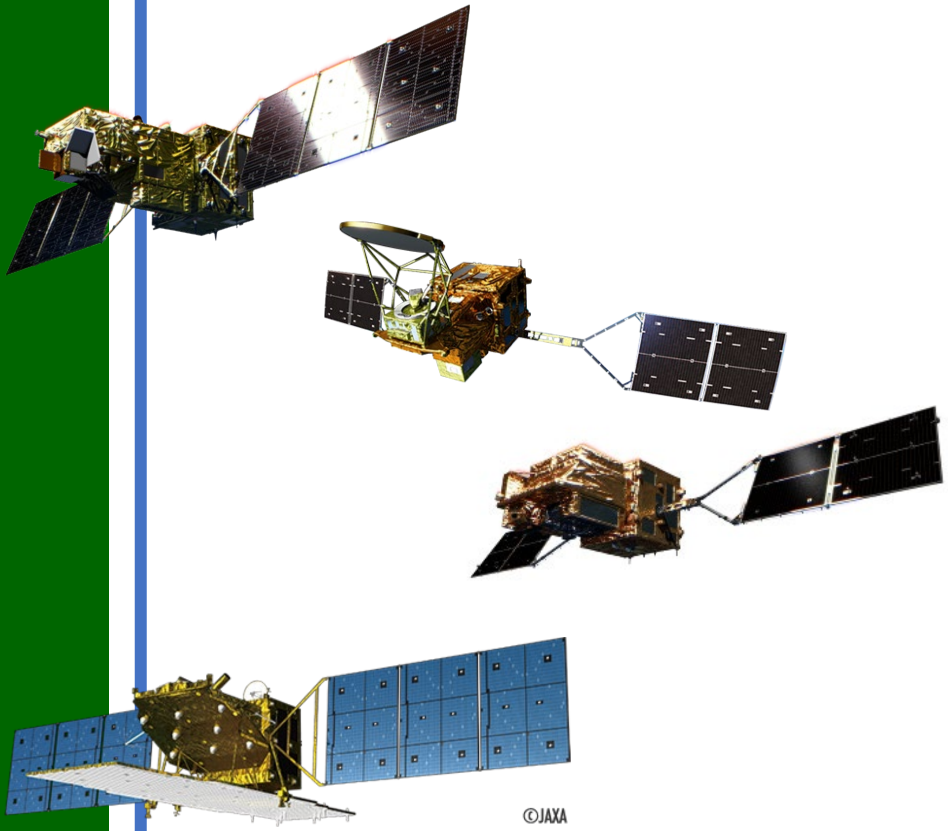
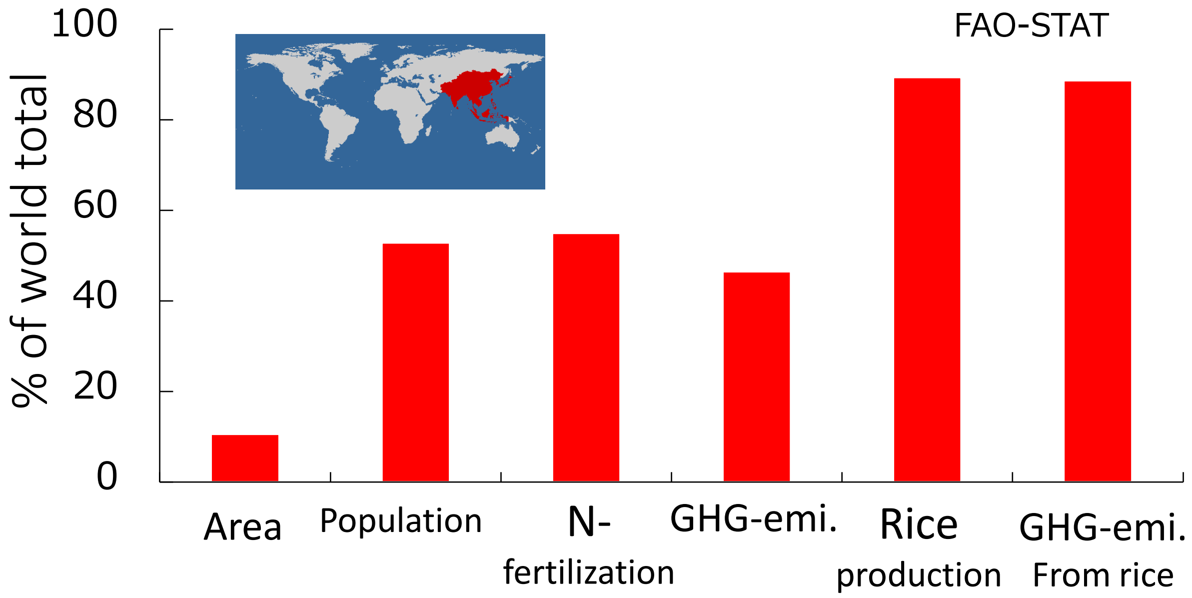
Quantifying methane emissions and rice productivity in the Mekong delta with a simultaneous data assimilation scheme on L/C-band SAR data and ground observation

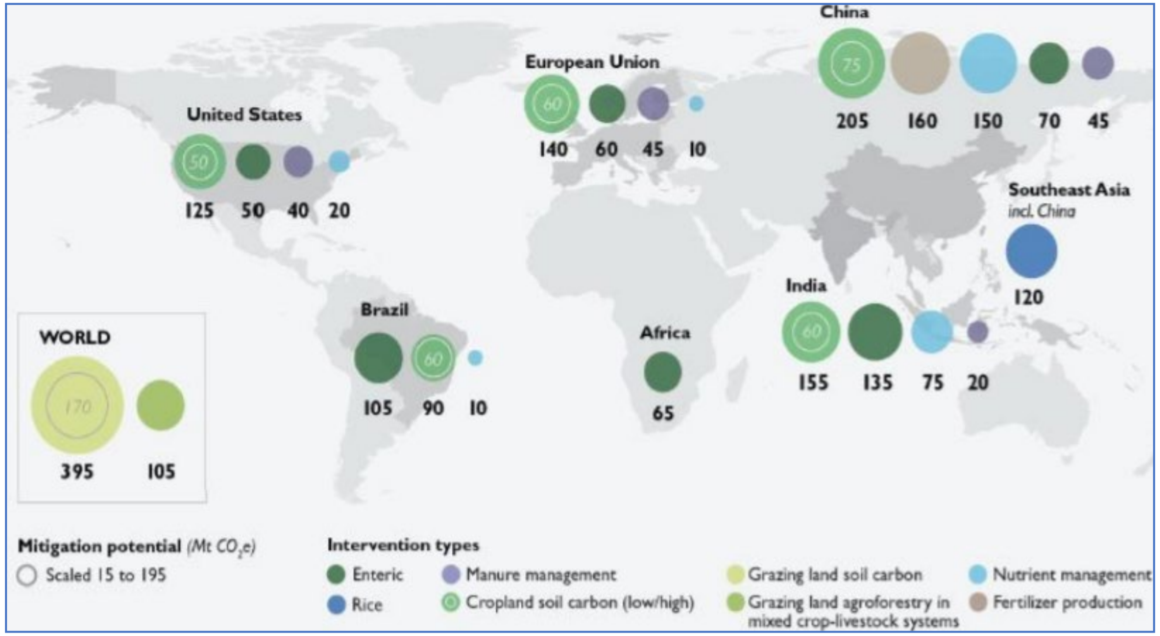


Hironori Arai1), Thuy Le Toan1),
Wataru Takeuchi2), Kei Oyoshi3), Hoa Phan1),
Stephan Mermoz1), Alexandre Bouvet1),
Lam Dao Nguyen4),
Tamon Fumoto5), Kazuyuki Inubushi6)

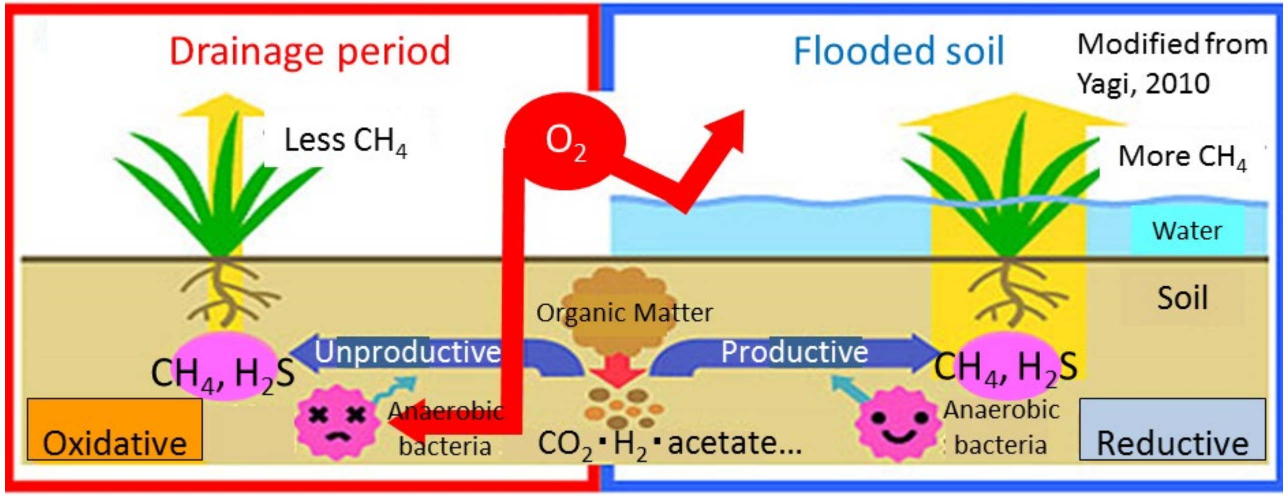
Counter measure: Intermittent irrigation

The necessity of quantifying GHG mitigation effect and rice productivity



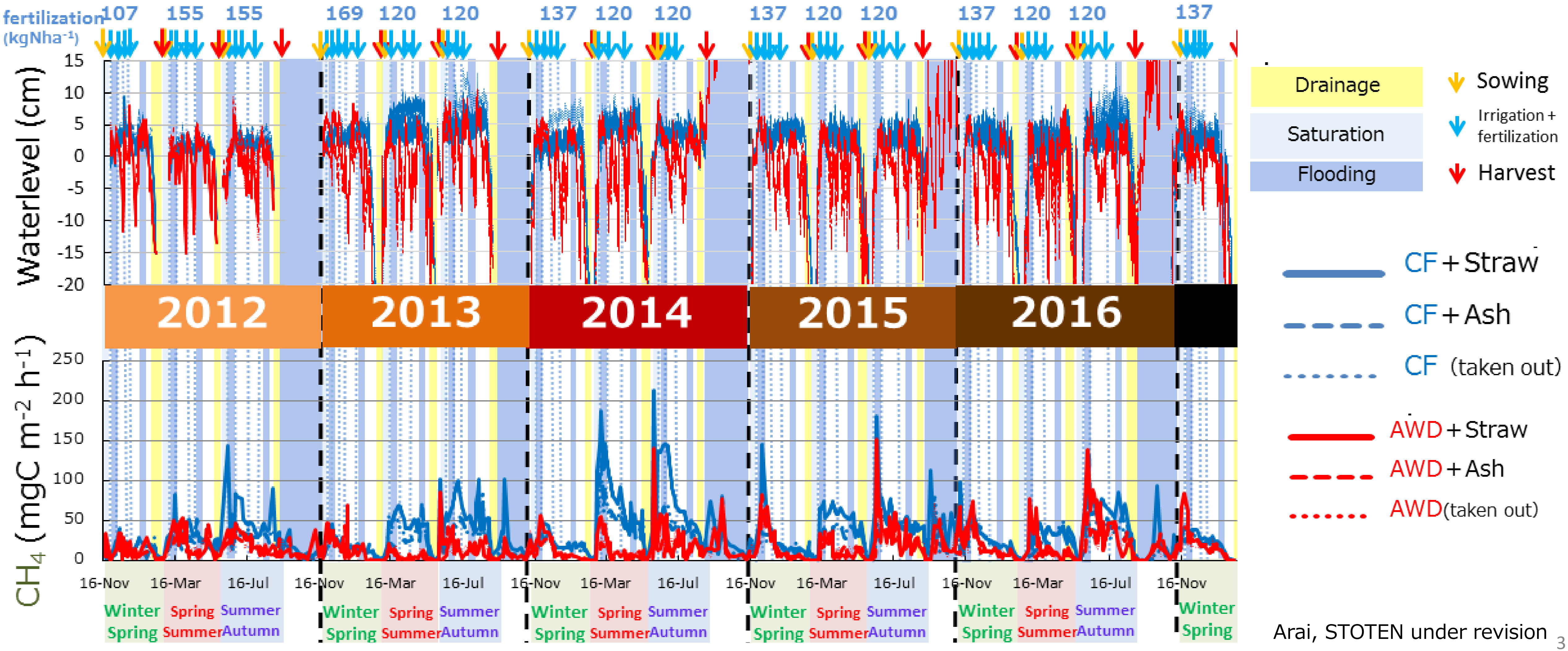


Source: CEA analysis based on: Alexandratos and Bruinsma, 2012
Jhanvi Saini and Rajan Bhatt Current Journal of Applied Science and Technology · April 2020



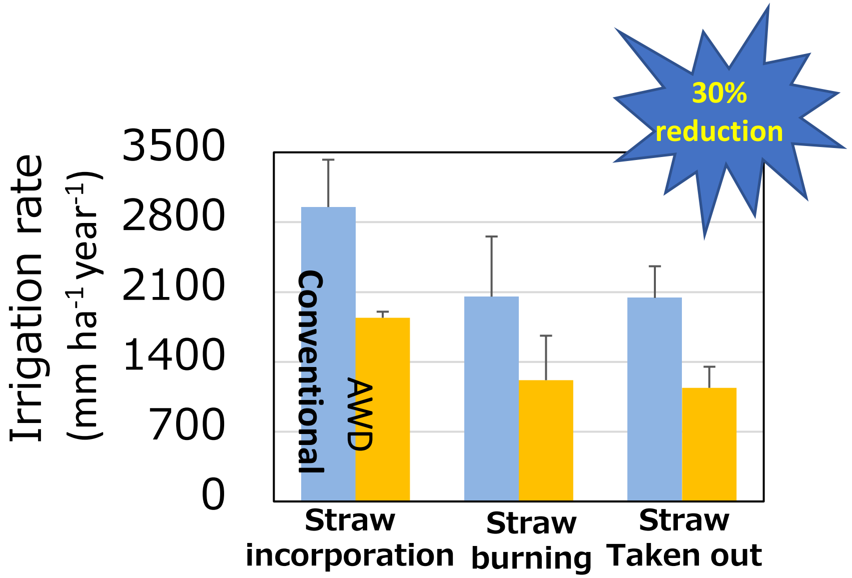
AWD has been based on research works carried out in last decades

Multi-year study conducted on farmer fields in the Mekong Delta

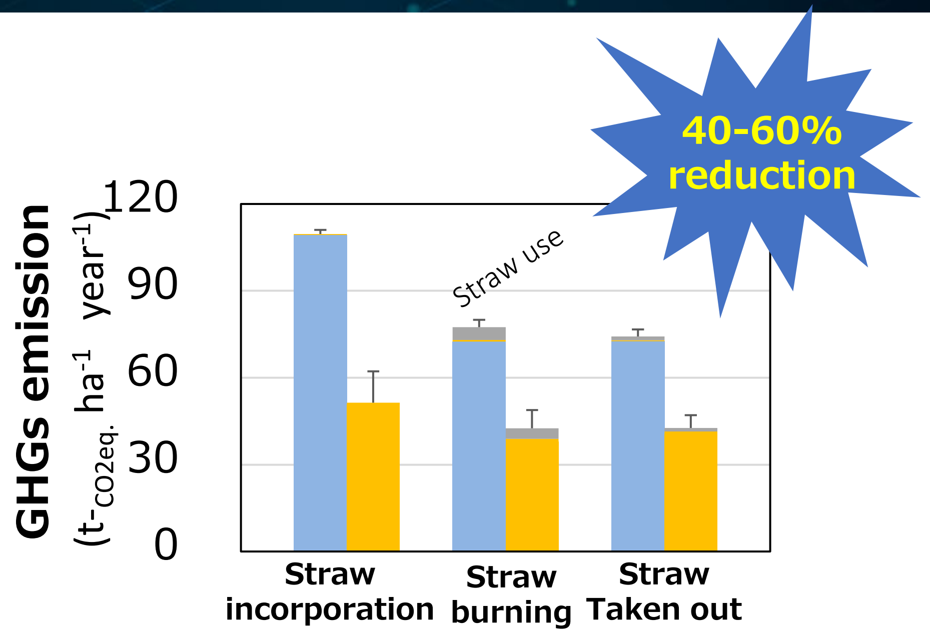


Arai, STOTEN under revision

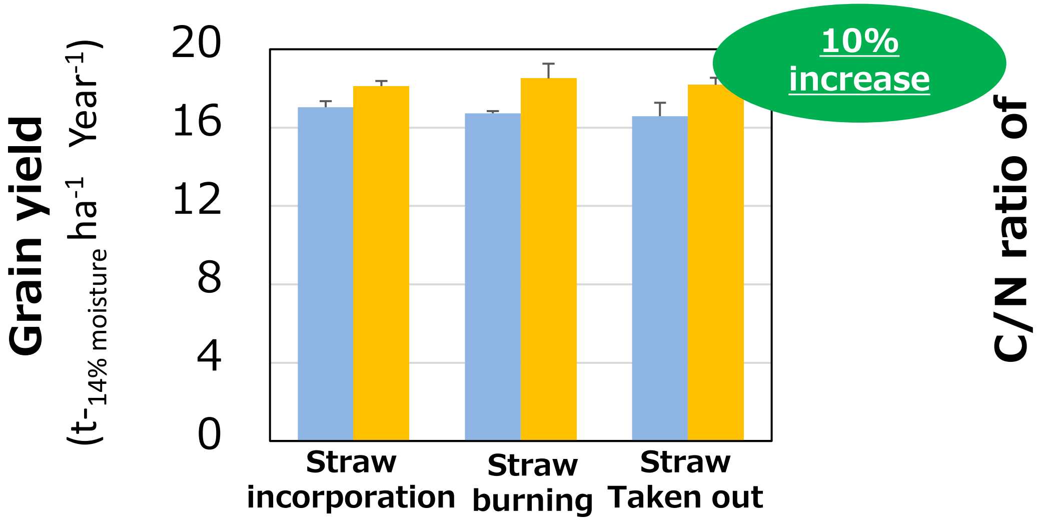
AWD reduces methane emission, water demand, with slightly improved grain yield and quality (2012-2016 experiment)



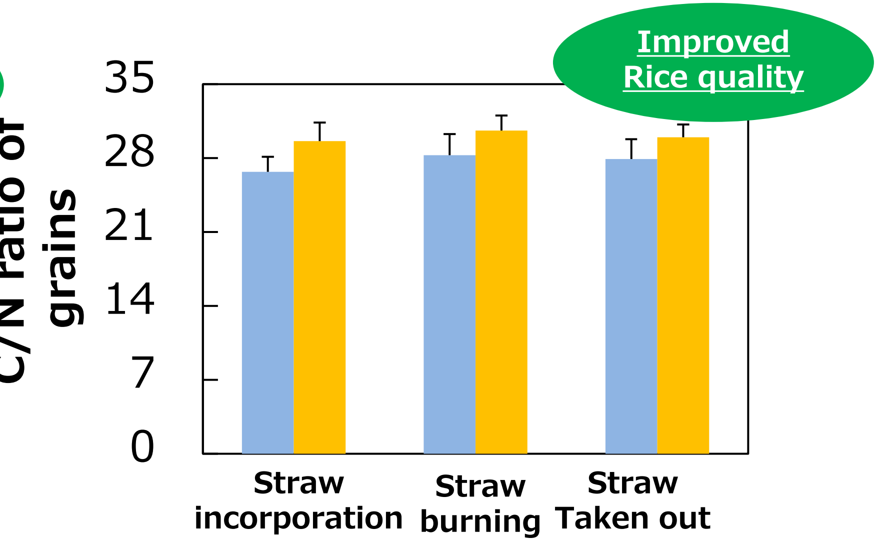
30% reduction



40-60% reduction



10% increase

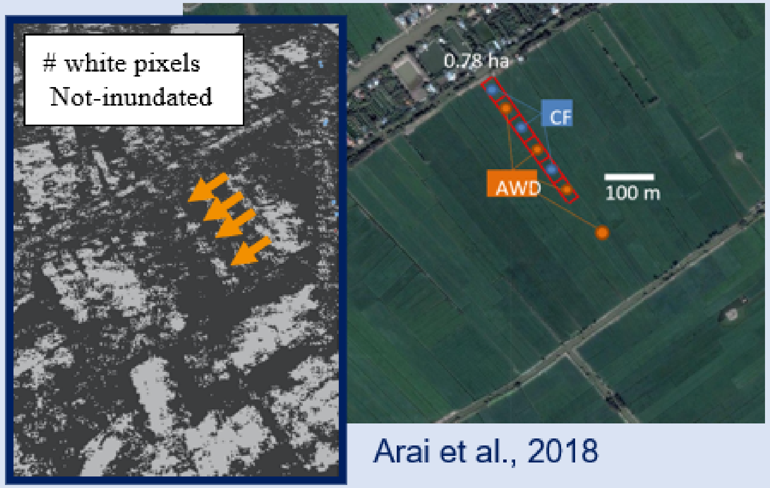


Improved Rice quality

Arai et al., SSPN 2021

L-SAR observation on inundation

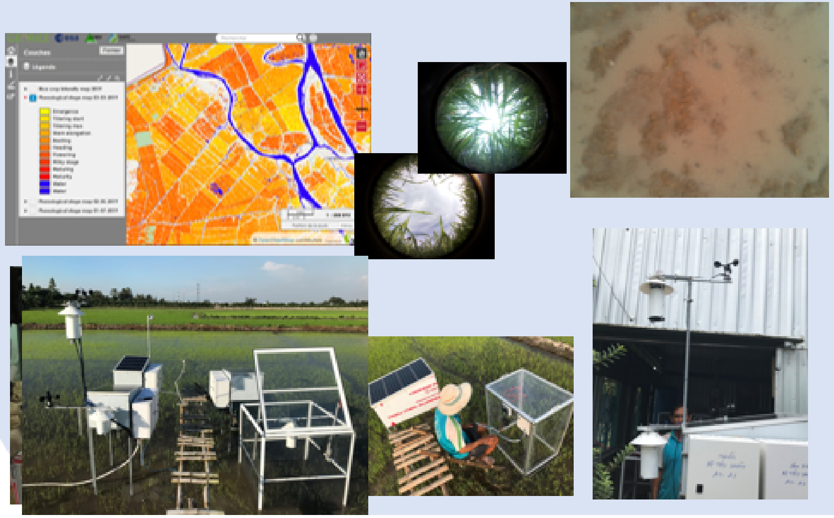
ALOS-2/4, NISAR, ROSE-L



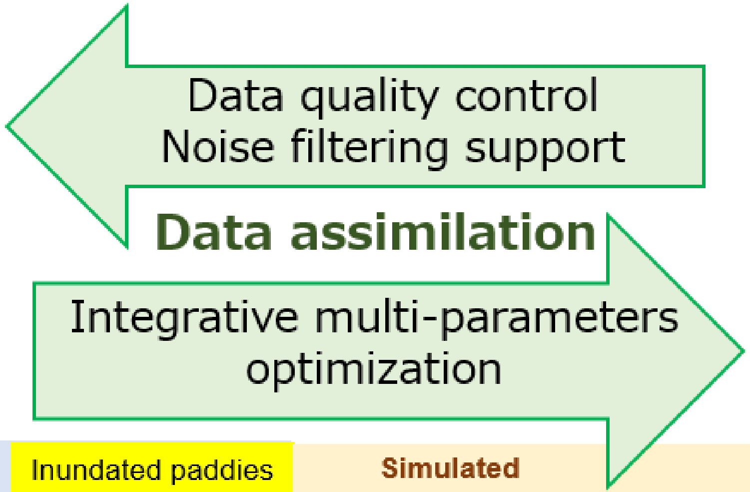
Arai et al., 2018

GeoRice & IoT tech.

Regional Rice monitoring in S E Asia with Sentinel-1
http://www.georice.net/lm/index.php/



Pixel-based (50m-res.) Inversion of Daily waterlevel/GHGfluxes, rice growth/yield and Nitrogen-usage



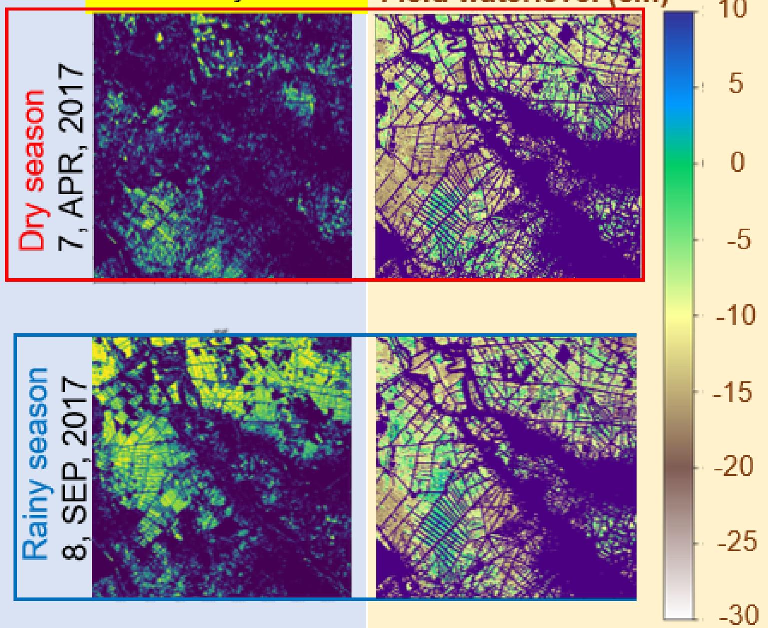
Data quality control
Noise filtering support

Data assimilation

Integrative multi-parameters optimization

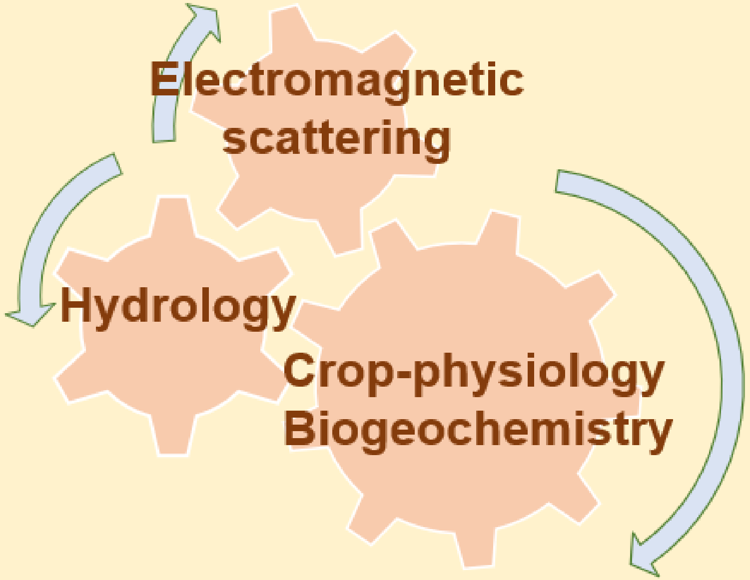
Inundated paddies detected by ALOS-2

Simulated Field waterlevel (cm)



Cyber-LCA coupling system

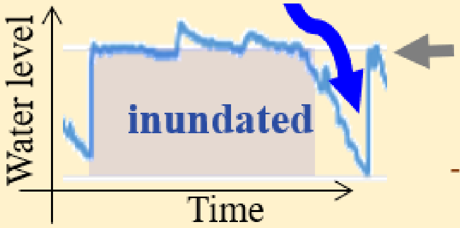
w/ high spatio-temporal resolution models

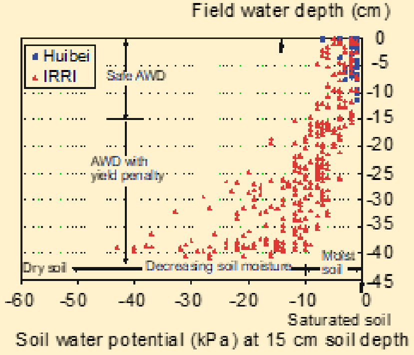


Electromagnetic scattering

Hydrology

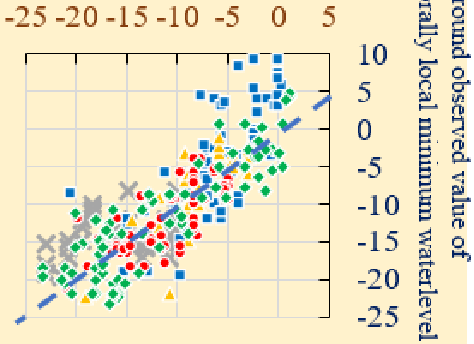
Crop-physiology Biogeochemistry





Lampayan et al., 2015

Simulated values of water level (cm below soil surface)

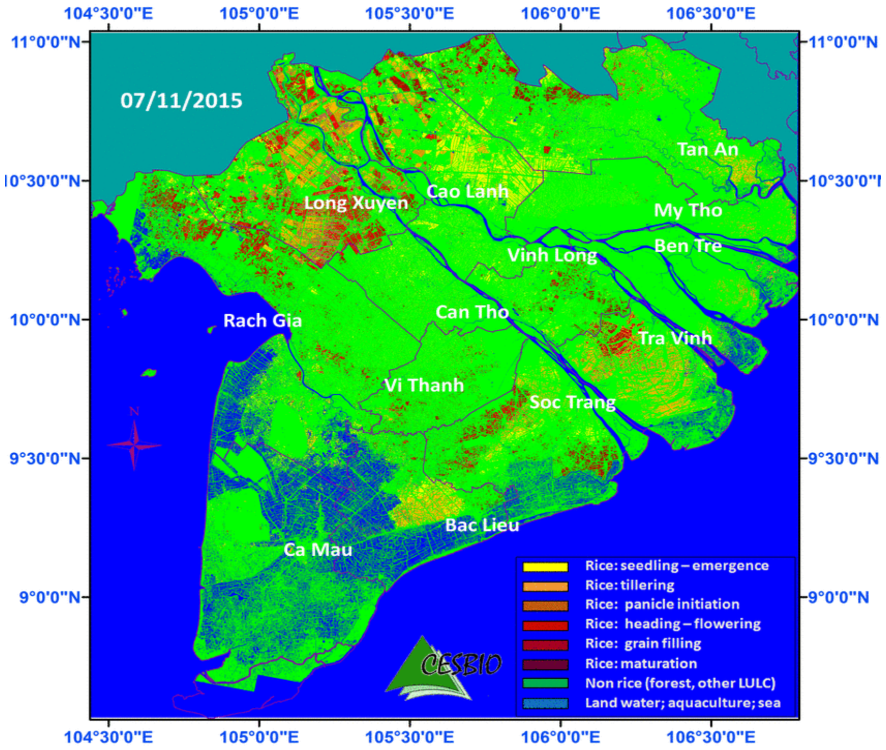


Data from 5 sites x 5 plots x 10 seasons

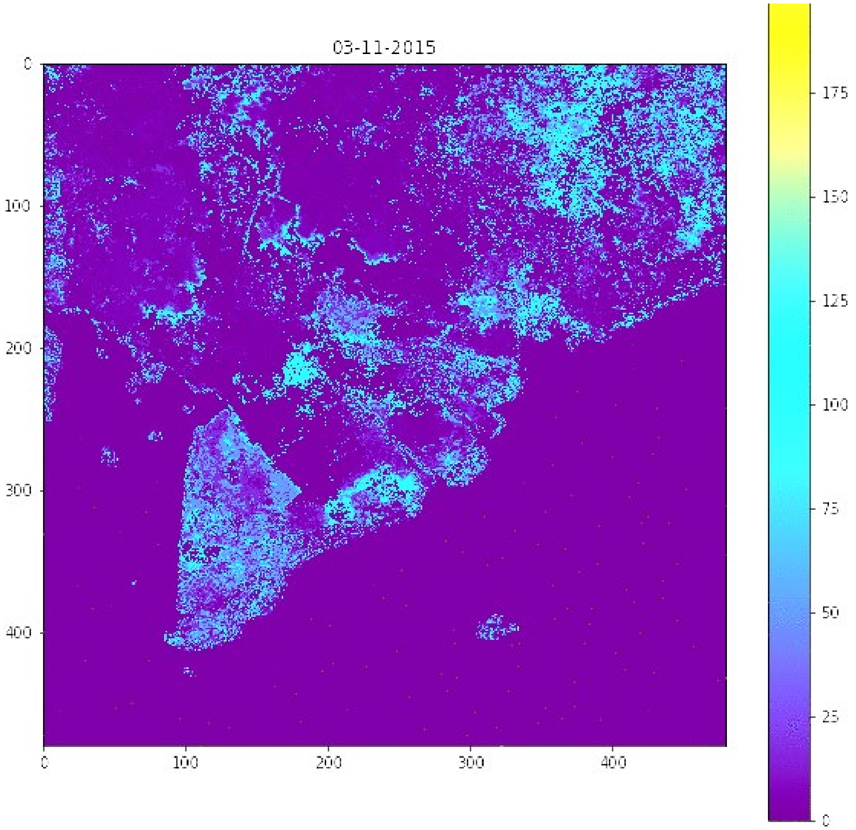
Arai et al., 2021 RSE submitted

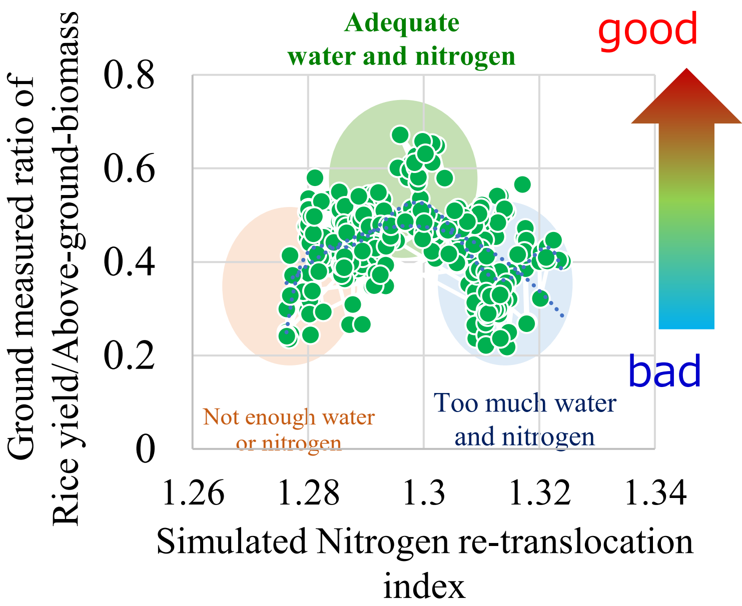
Rice phenology and satellite data pixel based simulation of CH_4 emission

Sentinel-1 to monitor rice growth



Simulated daily CH_4 fluxes ($kg\ C\ km^{-2}\ h^{-1}$)

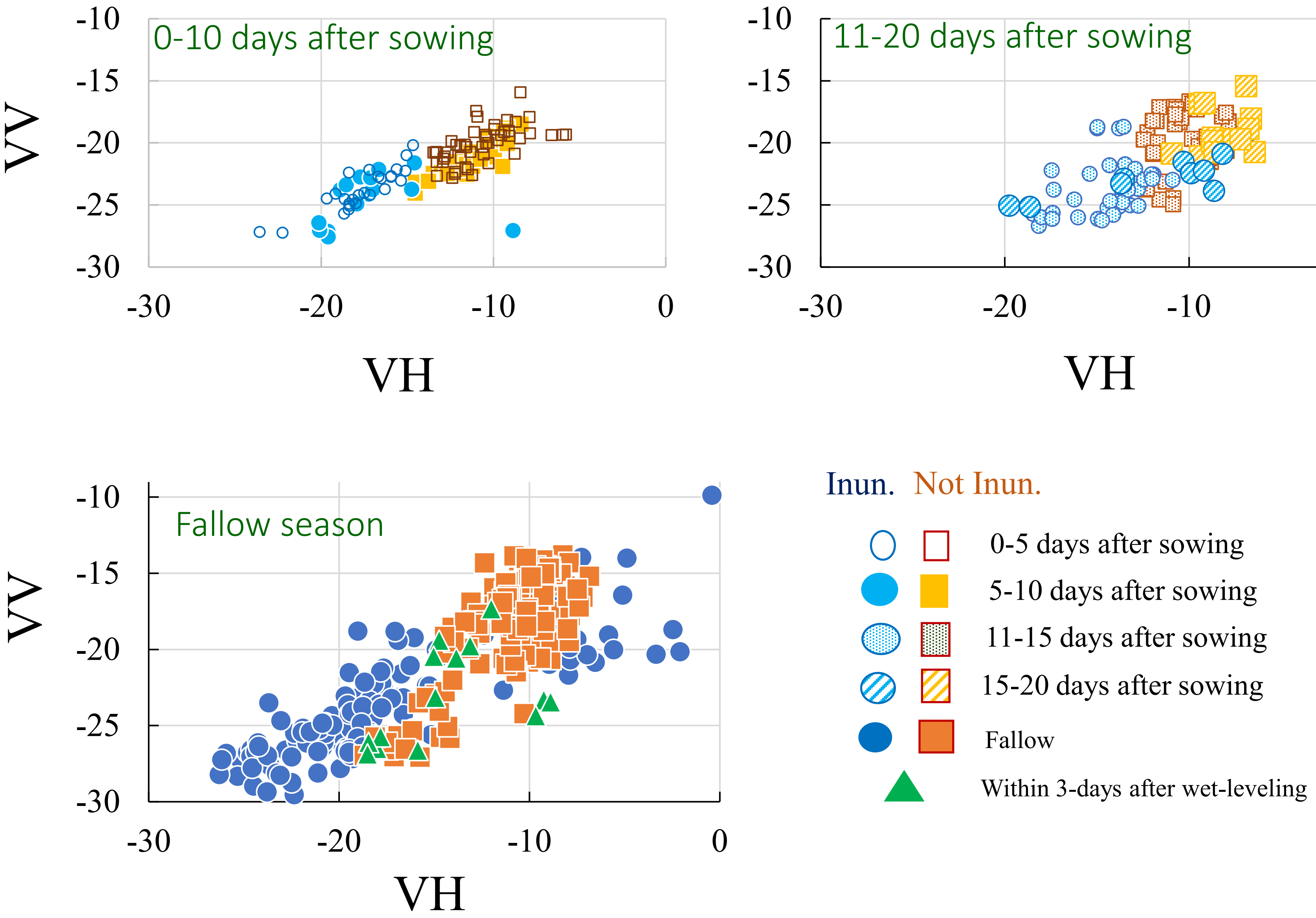




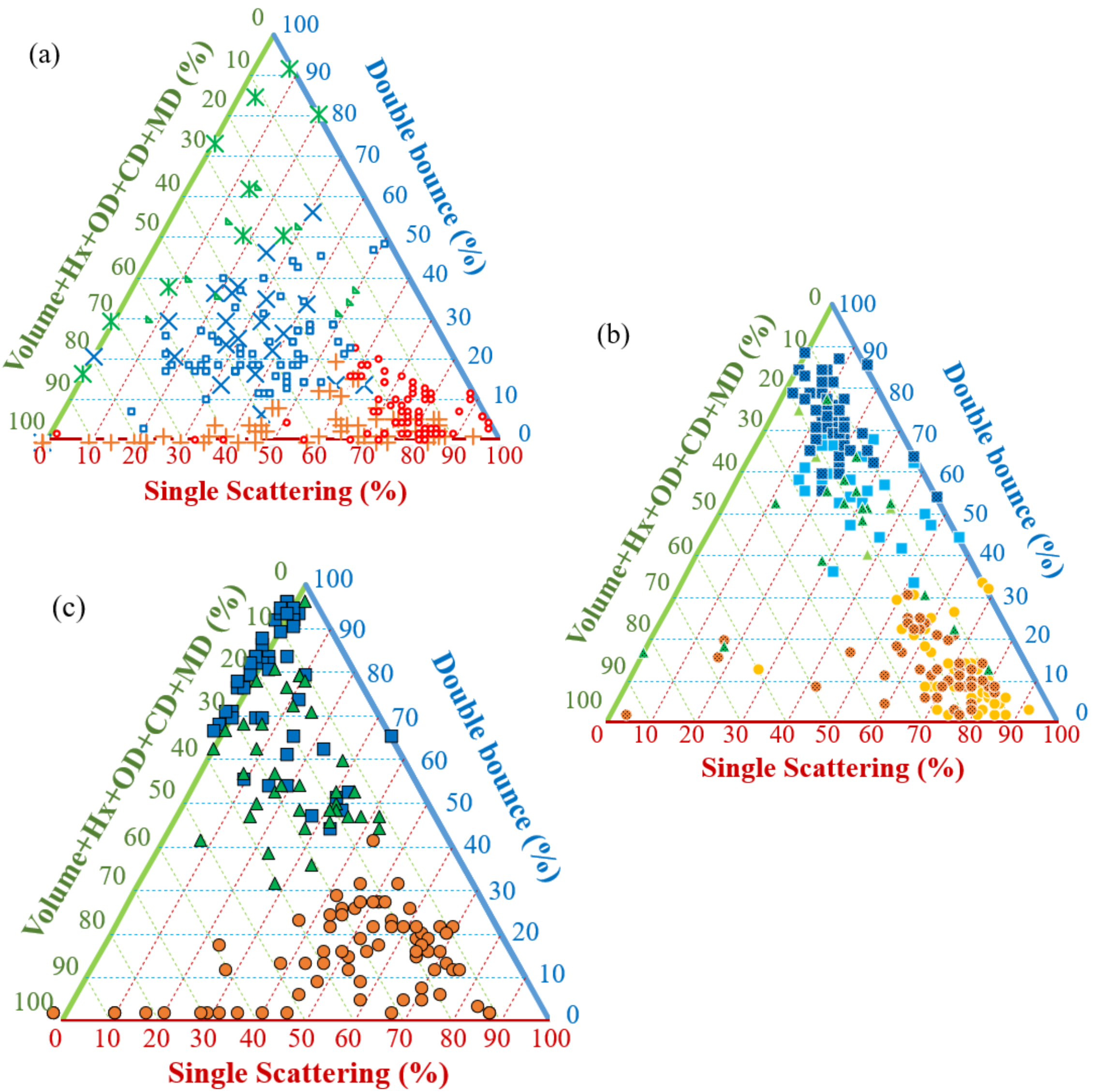
Arai et al., Springer, 2021

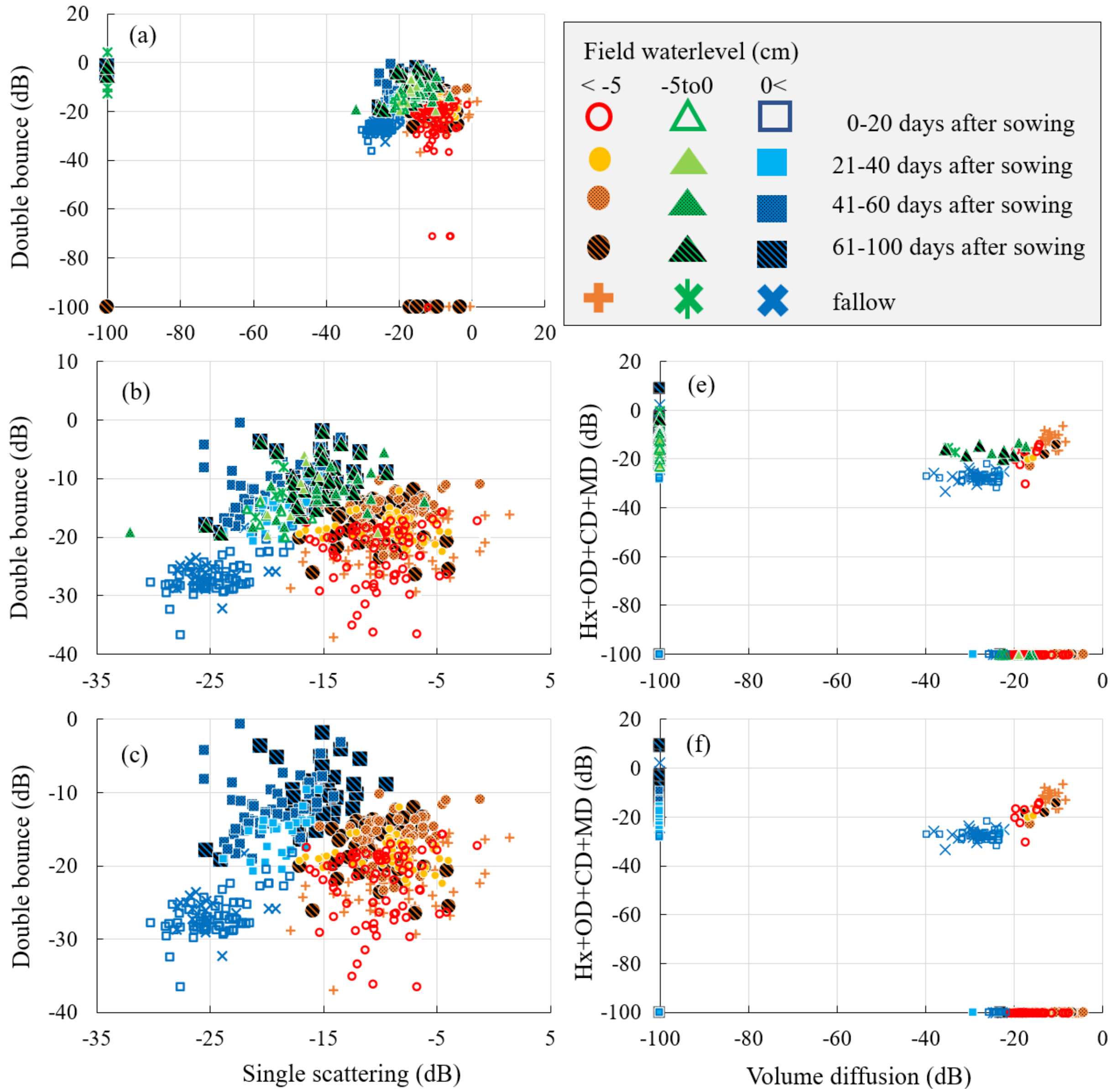
C-band Sentinel-1 rice monitoring

-inundation detectable at early rice growing stages-



L-band PALSAR-2 rice monitoring
-inundation detectable in the whole stages-





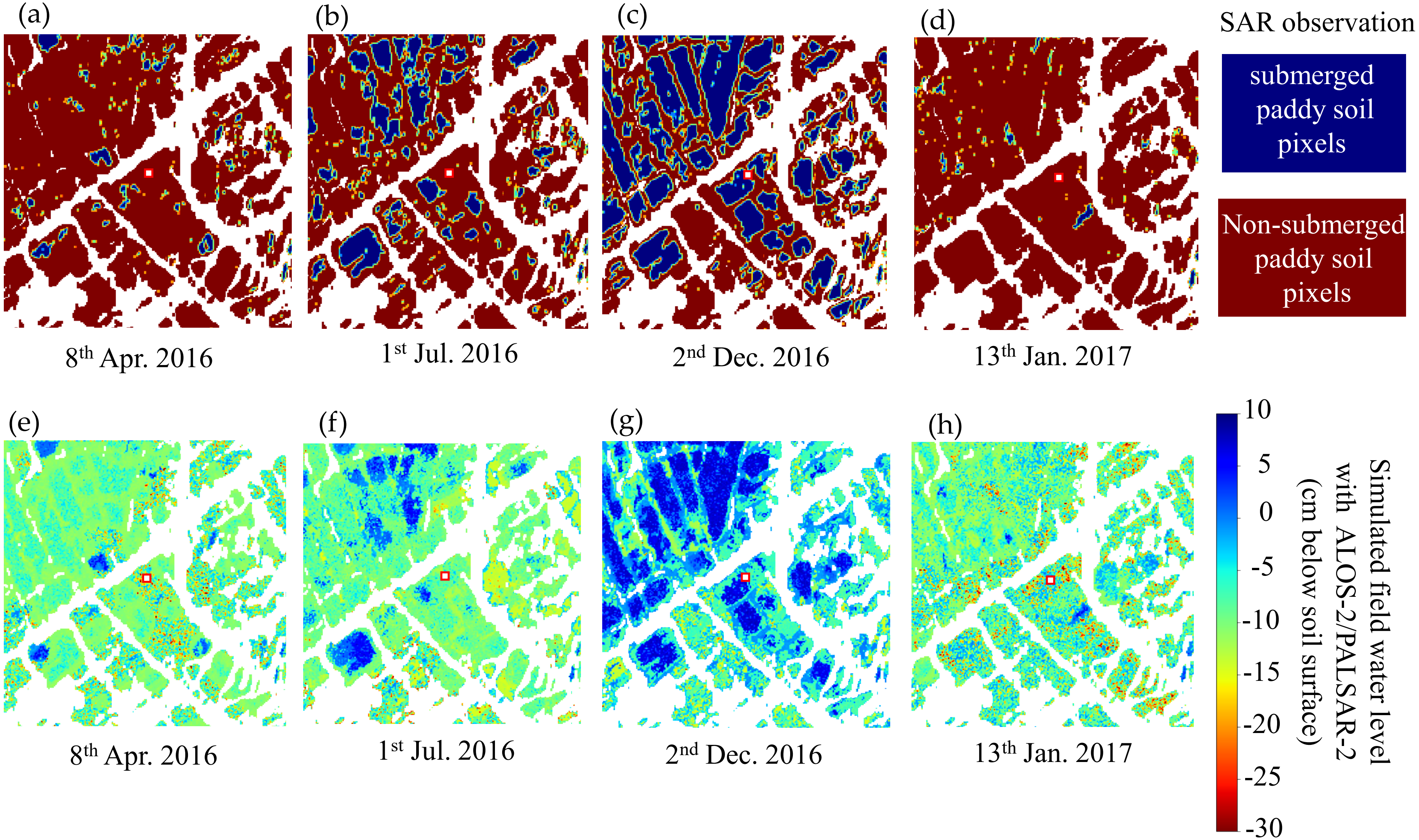
Arai et al., RSE under revision

σ^0 based inundation detection with ALOS2-HR data

white pixels
Not-inundated

69 days after sowing, 6th May 2016

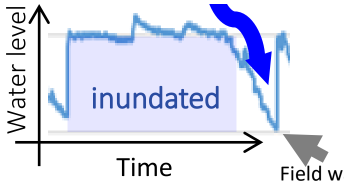
SAR data assimilation of field water level simulation
-binding cyber space and real space-



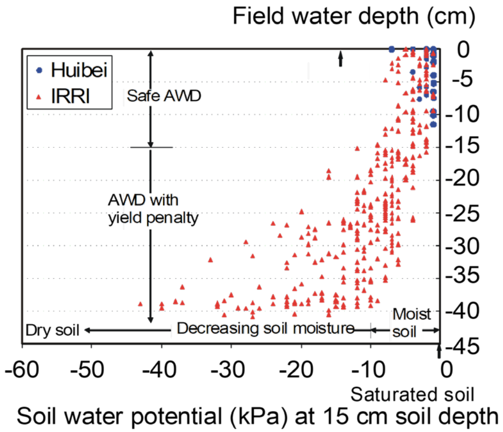
Note Lite blue: Not submerged (i.e., water level is lower than 0) Blue: submerged (i.e., water level is taller than 0)

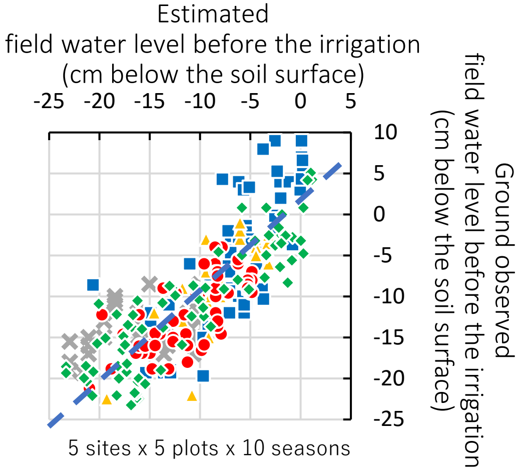
Arai et al., RSE under revision

How deep the field water was dropped by next irrigation?
– Estimation by DA model parameter estimation -

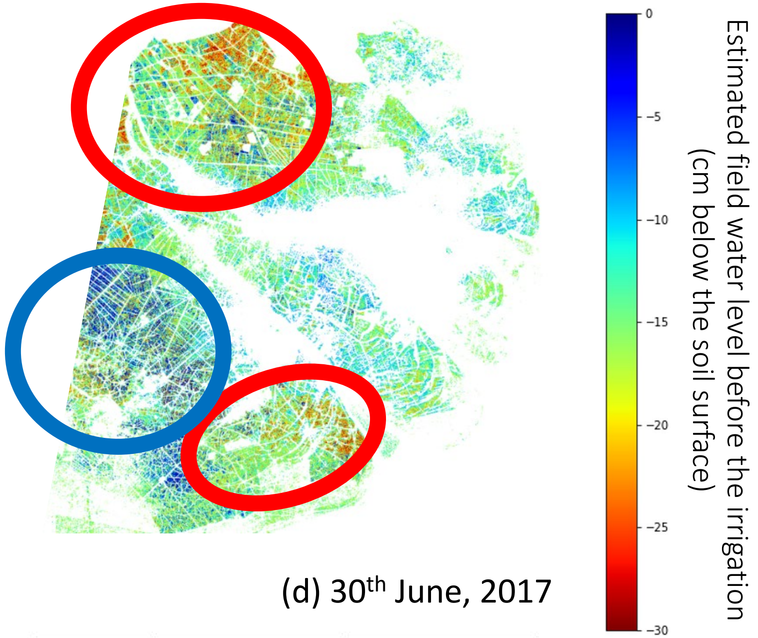


Field water level before the irrigation

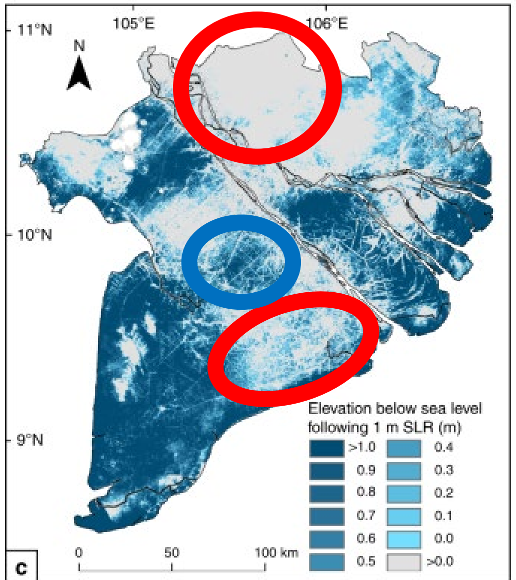


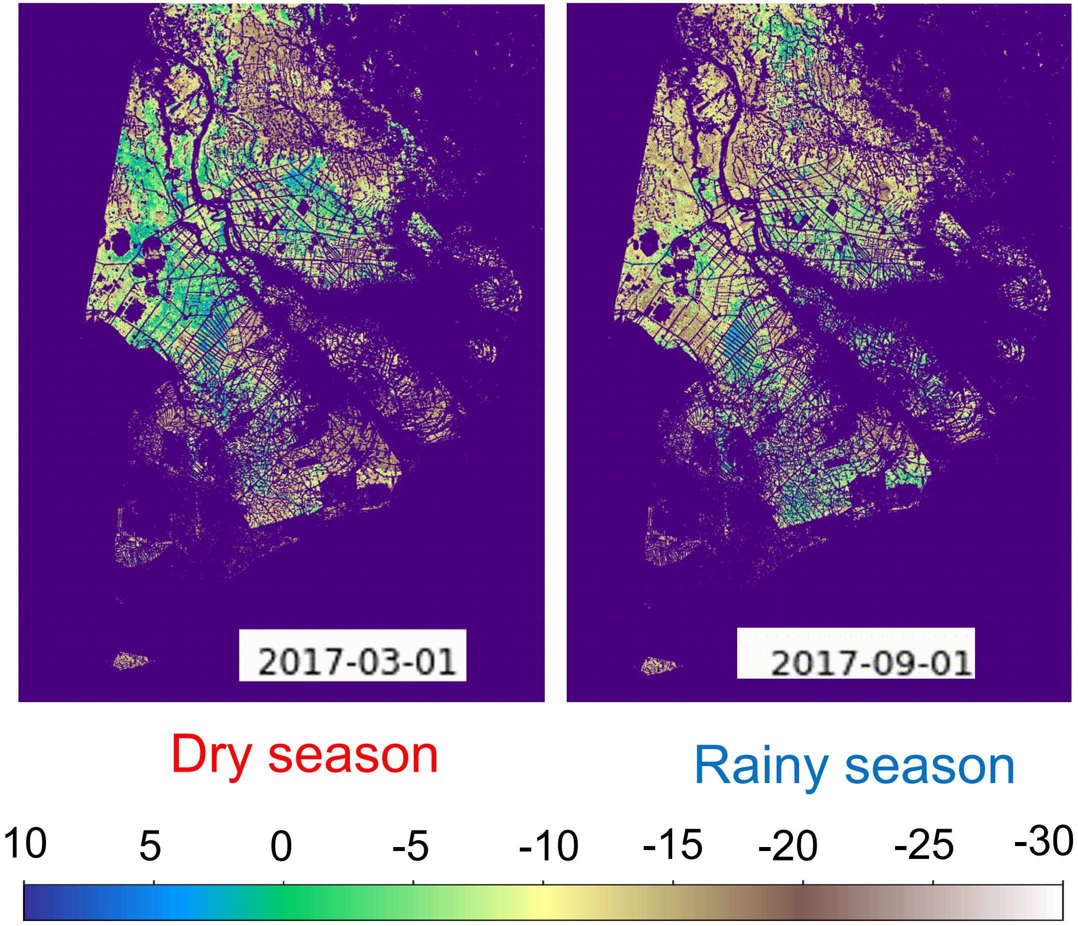


5 sites x 5 plots x 10 seasons



(d) 30th June, 2017





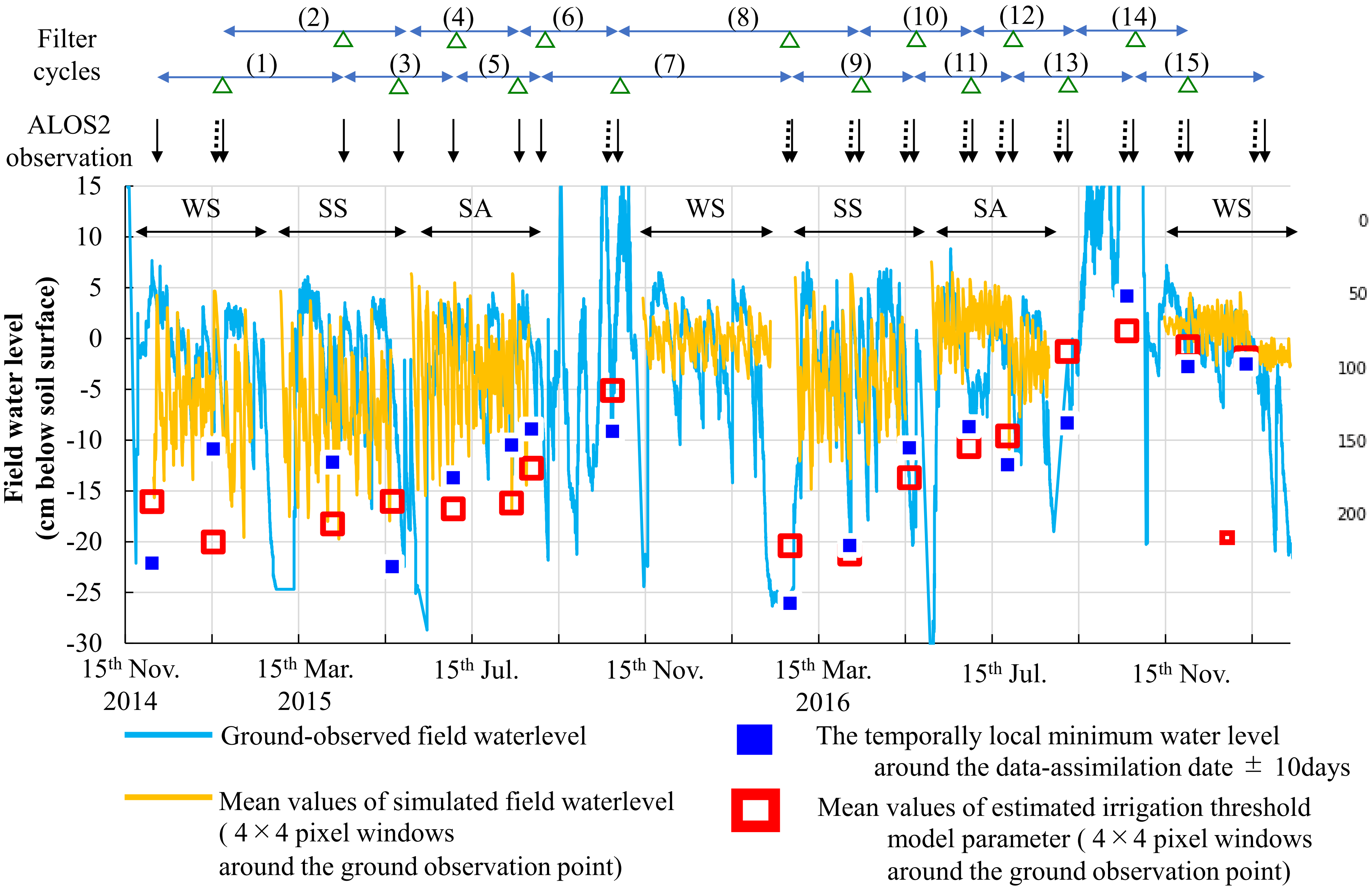
Dry season

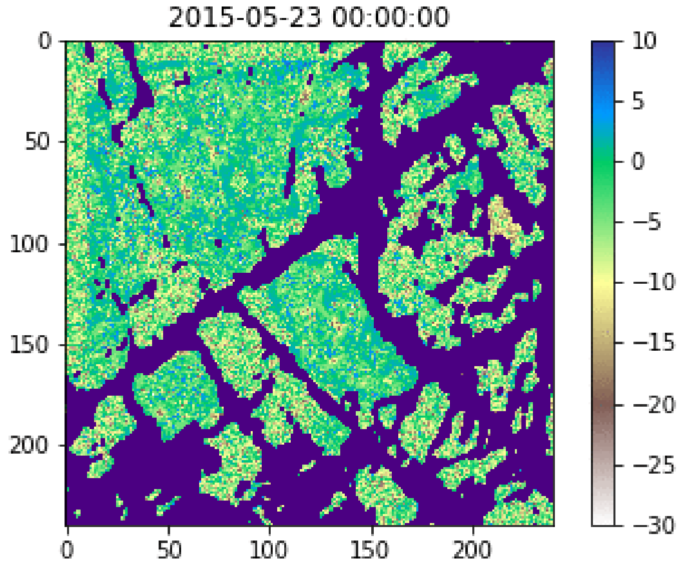
Rainy season

Field waterlevel (cm)

Arai et al., RSE
under revision

A sample of validation result with ground observation data –semi dyke system-

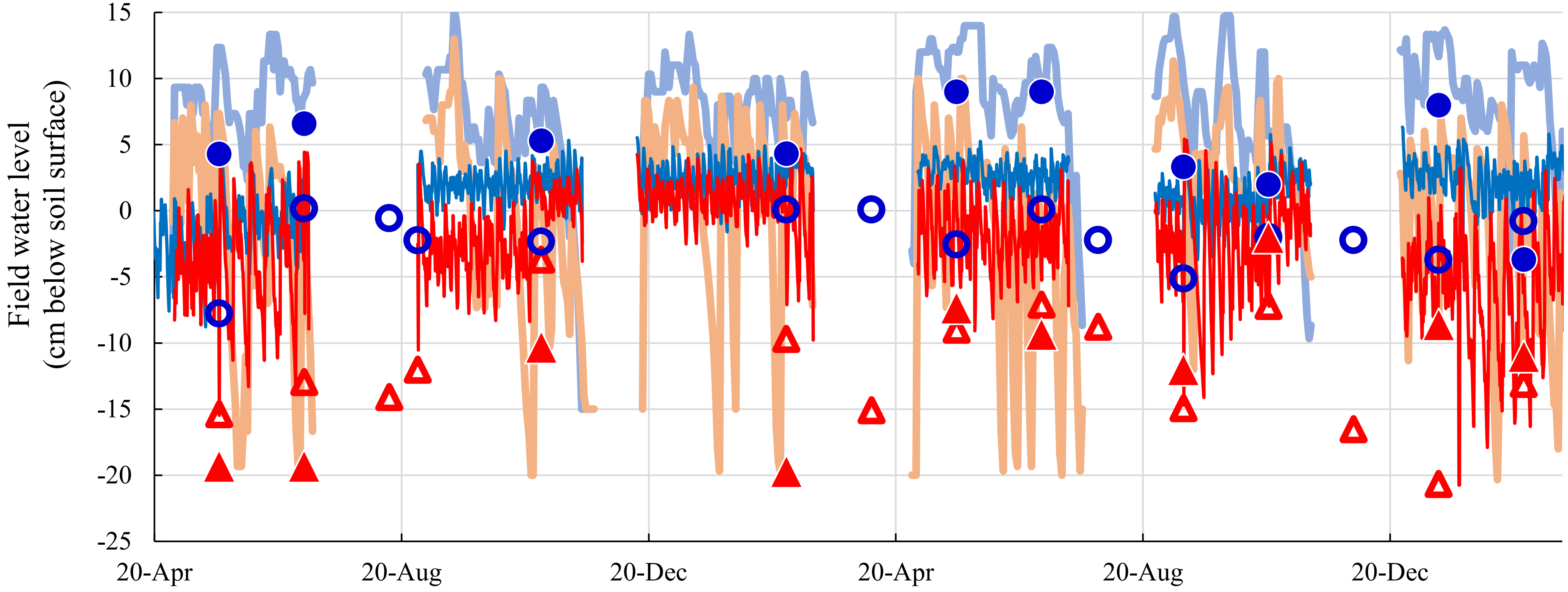




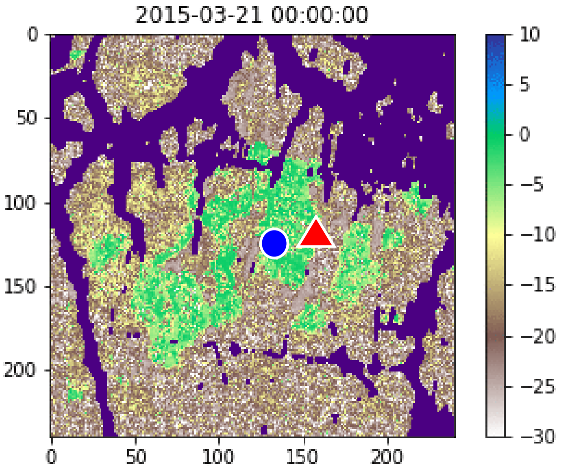
Field waterlevel (cm)

Arai et al., RSE under revision

A sample of validation result with ground observation data –full dyke system-



Simulated field water level (cm below soil surface)



Ground-observed field waterlevel

— Continuously inundated paddy

— Paddy with intermittent drainage

Mean values of simulated field waterlevel
(4 × 4 pixel windows around the ground observation point)

— Continuously inundated paddy

— Paddy with intermittent drainage

The temporally local minimum waterlevel

● Continuously inundated paddy

▲ Paddy with intermittent drainage

Mean values of estimated $D_{\text{before irrigation}}$
(4 × 4 pixel windows around the ground observation point)

○ Continuously inundated paddy

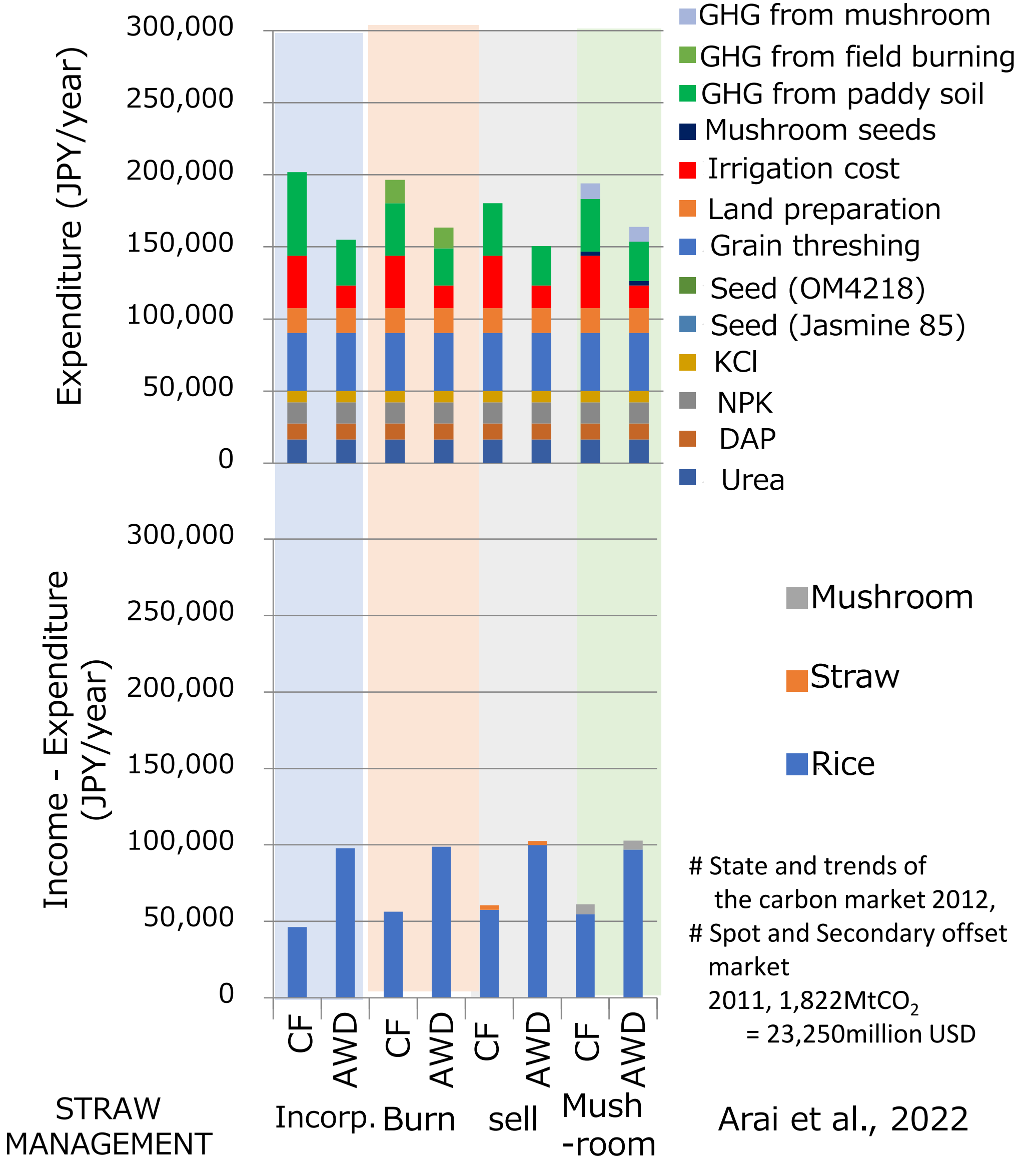
△ Paddy with intermittent drainage

Arai et al., RSE
under revision

Economic assessment of GHG mitigation measures under large uncertainties

Clear cost/benefits and actual farmers' participation are the keys to the adoption of new technologies by farmers.

Transparent MRV system on baselines/mitigation-effects with EO data should be enhanced.

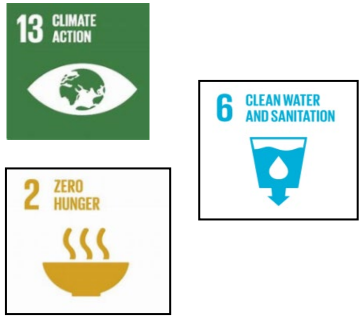


State and trends of the carbon market 2012,
Spot and Secondary offset market 2011, 1,822MtCO_2 = 23,250million USD

Arai et al., 2022

To summarise and conclude

1. AWD practices recognised to be a good option for mitigation of GHG emissions from rice fields:
   - positive environmental impact,
   - adapted to climate change (water scarcity),
   - ensure food security,
   - preserve affordability of food



2. EO data can provide geospatial information on rice growth (S1) and field inundation status (ALOS-2-PALSAR-2), necessary for GHG accounting and for monitoring of food production

3. The requirements for future space observations will be for L-band SAR with systematic acquisitions and high temporal frequency (beyond ALOS 4 and NISAR, of 12-14 day repeat cycle, ROSE-L).

4. Future operational application could be used by local stake-holders with low- computing cost but advanced process-based simulation model which considers local difference of soil parameters and high spatio-temporal resolution EO data.