

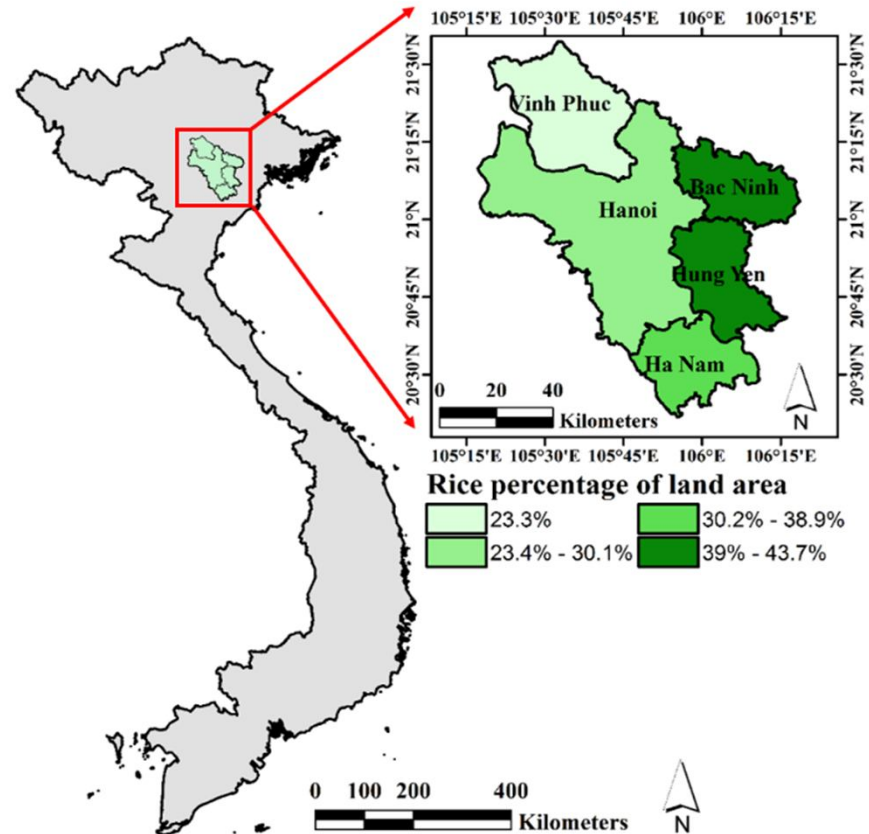
Rice Mapping in Red River Delta, Vietnam Using Sentinel 1-A Datasets

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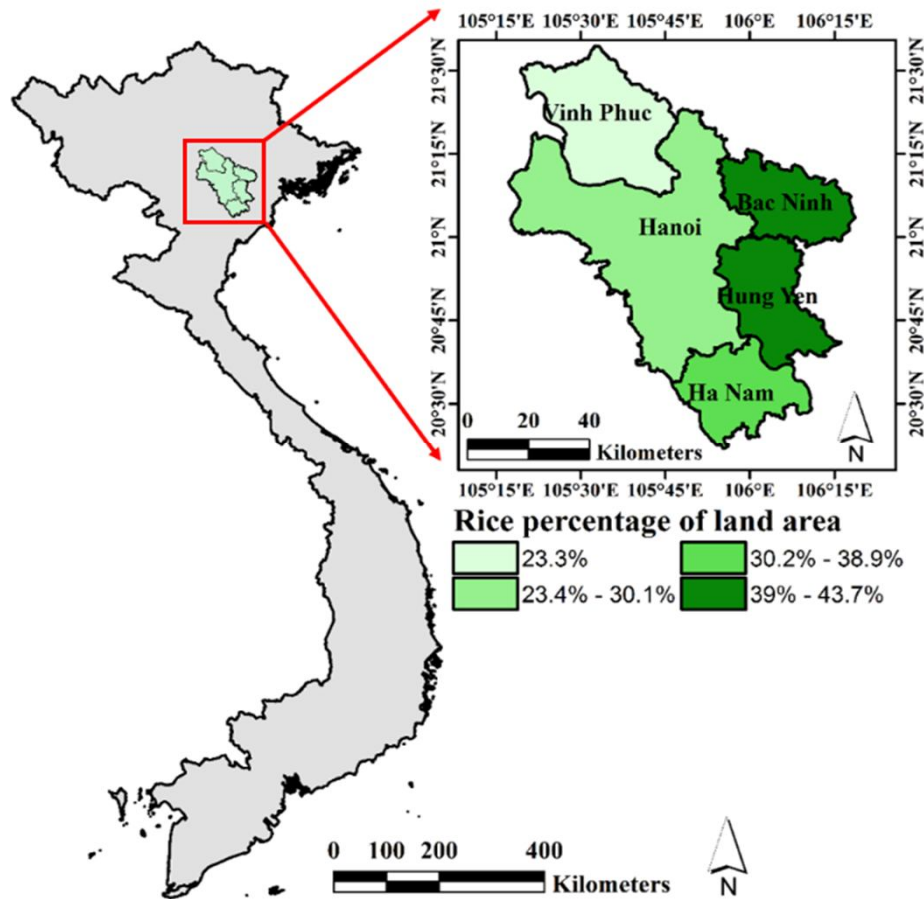


Introduction

- Mapping and monitoring of paddy rice is important for Hanoi, Vietnam to understand land cover and land use changes. Ag. Areas are fast declining due to increasing urbanization.
- Irrigated Rice is the dominant crop with two main seasons: a winter crop typically planted after the Tet holiday during February, and a spring crop planted in late-June or July.

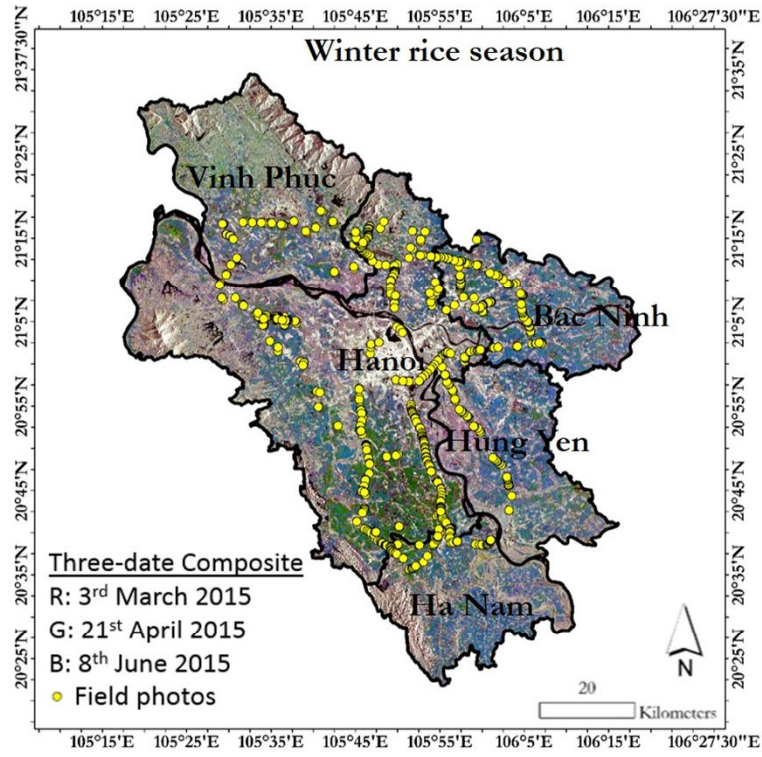


Study Area



- Hanoi Capital Region includes rice producing hotspot provinces of Bac Ninh, Hung Yen, Vinh Phuc, and Ha Nam.
- The HCR includes much of the Red River Delta, Vietnam's oldest and 2nd largest rice producing region, accounting for about 20% of the country's total rice production (Vietnam Govt. stats 2016).

A



Harvested fields with residues



Typical machine-harvested field in Hanoi province with dry rice straw laid in neat rows;



Typical rice straw pile prior to burning near Hanoi City.

Residue burning

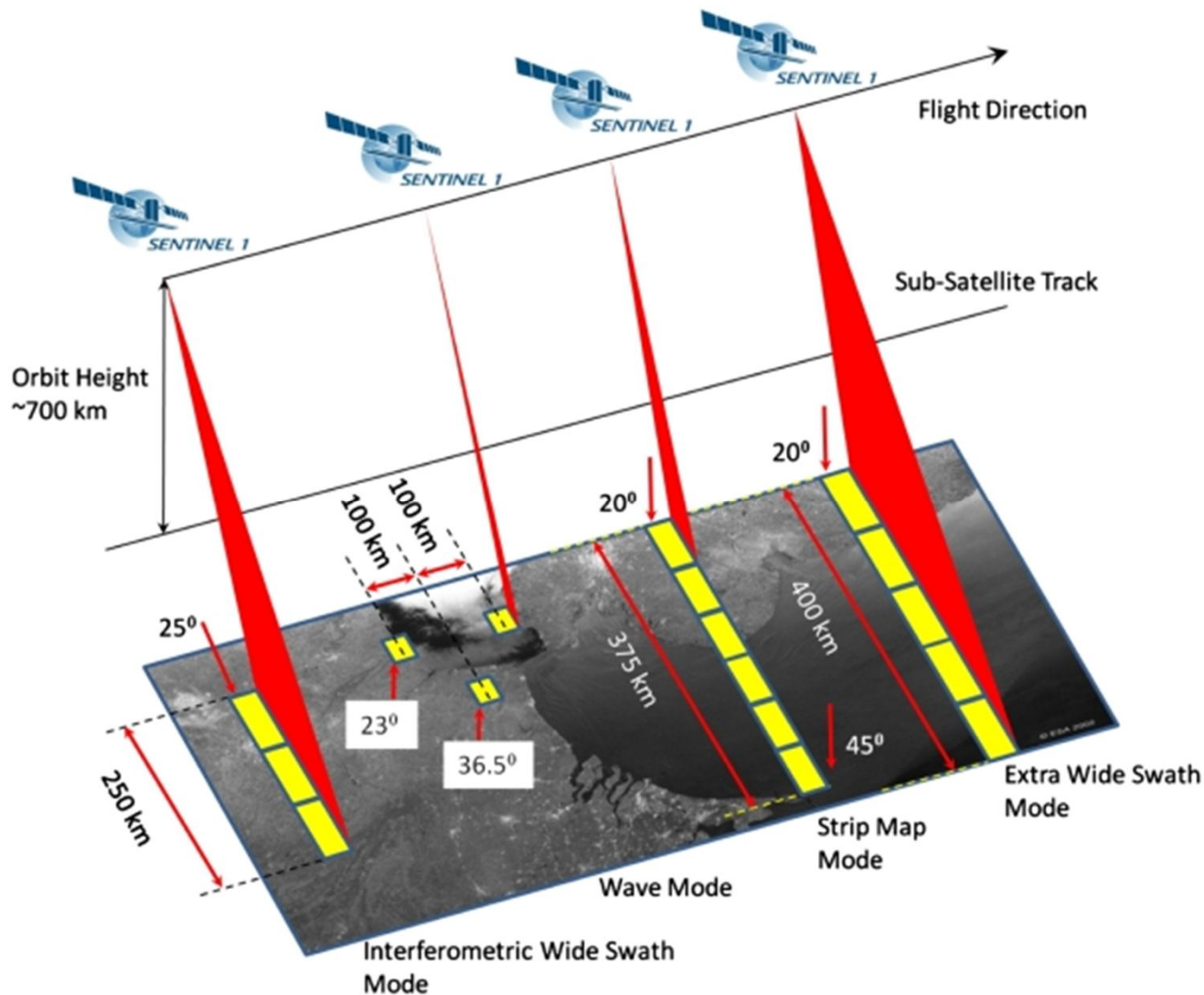


Typical post-burned rice field in Hanoi Province, Vietnam. Most straw is burned efficiently, however much stubble is left incompletely combusted.



Rice straw pile burning.

Sentinel 1 Data



Strip Map (SM): 80 km swath, 5 x 5 m spatial resolution

Interferometric Wide Swath (IW): 250 km swath, 5 x 20 m spatial resolution

Extra-Wide Swath (EW): 400 km swath, 20 x 40 m spatial resolution

Wave (WV): 20 x 20 km, 5 x 5 m spatial resolution

Interferometric Wide Swath

Characteristic	Value
Swath width	250 km
Incidence angle range	29.1° - 46.0°
Sub-swaths	3
Azimuth steering angle	± 0.6°
Azimuth and range looks	Single
Polarisation options	Dual HH+HV, VV+VH Single HH, VV
Maximum Noise Equivalent Sigma Zero (NESZ)	-22 dB
Radiometric stability	0.5 dB (3 σ)
Radiometric accuracy	1 dB (3 σ)
Phase error	5°

Level-1 Single Look Complex data comprising complex imagery with amplitude and phase (systematic distribution limited to specific relevant areas) (typical size 8GB/product)

Level-1 Ground Range Detected data with multilook intensity only (systematically distributed) (typical size 1GB/product)

*Pre-processing: Multilook (20m resolution)-Radiometric calibration to Sigma nought)-
Geocorrection-Terrain Correction with SRTM 30m using Range-Doppler Terrain Correction-
Speckle Filtering using Lee filter;*

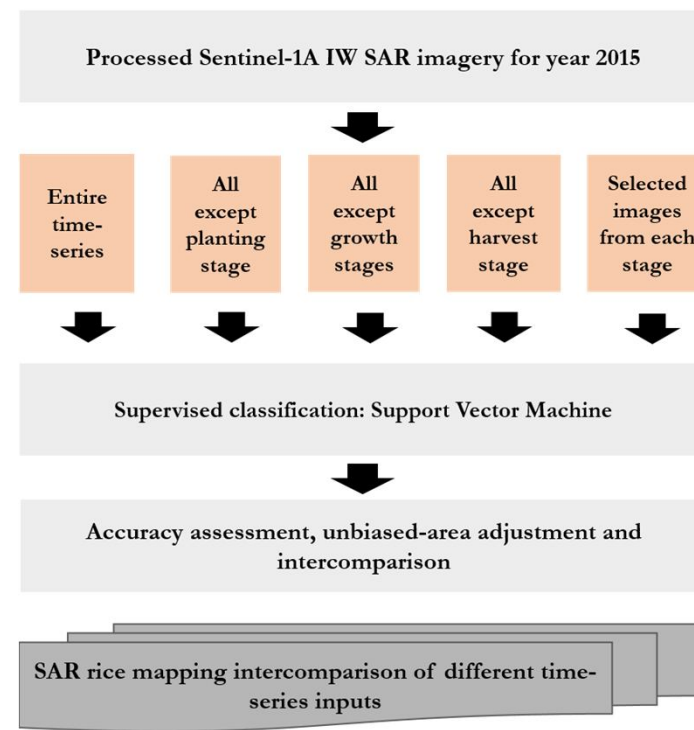
Research Objectives/ Questions

- How well do the different scenarios of time-series SAR inputs for paddy rice mapping compare?
- What are the resulting map accuracies and uncertainty; Do scenarios with imagery from selected crop stages perform well compared to full time-series?
- How much of the land area is attributed to single cropped rice versus double cropped rice?

Research Objectives

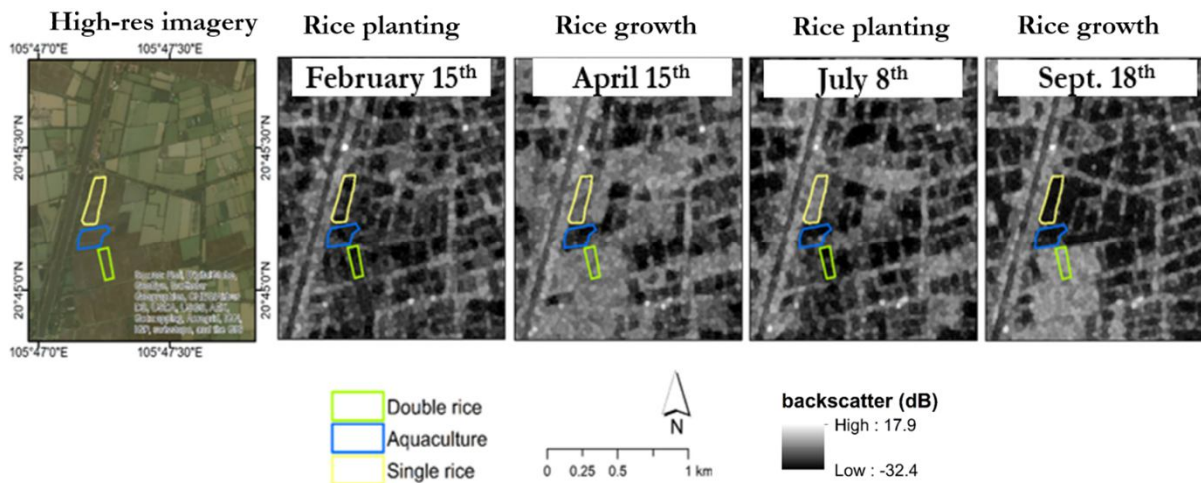
- Compare 5 different time-series mapping scenarios using SVM classification
- Evaluate accuracy, determine unbiased areal estimates and compare variation

Scenario	Input images	Number of images
Scenario 1	Entire time-series	46
Scenario 2	All images except planting stage	32
Scenario 3	All images except growth stage	22
Scenario 4	All images except harvest stage	25
Scenario 5	Images selected from each stage	18



Double and Single Cropped Rice Phenology

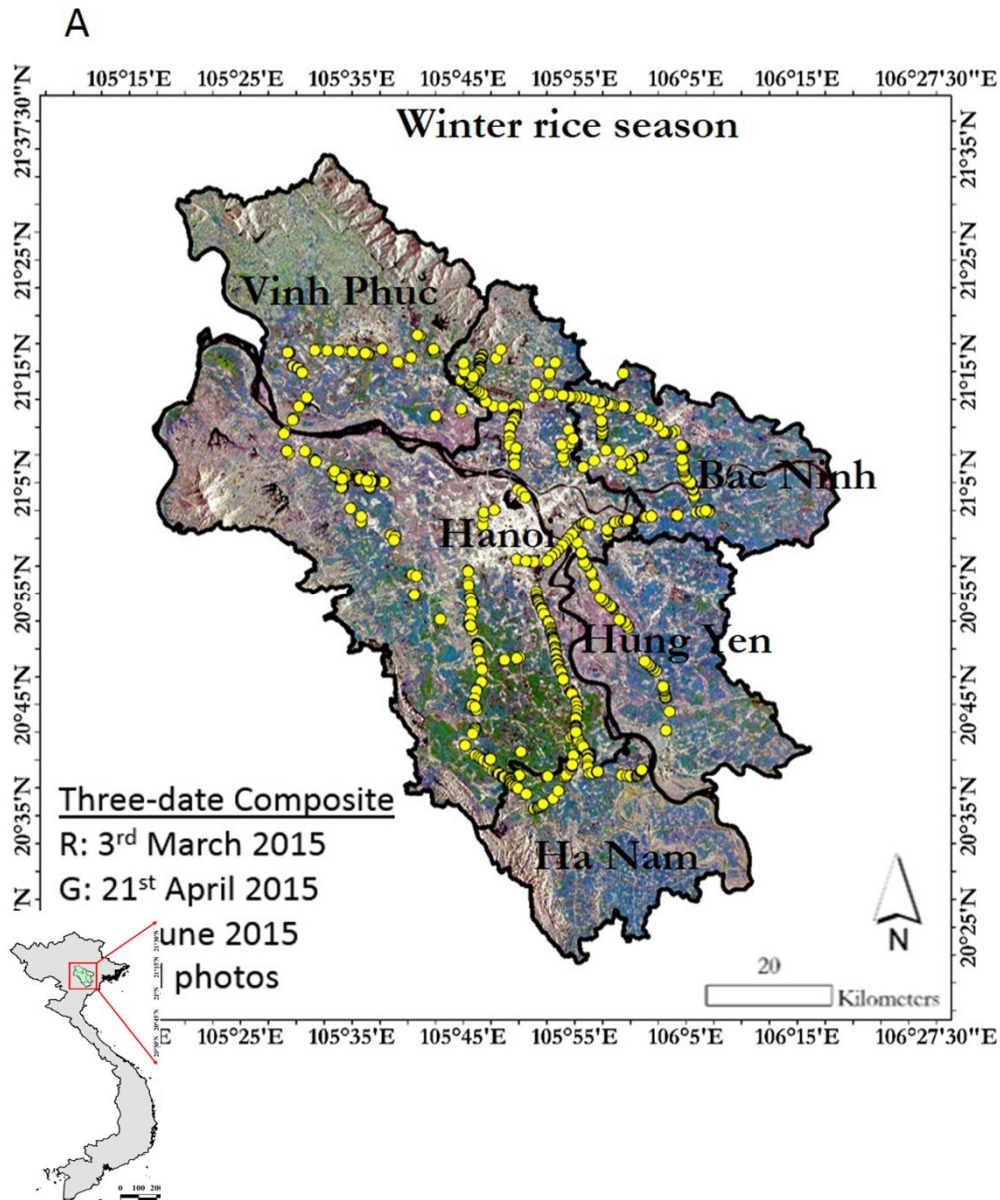
- Two seasons of rice (winter and spring)
- Some locations only plant winter rice and leave fields flooded for aquaculture



	J	F	M	A	M	J	J	A	S	O	N	D
Spring Paddy Rice												
Winter Paddy Rice												
Scenario 1												
Scenario 2												
Scenario 3												
Scenario 4												
Scenario 5												

Sowing	Blue
Growing	Green
Harvest	Yellow

Field Data Collection

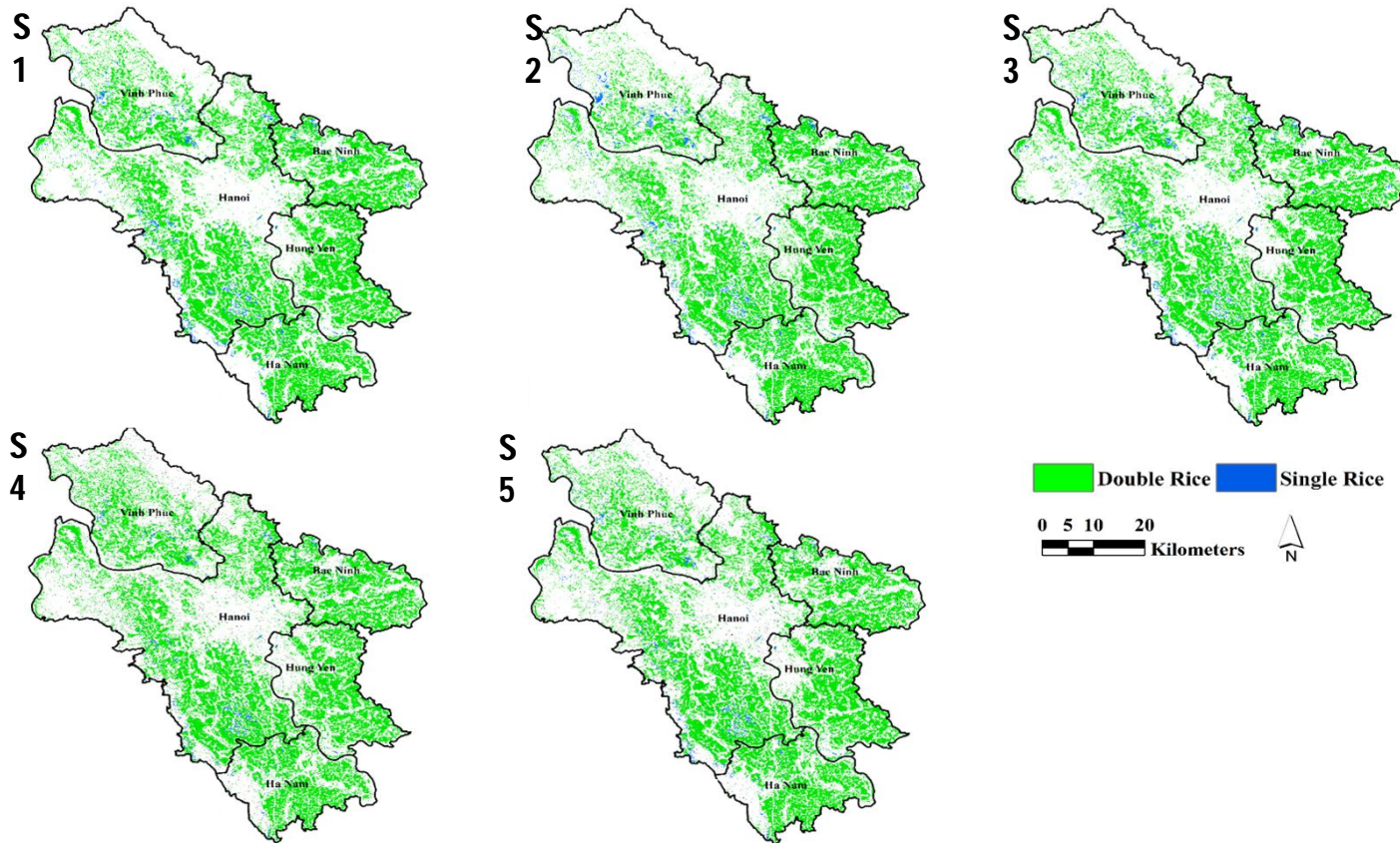


Fieldwork was conducted during May-June and September-October, 2016.

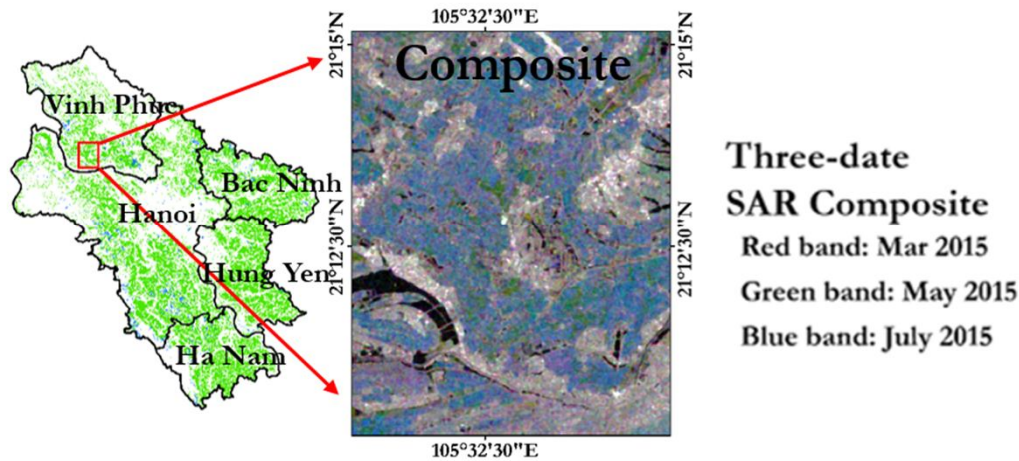
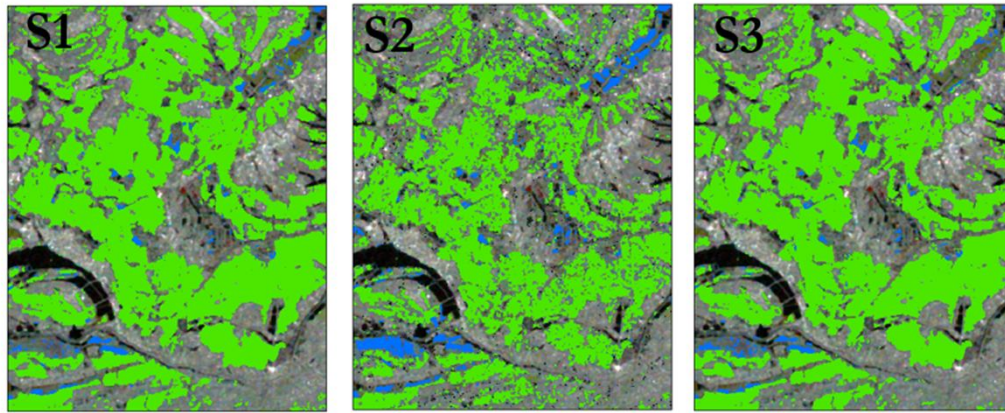
Surveys on the crop calendar, field conditions, and crop rotation, with 921 geotagged photos of rice paddy fields and non-rice areas.

In addition very high resolution Google Earth Imagery + images from the EOMF library of georeferenced field photos (Xiao et al 2011), were used as training data for SVM classification.

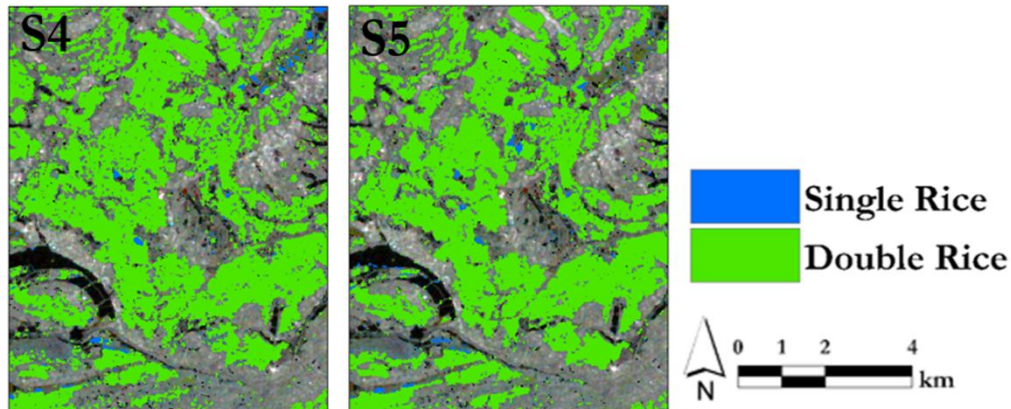
SVM Results



20m spatial resolution SAR-based paddy rice maps for each scenario. Most variation in Vinh Phuc province with Single cropped rice.



Three-date
SAR Composite
Red band: Mar 2015
Green band: May 2015
Blue band: July 2015



Close-up view in rice-dominated area bordering Hanoi and Vinh Phuc Provinces showing general agreement among scenarios 1,3, and 5, but with most notable variation in planting (S2) and harvesting (S4) stages.

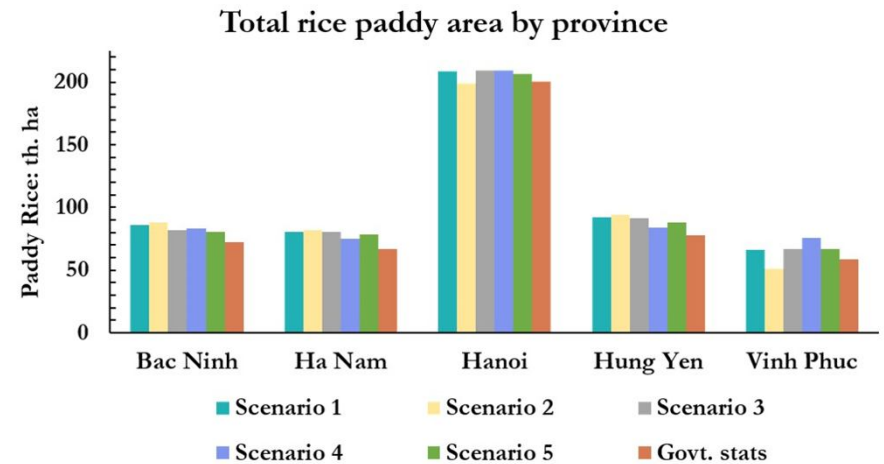
Results

Ground Truth							Ground Truth						
Scenario 1	Class	Double rice	Single rice	Non-rice	Total	Adj. User's accuracy	Scenario 4	Class	Double rice	Single rice	Non-rice	Total	Adj. User's accuracy
	Double rice	1458	6	118	1582	92.2%		Double rice	1404	15	192	1611	87.2%
	Single rice	41	530	27	598	88.6%		Single rice	4	522	32	558	93.5%
	Non-rice	85	8	2023	2116	95.6%		Non-rice	176	7	1944	2127	91.4%
	Total	1584	544	2168	4296			Total	1584	544	2168	4296	
	Adj. producer's accuracy	92.0%	78.1%	96.0%				Adj. Producer's accuracy	84.5%	58.5%	93.6%		
						Adj. Accuracy 94.3% ($\pm 0.74\%$)							
Scenario 2	Class	Double rice	Single rice	Non-rice	Total	Adj. User's accuracy	Scenario 5	Class	Double rice	Single rice	Non-rice	Total	Adj. User's accuracy
	Double rice	1341	23	219	1583	84.7%		Double rice	1427	8	132	1567	91.1%
	Single rice	15	489	60	564	86.7%		Single rice	28	524	34	586	89.4%
	Non-rice	228	32	1889	2149	87.9%		Non-rice	129	12	2002	2143	93.4%
	Total	1584	544	2168	4296			Total	1584	544	2168	4296	
	Adj. Producer's accuracy	79.8%	48.2%	92.5%				Adj. Producer's accuracy	88.4%	65.1%	95.5%		
						Adj. Accuracy 86.8% ($\pm 1.16\%$)							
Scenario 3	Class	Double rice	Single rice	Non-rice	Total	Adj. User's accuracy							
	Double rice	1442	16	134	1592	90.6%							
	Single rice	24	498	31	553	90.1%							
	Non-rice	118	30	2003	2151	93.1%							
	Total	1584	544	2168	4296								
	Adj. producer's accuracy	89.4%	50.3%	95.4%									
						Adj. Accuracy 92.2% ($\pm 0.88\%$)							

Error matrices for each scenario. The values are the number of pixels for each category. The bias-adjusted producer, user, and overall accuracies are provided in the table. The overall accuracies for the maps range from 86.8% to 94.3% with 95% confidence intervals shown in parentheses.

Results

	Class	Classified area (ha)	Accuracy-adjusted area (ha)	95% Confidence Interval (ha)
Scenario 1	Double rice	260,519	260,892	255,481-266,303
	Single rice	11,544	13,095	11,546-14,644
	Non-rice	497,207	495,283	489,779-500,787
Scenario 2	Double rice	251,363	266,955	258,717-276,193
	Single rice	12,026	21,590	18,581-24,599
	Non-rice	505,881	480,724	472,878-488,570
Scenario 3	Double rice	259,575	262,935	256,784-269,086
	Single rice	10,785	19,266	16,449-22,083
	Non-rice	498,910	487,068	480,735-493,402
Scenario 4	Double rice	260,166	268,398	261,137-275,660
	Single rice	6,199	9,835	8,923-10,747
	Non-rice	502,905	491,036	484,085-497,987
Scenario 5	Double rice	256,629	264,452	258,038-270,867
	Single rice	8,627	11,837	9,951-13,723
	Non-rice	504,013	492,980	487,046-498,914



Classified map areas and accuracy for Single and double crop for different provinces

Rice paddy areas for different provinces

Results

Scenario	Input images	Number of images	Classification accuracy (%)
Scenario 1	Entire time-series	46	94.3
Scenario 2	All images except planting stage	32	86.8
Scenario 3	All images except growth stage	22	92.2
Scenario 4	All images except harvest stage	25	89.9
Scenario 5	Images selected from each stage	18	92.6

Conclusion

- *Using all time-series data for mapping can be computationally intensive for large areas.*
- *Targeted acquisitions at selected phenological stages can provide as accurate results as full time-series (in our case it is 40% less images compared to full time series).*