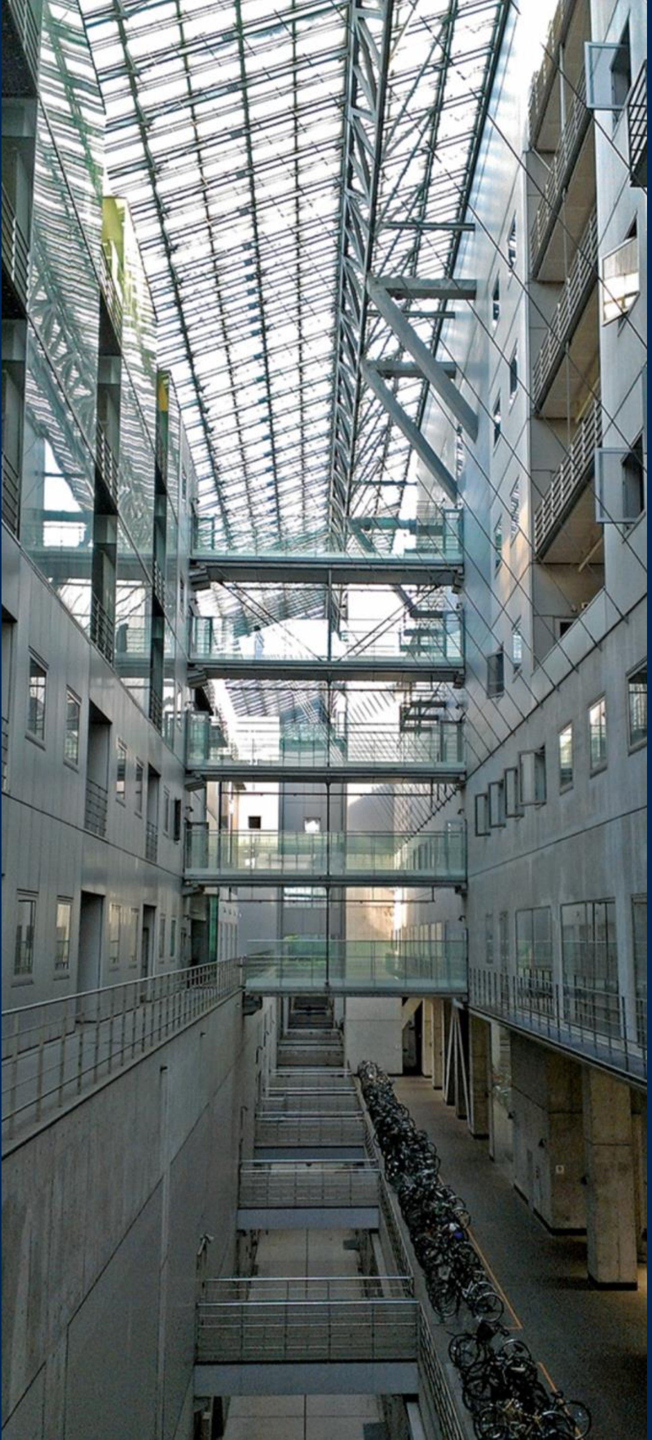


Quantifying GHG Budgets in Southeast Asia by Remote Sensing and Models

Dr. Wataru Takeuchi (Remote sensing)

Institute of Industrial Science
The University of Tokyo

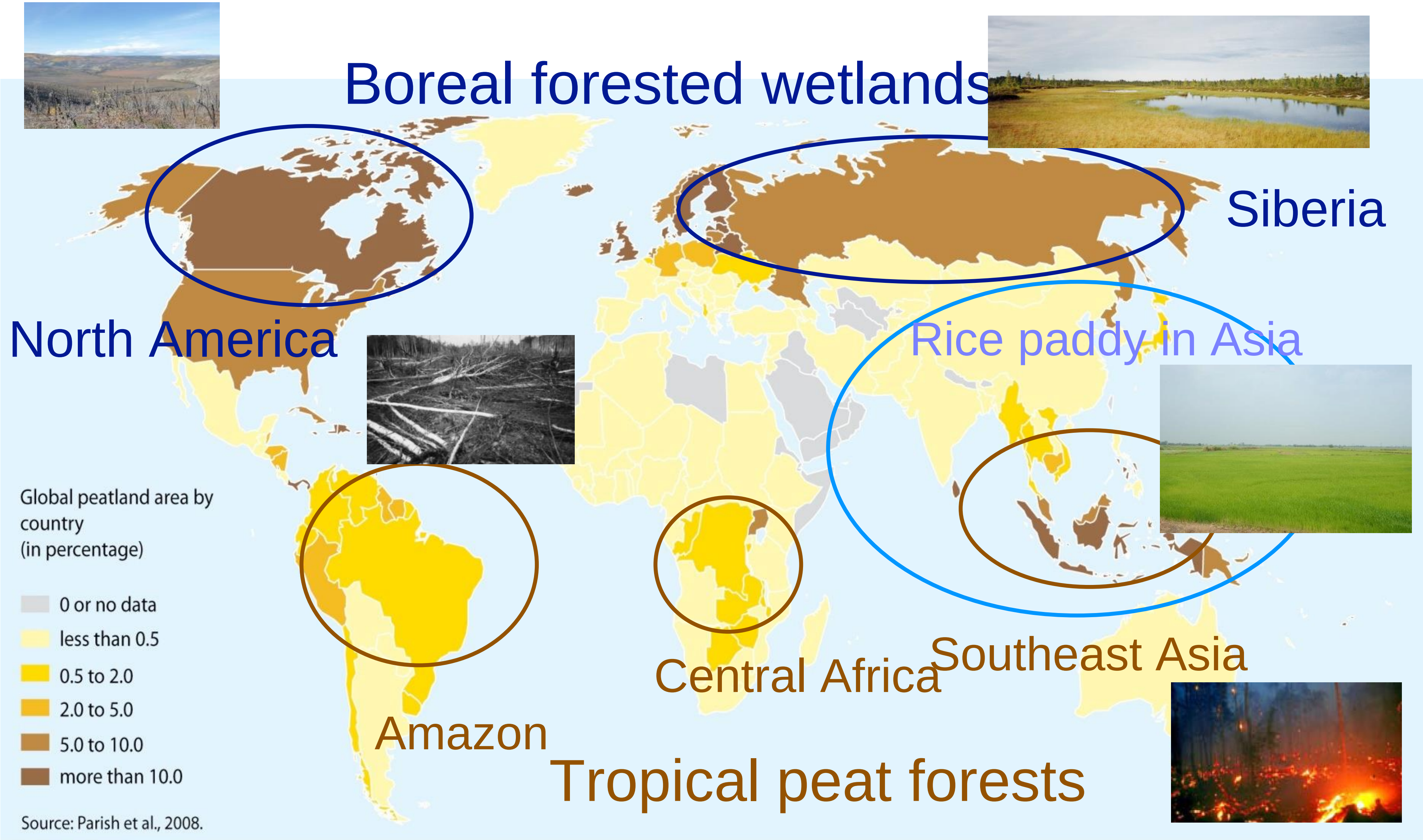
Sep. 19, 2017 @ GEOSS-AP, Hanoi, Vietnam

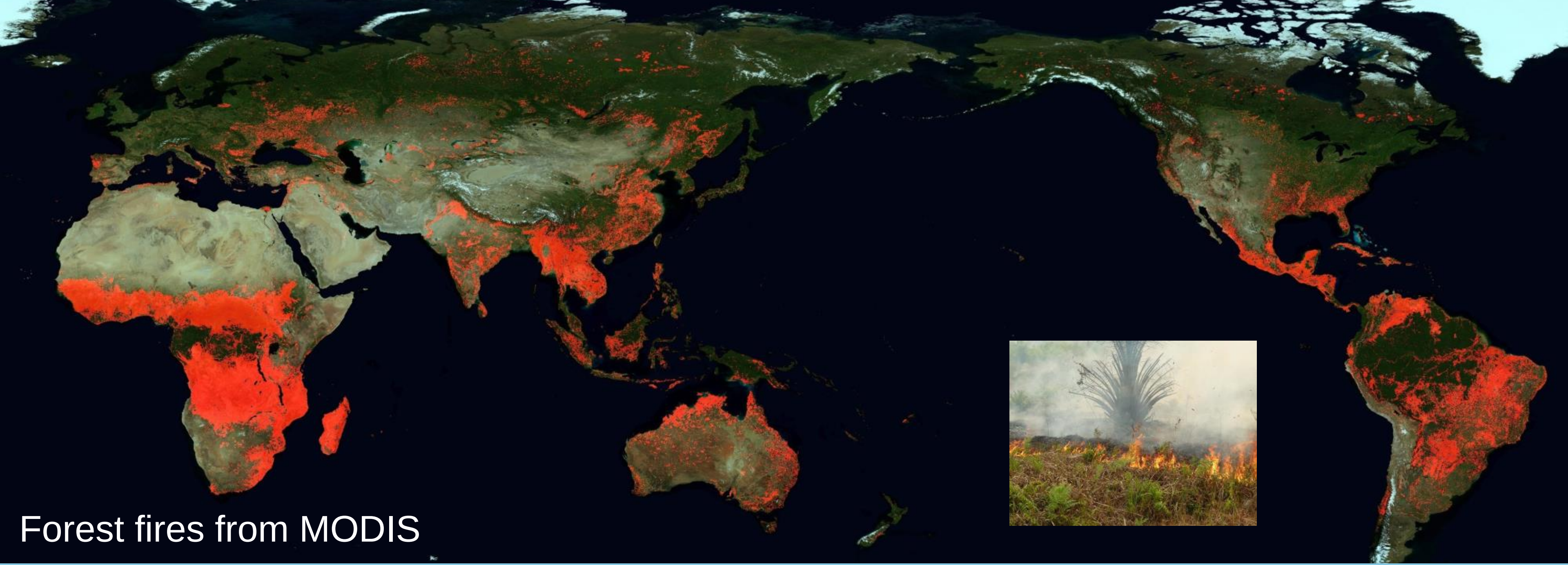
Today's contents

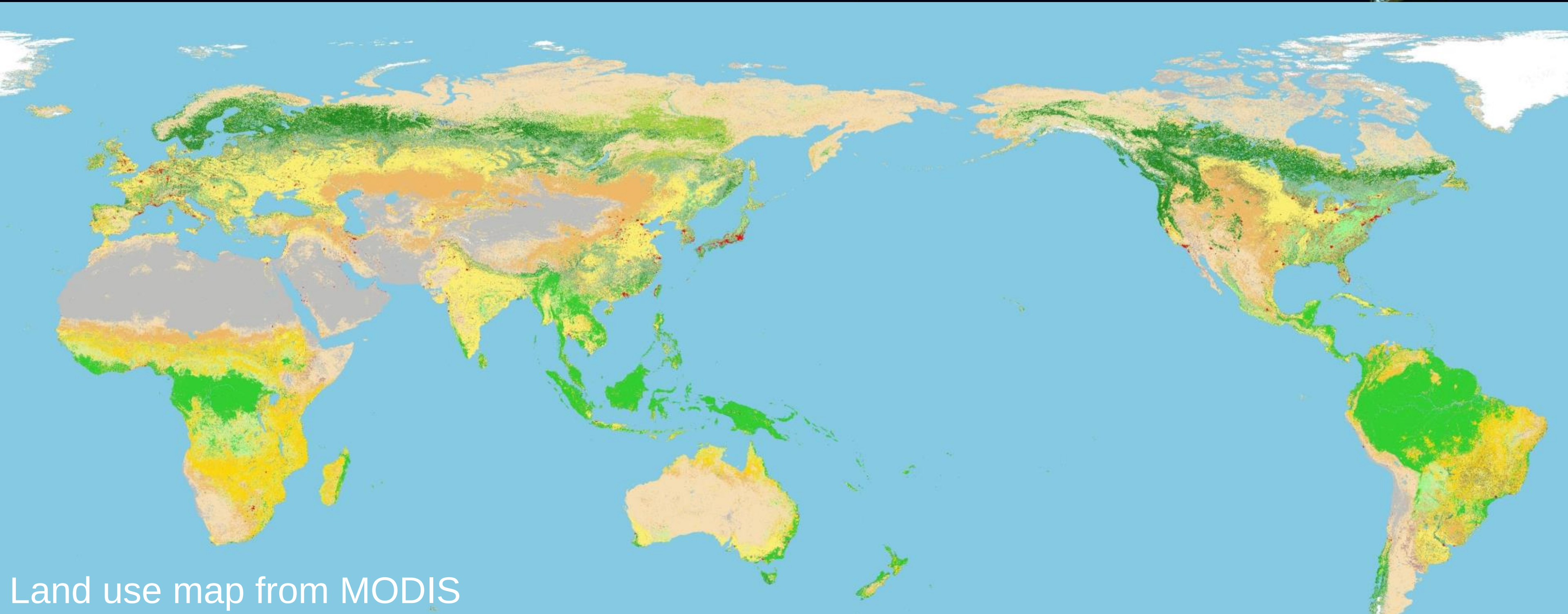
- Carbon-water simulator for wild fire emission estimation in Asia with bio-geophysical model and remote sensing
  (JICA-JST SATREPS and MEXT project)
- Mangrove and seagrass biomass mapping in Asia
  (JAXA SAFE project of APRSAF)
- CH4 emission observation from rice paddy field in Asia with remote sensing and in-situ measurements
  okyo-VAST JAXA initi

Carbon-water simulator for wild fire emission estimation in Asia with bio-geophysical model and remote sensing (JICA-JST SATREPS and MEXT project)

Carbon sequestration in peatlands as a source of CO_2 and CH_4




Forest fires from MODIS


Land use map from MODIS

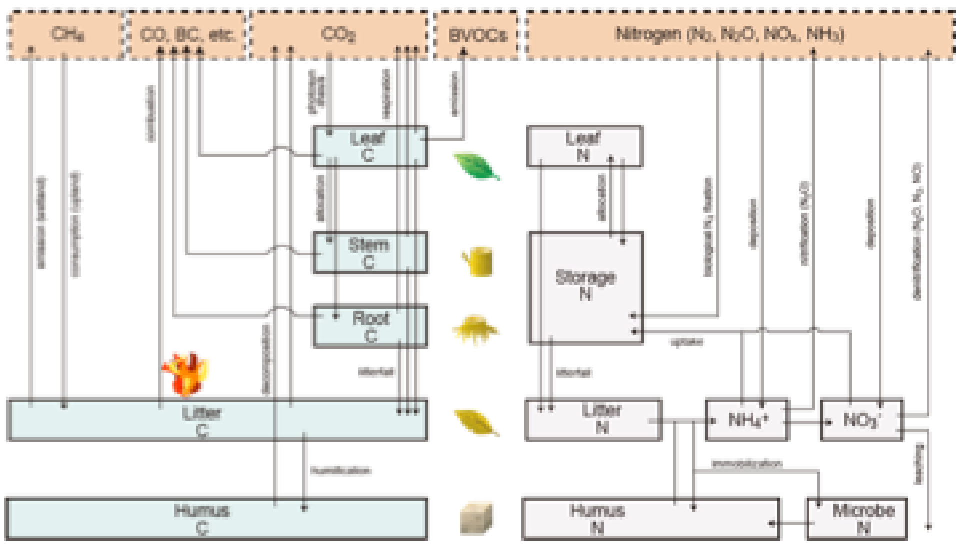
VISIT

Vegetation Integrated SImulator for Trace gases

(Developed in NIES & JAMSTEC)

Objectives

- Atmosphere-ecosystem biogeochemical interactions
- Especially, major greenhouse gases (CO_2, CH_4, and N_2O) budget [Tier 3]
- Assessment of climatic impacts and biotic feedbacks



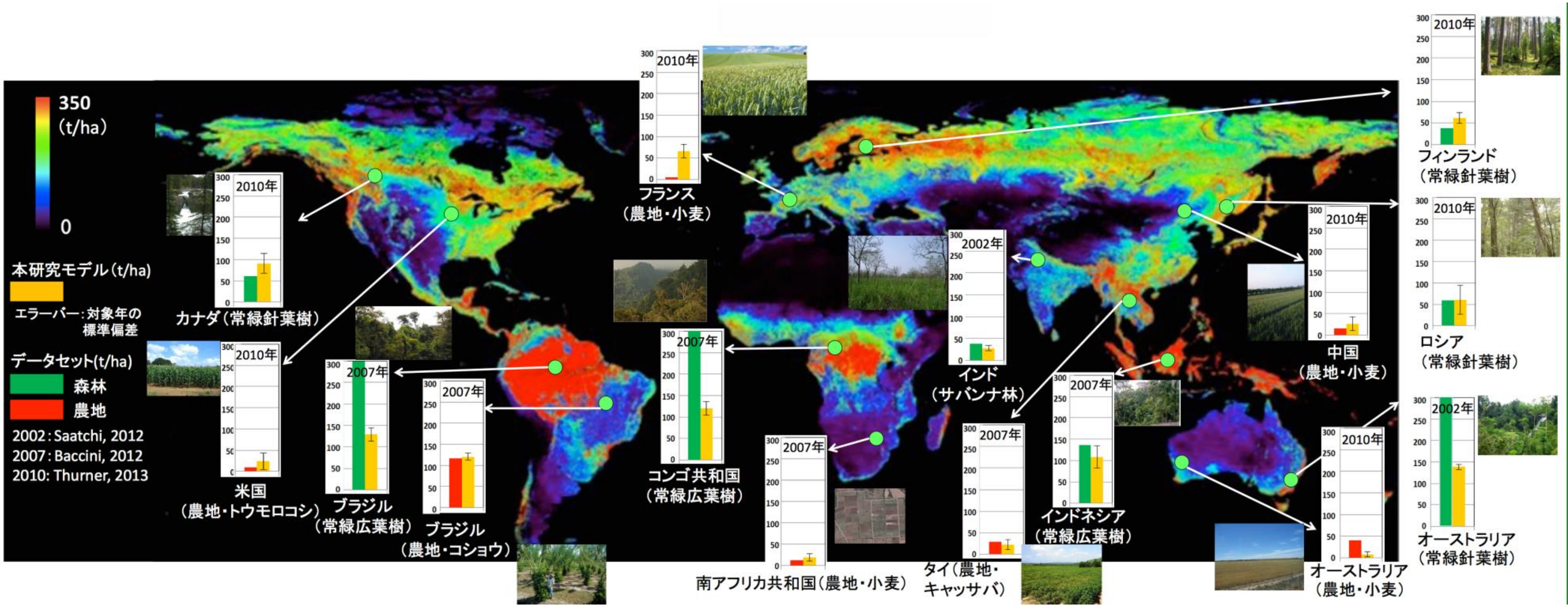
Carbon-cycle
(Sim-CYCLE-based)

Nitrogen-cycle

Point-global, daily-monthly

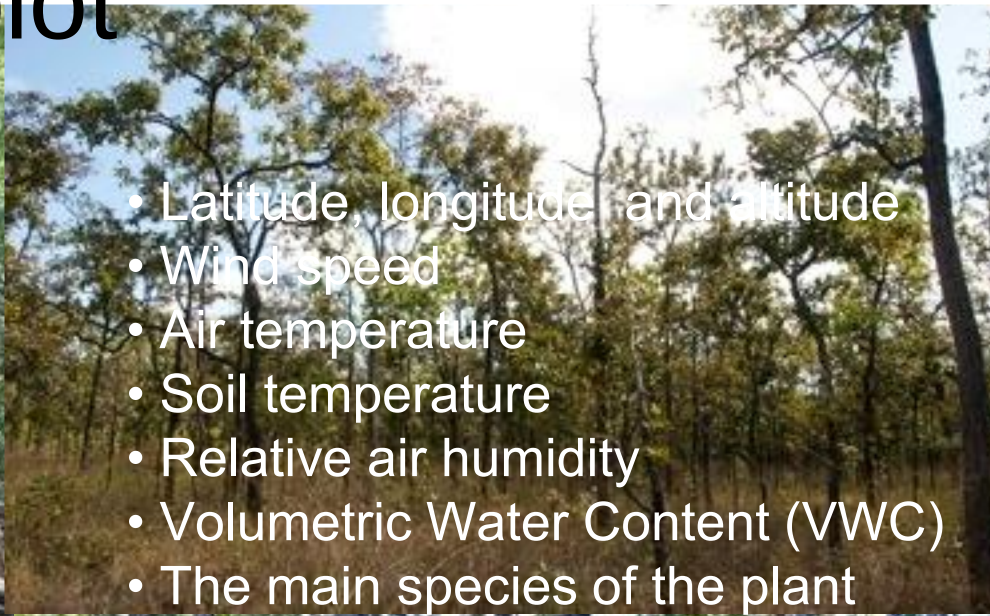
- CO_2: photosynthesis & respiration
- CH_4: production & oxidation
- N_2O: nitrification & denitrification
- LUC emission: cropland conversion
- Fire emission: CO_2, CO, BC, etc.
- BVOC emission: isoprene etc.
- Others: N_2, NO, NH_3, erosion

Global biomass in forest and agricultural land

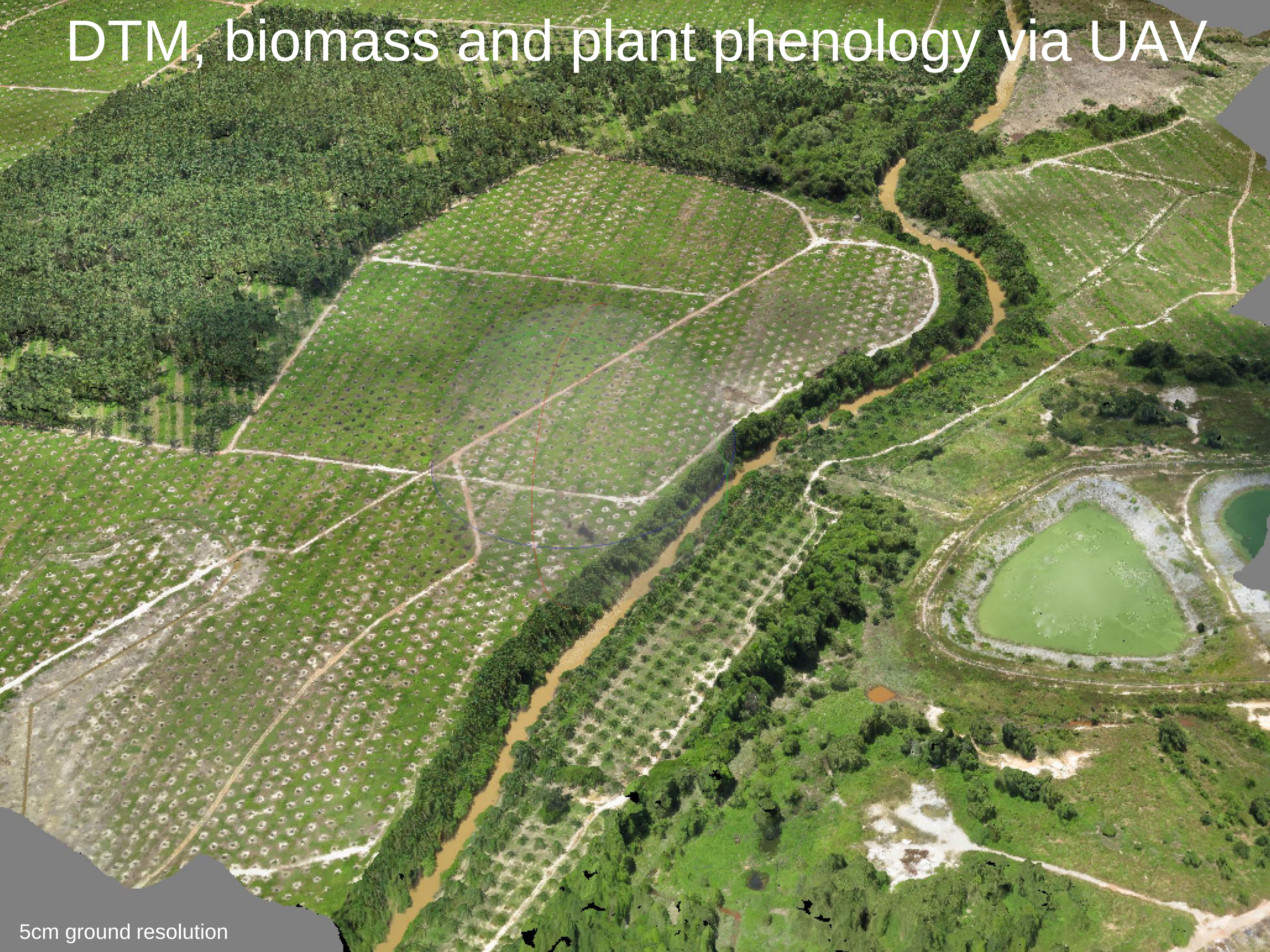


Tropical forest: 150-300 (tC/ha), Boreal forest: 50-70 (tC/ha)
Savanna: 20-30 (tC/ha), Agcitultural land: 2-10 (tC/ha)
grassland: 0.5 (tC/ha)

In-situ biomass measurement at sample plot

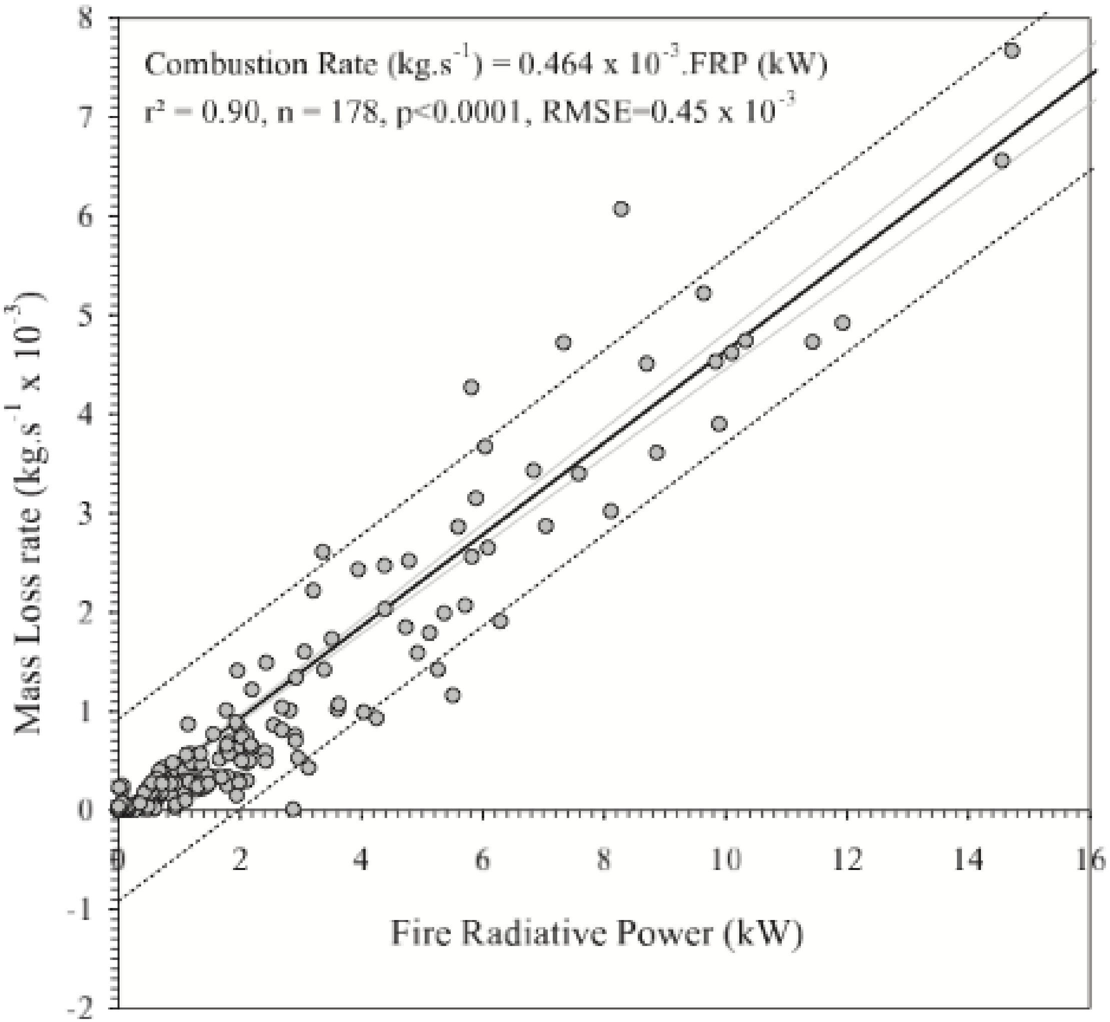


DTM, biomass and plant phenology via UAV



5cm ground resolution

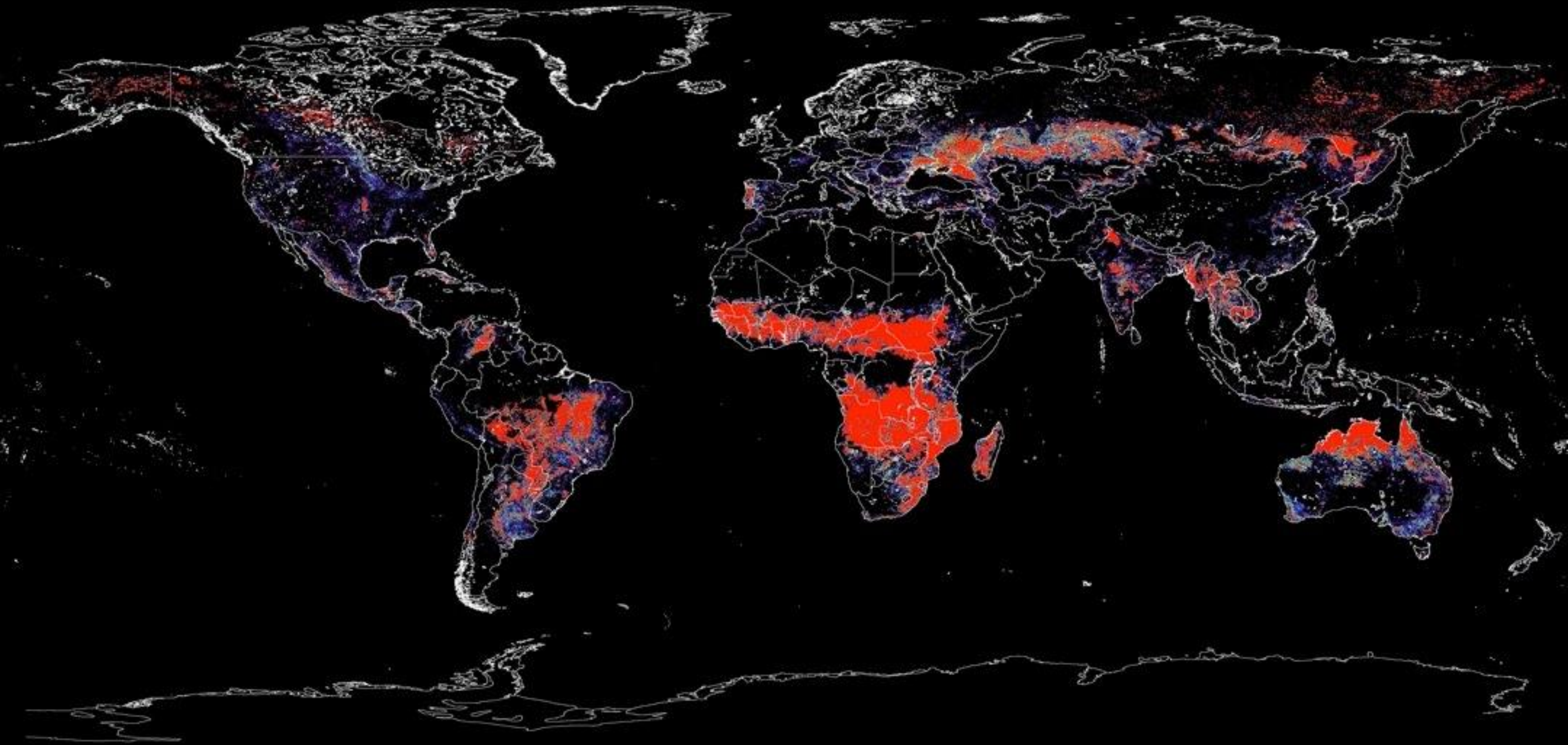
Biomass loss rate with FRP



[Wooster, 2005]

Figure 13. Relationship between biomass combustion rate and fire radiative power calculated from *Miscanthus* fires (in total twenty nine plots of the sort shown in Figure 12c). Source data were subsampled at a three-minute interval to avoid influences from temporal autocorrelation. The OLS linear best-fit passing through the origin (dark line) is shown, along with the 95% confidence intervals on the mean (grey line) and on the prediction (dashed line), the latter having slopes 0.446 and 0.482, respectively.

Annual carbon emissions (as g C/m^2/yr) averaged over 2002-2015



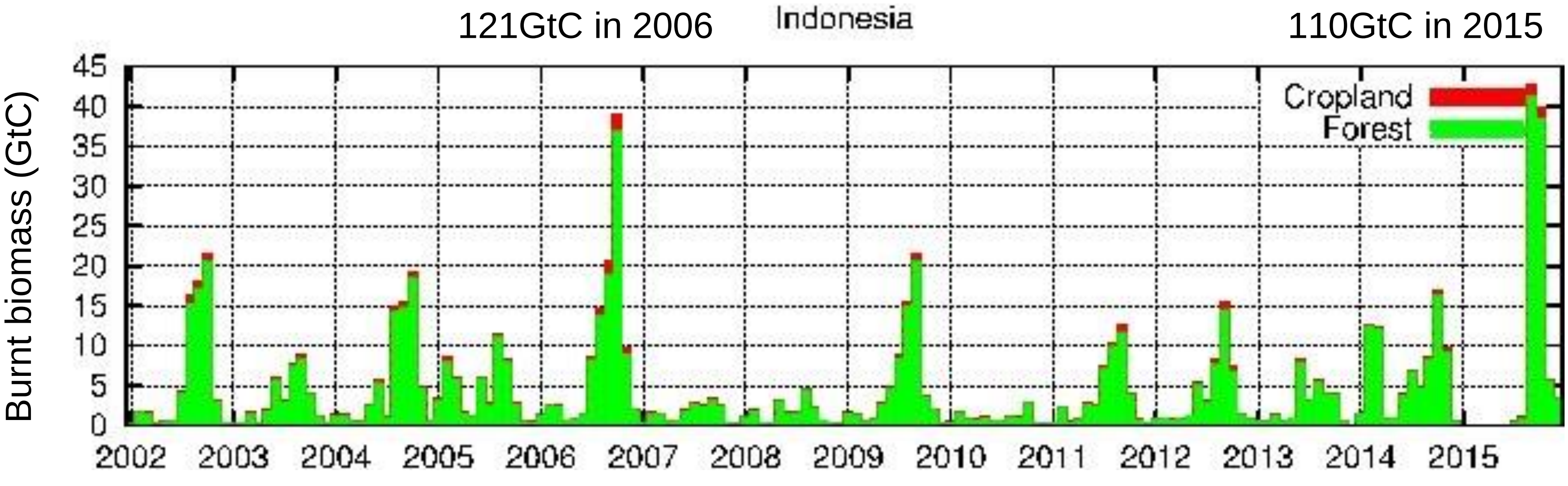
Above ground biomass

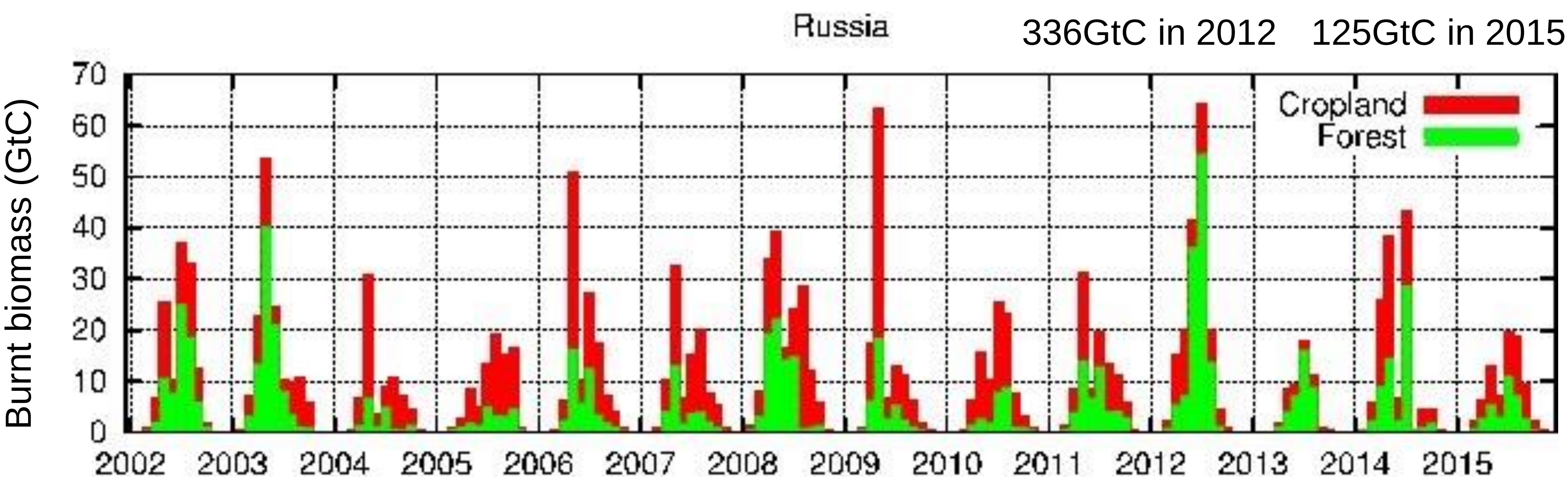
2.92±0.28 PgC/yr

[Takeuchi, in preparation]

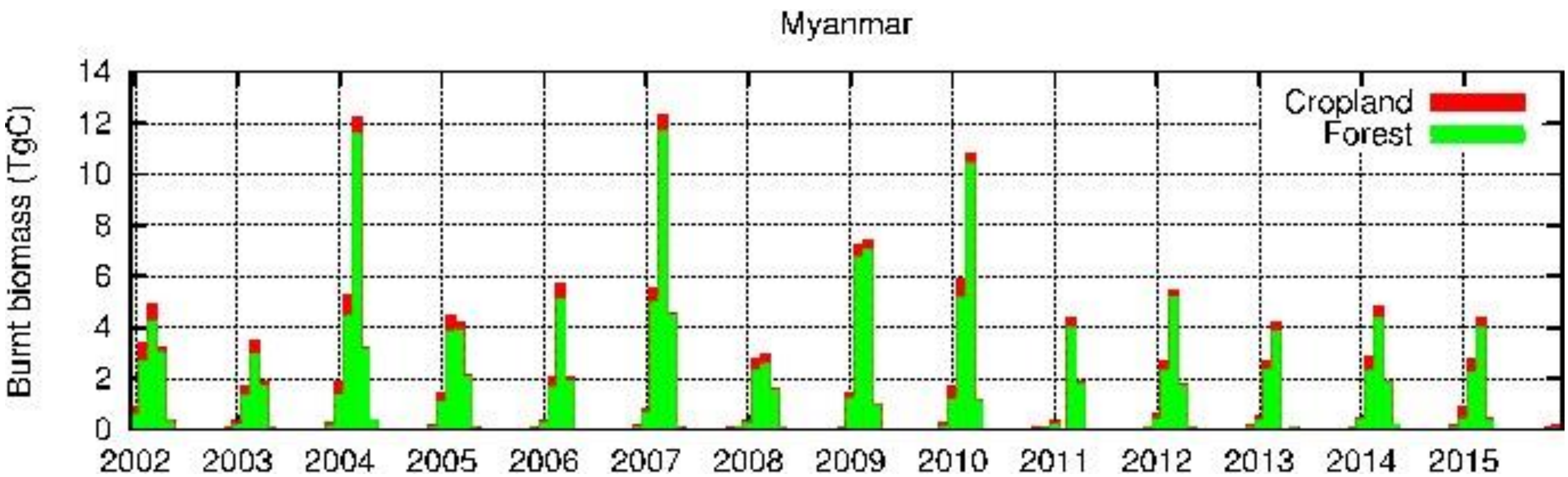
Carbon emissions in 2015 from wild fires hit the highest records in the last 15 years

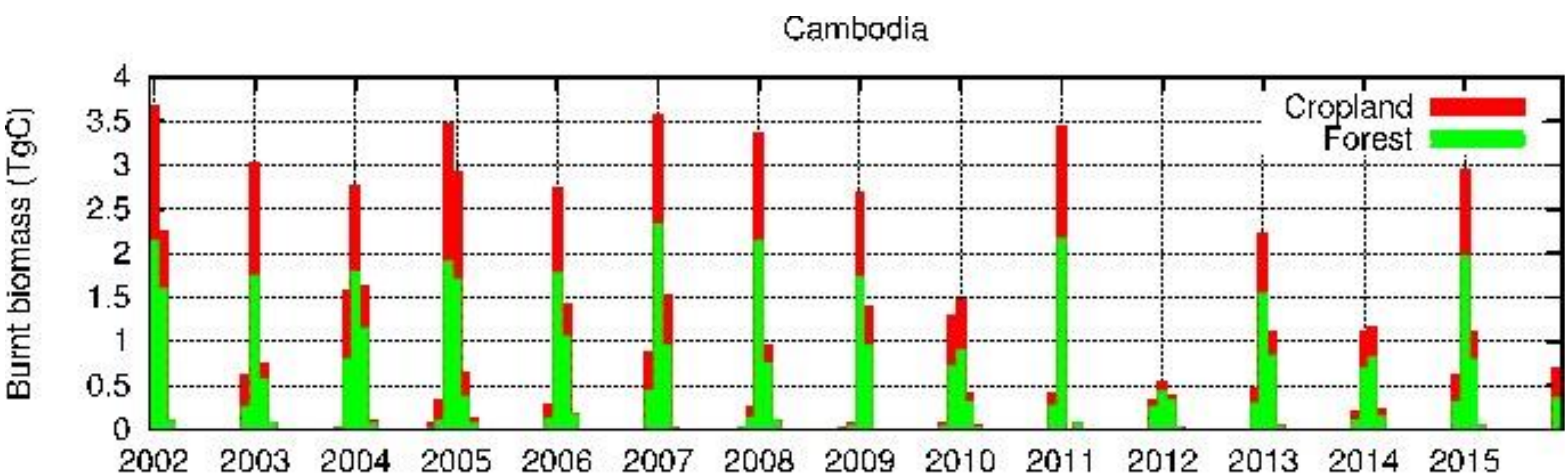
cf. 40GtC in 2015 from Japan in fossil fuel emission, 5th in the world

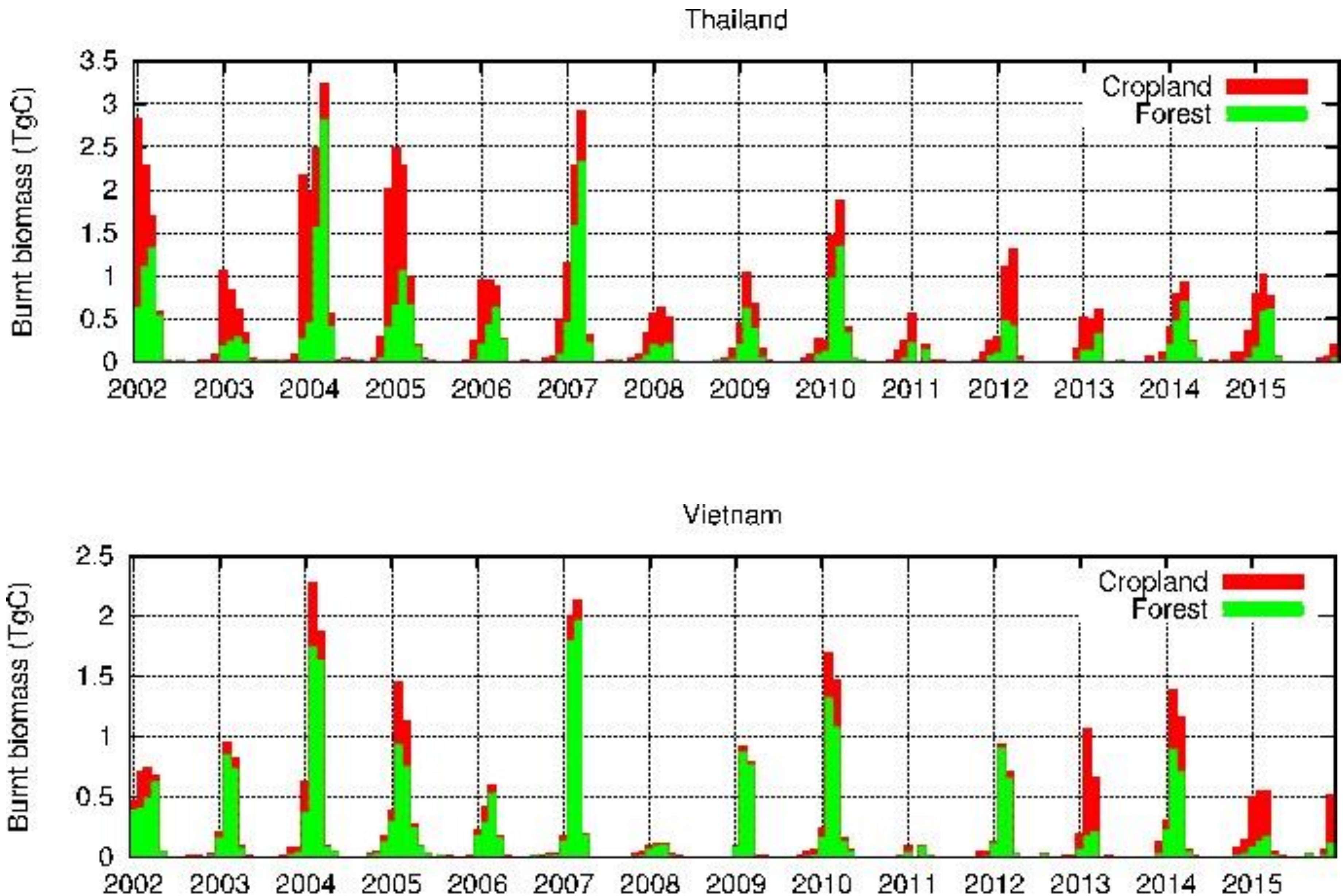




[Takeuchi, 2016]

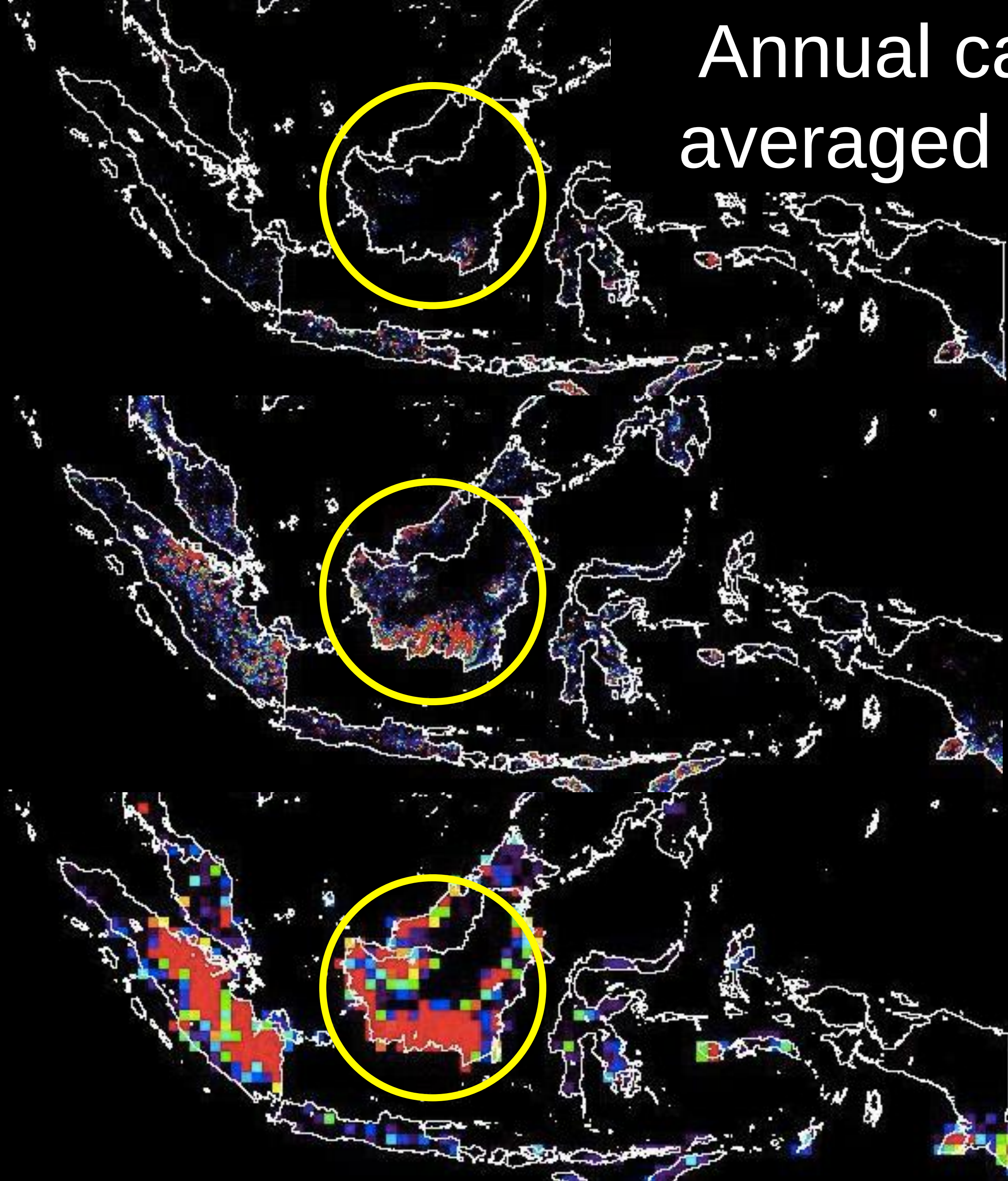

Myanmar
Burnt biomass (TgC)
0
2
4
6
8
10
12
14
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Cropland
Forest


Cambodia
Burnt biomass (TgC)
0
0.5
1
1.5
2
2.5
3
3.5
4
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Cropland
Forest



Thailand
Burnt biomass (TgC)
3.5
3
2.5
2
1.5
1
0.5
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Cropland
Forest
Vietnam
Burnt biomass (TgC)
2.5
2
1.5
1
0.5
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Cropland
Forest

Annual carbon emissions averaged over 2002-2010



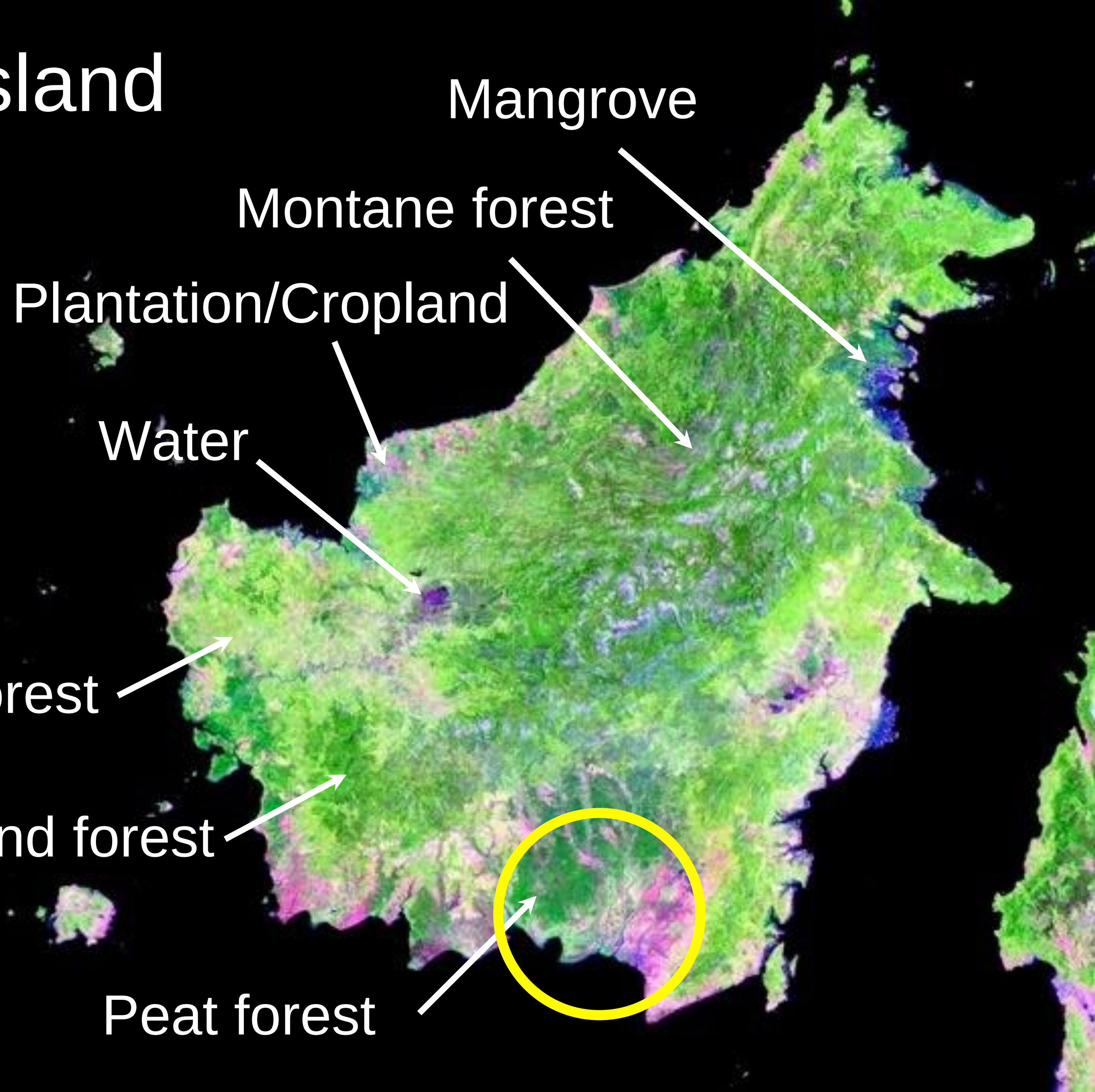
Above ground biomass (AGB)
0.5±0.4 TgC/yr

Soil organic carbon (SOC) by peat fire
34.2±27.0 TgC/yr

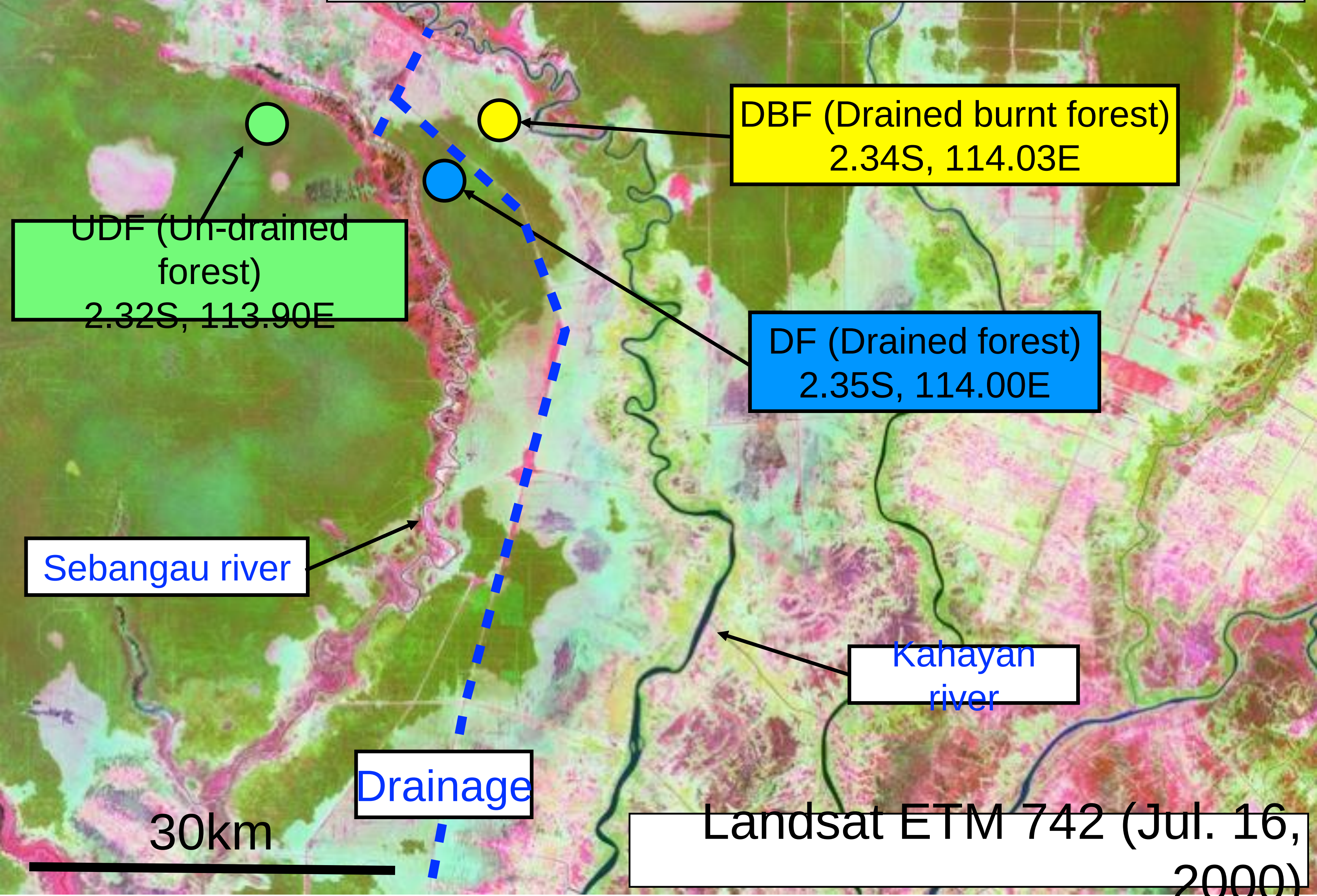
GFED3.1 (NASA)
76.8±96.8 TgC/yr

[W. Takeuchi, T. Hirano and O. Roswintiarti, 2011]

Borneo island



Flux measurement in central Kalimantan

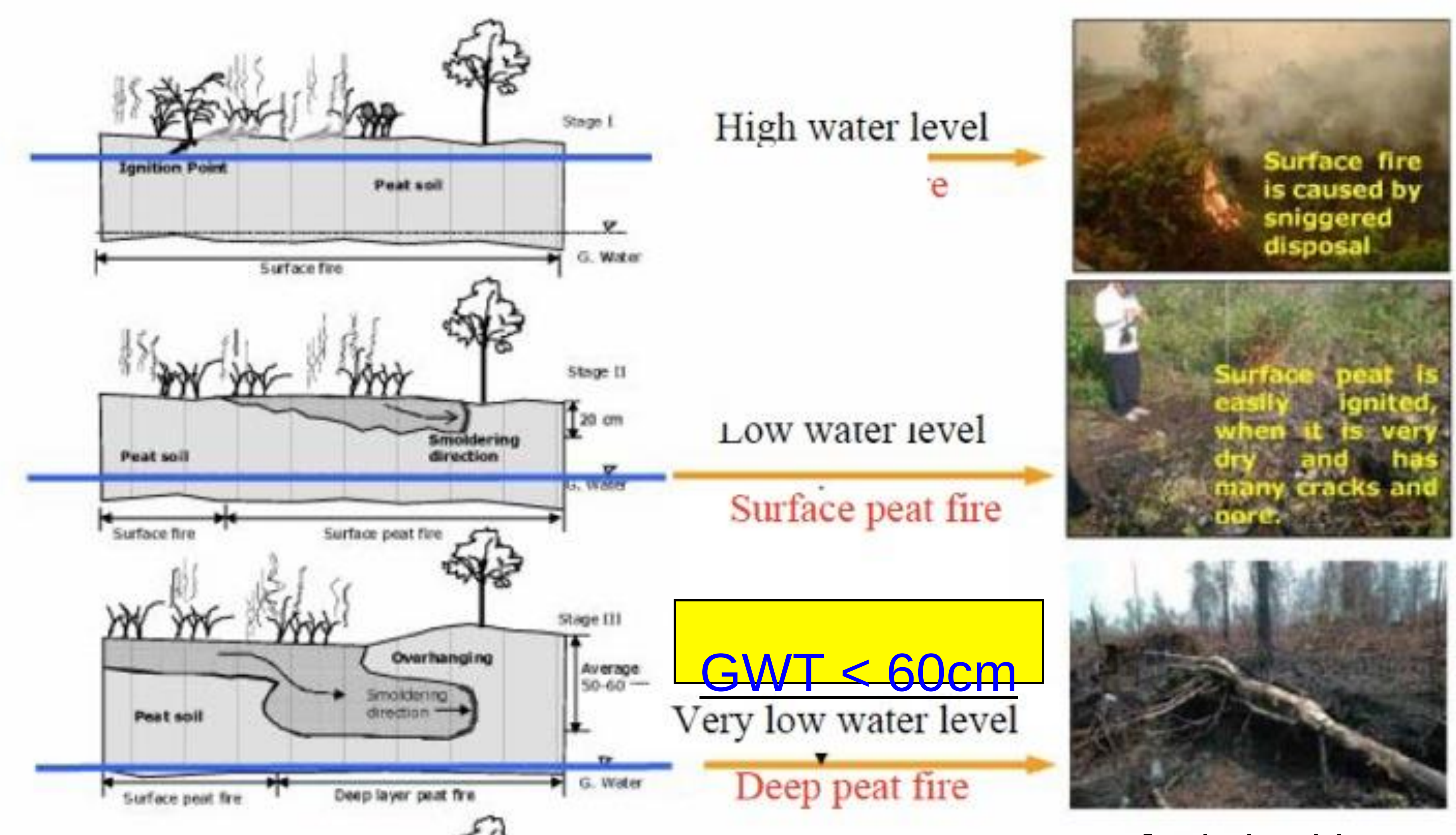



DF (Drained forest)
2.35S, 114.00E
Evapotranspiration 4mm/da
Precipitation 2000mm/yr


UDF (Un-drained forest)
2.32S, 113.90E


DBF (Drained burnt forest)
2.34S, 114.03E
[Hirano, 2008]

Combustion process of peat fire

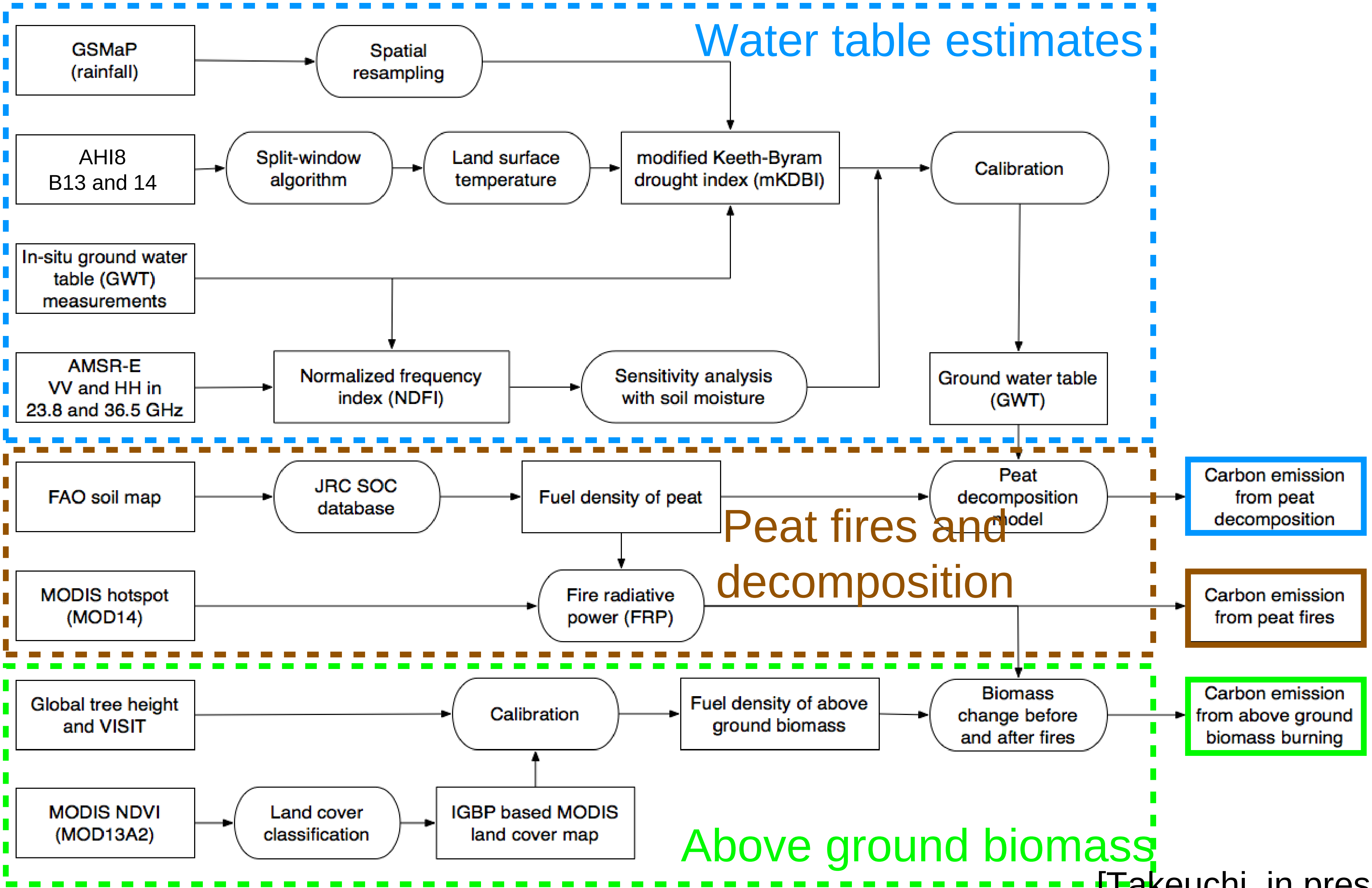


GWT < 60cm

[Takahashi, 2008]

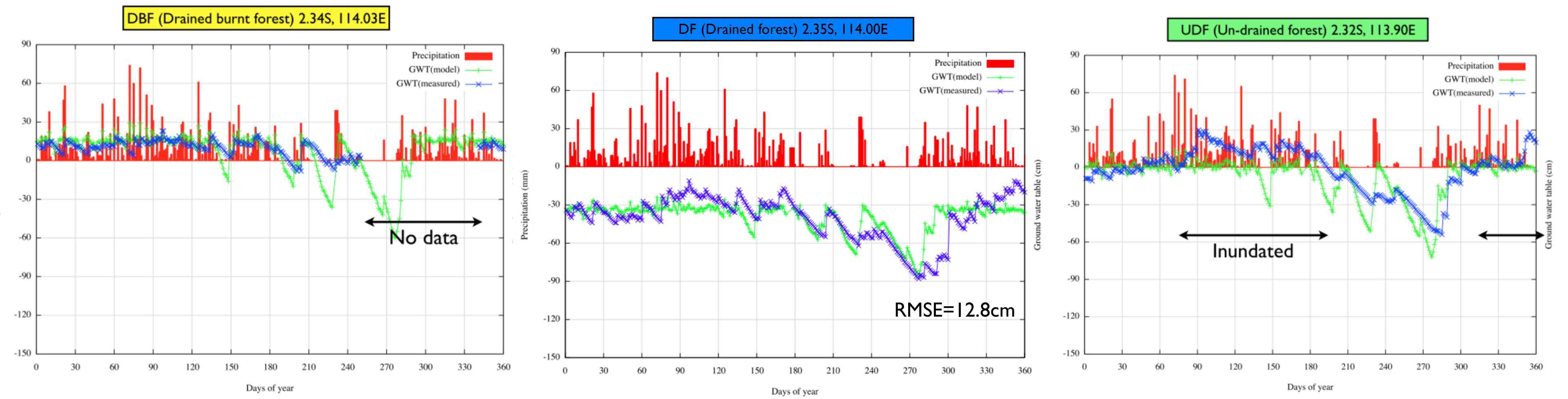
Ground water level is a governing factor in peat fire

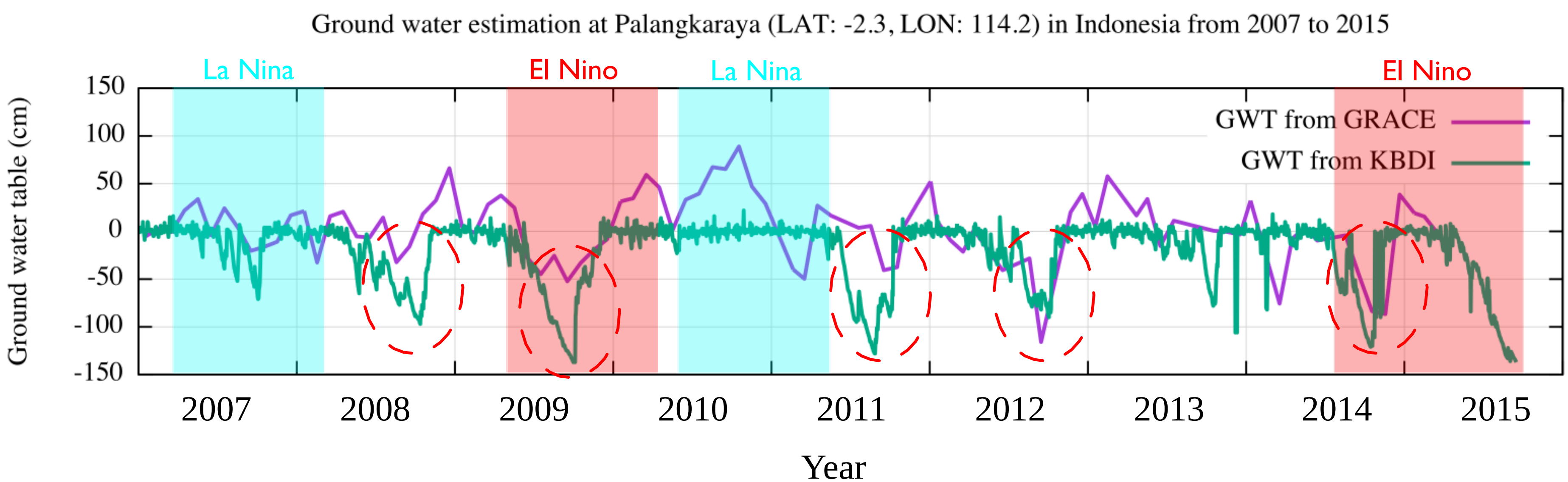
Water-carbon-simulator (WCS)



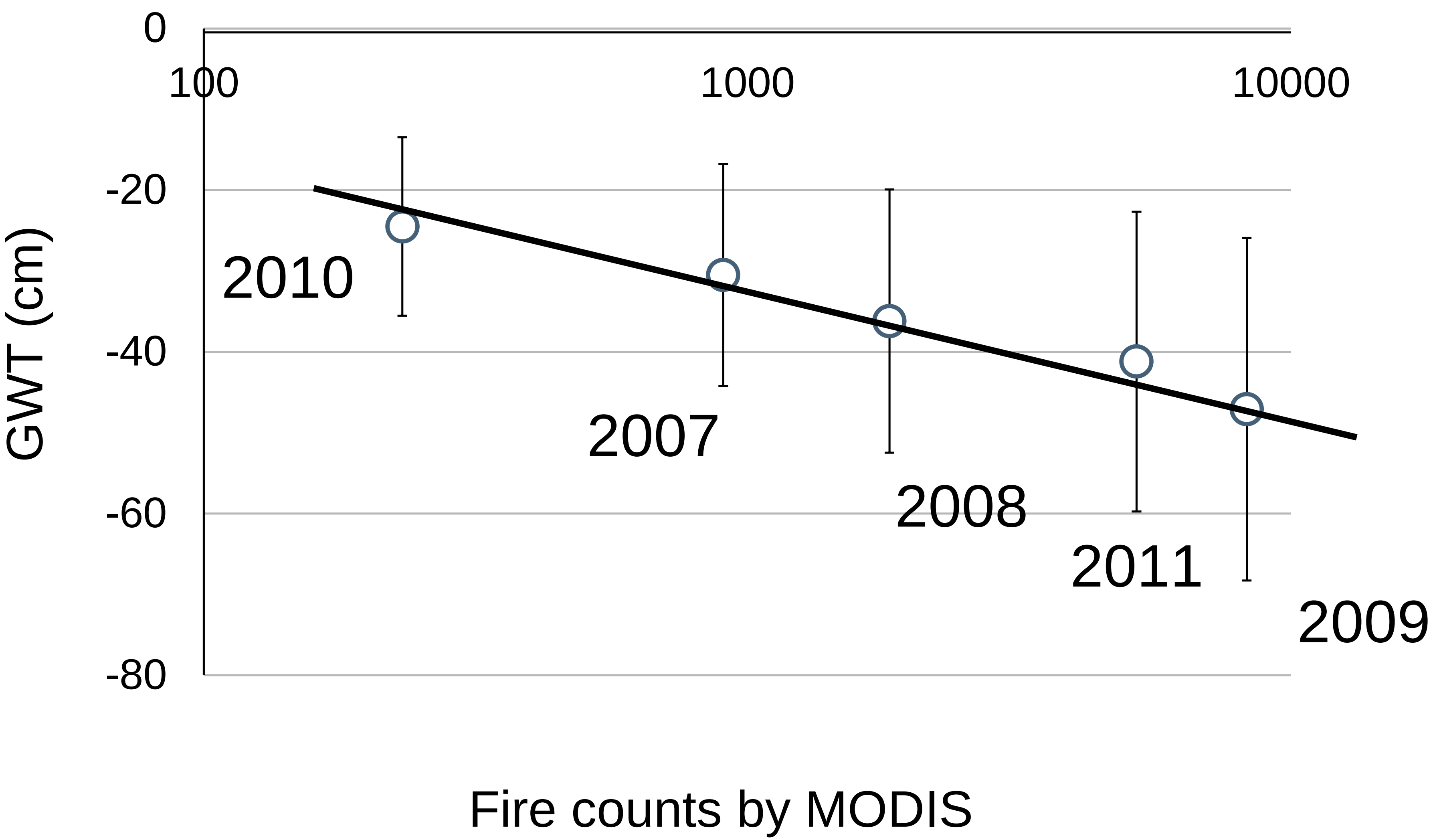
[Takeuchi, in press

Lower ground water table of peatland in Indonesia are prone to firesand large carbon emission sources

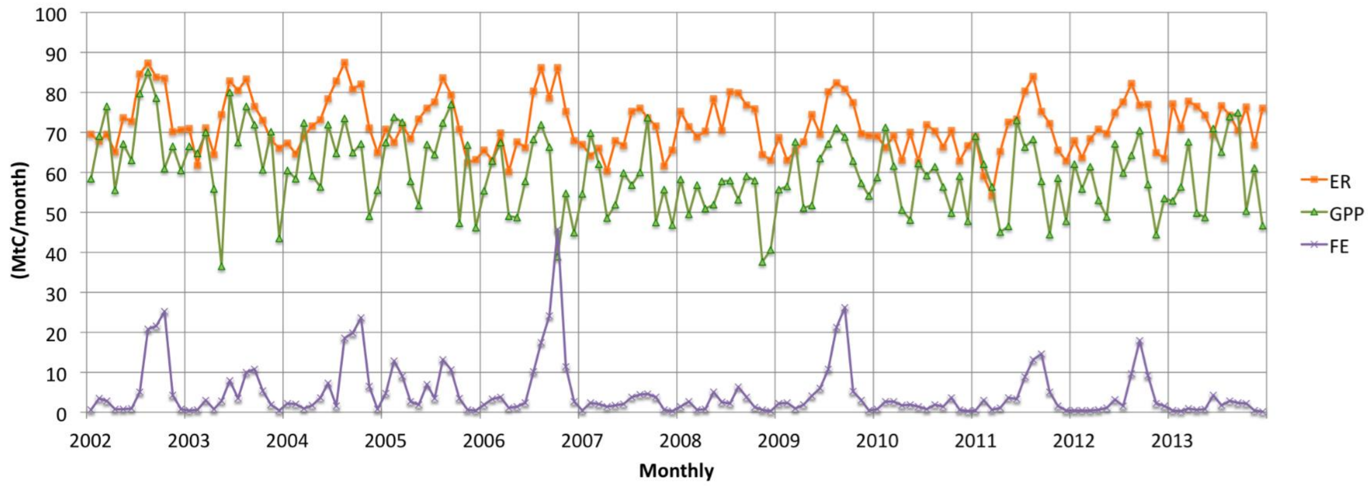




More fires in lower GWT years



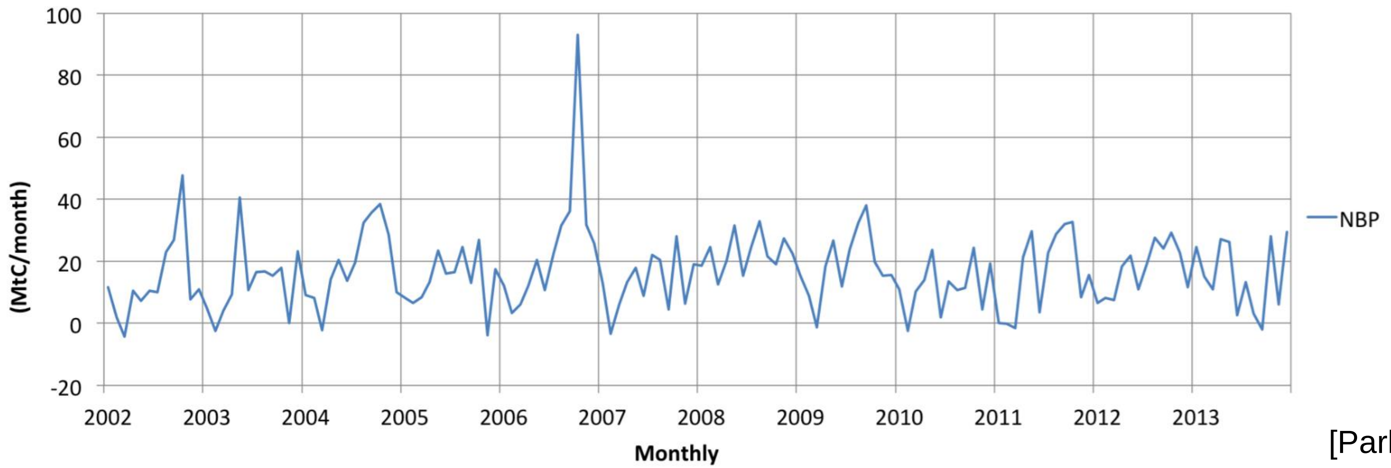
Comprehensive evaluation of carbon budget at peatland in Indonesia



(a) The sum of monthly ecosystem respiration (ER), gross primary production (GPP), and fire emission (FE) from whole peatlands of target area

C Source

C Sink

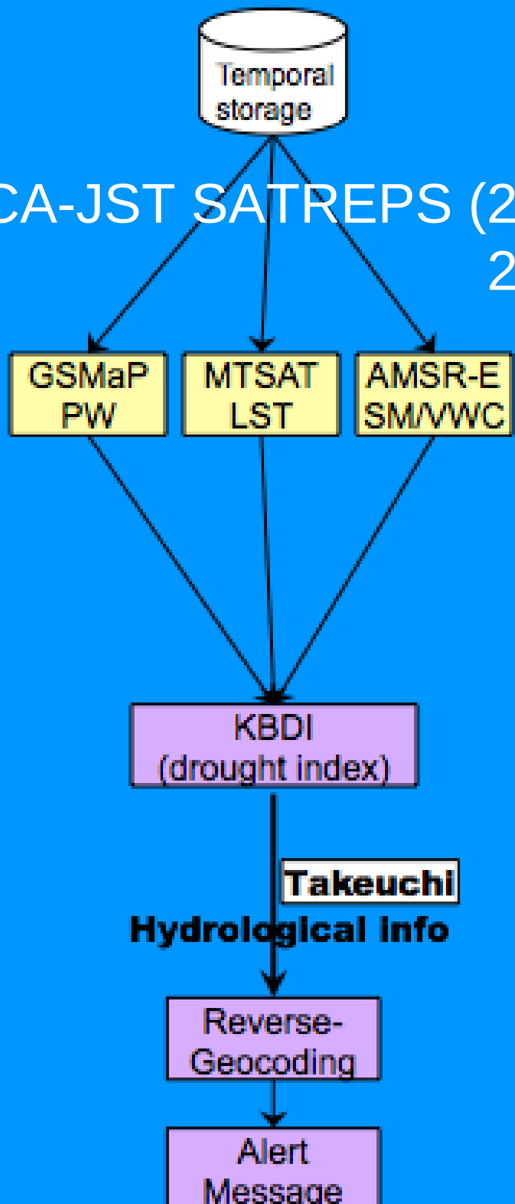


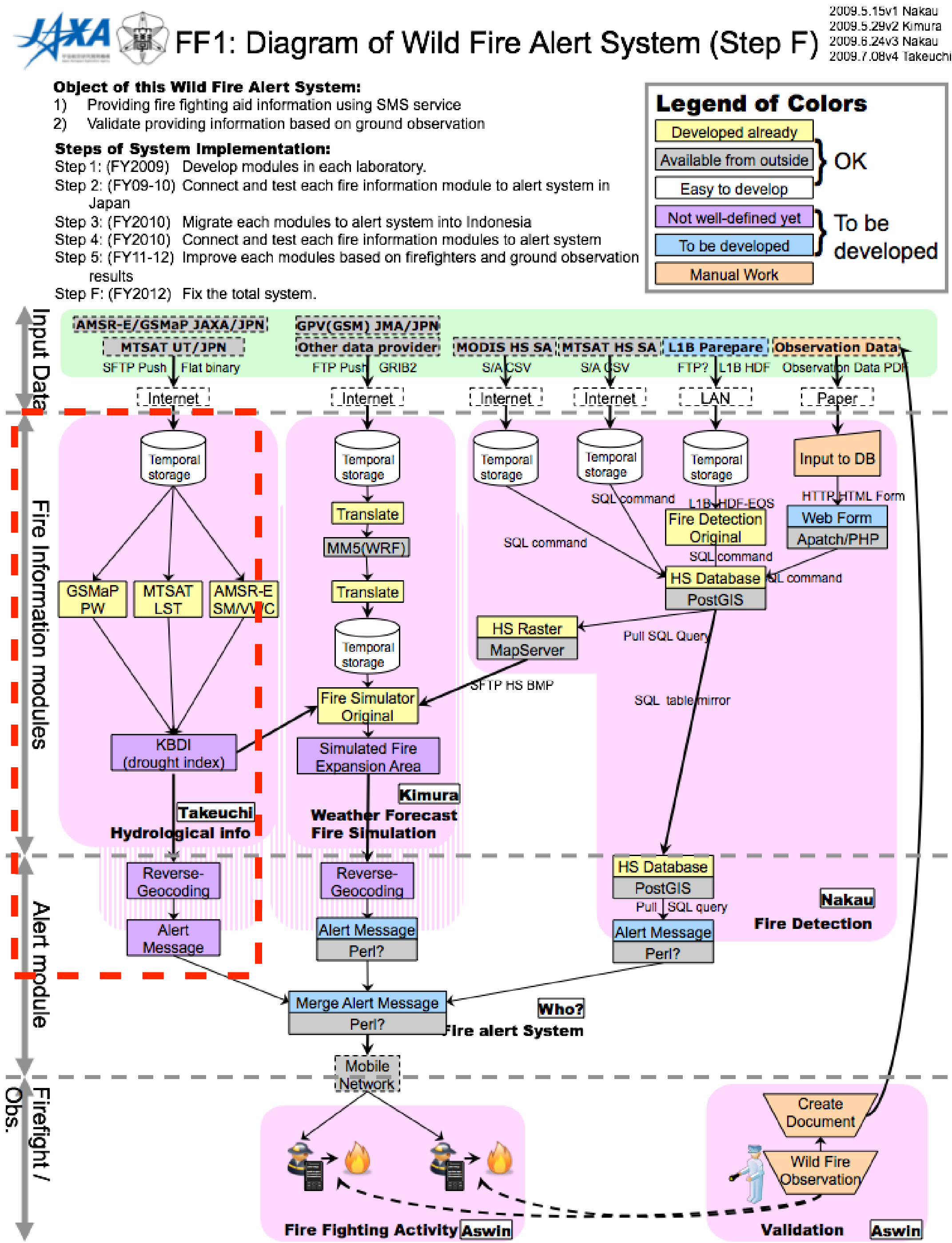
[Park, in review]

(b) NBP from peatlands in Indonesia during 12 years. Net biome production is including the balance among ecosystem respiration, gross primary production, and fire emission in this study

Near-real time fire detection and meteorological information dissemination to support fire fighters activity

JICA-JST SATREPS (2009-2013)

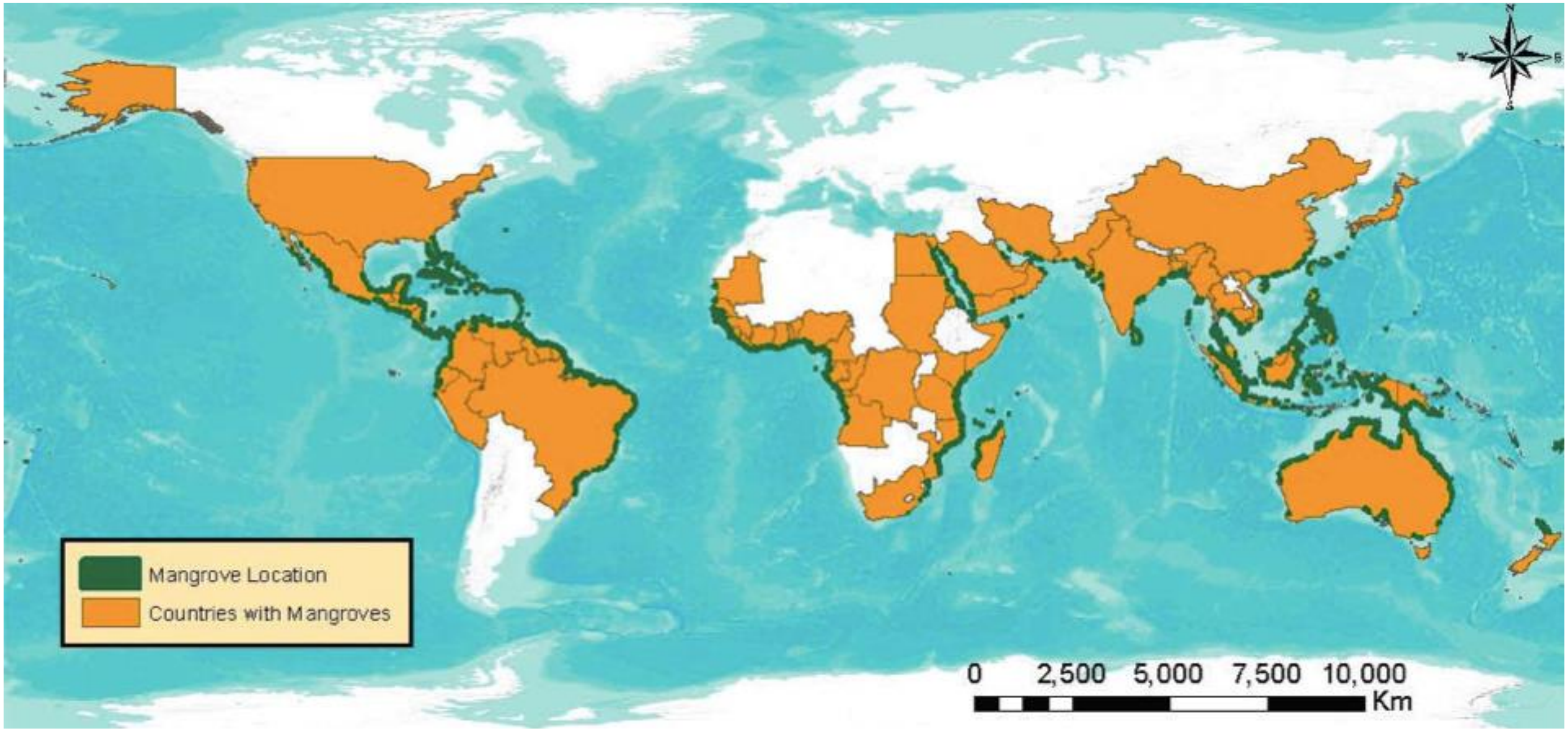




angrove and seagrass biomass mapping in As

(JAXA SAFE project under APRSAF)

Global mangroves in coastal ecosystems



A total of 15.2 million hectares of mangroves are exist worldwide and their main distribution is in the tropical areas. (USGS, 2009)

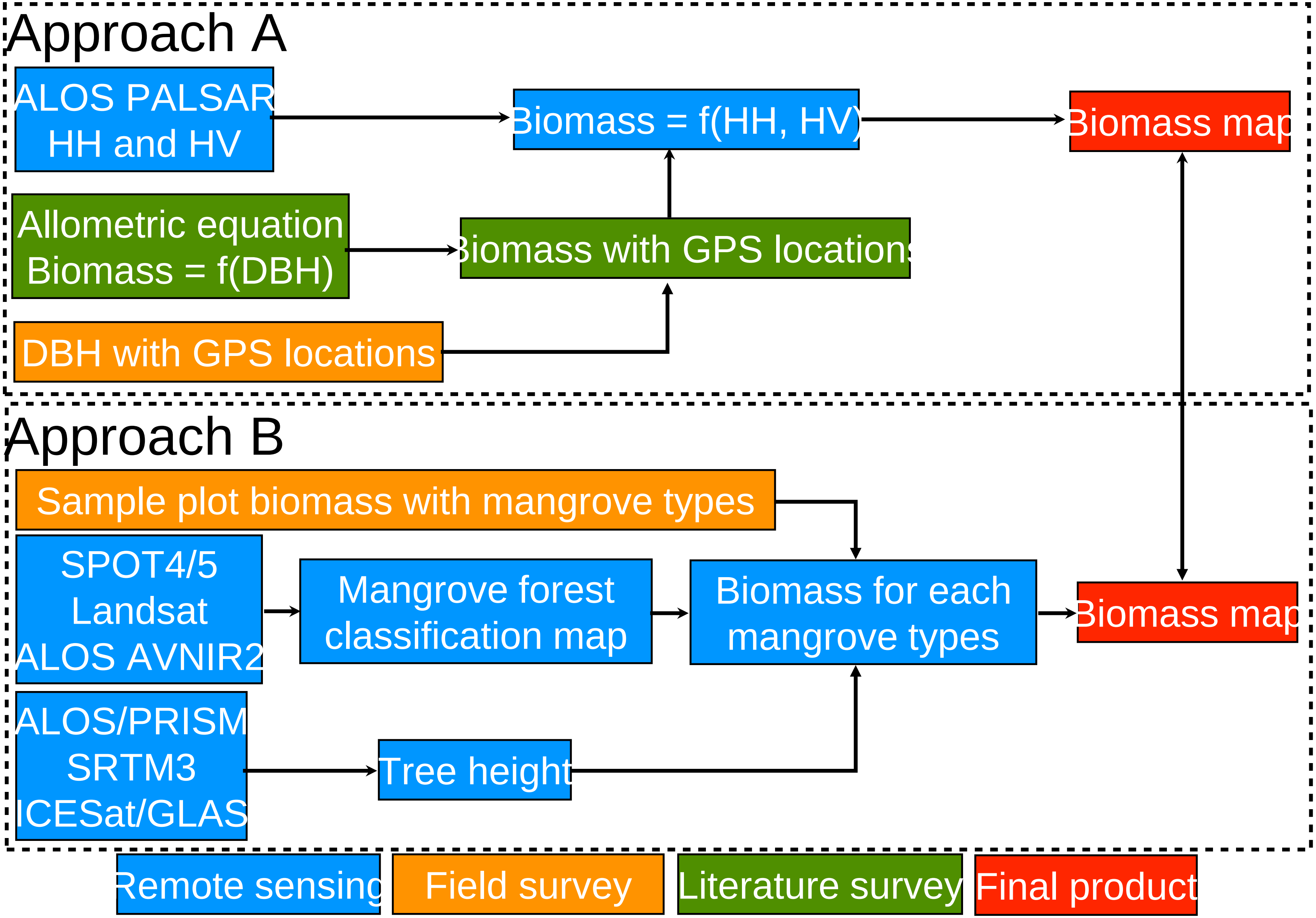
About one third of the world's mangroves are found in Asia (39%), followed by Africa (21%) and North and Central America (15%) (FAO, 2007).

Coastal ecosystems transfer carbon from the atmosphere and ocean into sediments

(Blue carbon)

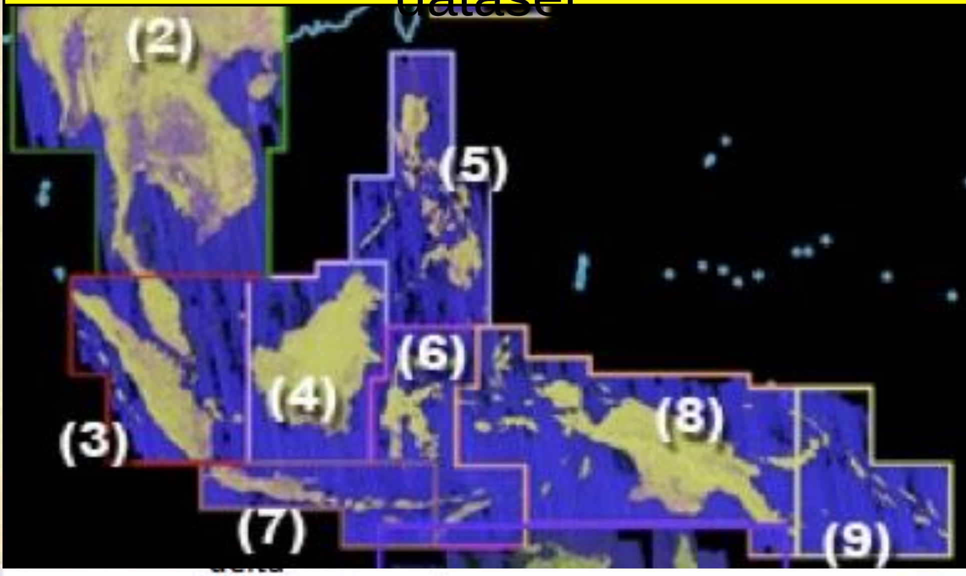
(Conservation international, 2011)

Mangrove above ground biomass estimation

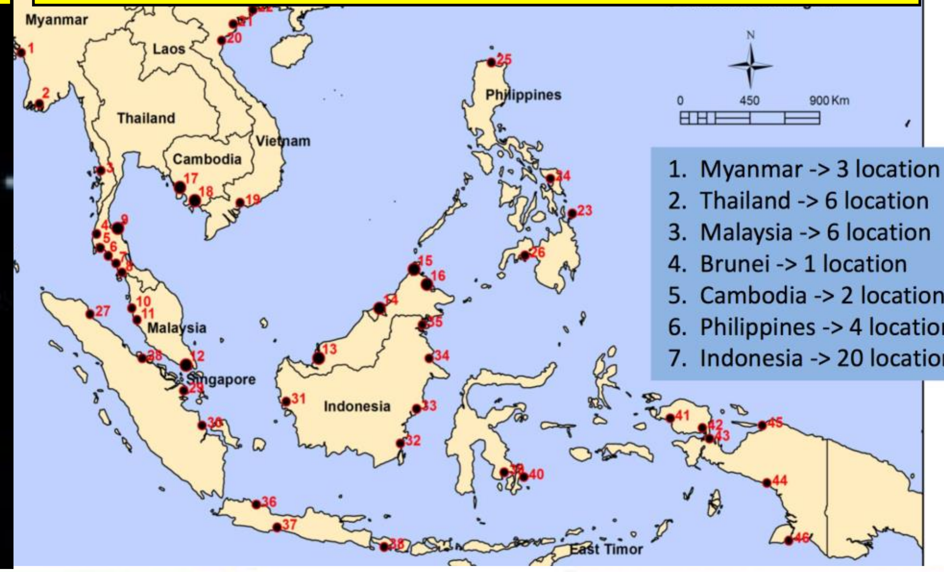


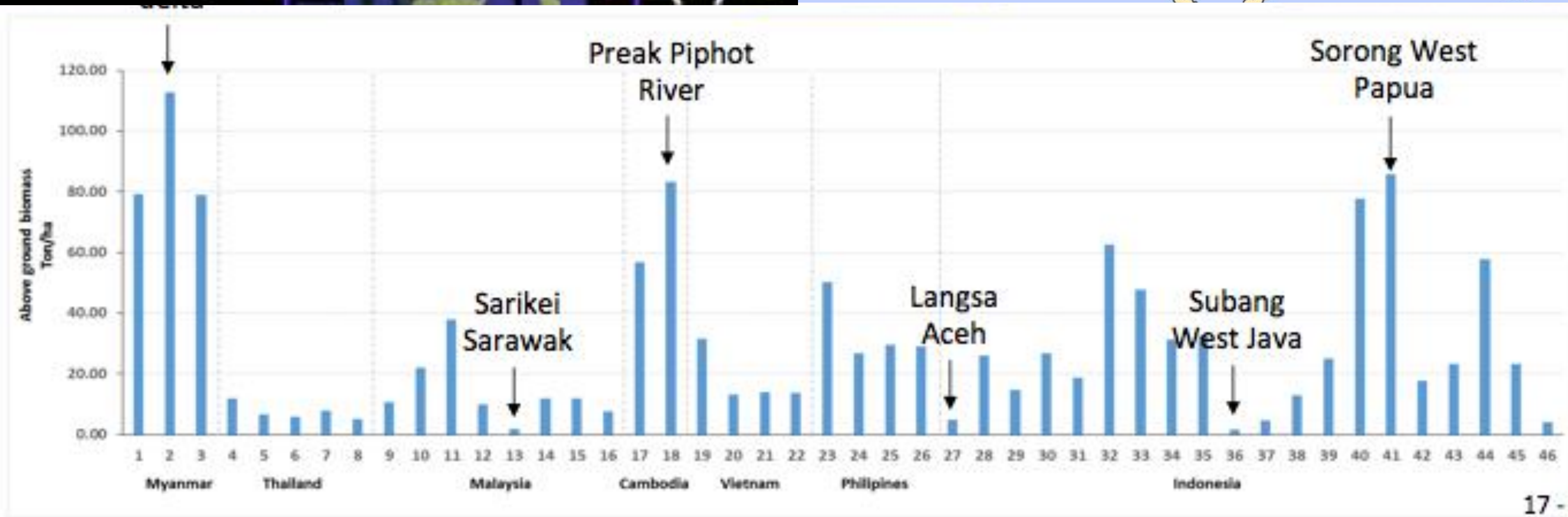
Above ground biomass in mangrove forest

JAXA PALSAR/PALSAR2 mosaic dataset



42 field measurement site in Asia

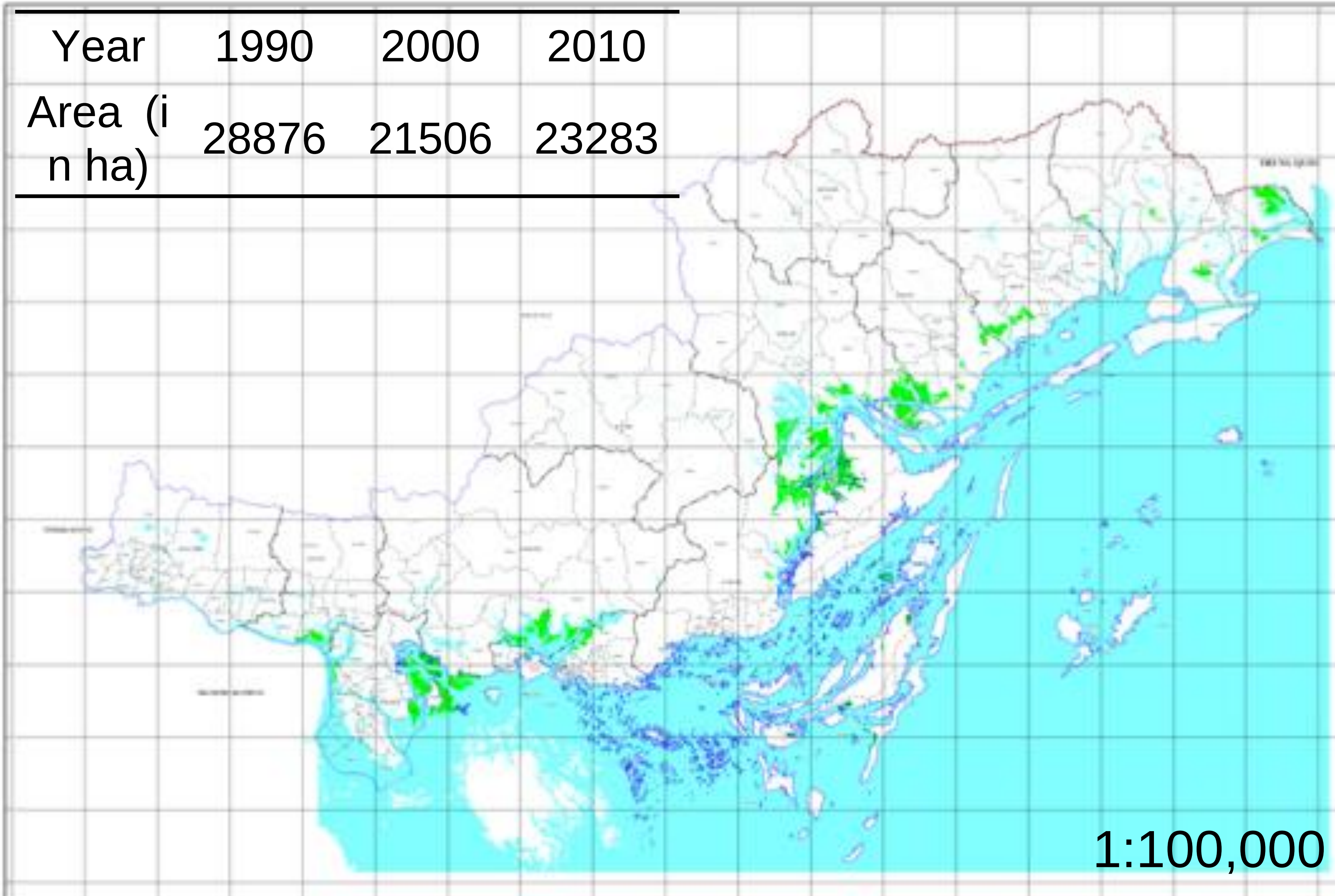




17 - 20

MANGROVE FOREST MAP 2000
QUANG NINH PROVINCE

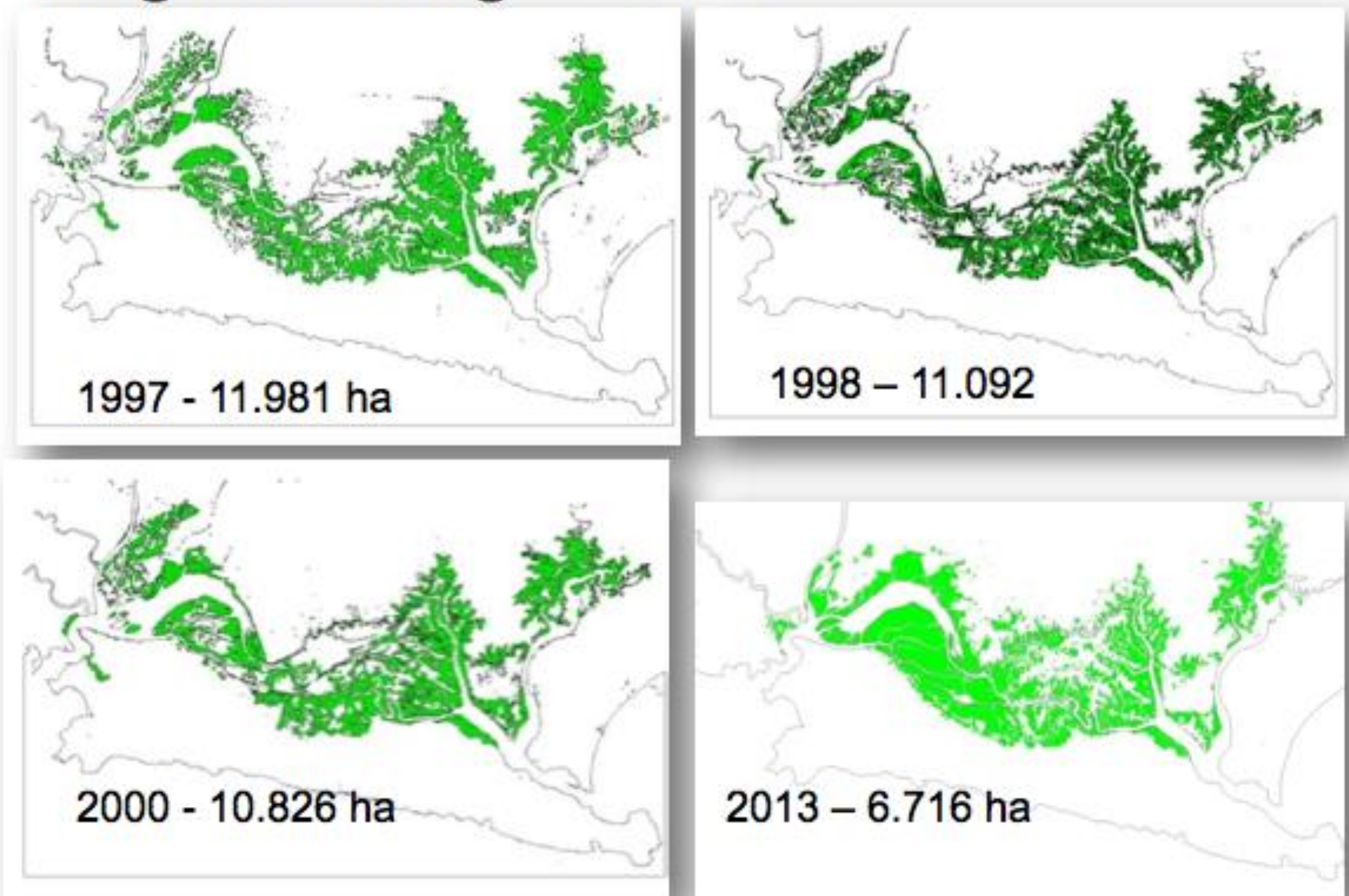
Year	1990	2000	2010
Area (in ha)	28876	21506	23283



1:100,000

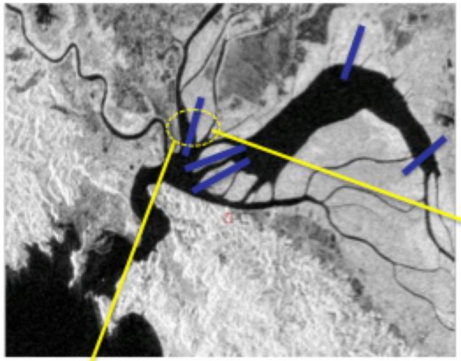
Mangrove change by Landsat from 1997 to 2013 Segara Anakan in Indonesia

- Mangrove change 1997-2013



1994 – 14.597 ha (Parwati, 2002)

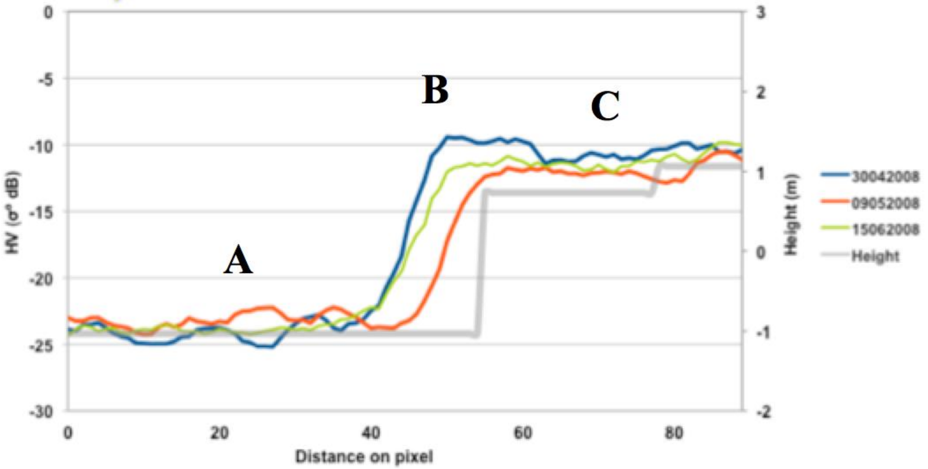
Impact of topography and tidal effect to mangrove biomass mapping

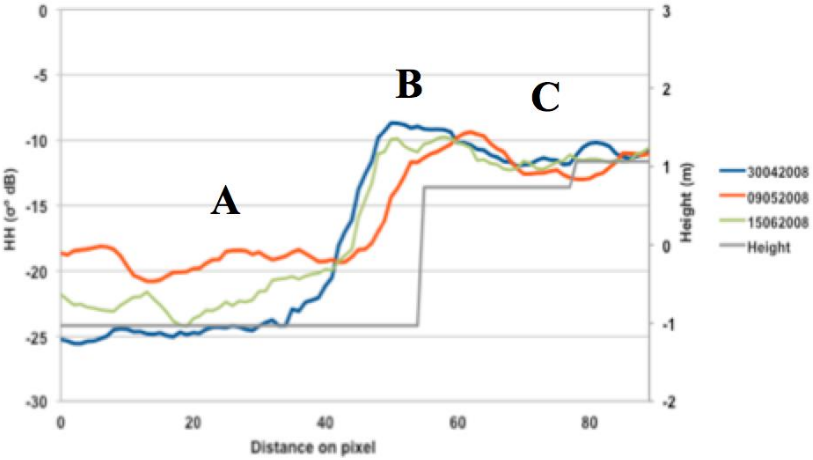


Tidal height :
30042008 : -0.4 meter
09052008 : 1.0 meter
15062008 : -0.2 meter

A. Water area
B. Area with strongly affected by tidal height
C. Area with not strongly affected by tidal height

Impact of tidal height → majority lower value on HV and HH



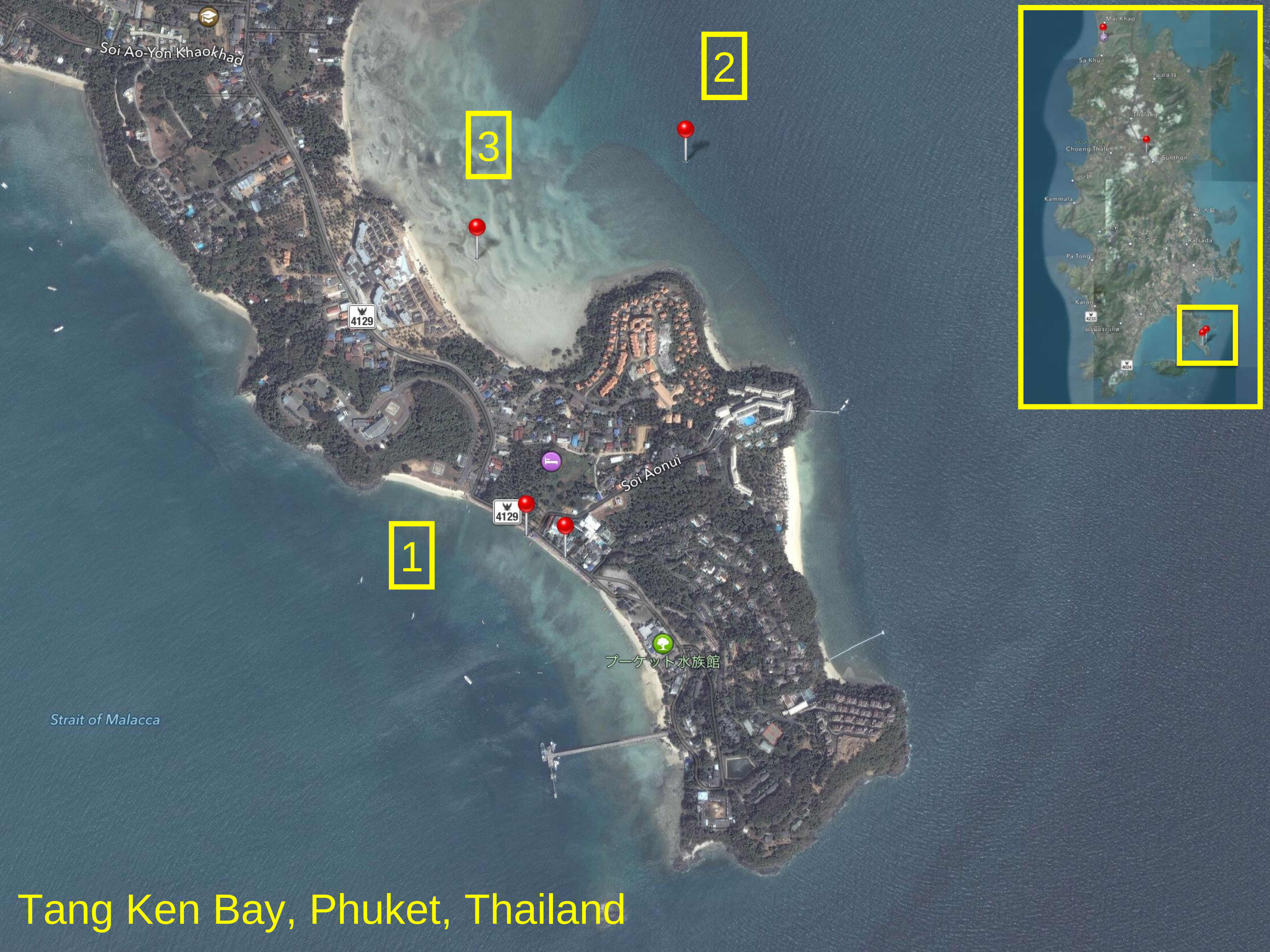


[Soni, Journal of Sensors, 2015]

Above ground biomass (AGB) estimation based on ALOS PALSAR considering impact of topography and tidal height

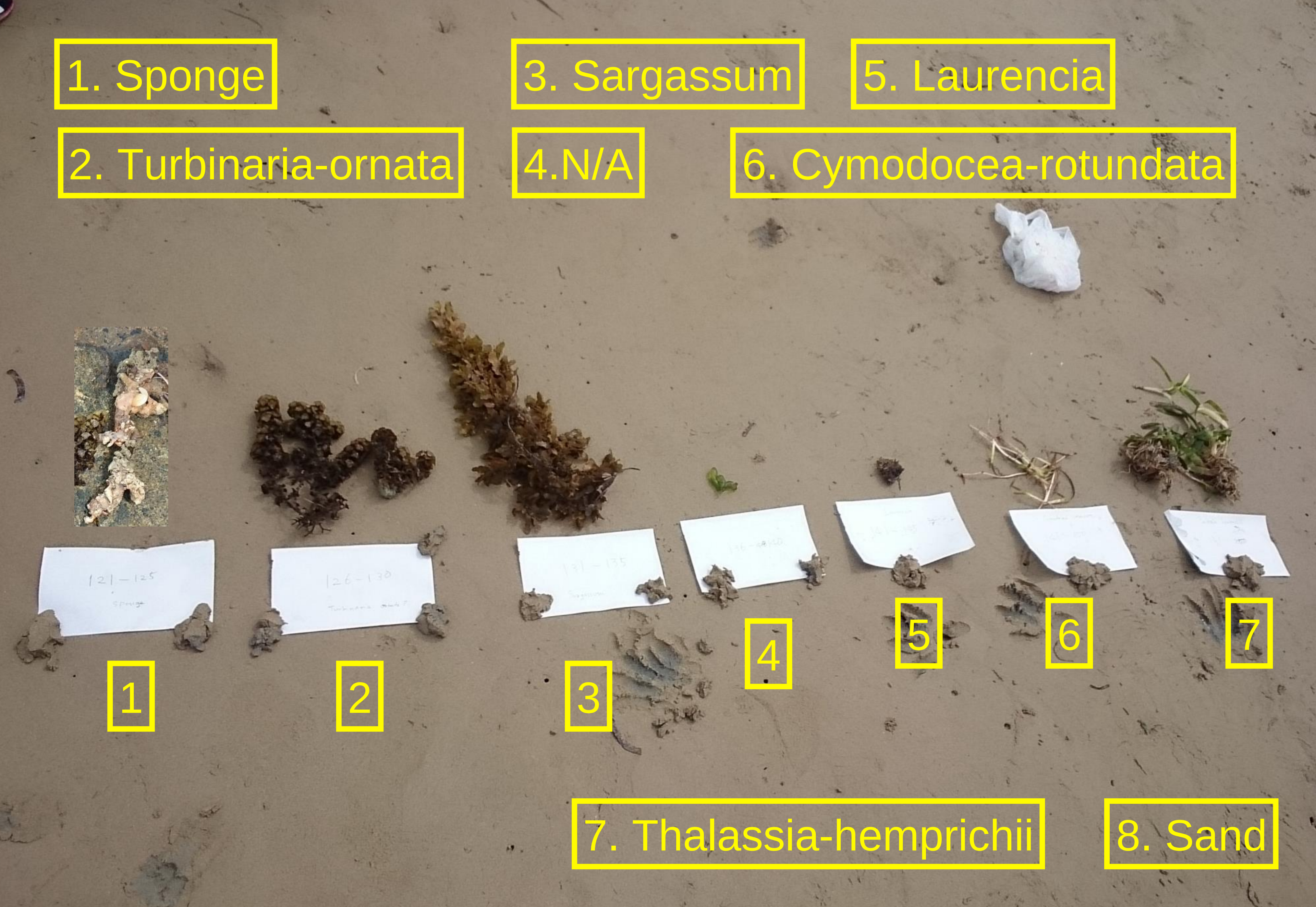
Site	Location of mangrove zones	Average level of topography (meters)	Impact of tidal height (on % area)	Averages AGB estimation (ton/ha)
a	Langsa Aceh	2.2 ± 5.4	95	1.57 – 20.65
b	Bengkalis Riau	4.9 ± 1.9	40	26.08
c	Indragiri hilir Riau	6.8 ± 4.7	4	14.64
d	Banyuasin South Sumatera	16.8 ± 4.9	4	26.68
e	Pontianak West Kalimantan	10.2 ± 3.3	4	18.76
f	Kota Baru South Kalimantan	9.5 ± 5.9	6	62.57
g	Kutai Kartanegara East Kalimatan	9.6 ± 4.8	6	47.59
h	Berau East Kalimantan	15.0 ± 5.4	4	31.38
i	Nunukan East Kalimantan	14.5 ± 3.4	4	32.51
j	Subang WestJava	3.0 ± 1.8	95	0.83 – 4.38
k	Cilacap Central Java	2.9 ± 2.1	90	1.70 – 19.36
l	Badung Bali	3.1 ± 2.0	73	3.47 – 85.56
m	Bombana South Sulawesi	8.8 ± 4.4	18	24.92
n	Muna South Sulawesi	10.6 ± 3.8	10	77.78
o	Sorong Papua	13.4 ± 4.5	5	85.76
p	Teluk Bintuni Papua	19.9 ± 11.2	6	17.79
q	Teluk Bintuni Papua	18.7 ± 8.3	4	23.30
r	Waropen Papua	19.3 ± 4.3	2	57.79
s	Asmat Papua	14.8 ± 3.5	2	23.30
t	Merauke Papua	11.7 ± 3.4	2	3.97

[Soni, Journal of Sensors, 2015]

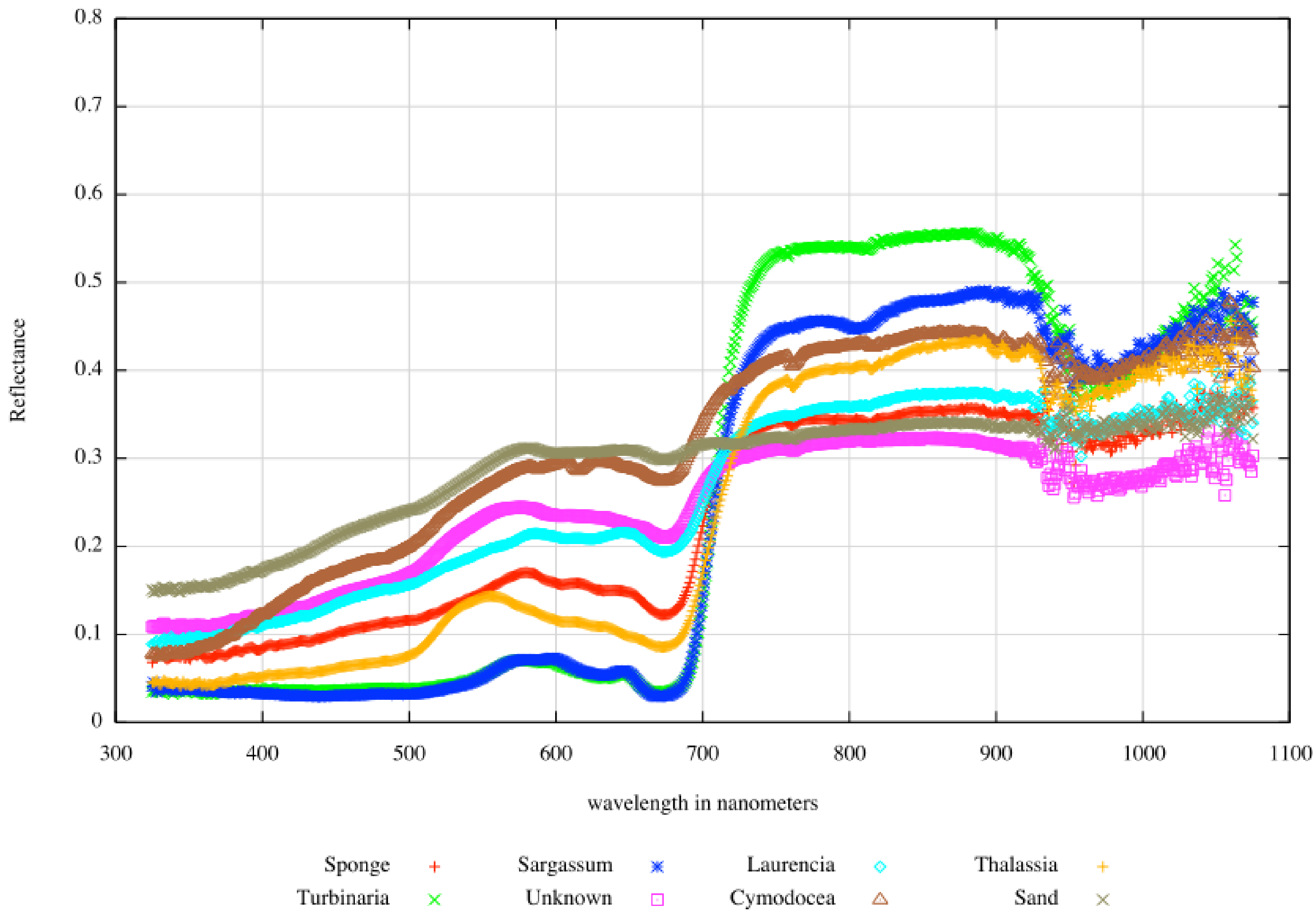

Soi Ao-Yon Khaokhad
2
3
4129
1
Soi Aonui
4129
プーケット水族館
Strait of Malacca
Mai Khao
Sa Khu
Thalang
Choeng Thale
Si Sunthon
Kammala
Pa Tong
Ratsada
Karon
Tang Ken Bay, Phuket, Thailand

1. Seagrass/Seaweed bed

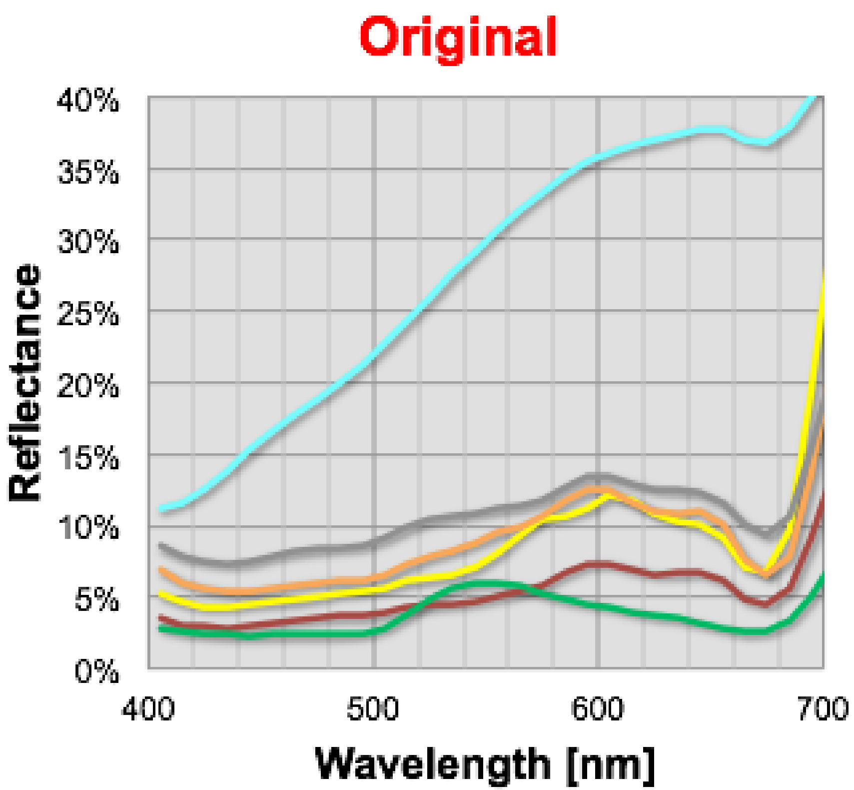
3. Spectral signature sampling by ADS handheld 2



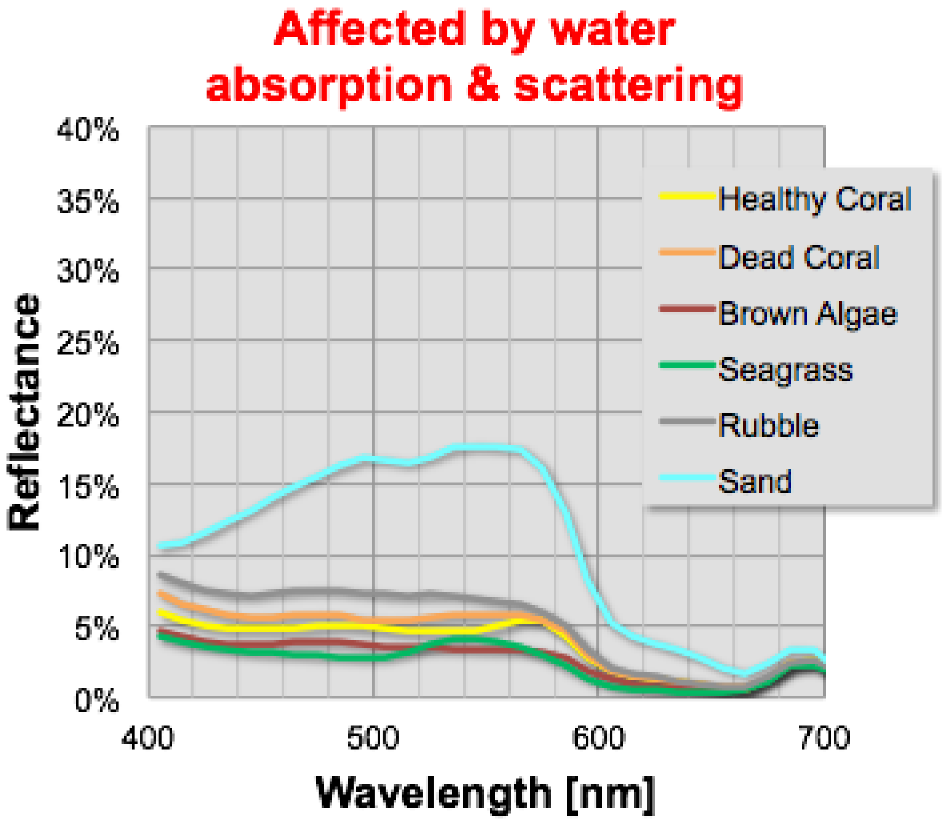
Spectral signatures of seagrass and seaweed



Water column effects on spectral reflectance



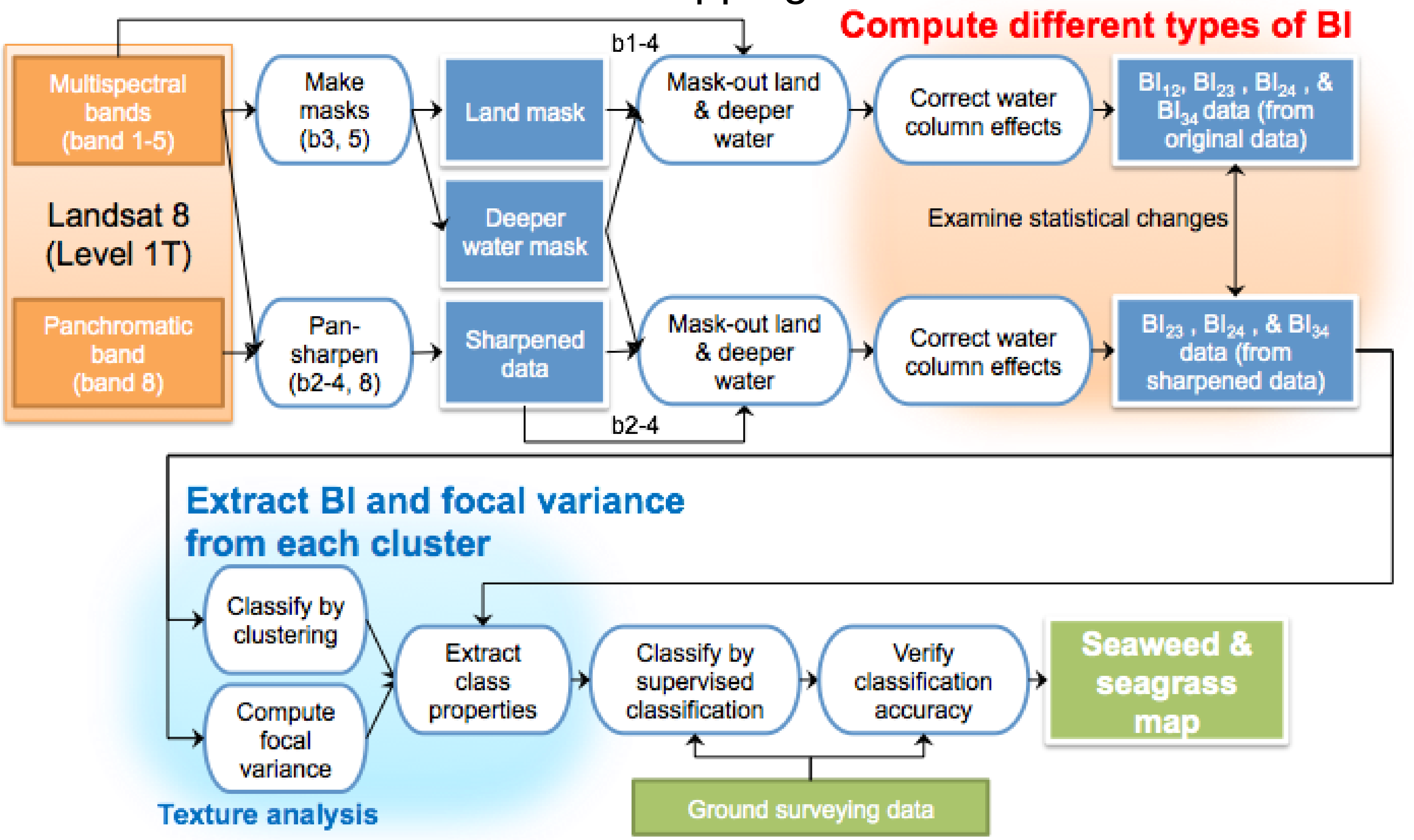
In-situ spectral reflectance, @ 0m depth (Yamano et al., 2003)



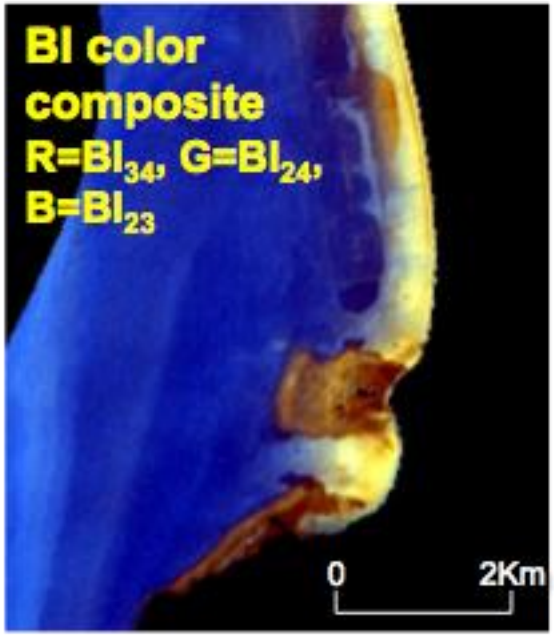
Simulated spectral reflectance on Case 1 water, @ 3m depth

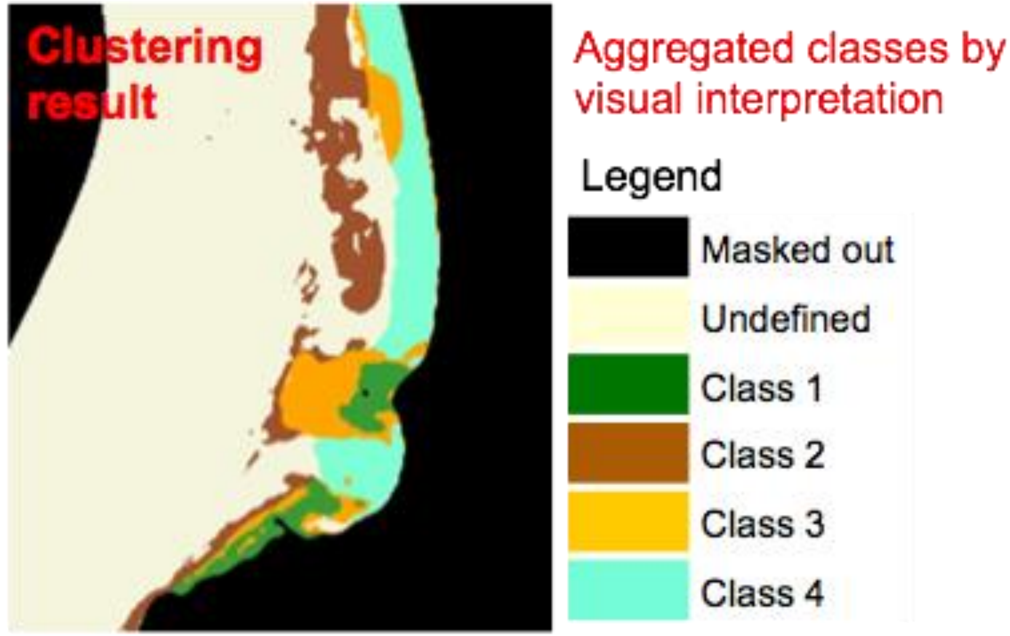
The effects are needs to be corrected!

Use of UAV and satellite remote sensing for extensive area mapping



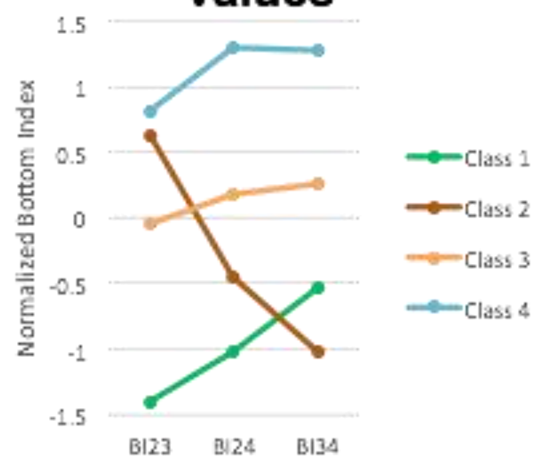
Preliminary results of analysis about optical and texture properties



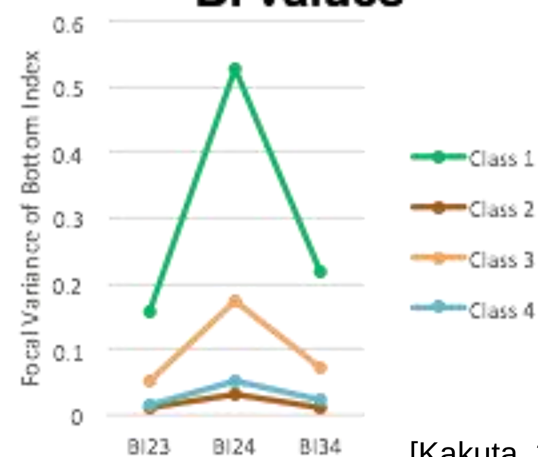


- Normalized average BI (density of benthic community) :
  - Class2 shows different pattern
  - Class1 is the lowest
  - Class4 is the highest
- Average focal variance (benthic roughness)
  - Class1 is the highest
  - Class2 & 4 are lowest

Normalized average BI values



Average focal variance of BI values



[Kakuta, 2016]

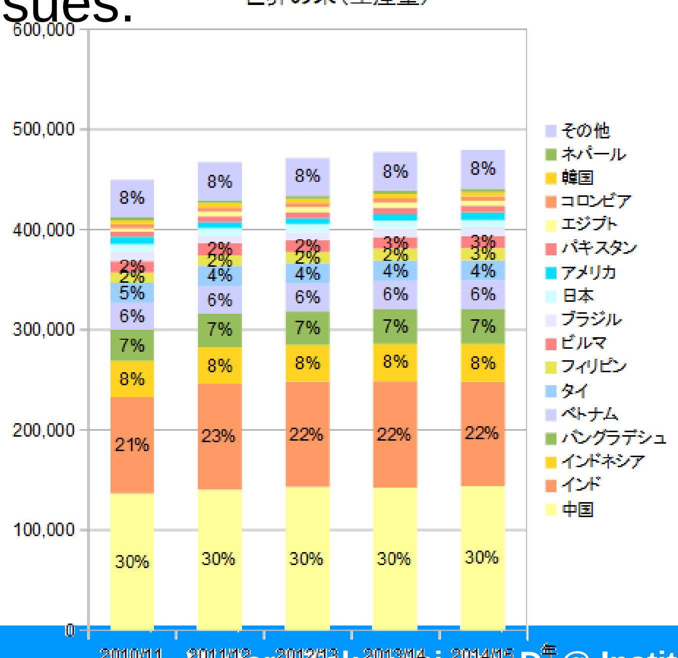
Concluding remarks

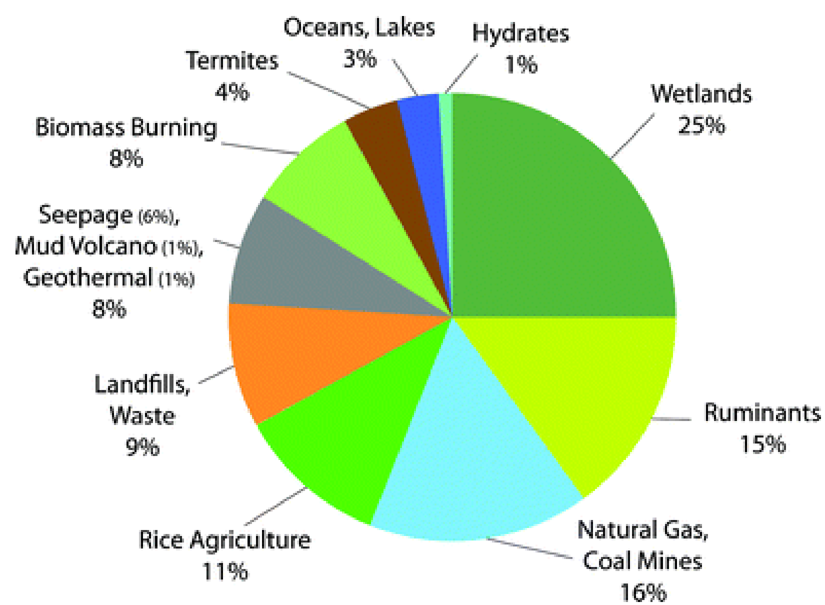
- Backscatter value of mangrove forest on HH value around -11 dB to - 6 dB and on HV value around -21 dB to -16 dB.
- Higher AGB of mangrove forest (average more than 80 ton/ha)
  - Meinmahla Kyun-Irrawaddy delta, Myanmar
  - Preak Piphot River, Cambodia
  - Sorong Papua, Indonesia
- Lower AGB of mangrove forest (average less than 5 ton/ha)
  - Sarikei Serawak, Malaysia
  - Langsa Aceh, Indonesia
  - Subang West Java, Indonesia
- In the future, we will try to improve the algorithm with included environmental conditions (i.e. moisture conditions, and weather dynamics) also topography and tidal height condition and more collecting ground survey data and information of AGB of mangrove forest in Southeast Asia for validation our result.

CH4 emission observation from rice paddy field in Asia with remote sensing and in-situ measurements (UTokyo-VAST-JAXA initiative)

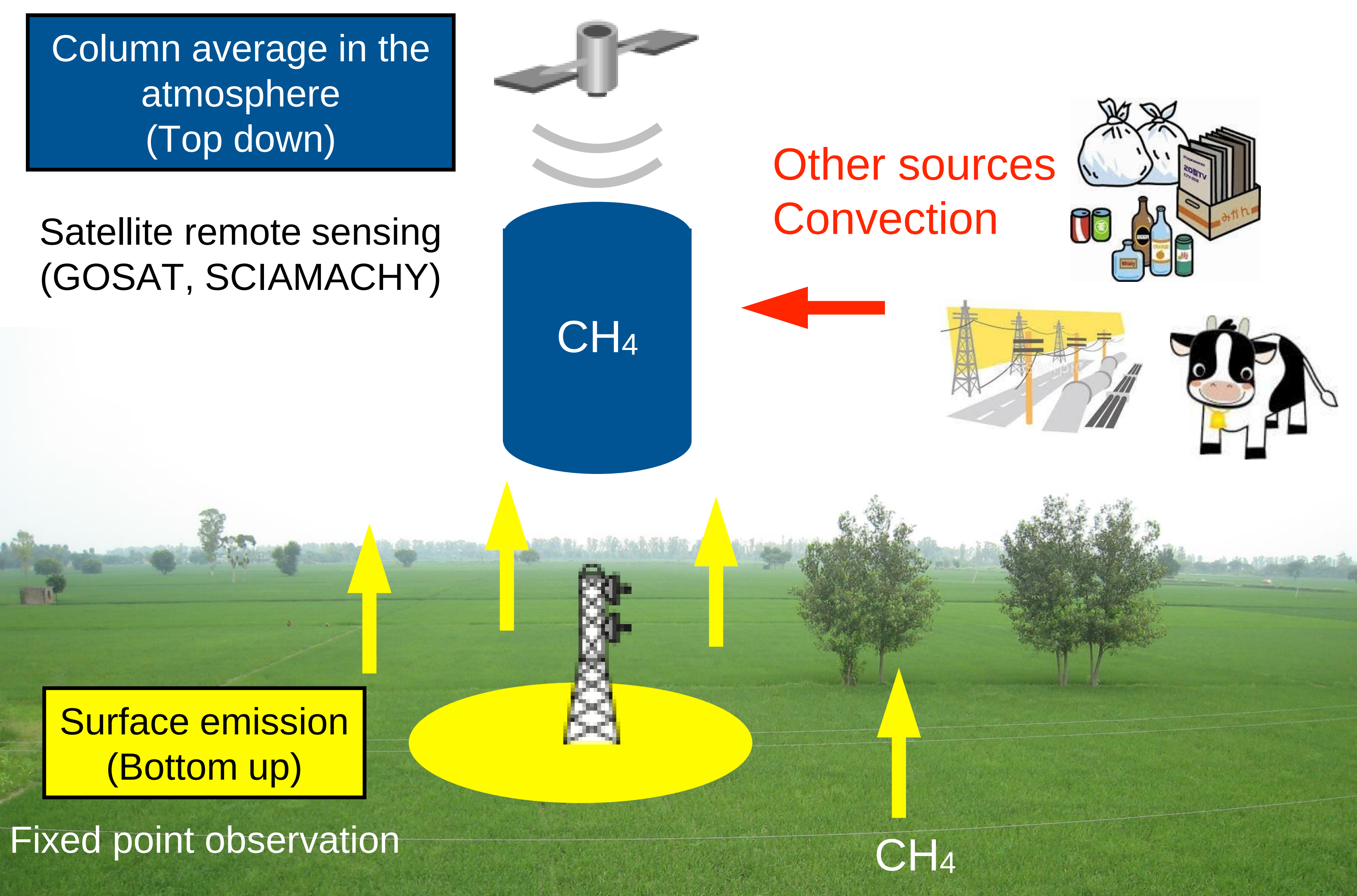
Rice paddy for food and CH4

- 90 % of paddy fields in the world are in Asian countries and they are important as a staple **food** source and a source of atmospheric methane **CH_4** [Wessmann, 2003].
- Important variable for **modeling** of regional biochemical cycle and climate [Dickinson, 1995].
- The improved understanding of paddy field distribution over **large spatial scale** has increased the interest in the above mentioned issues.

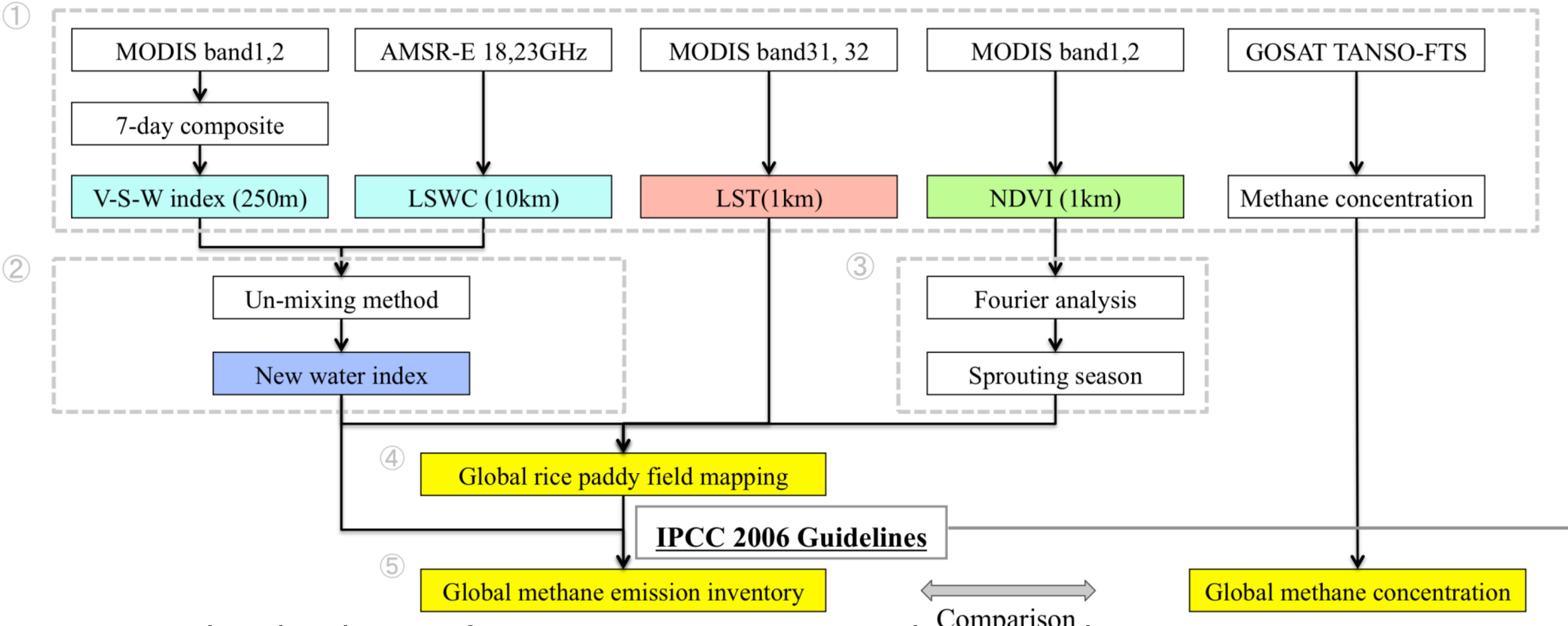




Top-down and bottom-up approach in CH_4 measurements

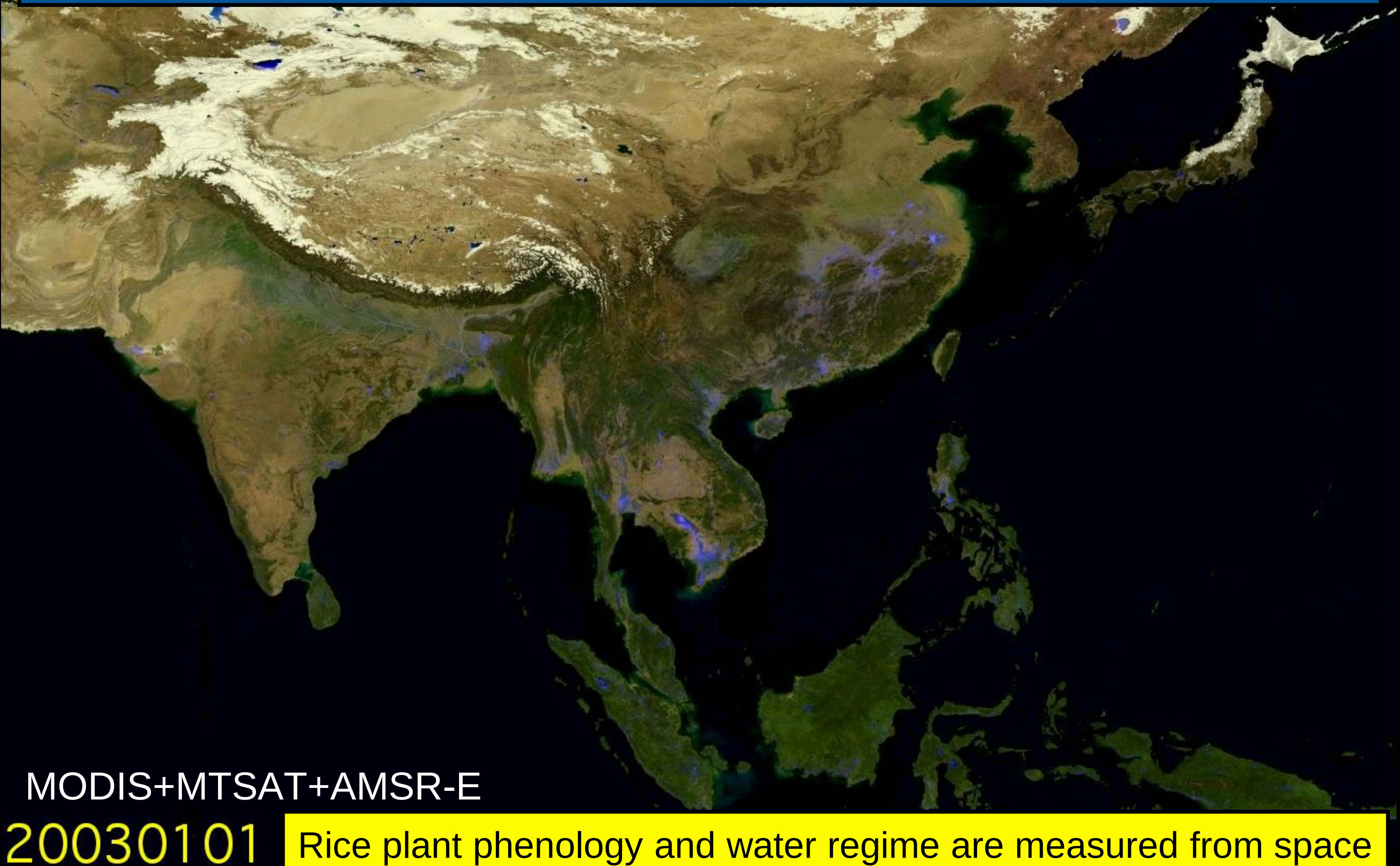


Global rice mapping and CH4 estimation flow



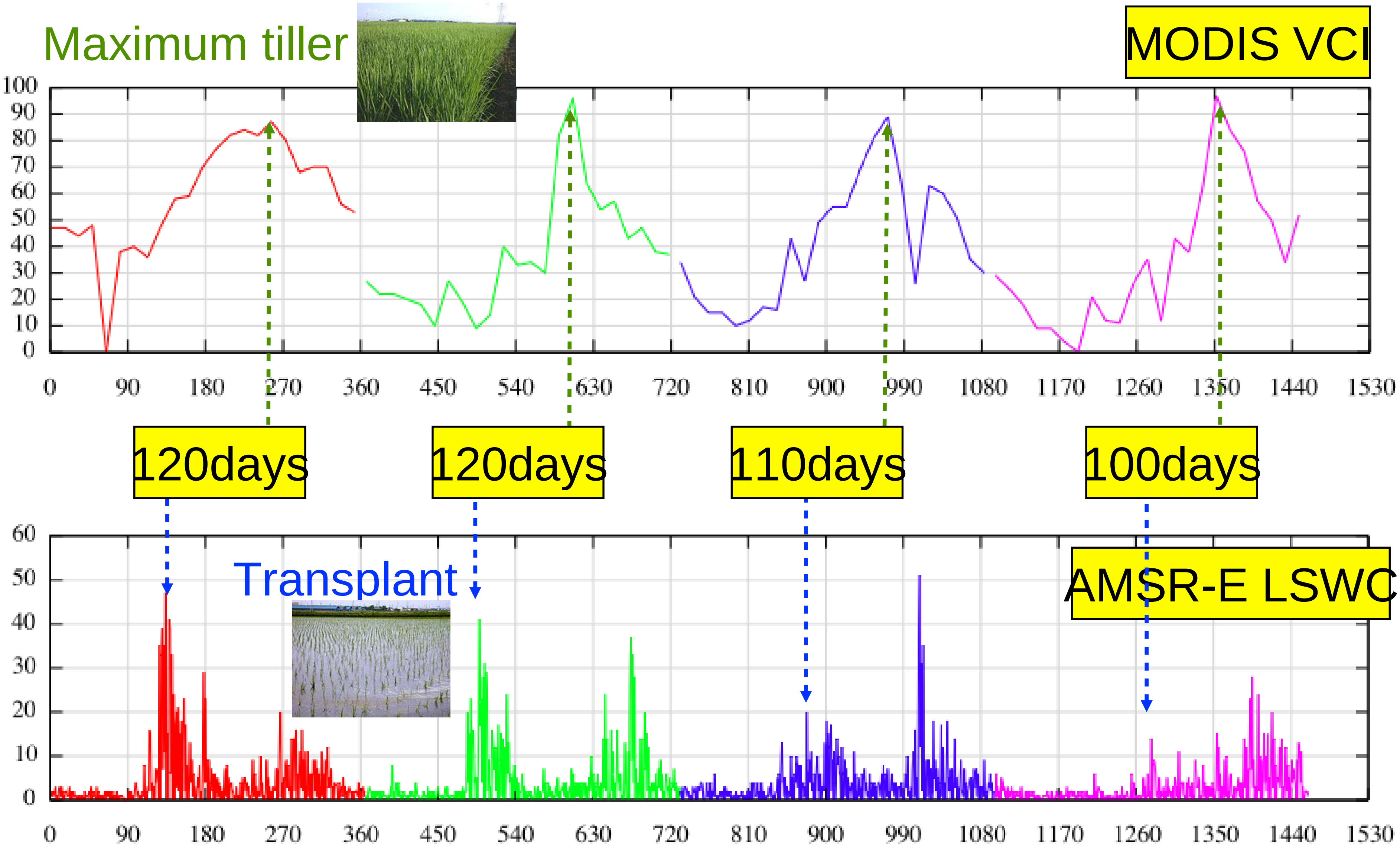
1. Preparing the dataset from MODIS, AMSR-E, and GOSAT data
2. Creating the new water index with LSWC and V-S-W by unmixing method
3. Assuming the sprouting season of rice by applying Fourier Transform to NDVI time series.
   Detecting rice cropping phenology where NDVI comes to its peak 60 days after the new water index rise and making the global rice paddy field mapping
4. Estimating methane emission from each rice crops by utilizing the map, the new water index

Completely cloud-free vegetation and water indices from satellite remote sensing and image processing



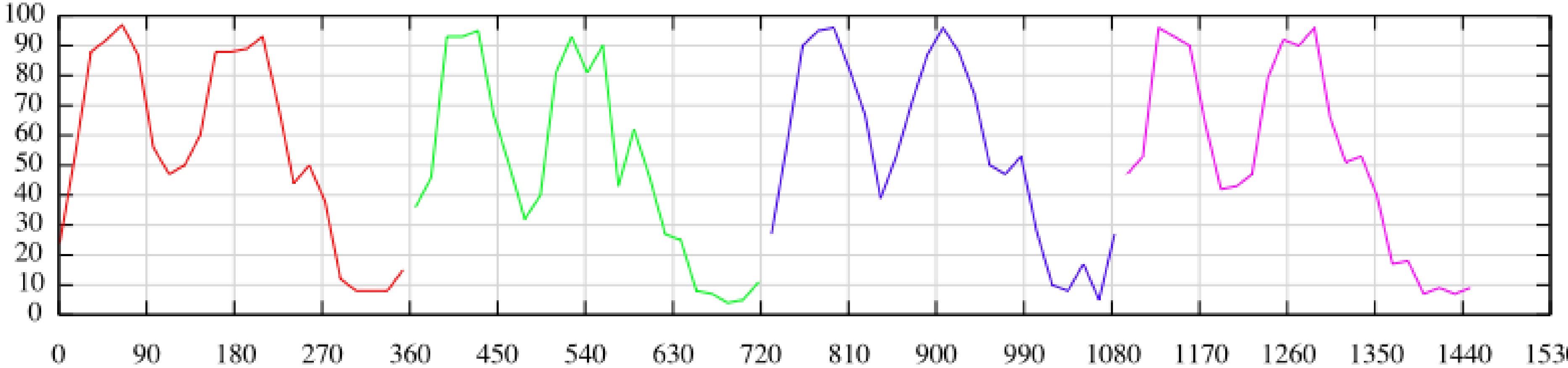
Rice plant phenology and water regime are measured from space

MODIS VCI and AMSR-E LSWC captures rice cropping patterns in Sukhothai

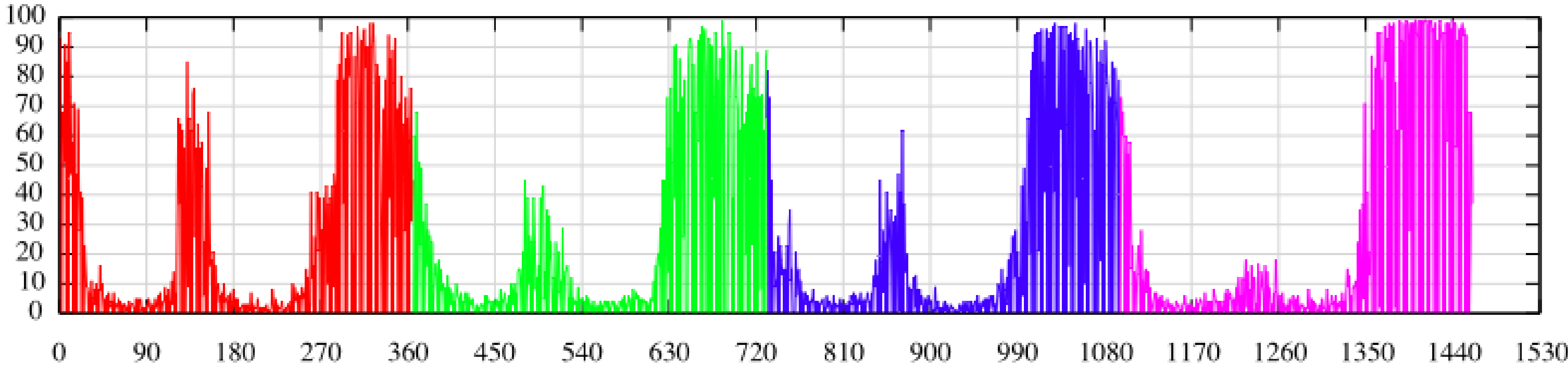


MODIS VCI and AMSR-E LSWC captures rice cropping patterns in Suphanburi

MODIS VCI

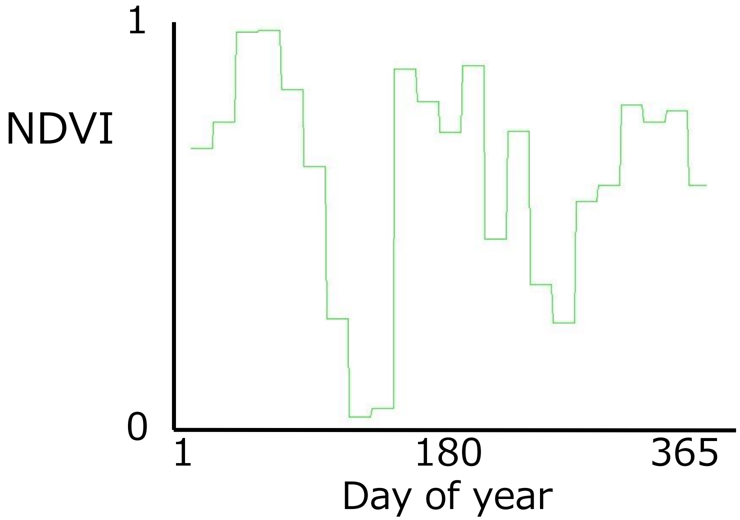


AMSR-E LSWC

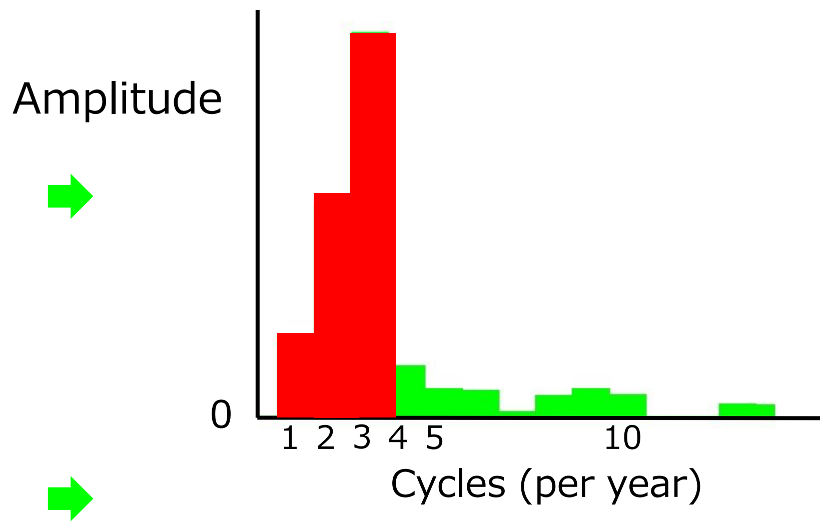


Fourier transform analysis of NDVI

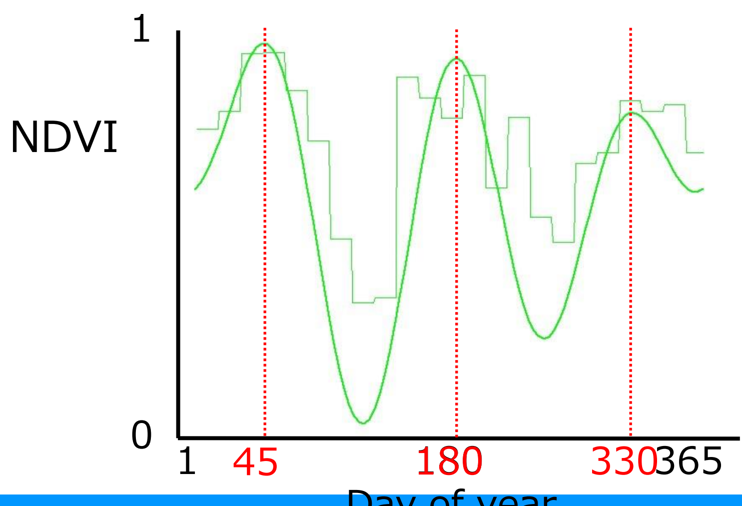
- Time series of NDVI in paddy field



- Extracted waves by Fourier transform

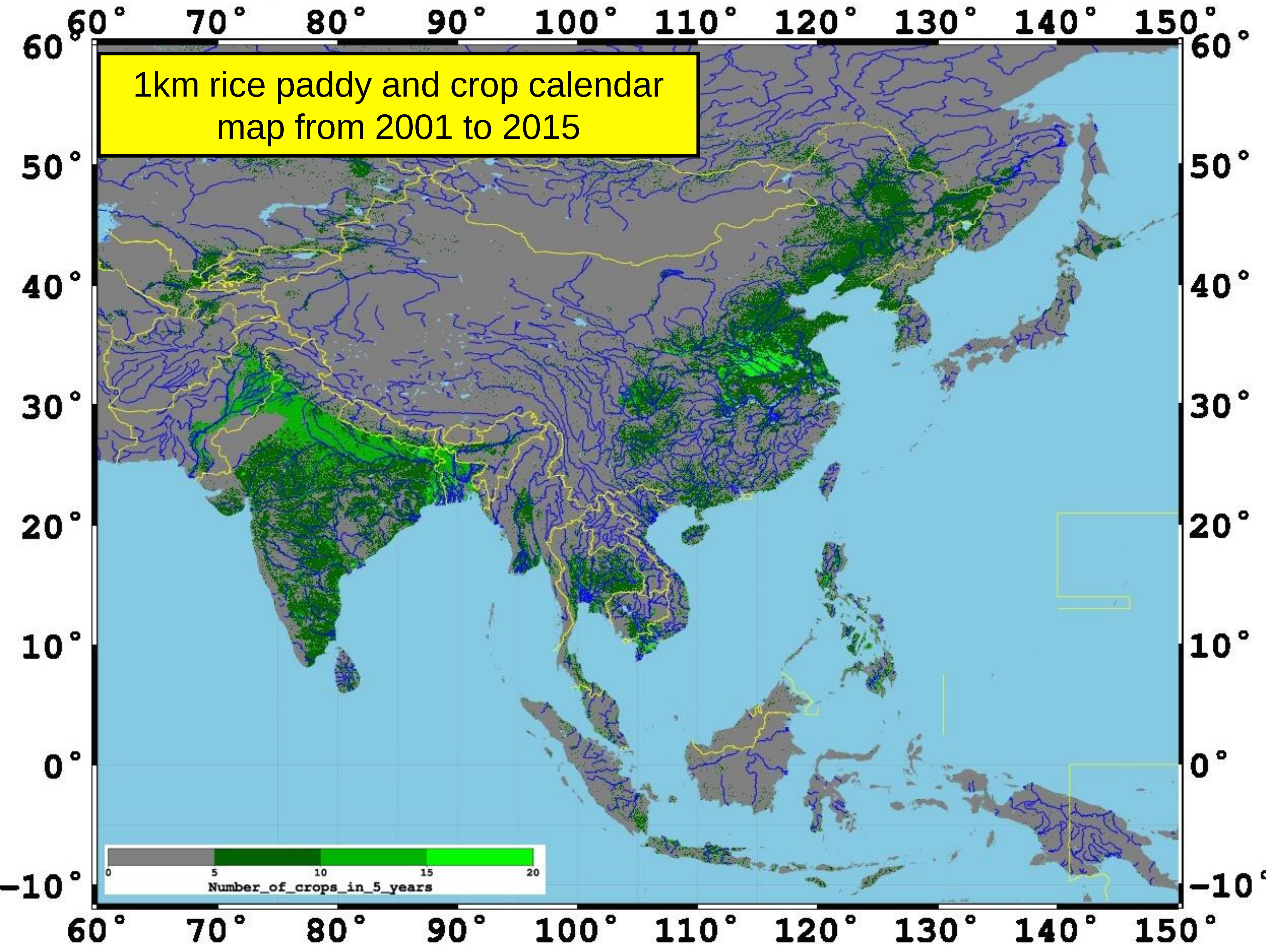


- Result of Fourier transform analysis



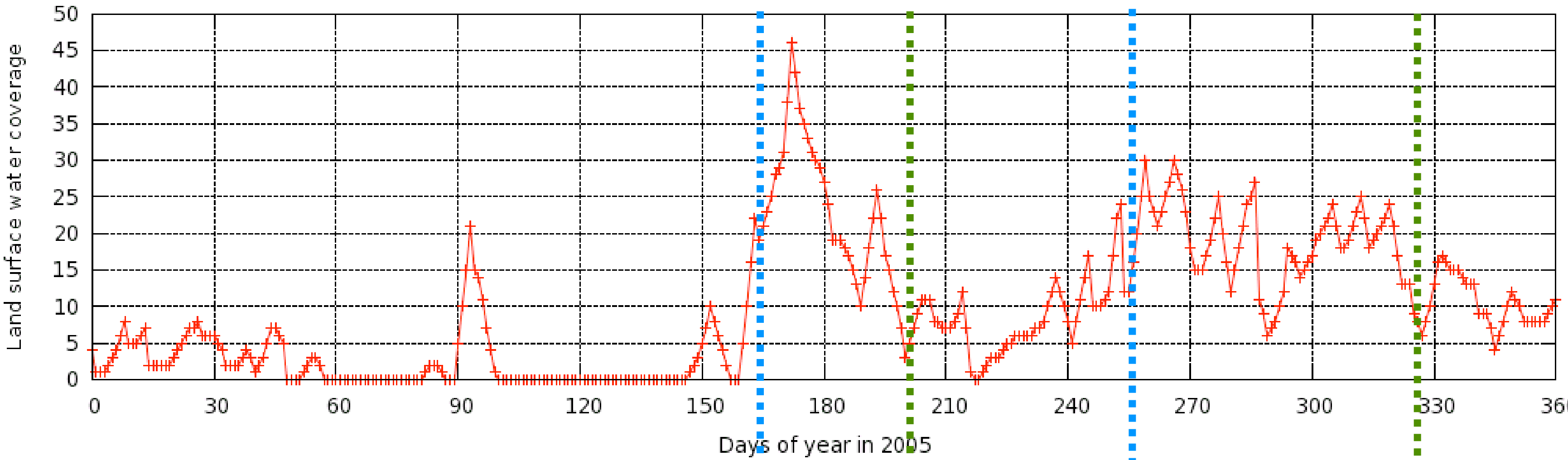
By compositing waves of lower cycles, we can detect the day of year when NDVI comes to its peak.

[Jonai, 2014, IGARSS]

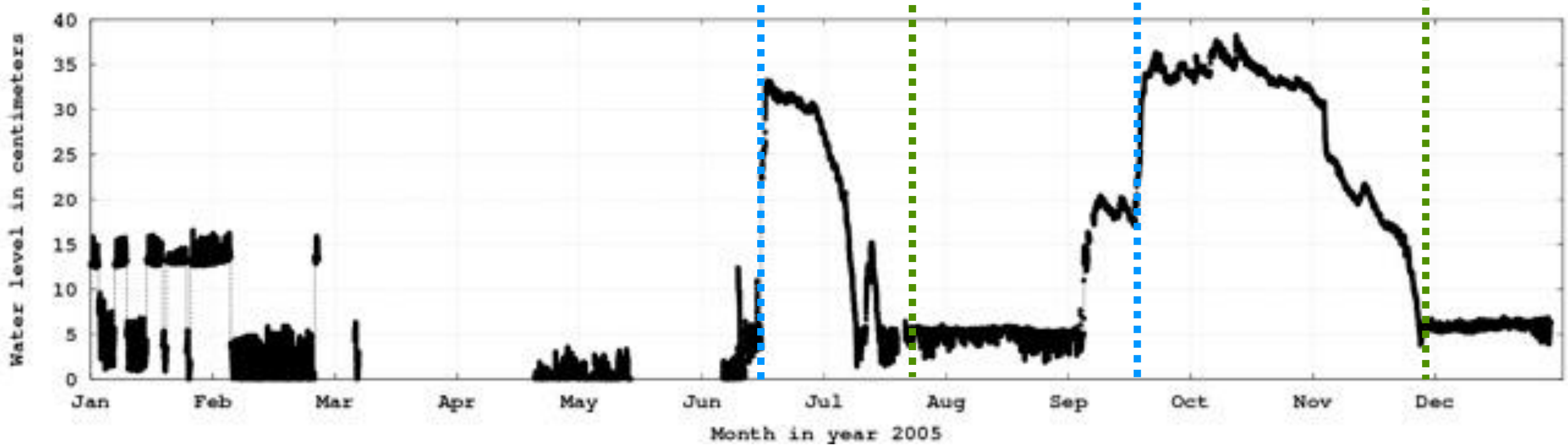

1km rice paddy and crop calendar map from 2001 to 2015
60° 70° 80° 90° 100° 110° 120° 130° 140° 150°
60° 50° 40° 30° 20° 10° 0° −10°
0 5 10 15 20
Number_of_crops_in_5_years

Rice field in Thailand
(Oct. 8, 2011 to Nov. 8, 2011)

Water coverage change timing delay to ground water level changes



(a) AMSR-E land surface water coverage measurements



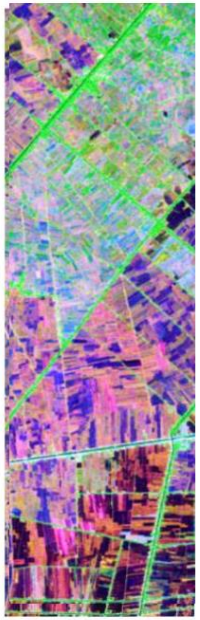
(b) Ground based water level measurements

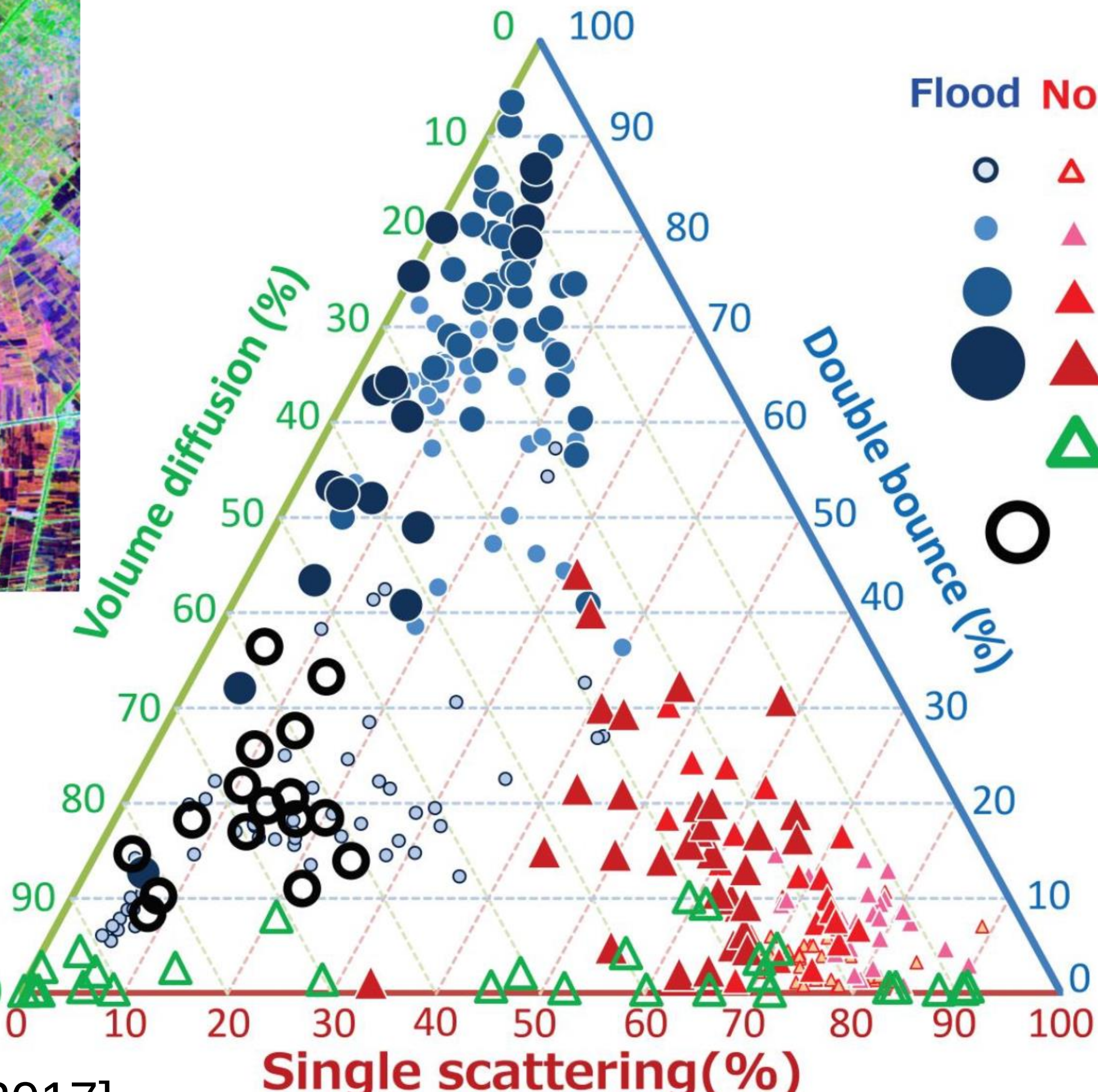
[Takeuchi 2011, ISRS]

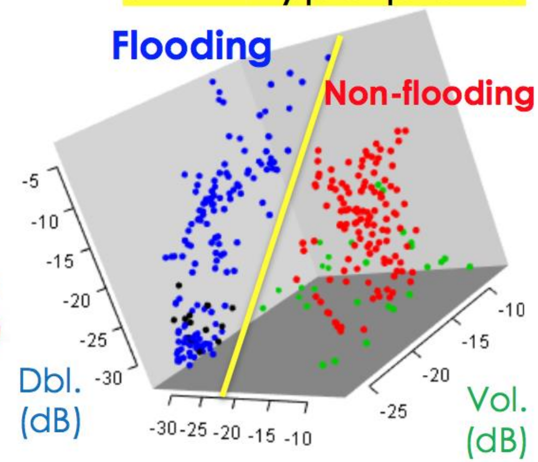
Synthetic Aperture RADAR [ALOS-2/PALSAR-2]

High-spatial resolution full polarimetric data

→ *Flooded soil detection irrespective of rice-growth stages*

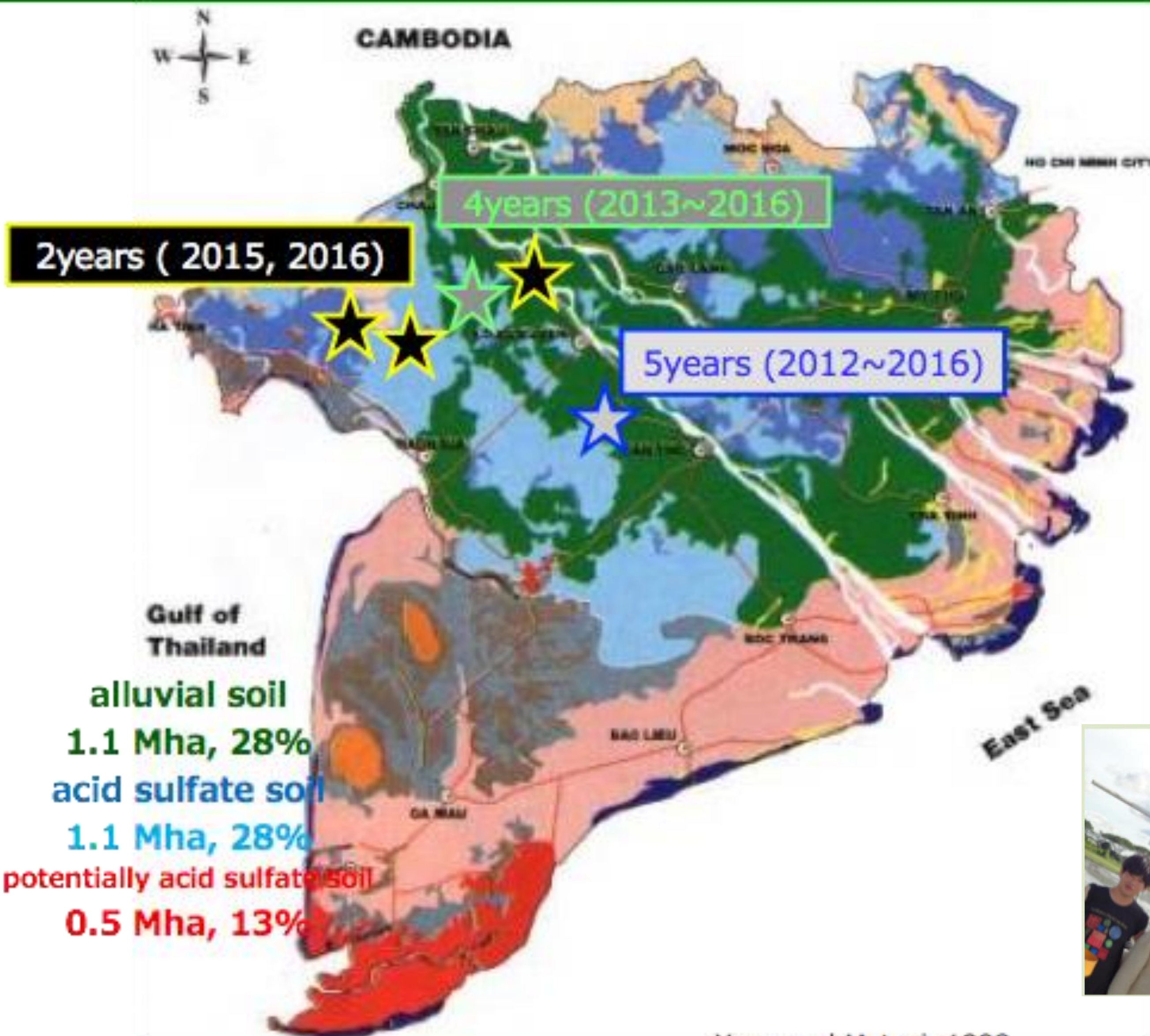






[Arai, 2017]

Obtained annual CH_4 emission data so far



Xuan and Matsui, 1998

EF baselines in philippines
(GoP 2014, Basak 2016)

- Single crop (rainy season)
- Single crop (dry season)
- double crop

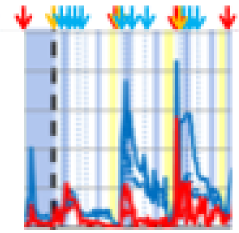
3)

CH4 flux measurement

Weather measurement station

- CH4 by laser meteorology
- Solar radiation (PYR)
- Soil mosture (EC-5)
- Air temperature and relative humidity (VP-3)
- Rainfall (ECRN-100)
- Wind speed and direction (Decagon)
- Data logger (Em50)
- Solar power supply and battery charger
- Data transfer via SIM
- Real-time data visualization at web

①Statistical modeling of daily CH_4 flux (mg C m^{-2} day^{-1})

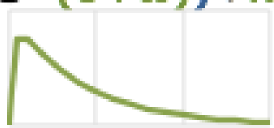


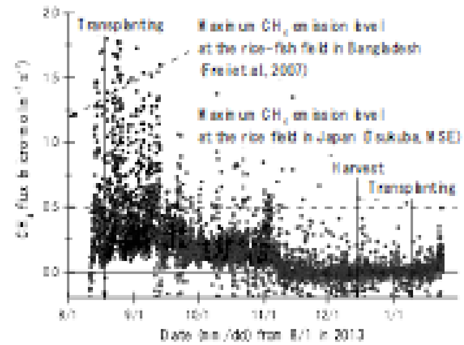
Daily CH_4 fluxes

= γ * *carbon_management* / *nonflooding_fallow* / *flooding_fallow* / *water_management* *α*β

Carbon_management

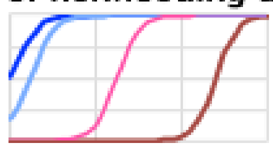
$=[\exp(-DAS*\delta)-\exp(-DAS*(\delta+\omega))+\kappa]$





Nonflooding_fallow

= [1+EXP(-1* ζ *(*DAS* – ι* days of nonflooding days of the former fallow))]



Flooding_fallow

= EXP(ε * days of flooding days of the former fallow)

Water_management

= EXP(η * flooding days during the last 10days)

DAS←*days after sowing*

α ←straw incorporation coefficient

β ←acid sulfate・coastal sandy soil coefficient

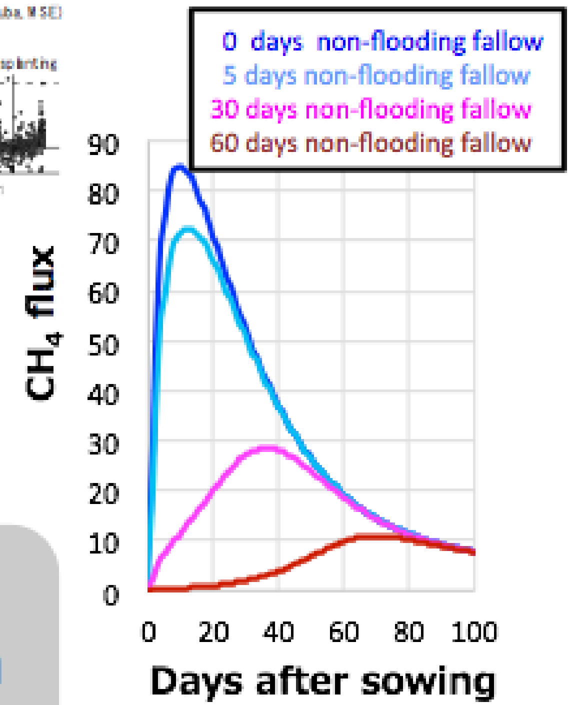
γ, η, δ, ε , ω , ζ , ι, κ←constant (>0)

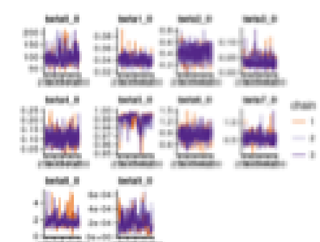
Year

Season

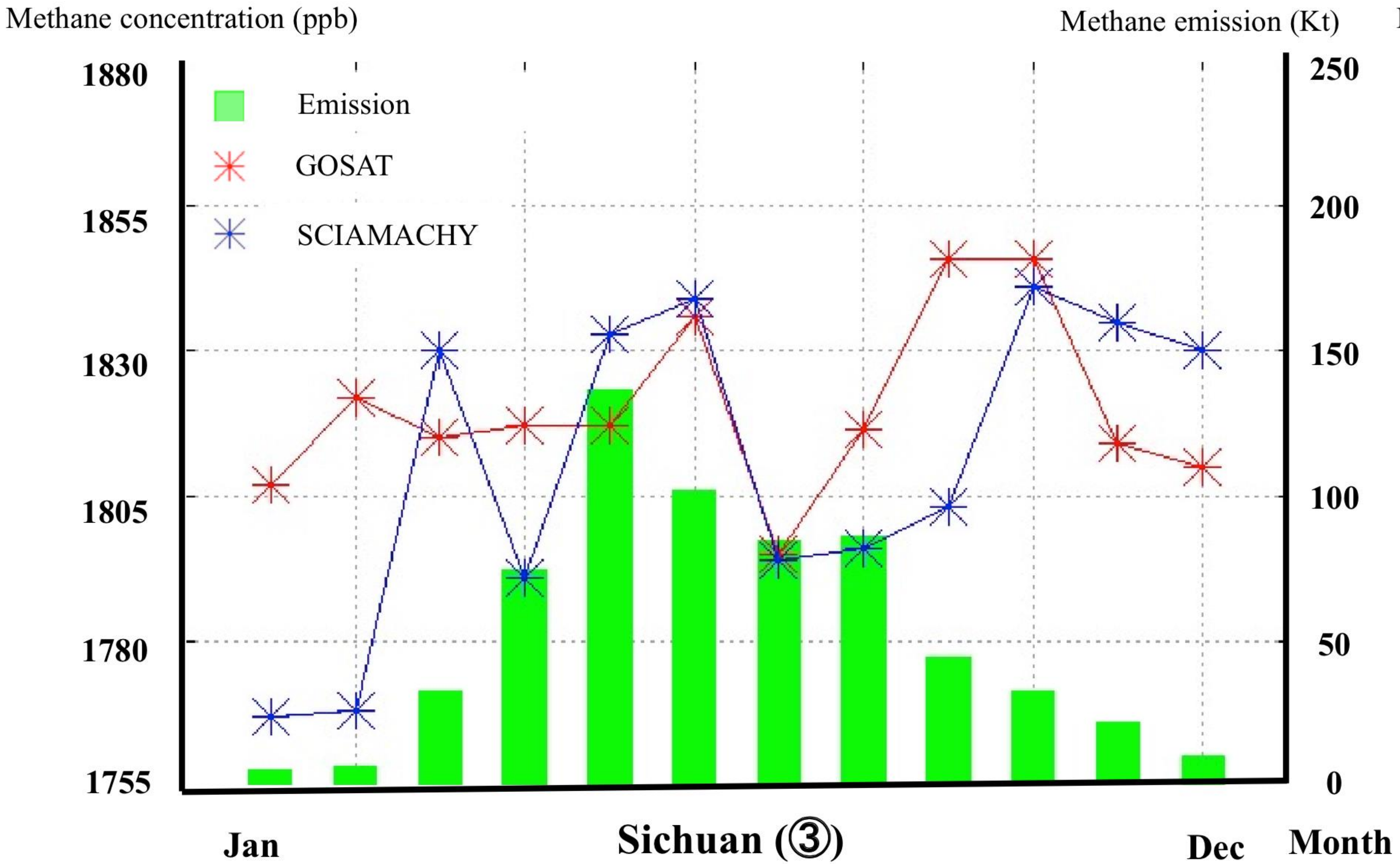
Region

CF or AWD





CH4 emission compared with column average by GOSAT and SCIAMACHY in Sichuan



Top 20 CH4 emitting country from rice paddy field

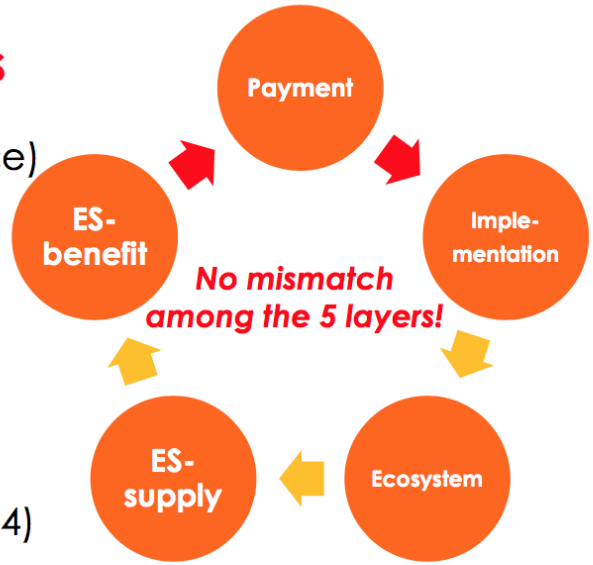
Coutry	Emission (100Gt)	EDGAR(100Gt)
China	9,301	14,130
India	8,201	3,979
Indonesia	2,985	2,658
Thailand	2,350	2,185
Bangladesh	2,286	2,213
Vietnam	2,149	1,820
Myanmar	1,442	1,555
Canbodia	486.3	489.3
Japan	363.7	764.9
SriLanka	296.7	264.9

Coutry	Emission (Gg)	EDGAR(Gg)
United States	289.2	394.6
Nigeria	279.8	321.3
Pakistan	196.8	851.2
South Korea	177.7	309.8
Nepal	156.8	360.1
Iran	130.7	145.2
Philippines	122.5	1,075
Laos	88.15	115.7
Mali	83	51.82
Guinea	76.89	58.62
World total	31,750	35,060

[Jonai, 2014]

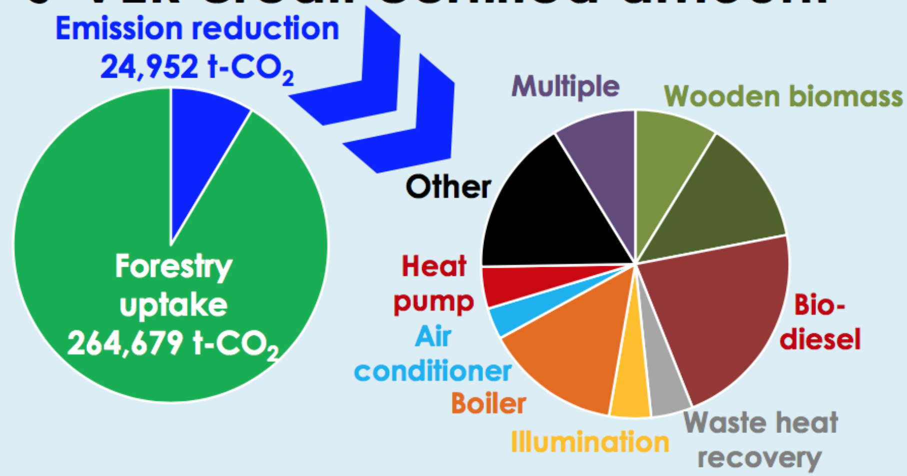
Social-ecosystem study

Lack of
Policy-oriented PES
(Payment for the Environment Service)
Study
(Lasswell, 1971;
Morcol, 2012)



(Ota & Uehara, 2014)

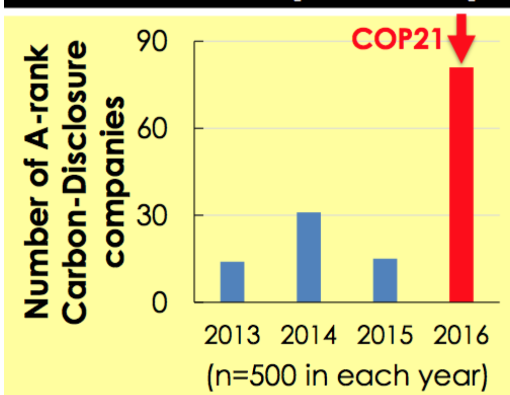
J-VER credit certified amount

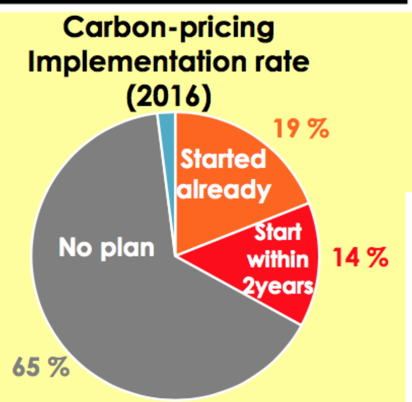


Still no J-VER methodology on CH_4 emission reduction through paddy water management.

The *significance of CH_4 from rice paddies is not recognized by stake holders.*

Social marketing on major player in Japanese private sector





Carbon credit demand is becoming significant drastically!

Robust & transparent scientific evidence & MRV system is important !

Data source: CDP DRIVING SUSTAINABLE ECONOMIES; 環境省 Ministry of the Environment

Concluding remarks

- Vegetation and water condition mapping of rice paddy field from remote sensing is demonstrated and global rice paddy and crop calendar mapping was carried out with 1km grid scale
- CH_4 emission were estimated with remote sensing and emission factors by IPCC guideline 2006. They were compared with column average CH_4 concentration and similar patterns were found in time-series of behaviors.
- CH_4 emission were compiled in country level and compared with EDGAR database in good agreement.


Thank you