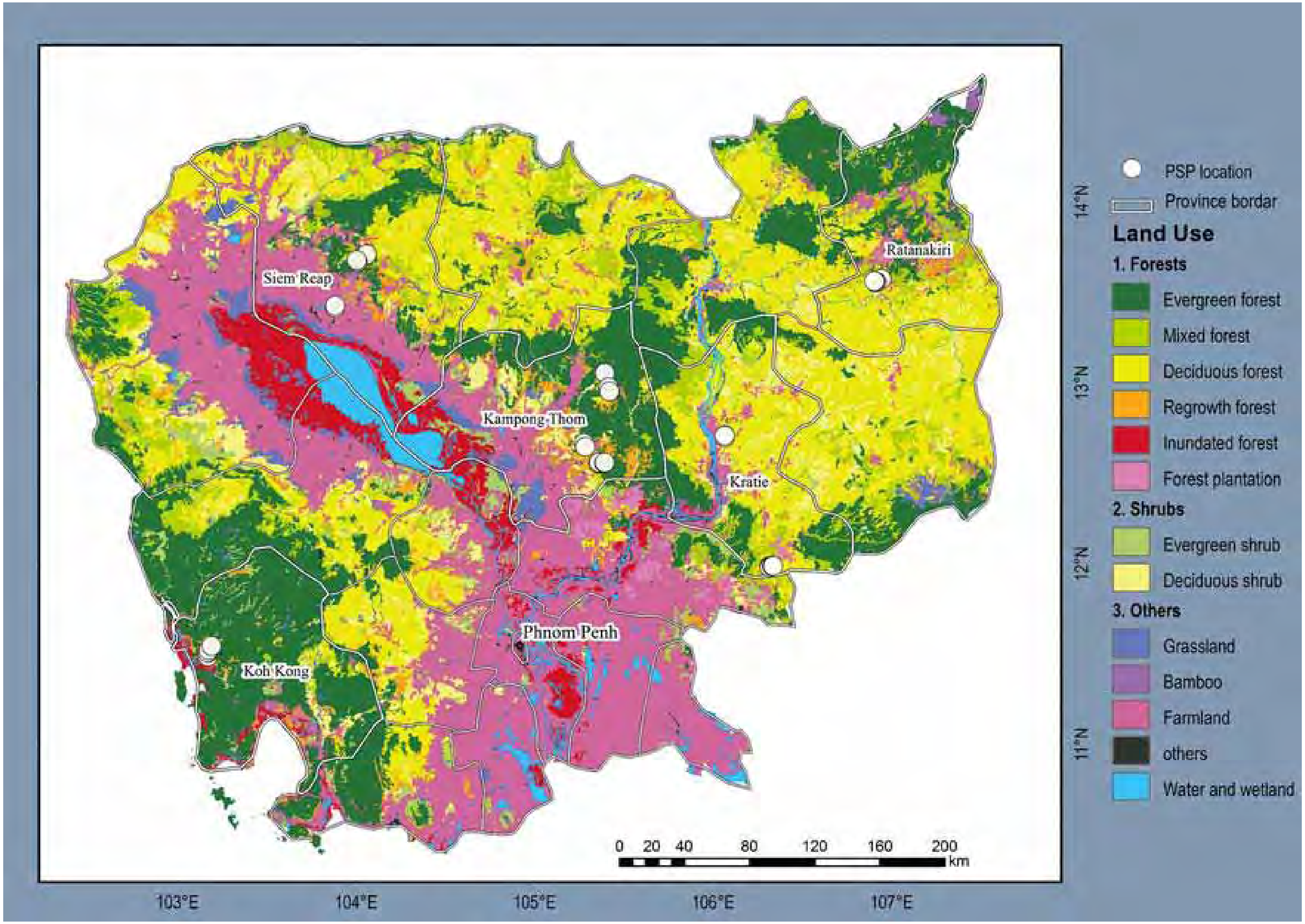
Forest Classification in Cambodia

Type	Area (ha)	Ratio (%)
Evegreen forest	3,668,902	34.2
Semi-evergreen forest	1,362,638	12.7
Deciduous forest	4,692,098	43.7
Bamboo forest	35,802	0.3
Wood shrubland (evergreen)	37,028	0.3
Wood shrubland (deciduous)	96,387	0.9
Other forest	837,926	7.8
Forest total	10,730,781	100.0

Modified by the authors from Forestry Administration (2010).

Samreth et al. (2012) http://www.jircas.affrc.go.jp/english/publication/jarq/46-2/46-02-10.pdf

Forest cover of Cambodia and PSPs by Forestry Administration



Samreth et al. (2012) http://www.jircas.affrc.go.jp/english/publication/jarq/46-2/46-02-10.pdf

PSP data and equations for biomass estimates

- 100 permanent sampling plots
  - 85 in evergreen forests (including semi-evergreen forests)
  - 15 in deciduous forests
- Plot size: 50 m x 50 m (2,500 m^2)
- DBH of trees ≧7.5cm in DBH, species

- Equations and parameters for estimating biomass carbon

Tree biomass=4.08 × $ba^{1.25}$ × $D^{1.33}$ (n = 530, R^2 = 0.981, p < 0.0001)

Applicable generically to tropical and subtropical trees with 1<DBH<133 cm.

ba: basal area (calculated from DBH), m^2;

D: basic density (determined with information of tree species);

Carbon fraction: 0.5

Samreth et al. (2012) http://www.jircas.affrc.go.jp/english/publication/jarq/46-2/46-02-10.pdf

The nationwide forest carbon stock in Cambodia (A tentative figure)

Forest type	Forest area In 2006 ha	Averaged carbon stock In 2000-2001 Mg-C ha^{-1}	Total carbon stock Tg-C
Evergreen forest*	5,031,540	163.8 ± 7.8	824.2 ± 39.2
Deciduous forest	4,692,098	56.2 ± 6.7	263.9 ± 31.3
Total	9,723,638		1,088.1 ± 50.2

* Including Semi-evergreen forest.
Carbon stocks are shown in mean ± standard error.

Samreth et al. (2012) http://www.jircas.affrc.go.jp/english/publication/jarq/46-2/46-02-10.pdf

Required number of sample plots for av. carbon stock at a 5% level of precision and a 95% confidence level

USD 336,000

- 336 plots
  - 260 for evergreen forest, 76 for deciduous forest
- Since most developed countries designed their NFIs (national forest inventories) at the same precision and confidence levels, a sampling design using 336 plots may be acceptable for most countries.
- However, forests in the PSPs are sometimes destroyed in the region under pressure of DD. A sufficient number of extra plots are vital and required number of plots should be monitored to be able to add extra plots if necessary.

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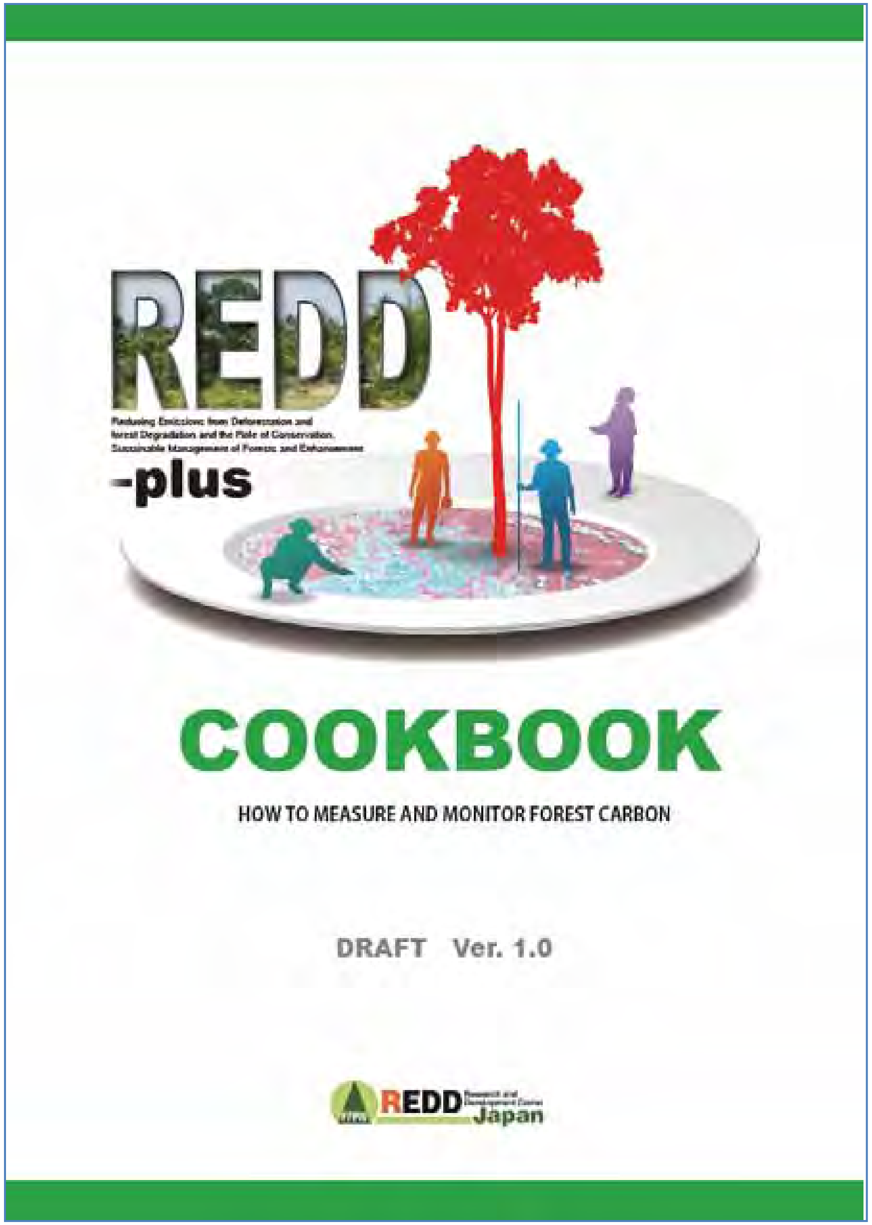
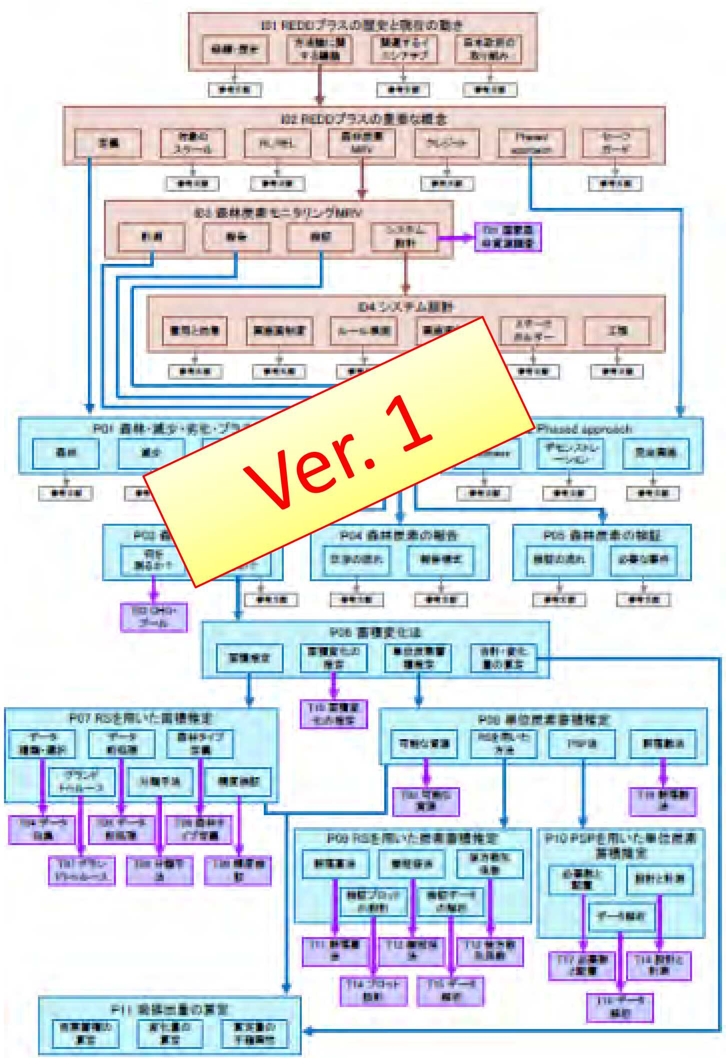


"Cook-book - How to measure and monitor forest carbon" *compiles our latest knowledge in forest carbon measurement.*

The book will be available at COP18-***Doha Climate Change Conference - November 2012***

REDD+ cookbook aims:



- To be a manual like an easy-to-understand cookbook.
- For governments (introduction), experts & their C/Ps, private consultants, NGOs (planning), researchers (technology) etc.
- Not only explaining each technology, but also piloting the procedure in combination with the technologies related to REDD+.

Conclusions

1. CO_2 emissions from biomass are the most important in the dry land forest, while in the drained peat swamp forest, CO_2 emissions from soil organic matter are the most important.

Considering requirements for carbon monitoring methods for REDD+,

2. Spaceborne optical sensors and microwave sensors are partly or partially available for monitoring forest area. Ground-based measurement is a practical approach for monitoring carbon stock per land area.
3. We estimated the nationwide forest carbon stock and required number of sample plots in Cambodia. By repeating this calculation, we could monitor the (historical) trend of forest carbon stock on a national scale and such data are useful to make reference (emission) levels.
4. More varied field data must be collected for improving methods.

Thank you for your attention.

kiono@ffpri.affrc.go.jp

Acknowledgement：

This research was conducted as part of the research program supported by the Ministry of the Environment, Japan and was partly supported by the emergency project to develop the structure of promoting REDD action funded by the Forestry Agency, Japan.