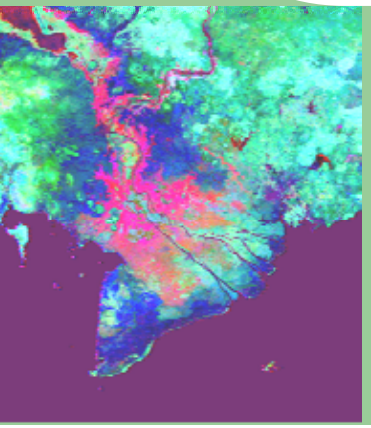
The 33rd Asian Conference on Remote Sensing
Pattaya, November 26-30, 2012

RICE MONITORING IN THE MEKONG DELTA, VIETNAM



Nguyen Lam-Dao VAST, Vietnam
Thuy Le-Toan CESBIO, France
Armando Apan USQ, Australia
Juliane Huth DLR, Germany
Phung Hoang-Phi VAST, Vietnam

Contents

1. Introduction
2. Data and method used
3. Results
4. Conclusions

Introduction

Research projects:

RICEMAN: Rice & Mangrove monitoring in Southern Vietnam (TerraSAR-X & ENVISAT-ASAR, 2010-2011)

Radar data

UNIVERSITY OF SOUTHERN QUEENSLAND

Rice crop monitoring using new generation synthetic aperture radar (SAR) imagery (ENVISAT-ASAR, 2007-08)

esa

Utilisation of SAR data for rice crop monitoring (ERS2-SAR, 1997-98)

Optical data

Introduction: Mekong Delta and study sites

Introduction

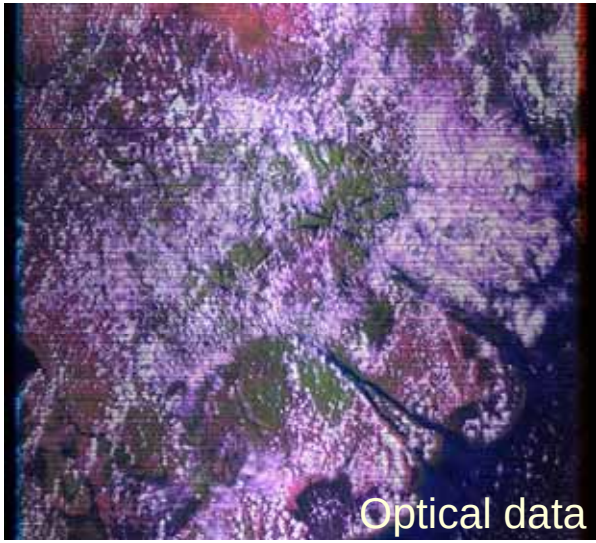
Why Remote Sensing ?

Satellite remote sensors can provide us synoptic measurements on large areas, near real time and low cost comparing to other traditional techniques.

Why Radar RS ?

- **All weather capability** (small sensitivity of clouds, light rain);
- **Day and night operation** (independence of sun illumination);
- **No effects of atmospheric constituents** (multi-temporal analysis);
- Etc.


Radar data


Optical data

Introduction: Spaceborne SARs

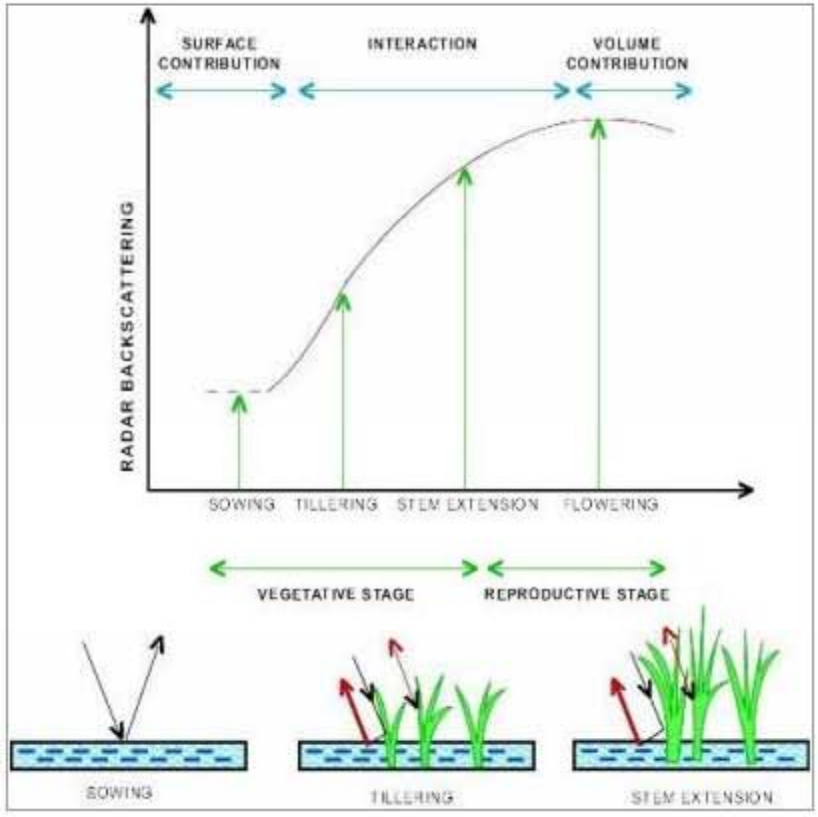
Satellite	Years	Agency	Frequency - Polarisation	Resolution - Swath	Special
ERS-1	1991-2000	ESA	C - VV	25 m 100 km	Interferometry (with ERS-2)
JERS	1992-1998	NASDA	L-HH	25 m 100 km	Region. mosaic available
ERS-2	1995	ESA	C - VV	25 m 100 km	Interferometry (with ERS-1)
RADARSAT-1	1995	CSA	C - HH	10 -100 m 45 - 500 km	Multi-incidence
ENVISAT - ASAR	2002	ESA	C - HH/VV/HV	25 - 1000 m 50 - 500 km	Multi-incidence
ALOS - PALSAR	2006-2011	JAXA	L - Polarimetric	10 - 100 m 100 - 350 km	Multi-incidence
TerraSAR-X	2007	DLR	X-Polarimetric	1 m	Interferometry 1 day
RADARSAT 2	2007	CSA	C - Polarimetric	< 10 m	Multi-incidence

New satellites: COSMO-SkyMed, RISAT, ALOS-2 & Sentinel-1 (2013)

Introduction

Why Radar RS for Rice ?

- Growing mainly in **tropical regions**;
- Rice: **staple food**;
- Population growth and Climate change → **Food security**.

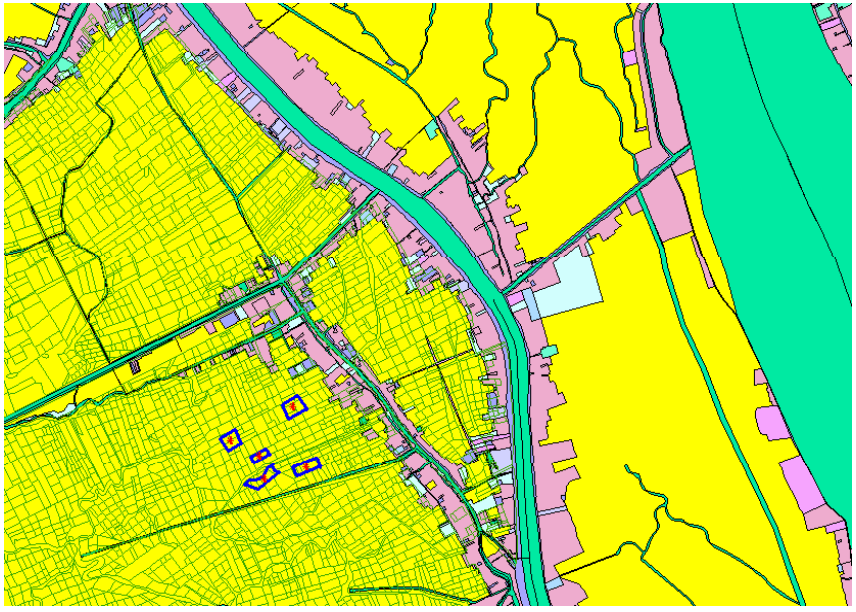


Operational System for Rice Crop Inventory

Introduction

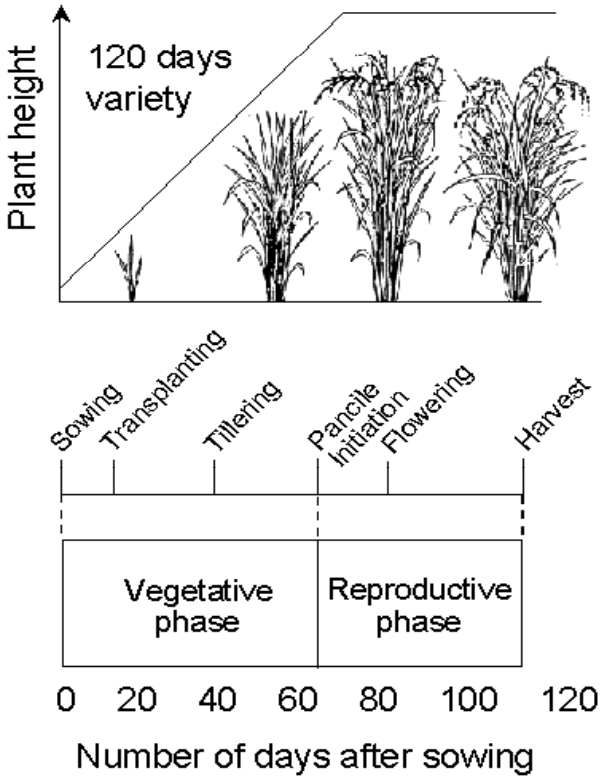
Why Radar RS for Rice in Mekong Delta ?

- **Size of rice field** ranging from small (0.5 – 2 ha) to large;
- **Sowing dates** are different from field to field (1-2 weeks);
- Different **rice cropping systems** from one area to another;
- **Cultural practices** (sowing, transplanting);
- **Seeds**.



Rice growing stages

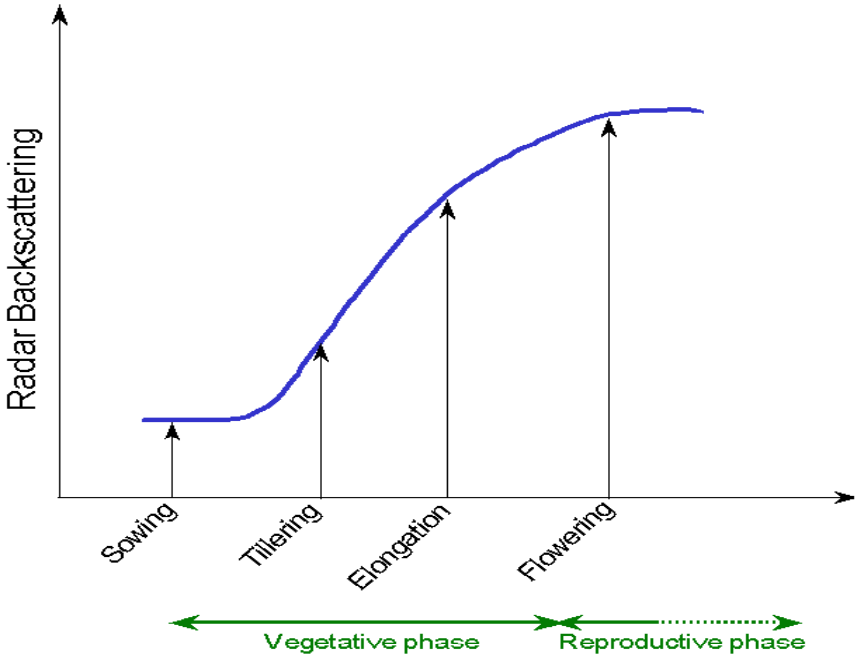
- The sowing-transplanting period;
- The growing period:
  1. **Vegetative** stage,
  2. **Reproductive** stage,
  3. **Ripening** stage;
- Fallow.



Pictures of rice growing stages

Physical basis of the radar backscatter from rice fields

- Before sowing: **very low** radar backscattering;
- During the vegetative phase: **steady increase** of the radar response;
- At the end of the ripening: **slight decrease** of the σ^o
- After the harvest: **low** radar backscattering.



Previous studies

Methods for rice mapping:

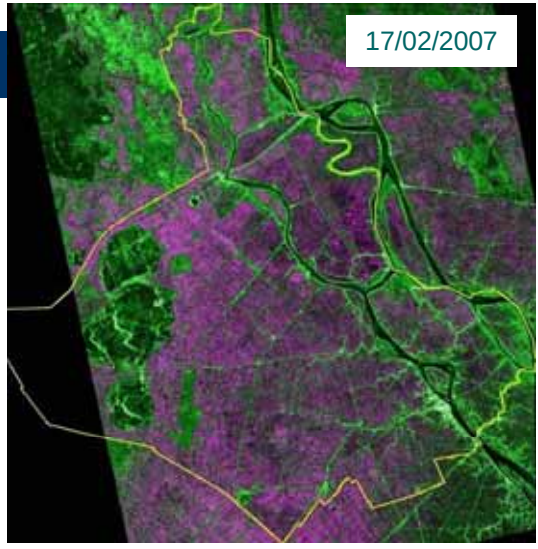
- Visual interpretation;
- Unsupervised classification;
- Maximum likelihood classifier;
- Artificial neural network classifier;
- Knowledge-based classifier;
- Temporal change measurement;
- Objected-oriented classifier;
- Single-date mapping algorithm;
- PCA based method.

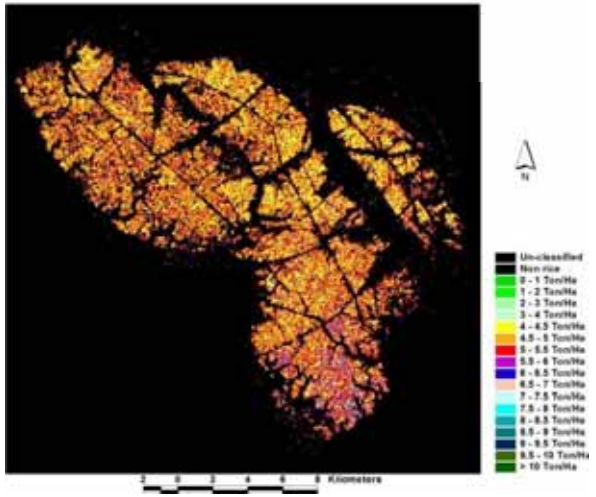
Methods for yield estimation:

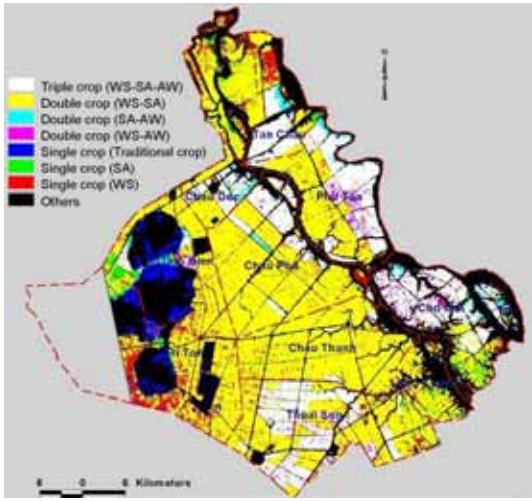
- Agro-meteorological model (AMM);
- Statistical model.

Objectives

- To evaluate the use of SAR data in **rice mapping** and **yield estimation**, towards **an operational system** for rice crop inventory in the Mekong Delta, Vietnam.

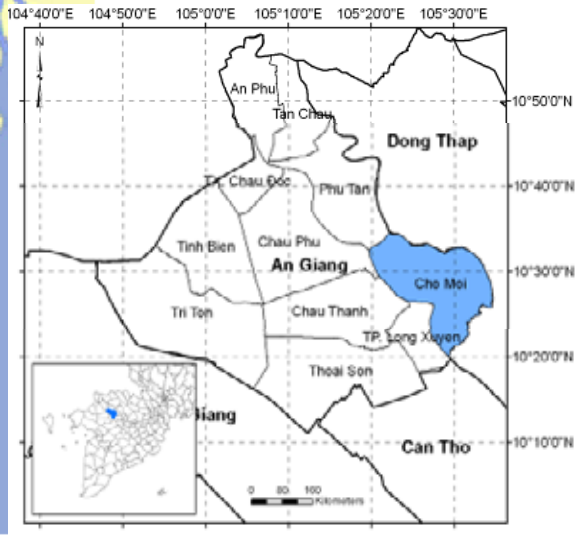






Study area: An Giang, Mekong Delta

- In 2011, An Giang: **3,843,600** ton; MD: **23,186,300** ton; VN: **42,324,900** ton (GSO, Vietnam)
- Rice cropping system: 1, 2 or 3 crop seasons
- Affected by flood: Strong
- Distance to HCMC: 200 km
- Local support: AGU, CLRRI



Rice cropping systems

Rice cropping system	Rice season
Single rice crop	Traditional rice (rain-fed)
Double rice crop	Summer Autumn – Autumn Winter (rain-fed)
	Winter Spring – Summer Autumn (irrigated)
Triple rice crop	Winter Spring – Summer Autumn - Autumn Winter

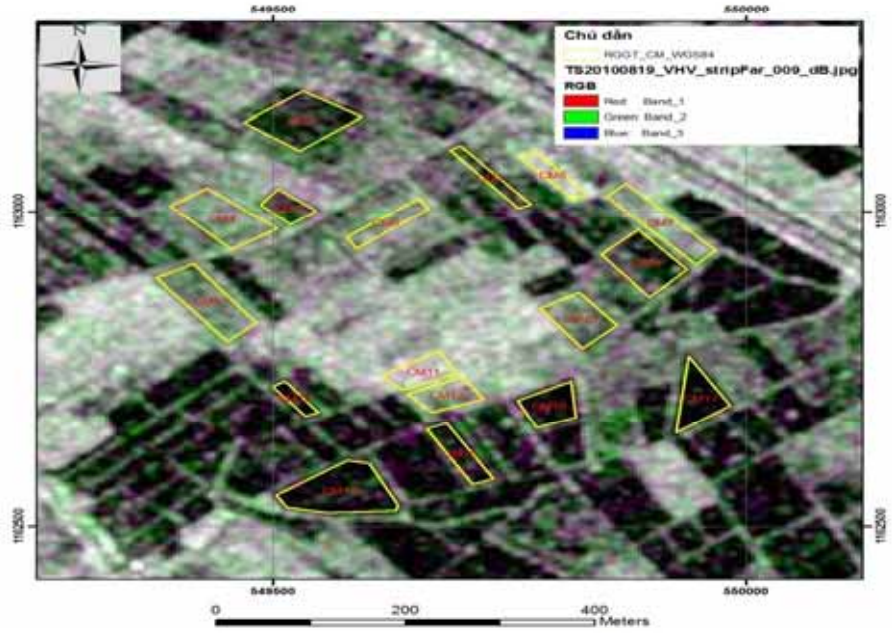
Main rice-based cropping systems

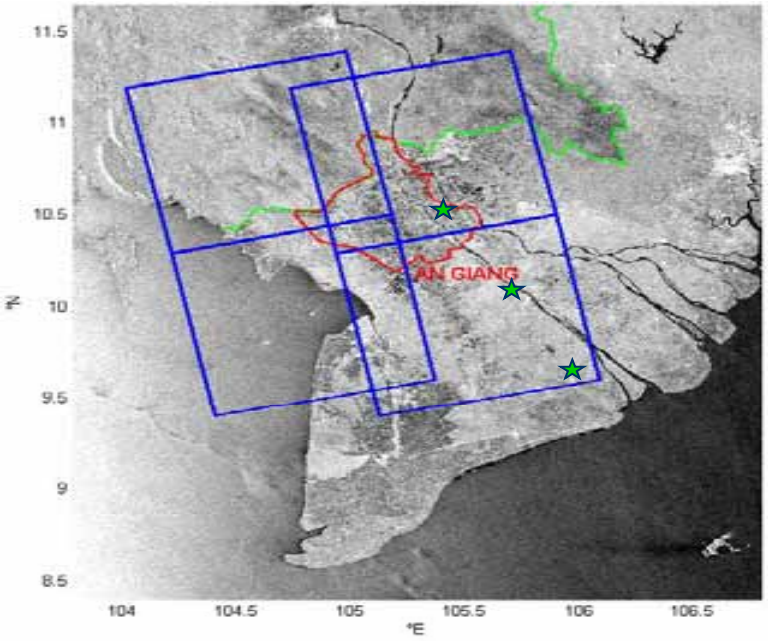
Rice seasons

Rice crop		Planting	Harvesting
English name	Local name		
Winter Spring	Dong Xuan	Nov./Dec.	Mar./Apr.
Summer Autumn	He Thu	Apr./May	Jul./Aug.
Rainy season	Thu Dong (Autumn Winter)	Jul./Sep.	Oct./Dec.
	Mua (Traditional rice)	Jul./Sep.	Nov./Jan.

Main rice seasons

Methods – Sample rice fields





Sample rice fields in Cho Moi (An Giang)

Ground data collection at Cho Moi district

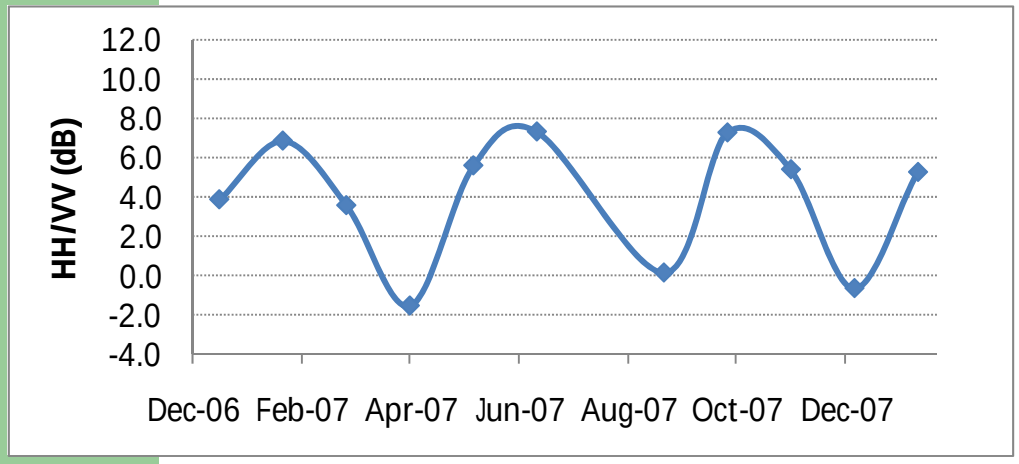
SAR data used

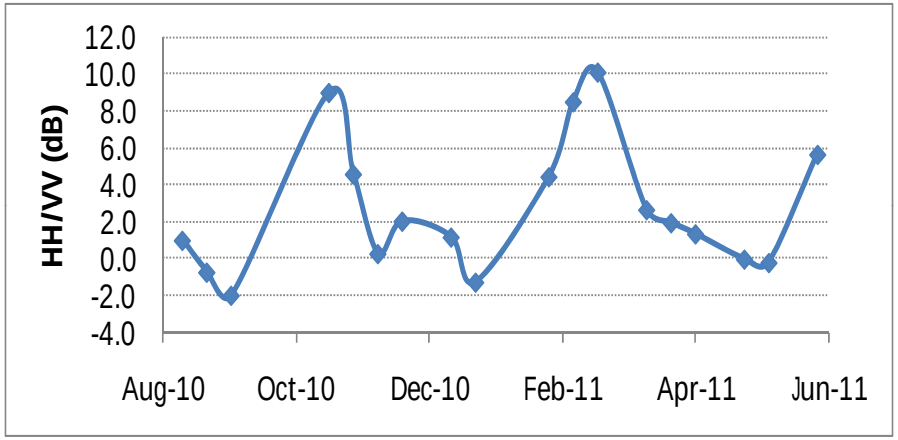
TerraSAR-X data:
- Band: X
- Wavelength: 3.1 cm
- Polarisation: HH&VV
- Resolution: 3 m (SM)

ENVISAT ASAR data:
- Band: C
- Wavelength: 5.6 cm
- Polarisation: HH&VV
- Resolution: 30 m (APP)

No.	Sensor-Mode	Date of image	No.	Sensor-Mode	Date of image	No.	Sensor-Mode	Date of image
1	ASAR APP	13-Jan-07	11	ASAR APP	22-Feb-08	21	TSX SM	31-Jan-11
2	ASAR APP	17-Feb-07	12	TSX SM	19-Aug-10	22	TSX SM	11-Feb-11
3	ASAR APP	24-Mar-07	13	TSX SM	30-Aug-10	23	TSX SM	22-Feb-11
4	ASAR APP	28-Apr-07	14	TSX SM	10-Sep-10	24	TSX SM	16-Mar-11
5	ASAR APP	2-Jun-07	15	TSX SM	24-Oct-10	25	TSX SM	27-Mar-11
6	ASAR APP	07-Jul-07	16	TSX SM	04-Nov-10	26	TSX SM	07-Apr-11
7	ASAR APP	15-Sep-07	17	TSX SM	15-Nov-10	27	TSX SM	29-Apr-11
8	ASAR APP	20-Oct-07	18	TSX SM	26-Nov-10	28	TSX SM	10-May-11
9	ASAR APP	24-Nov-07	19	TSX SM	18-Dec-10	29	TSX SM	01-Jun-11
10	ASAR APP	29-Dec-07	20	TSX SM	29-Dec-10			

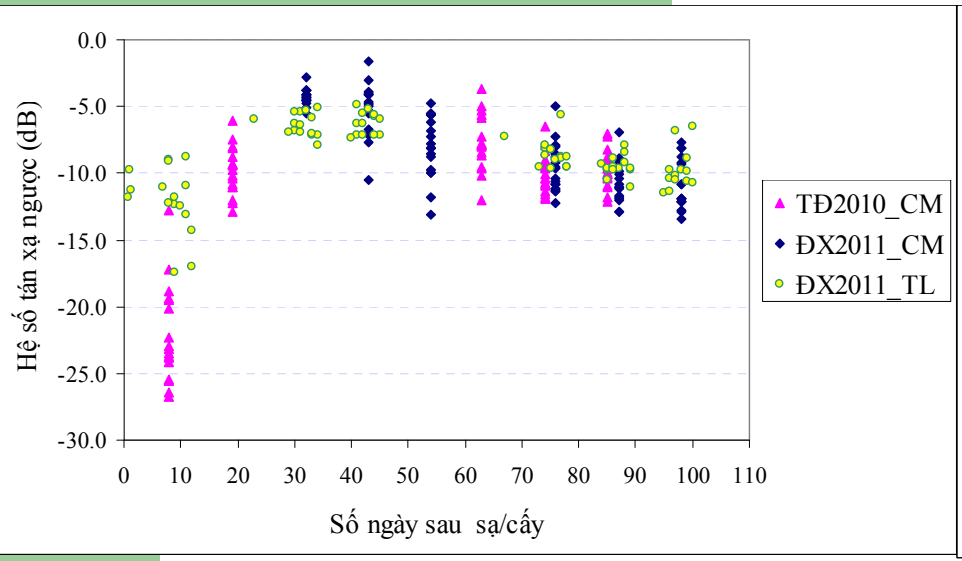
Results – Rice backscatter analysis

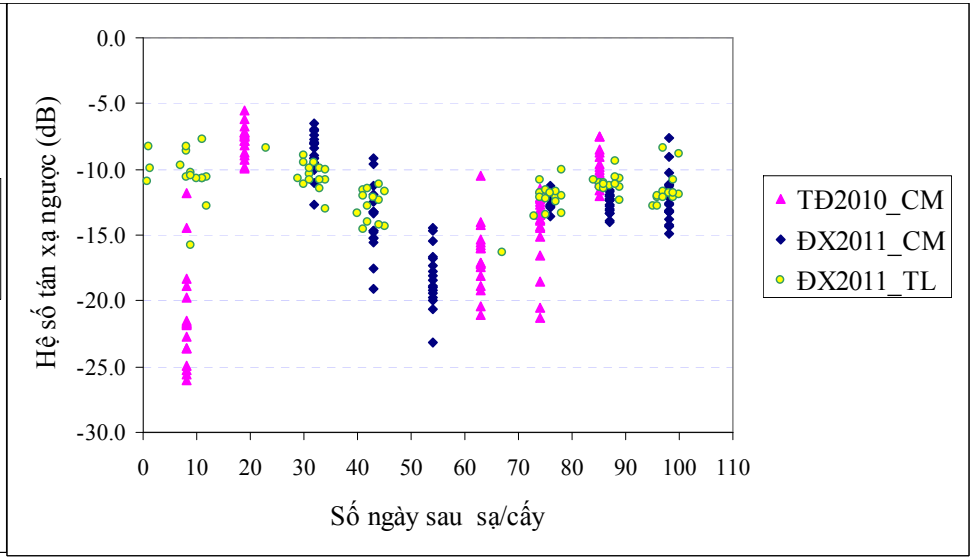


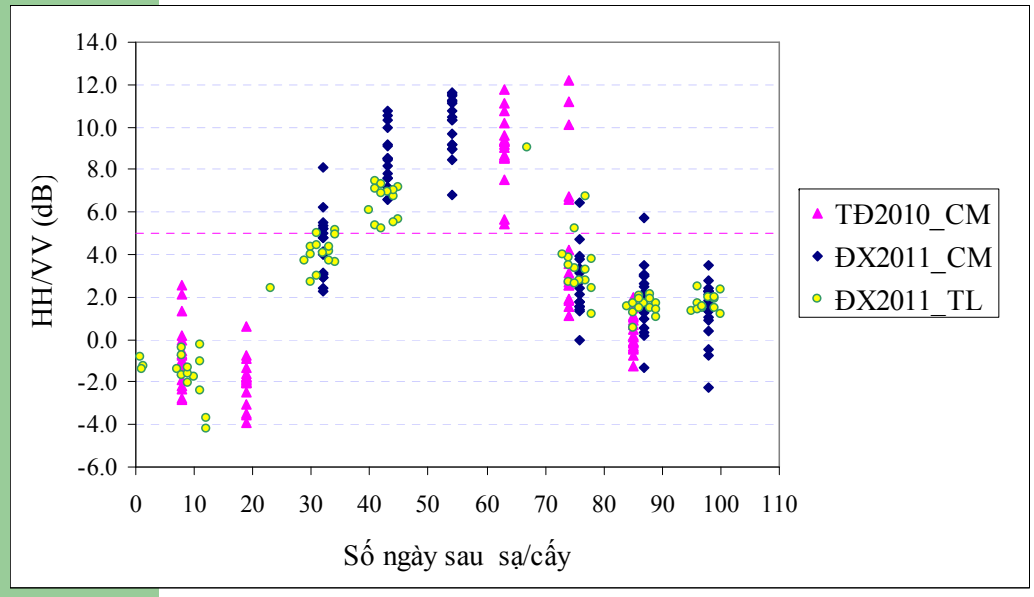


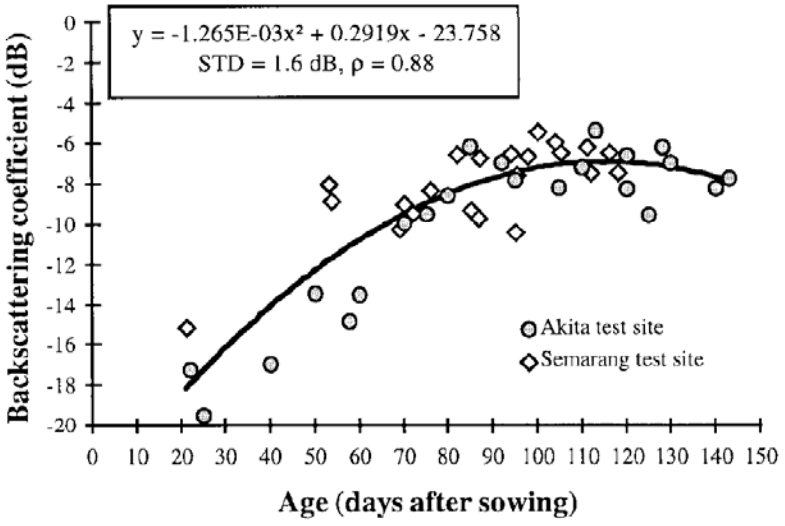
Temporal variation of average polarization ratio HH/VV of ASAR APP (left) and TSX SM (right) for sample rice fields in Cho Moi

Results – Rice backscatter analysis of TSX SM (2010-2011)



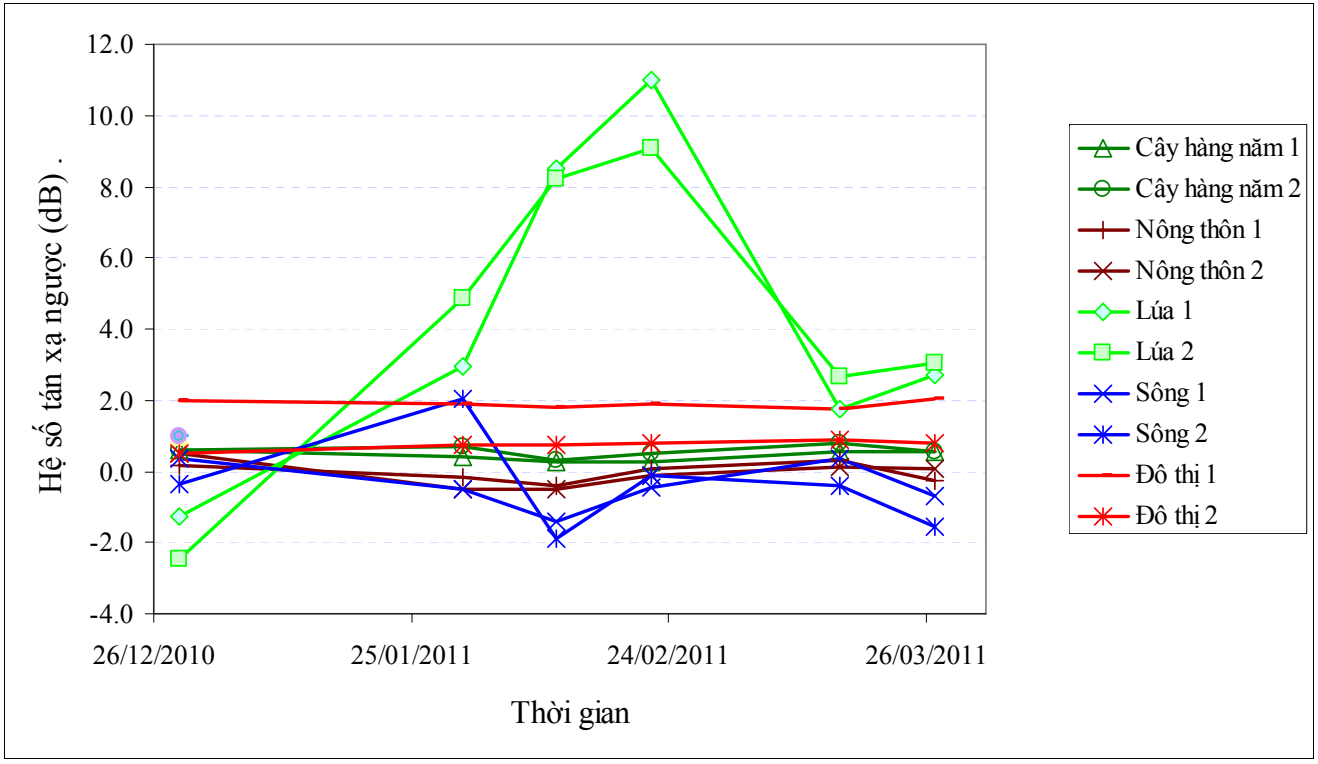






δ_O charts of HH (UL), VV (UR) & HH/VV (LL) data

Results – Rice backscatter analysis (2010-2011)



HH&VV ratio of land use / land cover classes

Rice mapping (2010-2011)

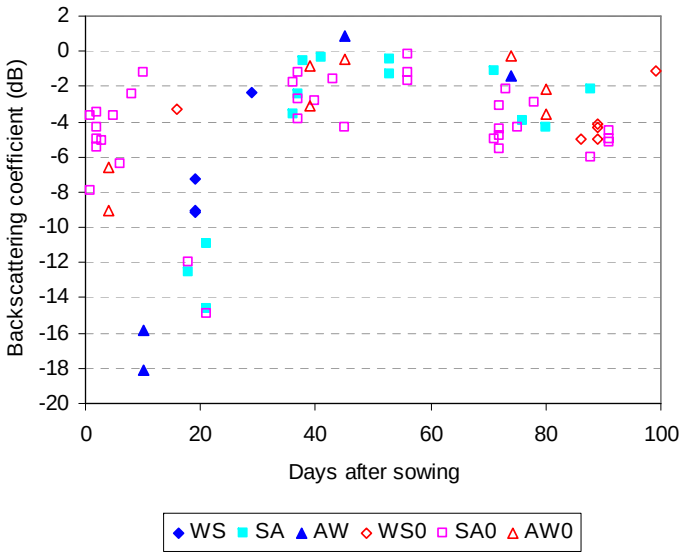
Using **single-date TSX SM image taken at the middle of crop season** (i.e. Oct. 2010 for Autumn Winter crop in Cho Moi)

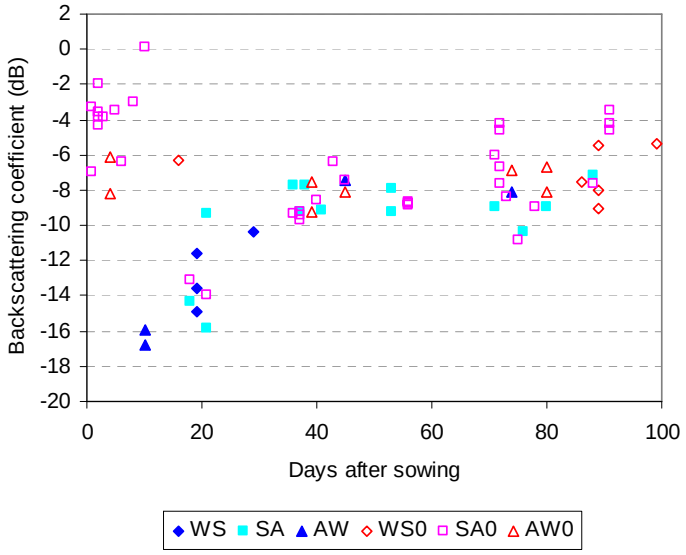
- HH/VV ratio > 5 dB

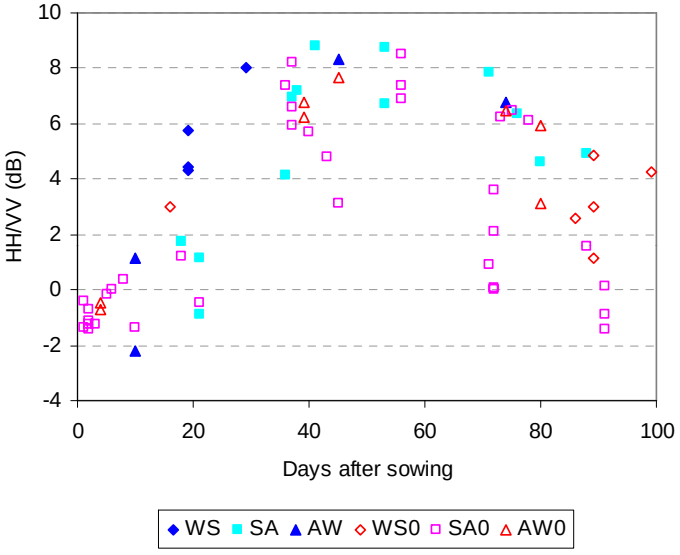
Ratio value (dB)	Rice pixels in samples (%)
3	99.6
4	98.1
5	**95.4**
6	89.4
7	80.5
8	68.9

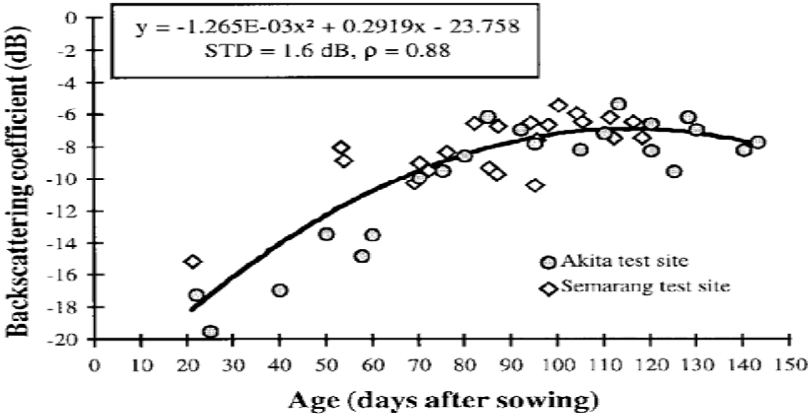
Results – Rice backscatter analysis of ASAR APP (2007)

Effect of water / no water







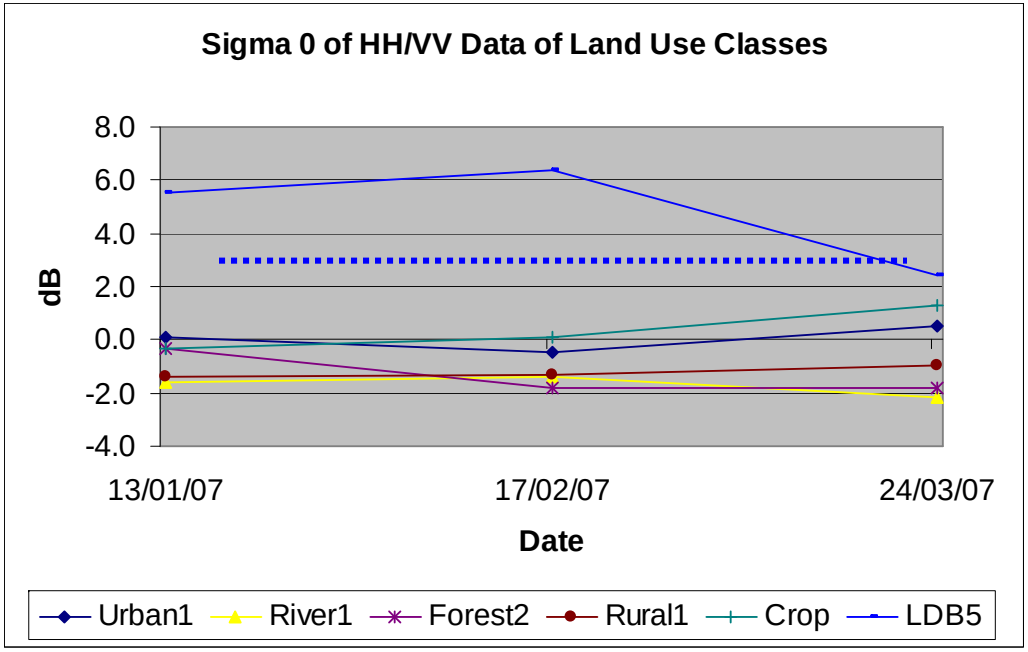


δo charts of HH (UL), VV (UR) & HH/VV (LL) data

Rice mapping (2007)

Using **single-date ASAR APP image taken at the middle of crop season** (i.e. Feb. 2007 for Winter Spring crop in An Giang)

- HH/VV ratio > 3 dB



Rice mapping (TerraSAR-X, 2011)

(a) 31/01/2011

(b) 11/02/2011

(c) 22/02/2011

(d) 31/01/2011 and 11/02/2011

(e) 31/01/2011 and 22/02/2011

(f) 31/01/2011, 11/02/2011 and 22/02/2011

Rice mapping (TerraSAR-X, 2011)

Date of TSX SM image	Estimated area (ha)	Statistical data (ha)	Percentage difference (%)
31/01/2011	8954	11992	-25.3
11/02/2011	9260	11992	-22.8
22/02/2011	7612	11992	-36.5
31/01/2011 and 11/02/2011	12065	11992	0.6
31/01/2011 and 22/02/2011	12539	11992	4.6
31/01/2011, 11/02/2011 and 22/02/2011	12846	11992	7.1

Rice mapping (ASAR, 2007)

(a) 13/01/2007

(b) 17/02/2007

(c) 24/03/2007

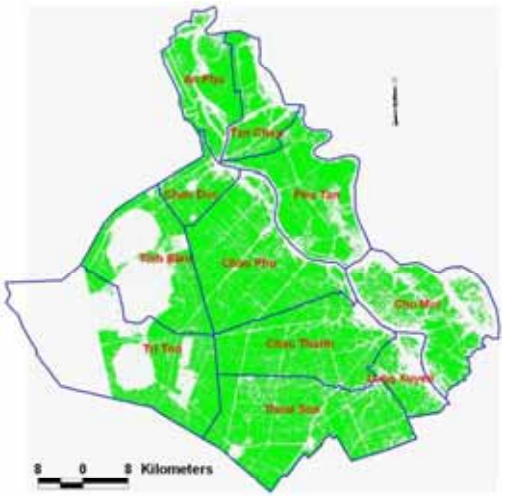
(d)13/01/2007 and 17/02/2007

(e)13/01/2007, 17/02/2007 and 24/03/2007

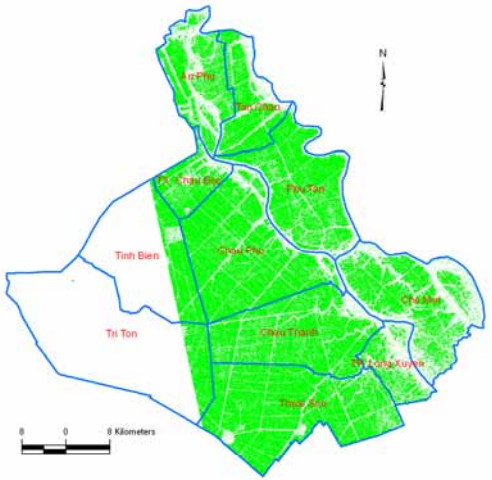
Date of ASAR APP image	Estimated area (ha)	Statistical data (ha)	Percentage difference (%)
13/01/2007	141388	193242	-26.8
17/02/2007	184123	193242	-4.7
13/01/2007 and 17/02/2007	206567	193242	6.9
13/01/2007, 17/02/2007 and 24/03/2007	209258	193242	8.3

Rice maps in An Giang from ASAR APP (2007-2011)

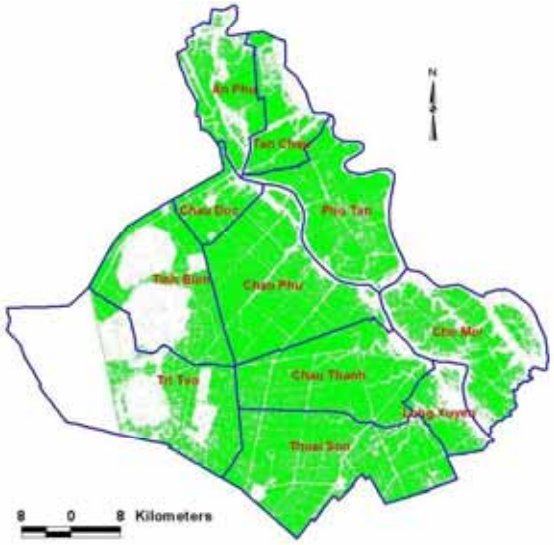
WS 2007 crop



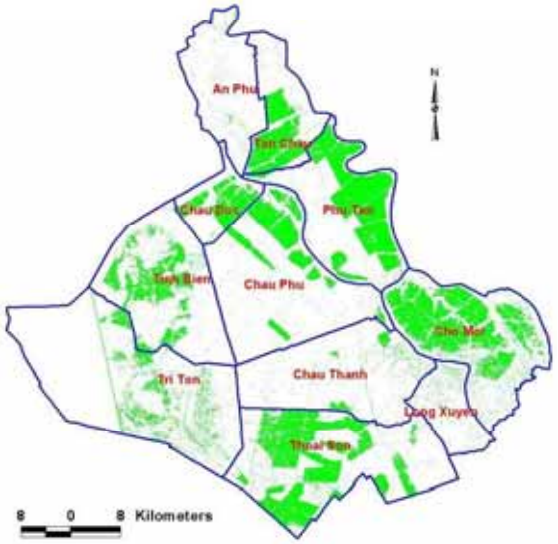
WS 2008 crop



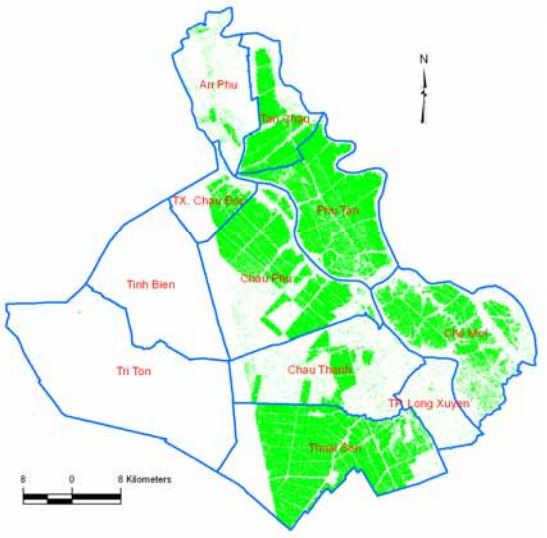
WS 2011 crop



SA 2007 crop

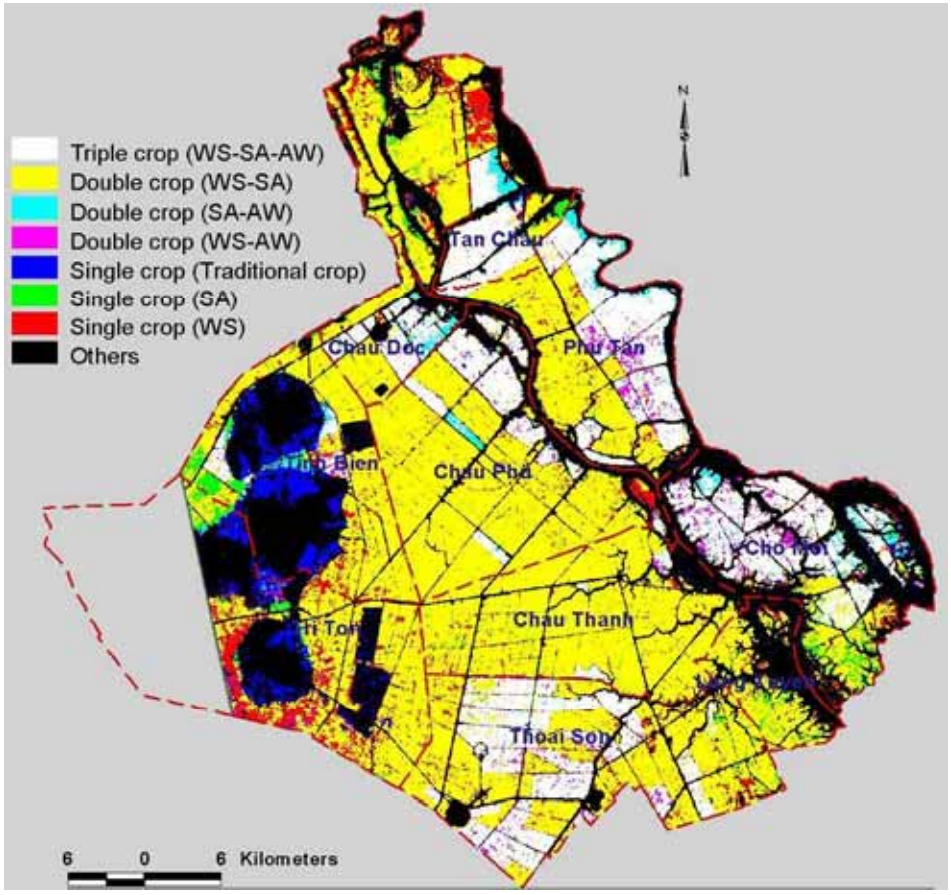


AW 2007 crop

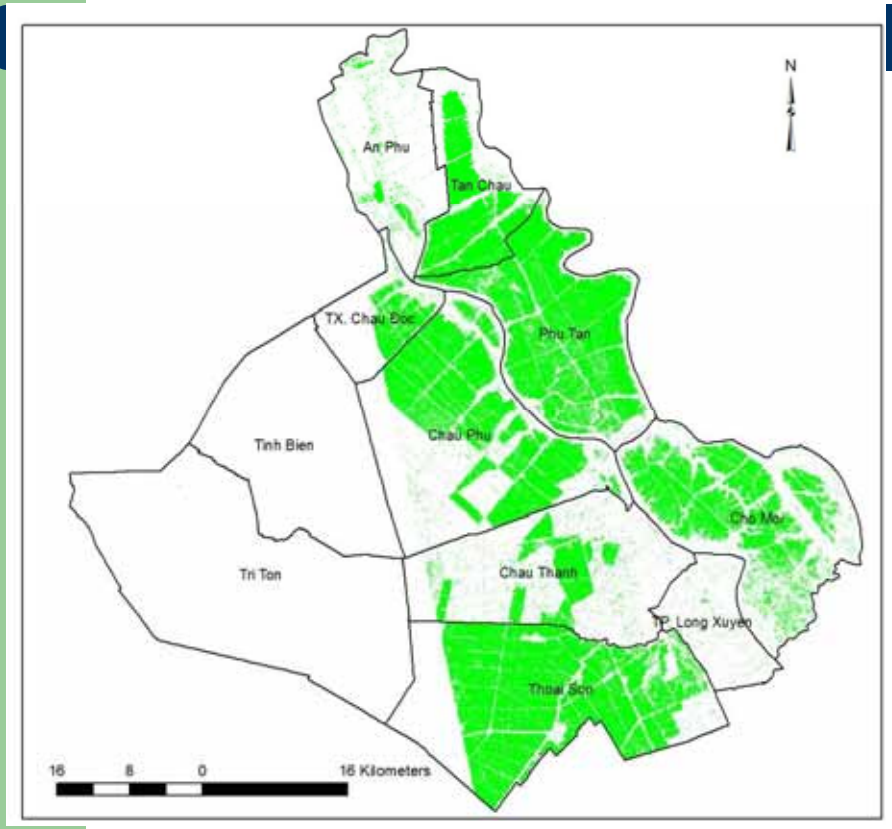


AW 2010 crop

Rice cropping system map (ASAR, 2007)

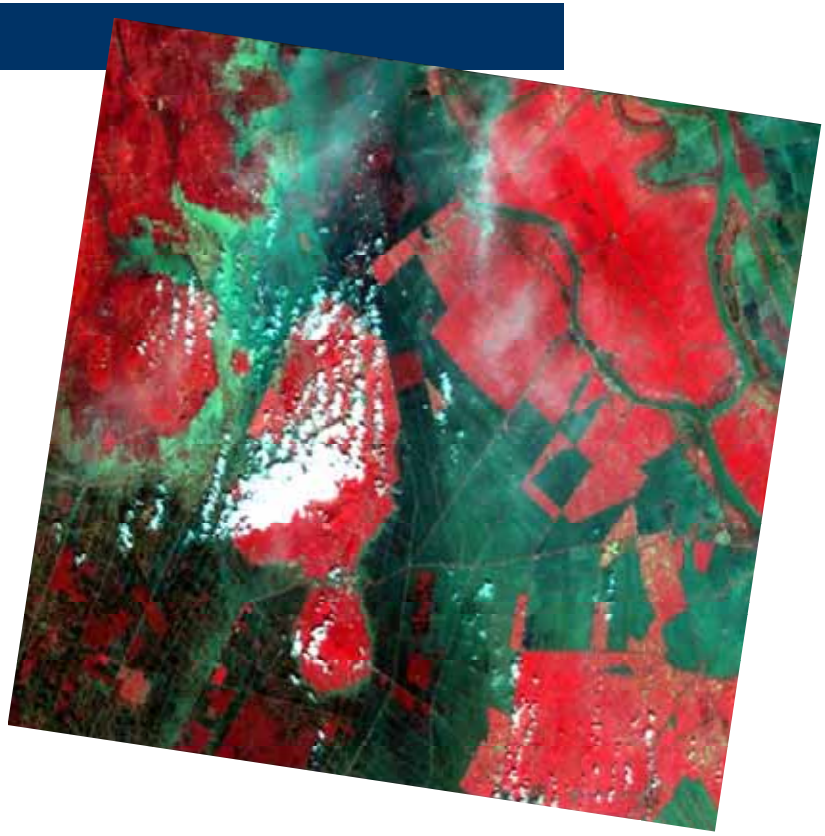


Rice map from radar and optical data (2010)



AW2010, An Giang province

(ASAR APP, 09/10/2010)

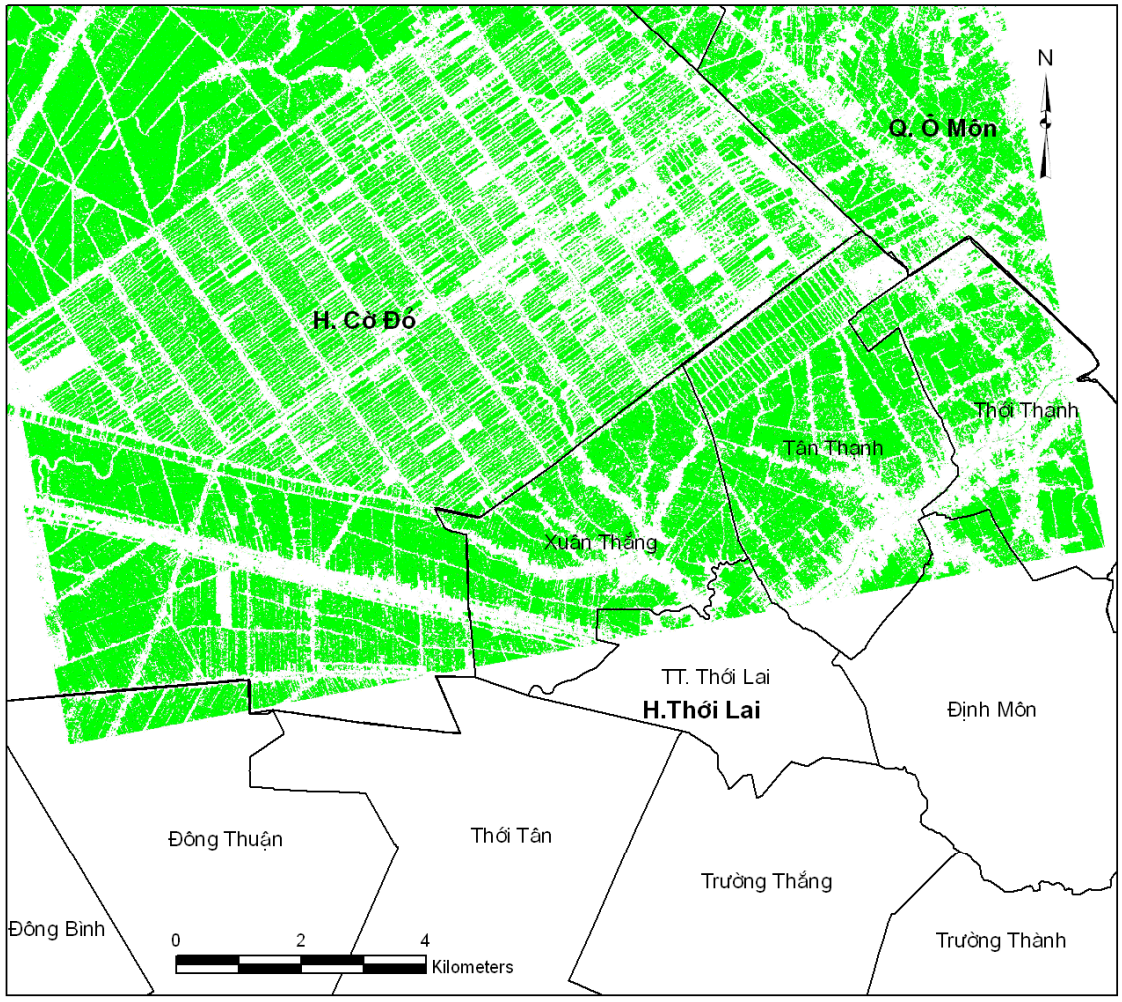


AW2010, An Giang province

(SPOT 4, 06/10/2010)

Rice mapping (2011)

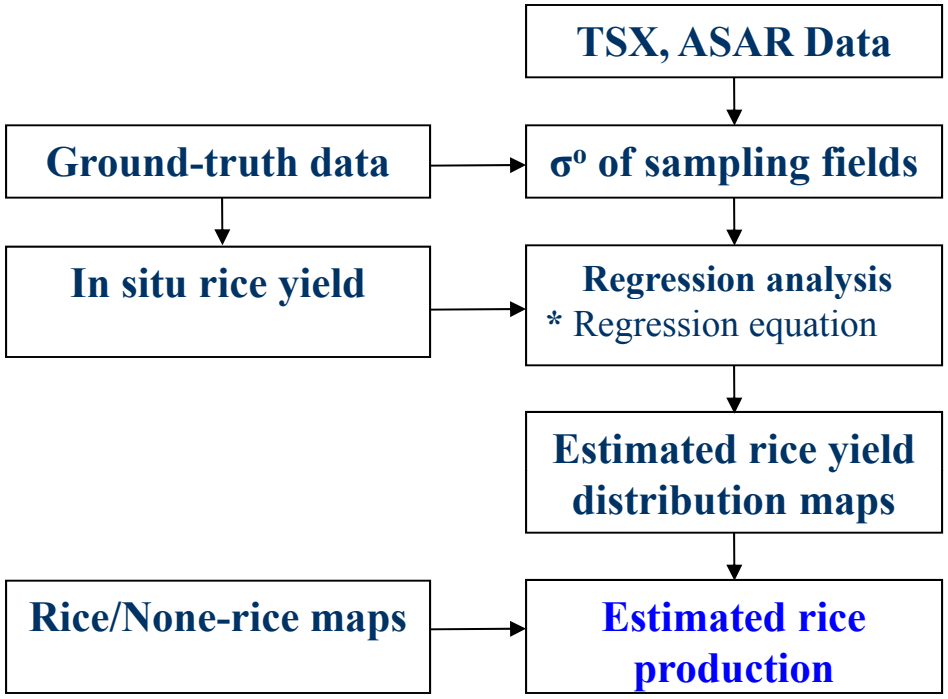
Commune Name	Rice from TerraSAR-X (ha)	Rice Statistical data (ha)	Percentage error (%)
Xuan Thang	760	877	**-13.3**
Tan Thanh	942	951	**-0.9**



Winter Spring 2011 crop in Thoi Lai (using 29/12/2010 & 31/01/2011 TSX SM)

Rice yield estimation

Statistical model based method



Statistical model (multiple linear regression analysis)

TSX SM data used (2010)

Image No.	Date of image acquisition	Number of days after sowing
1	30/08/2010	8
2	10/09/2010	19
3	24/10/2010	63
4	04/11/2010	74
5	15/11/2010	85

List of TSX SM HH&VV image acquisition date
and days after sowing in Autumn-Winter 2010 crop in Cho Moi

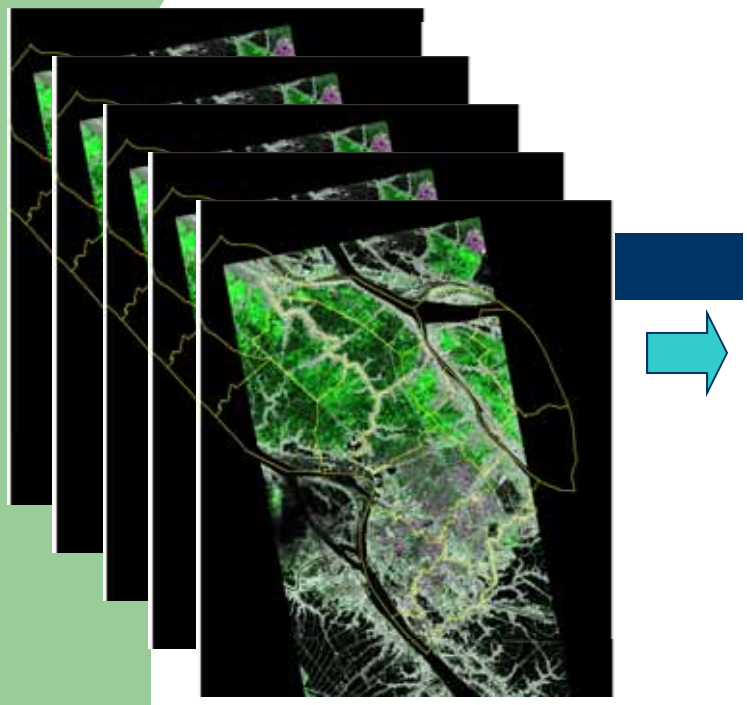
Correlation between HH/VV ratios and sample rice yield

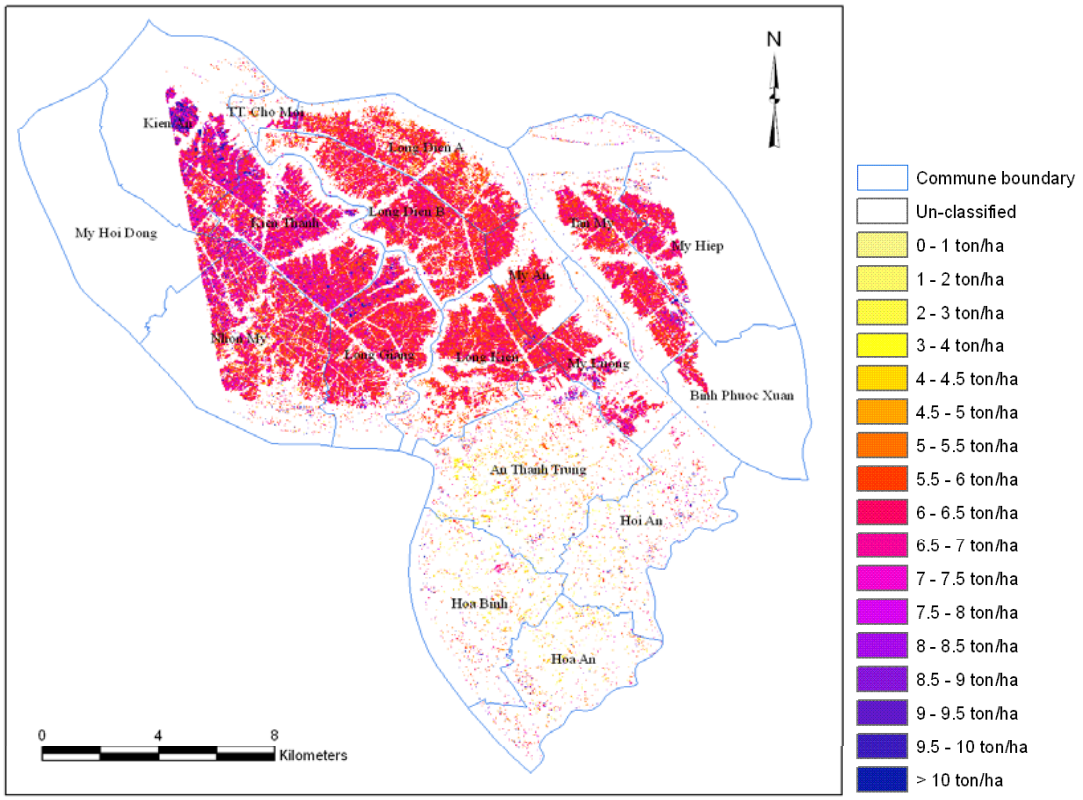
Case	Image combination	r^2
1	**1, 2, 3, 4, 5**	**0.795**
2	2, 3, 4, 5	0.795
3	1, 2, 3, 5	0.781
4	1, 3, 4, 5	0.779
5	1, 2, 3, 4	0.681
6	1, 2, 4, 5	0.494
7	**2, 3, 5**	**0.781**
8	1, 3, 5	0.765
9	3, 4, 5	0.754

Case	Image combination	r^2
10	1, 2, 3	0.659
11	1, 3, 4	0.623
12	2, 3, 4	0.614
13	1, 2, 5	0.494
14	2, 4, 5	0.401
15	1, 4, 5	0.379
16	1, 2, 4	0.088

AW 2010 Crop in Cho Moi

AW 2010 Crop, Case 1





$$Y_{Ra} = 0.0008*Ra_1 - 0.0414*Ra_2 + 0.0071*Ra_3 - 0.0009*Ra_4 + 0.0930*Ra_5 + 0.4949$$

$r^2 = 0.795$, $se_y = 0.18$ ton/ha

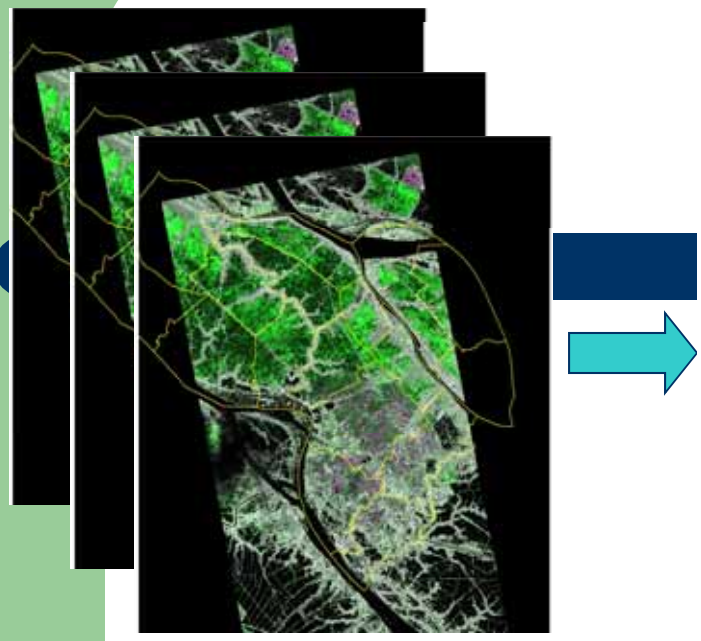
Where: Y_{Ra}: rice yield (kg/m2),

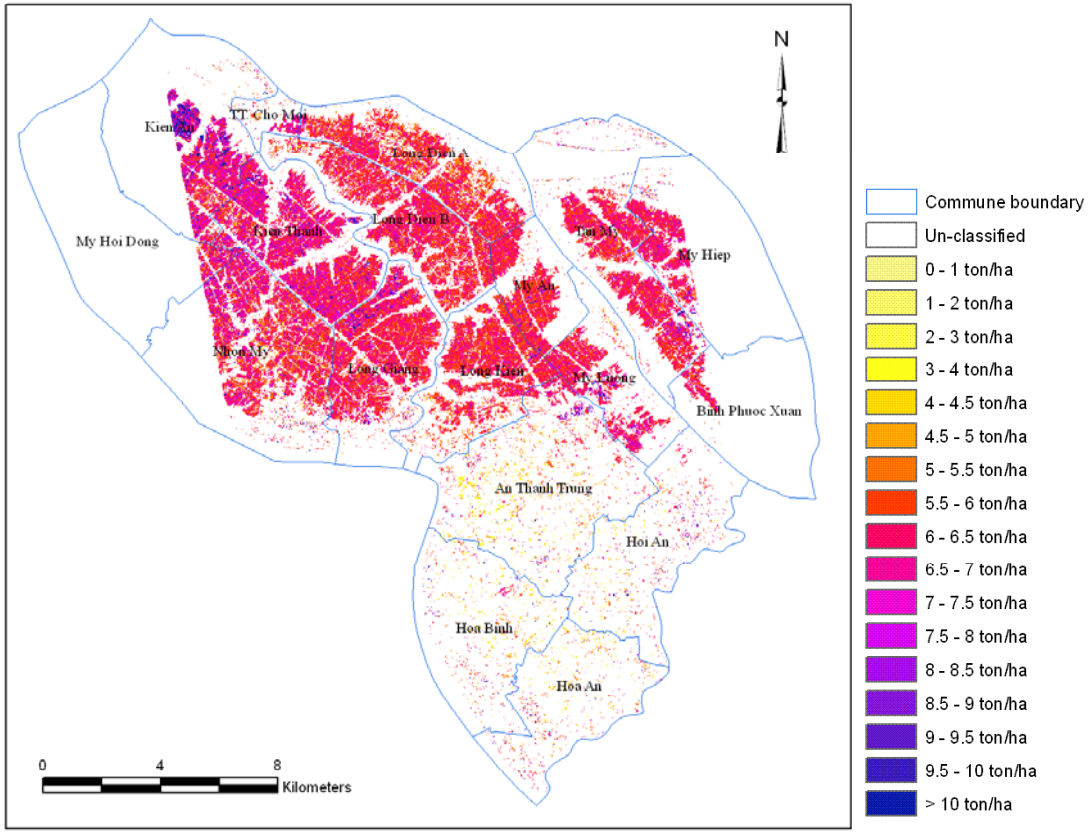
Ra_1 : polarisation ratio of first date image,
Ra_2 : polarisation ratio of second date image,
Ra_3 : polarisation ratio of third date image,
Ra_4 : polarisation ratio of four date image,
Ra_5 : polarisation ratio of five date image,
r^2 : the coefficient of determination,
se_y : the standard error for the y estimate.

A distribution map of estimated rice yield in AW 2010 crop at Cho Moi district using five-date polarisation ratios:

- SM 30/08/2010 (8)
- SM 10/09/2010 (19)
- SM 24/10/2010 (63)
- SM 04/11/2010 (74)
- SM 15/11/2010 (85)

AW 2010 Crop, Case 7





$Y_{Ra} = -0.0422*Ra_1 + 0.0068*Ra_2 + 0.0969*Ra_3 + 0.4918$

$r^2 = 0.781$, $se_y = 0.16$ ton/ha

where Y_{Ra} : rice yield (kg/m2),
Ra_1 : polarisation ratio of first date image,
Ra_2 : polarisation ratio of second date image,
Ra_3 : polarisation ratio of third date image,
r^2 : the coefficient of determination,
se_y : the standard error for the y estimate.

A distribution map of estimated rice yield in AW 2010 crop at Cho Moi district using there-date polarisation ratios:

- SM 10/09/2010 (19)
- SM 24/10/2010 (63)
- SM 15/11/2010 (85)

Percentage error by commune derived from two cases

Commune name	Estimated production (Ton)	Agency data (Ton)	Percentage Error (%)
Long Kien	4215	5880	-28.3
My Luong town	2069	2204	-6.1
Long Giang	5968	5940	0.5
My An	2449	1659	47.6
Kien Thanh	7297	7800	-6.5
Long Dien B	5832	5490	6.2
Tan My	4493	4680	-4.0
Long Dien A	4662	5292	-11.9
Cho Moi town	228	342	-33.3
Total	**37212**	**39287**	**-5.3**

Case 1 (five-date data)

Commune name	Estimated production (Ton)	Agency data (Ton)	Percentage error (%)
Long Kien	4214	5880	-28.3
My Luong town	2081	2204	-5.6
Long Giang	5992	5940	0.9
My An	2461	1659	48.3
Kien Thanh	7331	7800	-6.0
Long Dien B	5820	5490	6.0
Tan My	4521	4680	-3.4
Long Dien A	4655	5292	-12.0
Cho Moi town	229	342	-33.0
Total	**37303**	**39287**	**-5.0**

Case 7 (three-date data)

Rice yield estimation from ASAR APP (2007)

Multiple linear regression analysis were performed using LINEST function:

Rice crop	r^2		
	HH	**VV**	**HH/VV**
WS 2007	0.575	0.661	0.675
SA 2007	0.653	0.328	0.833

Rice yield estimation (2007)

The regression equations between in situ rice yield and polarisation ratios of sampling fields at Cho Moi district in **WS & SA 2007** crop using LINEST function:

- WS crop: $\mathbf{Y_{Ra} = -0.033\ Ra_1 + 0.017\ Ra_2 + 0.019\ Ra_3 + 0.628}$

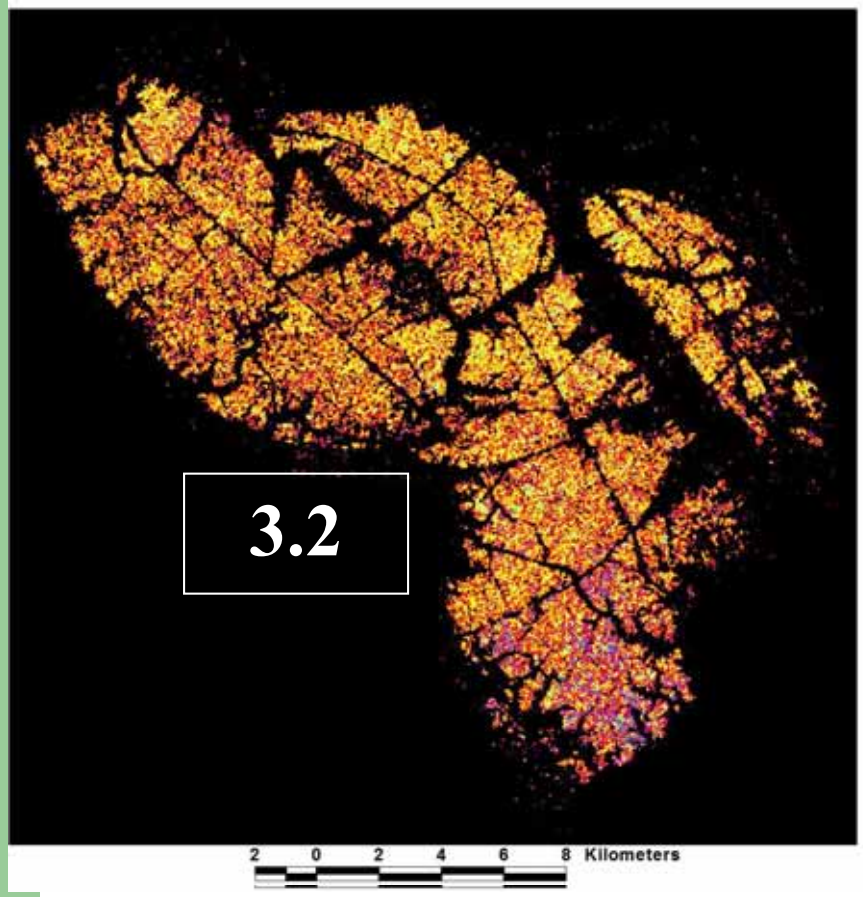
  $r^2 = 0.675$, $se_y = 0.38$ ton/ha

- SA crop: $\mathbf{Y_{Ra} = 0.072\ Ra_1 - 0.017\ Ra_2 - 0.002\ Ra_3 + 0.503}$

  $r^2 = 0.833$, $se_y = 0.11$ ton/ha

Y_{Ra} : rice yield (kg/m^2),
Ra_1 : polarisation ratio of first date image,
Ra_2 : polarisation ratio of second date image,
Ra_3 : polarisation ratio of third date image,
r^2 : the coefficient of determination,
se_y : the standard error for the y estimate.

Rice yield map in Cho Moi (2007)



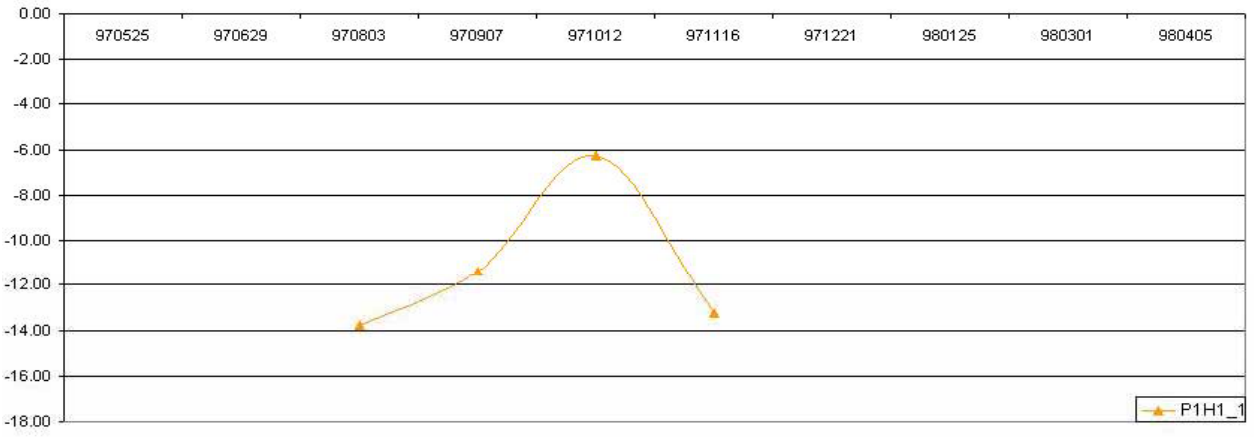
Rice crop	Statistical data (Ton)	Estimated Production (Ton)	Percentage error (%)
WS 2007	131,595	106,128	**-19.4**
SA 2007	79,256	81,820	**3.2**

Summer Autumn 2007 rice crop

Agrometeorological model based method

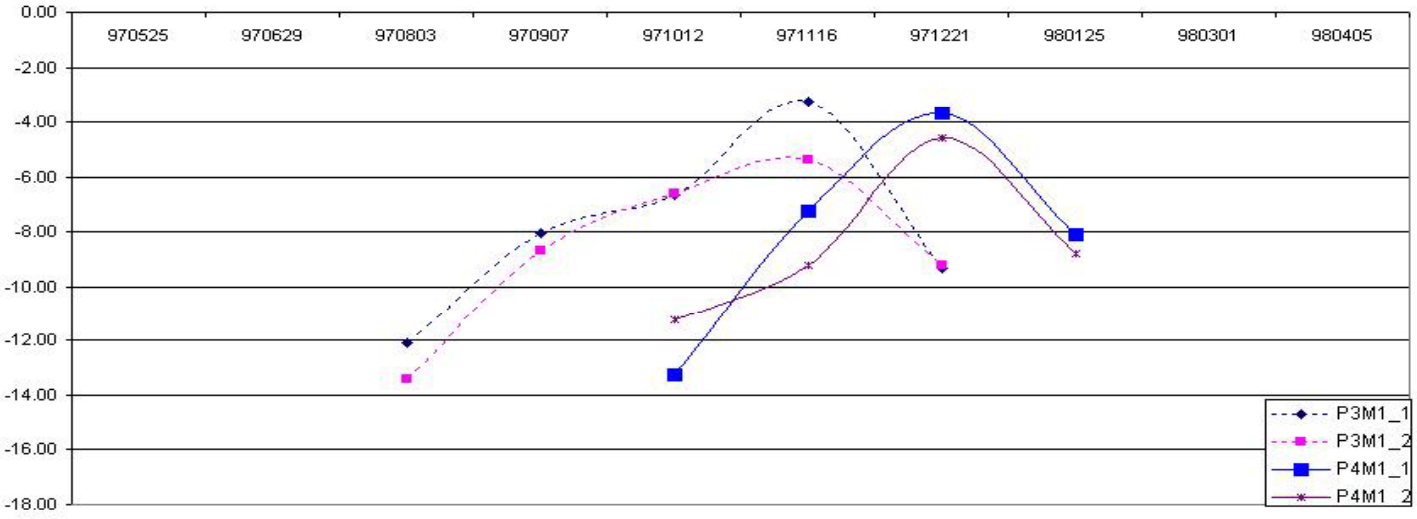
Triple Crop Rice

- ✓ **The approach consists in coupling ERS-SAR data and the ORYZA rice production model in order to simulate plant growth and thus the final yield;**
- ✓ **the selected rice fields were represented the various rice cropping systems;**
- ✓ **rice field located in Ke Sach district was represented for triple crop rice fields. Its estimated yield of HT crop in 1997 was 4,432 kg/ha. The statistical average yield of HT crop in 1998 was 4,802 kg/ha for Ke Sach district.**



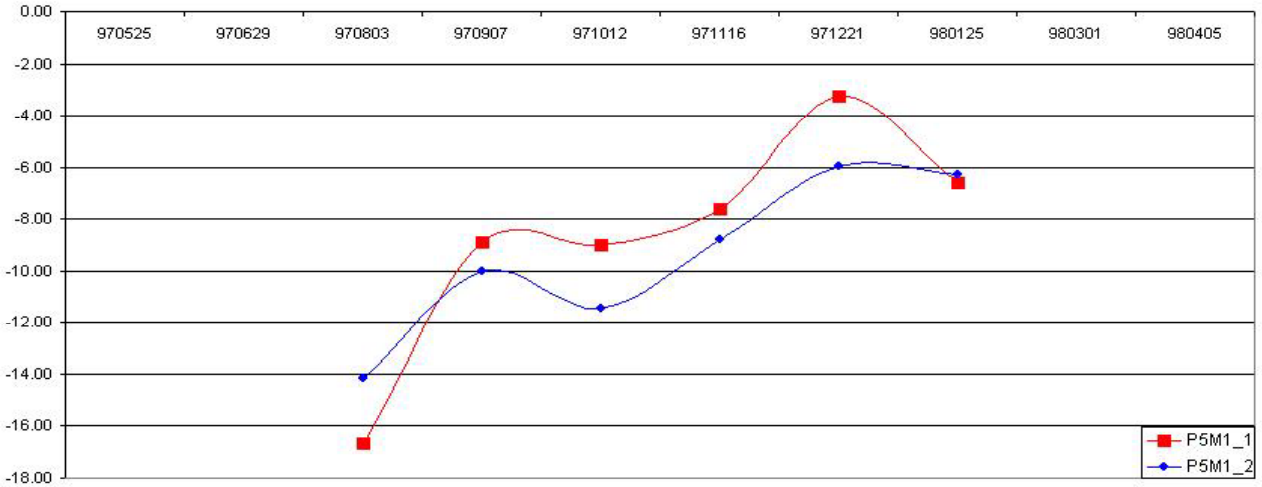
Agrometeorological model based method
Double Crop Rice

- ✓ **selected fields located in My Xuyen district to predict the rice yield of M crop. Their estimated yield of 5,460 kg/ha for both fields. According to the statistical data in 1995 and 1998, the average rice yields of M crop in My Xuyen district were 3,912 kg/ha and 3,372 kg/ha respectively;**
- ✓ **The rice yields of fields named P4M1_1 in Soc Trang town and P4M1_2 in Ke Sach district were estimated for TD crop of double crop rice (HT-M). Their predicted yields were 4,886 and 4,562 kg/ha respectively. The statistical average rice yields were 4,147 kg/ha (1995), 4,105 kg/ha (1998) in Soc Trang town and 3,987 kg/ha (1995), 3,634 kg/ha (1998) in Ke Sach district.**



Agrometeorological model based method
Single Crop Rice

- ✓ **The yield of long-duration rice was predicted from the fields P5M1_1 and P5M1_2 situated in Vinh Chau and Thanh Tri, respectively. Their productivity was 4,237 kg/ha for P5M1_1 and 4,274 kg/ha for P5M1_2. While the statistical data of average yields in Vinh Chau and Thanh Tri were 3,328 (1995), 1,952 kg/ha (1998) and 2,938 (1995), 2,948 kg/ha (1998) respectively;**
- ✓ **It can be noted that the provincial average rice yields in the year 1998 were 4,521 kg/ha (DX crop), 4,348 kg/ha (HT crop) and 2,873 kg/ha (M crop).**



Conclusions

- The radar backscattering behaviour of rice is much different from that of the traditional rice plant;
- The temporal changes of radar backscattering of HH and VV are different during rice growing stages;
- HH/VV ratio of the single-date Envisat-ASAR APP and TerraSAR-X SM image acquired in the middle period of the crop season is a good rice classifier;
- The results using ASAR APP and TSX SM data acquired at a single date have provided a high accuracy of planted rice areas, and three acquisition dates are sufficient to mapping cropping systems during a year (triple crops);
- The study also pointed out that at least three-date SAR data (TerraSAR-X SM, Envisat-ASAR APP) can be used to estimate the rice yield and finally rice production by using statistical model (multi linear regression analysis).
- Result of predicted rice yield of the SA1997 crop based on agro-meteorological model in the study site of Soc Trang was reasonable. But it is necessary to have ground data for accuracy assessment of estimated rice yields.

Further works

- Using various SAR and optical RS datasets, i.e. PALSAR-2, VNREDSat-1 for rice mapping and yield estimation in the Mekong Delta, Vietnam;

- AsiaRiCE.

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thank you