Findings in REDD related research programs in terms of the link between remote sensing and ground measurement

International Seminar on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD), 10-12 March, 2010, Tokyo, Japan

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3. Peat swamp forest under drainage influence (Indonesia)

Research programs supported by MoE, Japan

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Requirements for monitoring methods for REDD

- Accuracy
  - Less errors in each element
  - Covering all important elements
- Large-scale
- Semi-real time
- Choices
  - Cause of DD, data availability, cost, etc.

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Importance assessment of GHG subcategories in total potential of CO_2-e emission from forest degradation in the test-sites

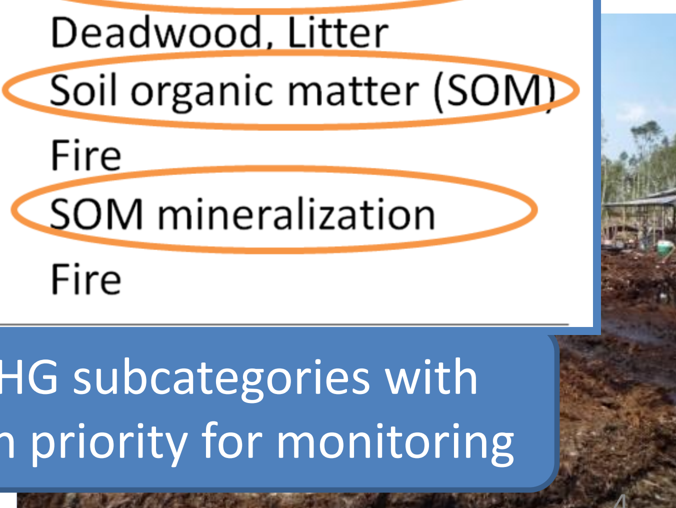
GHG	Subcategory
CO_2	AG and BG biomasses
	Deadwood, Litter
	Soil organic matter (SOM)
N_2O	Fire
	SOM mineralization
CH_4	Fire

GHG subcategories in forestland (IPCC 2003)

		from more or less ...oject data		Estimates from the default values in GPG (IPCC 2003)
		...356)		
		...36) >		
			0%	
		(3-31)		
		...37 (...		
Peat swamp forest in the test-site in Indonesia				
CO_2	Biomass (aboveground and belowground)	242 (197-347)		
	Deadwood, litter	<54 (43-63) >		
	SOM (0-30 cm depth)	<315>		
N_2O	Fire	3 (2-4)		
	SOM mineralization	<39> (0-117)		
CH_4	Fire	28 (22-35)		
		681 (580-881)	100%	

Important assessment using GPG-LULUCF

GHG	Subcategory
CO_2	AG and BG biomasses
	Deadwood, Litter
	Soil organic matter (SOM)
N_2O	Fire
	SOM mineralization
CH_4	Fire



GHG subcategories with high priority for monitoring

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Requirements for monitoring methods for REDD

- Accuracy
  - Less errors in each element
  - Covering all important elements
- Large-scale → Use of remote sensing data is indispensable
- Semi-real time → Use of SAR data may be useful
  - Radar overcomes haze and cloud cover
- Choices
  - Cause of DD, data availability, cost, etc.

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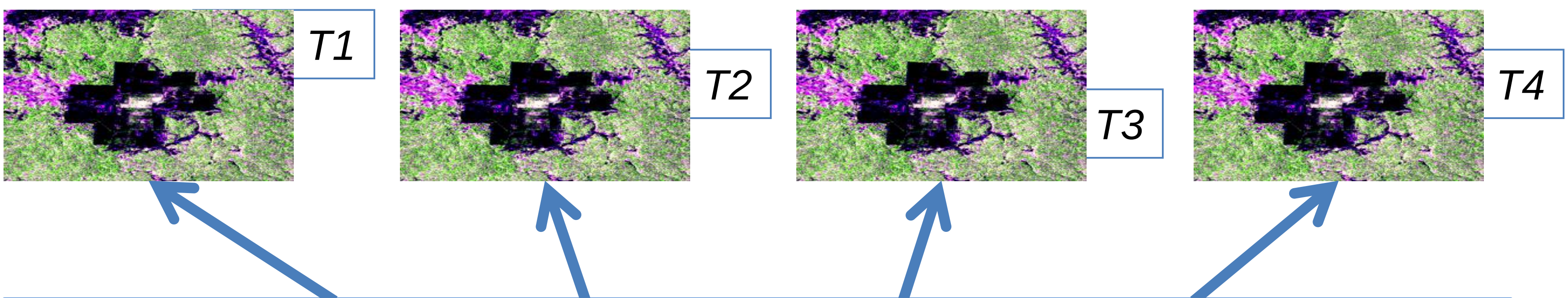
A proposed simplified method for estimating CO_2-e emissions from deforestation and forest degradation

- The method is the calculation of carbon stock change by monitoring forest land and periodically summing up the forest area and its averaged carbon stock for important forest types.



Σ (Forest area$_i$ x Averaged carbon stock$_i$) = Total carbon stock

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Choices of monitoring methods for REDD

Objective variables	Approaches		Requirements	Costs	Spatial scale up	Technical difficulties	Applicability of the approach in estimating anthropogenic GHG emissions by each activity: Conversion to crop land	Reducing fallow period of slash-and-burn agriculture	Logging	Fuel wood collection	Improvement in accuracy expected by local people participating in the monitoring
Forest area	Land cover classification		Remote sensor with medium or higher resolution	Medium	Easy	･Not applicable when clouded	Possible	Possible	Partially possible	Partially possible	Low
			SAR with microwaves longer than L-band	Medium	Easy	･Not applicable to areas with steep slopes	Possible	Possible	?	?	Low
Averaged carbon stock per unit land area	Gain-loss method	Growth rate, removal rate	Measureme… ground			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	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	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	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	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	High
		Backscattering-coefficients	SAR with microwaves longer than L-band	Low	Medium	･Not applicable to areas with steep slopes ･Not applicable to high biomass forest	Partly possible	Partly possible	Impossible	Impossible	Low

3 examples of choice

This table is applicable to dry land forest.

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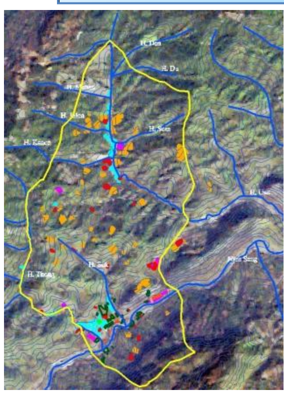
1. Secondary forest in slash-and-burn fallow land (Laos)

A flow for estimating chronosequential changes in carbon stock in slash-and-burn fallow land

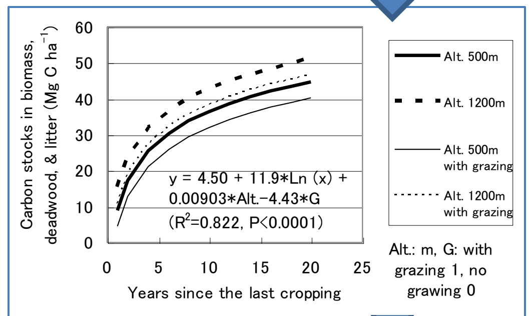
Chronosequential analysis of satellite images of Landsat/ETM+, ASTER, etc.



Time and spatial distribution of cropping land

Oral history

Plot setting and ground measurement



Relationship between Community age and carbon stock

Changes in land area for slash-and-burn agriculture

Changes in mean fallow period

Fallow-period-average carbon stock

Chronosequential changes in carbon stock

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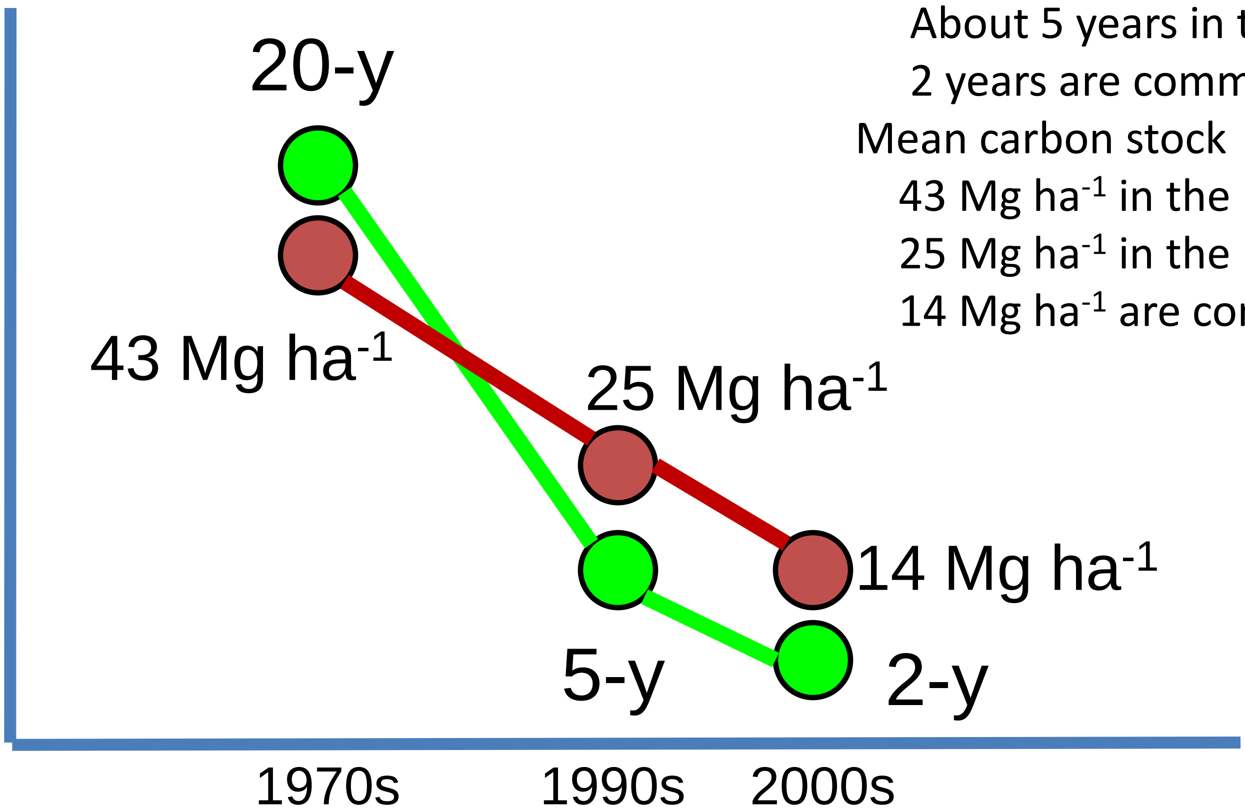
- Fallow period and carbon stock have been drastically reduced in northern Laos



Mean fallow period

About 20 years in the 1970s*

About 5 years in the 1990s*.

2 years are common in the 2000s.

Mean carbon stock

43 Mg ha^{-1} in the 1970s

25 Mg ha^{-1} in the 1990s

14 Mg ha^{-1} are common at present

* Roder, 1997.

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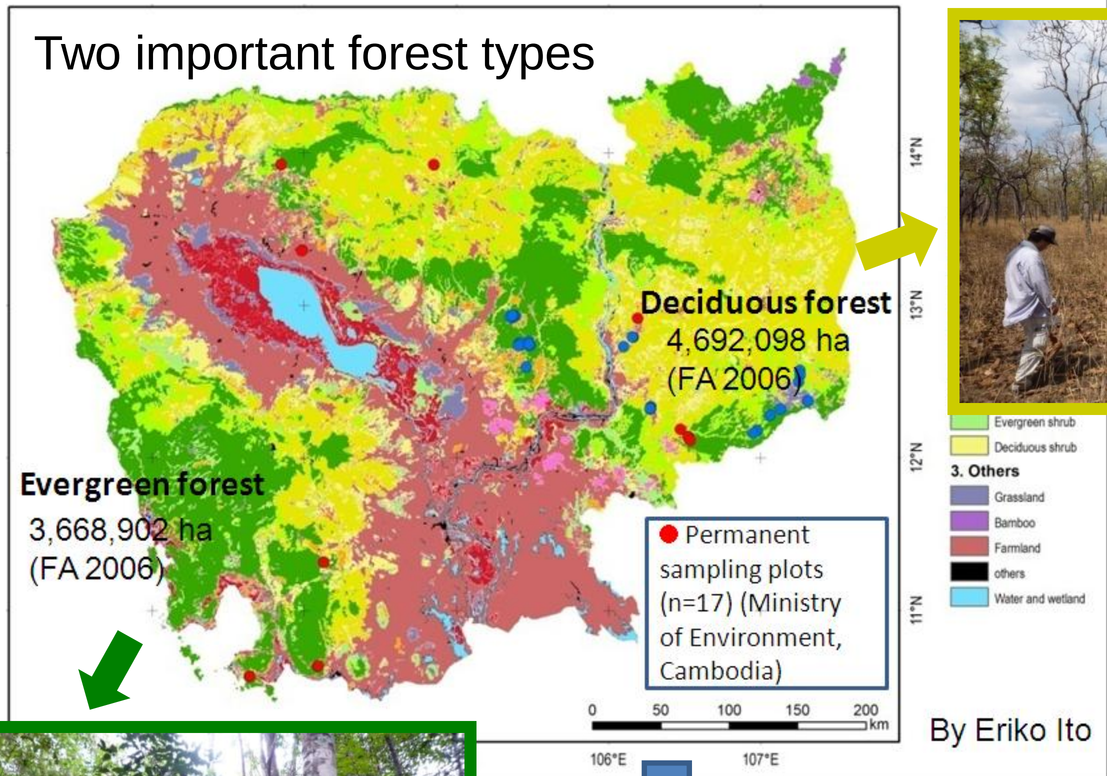
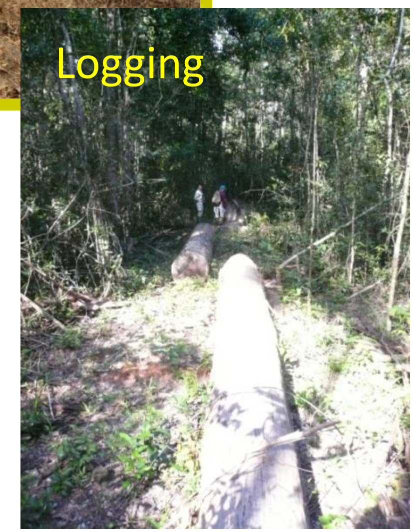
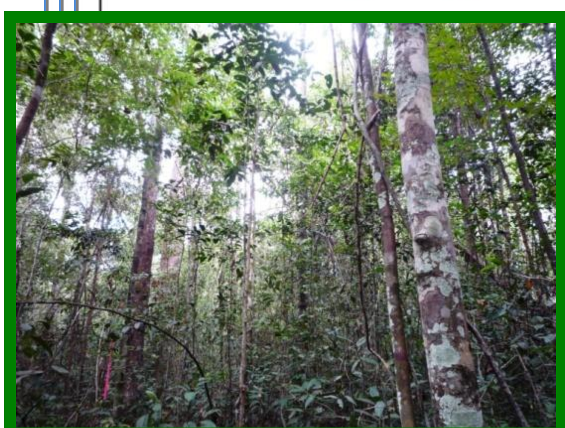
2. Nationwide forest (Cambodia)







A flow for estimating nationwide forest carbon stock

Σ (Forest area$_i$ x Averaged carbon stock$_i$) = Total carbon stock

Chronosequential analysis of satellite images of Landsat

Monitoring vegetative changes in permanent sampling plots (PSPs)

Stratification

Existing PSPs were combined and redesigned.
Number of PSPs required?

Changes in forest area of important forest types

Changes in averaged carbon stock of important forest types

Chronosequential changes in carbon stock

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Data for averaged carbon stock

- 155 permanent sampling plots (PSPs)
  - 17 by Ministry of Environment , Cambodia
  - 138 by Forestry Administration, Cambodia
- Plot area: 2,000–2,500 m^2
- DBH of trees ≧5 cm in DBH, species
- Equations and parameters for estimating biomass carbon

Leaf weight: $Wl = 173\ \boldsymbol{ba}^{0.938}$ ($n = 509$, $R^2 = 0.780$, $P < 0.001$)

Branch weight: $Wb = 0.217\ \boldsymbol{ba}^{1.26}\ \boldsymbol{D}^{1.48}$ ($n = 509$, $R^2 = 0.910$, $P < 0.001$)

Stem weight: $Ws = 2.69\ \boldsymbol{ba}^{1.29}\ \boldsymbol{D}^{1.35}$ ($n = 509$, $R^2 = 0.971$, $P < 0.001$)

Root weight: $Wr = 0.500\ \boldsymbol{ba}^{1.20}\ \boldsymbol{D}^{1.33}$ ($n = 509$, $R^2 = 0.943$, $P < 0.001$)

ba: basal area, m^2; ***D***: basic density; Carbon fraction: 0.5

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Other carbon pools are negligible or not available

- Understory and litter:
  Destructively sampled.
- Deadwood:
  Non-destructively sampled.
- SOM:
  Not considered at present because no data available.

The averaged carbon stock (PSPs)

Evergreen forest 140.0 ± 89.5 (SD) Mg-C ha^{-1} (n = 117)

Deciduous forest 74.5 ± 49.9 (SD) Mg-C ha^{-1} (n = 38)

- UNFCCC provided a tool applicable for carbon-stock-monitoring purposes and estimates the number of permanent sample plots (PSPs) needed for monitoring changes in carbon pools at a desired precision level and the costs of establishment of the plots. http://cdm.unfccc.int/Reference/tools/ar/methAR_tool03_v01.pdf

- Numbers of PSPs required for reliable estimation were 66 for EF and 50 for DF. Additional 12 DF PSPs are needed.

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The nationwide forest carbon stock (Cambodia) (tentative)

Σ (Forest area$_i$ x Averaged carbon stock$_i$) = Total carbon stock

Forest type	Forest area	Averaged carbon stock	Total carbon stock
	km^2	Mg-C ha^{-1}	Tg-C
EF	36,689	140.0 ± 89.5	513.6 ± 328.3
DF	46,921	74.5 ± 49.9	349.4 ± 234.3
Total	83,610		863.0 ± 403.3

3. Peat swamp forest under drainage influence (Indonesia)

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A flow for estimating carbon stock of peat swamp forest under drainage influence

Σ (Forest area$_i$ x Averaged carbon stock$_i$) = Total carbon stock

Chronosequential analysis of satellite images of Landsat/ETM+ and ALOS PALSAR

↓

Changes in forest area of important forest types

↓

Monitoring vegetative and peat soil changes in PSPs

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Changes in averaged carbon stock of important forest types

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Chronosequential changes in carbon stock

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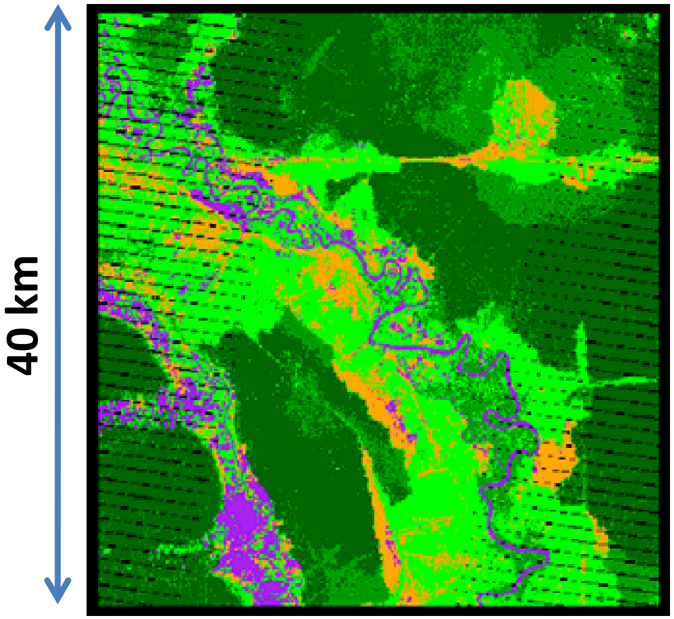
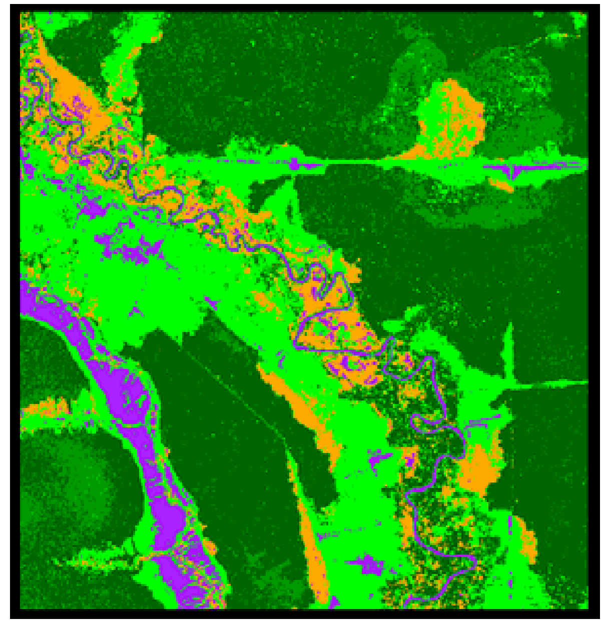
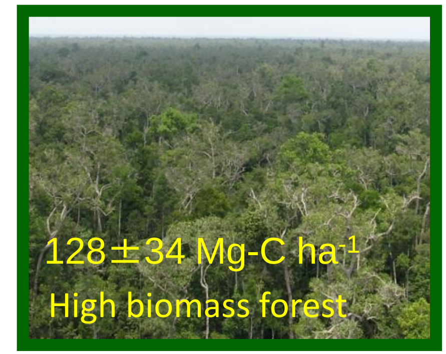
Land-cover classification by Landsat/ETM+ and ALOS PALSAR data

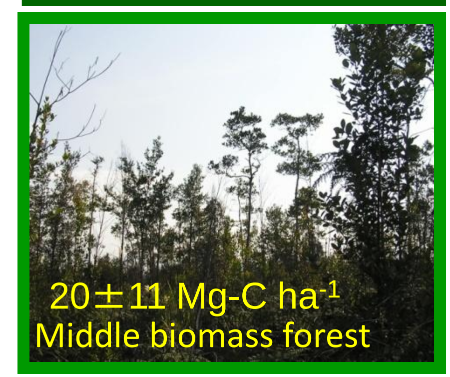


By Landsat/ETM+



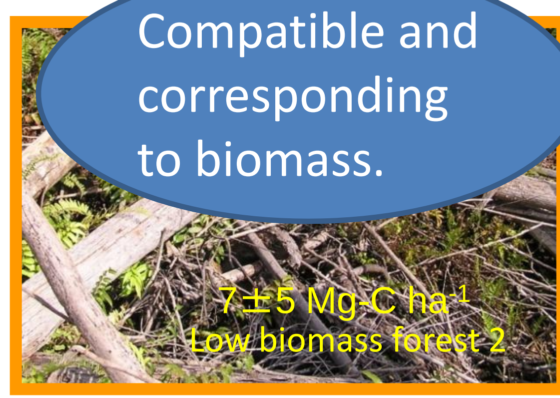
By ALOS PALSAR ©JAXA, METI





- High biomass forest
- Middle biomass forest
- Low biomass forest 1
- Low biomass forest 2
- Water

Compatible and corresponding to biomass.



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Takahashi et al. 2009

The forest carbon stock in the test site (Indonesia) (tentative)

	Forest type	Forest area km^2	Averaged carbon stock $Mg\text{-}C\ ha^{-1}$	Total carbon stock Tg-C
Landsat /ETM+	High BF	677	128 ± 34	8.7 ± 2.3
	Middle BF	297	20 ± 11	0.6 ± 0.3
	Low BF1	491	4 ±2	0.2 ± 0.1
	Low BF2	148	7 ±5	0.1 ± 0.1
	Total	1,726		9.6 ± 2.3
ALOS PALSAR	High BF	850	ditto	10.9± 2.9
	Middle BF	195	ditto	0.4 ± 0.2
	Low BF1	489	ditto	0.2 ± 0.1
	Low BF2	151	ditto	0.1 ± 0.1
	Total	1,799		11.6 ± 2.9

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- By moderately classifying forest types, using land-area data on each forest type, and determining averaged carbon stock of each forest type, we can expect a reasonably accurate estimation of carbon stock of the region.
- However, in reality **half** (Cambodia) and **two-thirds** (Indonesia) of the forests in the sampling plots were destroyed or heavily logged or burnt and declining carbon stock occurred within 3 years of observation.

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- A sufficient number of extra plots and frequent updating of forest area and its averaged carbon stock data are vital in the region under pressure of DD.
- ALOS PALSAR data have enough potential for extracting forest area of important forest types similar to Landsat/ETM+ data and may have advantage of possibilities of semi-real time (frequent) monitoring of forest land.

Once 46-days

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Conclusions

- Requirements for monitoring methods for REDD may include accuracy, large scale, semi-real time, and choices for tiers.
- A proposed simplified method is the calculation of carbon stock change by monitoring forest land and periodically summing up the forest area and its averaged carbon stock for important forest types.
- Reasonably accurate estimation of carbon stock can be expected by classifying forest types, using forest-area data on each forest type by remote-sensing, and determining averaged carbon stock of each forest type by the ground measurement.
- ALOS PALSAR may have the advantage of possibilities of semi-real time monitoring of forest land.
- Approaches using PSPs are considered to be robust. However, in the region under pressure of DD, a sufficient number of extra plots and frequent updating of data are vital.

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Thank you for your kind attention.

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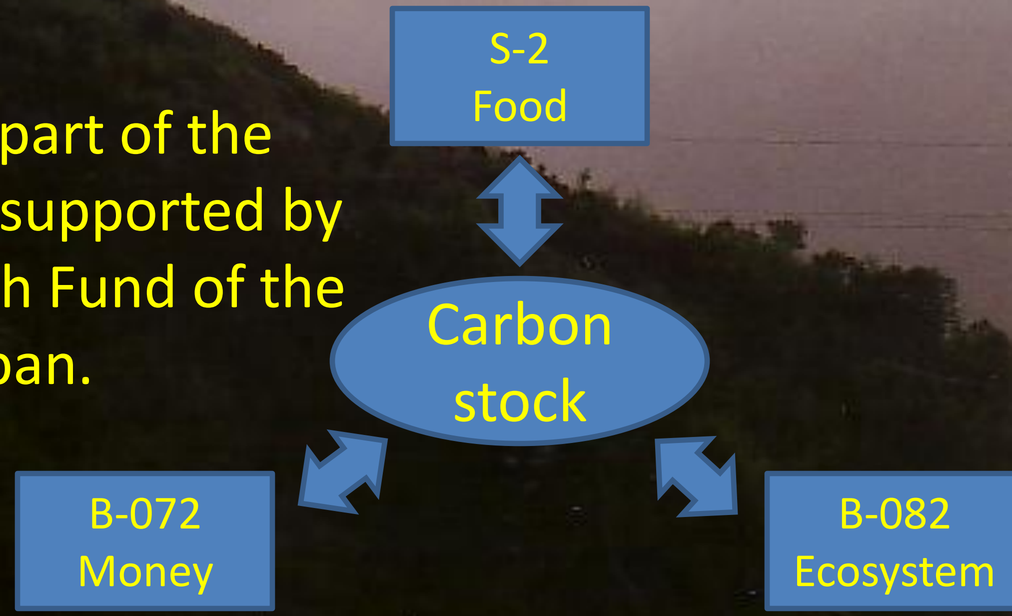

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