ALOS PALSAR DATA FOR TROPICAL FOREST INTERPRETATION AND MAPPING

M. Mahmudur Rahman [*] , Josaphat Tetuko Sri Sumantyo

Microwave Remote Sensing Laboratory, Center for Environmental Remote Sensing, Chiba University
1-33, Yayoi, Inage, Chiba 263-8522 Japan- mahmud@restaff.chiba-u.jp, jtetukoss@faculty.chiba-u.jp

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ABSTRACT:

Tropical forest cover is changing in many parts of the World and got attention to the global community since it is one of the main drivers of climate change. Microwave sensor data is useful to monitor forest coverage since presence of cloud often obscures for a continuous and periodic monitoring by optical sensors. The objective of this investigation was to examine the newly available Advanced Land Observation Satellite (ALOS) PALSAR polarimetric data for forest interpretation and mapping. The study area was located in the tropical forest region of South-eastern Bangladesh. The area covers with tropical wet evergreen and semi-evergreen forest, plantation, mixed bamboo and scrubby re-growth. Forest and forest mosaic could be separated from other land covers (water, agriculture shrimp farms etc). Forest appears in cyan in VV, VH and HV (RGB) composition, while forest mosaic in dark red and cyan. Large-scale plantation is distinguishable from natural vegetation based on texture. The study developed an interpretation key for the study region. Visually interpreted PALSAR image was digitized on-screen to prepare forest cover map. The map was verified with Landsat Enhanced Thematic Mapper Plus (ETM+) image, which was earlier validated on the ground. The result of this investigation will be useful for interpretation, delineation and mapping of forest cover using PALSAR polarimetric data in similar forest ecosystems.

1. INTRODUCTION

Quantitative assessment of land cover is important for a country to make proper planning, and in global scale the database will be helpful to understand the trends of Earth surface alteration and its linkage to the climate change. Synthetic Aperture Radar (SAR) both independently and jointly with optical sensors are suitable to prepare land cover maps. Commercial and experimental SAR data are available from European Resource Satellite 1/2 (ERS-1/2), Envisat ASAR, SIR A, B or C, Radarsat-1/2, Japanese Earth Resource Satellite-1 (JERS-1), Advanced Land Observation Satellite (ALOS) PALSAR etc.

The capabilities of SAR to separate forest with other land covers make it a useful tool for forest cover mapping, while it can work in all-times (both day and night) and weather conditions. Since the inception of various frequencies of SAR (mostly in C and L bands) on-board satellite and aircraft, the data have been used to prepare land/forest cover maps. Visual interpretation map of SIR-A data was prepared for Pensacola, Florida and Mobile, Alabama (Lo, 1988). The study interpreted crop-land, built-up areas and highway. Land-cover map was prepared for northern Michigan using ERS-1 and JERS-1 data (Dobson *et al.*, 1996). Knowledge based classification using a hierarchical decision rule was applied to classify different types of vegetations and flat surface. The thematic classification map was visually compared to the manual air-photo interpretation of land covers. Land cover classification was done in eastern Michigan using SIR C/X SAR data (Pierce *et al.*, 1998). The study could separate flat surfaces with different categories of vegetations reasonable well using multi-temporal data. JERS-1 SAR data was used to prepare forest cover maps in different test sites of Germany, the UK, Sweden and Russia (Thiel *et al.*, 2006). The study applied object-oriented image classification to extract forest, non-forest and deforested areas on the multi-temporal images acquired on the period of 1992-1998.

Several studies jointly applied optical and microwave data for land/forest cover mapping. Forest map was prepared for Tanana River flood-plain, interior Alaska from multi-date three-frequency polarimetric SAR and SPOT data (Rignot *et al.*, 1994). The study separated open water of rivers and lakes and various types of vegetations. The study examined the classification accuracy with different polarimetry, frequency and time of AIRSAR and optical (SPOT) sensor data. SIR-A and Landsat MSS data were jointly used to prepare landuse maps of Tianjin, North China (Jiyuan *et al.*, 1986). The study developed an interpretation key for SIR-A image.

Forest cover maps were prepared for the boreal, temperate and tropical forests using SAR data. Forest was separated from non-forest regions using multi-temporal C-band ERS SAR data on the test sites of United Kingdom, Poland and Finland (Quegan *et al.*, 2000). The study applied a threshold value to separate forest from other classes. Tropical rainforest of Borneo was mapped from SIR-B data of different incidence angles (Ford and Casey, 1988). Different vegetation covers along with wetlands and clear-cut areas were distinguished. Forest cover mapping was done with JERS-1 SAR data on the coastal regions of Gabon (Simard *et al.*, 2000). The study used decision tree method utilizing both radar amplitude and texture information. Forest cover map was prepared for Southern

[*] Corresponding author & permanent affiliation: Bangladesh Space Research & Remote Sensing Organization (SPARRSO), Agargaon, Sher-E-Bangla Nagar, Dhaka-1207, Bangladesh.

Chittagong using JERS-1 SAR data (Rahman and Sumantyo, 2007) and the study separated forest, degraded forest, shrubs, coastal plantations, agriculture, shrimp-farms, urban and water.

Recently L-band ALOS PALSAR data become available and it is useful to investigate their potential for land and forest cover mapping in different terrestrial ecosystems. The objective of this investigation was to examine this newly available data-set for forest cover mapping in the tropical forest regions of South-eastern Bangladesh.

2. MATERIALS AND METHODS

2.1 Descriptions of Study Area

The study area was located between $21^0 29'$ to $21^0 40'$ N and $92^0 01'$ to $92^0 10'$ E (Figure 1) in South-eastern Bangladesh and distributed over approximately 300 sq. km. Sub-tropical monsoon climate prevails in the study region and has three distinct seasons: pre-monsoon hot season (March-May), rainy monsoon season (June-October) and cool dry winter (November-February). Monsoon usually accounts for about 80% of average annual rainfall in the region.

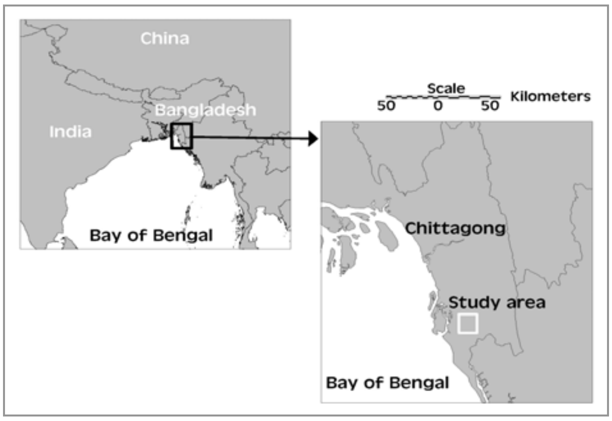

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Figure 1. Location of the study area

he forests in the region are classified as tropical wet ever-green and semi-evergreen forests (Champion *et al.*, 1965, Figure 2). Evergreen stratum is characterized with *Dipterocarpus* species. Sometimes a certain proportion of deciduous trees are also present in the upper canopy of the forests. Gregarious formation of *Dipterocarpus* species is also noticed in some places with the rare occurrence of any other species. Bamboo appears in several places where upper canopy is removed, but is absent in the virgin forests where cane and palms are the main woody monocotyledons (Khan, 1979).

Due to extreme human interference virgin forests are seldom noticed. Most of the crops are secondary re-growth and still in the process of succession to climax evergreen type. The process of succession is often hindered by human disturbance and thus leads to scrubby forests in many locations (Khan, 1979).

Figure 2. Tropical wet evergreen and semi-evergreen forest of the study area (photograph was acquired during 2002-2003)

2.2 Data Sets

ALOS PALSAR polarimetric data on 9 March 2007 was used in the study. The data has four different modes: HH, HV, VH and VV polarization (Table 1). Landsat Enhanced Thematic Mapper Plus (ETM+) of 136/045 (path/row) on 19 December 1999 assisted the interpretation procedure. Digital elevation model (DEM) of Shuttle Radar Topographic Mission (SRTM) data was used to ortho-rectify ALOS PALSAR data.

Incidence angle	Polarization	Explanation
21.5^0	HH	• Horizontally polarized transmission • Antenna only received horizontal polarization
	HV	• Horizontally polarized transmission • Antenna only received vertical polarization
	VH	• Vertically polarized transmission • Antenna only received horizontal polarization
	VV	• Vertically polarized transmission • Antenna only received vertical polarization

Table 1. The characteristics of data-sets

2.3 Methodology

ALOS PALSAR image (level 1.5) was ortho-rectified using SRTM digital elevation data and image header information. The study area was separated as subset. Geometric distortion on the image was further checked and corrected (only single-order) with the ortho-rectified Landsat ETM+ image, which was earlier verified on the ground. Speckles on the PALSAR image was reduced by 3X3 Lee-sigma filtering.

Land cover category		Physical characteristics	Interpretation keys	Land cover code
Level 1	Level 2			
Forest	Forest	• Tropical wet evergreen and semi-evergreen forest	• Light cyan • Medium texture • Irregular boundary • Located in the hilly terrain and topographic features are visible on the radar image	1
	Plantation	• Planted with various species (*Dipterocarpus turbinatus, Syszygium grande, Artocarpus chaplasha* etc.)	• Light cyan • Smooth texture • Ground information is sometimes necessary to separate this class from forest	2
Non-forest vegetation	Mosaic	• Formed after removal of forest	• Mixture of dark red and light cyan	3
	Shrubs	• Scrubby vegetation intermixed with grasses, seedlings and saplings of trees and bamboos	• Dark red • Scattered occurrence of white colour is sometimes noticed • Terrain features are often vivid	4
	Agricultural crops/Rural homesteads with tree coverage	• Paddy and other annual or perennial crops • Homestead with tree coverage	• White • Usually located in the plain-lands • Terrain feature is not visible	5
Non-vegetated	Bare-soil (dry/wet)	-	• Red • Appears in black if soil is flooded	6
	Shrimp farms/ Salt-beds	• Rectangle sized small pond like structure, used for the production of shrimps or salt • Shrimp-farms usually have a shallow depth of water. Salt-bed may have water or may be in dry condition	• Mixture of dark-red and light-red • Black rectangle shaped beds are often visible with red/bright ridges	7
	Water	-	• Dark tone	8

Table 2. ALOS PALSAR interpretation keys for Southern Chittagong, Bangladesh (VV→ Red, VH→ Green and HV→ Blue)

On PALSAR scene forest, plantation, forest mosaic, shrubs, agriculture/rural settlements with tree cover, bare-soil, shrimp-farms/salt-beds and water-body could be distinguished. Visually interpreted image was digitized on-screen to prepare forest (land) cover map. Several field-visits were done during the winter season of 2002-2003 and 2003-2004.

3. RESULTS AND DISCUSSION

Radar imagery is the result of radar signals, depends upon system parameters (wavelength, polarization and incident angle) and terrain parameters (complex dielectric constant, surface roughness, terrain geometry, and surface and volume scattering). Different elements of image interpretation (tone or colour, size, shape, texture, shadow, pattern, association etc.) assisted in radar image interpretation. In RGB (VV, VH and HV) visualization, forest appears in cyan, soil in red and water in black. Land-cover characteristics and interpretation remarks are listed in Table 2. The appearance of different land covers on the image is presented in Figure 3.

Land cover map was prepared from Polarimetric SAR data using visual interpretation technique and digitizing on-screen (Figure 4). Forests are usually concentrated in the hilly terrain. The locations of shrubs and degraded forests are close to the vicinity of settlements. Low-lying coastal zones dominated by shrimp-farms and salt-beds are distributed in the eastern and north-eastern part of the study area. Rural-settlements are located in the fringe of shrimp-farms and hills in the north, concentrated in central-east and sporadically distributed in the south-west.

Four major land-covers are dominated in the study area: forest (5 955 ha), forest mosaic (5 678 ha), low-lying coastal zones (5 107 ha) and agriculture & bare-soil (10 561 ha). The class bare-soil may be contemporary and usually represents the cultivable agricultural lands on the plain-land. Bare soil on the hills could be the result of repeated disturbance on the forest. The details of land cover statistics are presented in Table 3.

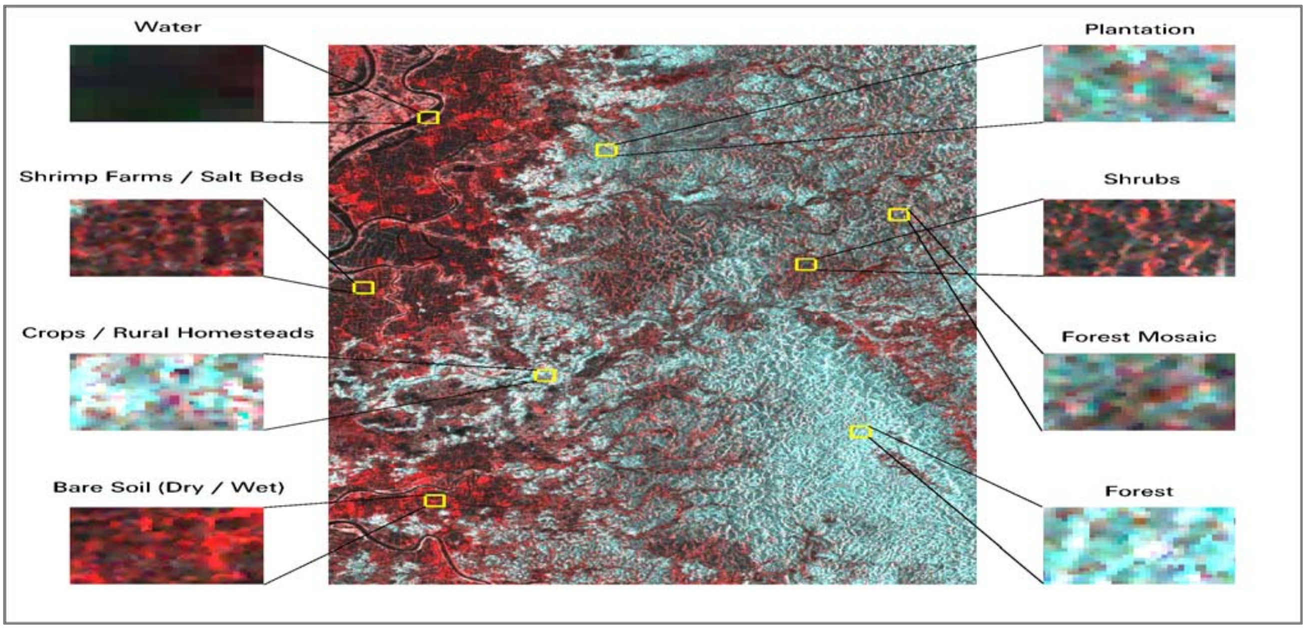

Figure 3. Appearance of different land covers on PALSAR scene (VV→ Red, VH→ Green and HV→ Blue)

Landcover / Landuse	Area (ha)	Percentage
Forest	5 955	18.54
Plantation	2 349	7.32
Forest mosaic	5 678	17.68
Shrubs	2 209	6.88
Crops/Homesteads	4 082	12.71
Bare soil	6 479	20.18
Shrimp farms/Salt-beds	5 107	15.90
Water	253	0.79
Total	32 111	-

Table 3. Extent of different land covers in the study area

Polarimetric PALSAR data could distinguish forest from other land covers based on colour and texture. Plantation could be interpreted using texture; this class has smoother texture than natural forest. The separation of shrubs and forest mosaics from other land covers is possible using colour and contextual information (i.e. terrain feature). Single polarization (HH) L band JERS-1 SAR image could separate forest and degraded forest (sometimes may be represented as forest mosaic) in the South-eastern Bangladesh (Rahman and Sumantyo, 2007); PALSAR polarimetric data distinguished additional classes-shrubs and homestead forests (intermixed with agricultural crops). On the other hand, Landsat ETM+ optical data interpreted four different categories of natural vegetation (primary forests, secondary forests, bamboo and shrubs) and four types of plantations (acacia, rubber, indigenous species and teak/scattered trees) in that region (Rahman, 2008).

4. CONCLUSION

Current study prepared (i) an interpretation key to delineate forest and other land cover types and (ii) land/forest cover map for Southern Chittagong using ALOS PALSAR polarimetric data. This study used visual interpretation and digitizing on-screen technique to prepare land cover map. Further study should concentrate on digital classification for forest mapping using both polarimetric SAR intensity and texture information.

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REFERENCES

Champion, H. G., Seth, S. K. and Kattak, G. M., 1965. *Forest Types of Pakistan*. Pakistan Forest Institute, Peshawar, 238 p.

Dobson, M. C., Pierce, L. E. and Ulaby, F. T., 1996. Knowledge-based land-cover classification using ERS-1/JERS-1 SAR composites. *IEEE Transactions on Geoscience and Remote Sensing*, 34(1), pp. 83-99.

Ford, J. P. and Casey, D. J., 1988. Shuttle radar mapping with diverse incidence angles in the rainforest of Borneo. *International Journal of Remote Sensing*, 9(5), pp. 927-943.

Jiyuan, L., Xuyan, T. and Jinkai, X., 1986. Application of Shuttle Imaging Radar data for land use investigations. *Remote Sensing of Environment*, 19, pp. 291-301.

Khan, S. A., 1979. Revised working plan for the forests of Chittagong Division (for the years 1978-79 to 1987-88). Volume 1. Forest Department, Government of Bangladesh, Dhaka.

Lo, C. P., 1988. Comparative evaluation of the Large Format Camera, Metric Camera and Shuttle Imaging Radar-A data content. *Photogrammetric Engineering & Remote Sensing*, 54(6), pp. 731-742.

Pierce, L. E., Bergen, K. M., Dobson, M. C. and Ulaby, F. T., 1998. Multitemporal land-cover classification using SIR-C/X-SAR imagery. *Remote Sensing of Environment*, 64, pp. 20-33.

Quegan, S., Toan, T. L., Yu, J. J., Ribbes, F. and Floury, N., 2000. Multitemporal ERS SAR analysis applied to forest mapping. *IEEE Transactions on Geoscience and Remote Sensing*, 38(2), pp. 741-753.

Rahman, M. M., 2008. *Topical Deforestation and Carbon Emission: Estimations Based on Remote Sensing.* Rhombos Verlag, Berlin, 239p.

Rahman, M. M. and Sumantyo, J. T. S., 2007. Application of JERS-1 SAR Data for Tropical Forest Cover Mapping. In: *Proceedings of 13th CEReS International Symposium on Remote Sensing: Disaster Monitoring and Mitigation in Asia*, Chiba, Japan, pp. 73-83.

Rignot, E. J. M., Williams, C. L., Way, J. and Viereck, L. A., 1994. Mapping of forest types in Alaskan Boreal Forests using SAR imagery. *IEEE Transactions on Geoscience and Remote Sensing*, 32(5), pp. 1051-1059.

Simard, M., Saatchi, S. S. and Grandi, G. D., 2000. The use of decision tree and multiscale texture for classification of JERS-1 SAR data over tropical forest. *IEEE Transactions on Geoscience and Remote Sensing*, 38(5), pp. 2310-2321.

Thiel, C., Weise, C., Riedel, T. and Schmullius, C., 2006. Object based classification of L-band SAR data for the delineation of forest cover maps and detection of deforestation. 1st International Conference on Object-Based Image Analysis (OBIA 2006), July 4-5, 2006, Salzburg, Austria. http://www.commission4.isprs.org/obia06/papers.htm (accessed 24 April 2008)

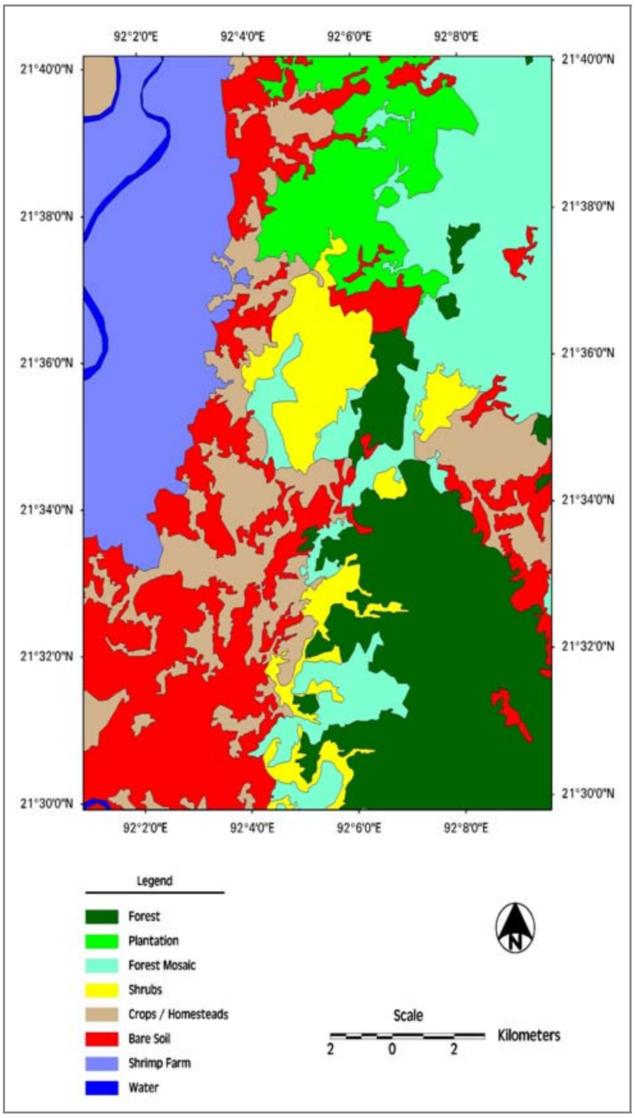

Figure 4. Forest (land) cover map of Southern Chittagong using PALSAR polarimetric data