Rice-planted area mapping using ALOS-2 PALSAR-2 data with machine learning over Southeast Asia

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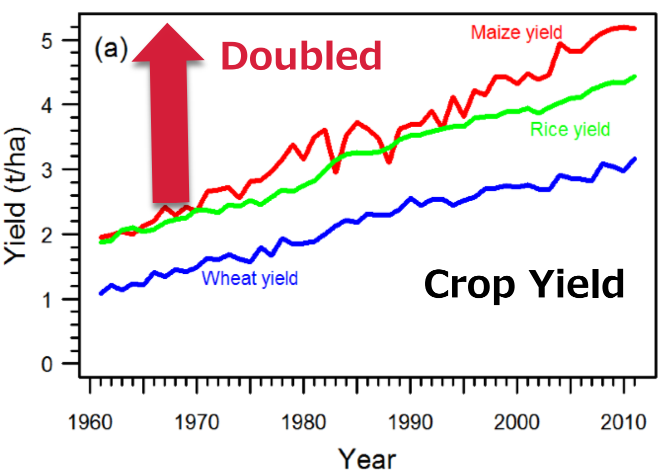
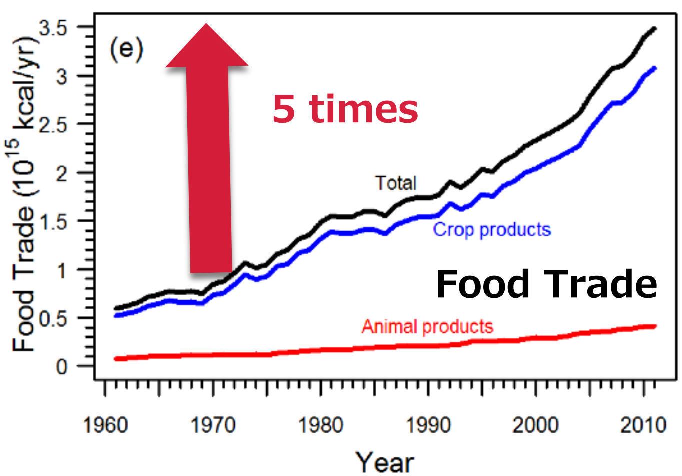
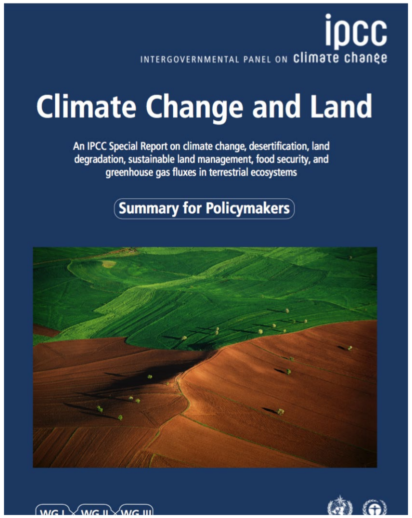
Food Security Issue as Global Agenda

- 12% of Global ice-free land surface is used as cropland (2% for irrigated).
- **Crop yield has doubled since 1961**, accompanied by greater use of nitrogen fertilizers and water resources for irrigation.
- However, **821 million people are currently undernourished,** and **need to produce about 50% more food** by 2050 to feed the increasing world population.
- **Global food trade** has increased by **around 5 times** between 1961 and 2013.
- The food system is under pressure from **non-climate stressors (population and economic growth)** and from **climate change (increase in extreme events such as drought or flood)**.





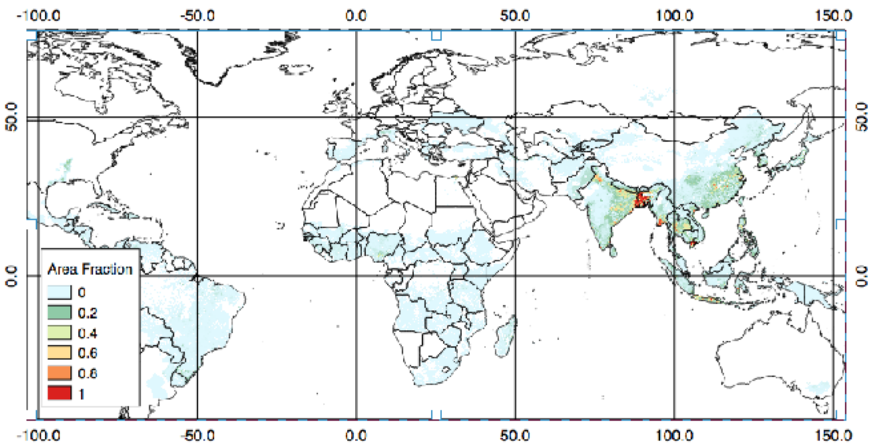


[IPCC Special Report, 2019]

Satellite-derived agriculture related information is important to improve global food security affected by non-climate stressors and climate change.

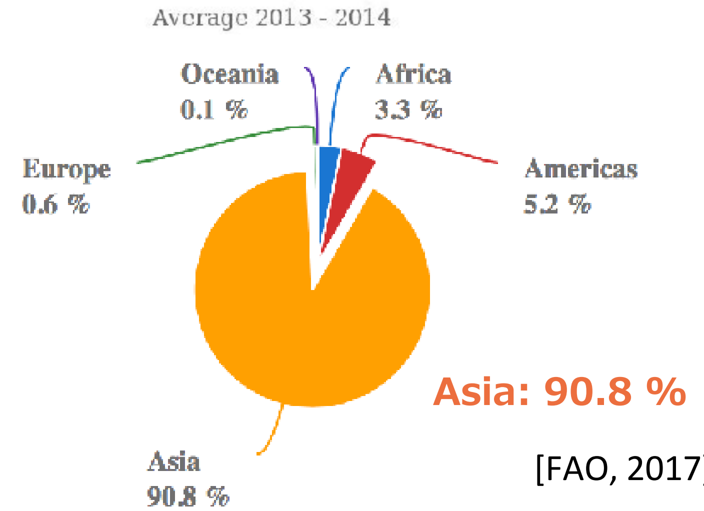
Rice Crop in Asia

Rice Cropping Area Fraction



[Monfreda, C., N. et al., 2008]

Production share of Rice, paddy by region



[FAO, 2017]

- In Asia, rice is a staple cereal crop, the continent accounts for about **90% of the global rice production and consumption.** [FAO, 2017]
- **Rice-planted area map is fundamental tool** to estimate rice production, quantify the carbon, water cycle or methane emission via paddy fields.
- **High crop intensity (double or triple cropping)** and **complicated crop calendar** [Sakamoto et al., RSE, 2006]
- **Cultivated mainly in rainy season** when the utilization of optical sensor is limited, **Synthetic Aperture Radar (SAR) is therefore a robust tool because it penetrates cloud cover** [Whitcraft et al., RSE, 2015]

Objectives

- (1) Develop **ALOS-2 PALSAR2 (L-band SAR) based rice-planted area map**,
  (2) Conduct **cross-comparison with Sentinel-1 (C-band SAR)** based map developed by **CNES/CESBiO** under the ESA's GEORICE project and **VNSC (Vietnam National Space Center)**

- This comparison study has been conducted **under the framework of VNSC's CEOS 2019 chair initiative** for the improvement of rice mapping algorithm.

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In this collaboration,

- Considering time and cost consuming issues, **JAXA** developed **ALOS-2 based rice map** using machine learning.
    - **Unsupervised classification (k-means)** result from ALOS-2 ScanSAR data : generated Training data
    - **Supervised classification(random forest)** with time-series metrics of SAR data: applied to identify rice-planted area for four countries (Cambodia, Lao PDR, Thailand, and Vietnam)

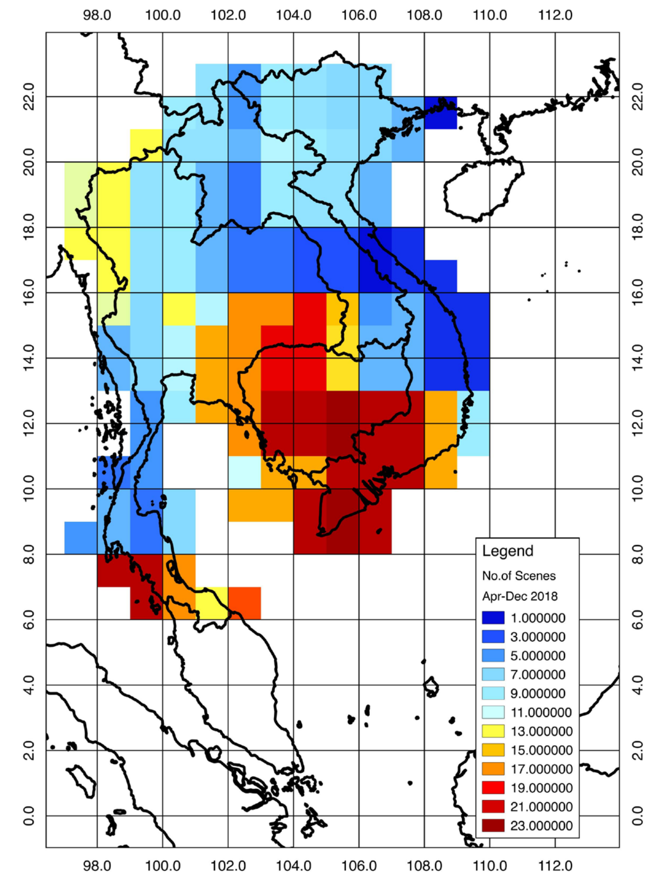
Study Area and Used Data

- **Study Area**
  - Four South-east Asian countries located in Lower Mekong River Basin including **Cambodia**, **Lao PDR**, **Thailand**, and **Vietnam**

- **Target**
  - Rainy season rice in 2018 (May to Nov)

- **Satellite Data**
  - **ALOS-2 PALSAR-2 ScanSAR Data** (L-Band, HH and HV polarization)
  - **Ortho-rectified and slope-corrected data** processed by Sigma-SAR (Shimada, 1999, 2010)
  - Tiled product is 1x1deg with 50 m grid size processed for JICA-JAXA Forest Monitoring System (JJ-FAST)

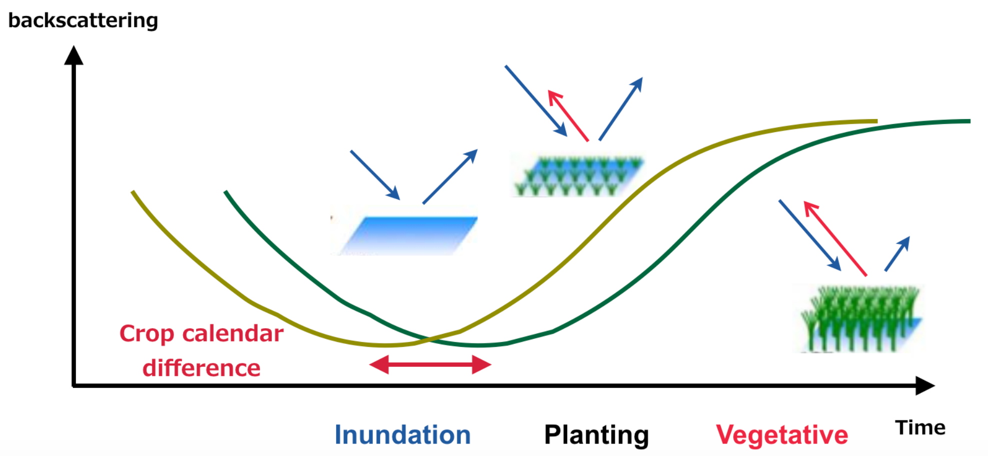
- **Ancillary Data (used for cropland masking)**
  - SERVIR Mekong Land Cover Map https://www.landcovermapping.org/en/landcover



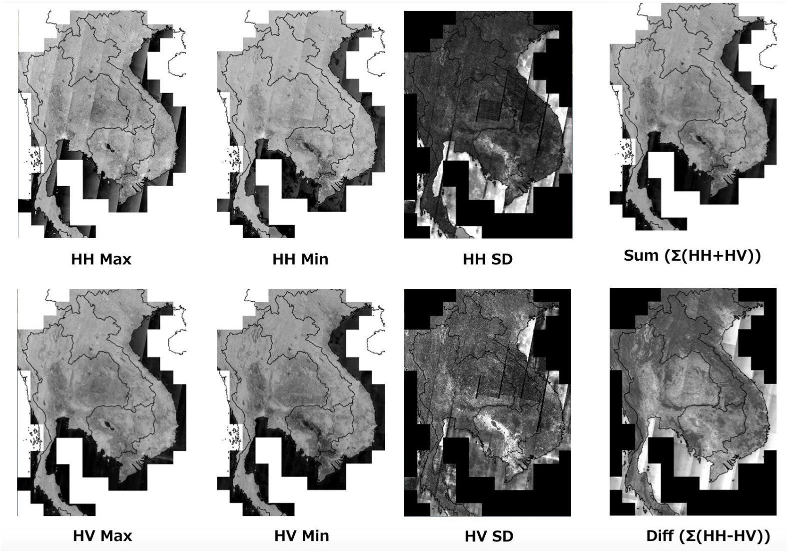
The number of ALOS-2 ScanSAR observations for used tiles (Apr-Dec, 2018)

SAR time-series metrics used for the classification

- **Rice cropping phenology is highly variable in the Tropical region** including Southeast Asia because of adequate temperature and solar radiation.
- **In order to compensate for the phenological variations**, **time-series metrics (e.g. max, min, ave etc.) calculated within the pre-defined cropping season** were used for the features of classification using machine learning.



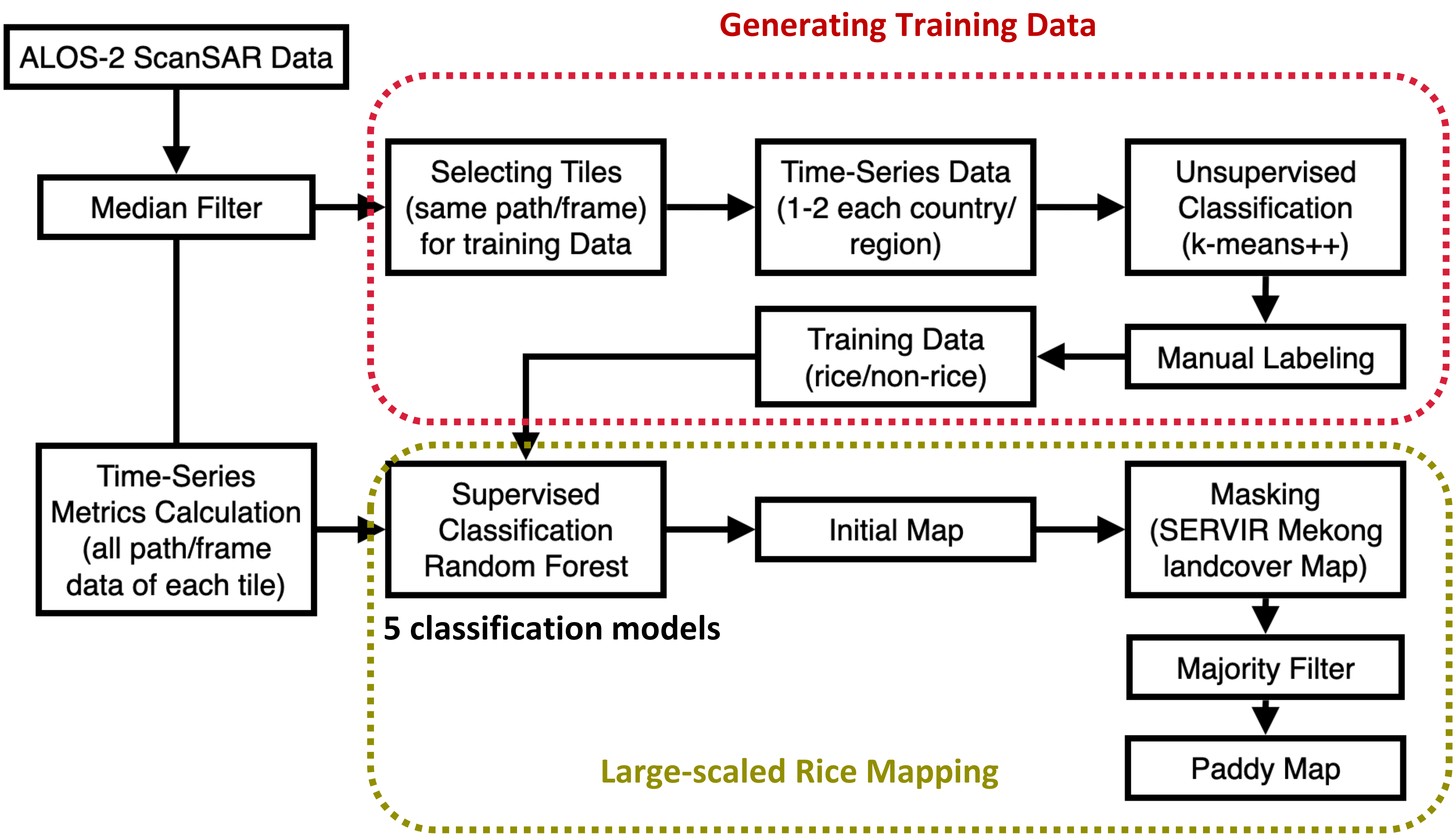
Variable timings of planting by region within rainy season



Examples of time-series metrics calculated from time-series ALOS-2 ScanSAR data

Overview of the Rice Mapping Algorithm

- Utilize both **unsupervised classification (k-means++)** and **supervised classification (Random Forest).**
- Unsupervised classification result with manual labeling was used for the input training data for supervised classification (random forest).



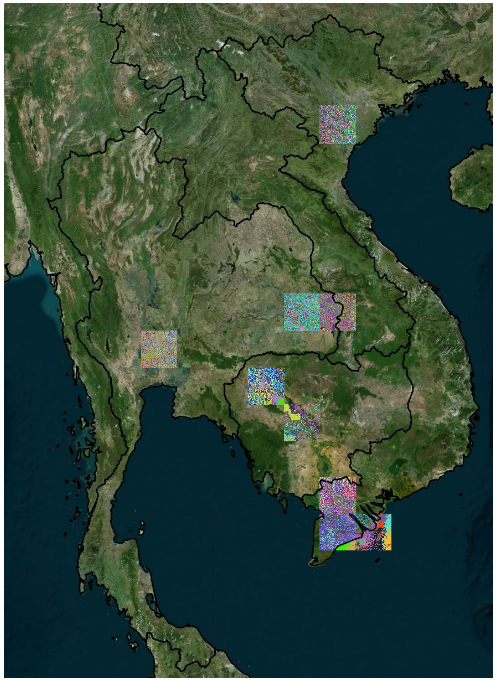
Classification Model Evaluation

- Training data were randomly sampled (10,000 pixels from each selected tile)
- **Five Random Forest classification models** were tuned for each region (South Vietnam, North Vietnam, Thailand, Cambodia, Lao PDR).
- **All countries/regions except Thailand showed total accuracy more than 0.91**, Thailand showed relatively low accuracy and this would be mainly due to different cropping system (irrigation/rainfed) between central and northeast region.

Overall accuracy for random forest classifier of each region

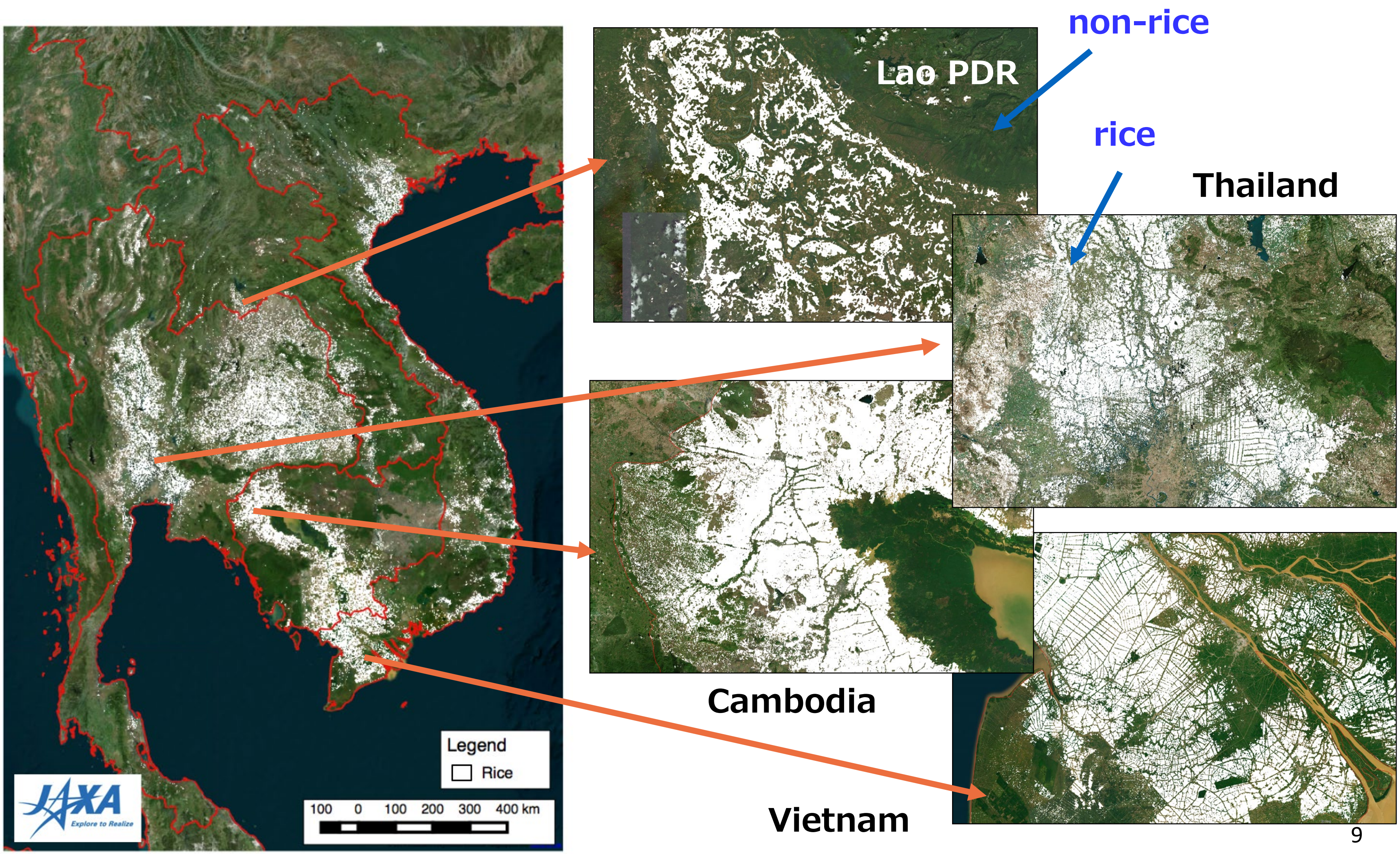
Country/Region	n (modeling) pixels	n (test) pixels	**Overall Accuracy**
Vietnam/South	5,000	5,000	**0.911**
Vietnam/Others	5,000	5,000	**0.986**
Thailand	10,000	10,000	**0.799**
Cambodia	10,000	10,000	**0.915**
Laos PDR	5,000	5,000	**0.929**

Selected tiles for training data



Output: Rice-planted area map of rainy season rice in 2018

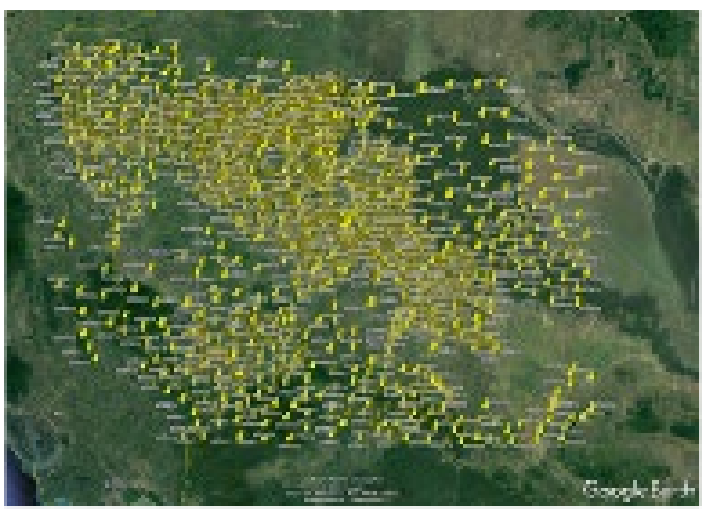
- Rice-planted area map(ALOS-2) of rainy season in 2018 for Lower Mekong river countries (Cambodia, Lao PDR, Thailand, and Vietnam).



Mapping Accuracy Assessment in Cambodia

Validation result

- **Total accuracy is 0.87 with kappa coefficient of 0.74**
  - **Validation was conducted by the visual interpretation** using Very High Resolution optical satellite data **on Google Earth** around Battambang province, Cambodia.
  - 2,131 points were manually sampled and classify rice or non rice.
- Overestimation of rice planted area(“204” in the table) would be mainly due to the limitation of spatial resolution since many non-rice points surround by paddy rice were mis-classified as rice-planted area.



Comparison of classification result and the validation data

		validation data		
		rice	non-rice	Total
classification result	rice	872	204	1,076
	non-rice	77	978	1,055
	Total	949	1,182	2,131

Contribution through Cross-comparison with Sentinel-1 Derived Rice Map

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- Then, resulted ALOS-2 based rice map was **compared with other rice maps developed by Vietnam National Space Center(VNSC) and CNES/CESBiO** under the collaboration of the **VNSC's 2019 CEOS chair initiative** on rice monitoring.
  - **CNES/CESBiO** developed rice map using **Sentinal-1** data for same four countries as JAXA, under **ESA GEORICE project**.
  - **VNSC** developed rice map for Vietnam using **Sentinal-1** data.

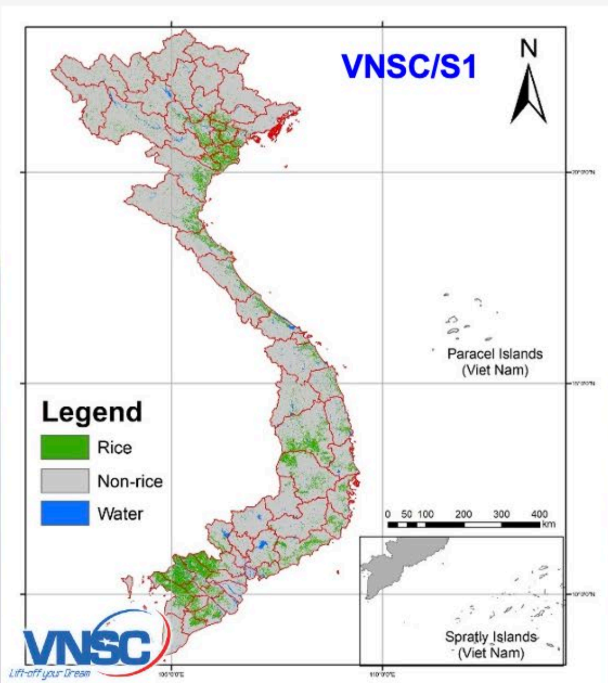
- Target: 2018 Rainy season rice

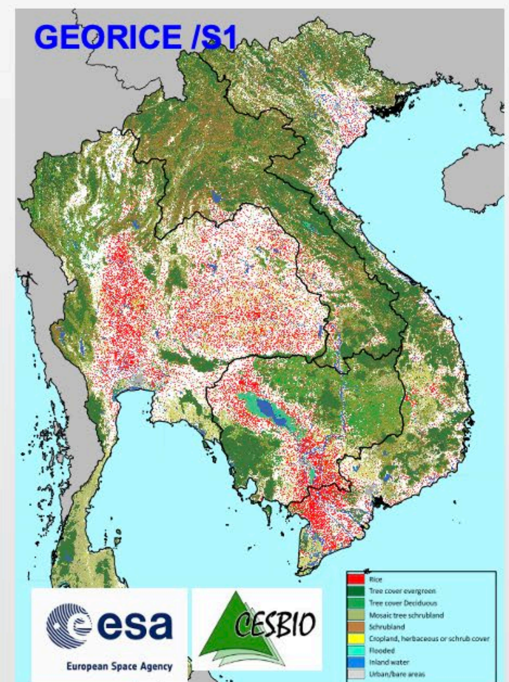
Rice monitoring - Achievements

Work in progress: Cross comparison among rice maps of Mekong region by VNSC (using S1), JAXA (ALOS-2) and CESBIO (S1) in cooperation with respective countries (space agencies and ministries of agriculture) under APRSAF SAFE and other regional framework.

Asia-RiCE Crop Estimation and Monitoring

Images derived from different algorithms





Around Mekong-river basin

[Dr. Nguyen Lam Dao, VNSC, 2019]

Comparison result between ALOS-2 and Sentinel-1 based Map

- Compared with Sentinel-1 based rice map developed by CNES/CESBiO under the ESA's GEORICE project
- White parts indicates the area where both JAXA and CESBiO identified as rice-planted area.
- Comparison results by the visual interpretation showed **good consistency between these products by visual interpretation**.
- **Further quantitative comparison or verification using in-situ data or national statistics**, as well as application to other regions, seasons and years, is necessary to identify the effect of differences in band frequency (C/L) or algorithms for **the improvement of mapping algorithm including integrated use of C/L band**.

- **White: both**
- **Blue: only JAXA**
- **Red: only CESBiO**

Conclusions

- This research **proposed to the rice mapping algorithm utilizing both unsupervised (k-means++) and supervised classification (random forest) result** by using time series ALOS-2 PALSAR-2 data.

- The developed rice-planted area map over Lower Mekong Basin showed **high accuracy for the most country/regions**.

- **Cross-comparison with Sentinel-1 based product** developed by VNSC and CNES/CESBiO has been done and confirmed **good consistency by visual interpretation** between these products, however, **further quantitative cross-comparison or validation efforts would be needed for the improvement of mapping algorithm** including integrated use of C/L band.

- As further research, rice mapping by **fusing L-band (e.g. ALOS-2/4 or NISAR) and C-band (e.g. Sentinel-1) data would be promising way to improve the product accuracy** since large amount of data and inherent information derived from C/L-band can be utilized.

Acknowledgement

- We would like to thank **Dr. Thuy Le Toan (CNES/CESBiO)** and **Dr. Nguyen Lam Dao (VNSC)** for sharing Sentinel-1 based rice map covering the Lower Mekong River Region under the framework of VNSC's CEOS Chair Initiative 2019.

Thank you very much for your attention.