International Meeting on Air Pollution in Asia – Inventories, Monitoring and Mitigation,

Hanoi, February 1-3rd, 2023

Monitoring rice paddies and methane emission in the Mekong Delta, Vietnam

Lam Dao Nguyen, Hoang Phi Phung, Nguyen Kim Thanh

HCMC Space Technology Application Center (STAC) – VNSC/VAST

Contents

Remote Sensing at VNSC

- State level research projects in recent years:
  - SAR applications (oil spill, forest monitoring, flood monitoring, 3D mapping)
  - Rice monitoring in the Mekong Delta and Red River Delta (VNRice)
  - Potential of solar energy
  - Environment of Ba river basin.
- Rice research projects (International collaboration):
  - 2019 CEOS Chair Initiatives
  - GEO-AWS EO cloud credits programme: Monitoring rice paddy and flood in the Lower Mekong Basin.
  - GEORice
  - VietSCO (Space Climate Observatory, CNES)
  - SAFE/APRSAF
  - Etc.

Rice Monitoring at VNSC

Asia-RiCE Technical Demonstrator Site –
An Giang & Mekong Delta, Vietnam (from 2013 -)

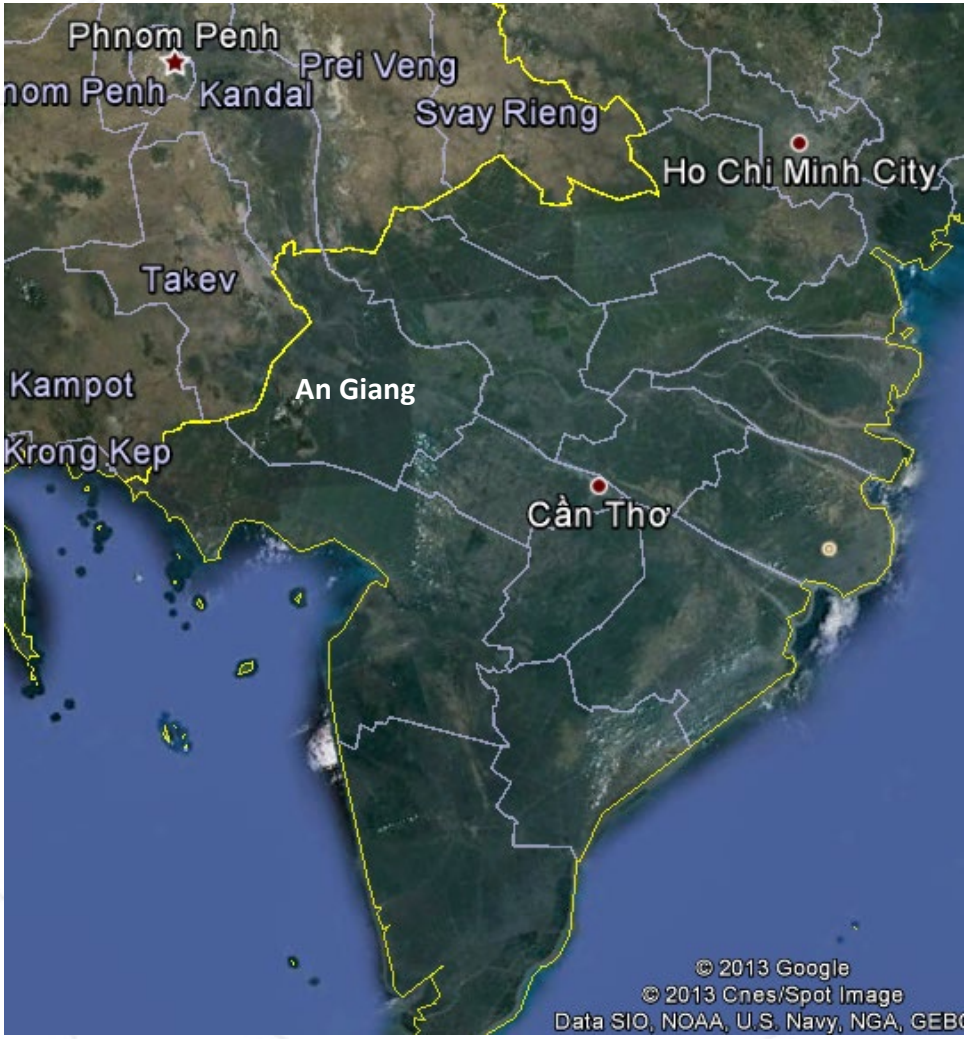
SAR data used for rice monitoring:

Before 2013:

- ERS-2, ENVISAT ASAR, TerraSAR-X SM

After 2013:

- COSMO-SkyMed, RADARSAT-2, ALOS-2, Sentinel-1



VNSC: 2019 CEOS Chair

- Application Focused Initiatives for Mekong river area
  - Carbon Observations (forested regions)
  - Observations for Agriculture (rice)

- Rice monitoring initiative

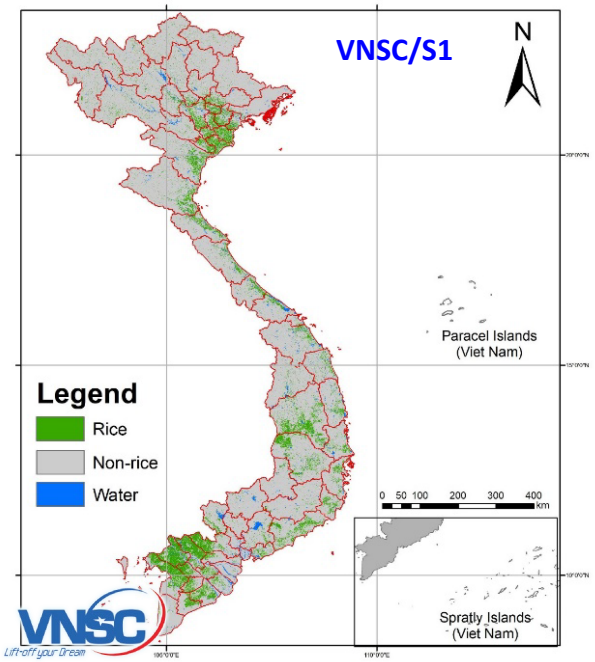
Achievements:

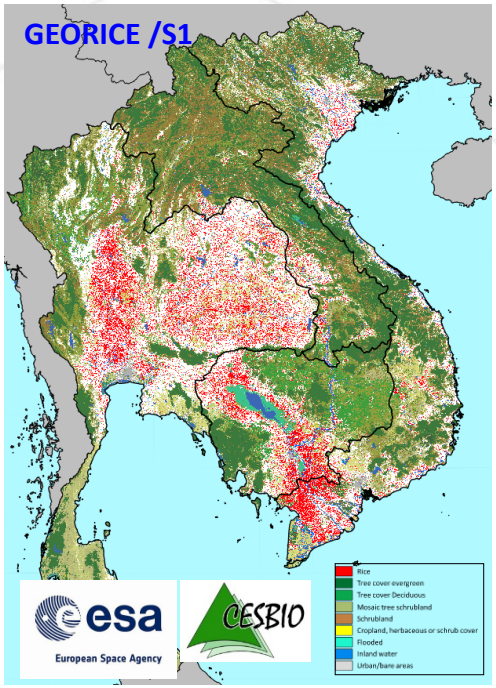
- Rice maps (crop season product) of the Mekong area evaluated by DCP&CIS/MARD.
- Rice phenology / growth stage monthly product of the Mekong Delta, Vietnam.
- Rice crop production / yield estimation (crop season product) of provinces in the Mekong Delta, Vietnam.

Achievements – Rice Monitoring

Linked with VNRice, ESA GEORice, JAXA and GEOGLAM Asia-Rice.

→ Cross comparison among rice maps in the rainy season 2018 of Mekong region made by 3 teams: VNSC (using S1), JAXA&RESTEC (ALOS-2) and CNES CESBIO (S1) under APRSAF SAFE and other regional framework.





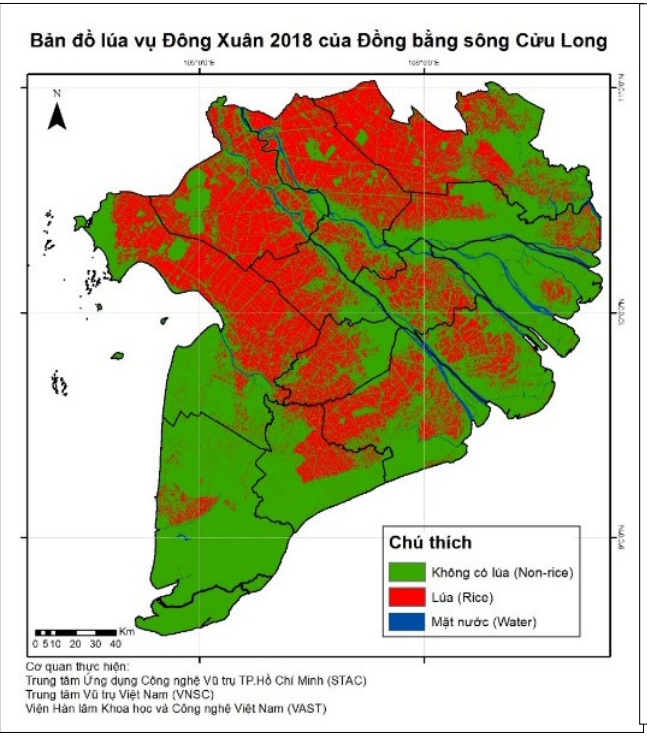
VNRice Research Project Results

VNRice project: Applied research on optical and radar remote sensing data for rice planted area monitoring and rice yield, production estimation in the Mekong Delta and Red River Delta

- Project code: VT-UD-08/17-20, which belongs to the National program on space science and technology (2016–2020)
- Project duration: 11/2017 – 2/2021
- Project lead: VNSC/VAST
- RS data used: Sentinel-1, Sentinel-2, Landsat-8

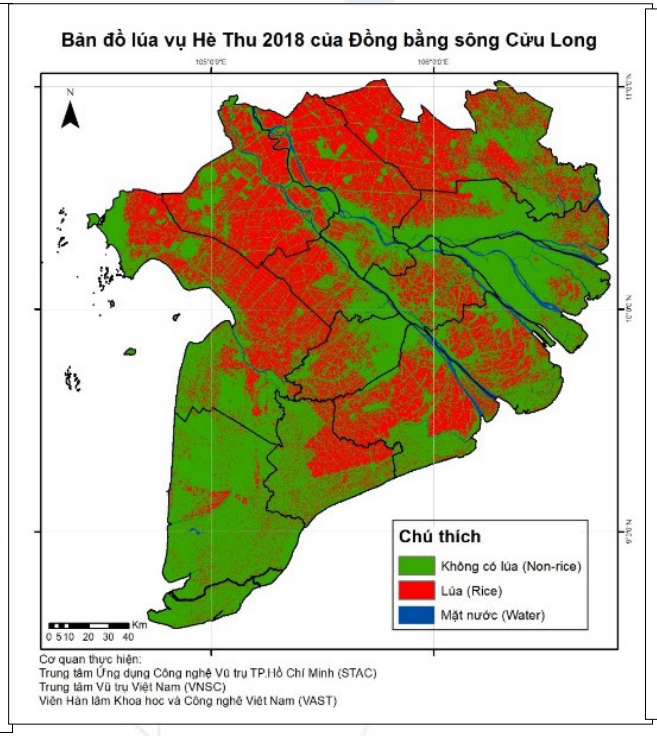
Achievements – Rice Monitoring

Map of WS Rice 2018



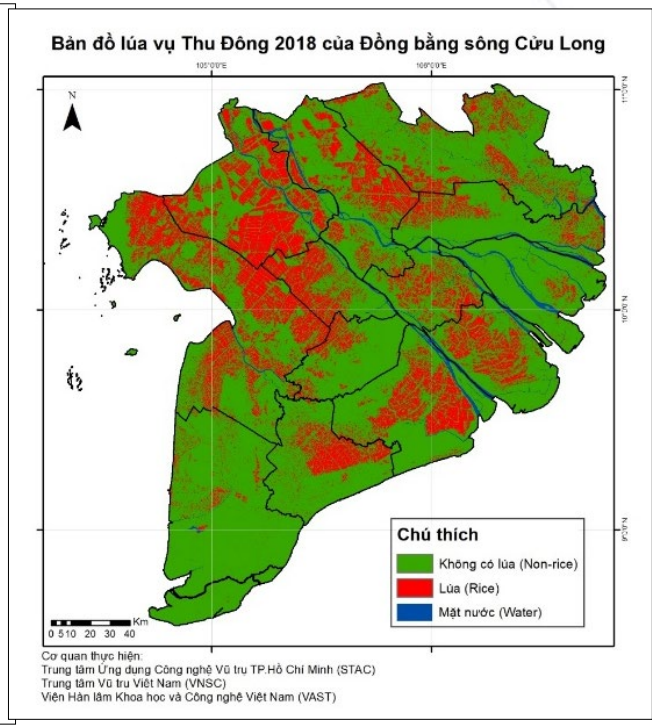
Overall acc.: 93%
Kappa: 0.85

Map of SA Rice 2018



Overall acc.: 92%
Kappa: 0.75

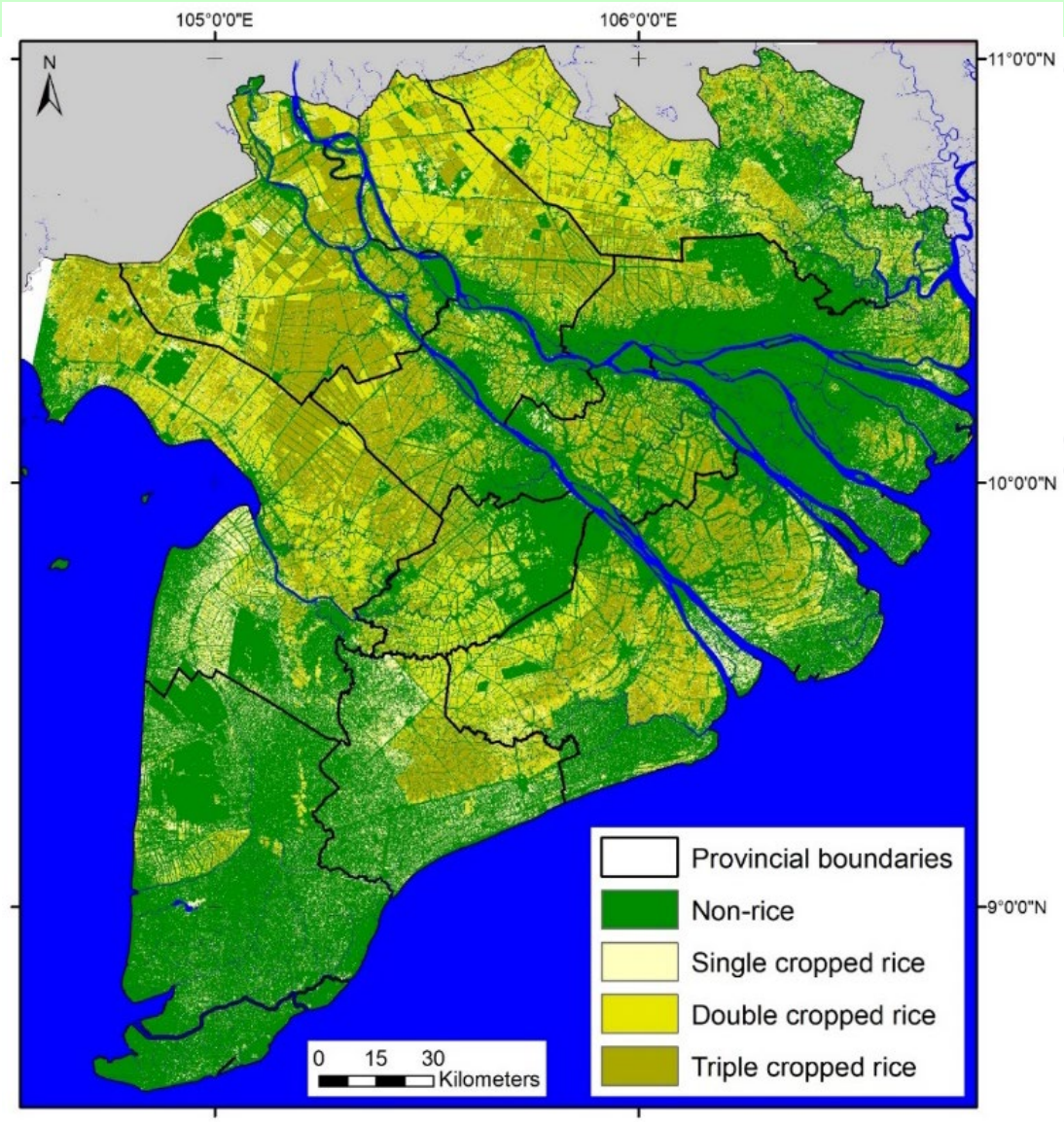
Map of AW Rice 2018



Overall acc.: 92%
Kappa: 0.84

Rice crop maps in 2018 in the Mekong Delta, Vietnam

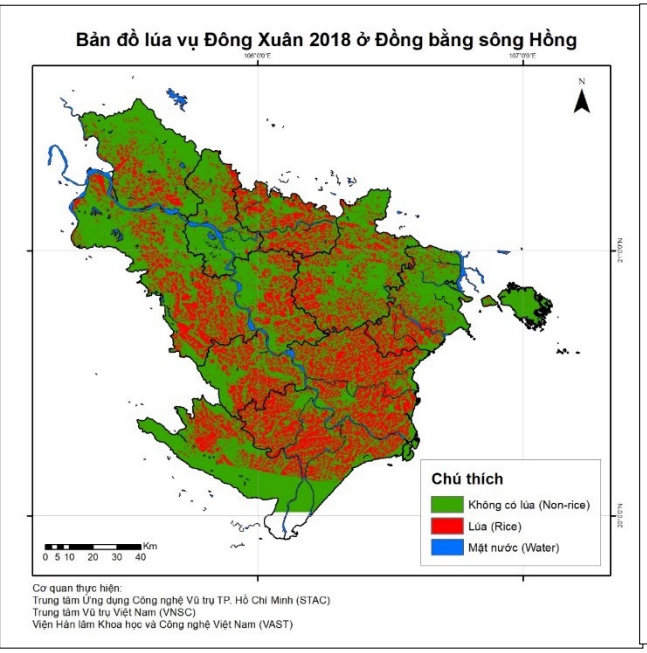
Achievements – Rice Monitoring



Combination of 3 rice crop maps → Rice cropping system map in the VMD

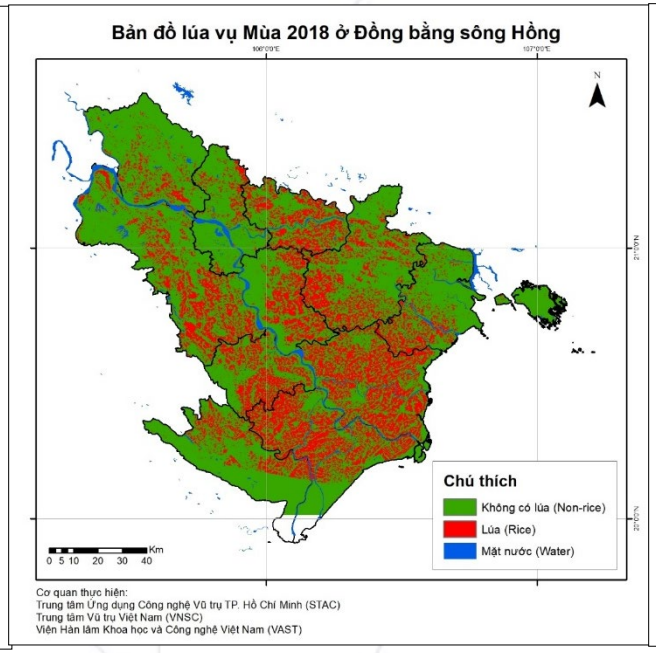
Achievements – Rice Monitoring

Map of WS Rice 2018



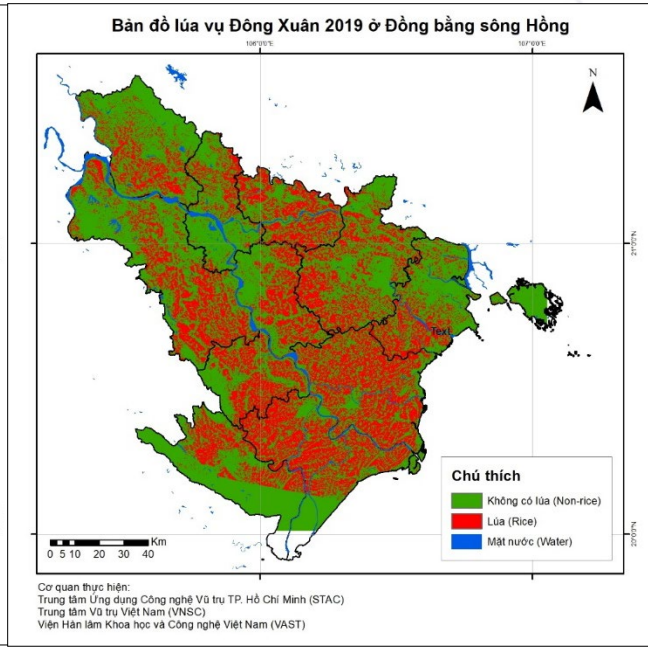
Overall acc.: 92%
Kappa: 0.81

Map of SA Rice 2018



Overall acc.: 94%
Kappa: 0.87

Map of WS Rice 2019



Overall acc.: 94%
Kappa: 0.87

Rice crop maps in 2018-2019 in the Red River Delta, Vietnam

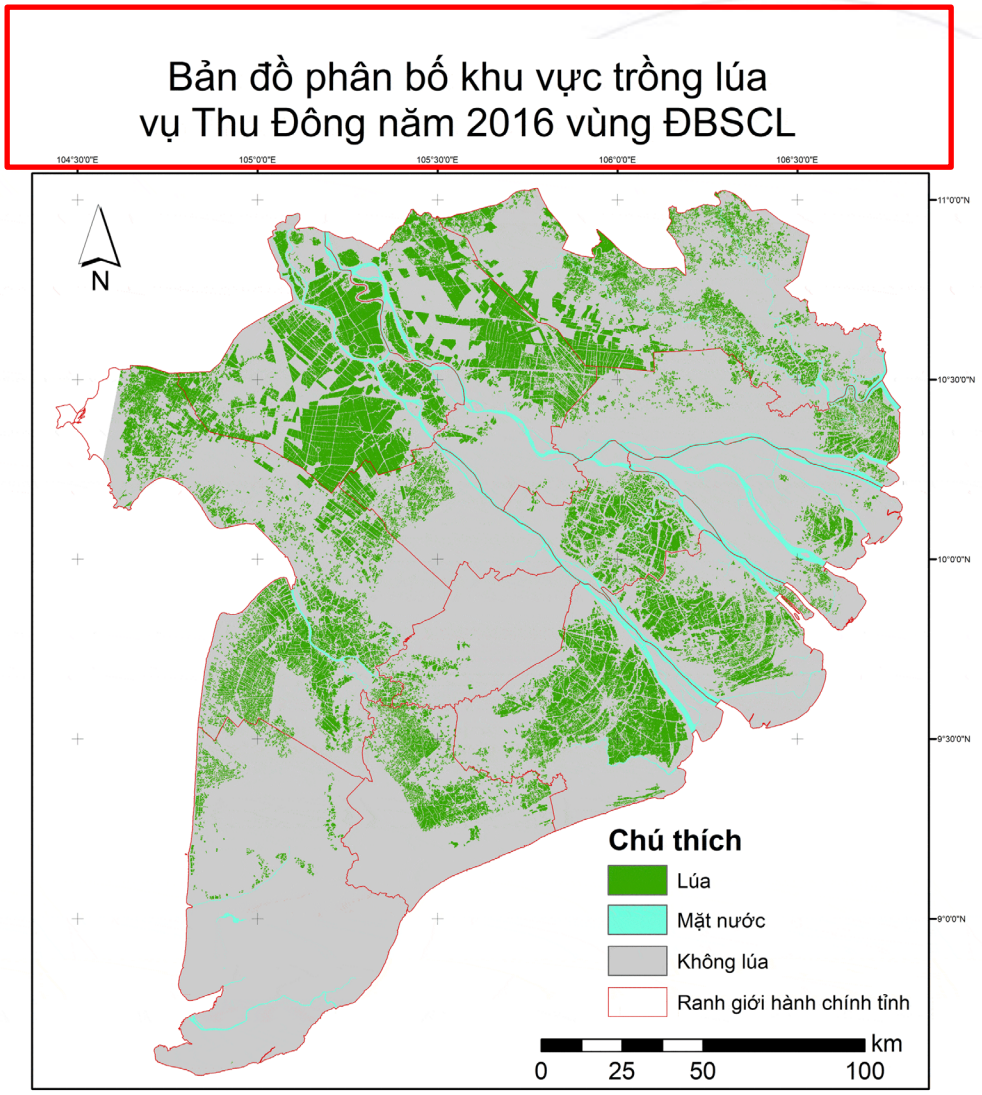
Achievements – Rice Monitoring

Đông Xuân: Winter-Spring

Hè thu: Summer-Autumn

Thu Đông: Autumn-Winter

Maps of rice crops from AW 2016 to AW 2018 in the Mekong Delta, Vietnam



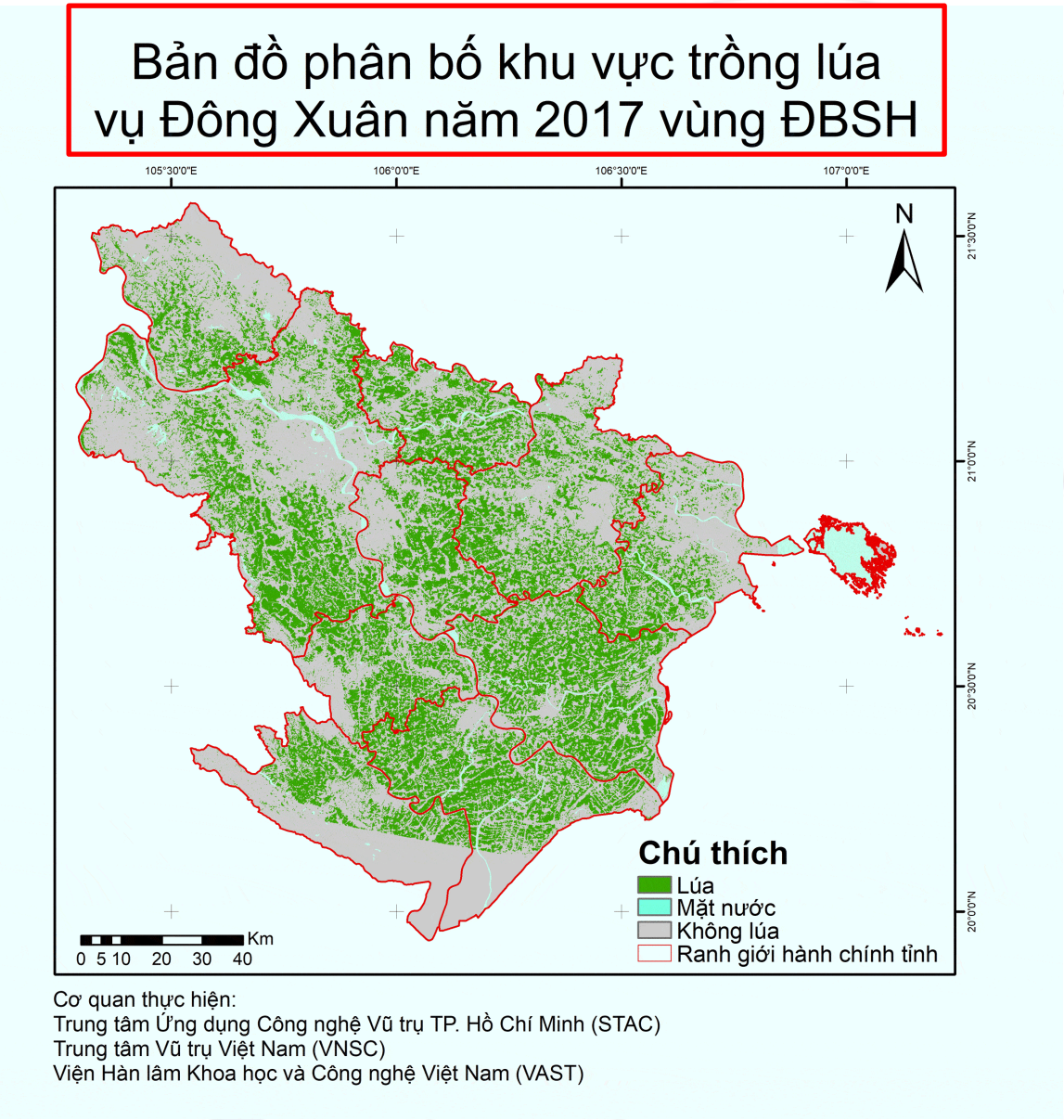
Cơ quan thực hiện:
Trung tâm Ứng dụng Công nghệ Vũ trụ TP. Hồ Chí Minh (STAC)
Trung tâm Vũ trụ Việt Nam (VNSC)
Viện Hàn lâm Khoa học và Công nghệ Việt Nam (VAST)

Achievements – Rice Monitoring

Đông Xuân: Spring paddy

Mùa: Winter paddy

Maps of rice crops from WS 2017 to WS 2019 in the Red River Delta



Achievements – Rice Monitoring

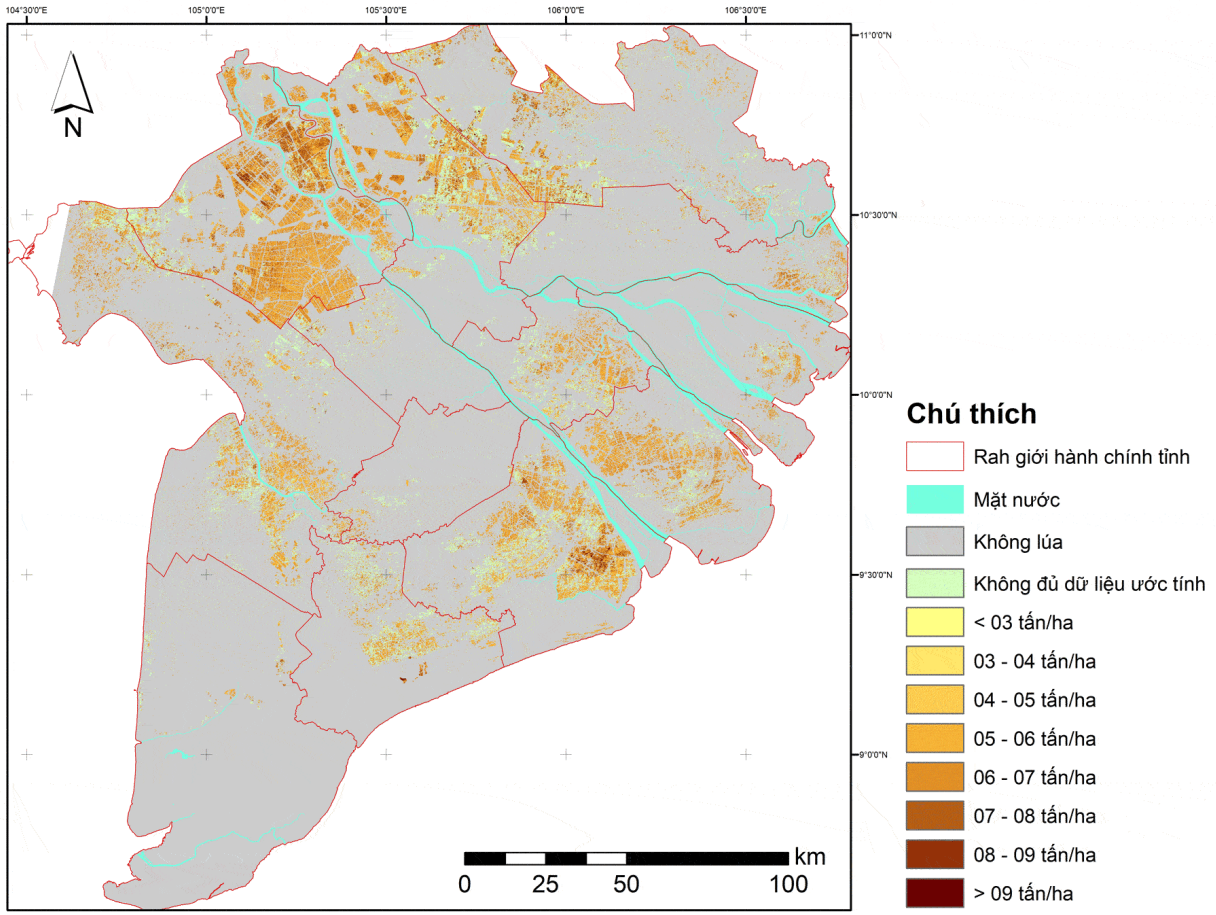
Đông Xuân: Winter-Spring

Hè thu: Summer-Autumn

Thu Đông: Autumn-Winter

Yield maps of rice crops from AW 2016 to AW 2018 in the Mekong Delta

Bản đồ ước lượng năng suất lúa
vụ Thu Đông 2016 khu vực ĐBSCL



Phung Hoang-Phi, Nguyen Lam-Dao, Vu Nguyen-Van-Anh, Thanh Nguyen-Kim, Thuy Le Toan, Tien Pham-Duy (2022). Rice Growth Stage Monitoring and Yield Estimation in the Vietnamese Mekong Delta Using Multi-temporal Sentinel-1 Data, Springer Book: Remote Sensing of Agriculture and Land Cover/Land Use Changes in South and Southeast Asian Countries, Pages 297-307.

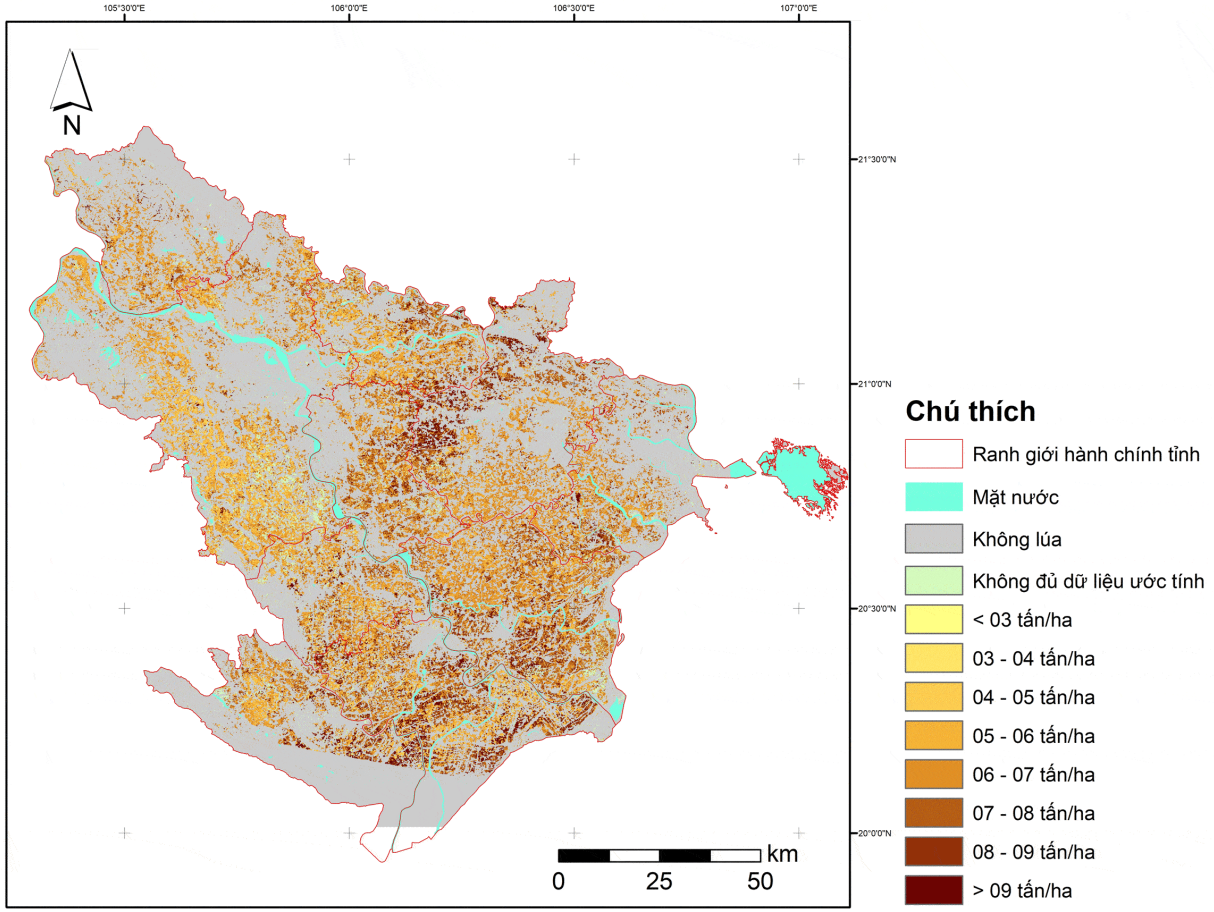
Achievements – Rice Monitoring

Đông Xuân: Spring paddy

Mùa: Winter paddy

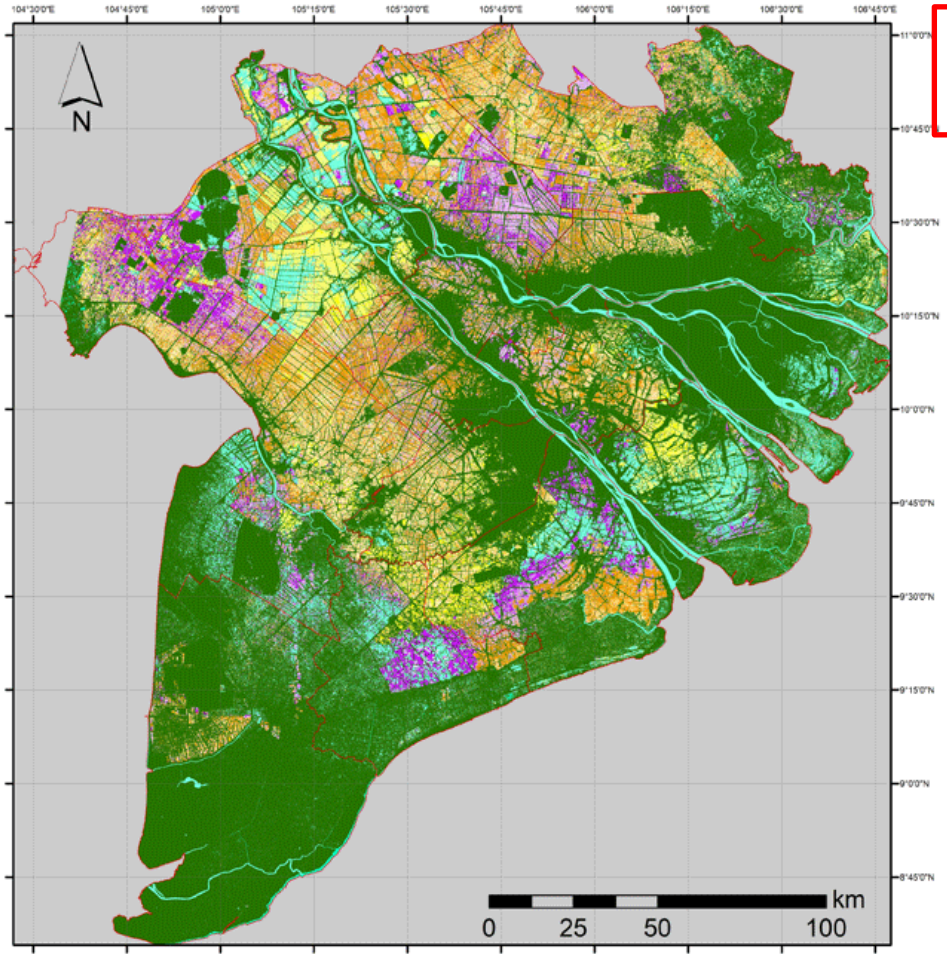
Yield maps of rice crops from WS 2017 to WS 2019 in the Red River Delta

Bản đồ ước lượng năng suất lúa
vụ Đông Xuân 2017 khu vực ĐBSH



Cơ quan thực hiện:
Trung tâm Ứng dụng Công nghệ Vũ trụ TP. Hồ Chí Minh (STAC)
Trung tâm Vũ trụ Việt Nam (VNSC)
Viện Hàn lâm Khoa học và Công nghệ Việt Nam (VAST)

Achievements – Rice Monitoring



Bản đồ ngày sau khi sạ/cấy khu vực ĐBSCL (13/01/2019)

Chú thích

- Không phải lúa
- Mặt nước
- Đất lúa sau thu hoạch
- 01 - 10 ngày
- 11 - 20 ngày
- 21 - 30 ngày
- 31 - 40 ngày
- 41 - 50 ngày
- 51 - 60 ngày
- 61 -70 ngày
- 71 - 80 ngày
- 81 - 90 ngày
- 91 - 100 ngày
- 101 - 110 ngày
- 111 - 120 ngày
- Khu vực bên ngoài
- Ranh giới hành chính tỉnh

Cơ quan thực hiện:
Trung tâm Ứng dụng Công nghệ Vũ trụ TP. Hồ Chí Minh (STAC)
Trung tâm Vũ trụ Việt Nam (VNSC)
Viện Hàn lâm Khoa học và Công nghệ Việt Nam (VAST)

The products have been provided to the Department of Crop Production (DCP) & Center for Informatic and Statistics (CIS) - MARD

Days after rice sowing/transplanting in 2019 in the Mekong Delta

Hoang-Phi Phung, Lam-Dao Nguyen, Nguyen-Huy Thong, Le-Toan Thuy, Armando A. Apan. Monitoring rice growth status in the Mekong Delta, Vietnam using multitemporal Sentinel-1 data. *J. Appl. Remote Sens.* **14**(1), 014518 (2020), doi: 10.1117/1.JRS.14.014518.

Diện tích lúa phân theo địa phương - Ngày 13/02/2021

Số liệu từ viễn thám

Đơn vị tính: ha

Diện tích lúa	0-10 ngày	10-20 ngày	20-30 ngày	30-40 ngày	40-50 ngày	50-60 ngày	60-70 ngày	70-80 ngày	80-90 ngày	90-100 ngày	100-110 ngày	110-120 ngày	Tổng
Long An	0	4,381	6,989	1,232	4,715	24,897	19,976	43,426	39,392	4,307	11,477	3,036	163,828
Tiền Giang	0	212	1,025	250	475	944	686	7,261	14,239	3,354	1,913	1,519	31,877
Bến Tre	0	4	47	5	45	579	127	1,447	1,751	50	389	43	4,489
Trà Vinh	0	487	4,887	2,354	11,065	11,193	2,665	3,385	2,974	2,310	3,515	506	45,341
Vĩnh Long	0	60	354	160	1,090	3,877	3,048	6,304	13,620	1,460	3,212	1,320	34,505
Đồng Tháp	0	4,876	7,627	2,514	5,423	8,232	5,544	24,271	38,078	6,575	14,022	5,242	122,403
An Giang	0	1,504	8,594	4,636	23,322	59,971	20,422	36,063	15,456	3,009	7,697	6,880	187,555
Kiên Giang	0	403	1,296	499	4,689	26,850	22,059	79,054	53,424	9,084	22,794	5,946	226,098
Cần Thơ	0	26	76	13	64	510	978	9,650	40,590	9,648	2,185	1,867	65,609
Hậu Giang	0	167	1,068	735	5,459	20,370	6,082	11,253	8,162	423	1,988	472	56,181
Sóc Trăng	0	2,869	10,137	5,461	14,304	18,415	2,390	4,860	18,913	8,068	10,277	3,103	98,797
Bạc Liêu	0	4,995	5,897	1,181	4,912	8,258	1,657	4,845	5,661	687	3,314	1,720	43,126
Cà Mau	0	0	18	37	1,694	7,581	1,912	3,301	2,062	416	2,176	1,059	20,255
ĐBSCL	0	19,985	48,015	19,076	77,258	191,677	87,546	235,121	254,320	49,389	84,960	32,714	1,100,062

Diện tích lúa theo tuổi lúa của các địa phương thuộc tỉnh Long An ngày 13/02/2021

Số liệu từ viễn thám

Đơn vị: ha

Diện tích lúa	0-10 ngày	10-20 ngày	20-30 ngày	30-40 ngày	40-50 ngày	50-60 ngày	60-70 ngày	70-80 ngày	80-90 ngày	90-100 ngày	100-110 ngày	110-120 ngày	Tổng
Bến Lức	0	6	81	44	264	72	10	90	353	18	207	150	1,294
Cần Đước	0	0	64	31	123	61	4	86	965	50	641	261	2,286
Cần Giuộc	0	0	1	9	21	30	0	21	200	55	252	122	713
Châu Thành	0	0	0	1	0	0	0	9	4	0	2	0	16
Đức Hòa	0	4	358	101	1,186	1,429	306	1,778	952	92	530	11	6,747
Đức Huệ	0	58	359	104	482	1,605	728	5,727	4,413	206	589	63	14,335
Tx. Kiến Tường	0	125	299	3	79	1,070	1,814	2,857	4,070	348	530	616	11,812
Mộc Hóa	0	92	138	47	375	5,911	3,323	4,328	4,973	507	838	80	20,611
Tp. Tân An	0	4	168	79	61	2	0	19	36	0	8	3	379
Tân Hưng	0	406	191	5	87	2,081	3,658	9,629	7,227	1,300	2,940	687	28,212
Tân Thạnh	0	3,242	3,823	283	443	1,335	1,596	2,495	1,626	221	426	208	15,699
Tân Trụ	0	13	289	78	74	5	0	174	582	30	147	34	1,426
Thạnh Hóa	0	96	124	142	975	7,153	2,627	3,629	1,773	170	741	201	17,631
Thủ Thừa	0	328	1,074	292	441	2,007	1,989	4,394	1,757	208	448	70	13,007
Vĩnh Hưng	0	7	17	12	90	2,083	3,915	8,133	10,345	1,089	3,154	520	29,365
Tổng	0	4,381	6,987	1,231	4,699	24,844	19,971	43,368	39,277	4,295	11,453	3,027	163,533

Achievements – Rice Monitoring

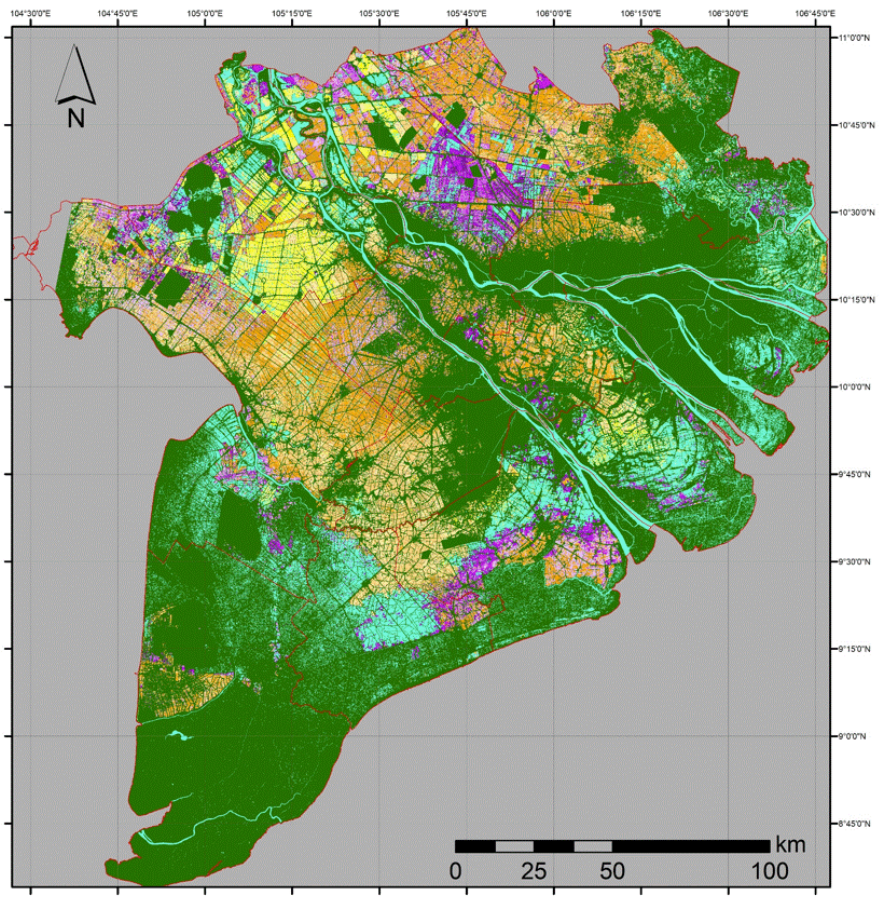
Diện tích lúa phân theo địa phương thuộc huyện Thoại Sơn - tỉnh An Giang - Ngày 10/03/2022

Số liệu từ viễn thám

Đơn vị tính: ha

	0-20 ngày	21-40 ngày	41-60 ngày	61-80 ngày	81-100 ngày	101-120 ngày	Tổng
Xã An Bình	0	0	56	1,362	667	19	2,105
Xã Bình Thành	0	0	61	526	1,558	11	2,156
Xã Định Mỹ	0	0	0	89	2,715	256	3,059
Xã Định Thành	0	0	14	549	1,797	71	2,430
Xã Mỹ Phú Đông	0	0	15	737	1,800	11	2,563
Thị trấn Núi Sập	0	0	21	199	53	2	274
Thị Trấn Óc Eo	0	0	35	325	57	0	417
Thị trấn Phú Hoà	0	0	0	46	167	36	249
Xã Phú Thuận	0	0	0	25	647	1,276	1,949
Xã Tây Phú	0	0	134	1,772	876	6	2,788
Xã Thoại Giang	0	0	0	588	1,507	5	2,100
Xã Vĩnh Chánh	0	0	0	69	1,658	991	2,719
Xã Vĩnh Khánh	0	0	8	458	1,507	384	2,357
Xã Vĩnh Phú	0	0	0	499	2,344	16	2,859
Xã Vĩnh Trạch	0	0	11	196	717	65	988
Xã Vọng Đông	0	0	0	742	1,475	15	2,232
Xã Vọng Thê	0	0	201	1,300	401	0	1,902
Tổng	0	0	556	9,480	19,947	3,163	33,146

Monthly Rice Maps



Bản đồ ngày sau khi sạ/cấy khu vực ĐBSCL (14/01/2020)

Chú thích

- Không phải lúa
- Mặt nước
- Đất lúa sau thu hoạch
- 01 - 10 ngày
- 11 - 20 ngày
- 21 - 30 ngày
- 31 - 40 ngày
- 41 - 50 ngày
- 51 - 60 ngày
- 61 -70 ngày
- 71 - 80 ngày
- 81 - 90 ngày
- 91 - 100 ngày
- 101 - 110 ngày
- 111 - 120 ngày
- Khu vực bên ngoài
- Ranh giới hành chính tỉnh

Cơ quan thực hiện:
Trung tâm Ứng dụng Công nghệ Vũ trụ TP. Hồ Chí Minh (STAC)
Trung tâm Vũ trụ Việt Nam (VNSC)
Viện Hàn lâm Khoa học và Công nghệ Việt Nam (VAST)

The products have been provided to the DCP & CIS - MARD

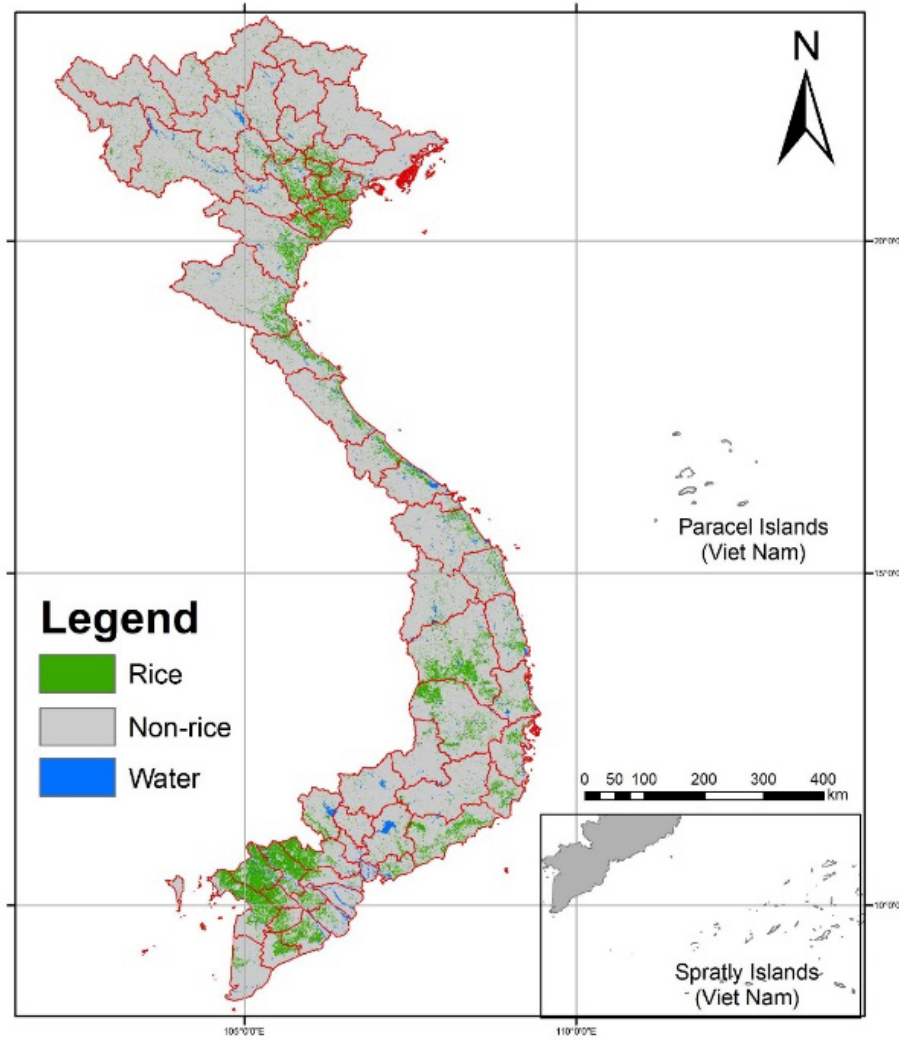
Days after rice sowing/transplanting in 2020 - 2022 in the Mekong Delta

Next Steps and Evolution

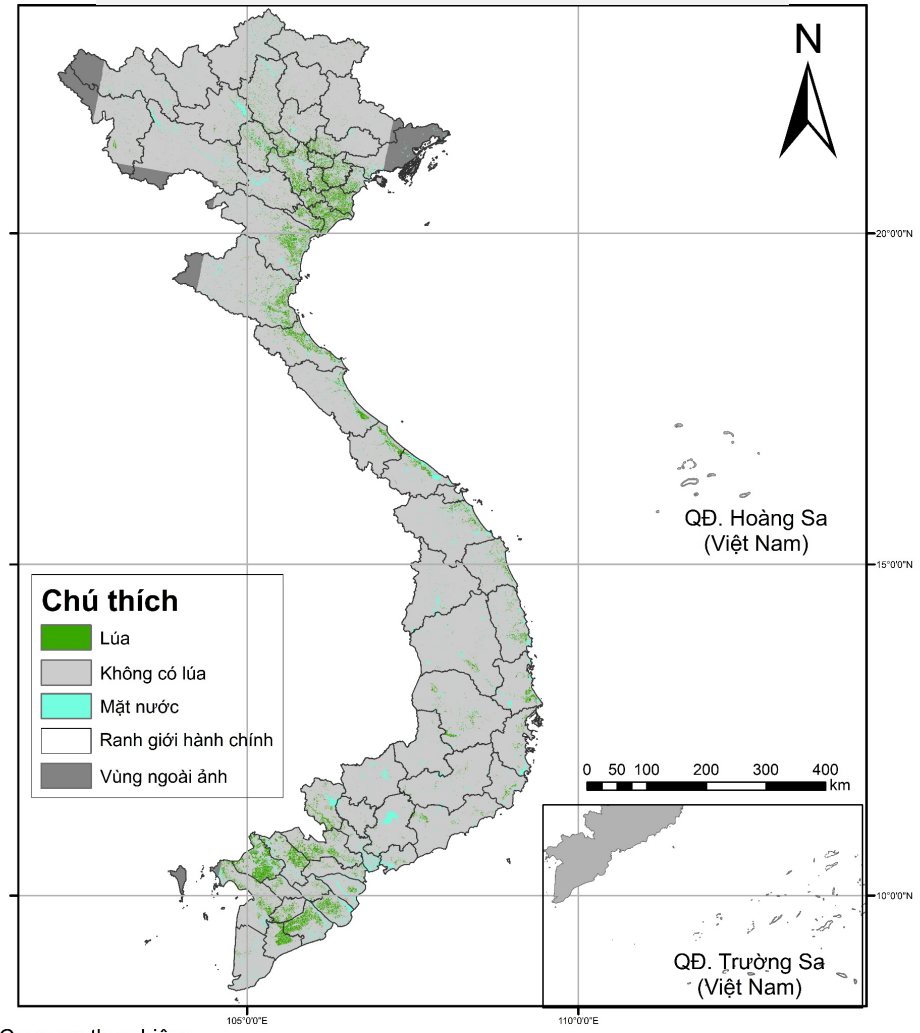
- VietSCO: Monitoring rice production areas affected by climate change in the Mekong Delta (CNES CESBIO, VNSC and other Vietnamese organisations).
- SAFE rice monitoring project (rice map comparison study for dry season in collaboration with JAXA and CNES CESBIO).
- CH4Rice SAFE project.
- Further works on rice monitoring will be conducted using other SAR data such as NovaSAR-1, ASNARO-2, NISAR, LOTUSat-1, etc.

Next Steps and Evolution

RICE MAP
RAINY SEASON 2018



RICE MAP
20-31/03/2019



Cơ quan thực hiện:
Trung tâm Ứng dụng Công nghệ Vũ trụ TP. Hồ Chí Minh (STAC)
Trung tâm Vũ trụ Việt Nam (VNSC)
Viện Hàn lâm Khoa học và Công nghệ Việt Nam (VAST)

Methane Emission from Rice Crops

(CH4Rice Project)

Lam Dao Nguyen (VNSC)
and SAFE Secretariat

Background of New SAFE Project

- IPCC reports a resumption of atmospheric CH_4 concentration growth since 2007, assess growth since 2007 to be largely driven by emissions from the fossil fuels and agriculture. [IPCC AR6, 2021]
- Methane emission from rice paddies are estimated to be about 8% of total global anthropogenic emission. [Saunois et al., 2020]
- The amount of CH_4 emission is a function of the number and duration of crops grown, water regimes, and soil type, temperature, and rice cultivar. [Guidelines for National Greenhouse Gas Inventories, IPCC, 2006]
- To achieve sustainable rice cultivation, accurate assessment of CH_4 emission is imperative and low CH_4 emission cultivation (e.g. Alternate Wetting and Drying: AWD) are effective.

Atmospheric CH4 Concentration (measured by SCIAMACHY)

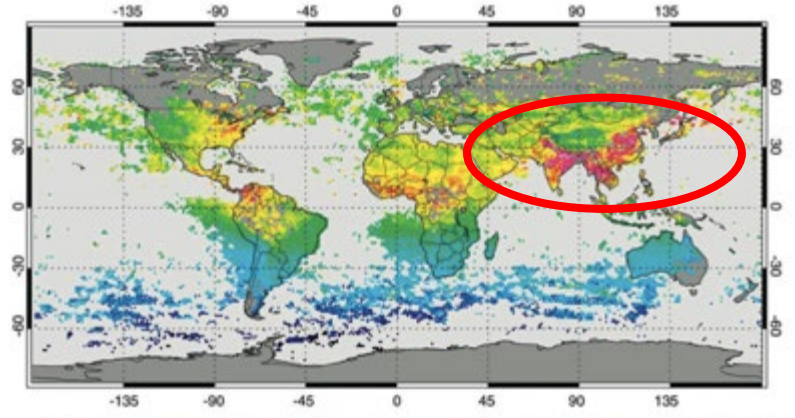
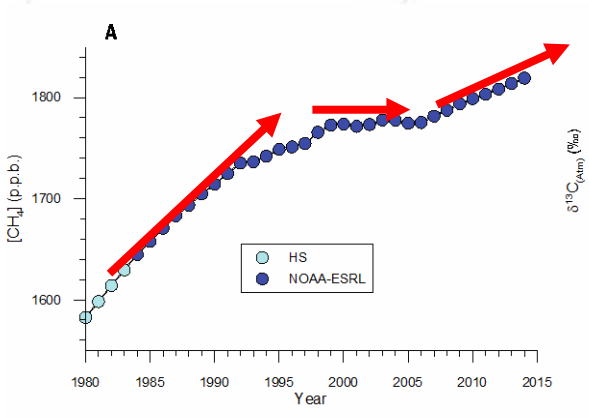


Fig. 2. SCIAMACHY measurements of column-averaged methane VMR in ppb units. The measurements are averaged over the time period of August through November 2003 on a 1° by 1° horizontal grid. At least 5 (and up to 150) measurements are taken for each grid cell. Only few observations are available over the ocean, because low ocean reflectivity substantially reduces the quality of the retrieval, leading in turn to unreliable measurements (standard deviation of the fit residual above 0.5%) that are discarded. Occasionally, sun glint or clouds at low altitudes allow measurement over the ocean.

13 MAY 2005 VOL 308 SCIENCE www.sciencemag.org

[Frankenberg et al., Science, 2005]

CH4 Global Trends



Ratio of emissions from fossil fuels

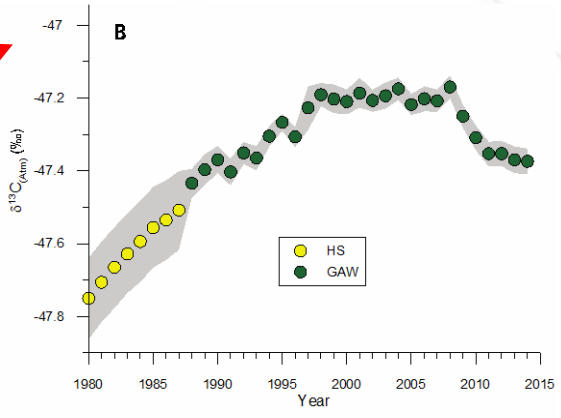


Fig. 1. Global trends in [CH_4] and $d^{13}C_{(Atm)}$. (A) Spliced records of globally averaged annual values for [CH_4] from a historic spline (HS) (light blue) (1) and the NOAA-ESRL global monitoring network (dark blue) (3). The uncertainty range is indicated by the thickness of the connecting line. (B) Spliced records of globally averaged annual values for $d^{13}C_{(Atm)}$ from a HS (yellow) (2) and atmospheric time series from contributing Global Atmosphere Watch (GAW) stations measured in our three laboratories (green). Gray shading shows the 1s confidence interval (CI). Details on the splicing and uncertainty estimates are provided in (25).

[Schaefer et al., Science, 2016]

Target of New SAFE Project

Expect to Contribute (Outcome)

- Climate change mitigation through CH_4 MRV (Monitoring, Reporting and Verification) using satellite and in-situ data
- Water management by efficient irrigation with lower CH_4 emission (e.g. Alternate Wetting and Drying: AWD)
- Regional and global sustainable agriculture related initiatives/activities (e.g. SDGs Goal2, GEOGLAM/Asia-RiCE, AOGEO etc.)

Implementation

- Development of the methodology to estimate the CH_4 emission from rice paddies
- Data/Tool/Knowledge sharing and capacity building for multi-lateral collaborations
- Promote dialog with stakeholders/end-users with showing results (considering national policy, try to reach related agencies)
- Synergies with SAFE Agromet and Rice Monitoring Projects.

Participating Agencies of New SAFE Project

Project Lead

- VNSC (Project Lead)

Potential Participating Agencies

- ISRO, GISTDA, JAXA, Bangladesh (with U-Tokyo), NSPO, APN/Nepal , ADPC, IRRI etc.
- Shared their past/current study and/or showed their interest at the last SAFE Executive Board Meeting

Implementation Arrangements: Methodology

CH_4 emission estimation from rice paddies (Bottom-up Approach) [IPCC, 2006]

- Multiplying emission factors by cultivation period and harvested area

Annual Methane Emissions

EQUATION 5.1

CH_4 EMISSIONS FROM RICE CULTIVATION

$$CH_{4\ Rice} = \sum_{i,j,k} (EF_{i,j,k} \bullet t_{i,j,k} \bullet A_{i,j,k} \bullet 10^{-6})$$

Emission Factors | **Cultivation Period** | **Harvested Area**

TABLE 5.12
DEFAULT CH_4 EMISSION SCALING FACTORS FOR WATER REGIMES DURING THE CULTIVATION PERIOD RELATIVE TO CONTINUOUSLY FLOODED FIELDS

Water regime		Aggregated case		Disaggregated case	
		Scaling factor (SF_w)	Error range	Scaling factor (SF_w)	Error range
	Upland [a]	0	-	0	-
Irrigated [b]	Continuously flooded			1	0.79 - 1.26
	Intermittently flooded – single aeration	0.78	0.62 - 0.98	0.60	0.46 - 0.80
	Intermittently flooded – multiple aeration			0.52	0.41 - 0.66
Rainfed and deep water [c]	Regular rainfed			0.28	0.21 - 0.37
	Drought prone	0.27	0.21 - 0.34	0.25	0.18 - 0.36
	Deep water			0.31	ND

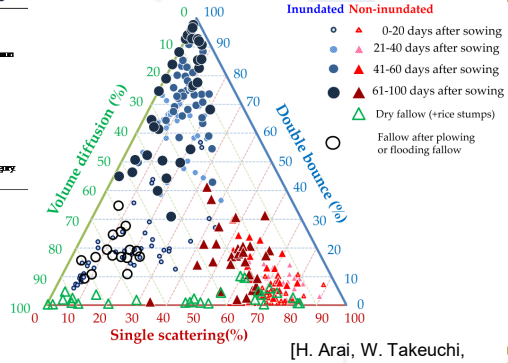
ND: not determined
[a] Fields are never flooded for a significant period of time.
[b] Fields are flooded for a significant period of time and water regime is fully controlled.
- Continuously flooded: Fields have standing water throughout the rice growing season and may only dry out for harvest (end-season drainage).
- Intermittently flooded: Fields have at least one aeration period of more than 3 days during the cropping season.
  - Single aeration: Fields have a single aeration during the cropping season at any growth stage (except for end-season drainage).
  - Multiple aeration: Fields have more than one aeration period during the cropping season (except for end-season drainage).

[c] Fields are flooded for a significant period of time and water regime depends solely on precipitation.
- Regular rainfed: The water level may rise up to 50 cm during the cropping season.
- Drought prone: Drought periods occur during every cropping season.
- Deep water rice: Floodwater rises more than 50 cm for a significant period of time during the cropping season.

Note: Other rice ecosystem categories, like swamps and inland, saline or tidal wetlands may be discriminated within each sub-category.
Source: Yan et al., 2005

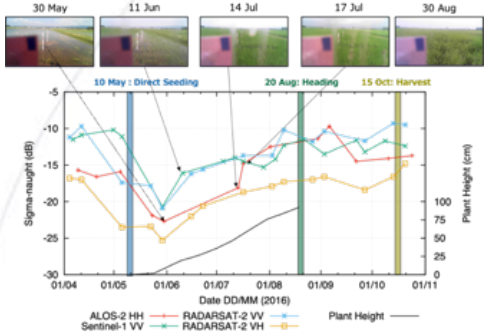
Supplemental use of Agromet data (synergy with agromet project)

Water regimes:
Water flooding identification using ALOS-2 full-pol data

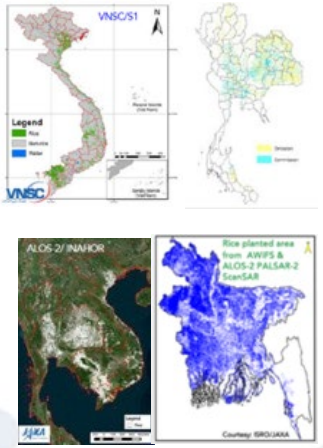


[H. Arai, W. Takeuchi, L. D. Nguyen et al., 2018]

Phenology (SAR and optical)



Rice Map (C/L-band SAR)



Synergy with Rice Monitoring Project

Implementation Arrangements: Methodology

Comparison with satellite-based CH4 (column density) (Top-down Approach)

- If in-situ CH4 data can be available, comparison with CH4 concentration measured by GOSAT-1/2, OCO-2, TROPOMI, IASI etc.
- Comparison with CH4 emission estimated by bottom-up approach.

Implementation Arrangements of New SAFE Project

Data/Tool/Knowledge sharing and capacity building for Multi-lateral Collaborations

- Assessment of whole region by collecting the result implemented in each country/region
- Sharing Satellite Data

  ALOS-2 (both full-pol and ScanSAR dual), NISAR, etc.
- Sharing Methodology

  Sharing tools on platform such as VEDAS, GEE, ODC, etc., and preparing tutorial materials.

Promote dialog with stakeholders/end-users with showing results

- Considering national policy, try to reach related agencies
- Governments in each country (agriculture/environmental/water management related ministries)
- Contribute to International initiatives such as the Asia-RiCE/GEOGLAM, CEOS AOGEO and ASEAN SCOSA
- Dialog with JAIF, ADB, JICA for funding of the project implementation
- Collaboration with international initiatives related to methane emission

  UNEP/International Methane Emissions Observatory (IMEO), etc.

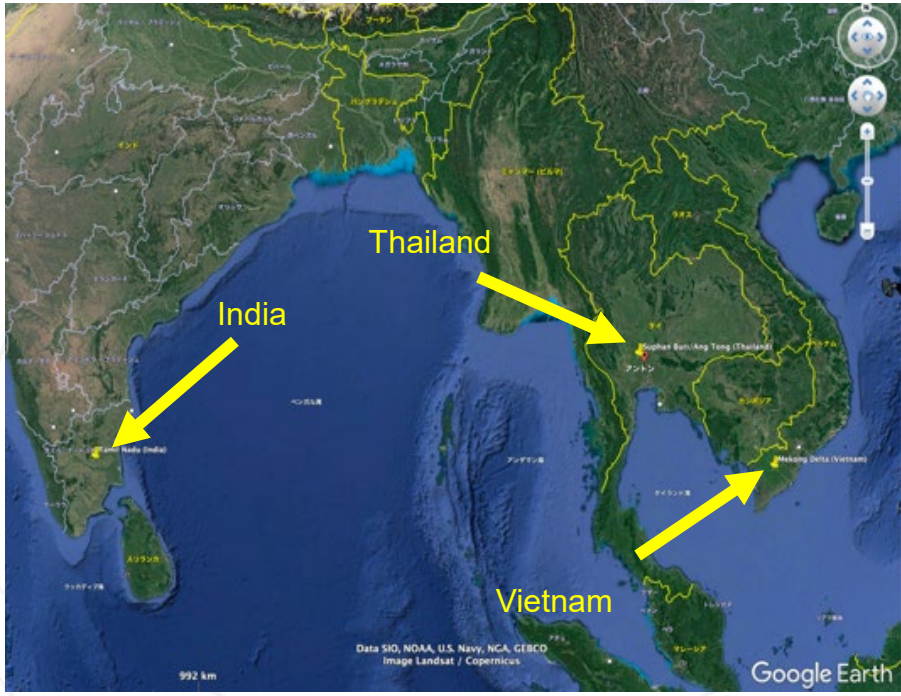
Future Plan of New SAFE Project

Preparing workplan

- Implementation framework
- Schedule
- Selecting study areas for ALOS-2 full-pol observations (super sites)

Current sites for ALOS-2 full-pol observation super sites for rice monitoring

- Mekong Delta (Vietnam)
- Suphan Buri/Ang Tong (Thailand)
- Tamil Nadu (India)
- other sites ??



Thank you!

Lam Dao Nguyen

Email: ldnguyen@vnsc.org.vn