SUSTAINABLE DEVELOPMENT GOALS

RESPONSIBLE CONSUMPTION AND PRODUCTION

CLIMATE ACTION

Monitoring GHG emission from rice cropping and the dissemination status of mitigation activities

Hironori Arai[1,3], Wataru Takeuchi[1], Kei Oyoshi[2], Lam Dao Nguyen[4], Towa Tachibana[5], Ryuta Uozumi, Koji Terasaki[3], Takemasa Miyoshi[3], Hisashi Yashiro[3], Kazuyuki Inubushi[5]

Cycle from Observation to Countermeasure

To target

To solution

To target

Observ.
Survey

Modelling

Simulation
Forcast・eval.

Solution
design

optimi
zation

manage
ment

Evalu
ation

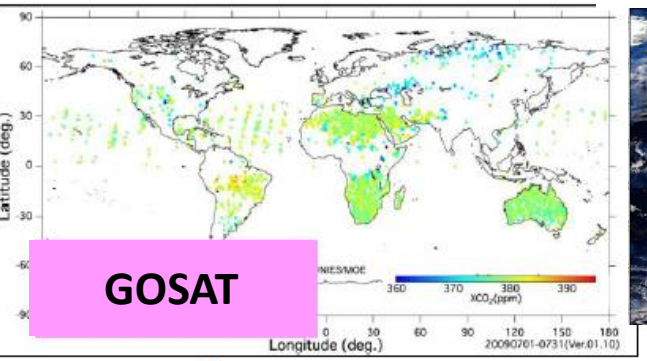
DATA

inform
ation

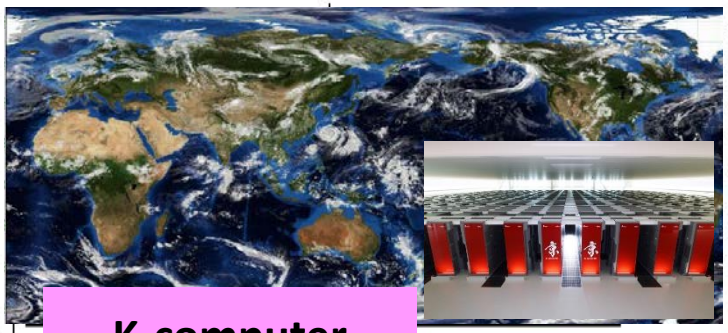
Estima
tion

Strategy

Policy



GOSAT



K-computer

Effect

Observation of the effect

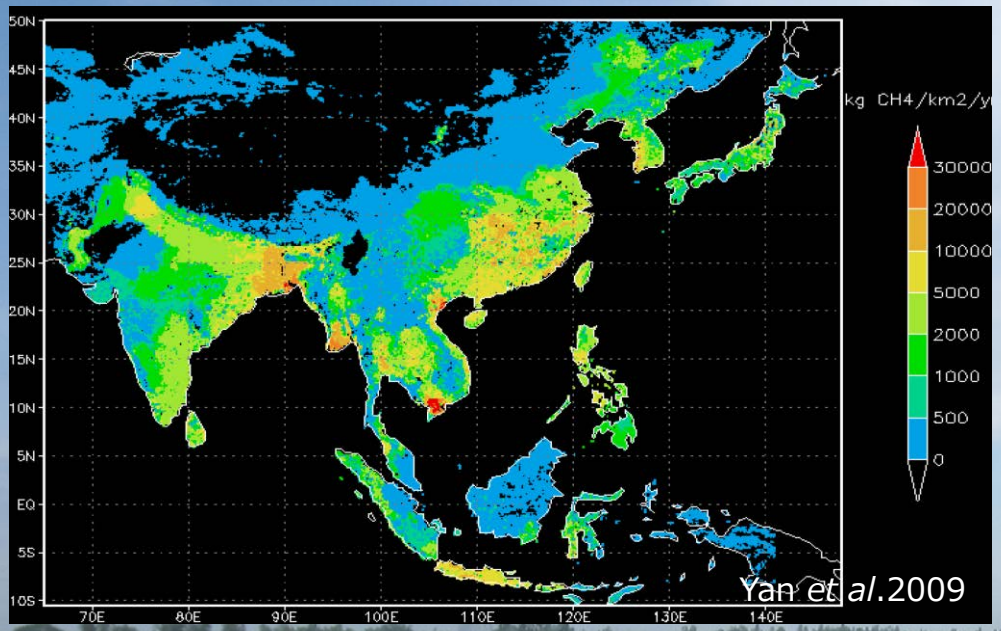
Modified from Yasuoka 2015

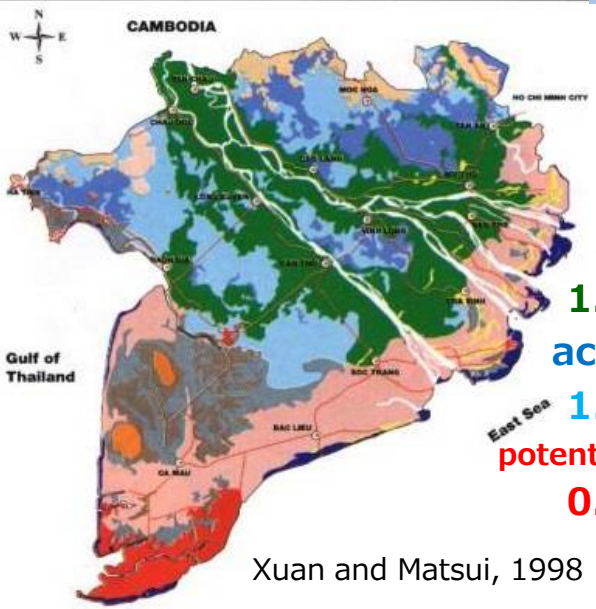
Outline

1. Background & Objective

2. Ground observation of greenhouse gas emission and semi-empirical modeling

3. Satellite remote sensing of GHG emitters
   - Cropping calendar & the adjacent fallow length
   - Paddy soil/water covered by rice plants
   - Top down verification with GOSAT





alluvial soil
1.1 Mha, 28%
acid sulfate so
1.1 Mha, 28%
potentially acid sulfat
0.5 Mha, 13%

Xuan and Matsui, 1998

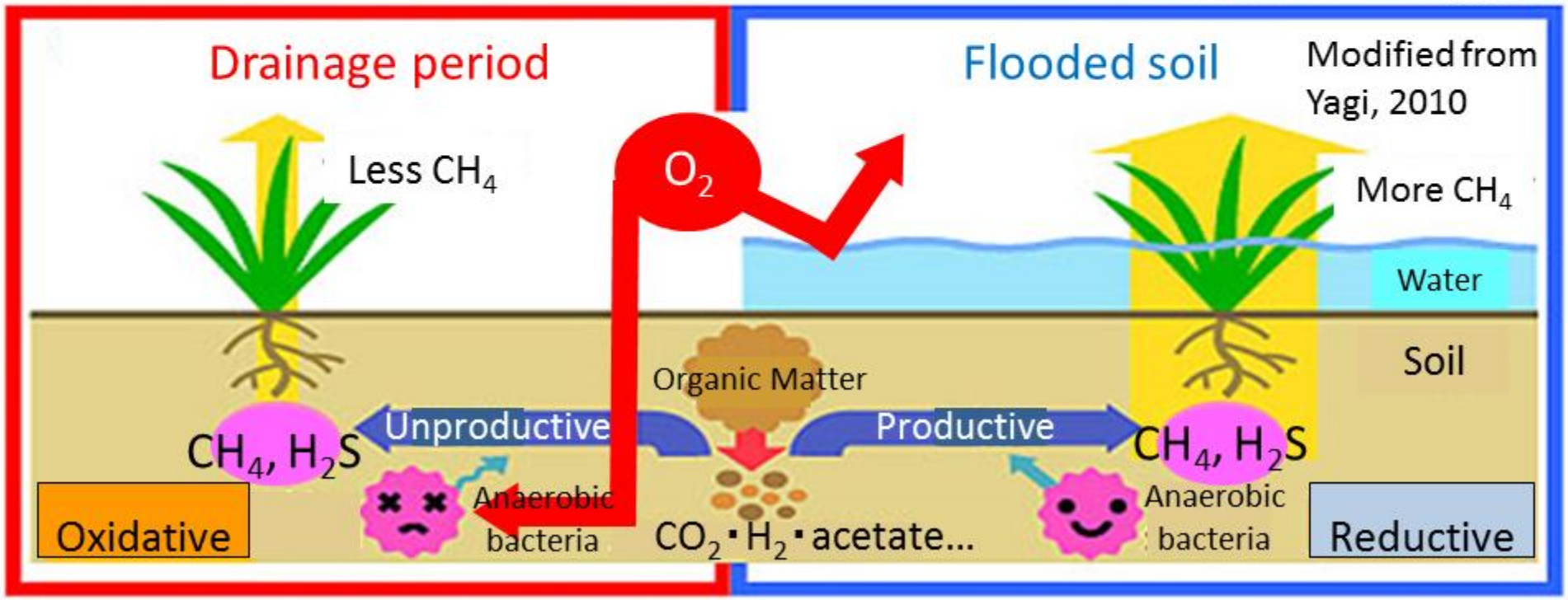
- **Continuously flooded nearly through a year**
  +
- **High straw production**

- **Anaerobic stress for rice production**
- **High GHGs emission**

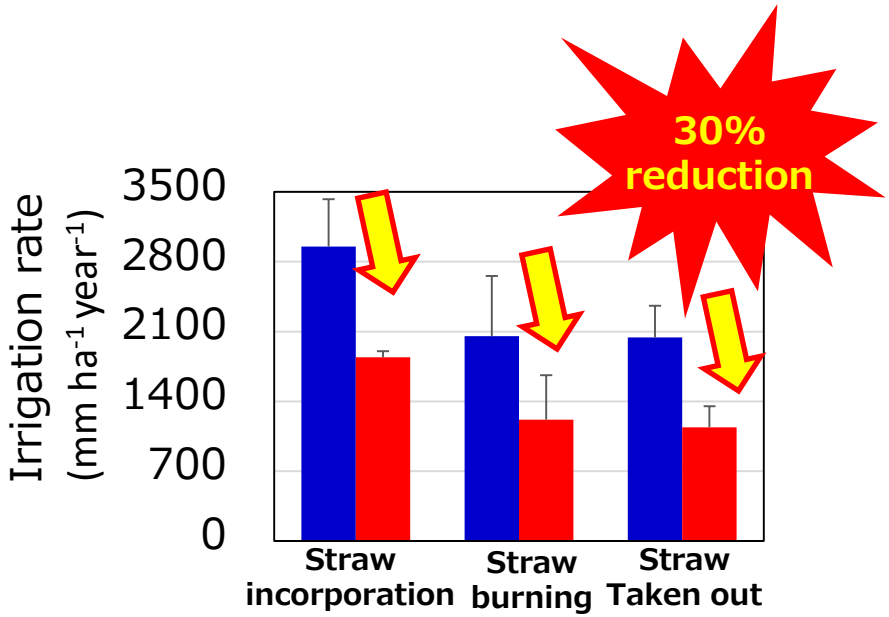
AWD

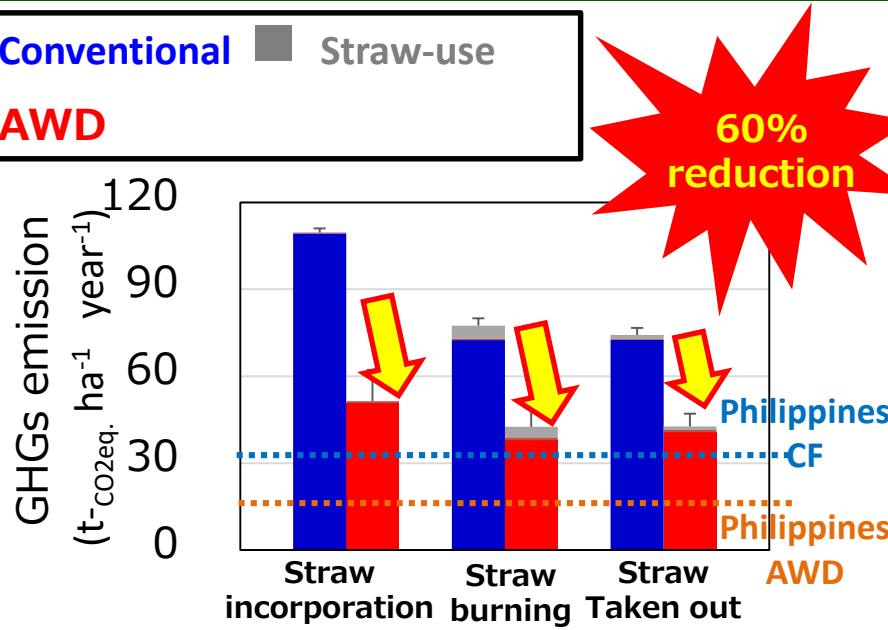
(**A**lternate **W**etting and **D**rying)

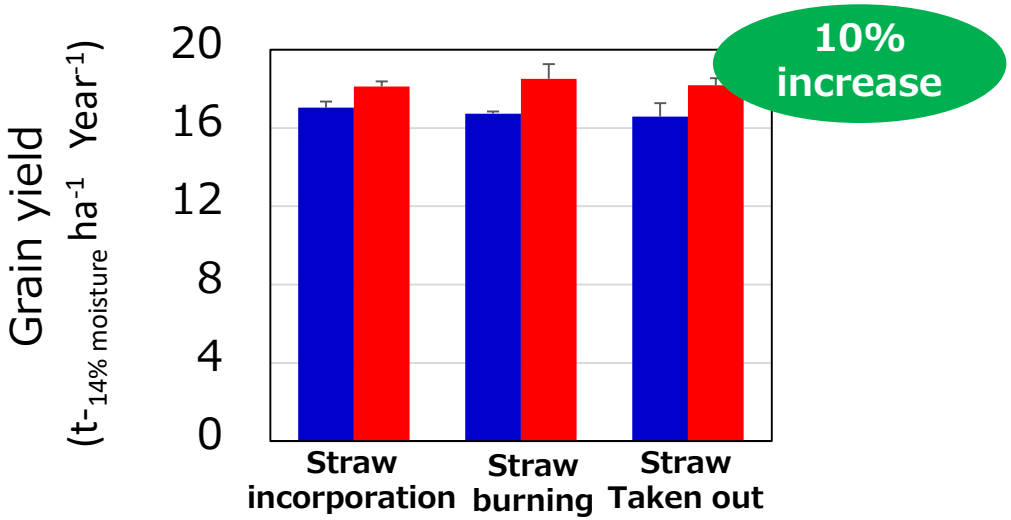
- Irrigation-water saving
- Anaerobic-stress mitigation
- GHGs mitigation

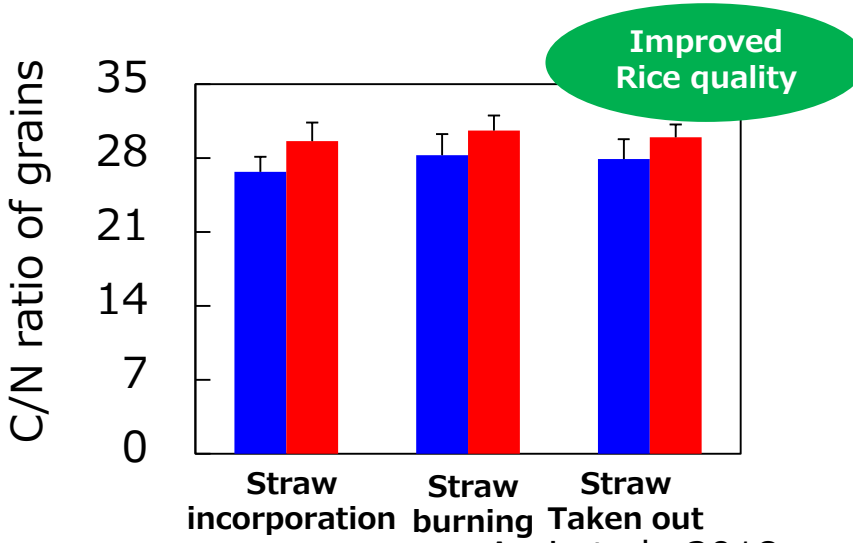


- Reduction of irrigation rate & GHGs (2012-2016)
- Increase of rice grains and its quality



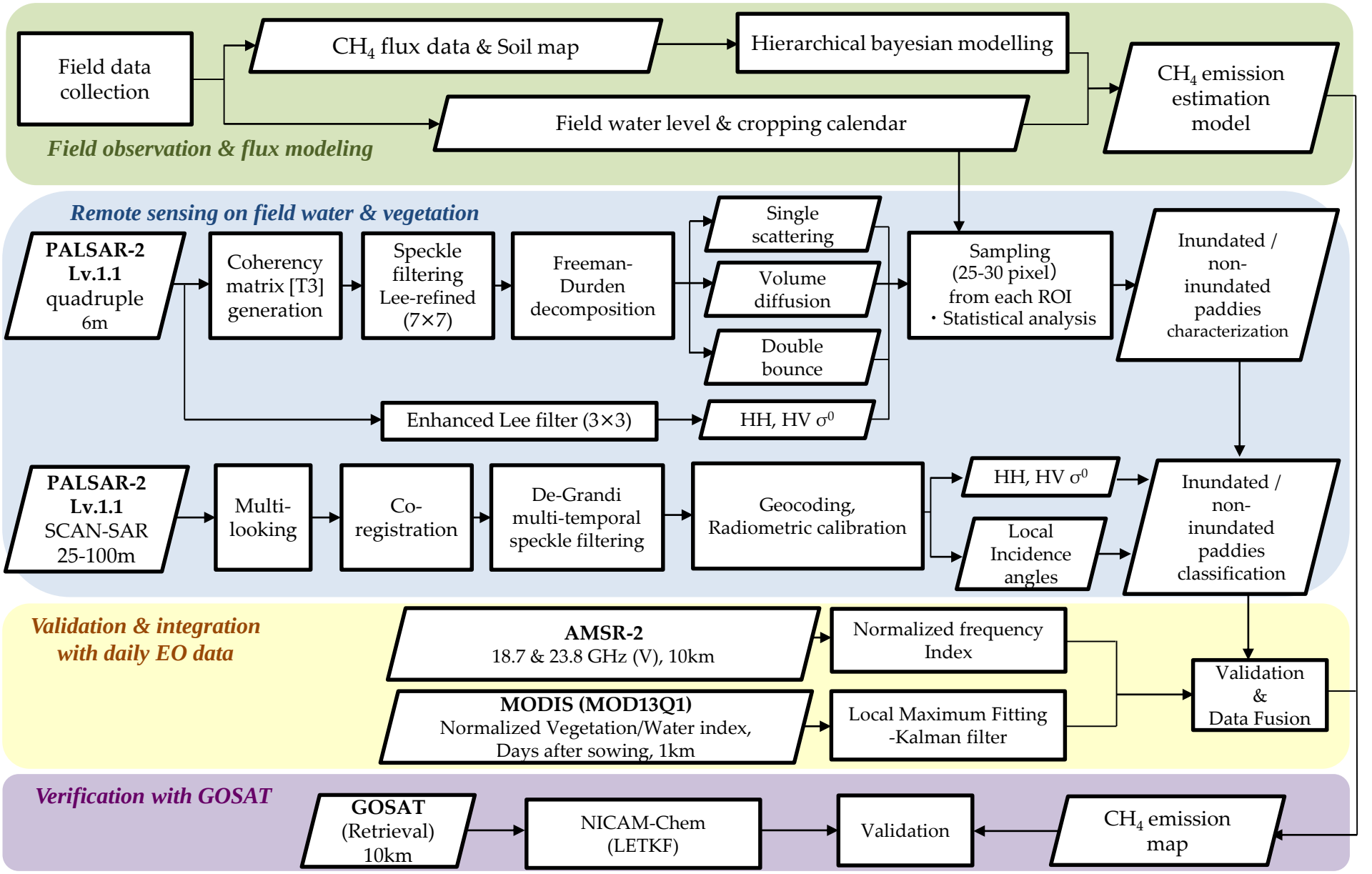




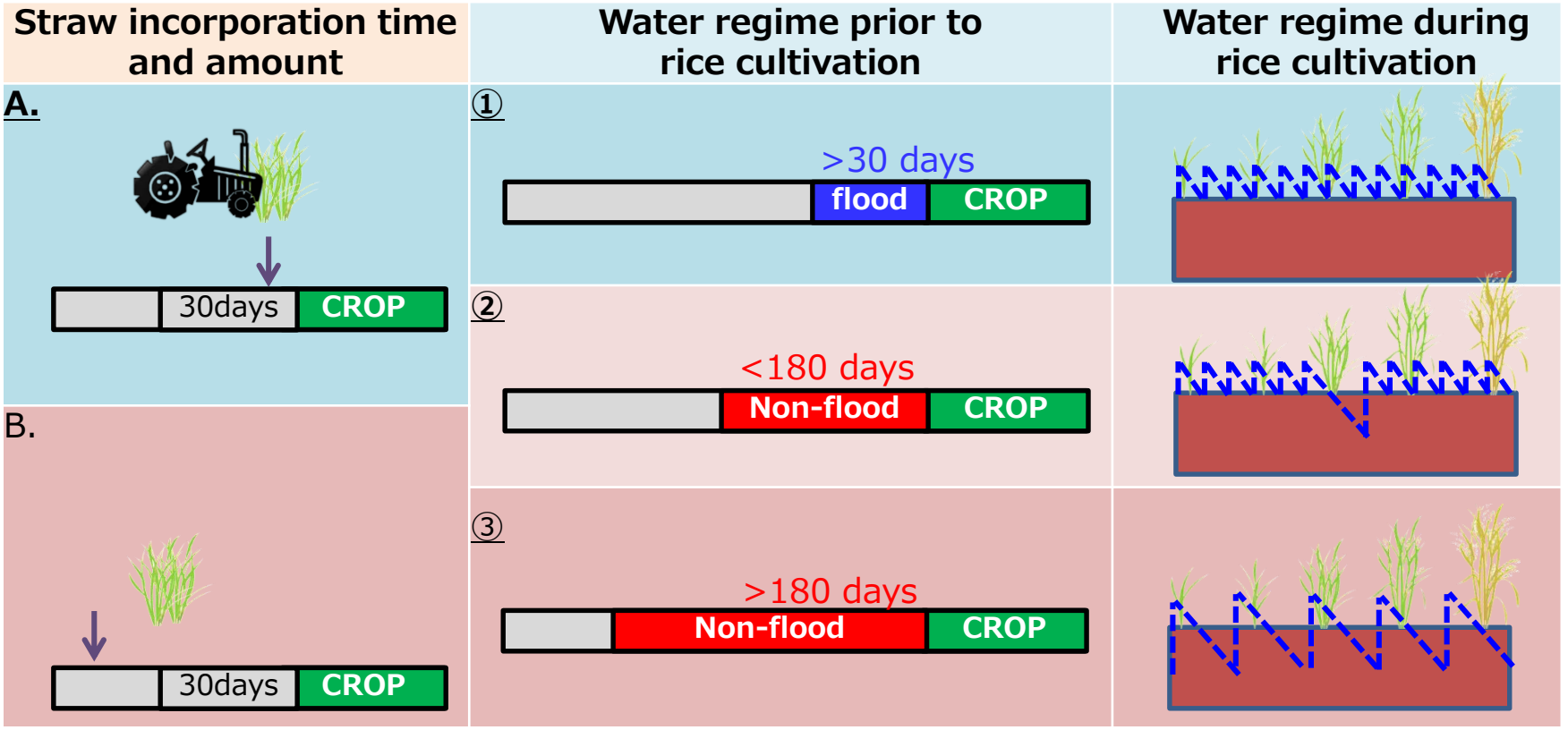


Arai et al., 2018

Flow chart


Field data collection
CH_4 flux data & Soil map
Hierarchical bayesian modelling
Field water level & cropping calendar
CH_4 emission estimation model
Field observation & flux modeling
Remote sensing on field water & vegetation
PALSAR-2 Lv.1.1 quadruple 6m
Coherency matrix [T3] generation
Speckle filtering Lee-refined (7×7)
Freeman-Durden decomposition
Single scattering
Volume diffusion
Double bounce
Sampling (25-30 pixel) from each ROI
・Statistical analysis
Inundated / non-inundated paddies characterization
Enhanced Lee filter (3×3)
HH, HV σ^0
PALSAR-2 Lv.1.1 SCAN-SAR 25-100m
Multi-looking
Co-registration
De-Grandi multi-temporal speckle filtering
Geocoding, Radiometric calibration
HH, HV σ^0
Local Incidence angles
Inundated / non-inundated paddies classification
Validation & integration with daily EO data
AMSR-2
18.7 & 23.8 GHz (V), 10km
Normalized frequency Index
MODIS (MOD13Q1)
Normalized Vegetation/Water index, Days after sowing, 1km
Local Maximum Fitting -Kalman filter
Validation & Data Fusion
Verification with GOSAT
GOSAT (Retrieval) 10km
NICAM-Chem (LETKF)
Validation
CH_4 emission map

IPCC guideline (Tier1)
[Emission factor × Scaling factor in IPCC guideline]



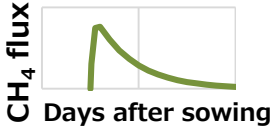
Semi-empirical **daily** CH_4 flux (mg C m^{-2} hr^{-1}) Model

CH_4 emission on a specific date

= γ * *carbon_management* / *non-inundated_fallow* / *inundated_fallow* * *water_management* *α*β

carbon_management (Michaelis-Menten KINETICS)

=[exp(-***DAS****δ)-exp(-***DAS****(δ+ω))+κ]



non-inundated_fallow (OXYDATION CAPACITY)

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

inundated_fallow

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

water_management

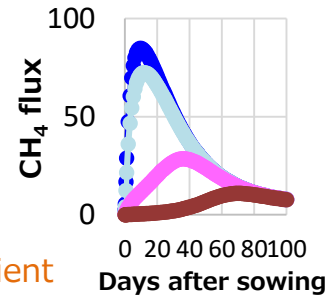
= EXP(η * **inundated days during the last 10days**)

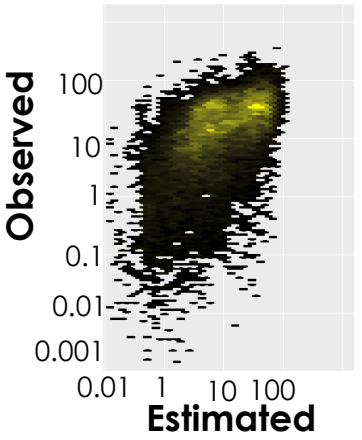
DAS←days after sowing

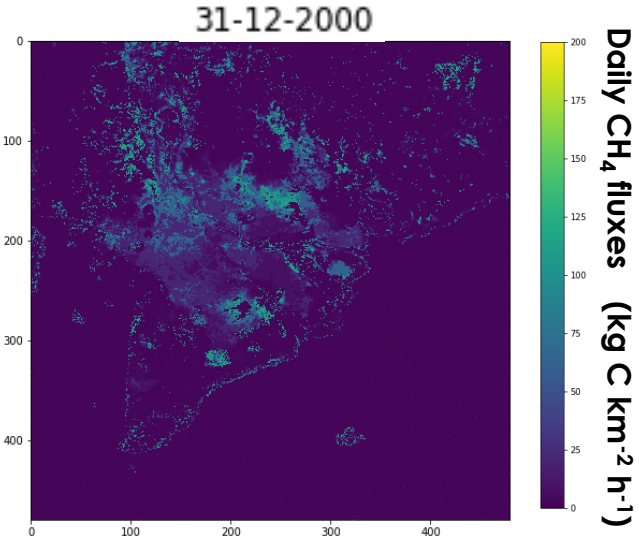
α ←straw incorporation coefficient

β ←acid sulfate・coastal sandy soil coefficient

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







Arai et al., 2018

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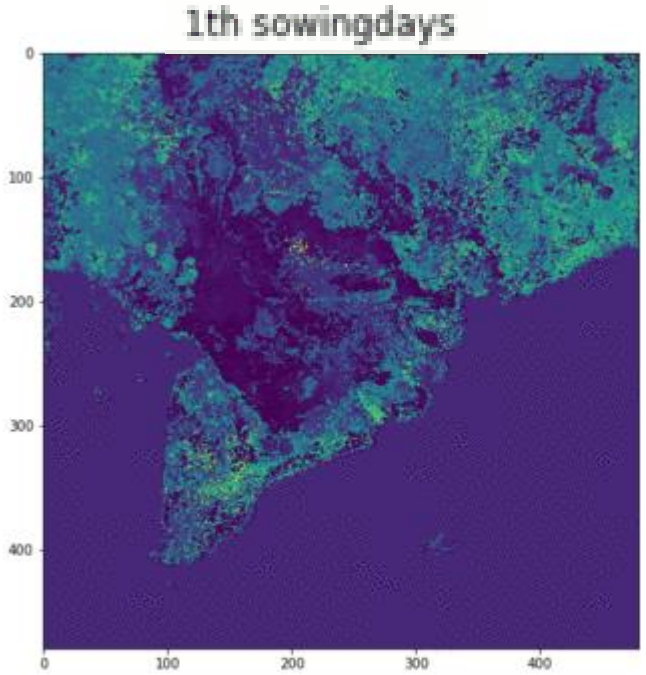
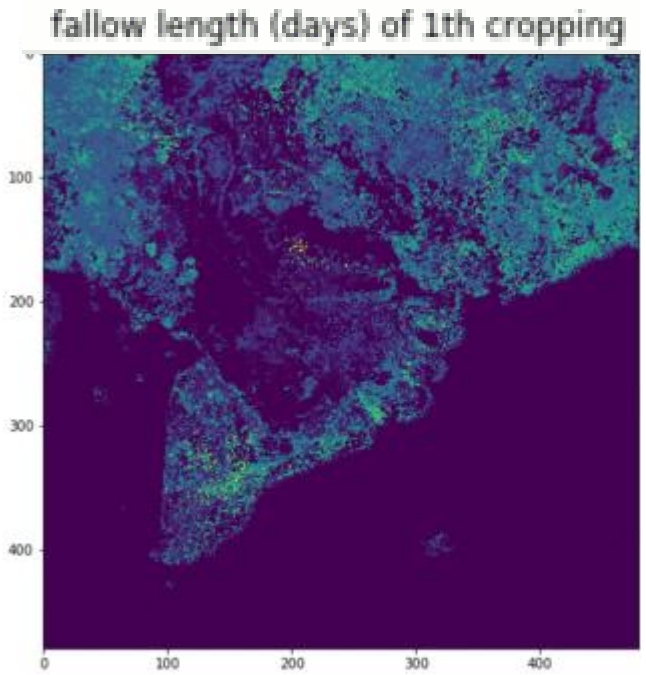
- **Top down verification with GOSAT**

Cropping calendar evaluation with MODIS-NDVI (LMF-KF) for GCOM-C

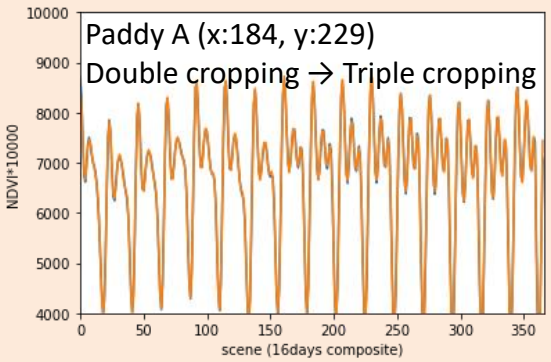
Sowing days (days after 2001/01/08)

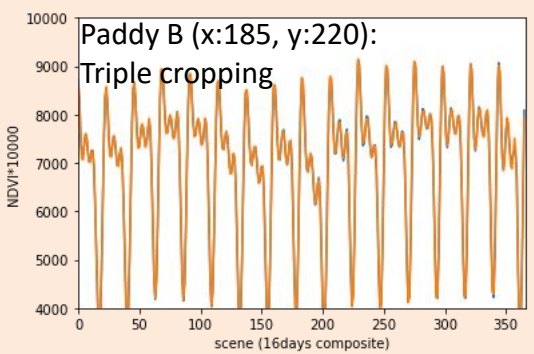




The adjacent fallow's length (days)

Samples of paddies

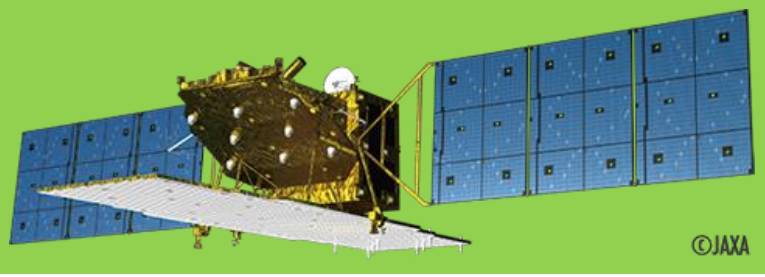


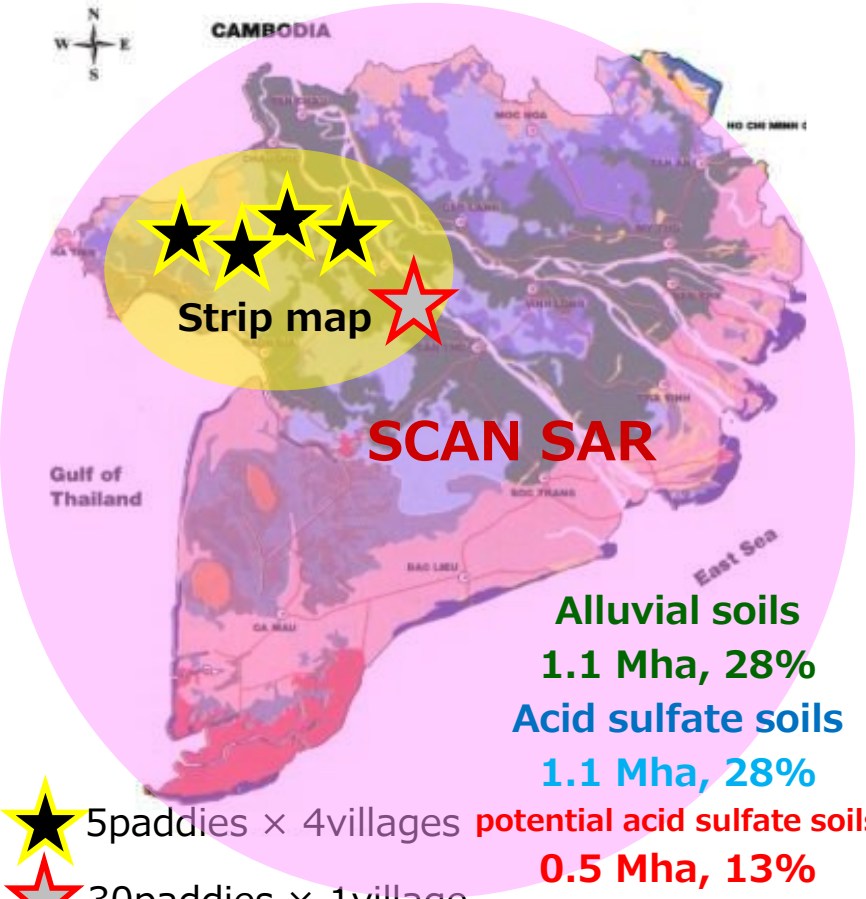


Arai et al., 2018

ALOS-2/PALSAR-2

– **L**band-**S**ynthetic **A**perture **R**adar –





Xuan and Matsui, 1998

PALSAR-2 Lv.1.1 (quad. CEOS) 23 scenes

- Coherency matrix [T3] generation
- Speckle filtering LEE refined (7×7)
- **Polarimetric decomposition**: Freeman-Durden; Cloud-Pottier
- Sampling (25-30pixel) from each ROI & Statistical analysis

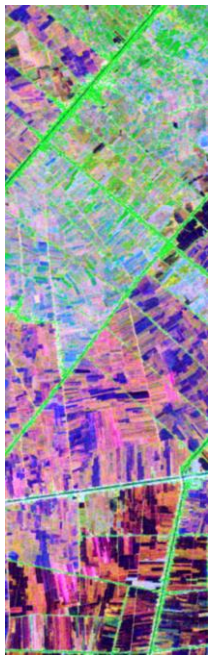
PALSAR-2 Lv.1.1 (SCANSAR CEOS) 105 scenes

- Multilooking
- Co-registration
- De Grandi multi-temporal filtering
- Geocoding & Radiometric calibration — HH; HV; Incidence angle
- Rice paddy masking & Statistical analysis

Classification of inundated paddies and non-inundated paddies which is covered by rice plants

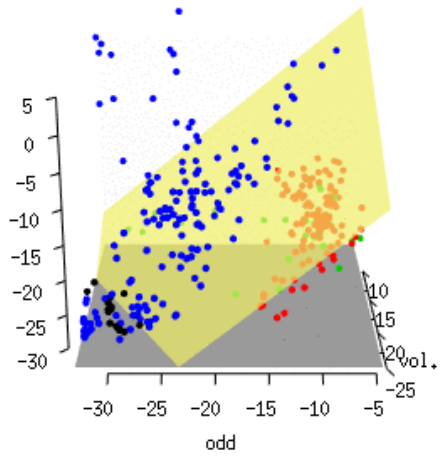
Modified from Avtar *et al*. 2012

-Freeman-Durden decomposition-



Inundated (cropping)

Inundated (fallow)

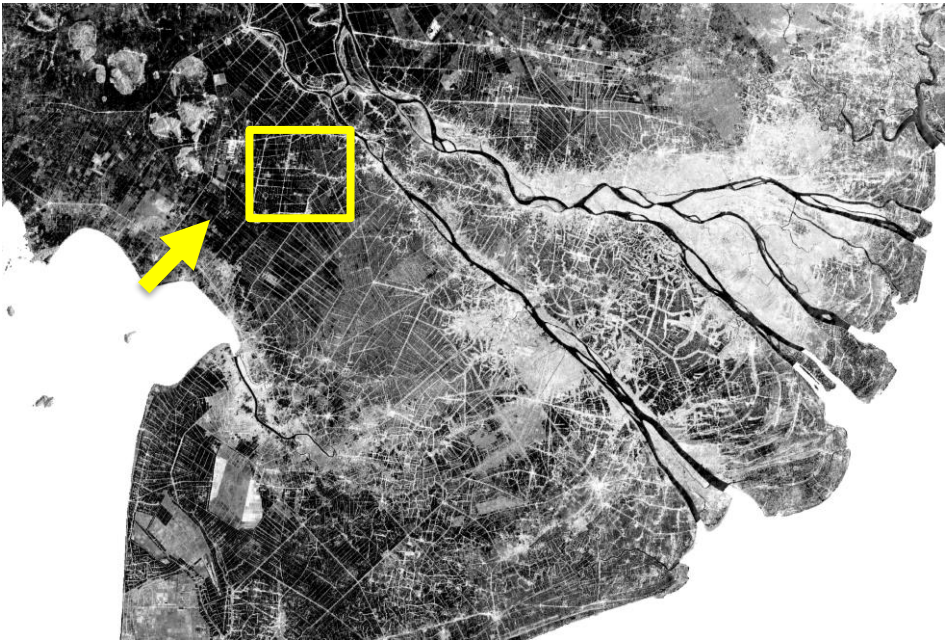


Non-inundated (cropping)

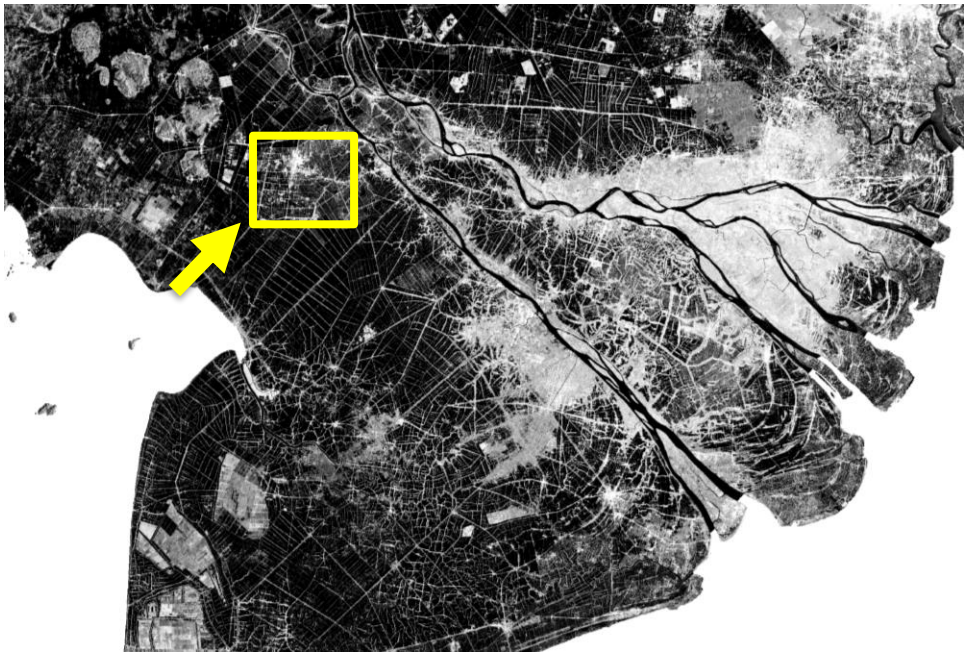
Non-inundated (fallow)

SCANSAR (intensity - HHσ^0)

Dry season (2015 Apr. 10)

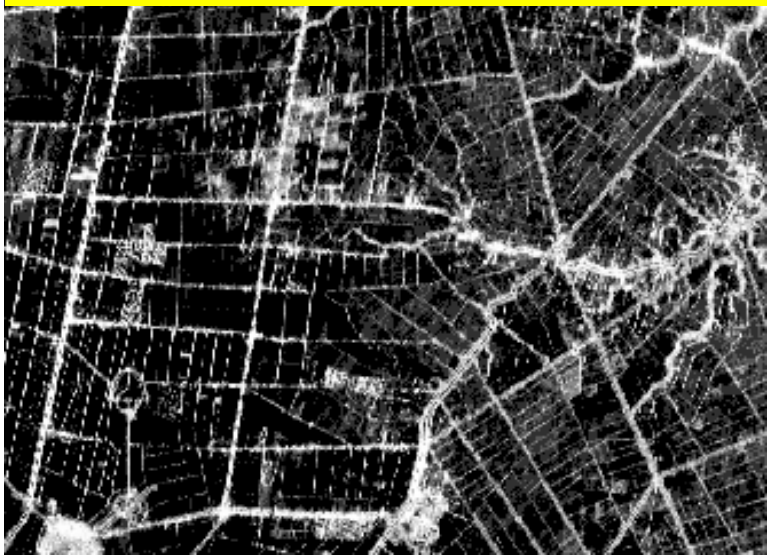


Flooding season (2015 Oct. 23)



Double bounce detection by SCANSAR (intensity - HHσ^0)

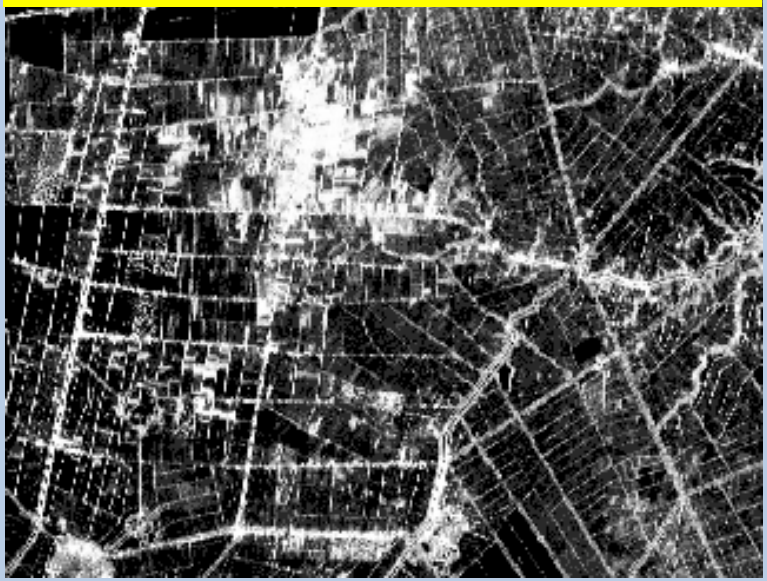
Dry season (2015 Apr. 10)



Rainy season (2015 Jul. 03)

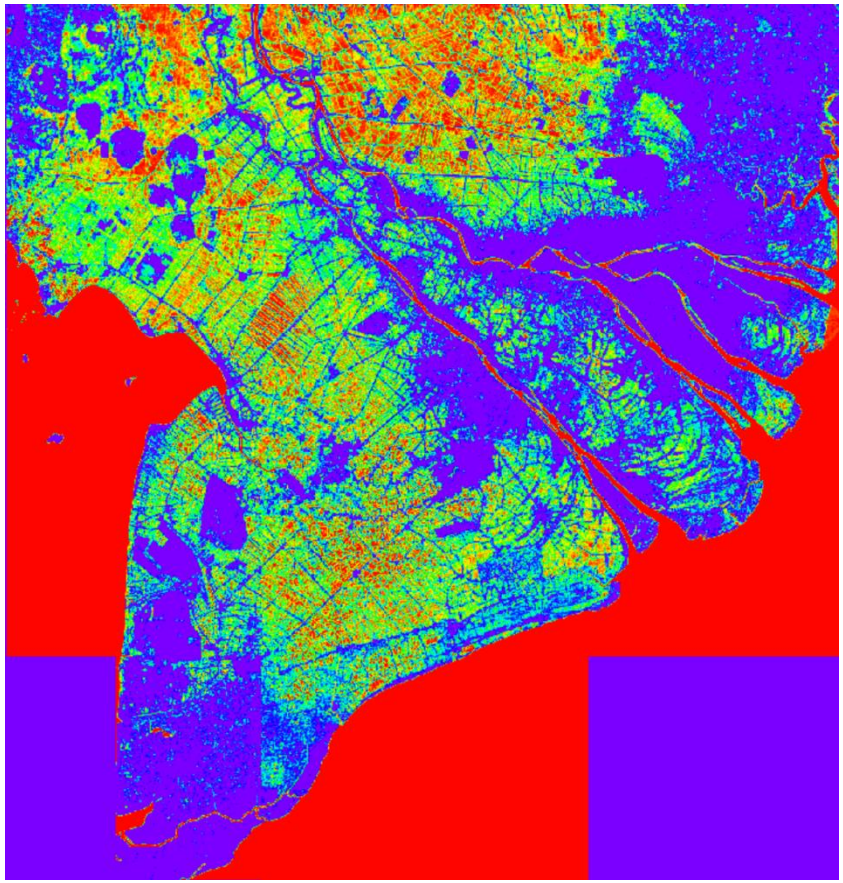
Flooding season (2015 Oct. 30) **-LANDSAT-8-**

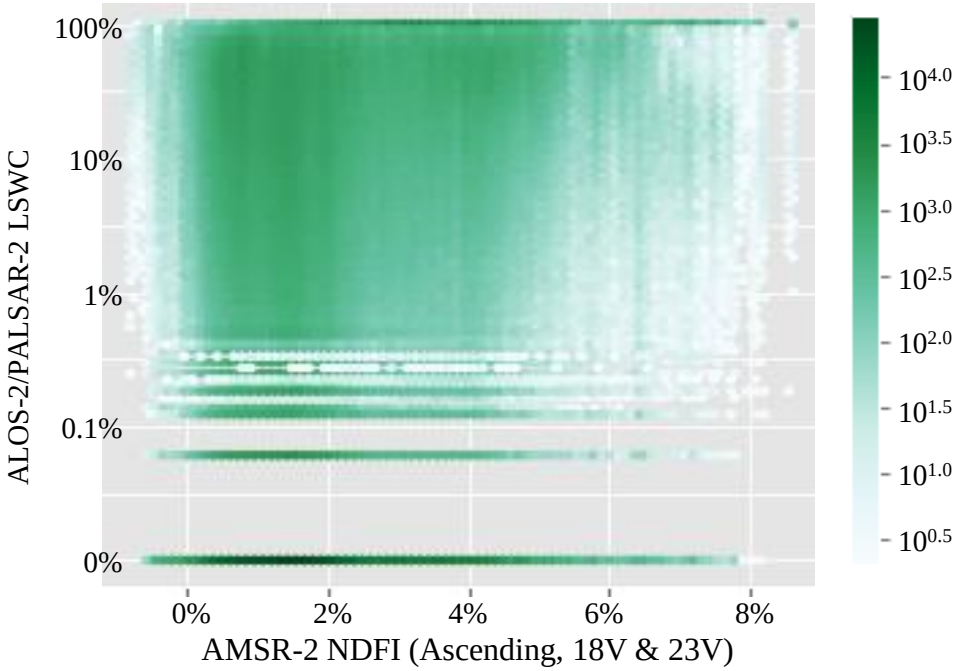
Flooding season (2015 Oct. 23)

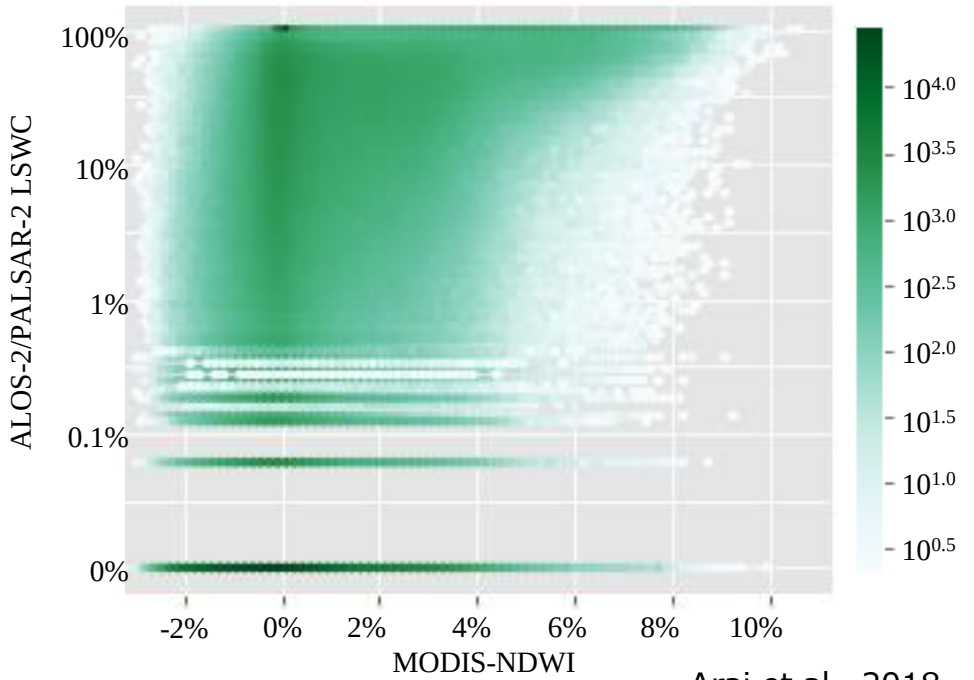


Floodability analysis

(Cumulative LSWC/
observation scenes)



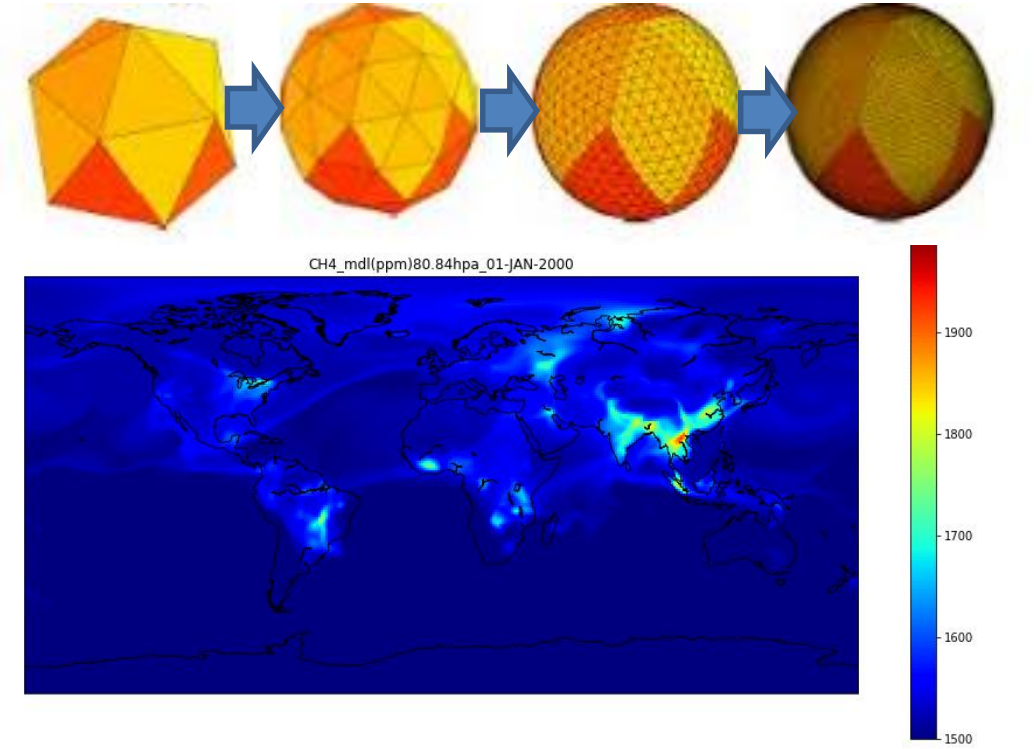




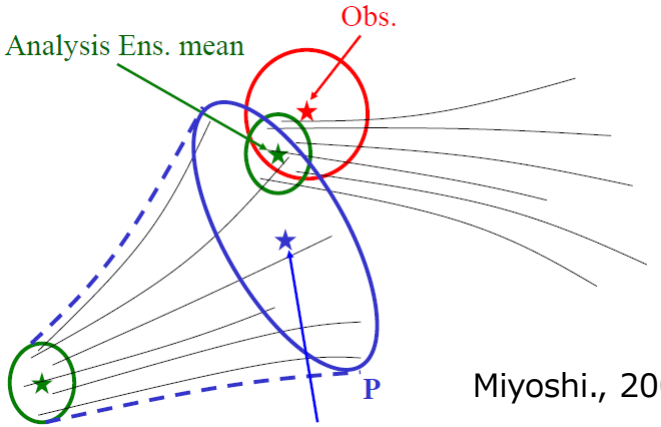
Arai et al., 2018

Inverse estimation of the emission using **NICAM-TM(Chem)-LETKF** with AMSU, PREPBUFR and **GOSAT** data

Nonhydrostatic **IC**osahedral **A**tmospheric **M**odel-**TM(Chem)**

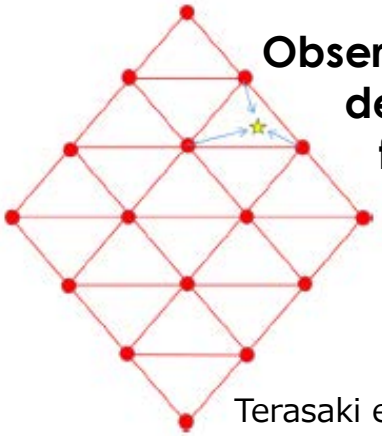


Local **E**nsemble **T**ransform **K**alman **F**ilter



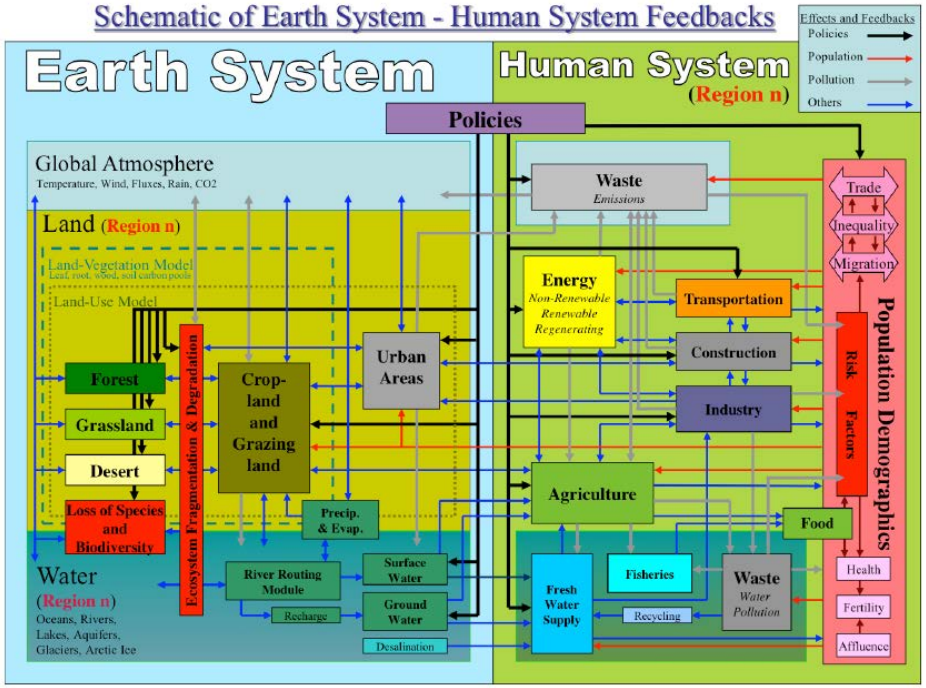
Miyoshi., 2005

Observation operator development for GOSAT



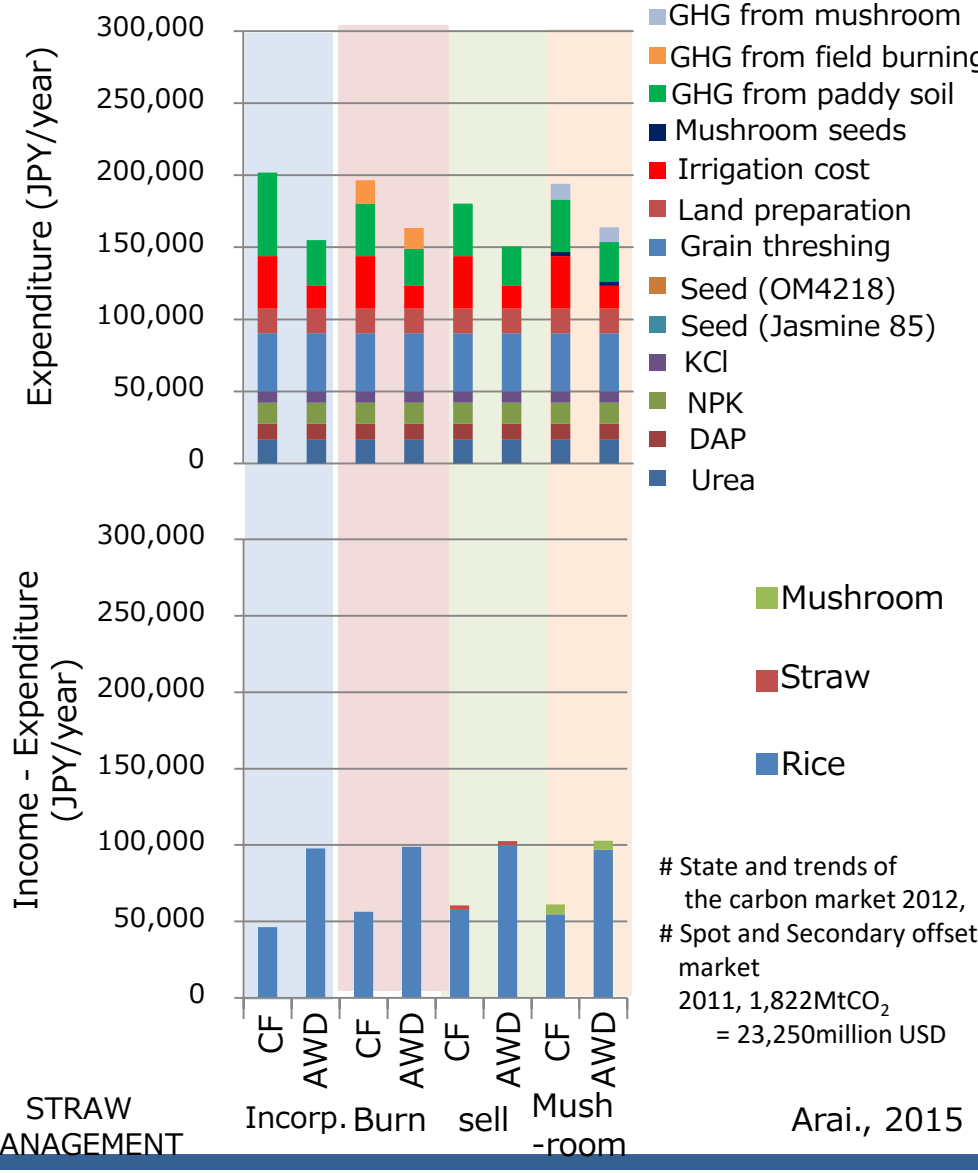
Terasaki et al., 2014

Economic assessment of GHG mitigation under various uncertainties



Kalnay *et al*. 2017

Transparent MRV system on baselines/mitigation-effects with satellite data is the key !



State and trends of the carbon market 2012,
Spot and Secondary offset market
2011, 1,822MtCO_2
= 23,250million USD

Arai., 2015

Thank you
for your attention