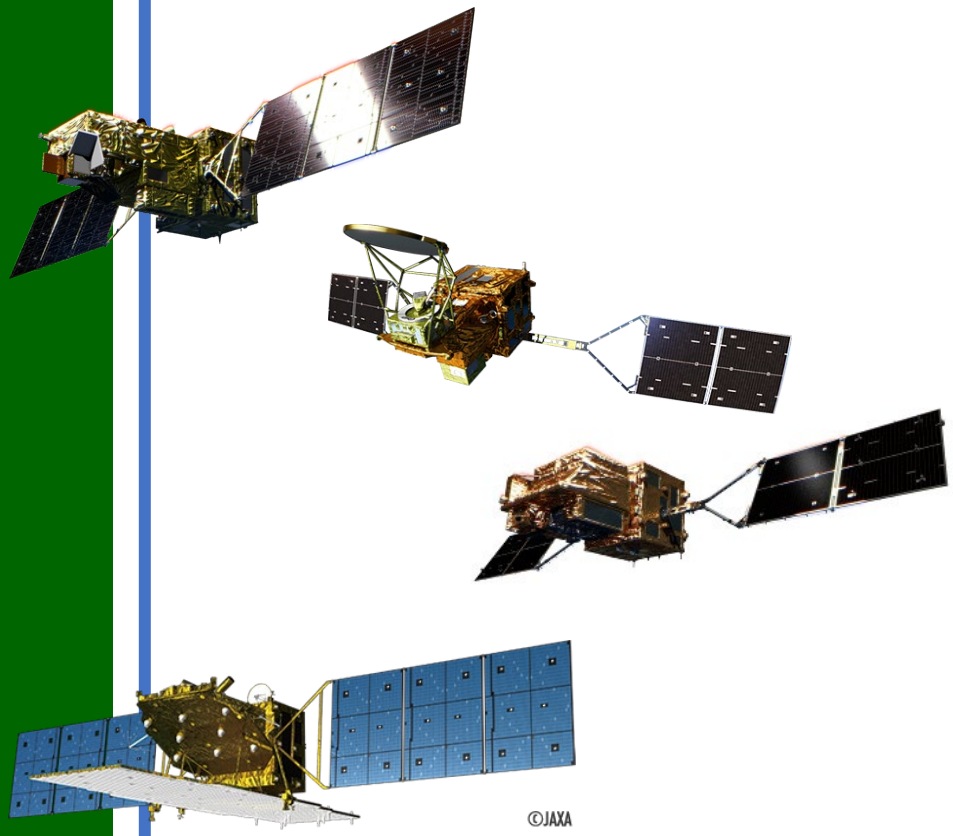
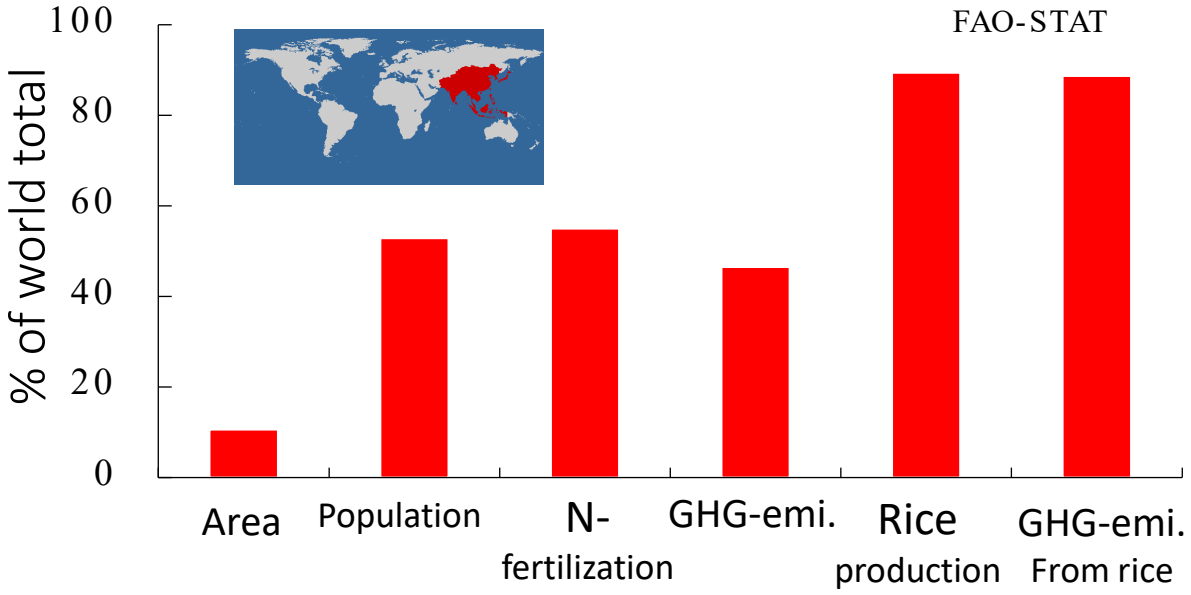
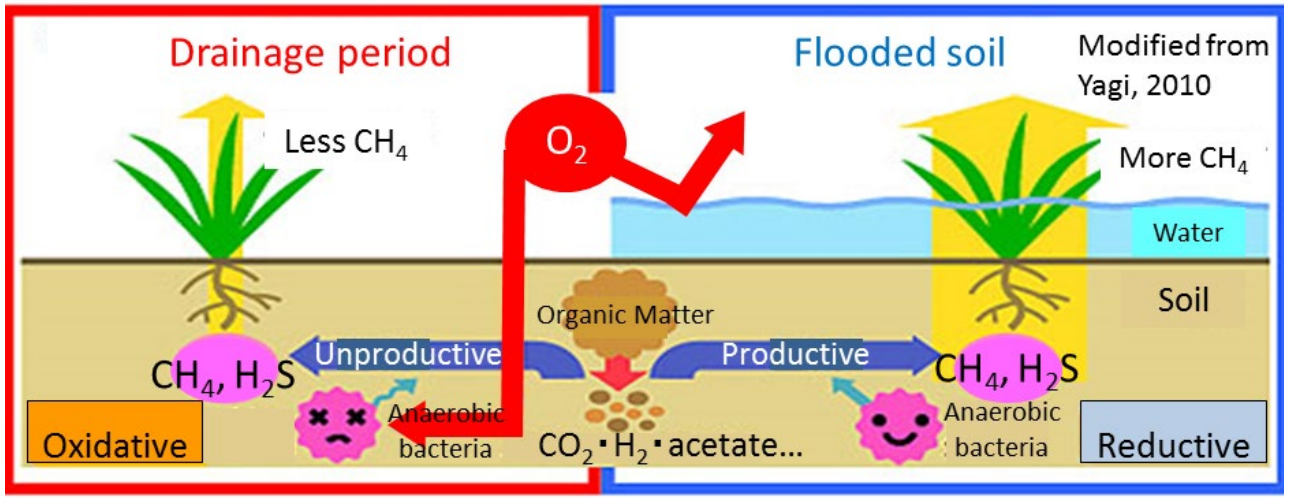
Pixel-based evaluation of rice production and related greenhouse gas emissions in the Mekong delta via a digital-twin system with a simultaneous data assimilation scheme of SAR data and ground observations

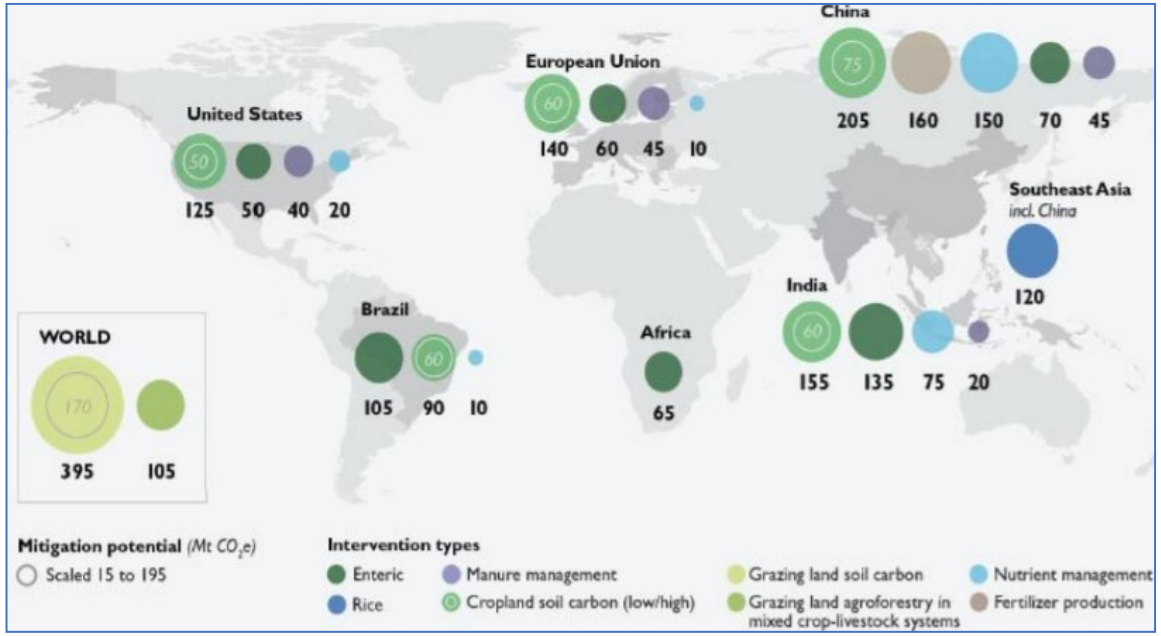
Hironori Arai[1)], Thuy Le Toan[1)], Mehrez Zribi[1)], Wataru Takeuchi[2)], Kei Oyoshi[3)], Lam Dao Nguyen[4)], Tamon Fumoto[5)], Shinich Sobue[3)]



Counter measure: Intermittent irrigation
The necessity of quantifying GHG mitigation effect and rice productivity



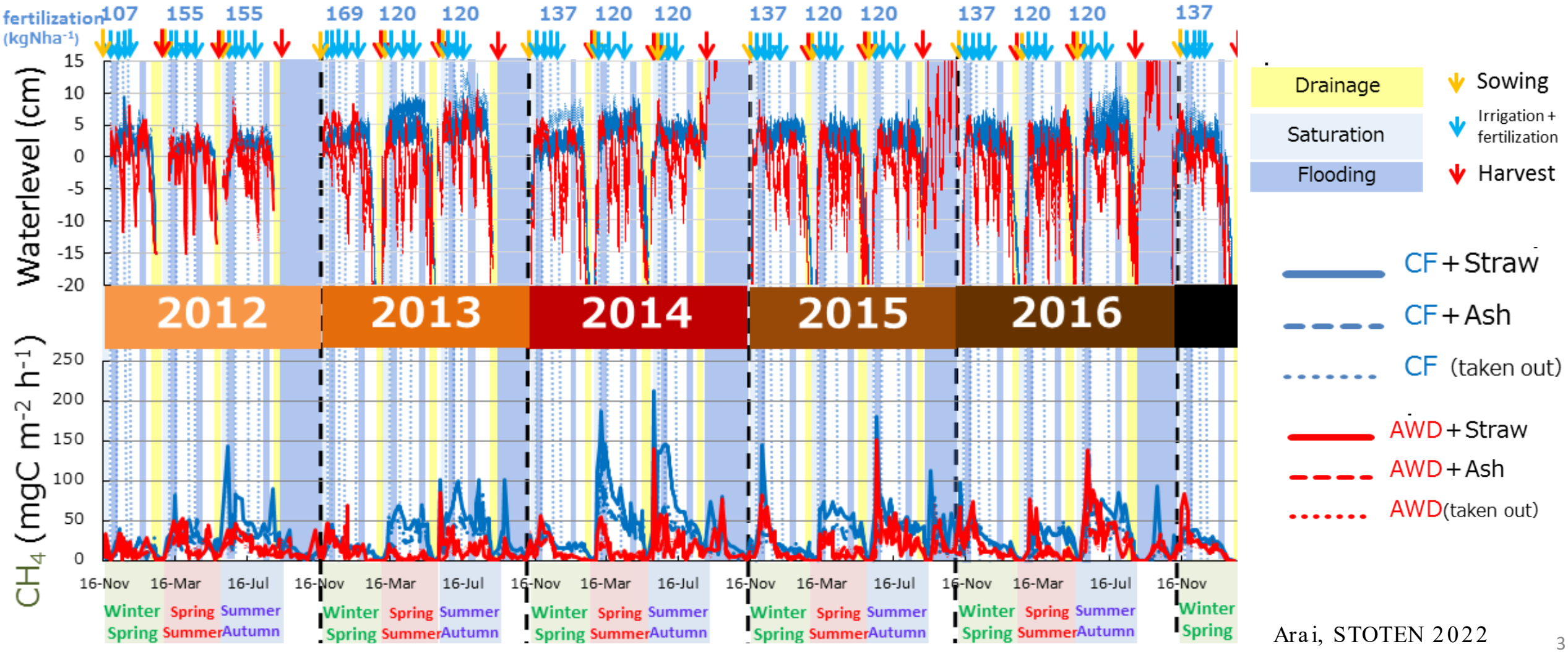




Source: CEA analysis based on: Alexandratos and Bruinsma, 2012
Jhanvi Saini and Rajan Bhatt Current Journal of Applied Science and Technology · April 2020

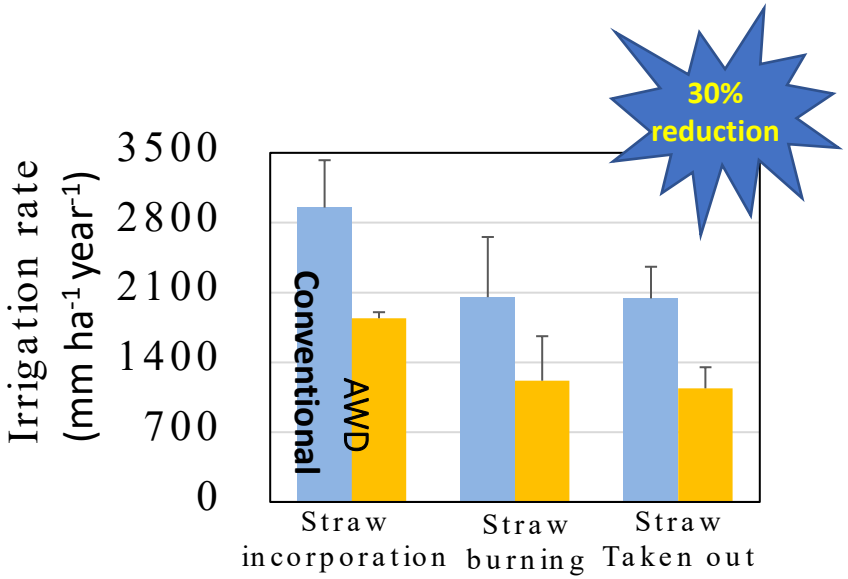
AWD has been carried out based on research works in last decades

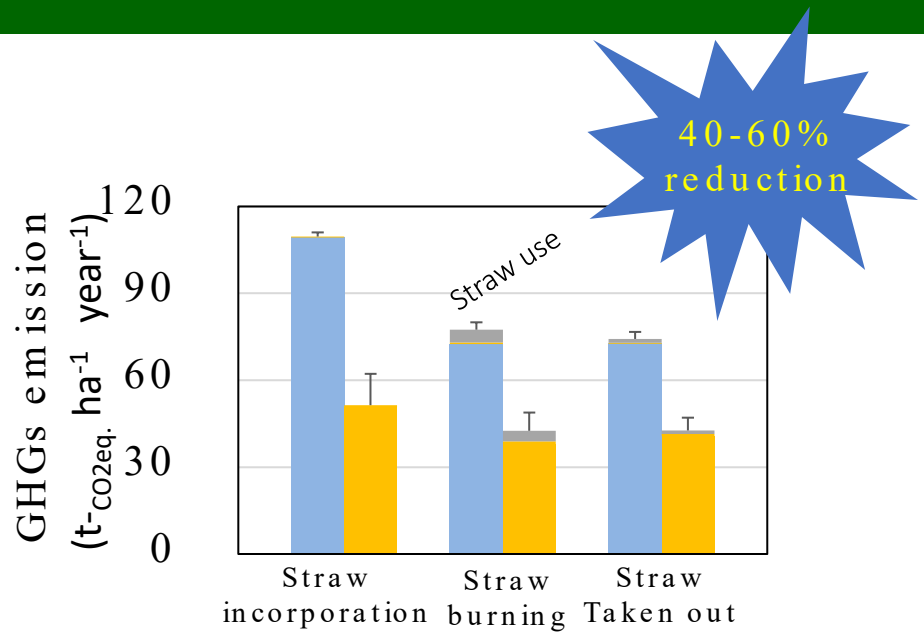
Multi-year study conducted on a farmer's fields in the Mekong Delta

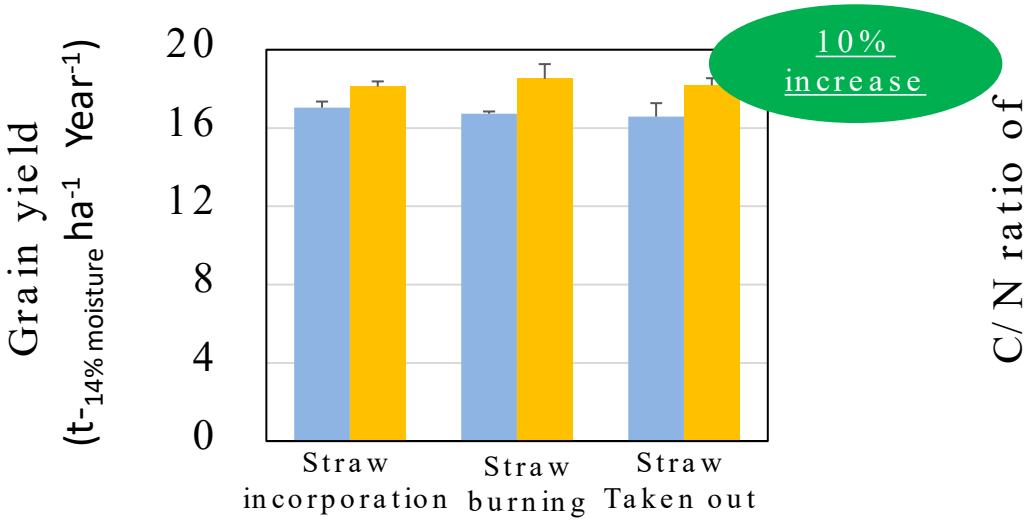


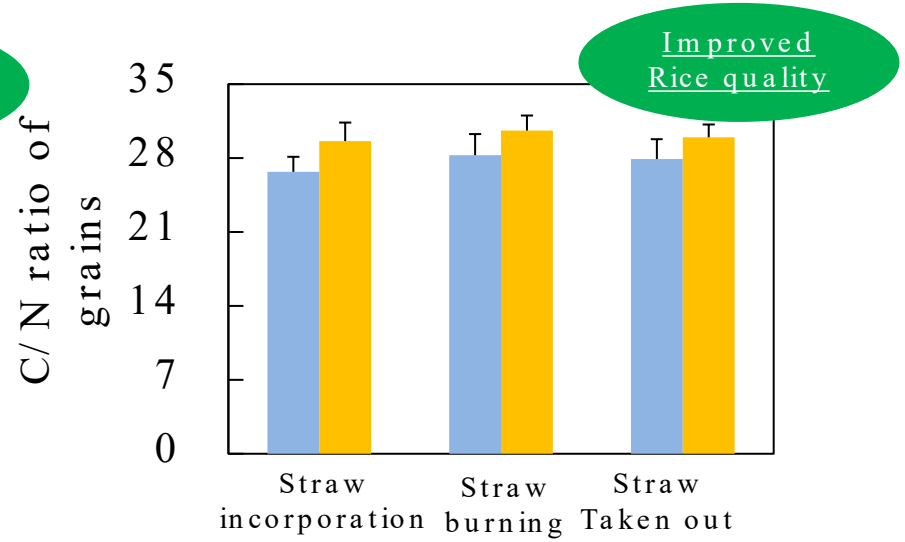
Arai, STOTEN 2022

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





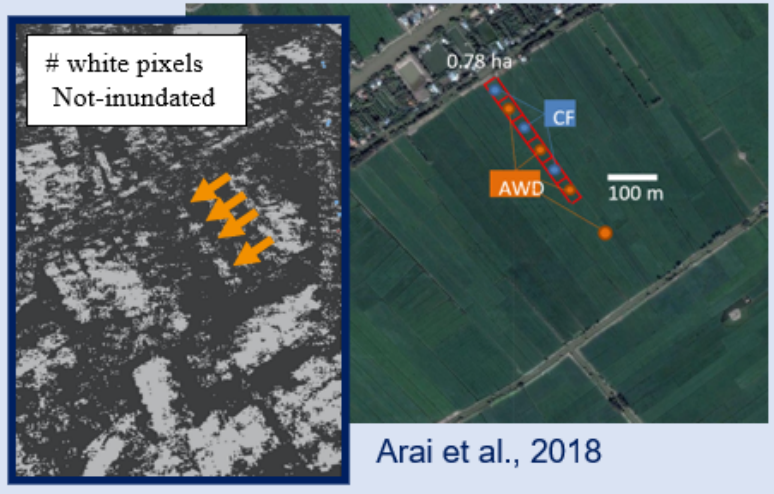




Arai et al., Springer 2022

L-SAR observation on inundation

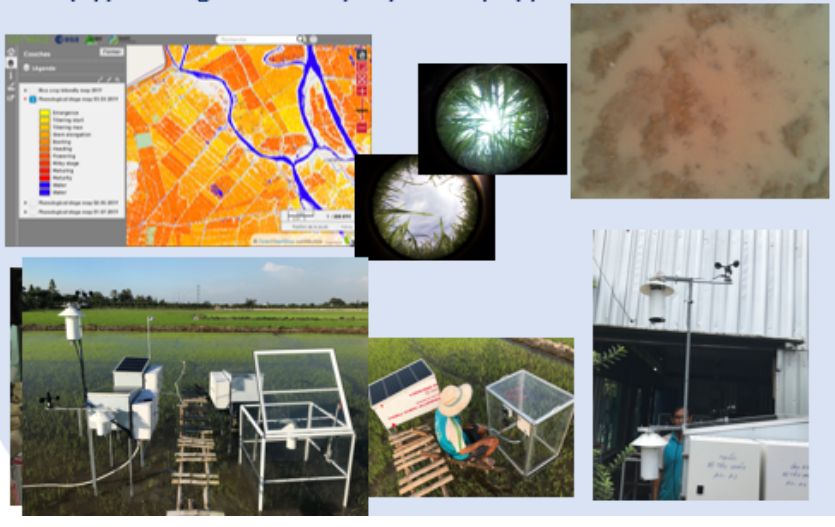
ALOS-2/4, NISAR, ROSE-L



Arai et al., 2018

GeoRice & IoT tech.

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

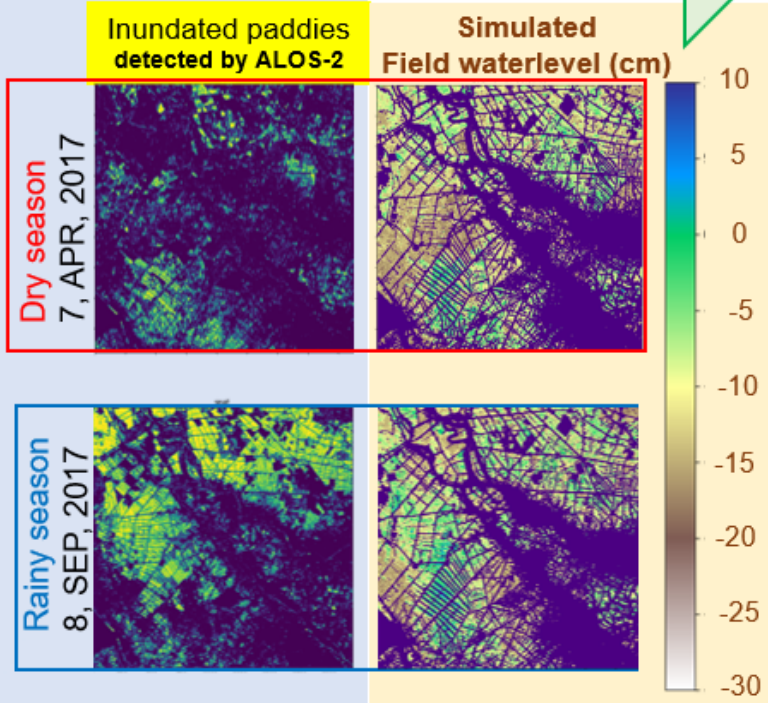


Pixel-based (50m-res.) Inversion of Daily waterlevel/GHGfluxes, rice growth/yield and Nitrogen-usage

Data quality control
Noise filtering support

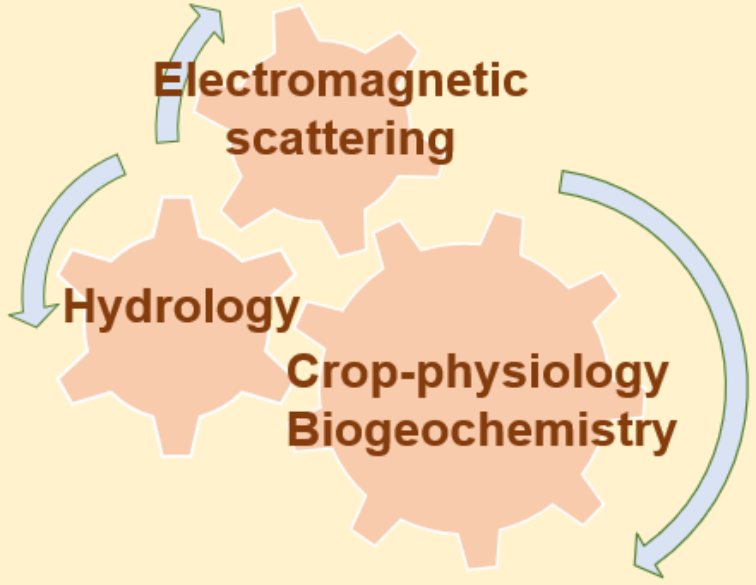
Data assimilation

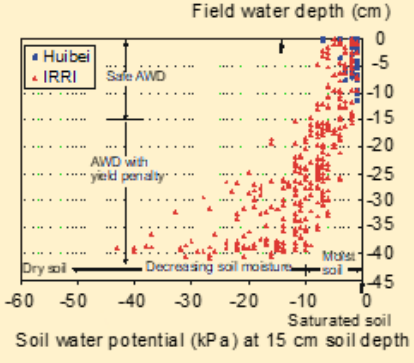
Integrative multi-parameters optimization



Cyber-LCA coupling system

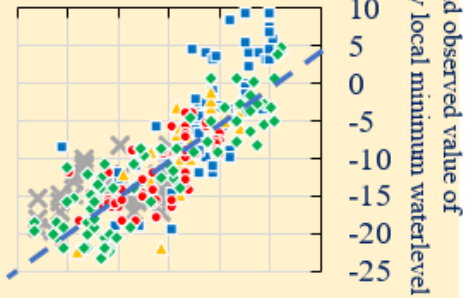
w/ high spatio-temporal resolution models





Lampayan et al., 2015

Soil-surface
Simulated values of water level (cm below soil surface)

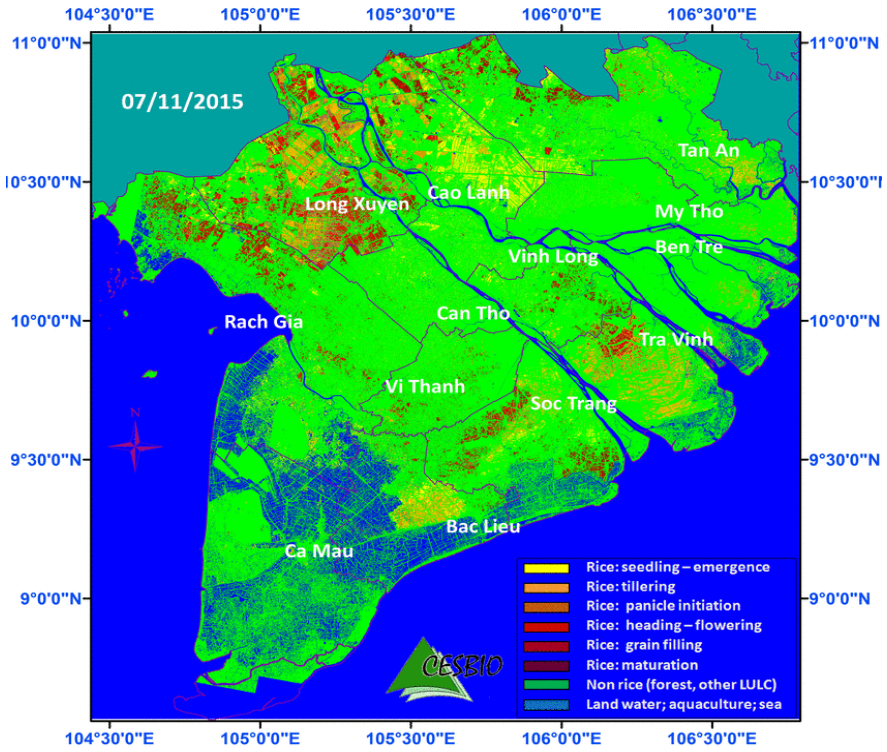


Data from 5 sites x 5 plots x 10 seasons

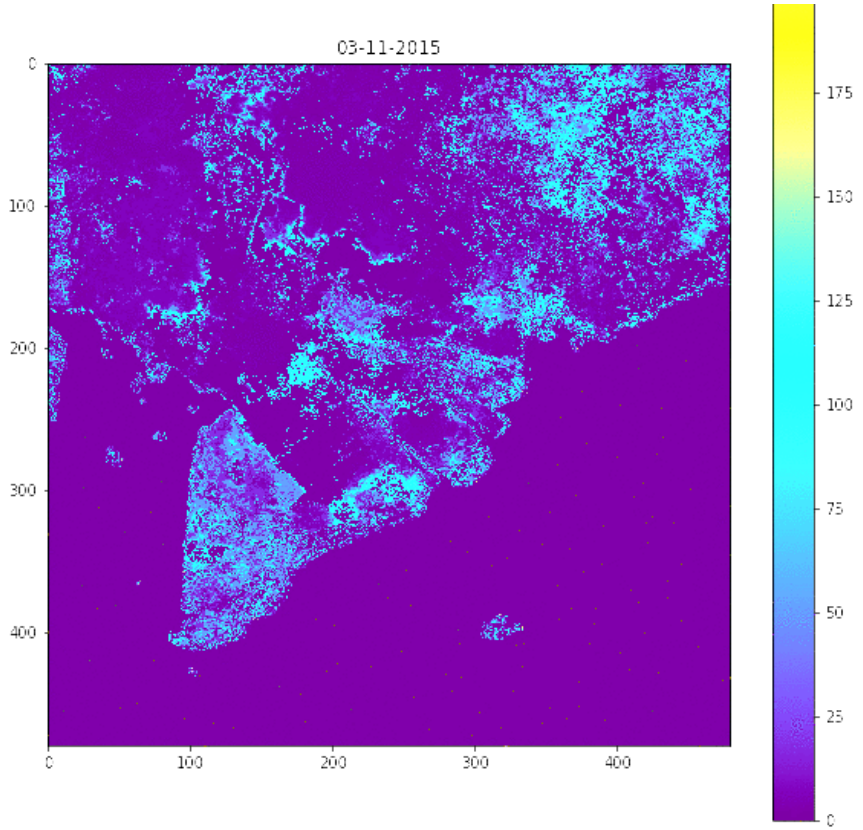
Arai et al., 2021 RSE submitted

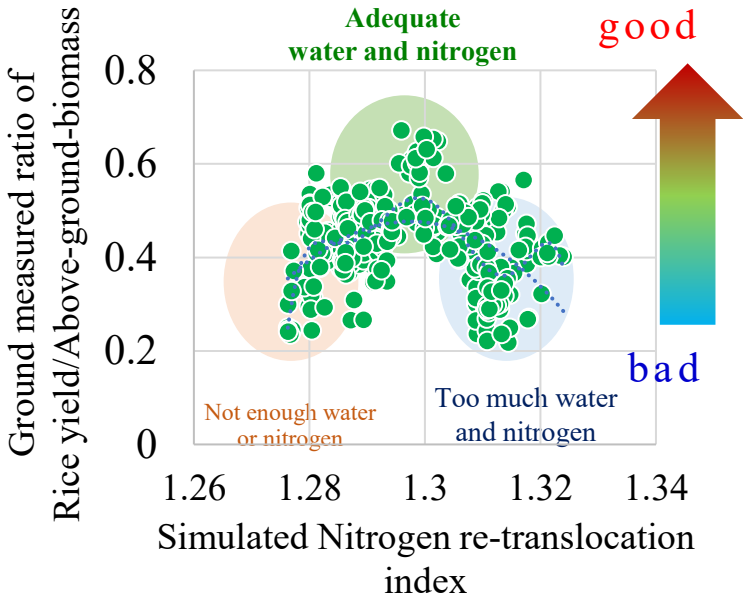
Rice phenology and satellite data pixel based simulation of CH_4 emission

Sentinel-1 to monitor rice growth



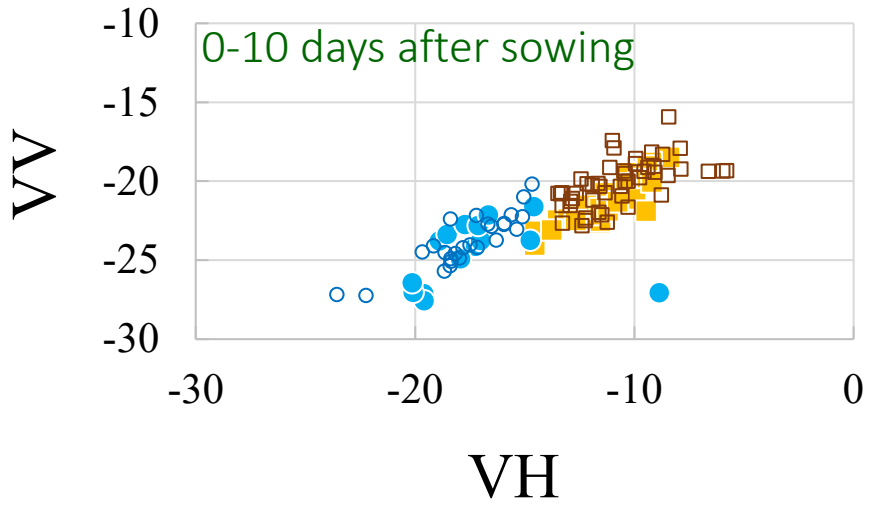
Simulated daily CH_4 fluxes (kg C km^{-2} h^{-1})

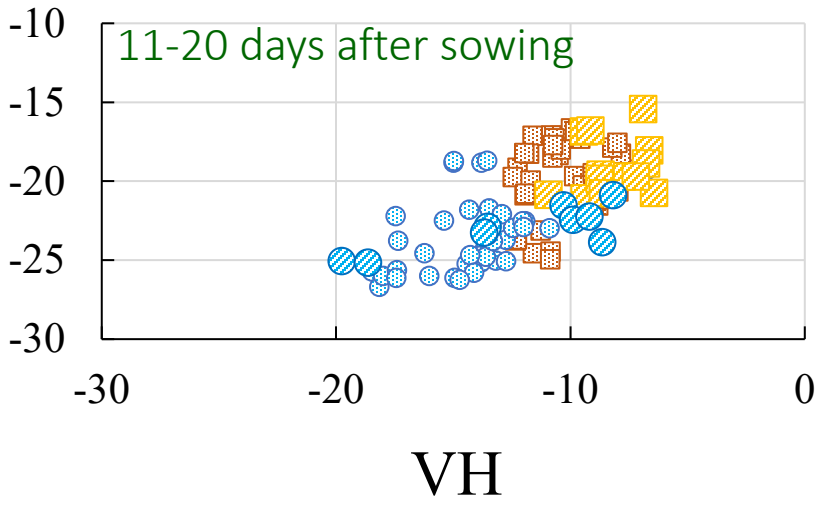


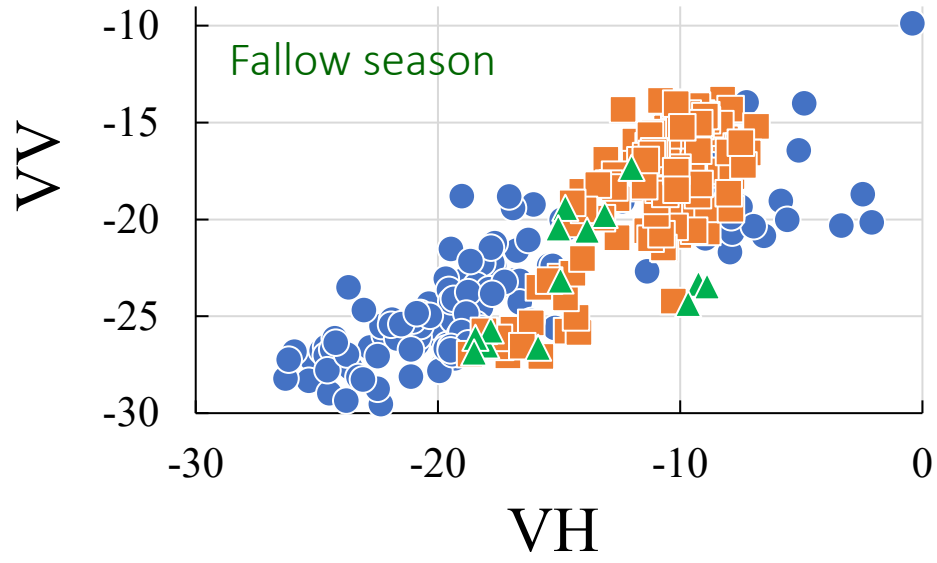


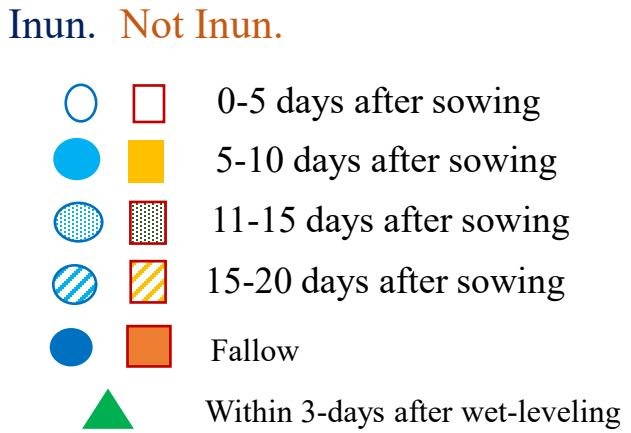
Arai et al., Springer, 2022

C-band Sentinel-1 rice monitoring
-inundation detectable at early rice growing stages-

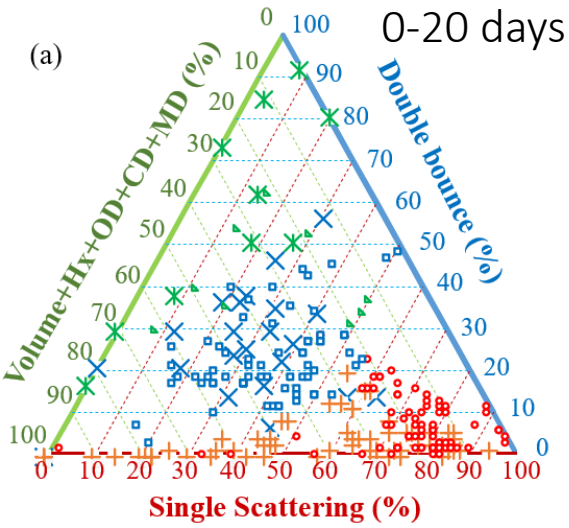




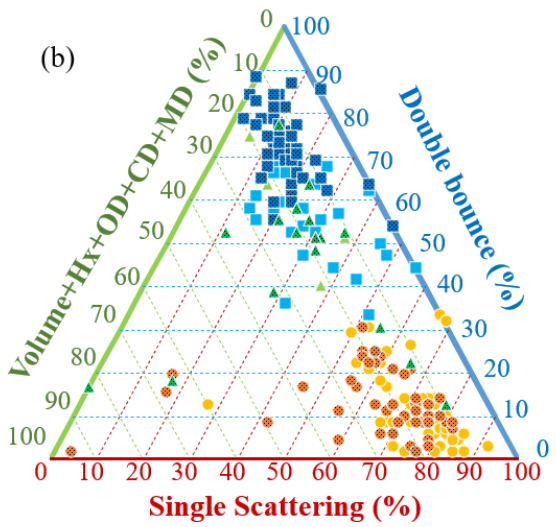




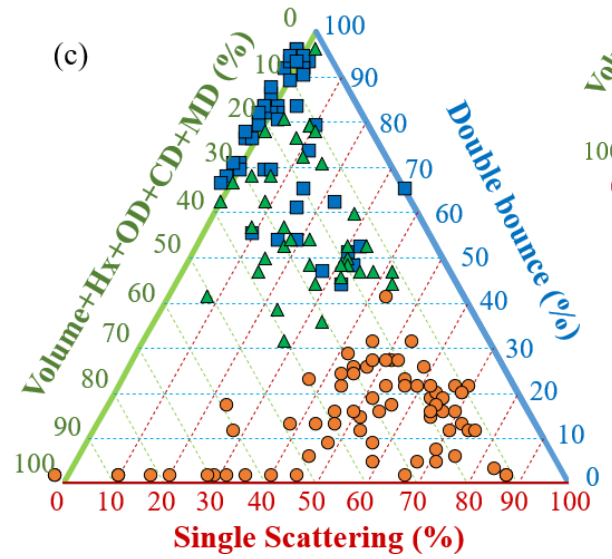
L-band PALSAR-2 rice monitoring
-inundation detectable in the whole stages-



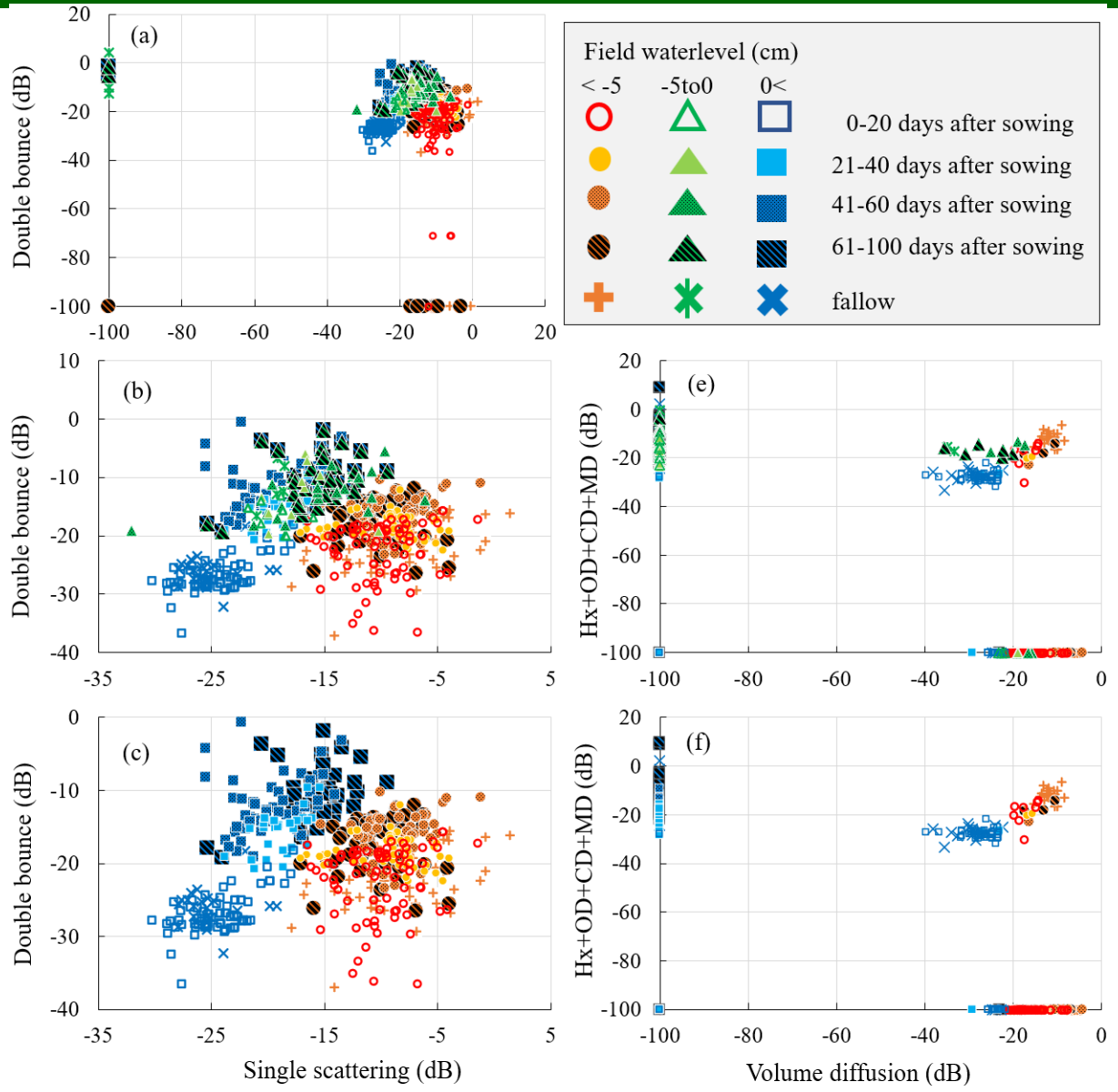
0-20 days after sowing + fallow



21-60 days after sowing

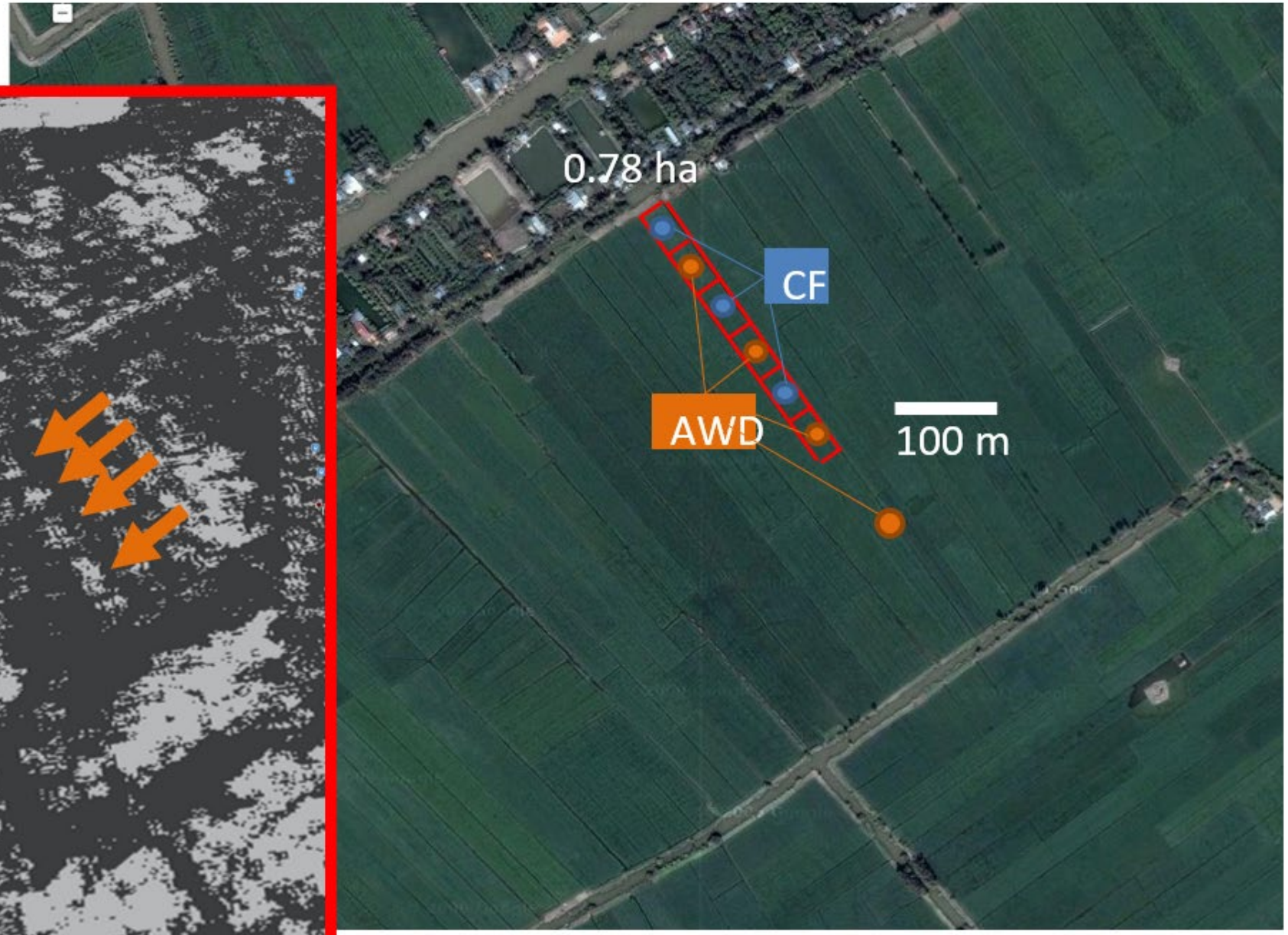


61-105 days after sowing



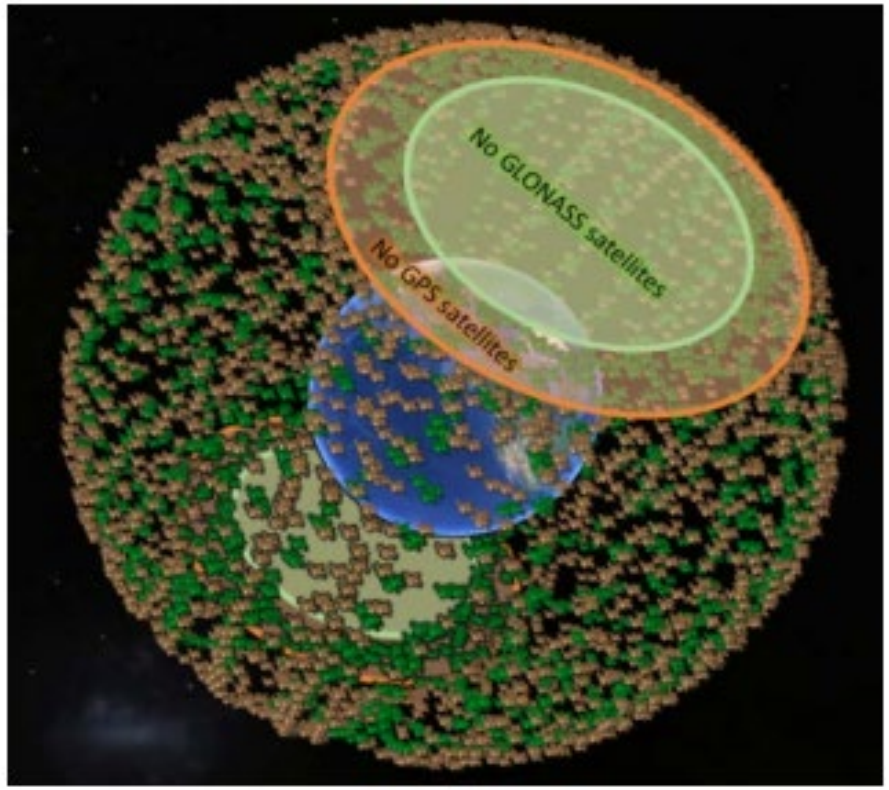
Arai et al., RSE 2022

σ^0 based inundation detection with ALOS2-HR data

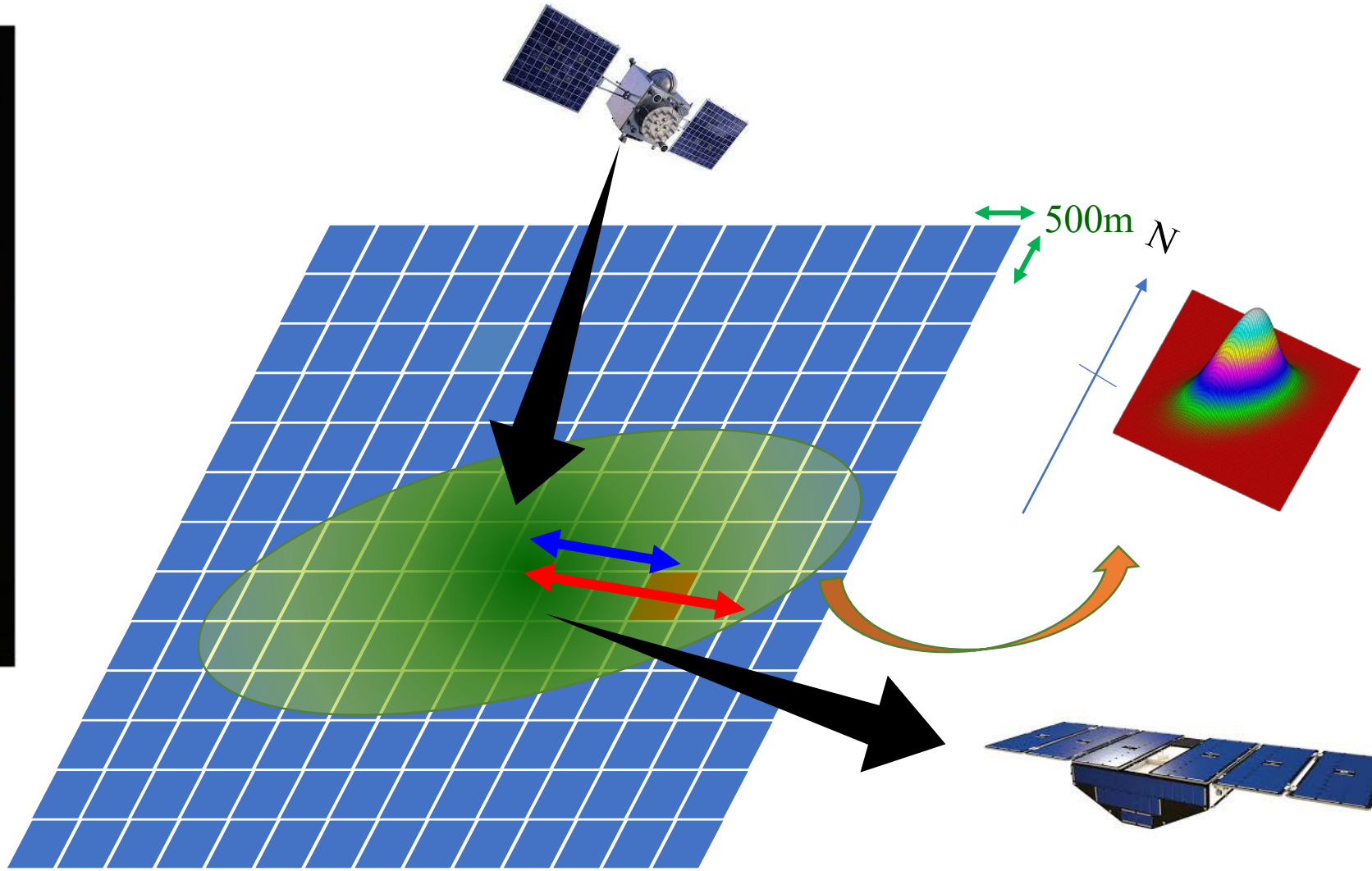


69 days after sowing, 6th May 2016

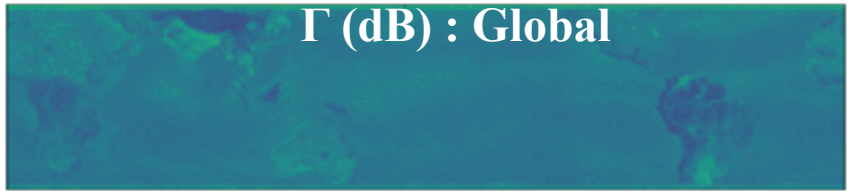
GNSS signals available for inundation detection



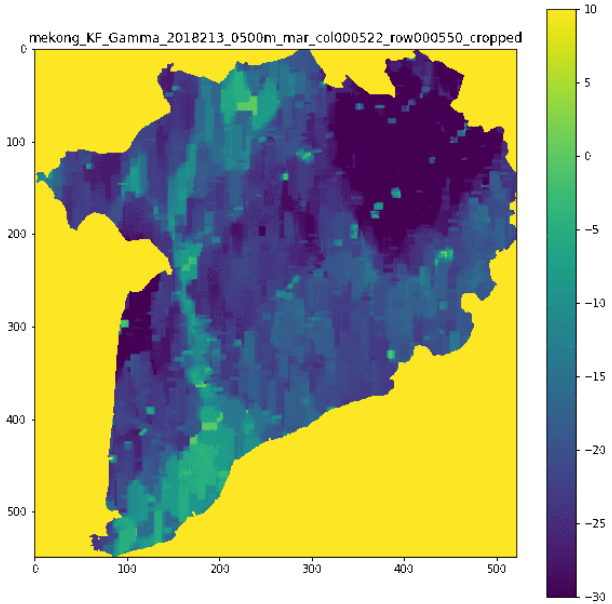
Here we can see the dense coverage of the two oldest GNSS constellations: the American GPS (orange) and the Soviet system GLONASS (green).

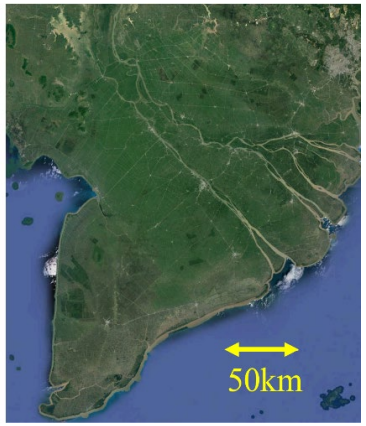


Kalman filter product (500m_res, 15-days resolution)

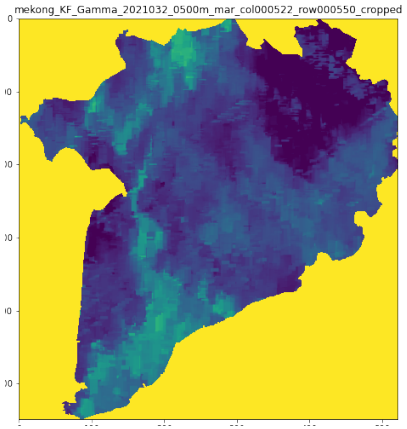


Γ (dB)

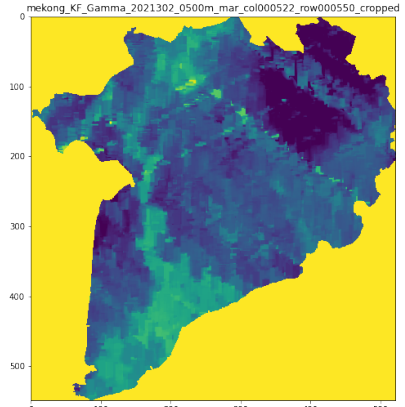


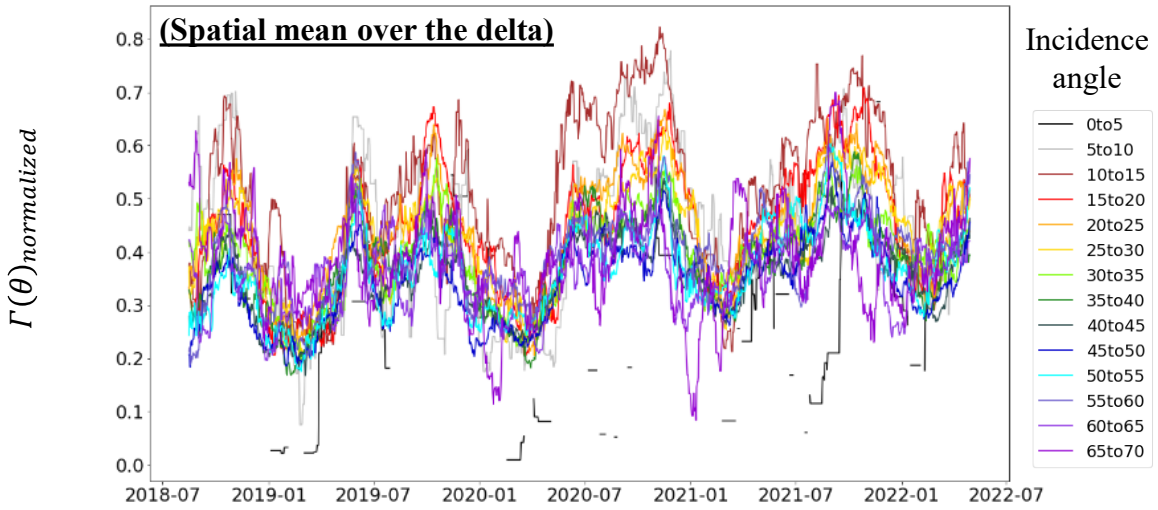


2021 **dry season**



2021 **rainy season**

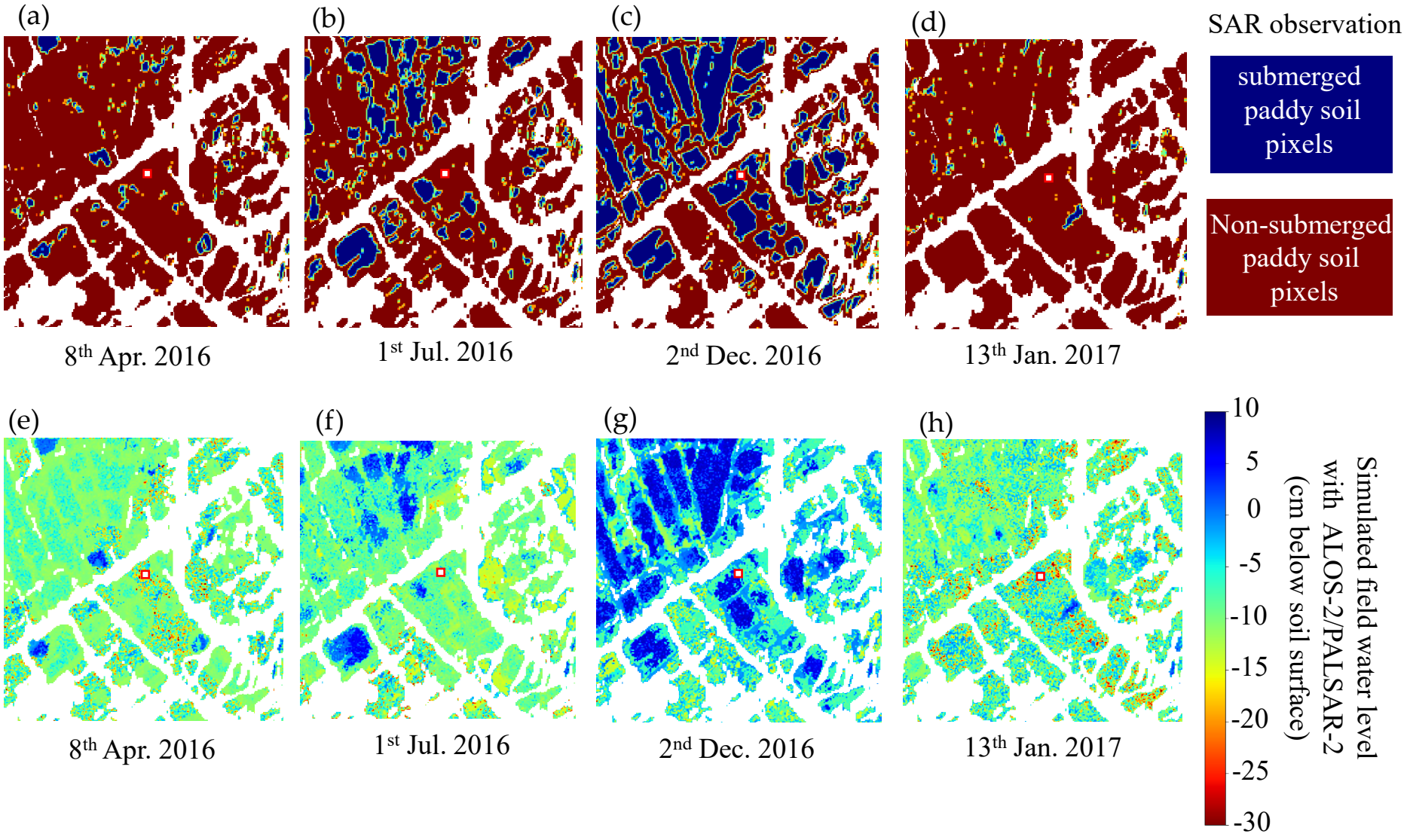




No more ad hoc parameter setting! Everything adaptive!!
We can use all specular signals ！
Spatio-temporal pattern clearly appears!

Arai et al., Remote sensing, under review

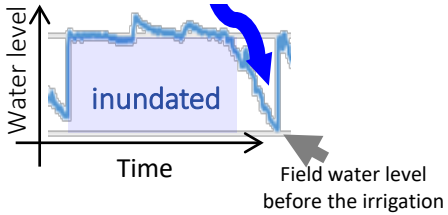
SAR data assimilation of field water level simulation
-binding cyber space and real space-

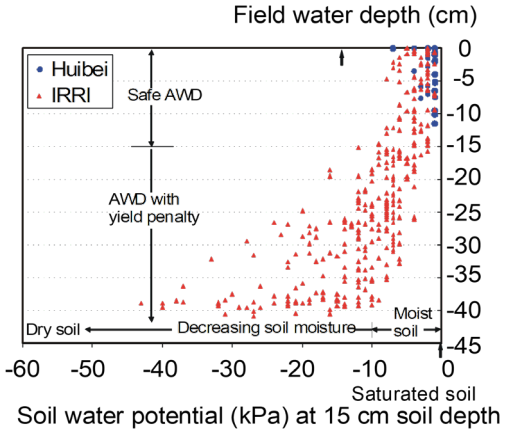


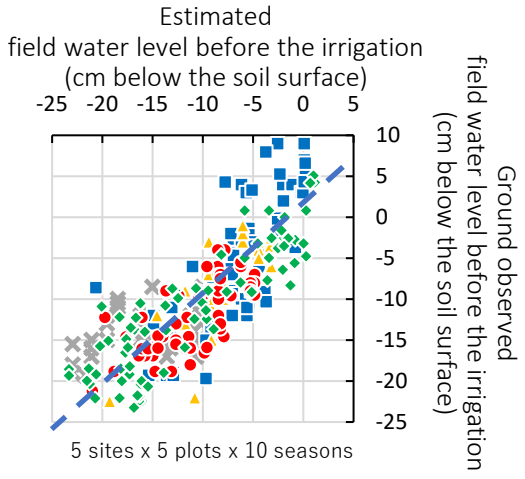
Note Lite blue: Not submerged (i.e., water level is lower than 0) Blue: submerged (i.e., water level is taller than 0)

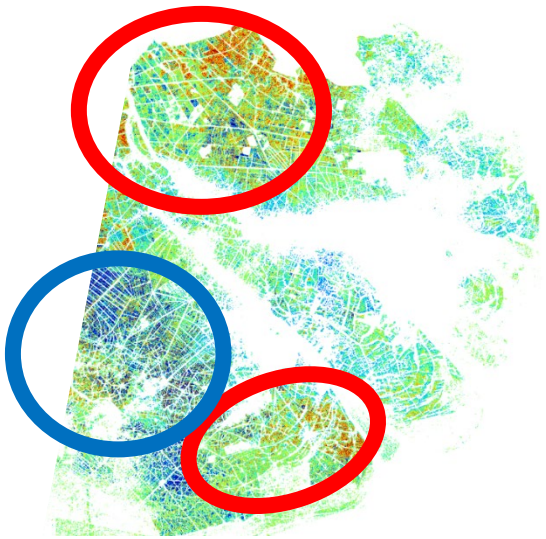
Arai et al., RSE 2022

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

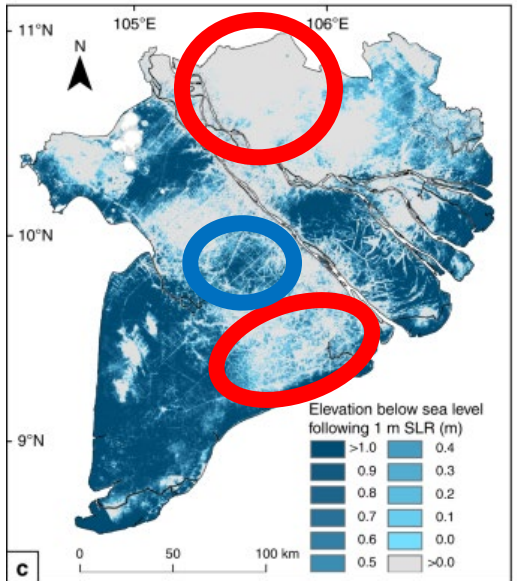


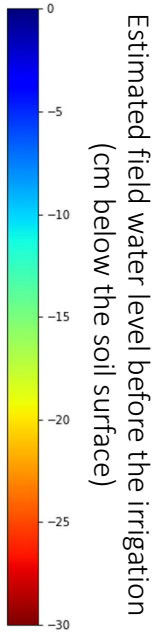


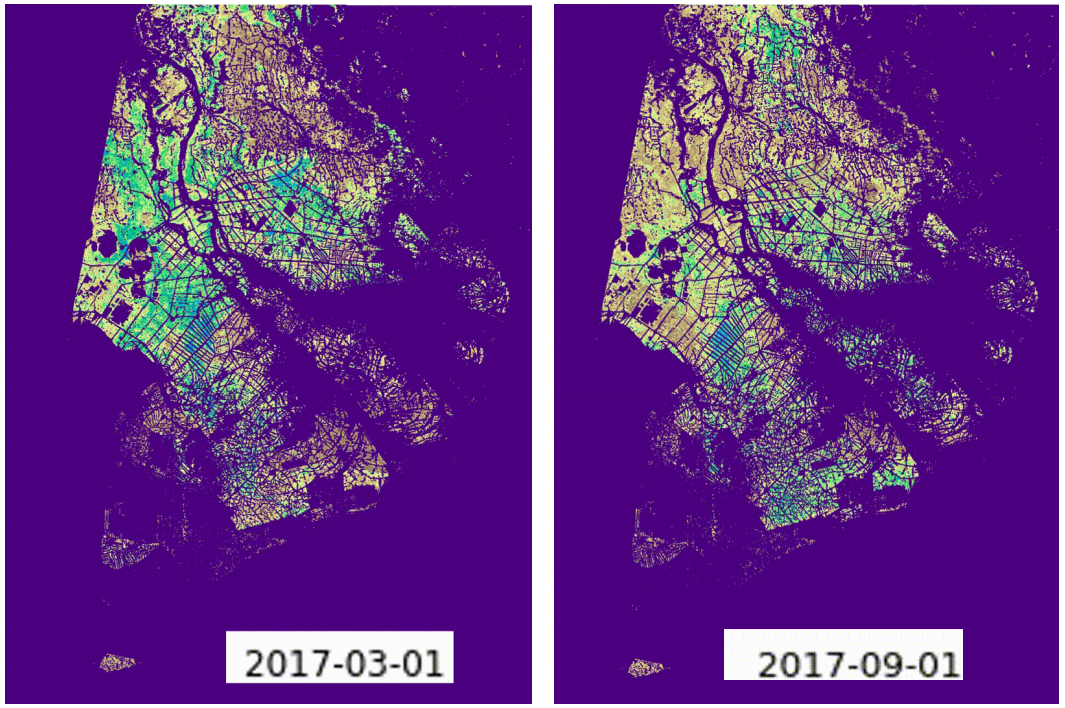




(d) 30th June, 2017

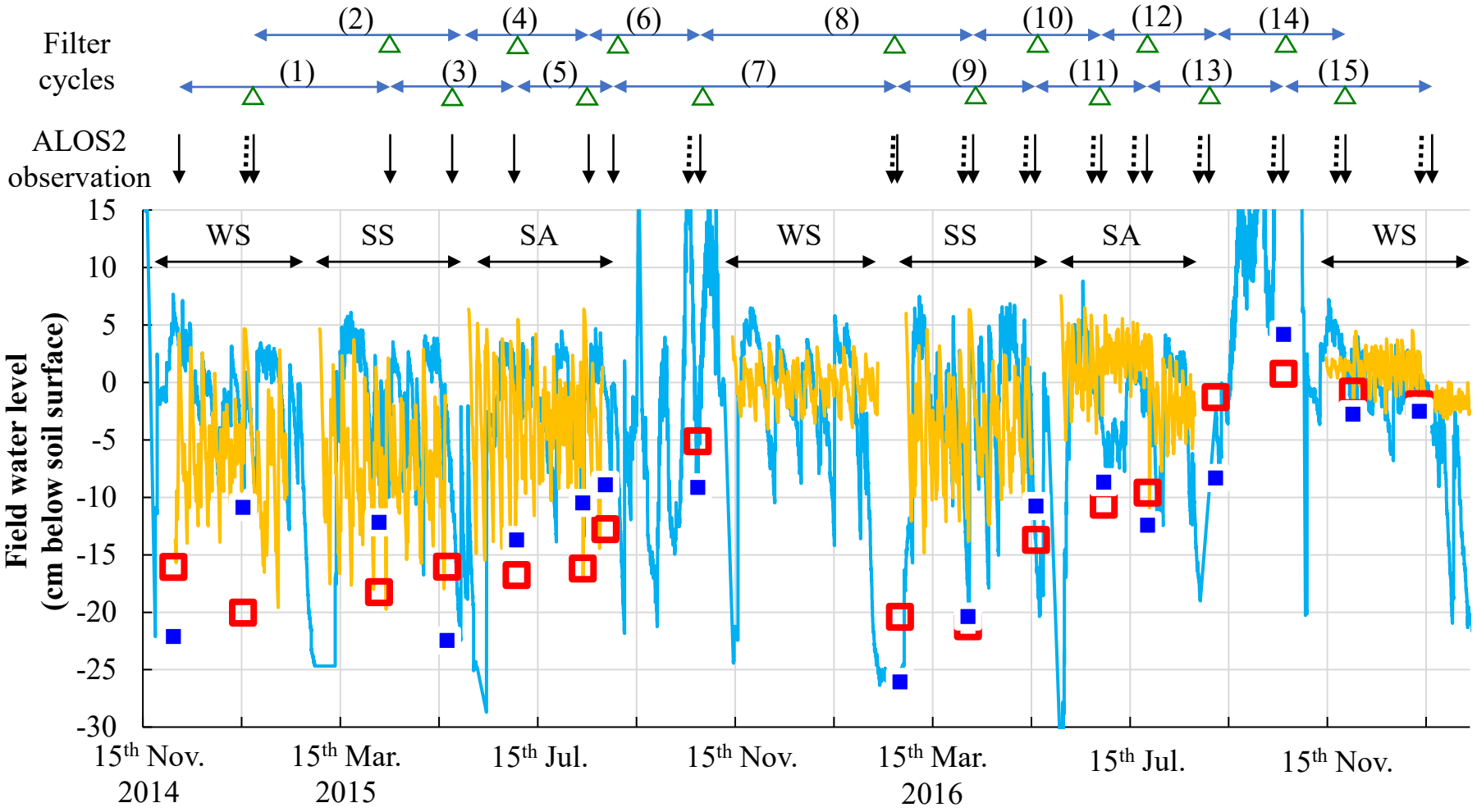


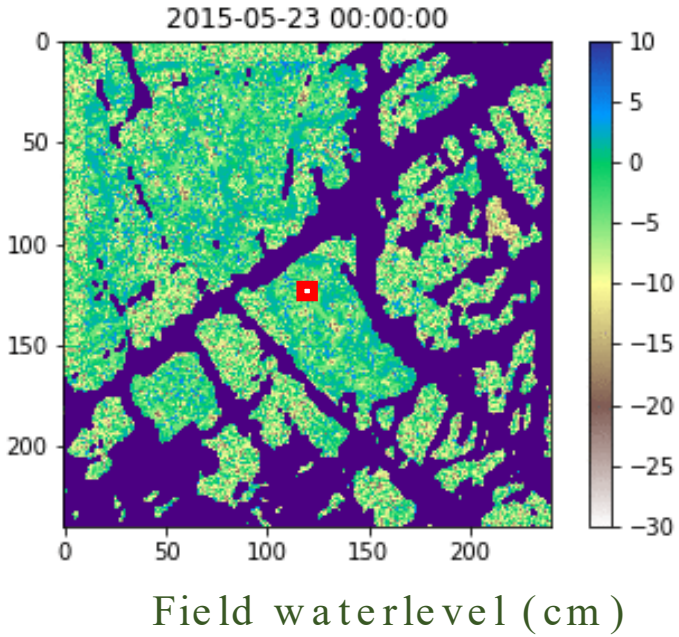




Arai et al., RSE 2022

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





Ground-observed field waterlevel

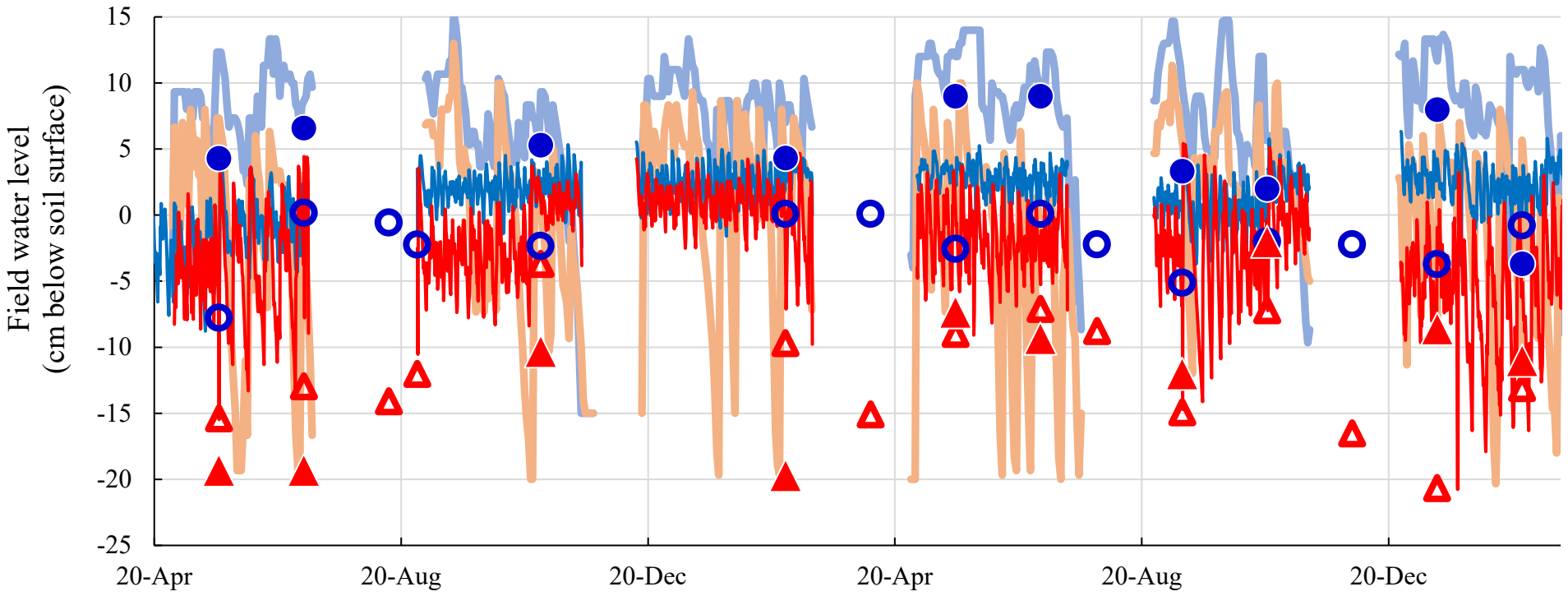
Mean values of simulated field waterlevel (4 × 4 pixel windows around the ground observation point)

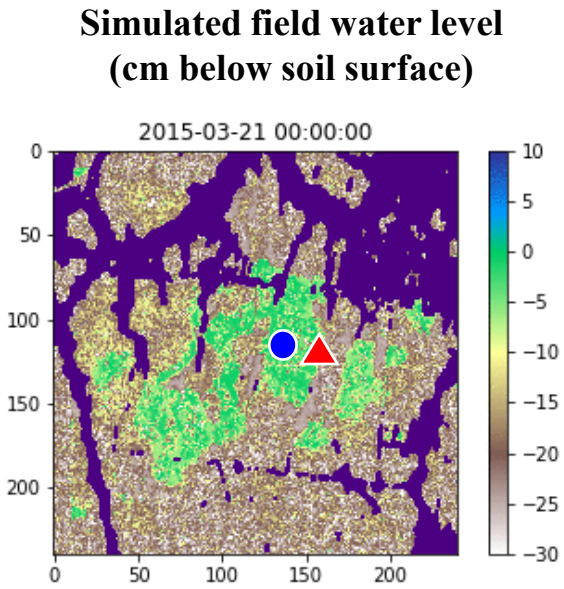
The temporally local minimum water level around the data-assimilation date ± 10days

Mean values of estimated irrigation threshold model parameter (4 × 4 pixel windows around the ground observation point)

Arai et al., RSE 2022

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





Ground-observed field waterlevel

- Continuously inundated paddy
- Paddy with intermittent drainage

The temporally local minimum 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

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

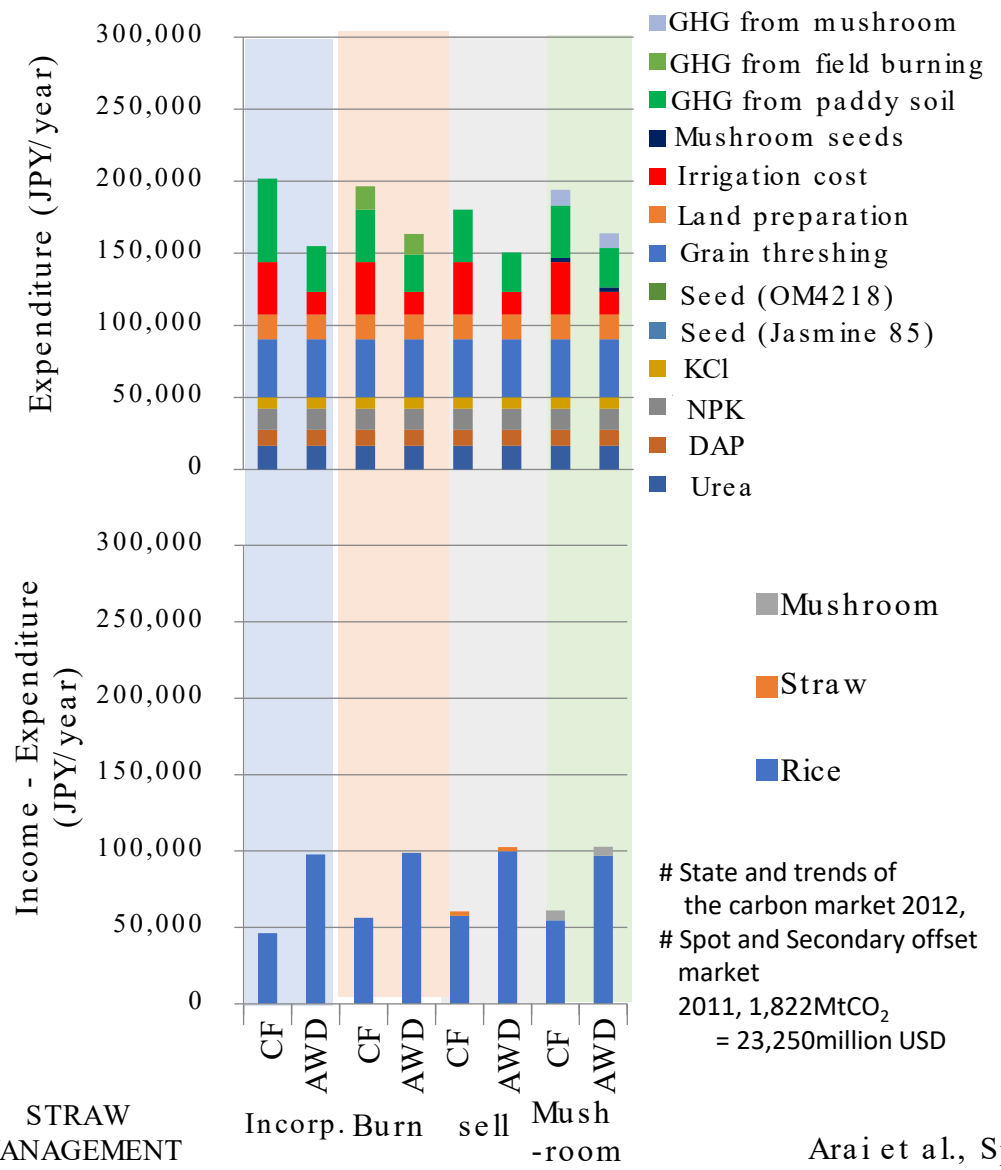
- Continuously inundated paddy
- Paddy with intermittent drainage

Arai et al., RSE 2022

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

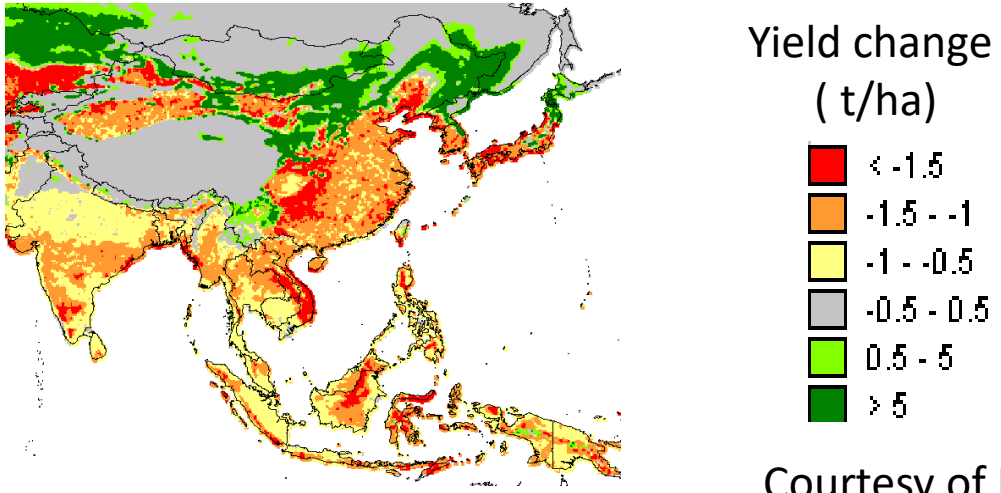
Arai et al., Springer, 2022

Adaptation for Drought and saline intrusion

Drought

- Irrigation status / soil moisture
  - SAR/GNSS-R (QZSS)
- Land surface temperature
  - Advanced Himawari Imager

Effect of 2 C warming on potential rice yield in Asia

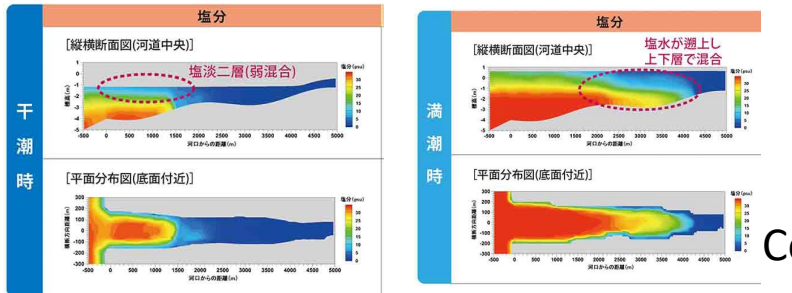


Courtesy of IRRI

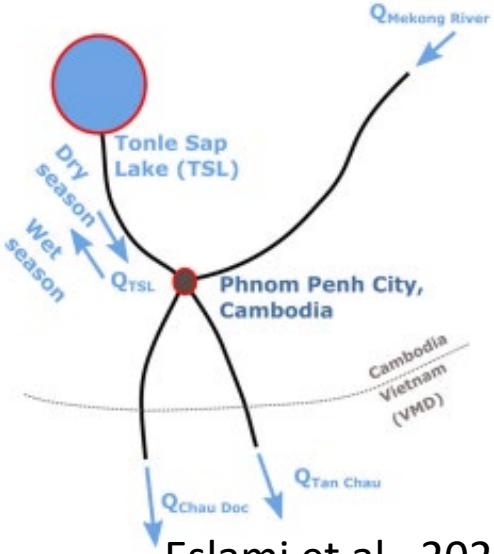
Saline intrusion

3D salt intrusion simulation coupling with crop/soil model

- bathymetry data around river mouth
- vertical profile of salt concentration in river
- ***discharge***



Courtesy of idea co. ltd



Eslami et al., 2021