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Forest and Land Cover Monitoring by Remote Sensing Data Analysis

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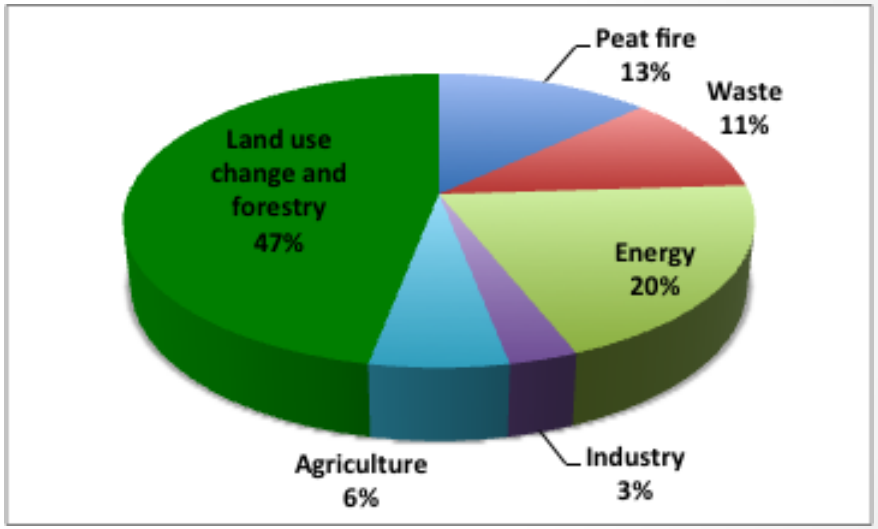
Introduction

- Since 1980ies, information about forest and land cover is importance for description and study of environment
- Forest and land cover:
  - the easiest detectable indicator of human intervention
  - a critical parameter for environmental databases
- Since 1980ies also,
  - the use of remote sensing data for supporting research on global change and sustainability is tremendous
  - Land use and land cover change became a key topic within global change research program (IGBP, ISSC, IAI, APN, START, GCTE, NASA-LCLUC, GLP, GOFC-GOLD)

- Why tropical forests are of particular interest in environmental study dealing with land cover and land use change ?
  - Tropical land is home to more than 55% of global population and human activities related to land use
  - Tropical ecosystem harbour a biodiversity, deforestation and land cover conversion
  - Tropical forest consist of a major terrestrial carbon sink and sources of emission.

- Tropical forests are under significant threat
- Deforestation directly cause carbon release to the atmosphere and accounts for one fifth of human induced emission of CO2 (IPCC 2007)
- In Indonesia, forest and land cover change are significant components of Indonesia's emissions profile (SNC, 2009)



- Since deforestation is almost occurring in tropical forests, thus the necessity of developing tool and providing spatially base data for monitoring deforestation and forest degradation has been underlined during COP13 in Bali

- Several effort to map land cover in the tropic region and to monitor forest cover change have been done in the past, however the scope of forest monitoring is much broader.

- 3 groups of research:
  - LCLUC and carbon dynamics
  - LCLUC and biological conservation
  - Vegetation activity and climate variability

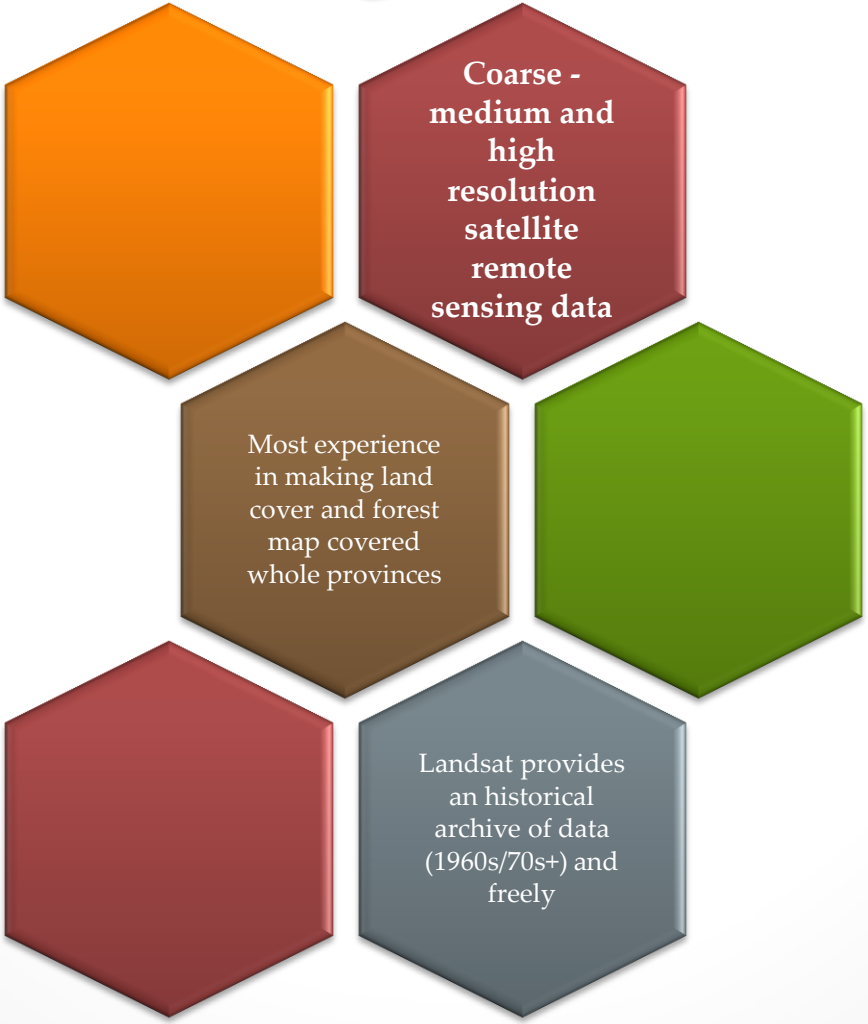
- Remote sensing data provide most reliable data source for accurately and objectively estimates change in forest over large area, particularly in remote area and difficult to access.

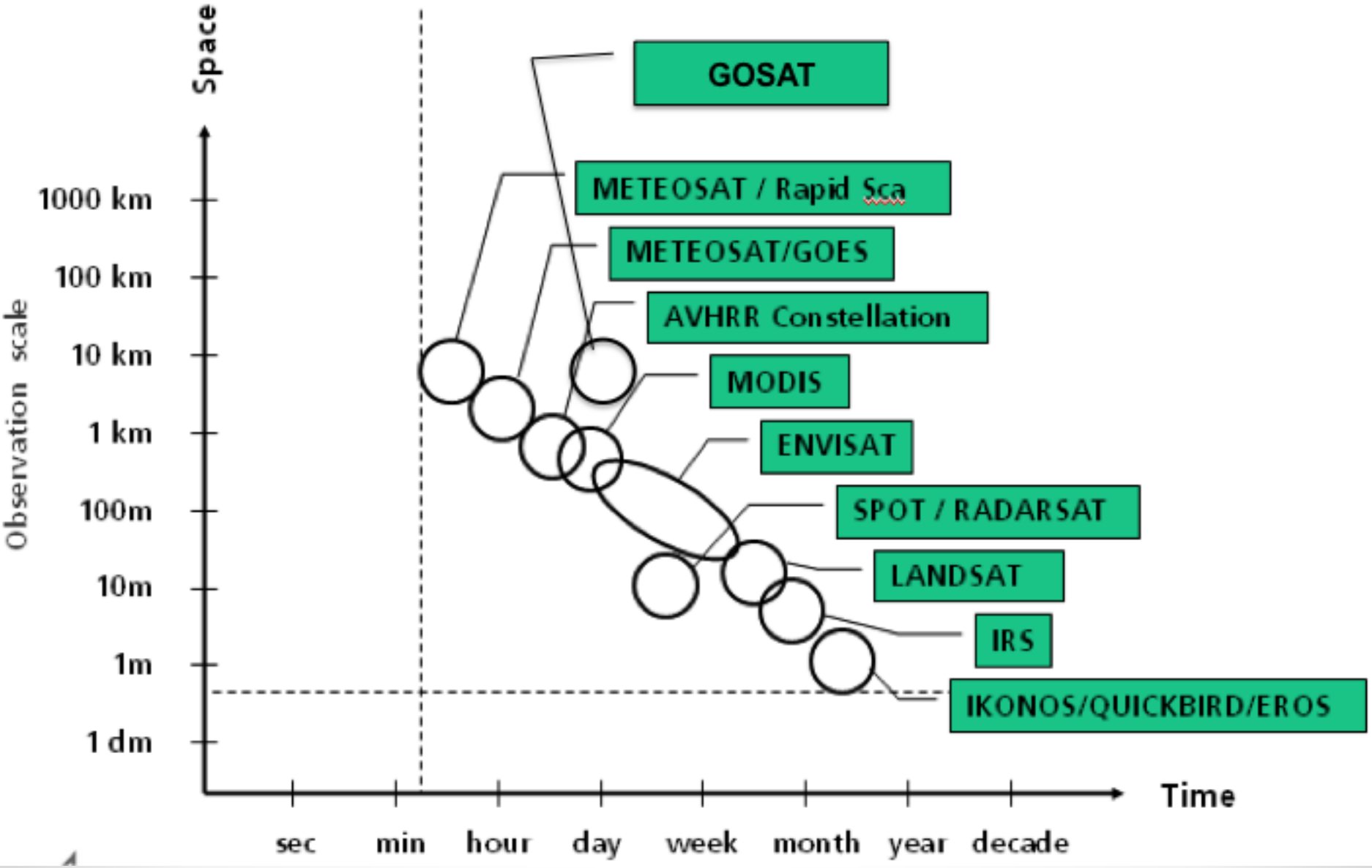
Remote sensing data analysis for land cover mapping and monitoring

- Success of land cover studies depend on the availability data at a desired spatial and temporal resolution

Level of resolution	Spatial resolution	Scale of study
Coarse - Medium	> 250 m	Global (< 1 : 250,000)
High	> 10 m	Regional (< 1: 25,000)
Very high	< 10 m	Local (> 1: 25,000)

The main types of data for forest monitoring in Indonesia



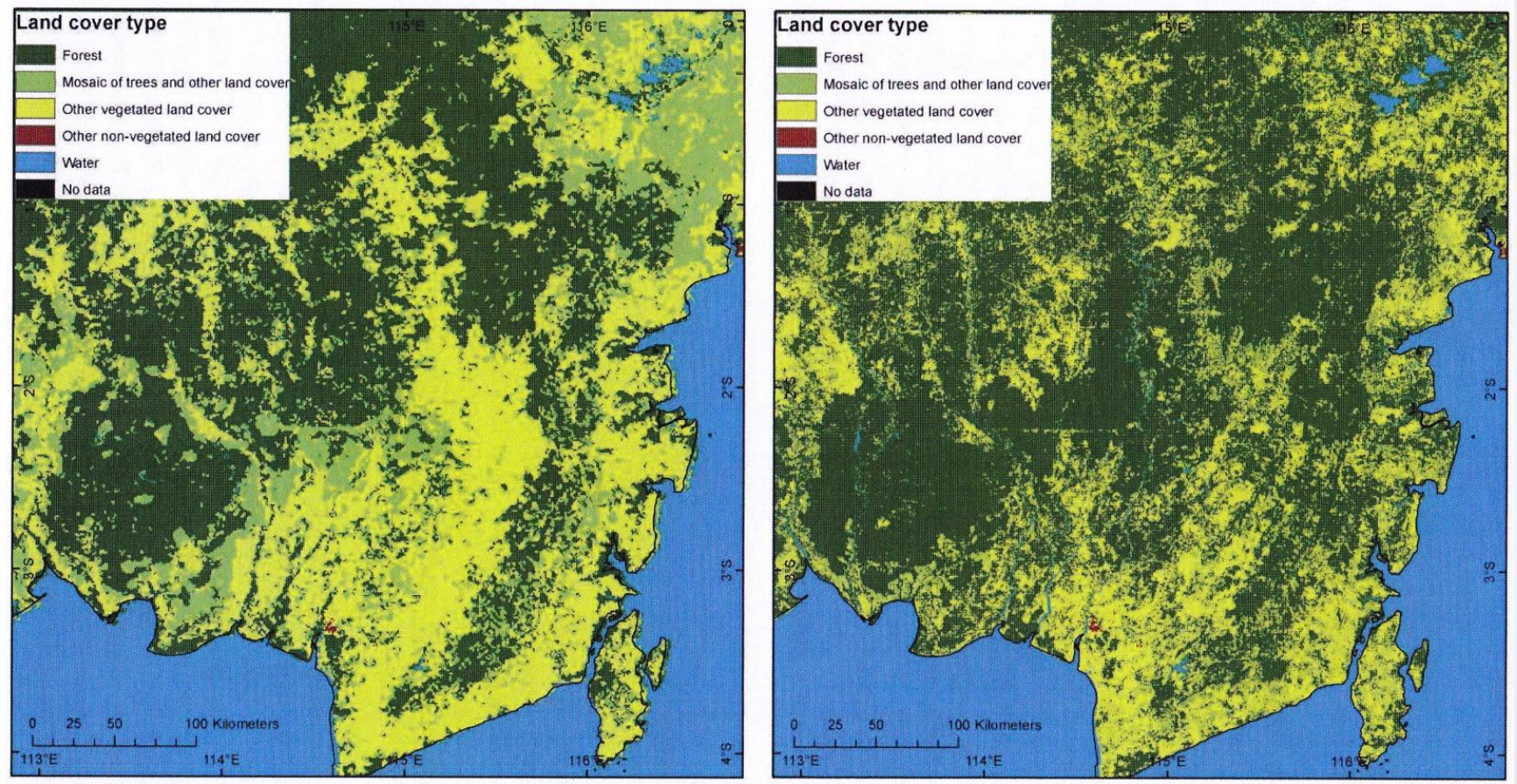

Space
Observation scale
1000 km
100 km
10 km
1 km
100m
10m
1m
1 dm
GOSAT
METEOSAT / Rapid Sca
METEOSAT/GOES
AVHRR Constellation
MODIS
ENVISAT
SPOT / RADARSAT
LANDSAT
IRS
IKONOS/QUICKBIRD/EROS
Time
sec
min
hour
day
week
month
year
decade

Land cover product in Indonesia (regional)

Land Cover	Period	Satellite Data	Resolution	Approach	Source
Land cover, Indonesa	2000 – 2011 (every 3 years)	Landsat 5/7	6.25 ha	Visual interpretation	MoF
Land cover, Indonesia	2000 - 2012	Landsat 5/7	25 m	Bayesian probability Network	LAPAN/INCAS
Land cover, Indonesia	2000 - 2010	Landsat 5/7	60 m	Tree class. algorithm	Univ. of Maryland
Land cover, Kalimantan	2009 - 2010	ALOS-PALSAR/RADAR SAT	50 m	Marcov random field	Wageningen Univ.
Land cover, Sumatra	2007 - 2010	ALOS-PALSAR	25 m	Random Trees, SVM, MLP (Multi Layer Perceptron)	Wageningen Univ.
Land cover, Indonesia	2000 - 2010	Landsat 5/7	30 m	Segmentation	ICRAF

Other product of land cover (global)

Product	Sensor	Reference year	Spatial resolution	Coverage	Classification scheme (legend)	Scientific reference	Data access / information
GLCC	AVHRR	1992	1 km	Global	IGBP (17 classes)	Loveland et al. (2000)	http://edc2.usgs.gov/glcc/
UMD land-cover	AVHRR	1992	1 km	Global	Simplified IGBP (14 classes)	Hansen et al. (2000)	http://glcf.umiacs.umd.edu/data/landcover/
TREES I	AVHRR	1992	1 km	pan-tropical	TREES (9 classes)	Achard et al. (2001)	http://www-tem.jrc.it/
Vegetation Continuous Fields (VCF)	AVHRR	1992	1 km	Global	continuous (% tree cover)	DeFries et al. (2000)	http://glcf.umiacs.umd.edu/data/treecover/
GLC2000	SPOT-VGT	2000	1 km	Global	LCCS	Bartholomé and Belward (2005)	http://www-tem.jrc.it/
MODIS land-cover	MODIS	2000	1 km	Global	simplified IGBP	Friedl et al (2002)	http://edcimswww.cr.usgs.gov/pub/imswelcome/
TREES II	SPOT-VGT	2000	1 km	Insular SE Asia	TREES (9 classes)	Stibig et al. (2003)	http://www-tem.jrc.it/
Vegetation Continuous Fields (VCF)	MODIS	2000-2005	500 m	Global	continuous (% vegetation cover)	Hansen et al. (2002)	http://glcf.umiacs.umd.edu/data/vcf/
GlobCover	MERIS	2005	300 m	Global	LCCS	Arino et al (2007)	http://ionia1.esrin.esa.int/index.asp
TREES III	MERIS, Landsat	1990 / 2000 / 2005	30 m (stratified irregular sample)	pan-tropical + Eurasia	N/A	N/A	http://ies.jrc.ec.europa.eu/
FRA 2010	Landsat	1990 / 2000 / 2005	30 m (systematic sample)	Global	FAO (8 classes)	N/A	http://www.fao.org/forestry/44375/en/
NASA LCLUC	MODIS, Landsat	2000 / 2005	30 m (stratified block sampling)	Global	N/A	N/A	http://lcluc.umd.edu/

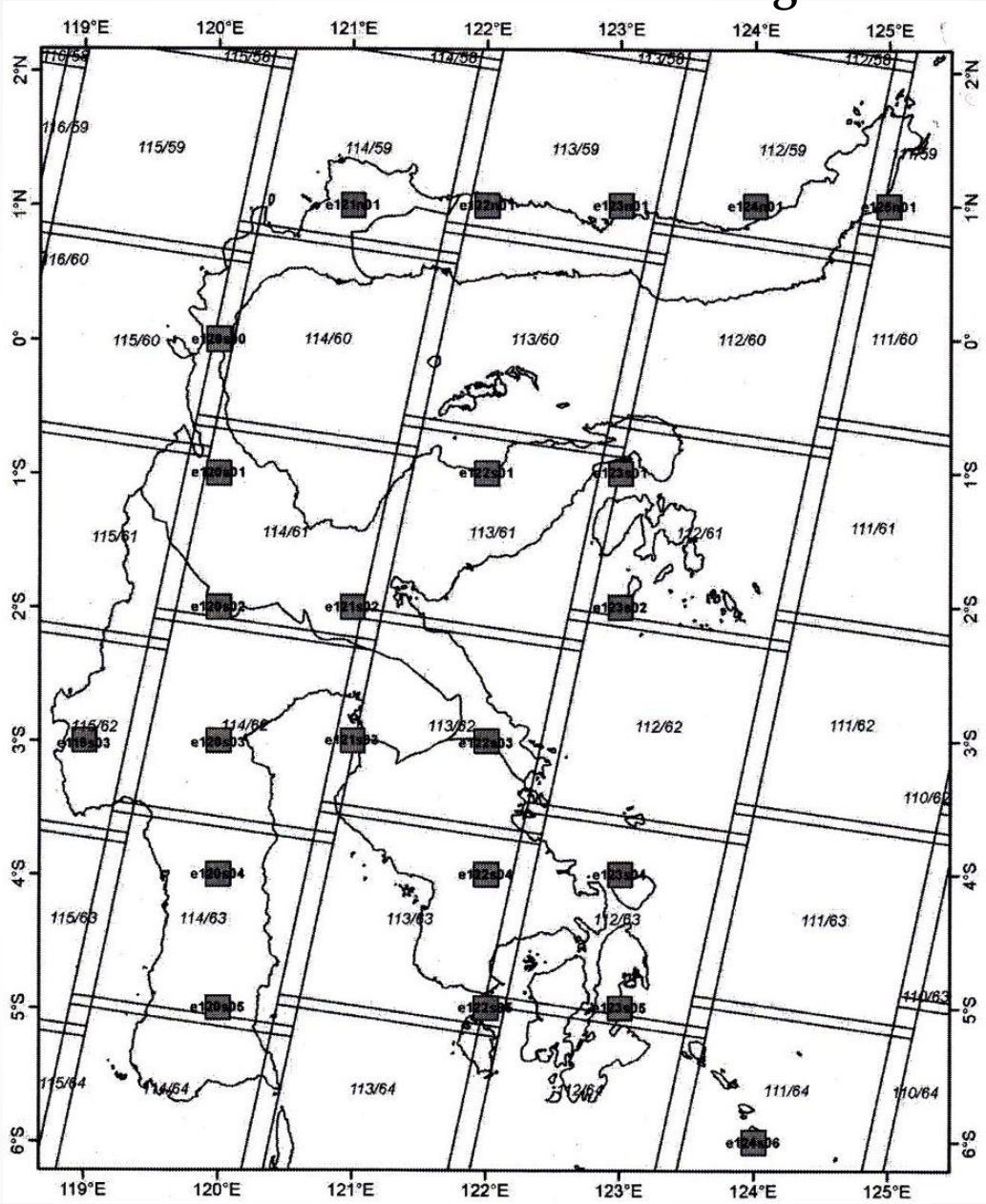


Landcover variation between GLC2000 (left, 1km resolution) and GlobCover (right, 300 m resolution)

- Challenges:
  - Difference in remote sensing satellite source
  - Difference in image analysis
  - Difference in land cover and use category;
  - Diversity in forest definition, deforestation

- Thus:
  - Disagreement among products
  - Inconsistency in land cover type
  - Land cover change and deforestation is different

Validation of GLC2000/GlobCover at regional level



Distribution of FRA2010 sampling

Results

FRA tile ID	Path/row Landsat ETM+		Landsat ETM+ annual net forest loss (%)	GLC2000/ GlobCover annual net forest loss (%)	Land surface per tile (%)
e119s03	115	62	-0.4	-4.2	100
e120s00	115	60	0.0	-10.1	94
e120s01	114	61	-1.8	4.8	100
e120s02	114	61	-7.6	-0.2	100
e120s03	114	62	0.0	-9.9	100
e120s04	114	63	0.0	-15.5	89
e120s05	114	63	0.2	6.6	100
e121n01	114	59	-0.6	-2.9	100
e121s02	114	61	clouds	-3.5	100
e121s03	113	62	1.4	-10.1	11
e122n01	113	59	-8.0	-8.4	79
e122s01	113	61	0.0	-12.1	69
e122s03	113	62	-2.2	-2.0	100
e122s04	113	63	1.5	-5.8	100
e122s05	113	63	-6.2	-11.9	3
e123n01	113	59	-3.0	-14.7	13
e123s01	112	61	-0.4	-8.3	1
e123s02	112	61	0.0	-9.2	1
e123s04	112	63	-2.4	-14.2	33
e123s05	112	63	clouds	-15.9	36
e124n01	112	59	0.0	-15.8	1
e124s06	111	64	-0.2	-14.5	21
e125n01	111	59	-0.4	15.1	9
Mean (area weighted)			-1.8	-5.9	
Standard error			0.54	1.67	

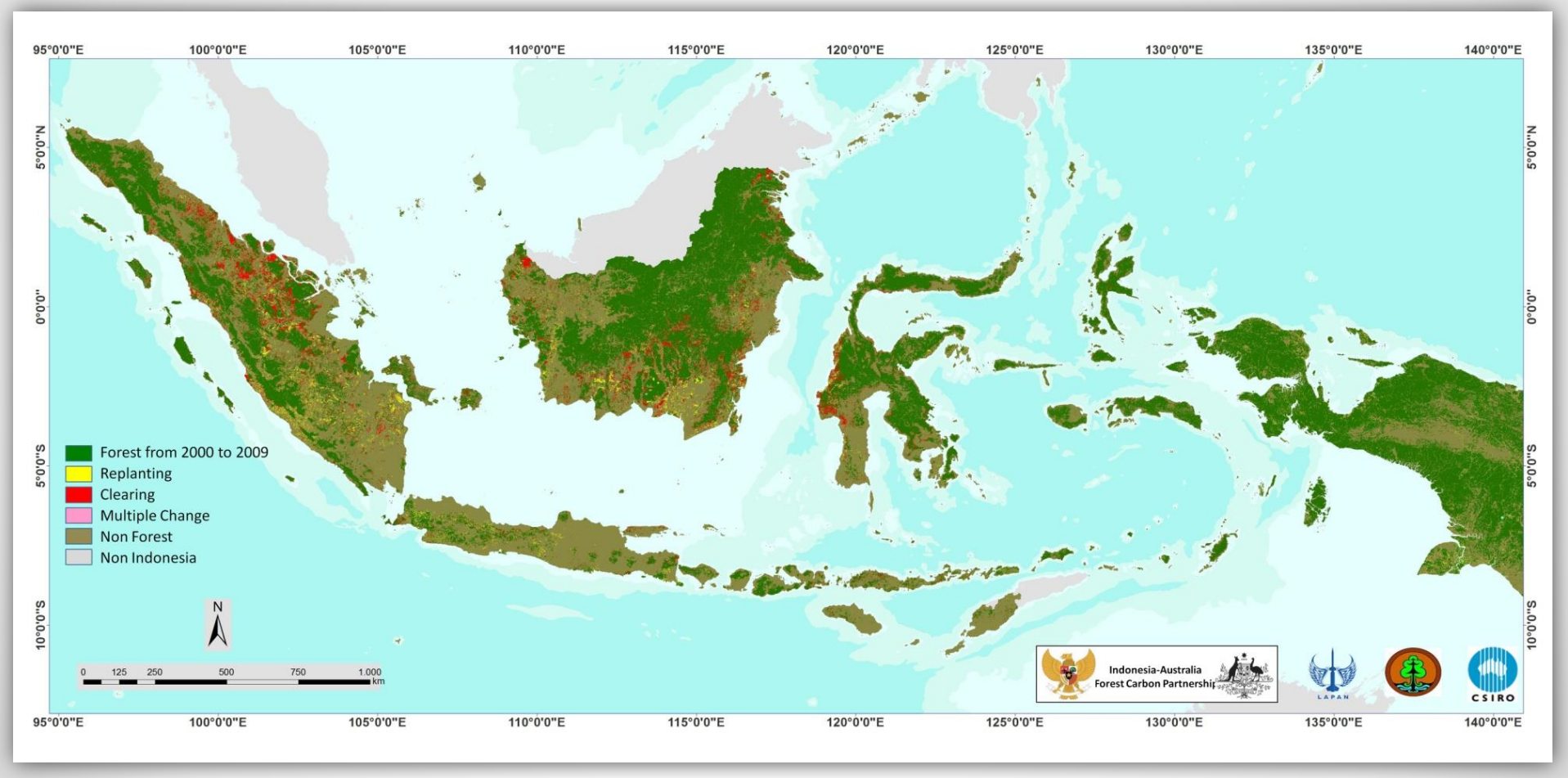
Mean annual forest los for Sulawesi:

- 1.8% based on Landsat ETM+,
- 5.9% based on global land cover products

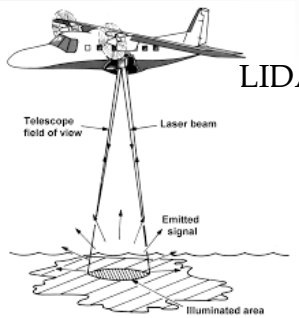
INCAS'Land Cover Product

- This data is part of Indonesia's National Carbon Accounting System (INCAS).
- a wall-to-wall monitoring of Indonesia's forest changes for the period 2000-2012 as inputs for carbon accounting
- The product was prepared by LAPAN (National Institute of Aeronautics and Space of Indonesia) supervised by CSIRO Australia
- Land cover type: forest and non-forest

Forest Cover Dynamic (2000 – 2009)



INCAS'S COMPONENTS



LIDAR

Biomass change

Terra-SAR
ALOS PALSAR

Landsat,
SPOT

Forest, land cover, deforestation,
Forest degradation/disturbance

MODIS

Wildfire detection mapping

GOSAT

CO2 Flux,
concentration

Biomas Classification:

Classification of forests into groups (biomass classes) that best explain the variation of biomass in undisturbed forest condition

Land Cover Change Analysis

Deforestation (permanent loss of forest cover)

Degradation (forest clearance and regeneration or partial removal)

Carbon Accounting and Reporting Model (ICARM)

Forest Disturbance Class Mapping

Minimal disturbance

Moderate disturbance

Heavy disturbance

Carbon stock estimation

Aboveground biomass

Belowground biomass

Litter

Debris

Soil

How to integrate satellite data source from different resolutions ?

Challenges for remote sensing based input for study of entvirontment

- Precise geometric co-registration of multi-temporal, -sensor and time series satellite data
- A robust pre-processing on data harmonization (spectral, spatial, temporal fitting)
- Detection of land cover modification in addition to land conversion
- Detection of abrupt and gradual change
- Detection and separation of spontaneous, seasonal, annual change from inter-annual and long term term
- Scale dependency of change estimates derived from satellite image at different spatial resolution
- Development of an appropriate mapping and change detection method
- Adoption of a consistent classification concept, i.e. using a hierarchical tree concept

Concluding remarks

- Development of comprehensive and reliable operational monitoring concept for forest and land cover change needs:
  - a robust pre-processing on data harmonization (spectral, spatial, and temporal fitting)
  - Integration of single mapping approaches
  - a data use policy on existing and planned multi-spectral satellite system and development of a multi-sensor

THANK YOU

Terima kasih