UNIVERSITY OF SOUTHERN QUEENSLAND

RICE CROP MONITORING USING NEW GENERATION SYNTHETIC APERTURE RADAR (SAR) IMAGERY

A Dissertation submitted by

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To my parents

ABSTRACT

Rice cultivation systems in various countries of the world have been changing in recent years. These changes have been observed in the Mekong River Delta, Vietnam, specifically in An Giang province. The changes in rice cultural practices have impacts on remote sensing methods developed for rice monitoring, in particular, methods using new generation radar data. The objectives of the study were a) to understand the relationship between radar backscatter coefficients and selected parameters (e.g. plant age and biomass) of rice crops over an entire growth cycle, b) to develop algorithms for mapping rice cropping systems, and c) to develop a rice yield prediction model using time-series Envisat (Environmental Satellite) Advanced Synthetic Aperture Radar (ASAR) imagery.

Ground data collection and *in situ* measurement of rice crop parameters were conducted at 35 sampling fields in An Giang province, Mekong River Delta, Vietnam. The average values of the radar backscattering coefficients that corresponded to the sampling fields were extracted from the ASAR *Alternative Polarisation Precision* (APP) images (C band, spatial resolution of 30 m, and swath width of 100 km). The temporal rice backscatter behaviour during the cropping seasons, including *Winter Spring* (WS), *Summer Autumn* (SA), and *Autumn Winter* (AW), were analysed for HH (Horizontal transmit and Horizontal receive), VV (Vertical transmit and Vertical receive), and polarisation ratio data. In addition, the relationships between rice biomass and backscattering coefficient of HH, VV, and polarisation ratio were established.

The methods were examined for rice identification and mapping in the study area by using ASAR APP and Wide Swath (WS) imagery. ASAR APP data were firstly used to determine the best method with high accuracy for rice delineation. Then, the proposed method was applied for ASAR WS data (C band, 150 m spatial resolution, and 450 km swath width), covering the entire agricultural region of the An Giang province. Based on the discovered relationships between rice parameters and radar backscattering, a *thresholding* method applied for polarisation ratio and VV polarisation values of single-date ASAR APP data acquired in the middle of

crop season was found to be the best method among various classification methods. Another threshold, i.e. the "*normalised difference polarisation ratio (NDRa) index*", where NDRa = (σ^0_{HH} in dB – σ^0_{VV} in dB) / (σ^0_{HH} in dB + σ^0_{VV} in dB), was formulated in this study for mapping the rice crops using ASAR APP image. The classification accuracy was assessed on the basis of the existing land use data and the published statistical data.

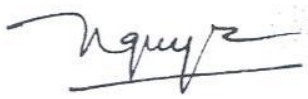
By using multiple regression analysis (rather than using an agro-meteorological model found unsuitable for modern rice cultural practices), the correlation between backscattering coefficients of multi-date ASAR APP images acquired during the crop season and the *in situ* measured yield was derived. The distribution maps of estimated rice yield were then produced based on that relationship. Consequently, rice production was finally estimated from these maps.

This study showed that the radar backscattering behaviour was much different from that of the traditional rice reported in previous studies, due to changes brought by modern cultural practices. HH, VV and HH/VV radar values were not significantly related to biomass (maximum r^2 = 0.494) due to the effect of water management, plant density and structure. Using the polarisation ratio and VV data of rice fields during a long period of the rice season, the thresholding method based on empirical relationships demonstrated a relatively simple but effective tool to accurately derive the rice/non-rice classes. The results using Envisat ASAR APP data acquired at a single date have provided the highest accuracy (99%) of provincial planted rice areas. To generate map of the rice area planted using three-date or two-date ASAR WS data, the integrated method (based on the temporal variation of the radar response and thresholding) yielded the highest accuracies of 99% and 95%, respectively, at the provincial scale. This study developed a method to generate an accurate map of rice growing area before the end of crop season using single-date ASAR APP image taken in the middle of the rice cropping season. During this period, the difference between the HH and VV values is the highest. On the other hand, the predictive model based on multiple regression analysis between *in situ* measured yield and polarisation ratios attained good results (97% accuracy) and thus proved to be a potential tool for rice yield prediction.

This study concluded that time-series Envisat ASAR imagery can generate accurate maps of rice planted areas. Since radar backscattering coefficients were found uncorrelated with plant biomass in the study area, the use of SAR imagery for agro-meteorological (crop growth) modelling for rice yield prediction will be less reliable. Conversely, the use of statistical modelling (regression approach) was found highly accurate to generate rice production forecasts. Further work is needed to examine and validate the rice mapping algorithm and statistical model-based method for rice yield estimation at other regions in the Mekong River Delta.

CERTIFICATION OF DISSERTATION

I certify that my ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.



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PUBLICATIONS PRODUCED FROM THIS DISSERTATION AND OTHER RELATED WORKS

Refereed Journals

1. BOUVET, A., LE-TOAN, T. and LAM-DAO, N., (2009). Monitoring of the rice cropping system in the Mekong delta using Envisat/ASAR dual polarization data. *IEEE Transaction on Geoscience and Remote Sensing*, Vol. 47, No. 2, pp. 517-526.

2. LAM-DAO, N., LE-TOAN, T., BOUVET, A., APAN, A., YOUNG, F., and LE-VAN, T., (2009). Effects of changing rice cultural practices on C-band SAR backscatter using Envisat ASAR data in the Mekong River Delta, *Journal of Applied Remote Sensing, Vol. 3, Iss. 1.*

3. LAM-DAO, N., APAN, A., LE-TOAN, T., BOUVET, A., YOUNG, F., and LE-VAN, T., (under revision). Rice crop monitoring and mapping in the Mekong Delta using Envisat ASAR APP and WS data, *Asian Journal of Geoinformatics*.

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1. LAM-DAO, N., APAN, A., YOUNG, F., LE-VAN, T., LE-TOAN, T. and BOUVET, A. (2007). Rice Monitoring Using ENVISAT ASAR Data: Preliminary results of a Case Study in the Mekong River Delta, Vietnam. Proceedings of "*The 28th Asian Conference on Remote Sensing*", Kuala Lumpur, Malaysia, November 2007 (ISBN 978-983-43550-0-5).

2. LAM-DAO, N., LE-TOAN, T., BOUVET, A., APAN, A., YOUNG, F., and LE-VAN, T., (2008). Effects of changing rice cultural practices on C-band SAR backscatter using ENVISAT ASAR data in the Mekong Delta. Proceedings of the Conference *"GeoInformatics for Spatial-Infrastructure*

Development in Earth and Allied Sciences (GIS-IDEAS)", Ha Noi, Vietnam, December 2008 (ISBN 978-4-901668-37-8).

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5. LAM-DAO, N., APAN, A., LE-TOAN, T., YOUNG, F., LE-VAN, T., and BOUVET, A., (2009). Towards an Operational System for Rice Crop Inventory in the Mekong River Delta, Vietnam Using Envisat ASAR Data. *7th FIG Regional Conference*, Ha Noi, Vietnam, October 2009.

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LIST OF ABBREVIATIONS

AGDARD	Department of Agriculture and Rural Development of An Giang province
AGSO	Statistical Office of An Giang province
ALOS	Advanced Land Observing Satellite
ASAR	Advanced Synthetic Aperture Radar
ASAR APP	Advanced Synthetic Aperture Radar Alternative Polarisation Precision
ASAR WS	Advanced Synthetic Aperture Radar Wide Swath
AW	Autumn Winter (crop)
CCRS	Canada Centre for Remote Sensing
dB	Decibel
DGPS	Differential Global Positioning System
Envisat	Environmental Satellite
ERS	European Remote Sensing Satellite
ESA	European Space Agency
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GPS	Global Positioning System
GSO	General Statistics Office of Vietnam
HH	horizontal transmit and horizontal receive
HV	horizontal transmit and vertical receive
IS	Image Swath
JERS	Japanese Earth Resources Satellite
LAI	Leaf Area Index
MODIS	Moderate Resolution Imaging Spectroradiometer
NOAA/AVHRR	National Oceanic and Atmospheric Administration/ Advanced Very High Resolution Radiometer
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PCA	Principle Component Analysis
RADAR	Radio Detection And Ranging
RISAT	Radar Imaging Satellite

SA	Summer Autumn (crop)
SAM	Spectral angle mapping
SAR	Synthetic Aperture Radar
SPOT	Systeme Probatoire d'Observation de la Terre
VH	vertical transmit and horizontal receive
VV	vertical transmit and vertical receive
WS	Winter Summer (crop)