Methods for estimating anthropogenic GHG emissions from tropical forests under the pressure of deforestation and forest degradation

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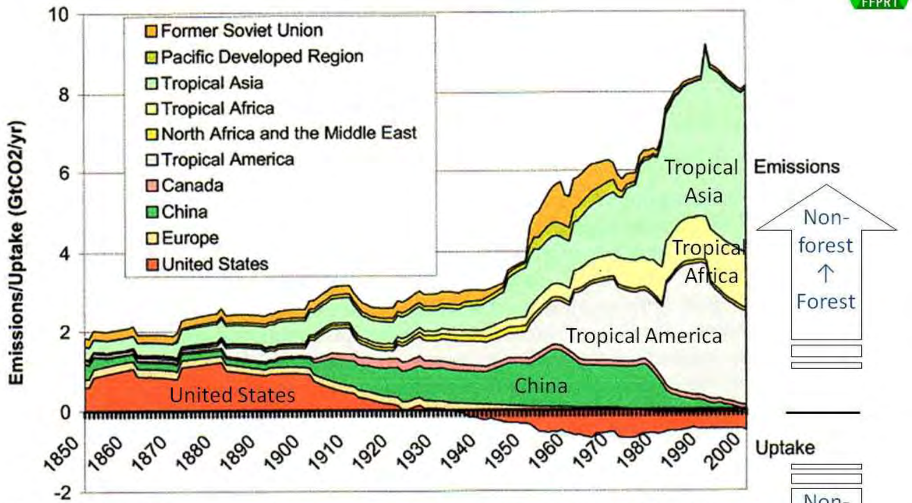
Contents

- How human being changes the tropical forest?
  - The patterns occurred in East Kalimantan, Indonesia
  - What will we do by REDD?
- Methods for estimating anthropogenic GHG emissions from tropical forests under the pressure of deforestation and forest degradation
  - Choices
  - Estimates of the nationwide forest carbon stock in Cambodia
- Requirements for the methods used in REDD+



Modified from http://www.hm-treasury.gov.uk/media/B/D/annex7f_land_use.pdf

Important direct DD drivers in the tropics

In general,

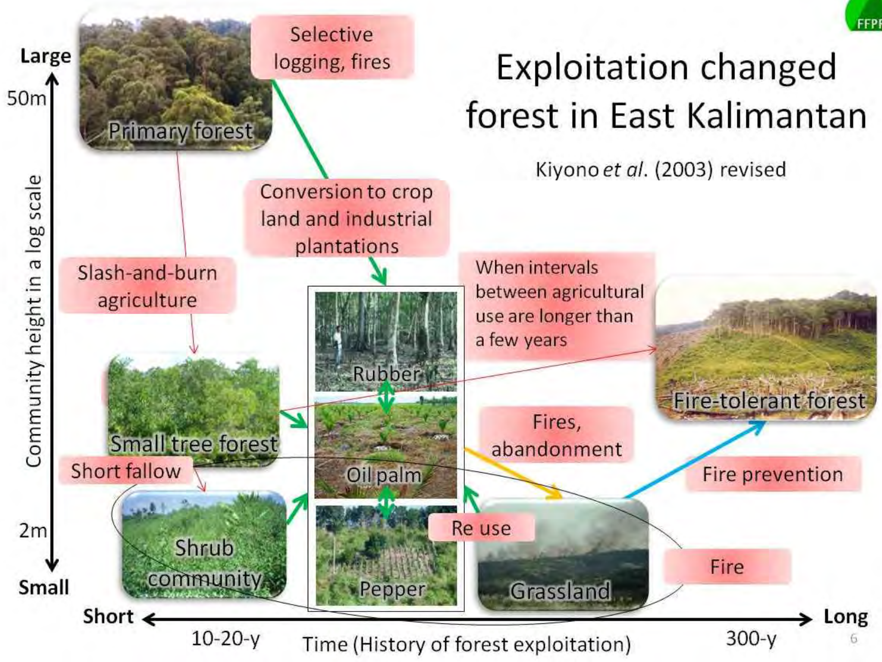
- conversion to crop land: Since the colonial period. For sugar cane, coffee, rubber, clove, pepper etc.
- SEA: In particular, induced by load construction for commercial logging.
- Amazon: In particular, induced by load construction for large-scale pasture establishment.
- Africa, South Asia, Central America: In particular, overuse of forest for fuels etc. by the increased population.

Geist and Lambin (2002)

The patterns occurred in East Kalimantan, Indonesia

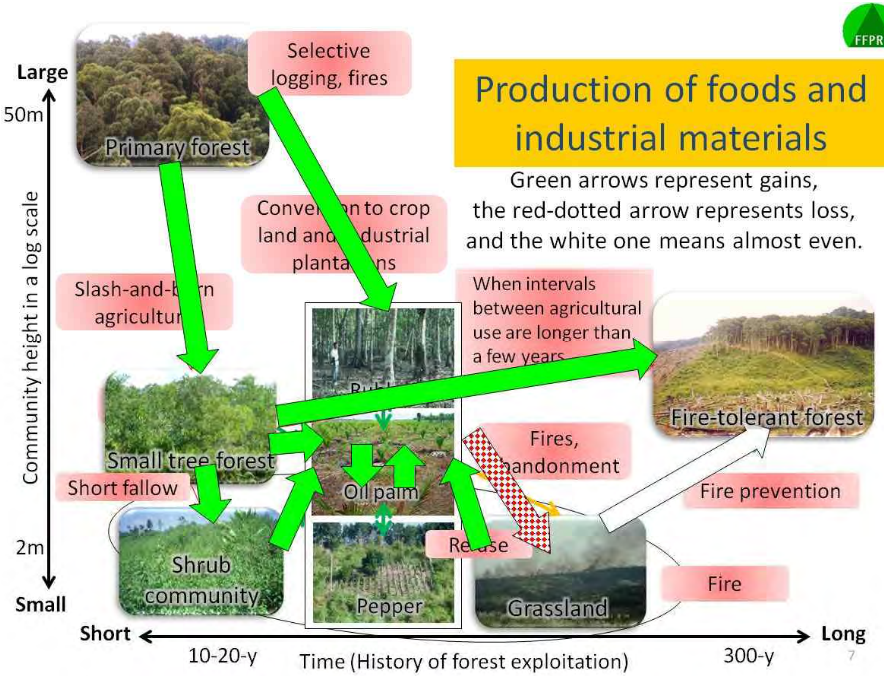
Exploitation changed forest in East Kalimantan

Kiyono *et al.* (2003) revised



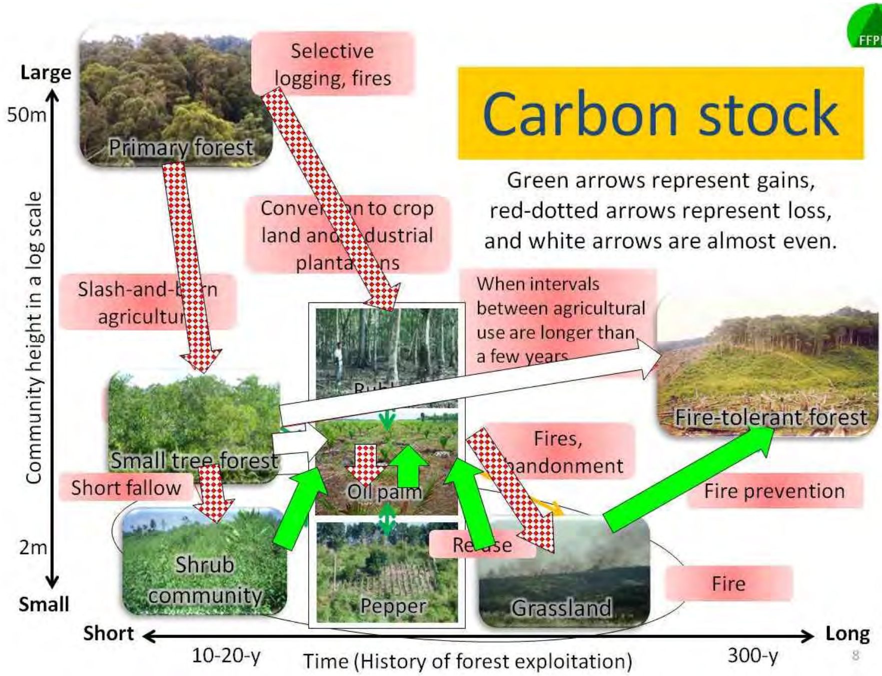
Production of foods and industrial materials

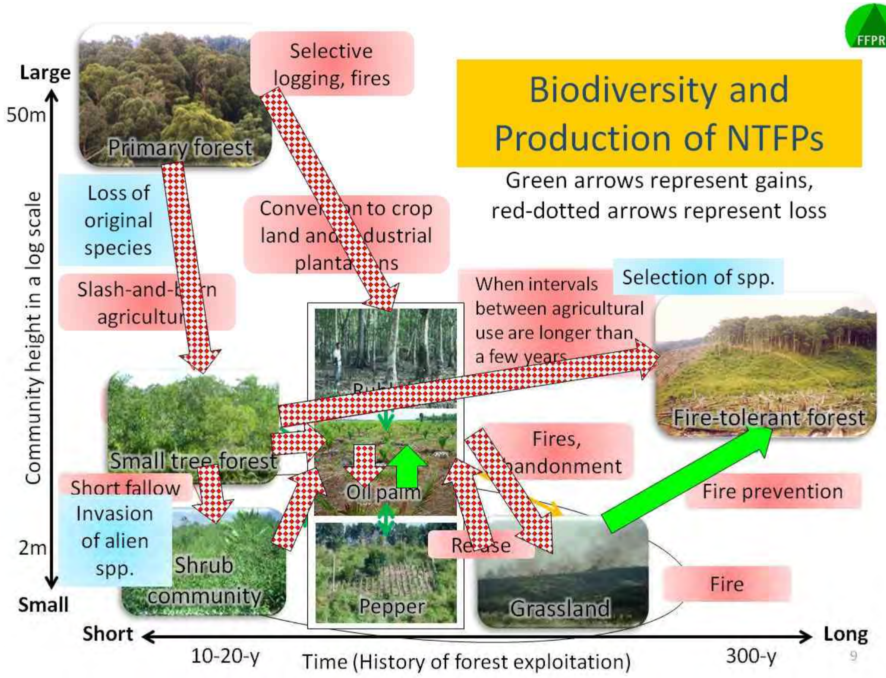
Green arrows represent gains, the red-dotted arrow represents loss, and the white one means almost even.



Carbon stock

Green arrows represent gains, red-dotted arrows represent loss, and white arrows are almost even.





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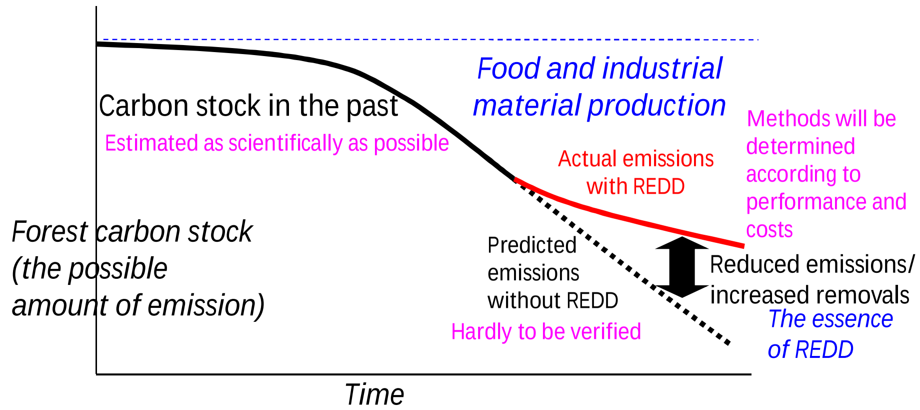
What will we do by REDD?

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 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.

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What will we do by REDD?

REDD+ does not only control vegetation, but also replace people's land-use systems with different systems.

The balance of nature (incl. art) is a key to the REDD+.

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

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A flow for estimating GHG emissions/removals and REDD effect (emission reduction)

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

Base map ← Ground truth

↓

Series of remote sensing images

↓

DD areas detection by monitoring forest land

↓ ← Carbon stock per land area for main forest types

Estimates of carbon stock change (GHG emissions/removals)

↓ ← Scenario emissions without REDD

Estimates of REDD effects (GHG emission reduction)

A matrix for choices of methods (Revised from Kiyono et al. 2011)

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

Approaches for estimating forest area

•Spaceborne optical sensors and microwave sensors are available only partly or partially with reasonable cost.
•There are more accurate and expensive approaches using airborne media.

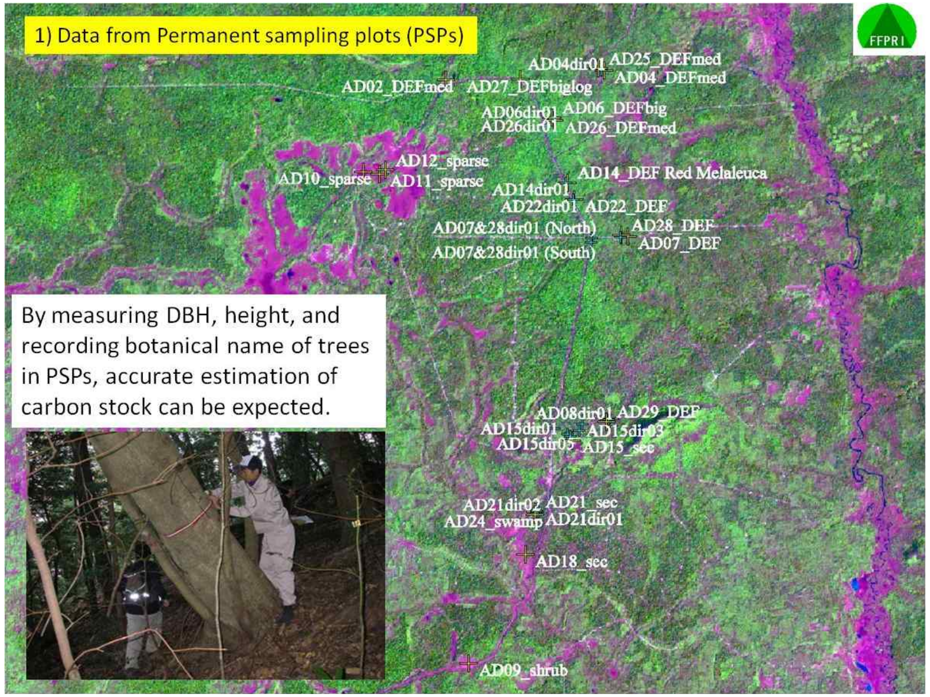
Forest land cover classification can partly or partially be achieved at reasonable cost using remote sensors with medium resolution. Successful imaging by means of optical sensors depends on the weather conditions. Recent research shows that spaceborne SAR (PALSAR) is available (withstands comparison with Landsat ETM+ in land cover classification of degraded tropical forest). However, SAR hardly provides reliable information on steep mountains.

Approaches for carbon stock per land area

•Approaches with reasonable cost are less. One is an approach with a parameter of community age applicable to slash-and-burn agriculture and industrial plantations. Another is backscattering coefficient of PALSAR partly applicable to land use change and slash-and-burn agriculture.
•There are more accurate but expensive approaches using parmanent sampling plots (PSPs) and LiDAR.

1) Data from permanent sampling plots (PSPs)
2) Community-age
3) Crown diameter
4) Overstory height
5) Backscattering coefficients of PALSAR

1) Data from Permanent sampling plots (PSPs)

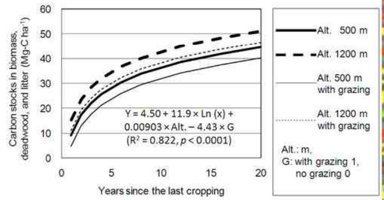


By measuring DBH, height, and recording botanical name of trees in PSPs, accurate estimation of carbon stock can be expected.

2) Community-age

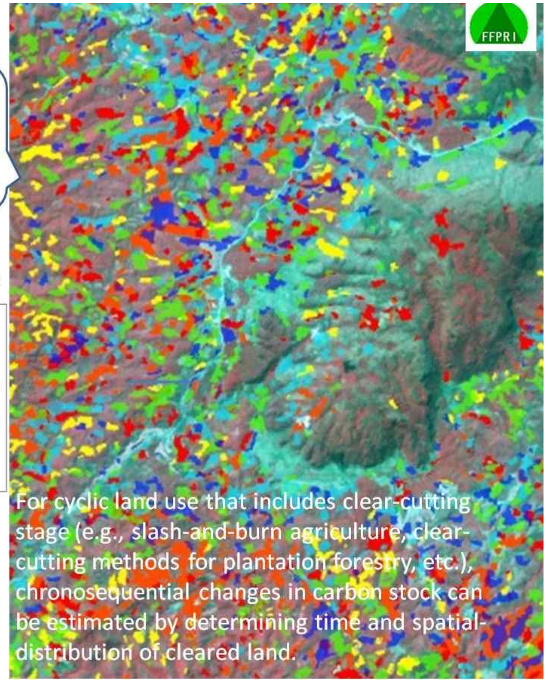
Cyclic land use that includes clear-cutting stage

A model with community age



Carbon stock per land area

By N. Furuya

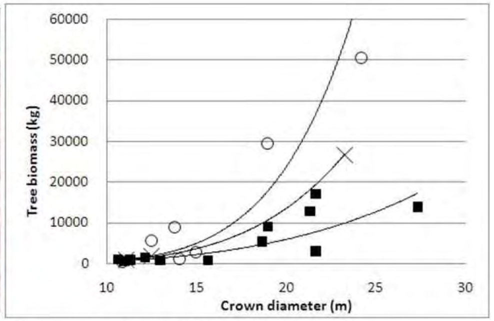


For cyclic land use that includes clear-cutting stage (e.g., slash-and-burn agriculture, clear-cutting methods for plantation forestry, etc.), chronosequential changes in carbon stock can be estimated by determining time and spatial-distribution of cleared land.

3) Crown diameter

Crowns of tall or separate trees in forests can be distinguished by airborne or high-resolution spaceborne sensors

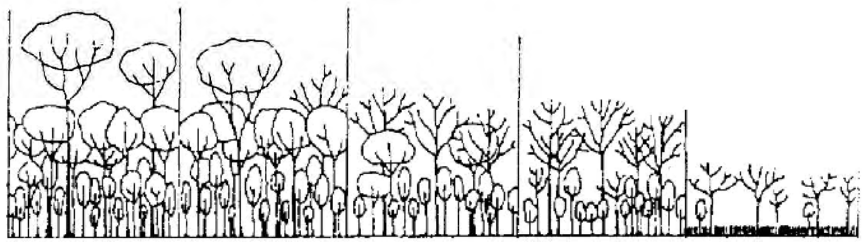
By N. Furuya



Kiyono et al. (2011)

4) Community height

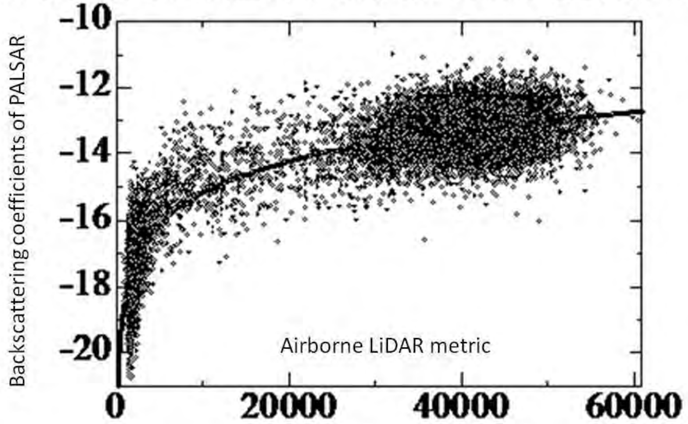
Community height can be used as a parameter for estimating biomass and ecosystem carbon stock in various plant communities.



Modified from Kira (1983)

5) Back scattering coefficients of PALSAR

Takahashi et al. (2010) demonstrated the close correlation between the values of backscattering coefficients of PALSAR and airborne LiDAR metric.



Modified from Takahashi et al. (2010)

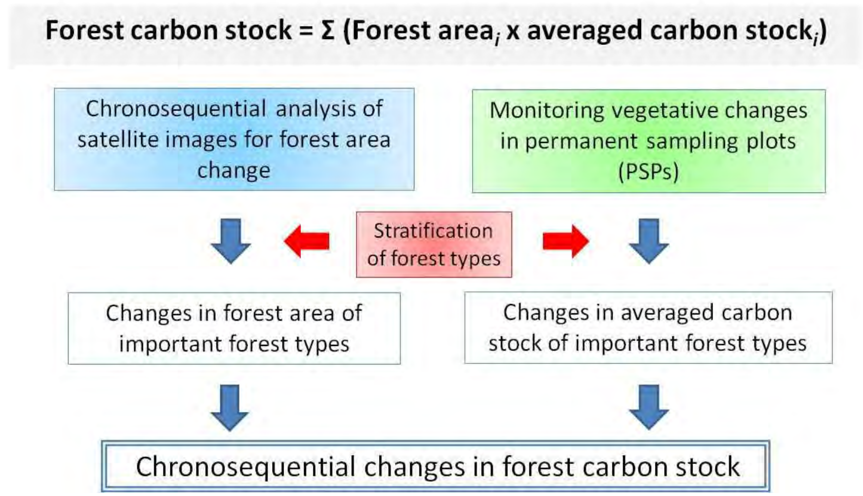
Estimates of the nationwide forest carbon stock in Cambodia

Forest Classification in Cambodia

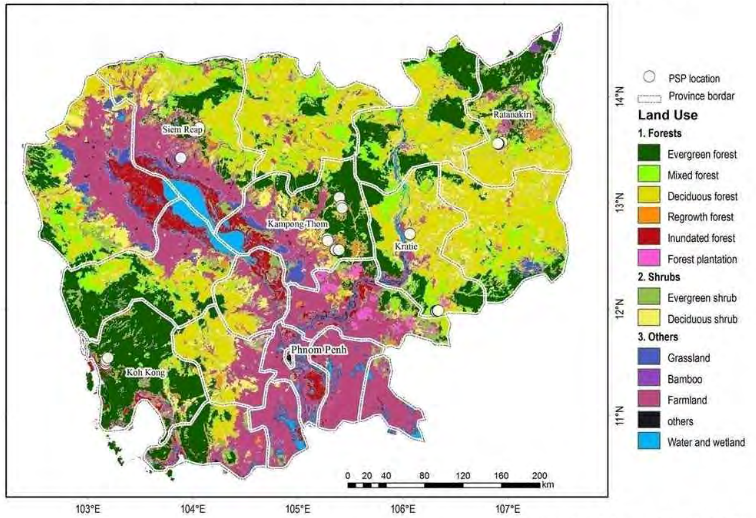
Type	Area ha	Ratio %
Evegreen forest	3,668,902	34.2
Semi-evergreen forest	1,362,638	12.7
Deciduous forest	4,692,098	43.7
Bamboo forest	35,802	0.3
Wood shrubland (evergreen)	37,028	0.3
Wood shrubland (deciduous)	96,387	0.9
Other forest	837,926	7.8
Forest total	10,730,781	100.0

Modified from FA (2010)

A flow for estimating nationwide forest carbon stock



Forest cover of Cambodia and PSPs by Forestry Administration



Modified from FA (2008)

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

Kiyono et al. (2011)

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Carbon stock in the other carbon pools were negligible or not available

- Understory
- Litter
- Deadwood
- Soil organic matter (SOM)

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

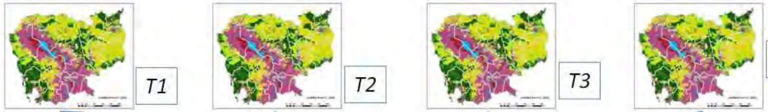
Forest type	Forest area In 2006	Averaged carbon stock In 2000-2001	Total carbon stock
	ha	Mg-C ha^{-1}	Tg-C
Evergreen forest*	3,668,902	163.8 ± 7.8	601.0 ± 28.7
Deciduous forest	4,692,098	56.2 ± 6.7	263.9 ± 31.3
Total	8,361,000		864.9 ± 42.5

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

A method for estimating CO_2 emissions/removals from forest

…..is the calculation of total carbon stock change by monitoring forest land and periodically summing the forest land area and its carbon stock per land area for important forest types.

Stock-difference method



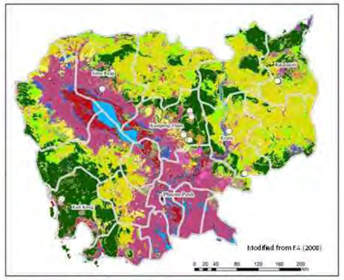
Σ (Forest land area$_i$ x Carbon stock per land area$_i$) = Total carbon stock

Challenges for improving estimates

1) Systematic sampling with sufficient plot number

2) Up-date of land classification

3) Establishment of allometry equations proper to Indochina



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Requirements for forest monitoring methods used in REDD+

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

Important assessment in the 2 different ecosystems

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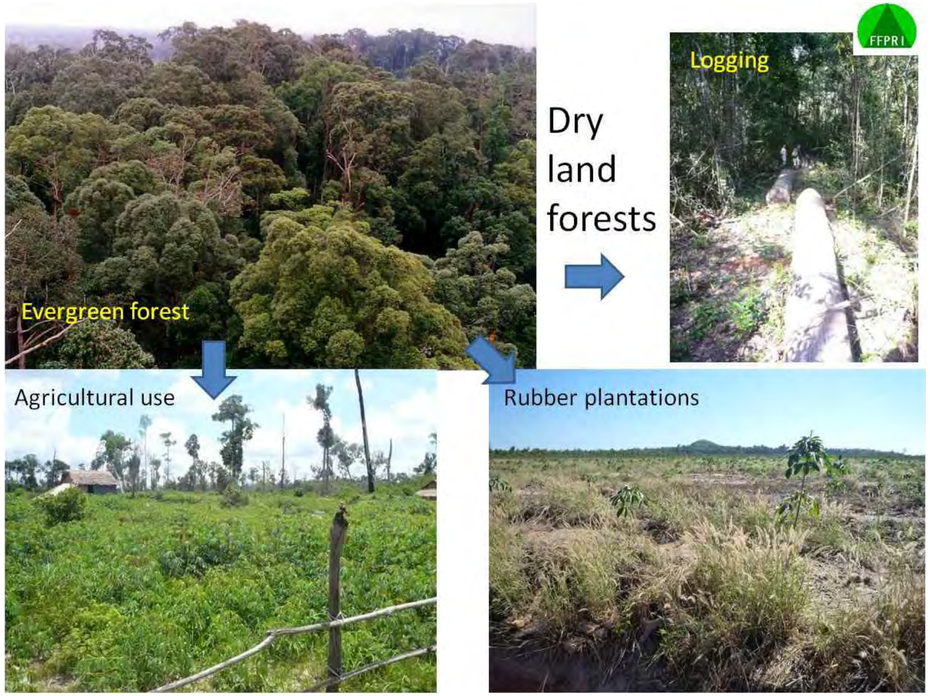
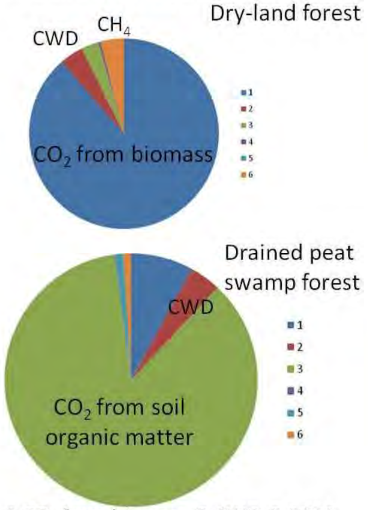


Importance assessment

Modified from Kiyono et al. (2011)



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%

Conclusions for the topics

Considering requirements for carbon monitoring methods for REDD+,

1. a practical method for estimating CO_2 emissions from DD is the calculation of total carbon stock change by monitoring forest land and periodically summing the forest area and its carbon stock per land area for important forest types.
2. For monitoring forest area, spaceborne optical and microwave (PALSAR) sensors are partly or partially available. In case both approaches are not appropriate, airbone media are considered to be an only alternative.
3. For monitoring carbon stock per land area, airborne media and/or ground-based measurement are the practical approaches.
4. CO_2 emissions from biomass are important in the dry land forest, while in the peat swamp forest, CO_2 emissions from drained soil organic matter are important. Such emission estimates are indispensable for effective overall estimates.
5. More varied field data must be collected for improving methods.

Thank you for your attention.

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Potential of Remote sensing for GHG inventory in REDD+

FFPRI

Forestry and Forest Products Research Institute

Yasumsa Hirata

1

Climate Change and Forest

Carbon Sink

- Trees absorb carbon dioxide when growing, and fix it inside.
- Promote trees’ growth by keeping forests healthy.

Emission Source of CO_2

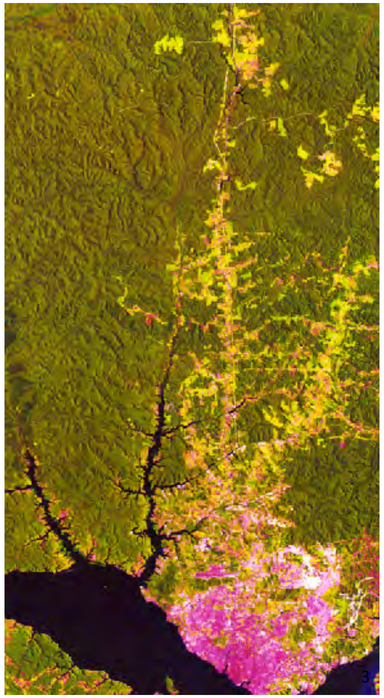
- Rapid deforestation and forest degradation in developing countries.
- Emission from deforestation and forest degradation accounts for 20% of anthropogenic emissions.

Need for International Approaches

2

Forest monitoring using remote sensing

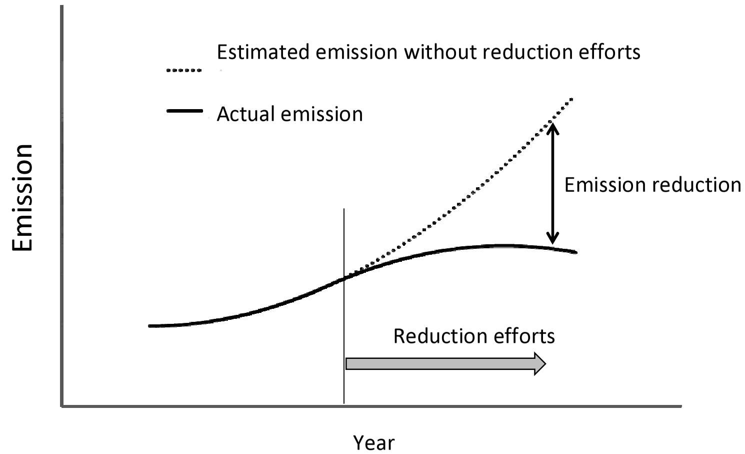
- Unique technique of forest monitoring in a large area.
- Essential tool to identify deforestation in developing countries.
- Extension of the usage through higher resolution and cost reduction



Satellite imagery in Manaus, Amazon

3

Concept of emission reduction



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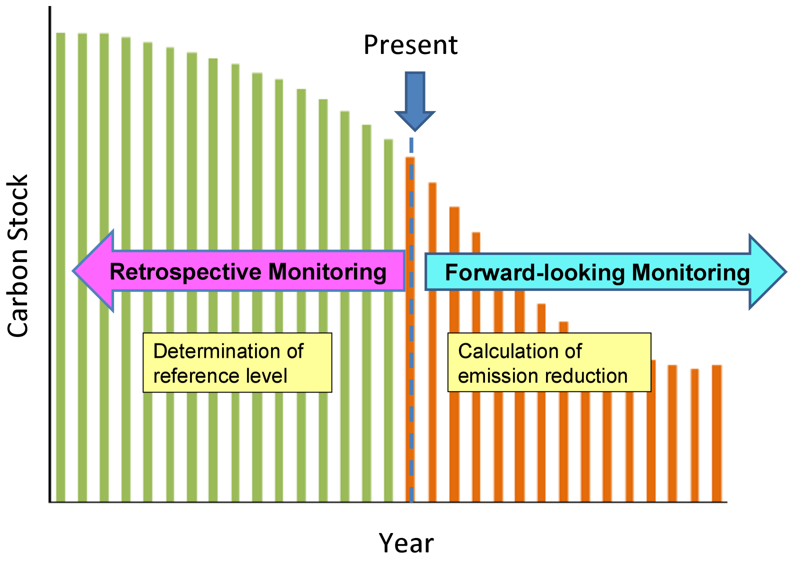
Two types of monitoring required for REDD



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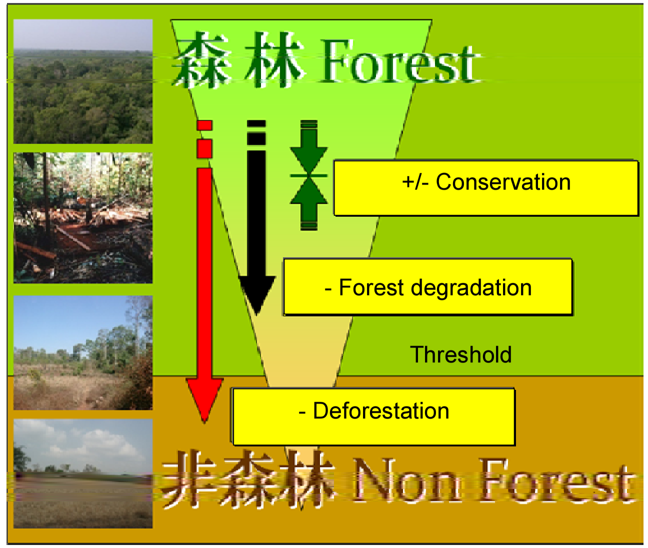
Definition of Forest, Deforestation, Forest Degradation, and Conservation



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Monitoring system required for REDD

- COP15 emphasized the importance of establishment of forest monitoring system in developing countries.
- The effectiveness of combining remote sensing and ground survey was confirmed.
- REDD+ assumes incentives for efforts on emission reduction.
- To be given the incentive, the methodology should be transparent and verifiable.
- Countries participating in REDD+ need to have MRV (Measurable, Reportable and Verifiable) methodology.

(GOFCGOLD Sourcebook 2009)

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Monitoring of Forest Degradation

Man-caused origins of forest degradation and possibilities of extraction at the Landsat level

Possible extraction	Constraint extraction and efforts for data increase	Near-impossible extraction
-deforestation -fragmentation of forests -recent slash-&-burn farms -major canopy fire -major roads -shift to three monocultures -water supply dam and flood disturbance -large-scale mining	-selective logging -surface fire in forests -old slash-&-burn farms -small-scale mining -narrow roads (6-20m) -thinning in canopy layer	-harvesting of non-wood plants -selective logging using old machines -narrow roads (6m or less) -thinning and logging in lower lasyer -invasion of alien species

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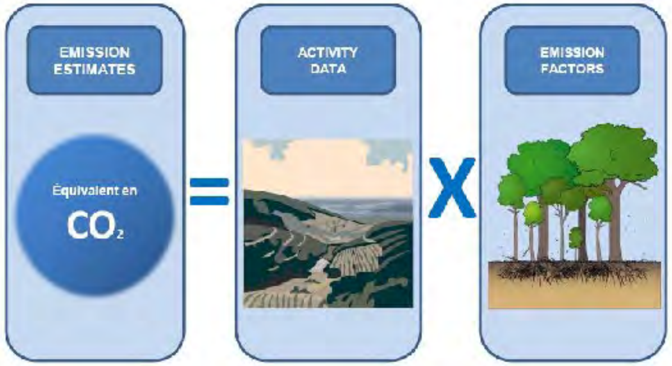
Basic equation of IPCC to assess greenhouse gas emissions from activities related to land use



Monitoring system under the UNFCCC provides not only forest areas and their changes but carbon stocks and their changes.

Danilo Mollicone, FAO

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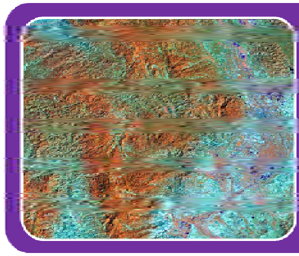
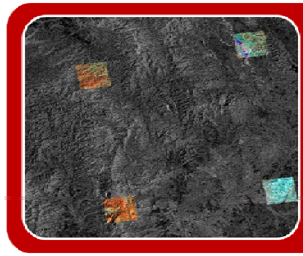
Wall-to-wall vs. Sampling



Wall-to-wall

- No leakage within the area
- Labor and cost consuming
- Difficult to acquire cloud-free data
- High applicability to local countermeasures

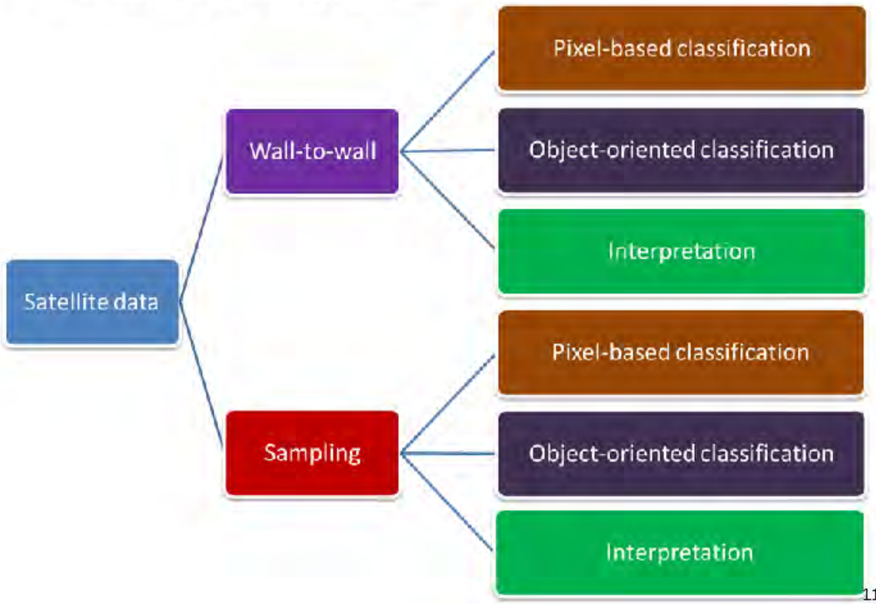


Sampling

- Accuracy by sampling rate
- Labor and cost can be reduced
- Greater possibility for data acquisition
- Applicability to local countermeasures ?

10

Forest remote sensing by satellite



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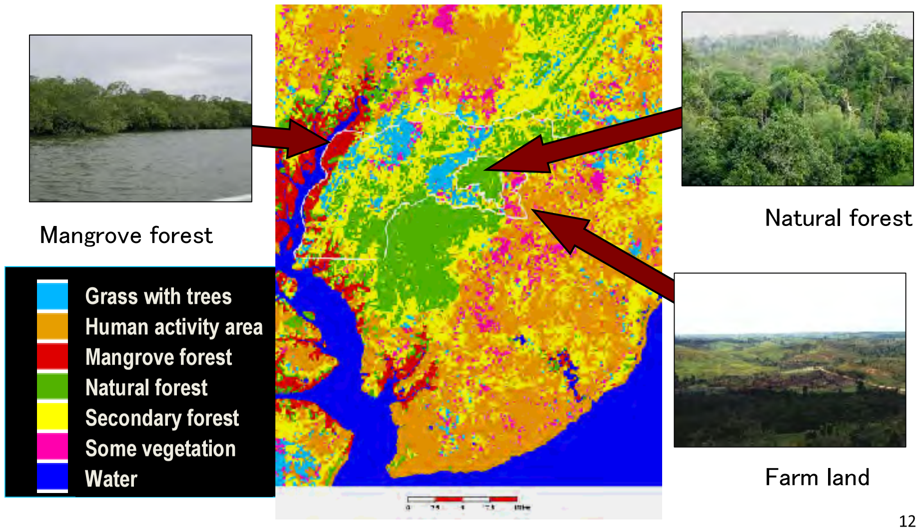
Making of land-cover map by pixel-based classification



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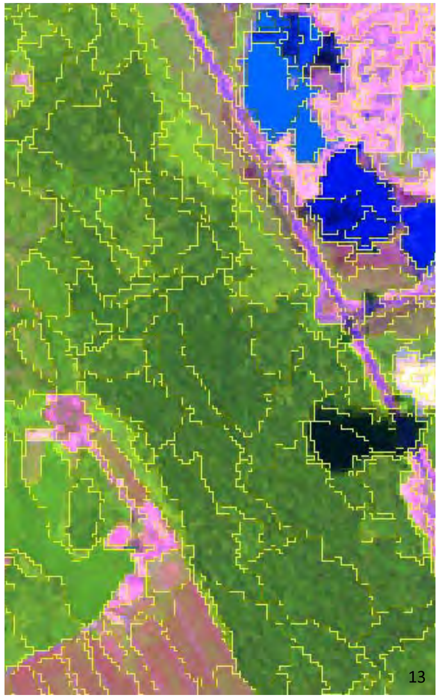
Object-oriented Classification

- The object-oriented approach is effective in segmenting an area that consists of various land cover types into objects with extensions of similar properties.
- Results from automatic classification are quite close to human interpretation.
- Advantages of handling by object (segment)



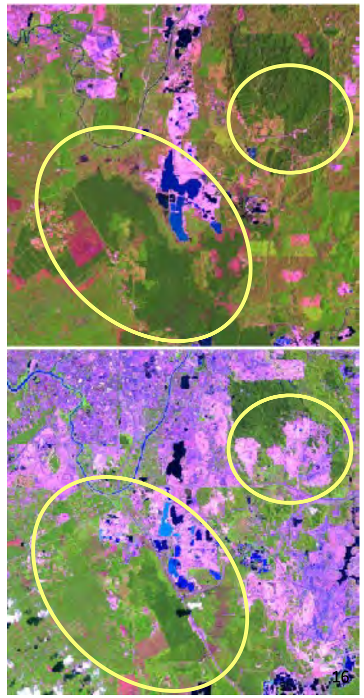
Interpretation of Images

- Illustrate boundaries of land-cover by human interpretation.
- Be able to suitably zone ambiguous areas.
- Interpreting technique is necessary.
- Results vary depending on interpreters.

Difficulty levels of monitoring of deforestation and forest degradation

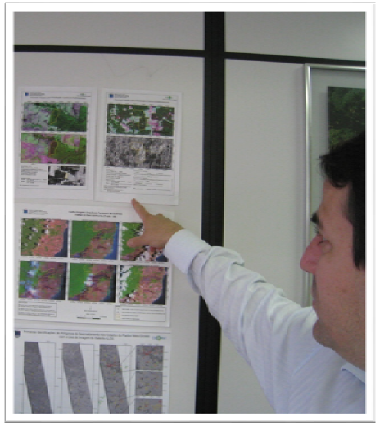
Monitoring of Deforestation

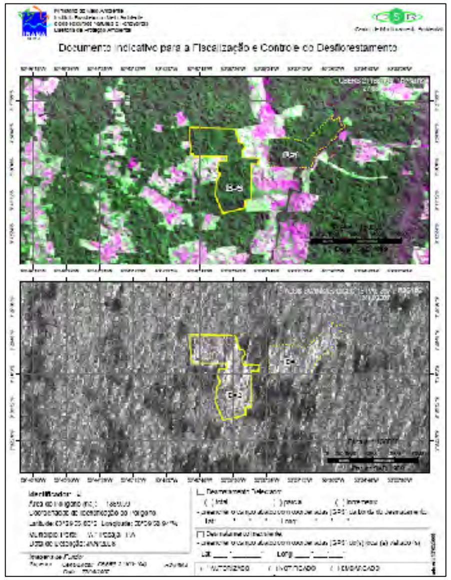
- Extracting changes of land use category
- Using properties of reflectance of each category
- Comparing multi-temporal
- Available to identify forest type change



Deforestation in Malaysia
Landsat Imagery
Upper: 1989, Lower: 2001

Surveillance of illegal loggings in the Amazonas using a Japanese satellite





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Monitoring of forest degradation

- Various causes of degradation
  - Illegal logging
  - Forest fire
  - Intolerable shifting slash-and-burn cultivation
  - Impact of development
- It is necessary to develop monitoring methods in accordance with each cause

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Forest degradation caused by selective loggings

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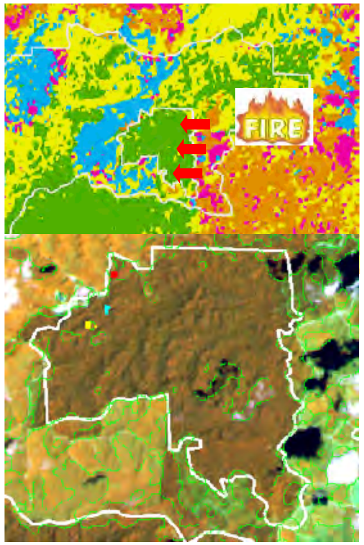
Forest Fire



- Types of fire
  - Canopy fire
  - Surface fire
    - Ex. Tropical seasonal forests in dry season
  - Peat fire
- Fire intensity
- Development vs. Restoration