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Microwave Remote Sensing for Land Cover Identification

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Abstract

This study considers the potential application of digital JERS-1 SAR data (L-band, 23.5 cm Wavelength) particularly for land cover monitoring. The SAR Data used in this study were acquired on 5 January 1998, 3 April 1998 and 17 May 1998 respectively. These three images available were from the dry season to the beginning of the rainy season. The study area selected is in the province of Khon Kaen, Northeast Thailand, which is covered by agricultural land, mainly paddy fields and upland crops. Multi-dates SAR data were firstly geocoded to UTM projection, then the data images were scaled from 16 bits to 8 bits. Some filtering and enhancement methods had to be applied in order to reduce speckle noise and to contrast the images. Composite color images were produced for visual interpretation and field surveys. After investigation of the ground truth, representative areas of each land cover type were identified and allocated to the images. The SAR data of training areas were statistically analysed and were supervise classified using Maximum Likelihood. The preliminary results show that general land cover categories could be well identified, such as water bodies, villages and some lineament features(airfield, road, canal). Separability matrices indicate the confusion between paddy and upland crops, forest and riparian forest. Therefore SAR data is useful for land cover characterization and for hydrology applications, but a specific methodology for the SAR system needs to be developed.

Introduction

The application of optical data (such as that obtained by LANDSAT and SPOT) has a limitation on weather conditions particularly for cloud coverage during rainy season. Presently, microwave remote sensing (radar system) is available and introduces a new generation of remotely sensed data application. The Synthetic Aperture Radar (SAR), a very high performance, is an active sensor operating in the microwave region. The advantageous characteristics of SAR are weather and sun-illumination independence, cloud and rain penetrating capability and fine resolution. The SAR data, on the other hand, provide substantial information under cloud and haze conditions. These are the major reasons that the SAR data have become popular in mapping land-cover. In addition, the visual appearance of the SAR image such as tone, texture, pattern and shape characteristics can be used in visual interpretation.

Microwave is generic name of electromagnetic spectrum with the wavelength of 1 mm. to 1 m. SAR transmits and receives backscattered waves from the ground and land cover (soil, vegetation etc). The amount of microwave backscattered will differ as a function of topography and geometry of surface roughness, height and structure of the vegetation, the amount of soil and canopy moisture, vegetation mass and the differences in the dielectric constant of the objects, therefore, the SAR system observes in term of volume information.

Many research applications have done by using SAR data for land cover mapping, particularly in tropical countries. Land cover classification is also useful for hydrology in term of estimation of runoff ratio, the variation of soil moisture and evapotranspiration at each land-use area. The SAR data have notable potential to monitor and assess hydrological phenomena such as the extent of surface water, inundated area, flood disaster and a real aridity in a river basin. Hydrological applications of remote sensed data in microwave region have lately attracted attention because of its potential to react to the extent and amount of water that has remarkably high value of dielectric constant in natural material of the earth.

The Japanese Earth Resource Satellite (JERS) was used in this preliminary study. JERS-1 was launched into a sun-synchronous orbit at an altitude of 568 km with a recurrent period of 44 days by the H-I launch vehicle on February 11, 1992 from National Space Development Agency of Japan (NASDA), Tanegashima Space Center. JERS-1 observes and collects data with Microwave Sensor and Optical Sensor (OPS). An optical sensor that measures light reflected from the earth's surface ranging from visible light to short-wave infrared light. The Synthetic Aperture Radar is an active microwave sensor, SAR has a ground resolution of 18 m x 18 m and observes for swath width of 75 km with frequency at 1.27 MHz (or 23.5 cm wavelength, L-band radar), HH polarization. JERS-1 objectives are for land surveys, agriculture, forestry, fishery, environmental and disaster protection and coastal surveillance.

Objective

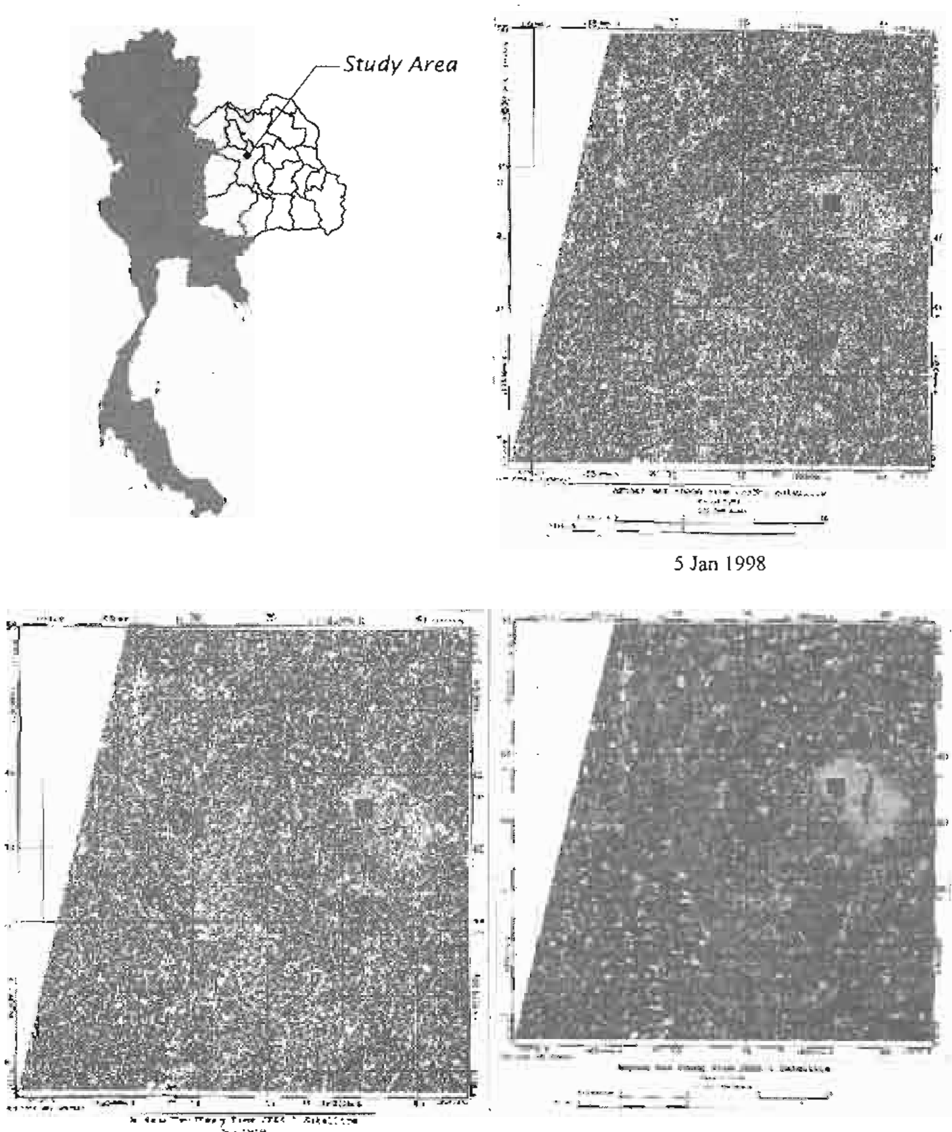
This preliminary study has an objective to investigate and to assess the potential application of using digital JERS-1 SAR imagery for land cover identification.

Study Area

The study area is located in the province of Khon Kaen, Northeast of Thailand(Figure1). It lies between latitude 16°29'-16°45'N and longitude 102°45'-103°01'E covering the area of approximately 825 sq.kilometers. The topography of the area is ranging from river terrace, flood plain, low to middle and high terrace, undulating features. The flood plain is elongate along Pong river. There are a linear villages settlement along this river banks. The amount of annual rainfall is approximately 1,200 mm. The major cultivations in this area are paddy and upland crops (cassava, sugarcane), for mixed orchard and forest found in the higher area. The typical orchard produce is papaya, mango, tamarind and eucalyptus. Vegetation cultivation, particularly that for cabbages, is carried out on the flood plains beside Pong river. Paddy fields consist of rainfed paddy fields and large area irrigated paddy fields under Nong Wai Irrigation project. Some second rices and vegetables are cultivated in this irrigated area in the dry season.

Data and Materials

1) JERS-1 SAR data, the three scenes of digital multi-temporal of SAR imagery are available and following acquired on 5 January 1998, 3 April 1998 and 17 May 1998 respectively, with path 124 and row 273. (Figure 1)
2) Topographic map at a scale of 1:50,000
3) Image processing analysis system of PCI EASY/PACE software.



5 Jan 1998

3 April 1998

7 May 1998

Figure 1 Study area and JERS-1 SAR original data images

Methodology

Geometric Correction

These three digital SAR imageries were geocoded against topographic map and registered to a Universal Transverse Mercator (UTM) projection. The SAR data for each scene have only a single panchromatic band and have digital number (DN) values ranging from 0 to 65,000 (they were coded on 16 bits). This poses a problem to display of the data. Computer monitor generally displays a monochrome image in 256 shades of grey level. Very few details can be made out of the original data. Therefore, the SAR data obtained 16 bits were compressed to 8 bits in order to obtain 256 values of intensity. Then the JERS-1 SAR data were displayed and examined.

Filtering of SAR data

The objective is to reduce speckle noise of the SAR image. A Frost filter using at 5x5 window size was employed as a spatially filter to the SAR data to remove the speckles noise while retaining the image sharpness.

Image Enhancement

All images were digitally enhanced using histogram equalization in order to increase the contrast of the image.

Visual Interpretation

Composite color images were generated for visual analysis and for a selection of profiles in representative areas for land cover type classification. Composite color image was composed of SAR data date of 3 April 1998 in red, date of 17 May 1998 in green and date of 5 January 1998 in blue respectively. Visual interpretation was investigated on the composite color image, general categories were identified and discussed base on topographic maps scale of 1:50,000 made by Royal Thai Survey Department and the others existing data.

Ground truth survey

Ground information was collected from field observation and made it possible to acquire necessary ground truth for image interpretation, analysis and image classification.

Training area and statistical analysis

The test sites or training areas were selected to get a representative through various land cover types and to have a good ground truth (polygons) available on the images. The statistics of pixels values(unitless) for all categories of training areas were obtained and discussed by means and standard deviation. Statistical characteristics of training area for various land cover derived from JERS-1 SAR data as shown in table 1.

Table 1
Statistical characteristics of pixels values of SAR images for land cover classification.

Land cover type	Image of 3 April 1998		Image of 17 May 1998		Image of 5 Jan 1998	
	Mean	Deviation	Mean	Deviation	Mean	Deviation
Paddy	18.375	4.529	12.816	2.947	16.159	4.367
Upland crops	12.153	3.232	11.927	3.371	14.212	3.816
Forest	20.770	3.190	20.264	3.53	23.032	3.909
Riparian forest	19.769	4.808	15.166	3.256	21.252	5.060
Village	45.023	21.840	34.873	15.365	46.305	21.849
Water body	7.598	1.348	5.605	1.289	8.635	1.785

Supervised classification

Some statistics were calculated for each land cover, for all images as illustrate in table 1. These three sets of data were used to classify by Maximum Likelihood method. Digital image processing technique was employed to identify and performed on PCI EASI/PACE software. The procedure of image processing as shown in Figure 2 as follow :

Results and Discussion

It was found that the variation of intensity values of all selected images were reduced on the filtered SAR Data compare to its original. Figure 3 presents the composite color image of three original SAR data and figure 4 indicates the same image after filtering with 5x5window size. The result is that it could reduce certain noise, cause image is smoother and keep lineament detail on the image. Figure 5 presents the composite color image after enhancement and some training areas allocation. Statistical characteristics analysis of the same area for three images taken almost in a dry season showed slightly differences in digital number value.

The supervised Maximum Likelihood classified results the six main classes as indicate in figure 6. The results of digital analysis confirmed the capability of SAR Data to separate confusing categories between village (urban) and water body as well as vegetation canopy condition, however more detail could be observed and discussed as follow:

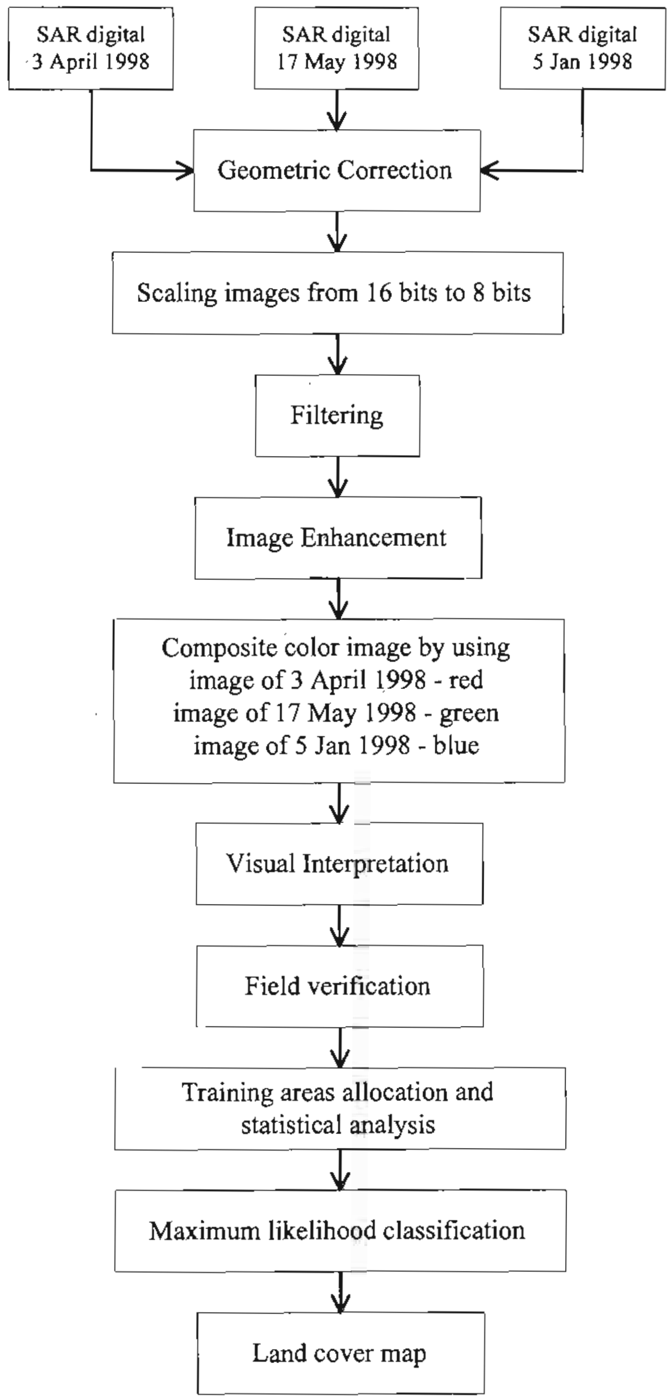


Figure 2 . General methodology of the digital image processing

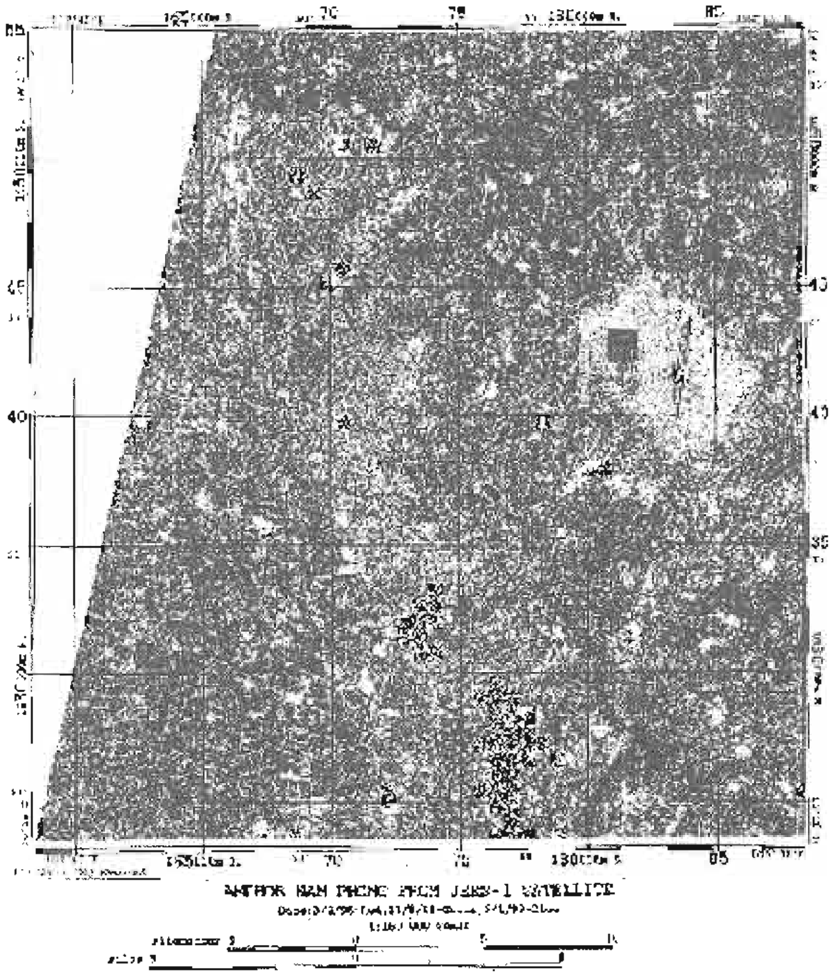


Figure 3 Composite color image of JERS-1 SAR before filtering

Vegetation

Backscattered signals of SAR data are sensitive to vegetation canopy structure (in term of volume). Complex canopy reflects high backscattering to the sensor since it gives a strong roughness characteristic, high signal returns appear very bright on the image. The forest along the river(riparian forest)seems to be not well separate from the forest. They both appear in bright color. Standing trees along river or canals which result a high contrast roughness.

Comparing to its surrounding appear in bright tone on SAR image. Paddy and upland crops appear dark in the SAR image, but there is a very bright parts because there are small crop plants in agricultural field. However they are brighter than the water bodies because crop grew large and wetness in the soil increase radar backscattering.

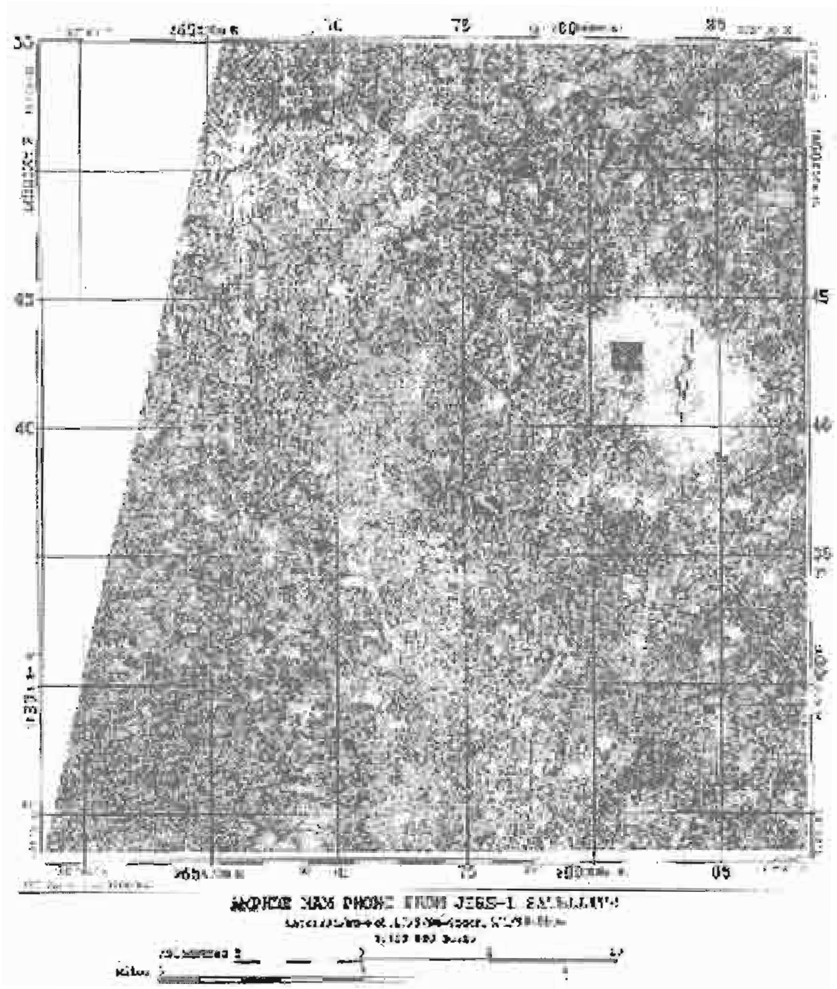


Figure 4 Frost Filtering method with 5x5 window size

Water bodies

Water bodies have a smooth specular surface, hence backscattered signal is very low or no back scattering to the sensor. Consequently, they appear in dark tone on the SAR image.

Village or urban

In village/urban, very rough object, backscattering detected is very high since it's composition is complex. Hence urban areas appear in very bright tone. SAR values in urban area are equally high in all seasons.

Lineament and other man made feature

The lineament features such as roads and canals were clearly seen as dark line. Air field, as it is flat objects, appears in dark zone.

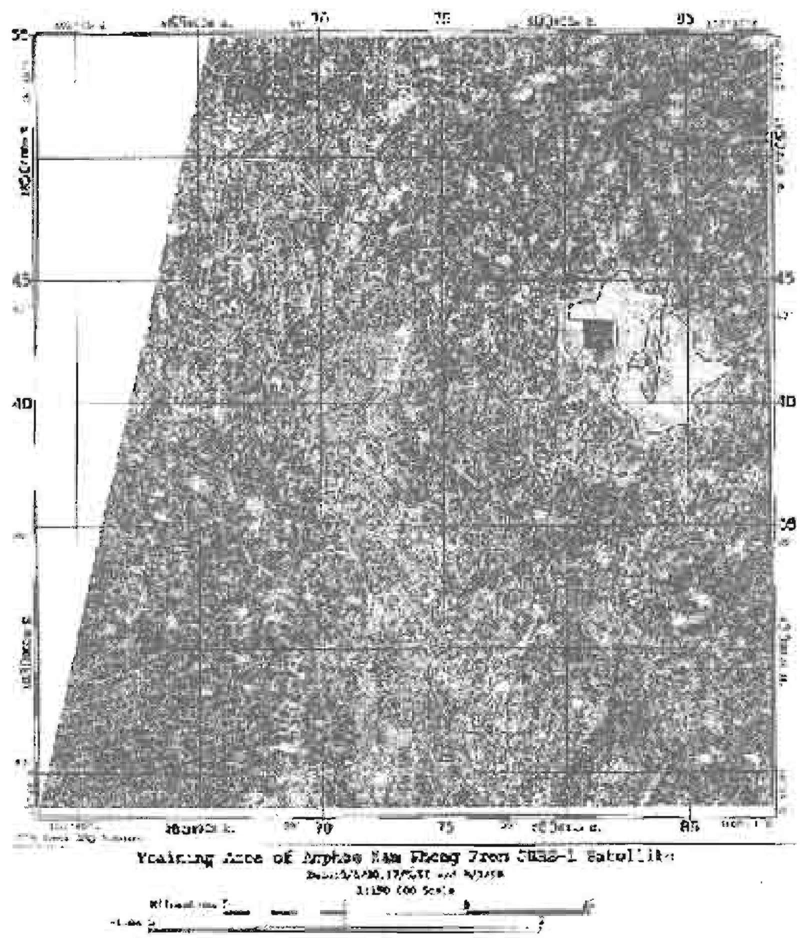


Figure 5 Composite color image and training areas for classification

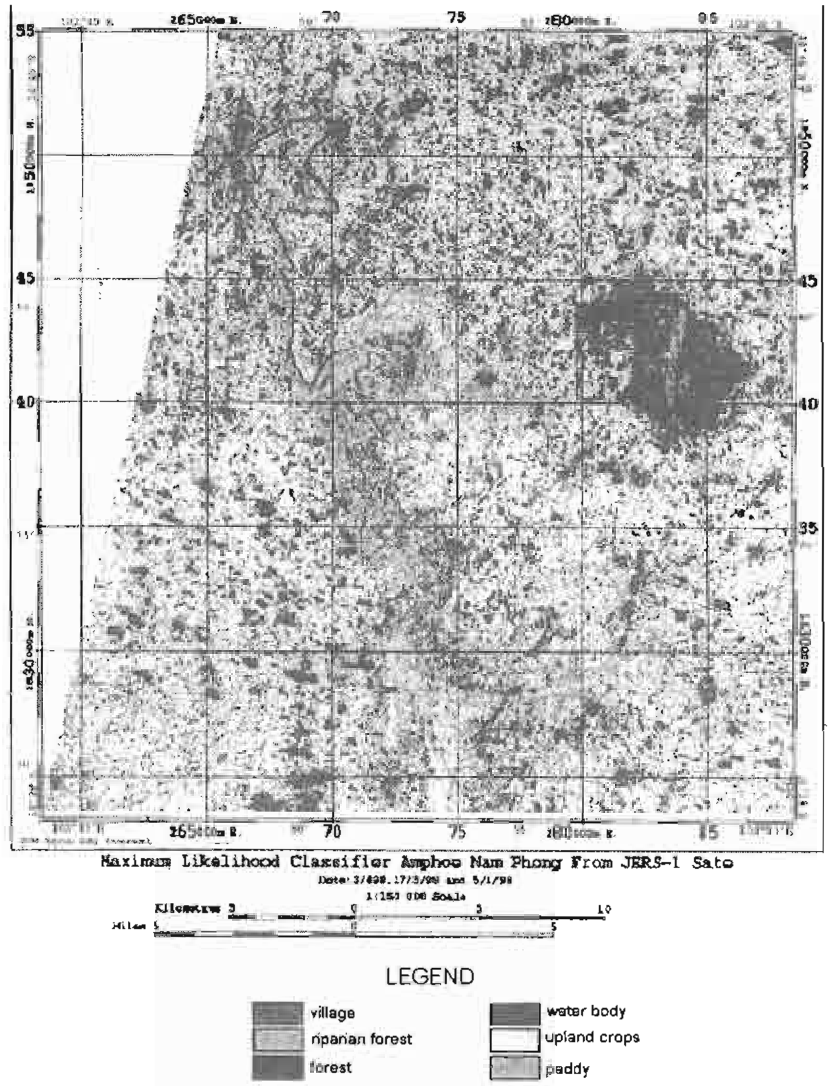


Figure 6 Land cover classification

Classification Separability

Results of the overall classification separability could be general assessed classification accuracy. The separability matrix is summarized in table 2.

Table 2
Separability matrix for land cover classification.

Land cover	Water	Village	Forest	Upland Crops	Paddy
Village	2.00000				
Forest	2.00000	1.99938			
Upland Crops	1.90709	2.00000	1.57533		
Paddy	1.99670	1.99986	1.97890	0.66823	
Riparian forest	1.99984	1.99645	0.57524	1.08362	0.37193

2.00 = very well separated between two classes
1.90 = well separated between two classes
< 1.70 = low separated between two classes

Land Cover Assessment

The overall results of land cover classification by Maximum Likelihood were calculated and summarized in table 3

Table 3
Area and Percentage of land cover in the study area

Land cover	Area(sq.kilometers)	Area in percentage
Paddy	123.87	15.02
Upland Crops	472.36	57.28
Forest	70.61	8.56
Riparian forest	82.37	9.99
Village	42.65	5.17
Water bodies	32.81	3.98
total	824.67	100

Conclusion

The results of this preliminary study show that multi-temporal JERS-1 SAR data could be used for analysis with the expectation of greater advantage for identification of crops types than a single wavelength image. The general result land cover classification was fairly obvious, superior at distinguishing water and village from other categories, but generally suffered for difficulty distinguishing among forest and riparian forest. Some paddy confused with upland crops. Backscattering are calculated, village is a highest, second is forest, and the lowest is water bodies. Classification by using SAR digital image found that land cover in this study area mostly are upland crops and paddy. Agriculture is still the main important for this region. For better results, a deeper understanding of the behavior of the radar backscatter and its relationship to the biophysical parameter is needed. Remarkable that, bright color means high backscatter and dark color means low backscatter to the sensor. In addition, the electromagnetic interaction with the target is also modified by the object's dielectric constant. Different characteristics of radar data, the traditional image analysis developed for conventional optical remotely sensed data cannot explore optimally the information content of SAR data. A specific algorithms for SAR classification need to be more developed.

Combination of SAR and optical data would lead to further significant improvement in classification accuracy and provide additional information especially in cloud and haze affect area. JERS-1 SAR is one of the microwave sensor especially to monitor land surfaces because of its capability of penetrating cloud and its high spatial resolution.

Acknowledgement

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References

1. Alves, D., and Skole, D. (1996), Characterizing Land Cover Dynamic Using Multi-temporal Imagery. IJRS.17: 835-839.
2. Kasisehke, E.S., Melack, J.M., Dobson,M.C. (1997), The Use of Imaging Radar for Ecological Application. A Review Remote Sensing of Environment. 59:141-156.
3. NASDA, (1992), User's Guide For JERS-1 SAR Data Formal. Tokyo.
4. Nasruddlin, N., et al. (1993), SAR and SPOT Data for Land Cover Mapping. Their Complementary and Integrated Characteristic. Proceeding SAR Data Analysis and Application, Bangkok, Thailand, 1993. pp.53-61.
5. Palagonas, M. (1993), Land Cover Mapping Using Synthetic Aperture Radar (SAR). Proceedings SAR Data Analysis and Application, Bangkok Thailand, 1993.pp.175-192.