Potential Use of Airborne Synthetic Aperture Radar to Monitor Agricultural Land Uses: A Case Study in Thailand

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Abstract: In 1996, Thailand's participation in the Pacific Rim as a part of NASA's Mission to Planet Earth (MTPE) Program, was titled "AIRSAR Thailand Project". In this project the Department of Land Development utilized Topographic SAR (TOPSAR) which had multi-frequencies: C band, L band, and P band with multi-polarization: HH, VV, and HV as well as C band VV DEM. Satellite data such as LANDSAT TM was also utilized for optimal use.

Results of AIRSAR image processing including data fusion among difference wavelength bands and polarization revealed the quality of AIRSAR that best suit for detection of agricultural land uses. The HH-L band AIRSAR was proven to be useful to distinguish among crop types when combined with appropriate data. The HH, VV, and HV-P band enhanced surface characteristics of swamp forest and wetland. In addition, TOPSAR has its great advantage for identification of salt farms and shrimp ponds.

Keywords: AIRSAR, TOPSAR, LANDSAT TM, multi-polarization, multi-frequencies.

1. Introduction

The Airborne Synthetic Aperture Radar was an all weather imaging tool able to penetrate through clouds and collect data at night. A flying AIRSAR instrument mounted on board a modified NASA DC-8 aircraft. During data collection, the airplane flew at 8 kilometers over average terrain height at velocity of 215 meters per second. AIRSAR served as a NASA radar technology tested for demonstrating new radar technology and acquiring data for the development of radar processing techniques and applications.

AIRSAR Thailand project was organized through Geo-Informatics and Space Technology Development Agency (Public Organization)-GISTDA. There were three concerned agencies including Land Development Department (LDD), Office of Agricultural Economic, and Royal Forest Department. LDD had conducted the project since 1997.

1) AIRSAR instrument

AIRSAR is a side-looking radar instrument that collects fully polarimetric (POLSAR) data at three radar wavelengths: C-band (0.057 m.), L-band (0.25 m.), and P-band (0.68 m.). In POLSAR mode data are collected at all four possible polarization combinations: horizontal transmit-horizontal receive (HH); horizontal transmit-vertical receive (HV); vertical transmit-horizontal receive (VH); and vertical transmit-vertical receive (VV). In TOPSAR mode two types of data are collected, namely XTI 1 and XTI 2. In the along-track interferometry (ATI) mode data are collected at two wavelength: C-band and L-band, VV polarization only.

2) AIRSAR data application

AIRSAR data can be used for a wide range of application including forest classification and ecosystem, land use classification, soil moisture measurement, wetland classification, geologic mapping, and natural hazard monitoring. POLSAR data are sensitive to the geometry and dielectric properties of the terrain being imaged. TOPSAR are sensitive to topography and the ATI can be used to measure the direction of ocean current movement.

2. Objective

The objective of the study was to test multi-band and polarization airborne SAR for demonstrating new radar technology and development of radar processing techniques and application on agricultural land use study.

3. Methodology

1) Methods

Methodology were as follow:

1. The 32 bit real AIRSAR data were compressed to 8 bit, rotated to represent true north-south direction, geometric corrected and transformed into standard

cartographic projection and scale, enhanced to improve visual interpretability of images by using PCI EASI/PACE software.

2. Specially designed algorithms for removal of speckle noise were applied to AIRSAR/TOPSAR data as following:
   1.Lee filter, with window size 7×7 and 11×11
   2. Gamma map filter
   3. Kuan filter.
3. Three band color composite radar images were created by assigning one polarized band to the red color gun, one to the green color gun, and one to the blue.
4. Multi-image composites of AIRSAR/TOPSAR and Landsat TM were produced using Image-Hue-Saturation color space transformation. The IHS component enhanced the distinguishability of interested features within multi-image composites.
5. Agricultural land uses in the study sites were identified.

2) Test sites

Phetchaburi and Narathiwat sites are along the eastern coast of Malay Peninsula. Phetchaburi is an area of mixed land use including orchards, rice paddies, mangrove forests, and urban. Narathiwat is an area of peat swamps which have become drier overtime. Surface characteristics of swamp forest can be observed.

3) Data used

AIRSAR data used in this project were TOPSAR, L-, P-band with HH, VV, HV polarization, C-band VV DEM, L-, P-band quad polarization that recorded on 3 December 1996 over Narathiwat site and 6 December 1996 over Petchaburi site.

4. Results

AIRSAR/TOPSAR processing operations served to correct both radiometric and geometric distortions within an image. TOPSAR data over two test sites were geometrically corrected to achieve the UTM projection using PCI Geometric Correction software. In order to move effectively display TOPSAR images three categories of digital enhancement techniques were applied as:

1. Grey level contrast enhancement.
2. Spatial filtering: Lee, Gamma Map, and Kuan filter.
3. Color enhancement: Intensity-Hue-Saturation (IHS) transformation.

After image processing, color composite produced from various TOPSAR bands and polarization as well as combination of Landsat TM and AIRSAR were used for identification of agricultural land uses.

1) Grey level contrast enhancement

Because each band of TOPSAR data were transmitted and received with different polarization: HH, VV, and HV, the intensity of received signals would rather differ from one to another. HV polarized signal was quite low, therefore it appeared darker than other polarized data. Histogram equalization stretch was then applied to L- and P-band quad polarization. Result is shown in Figure 1.

2) Spatial filtering

Three types of spatial filter, Lee, Gamma Map, and Kuan filter with 5× 5, 7×7, and 11×11 window size were applied to remove inherent noisy contained within AIRSAR images. The aim of these filters was to maximize the signal to noise ratios while at the same time preserving the tonal characteristics of data being filtered as shown in Table 1. Results have shown that Lee filter provides best results for both visual and digital analysis.

3) Color enhancement

Color composite images were produced from three different polarization of each wavelength band. Figure 2 has shown that combined three polarizations: HH, VV, and HV, P-band enhance surface characteristics of swamp forest and wetland over Narathiwat site. P-band TOPSAR data prove that the longer the wavelength, the more is the penetration through canopy surface. From this image detail of swamp forest represented by white, light green, yellow, and magenta color.

Figure 3 shows result of data fusion technique using an IHS color space. Landsat TM and TOPSAR data were transformed from Red-Green-Blue (RGB) components into IHS components. Intensity was replaced by L-band HH polarized TOPSAR. Hue was replaced by Landsat TM band 4 and Saturation contained band 3. Then IHS components were reversed to RGB components to produce color composite images. This fused image enhances detail of rice paddy in different colors ie; yellow as dried paddy, blue as wet paddy, and red as healthy paddy.

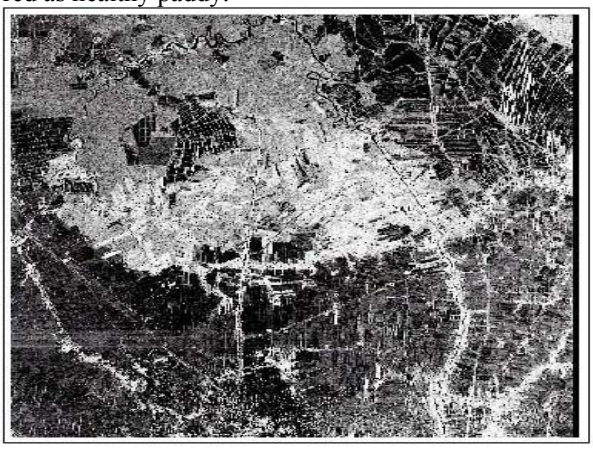

Fig. 1 Enhanced L-band, HH-polarized AIRSAR/TOPSAR
Table 1 Result of Lee Filter over Phetchaburi test site

olarize	Window size	lo. Of ass	Original Statistics		New Statistics	
			Mean	Std.	Mean	Std.
HH	7x7	1	50.29	52.21	49.73	41.60
		2			49.25	40.34
	11x11	1			49.70	40.02
		2			49.20	38.90
VV	7x7	1	63.83	56.39	63.29	44.75
		2			63.81	43.41
	11x11	1			63.27	43.03
		2			62.77	41.88
HV	7x7	1	62.34	59.35	61.76	48.94
		2			61.27	47.59
	11x11	1			61.71	47.22
		2			61.21	46.00

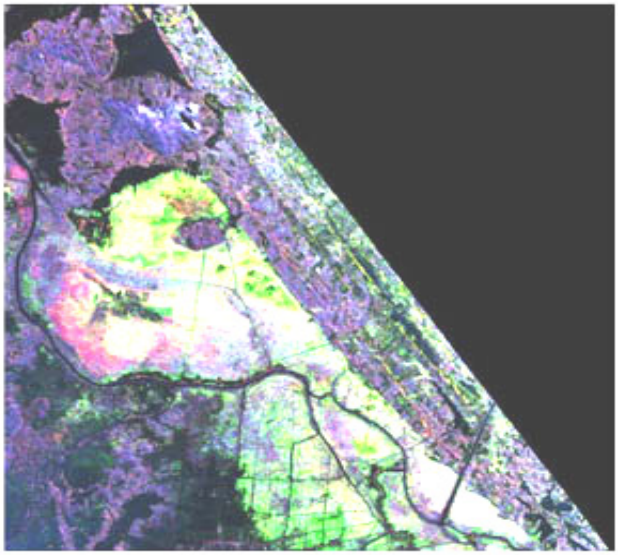

Fig. 2 Color composite of TOPSAR data over Narathiwat test site (Red = HH, Green = VV, Blue = HV polarization).

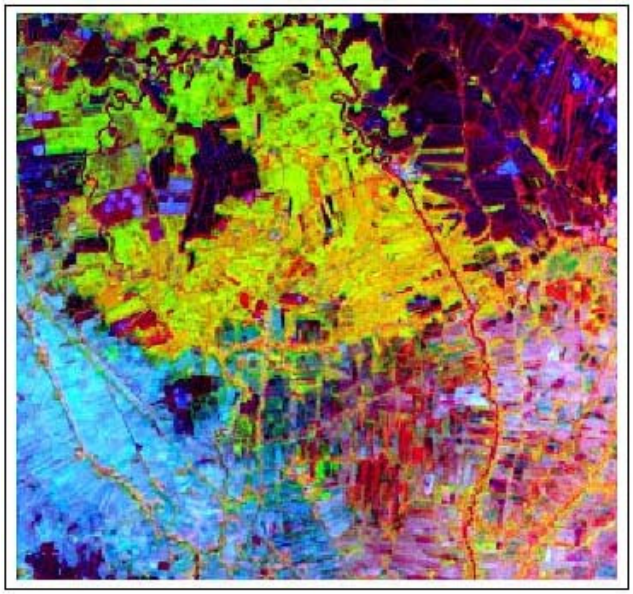

Fig. 3 Data fusion of TOPSAR and LANDSAT TM data (Intensity = L-band, Hue = TM band4, Saturation = TM band 3)

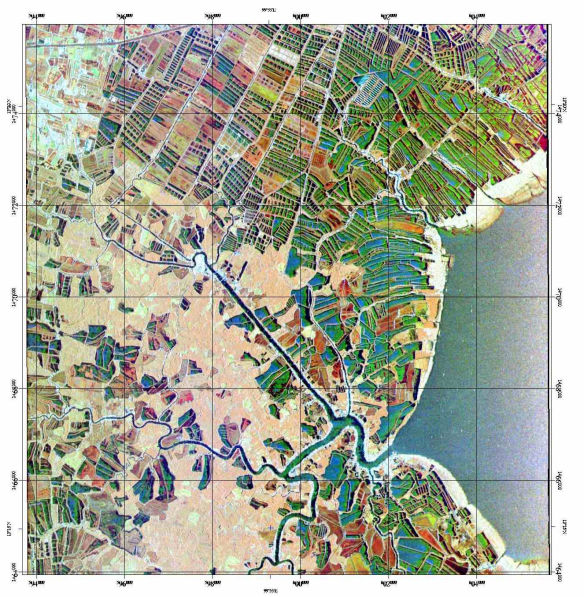

Fig. 4 Color composite TOPSAR images created from CvvDEM, L-, and P-band data

To enhance more detail on surface characteristics the C-band VV DEM was assigned to the red gun, L-band to the green gun, and P-band to the blue to create color picture as in Figure 4. By doing this some specific features such as shrimp farm and salt farm were able to identified. The C-VV band made image more interpretable.

5. Conclusions

AIRSAR/TOPSAR which has multi-frequencies: C-, L-,and P-band quad polarization and DEM data can be digitally processed in such a way that surface characteristics were enhanced. L-band data are very useful to monitor agricultural uses. P-band is suitable for wetland forest detection. L- and P-band together with DEM is helpful for identification of shrimp and salt farms.

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