Application of JERS-1 SAR Data for Tropical Forest Cover Mapping

M. Mahmudur RAHMAN[1] and Josaphat Tetuko Sri SUMANTYO[2]

[1, 2] Microwave Remote Sensing Laboratory, Center for Environmental Remote Sensing, Chiba University

1-33, Yayoi, Inage, Chiba 263-8522 Japan

E-mail: [1]mahmud@restaff.chiba-u.jp (Corresponding author)

Abstract

Monitoring of tropical forest cover is important because it is changing in many parts of the world. Synthetic Aperture Radar (SAR) is a useful tool to delineate the forest, as it can penetrate cloud, which often hinders the use of optical remote sensing in the tropics. The study area is located in the tropical forest region of south-eastern Bangladesh. The research used Japanese Earth Resource Satellite 1 (JERS-1) Synthetic Aperture Radar (SAR) imageries of 1997. Landsat Enhanced Thematic Mapper Plus (ETM+) imagery of 1999 assisted the interpretation procedure. Filed verification was done in 1998-1999. SAR imageries were geo-coded using previously rectified Landsat ETM+ pan image. Speckle noises on the imageries were removed by Lee-Sigma Filter. Three SAR scenes (Path/row: 144/264, 144/265, 145/264) were mosaiced. Relative image-to-image radiometric normalization was used to reduce the anomaly due to the differences in brightness before making the mosaic. The use of both SAR- intensity and texture image could separate forest from agriculture, shrimp farms, water and bare soil. Field-verification and the use of ETM+ optical image could differentiate eight different forest types (primary and secondary forest, bamboo, shrubs, plantation with indigenous species, Teak, Rubber and Acacia) but the use of only JERS-1 SAR image this was not possible. Finally, forest cover map prepared for the study area.

Key words: SAR, Tropical forest, Classification, Mapping

1. Background

Forest is the source of wood for energy, construction material, pulp and paper and many other versatile uses over centuries. Since the beginning of industrial revolution forest has been cleared in many parts of the world for industrial input and building materials. Population growth has also adversely affected the forest area; settlements and agricultural farmlands have replaced many forests. Until the late nineteenth century deforestation and forest degradation mostly took place in the temperate regions. Today, forest cover in the developed countries is still increasing slightly; between 1980 and 1995, there was an average increase of 1.3 million ha per year (FAO 1999). In the recent decades, many temperate forest stocks are expanding through the establishment of plantations, the re-growth of forests on abandoned agricultural lands, and increased growing stock of forest biomes. In contrast, tropical forests are dwindling; the rate of tropical deforestation is estimated to be 15.5 million per year in the period of 1980-1995 (FAO 1999).

As a consequence, periodic monitoring of forest is important. Application of optical sensor for continuous forest inventory often faces difficulties due to cloud coverage. On the other hand, Synthetic Aperture Radar (SAR) is a useful tool for monitoring of forest cover since it can penetrate the cloud. The objectives of this investigation are to (i) prepare forest cover map using Japanese Earth Resources Satellite-1 (JERS-1) SAR data and (ii) develop visual interpretation key for land cover interpretation using SAR data for south-eastern Bangladesh. Studies were conducted to prepare forest map using optical data (i.e. Rahman and Csaplovics 2001).

2. Literature Review

Many studies have used SAR for land cover and landuse mapping. Shuttle Imaging Radar-A (SIR-A) in association Landdsat Multispectral Scanner (MSS) data have been used to prepare a thematic map of south of Tianjin, north China (Jiyuan *et al.* 1986). The investigation interpreted nine different land covers and landuses: irrigated land, dry land, vegetable plot, orchard, pond, river and canals, residential area, railway and highway. Visual interpretation map was prepared from SIR-A data of Pensacola, Florida (Lo 1988). The investigation could separate cropland, built-up area and highway.

Forest was separated from non-forest area using multi-temporal C-band European Resource Satellite (ERS) SAR data on a range of test sites in the United Kingdom, Finland and Poland (Quegan *et al.* 2000). The study applied a threshold value for backscatter coefficient (dB) to distinguish forest from non-forest area. A knowledge-based classification using a hierarchical decision rule was applied to classify four different types of vegetation (Short Vegetation, Broadleaf, Upland Conifer and Lowland Conifer) and flat surface in northern Michigan (Dobson *et al.* 1996). The investigation used ERS-1 and Japanese Earth Resource Satellite-1 (JERS-1) data. The classification result was compared with classification based on air-photo interpretation.

Multidate three-frequency polarimetric AIRSAR data was applied for forest type mapping in the Tanana river flood-plain, interior Alaska using a maximum-a-posteriori Bayesian classifier (Rignot *et al.* 1994). Open water of rivers and lakes and five vegetation types were separated, dominated by White Spruce, Balsam Poplar, Black Spruce, Alder/Willow Shrubs and Bog/Fen/Non-forest Vegetation. Forest cover of East Kalimantan was mapped from L-band Shuttle Imaging Radar-B (SIR-B) data (Ford and Casey 1988). Five cover types: Tidal Forest, Swamp, Coastal Lowland Forest, Wetland and Clear-cut Areas were mapped but there was no attempt to prepare forest map with microwave data in the region.

3. Study Area

The study area is located at southern Chittagong, which is in the south-eastern part of Bangladesh. The area corresponds to the selected parts of three scenes (144/264, 144/265 and 145/264) of JERS-1 SAR image. The size of the study area is about 3000 sq. km (62 km x 47 km). It covers 21°24′to 21°50′ N Latitude and 91°48′ to 92°15′ E longitude (Figure 3.1).

The area is characterised with a sub-tropical monsoon climate with three distinct seasons per year: the pre-monsoon hot season from March through May, rainy monsoon season which lasts from June through October, and a cool dry winter season from November through February. Summer temperatures range from 26° to 32° C and winter temperatures 18° C to 29° C. Monsoon season starts in June and ends in October and accounts for 80% of the total rainfall. The average monthly rainfall varies from 400-500 mm in the monsoon period (June to October) to 100 mm in the dry period.

The forests of the study area are classified as tropical wet evergreen forests and tropical semi-evergreen forest (Champion *et al.* 1965, Figure 2). In the regional context the Chittagong flora differs from the Eastern Himalayan flora by the absence of Sal (*Shorea robusta*) and that from Myanmar by the absence of Teak (*Tectona grandis*). The outstanding feature of the forest vegetation is the frequent occurrence of the general Dipterocarpus, Quercus and Eugenia (*Syzygium* spp) (Baten 1969).

Since all the accessible areas were transformed to shifting cultivation, virgin forests are seldom noticed. Present crop mostly consists of secondary re-growth, which is still in the process of succession to the climax evergreen type. This process of succession is often influenced by the continuous human disturbance and thus leads to a drier scrubby forest or to a savannah in many areas (Khan 1979).

The Dipterocarps are the characteristic feature of evergreen stratum. A certain amount of deciduous species like Anacardaeous, Swintonia is often predominating. Sterculiaceae, Artocarpus and Sygigium those generally form an important part of the upper canopy are often present. Sometimes bamboo appears in several places when upper canopy is disturbed. Bamboo is typically absent in the virgin forests where canes and palms are the main woody monocotyledons. Tree ferns sometimes occur but epiphytes and ground-ferns are frequent. In certain areas, the gregarious occurrence of several Dipterocarpus species is common in top canopy with a seldom occurrence of any other species (Khan 1979).

The main characteristic of semi-evergreen forest is the dominance of appreciable proportion of deciduous species in the top canopy. The canopy is correspondingly lighter during the period of minimum rainfall (November to March) because of shedding leaves. Epiphytes, climbers and bamboos are often present in the lower canopy, which later in some extent are replaced by canes and palms in climax evergreen formation.

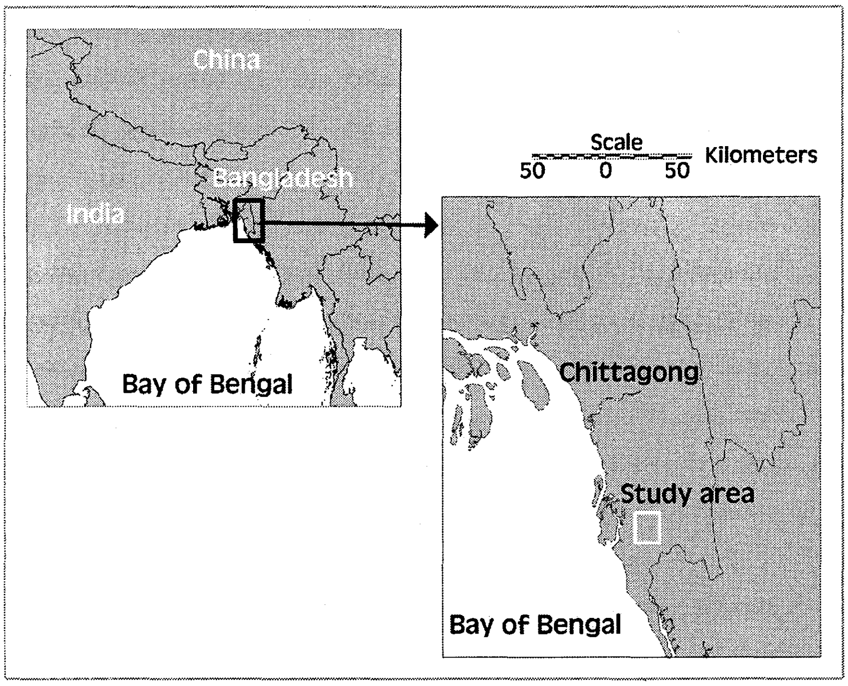

Figure 1. Location of the study area

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

4. Methodology

The study used (i) JERS-1 SAR data of path/row: 144/264 (08-02-1997), 144/265 (08-02-1997) and 145/264 (09-02-1997) and (ii) Landsat ETM+ images of 135/045 (14-02-2000) and 136/045 (19-12-1999). Level 0 JERS-1 SAR data was procured from Remote Sensing Technology Center (RESTEC) of Japan and was converted to 1.1 intensity image using the software provided by Japan Aerospace Agency (JAXA). Speckle noise on the imageries was reduced by 3x3 Lee-sigma filters. SAR images were geo-rectified with geo-coded Landsat ETM+ pan image mosaic using polynomial function 1. The RMS errors of geo-rectification were 1.6, 2.9 and 1.1 pixels for 144-264, 144-265 and 145-264 scenes respectively. Three scenes were joined to make a continuous image mosaic. A sub-scene from the mosaic was selected for mapping.

On the SAR image forest, degraded forest (scrubby vegetation associated with forest re-growth), agriculture, shrimp-farming, urban and water-body could be interpreted on the SAR image. Visually interpreted SAR image was digitized on-screen and forest (land) cover map was prepared. Field verification was done in several times during 1998-2004.

5. 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). Tone, texture, shape, size, shadow, pattern and association assisted in radar image interpretation. Land-cover characteristics and corresponding forest interpretation for the study area is presented in Table 1. Forest mosaic prepared from three JERS-1 SAR scenes is presented in Figure 3 and different land covers and landuses are indicated by a white square. Visual interpretation of SAR scene is presented in Figure 4.

Table 1. JERS-1 SAR interpretation keys for southern Chittagong, Bangladesh

Land cover / landuse type	**Physical characteristics**	**Interpretation keys**
Forest	•Tropical wet evergreen and semi-evergreen forest	•Medium tone •Rough texture
Degraded forest	•Formed after removal of primary forest by extreme human interference	•Medium tone (darker than forest)
	•Composition: re-growth and scrubby type of vegetation	•Terrain on the image is more vivid than forest class due to removal of tree coverage

Coastal plantation	•Planted with mangrove species (major species- *Sonneratia apetala*) on the newly accreted lands	•Medium tone •Smooth texture
Agriculture	•Agriculture area contains a mixture of different land cover / landuse: paddy crops; bare (both wet and dry) soil and flooded soil	•Heterogeneous (random mixture of dark and bright) tone
Shrimp farms	•Rectangle sized small pond like structure, used for the production of shrimps. It has shallow depth of water	•Appears as dark tone, a large number of white and thin lines are seen due to strong return echo (high reflectance) from the forward side (radar sensor) of the ridges
Urban	•Residential and official area mostly occupied by impervious surface (buildings and roads)	•Very bright tone
Rivers	-	•Irregular shaped dark line, sandwiched by two of bright lines especially near the coast
Sea	-	•Dark tone

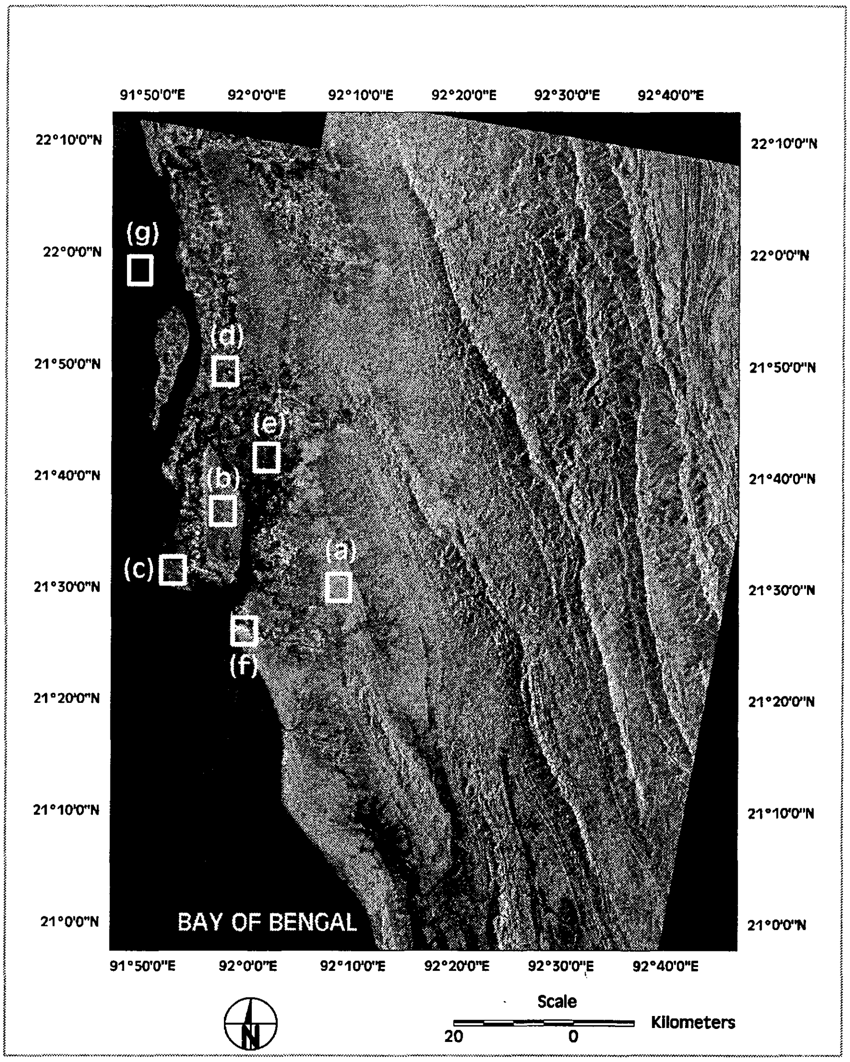

Figure 3. Mosaic of three JERS-1 SAR scenes (a) forest (b) degraded forest (c) coastal plantation (d) agriculture (e) shrimp farms (f) urban (g) water

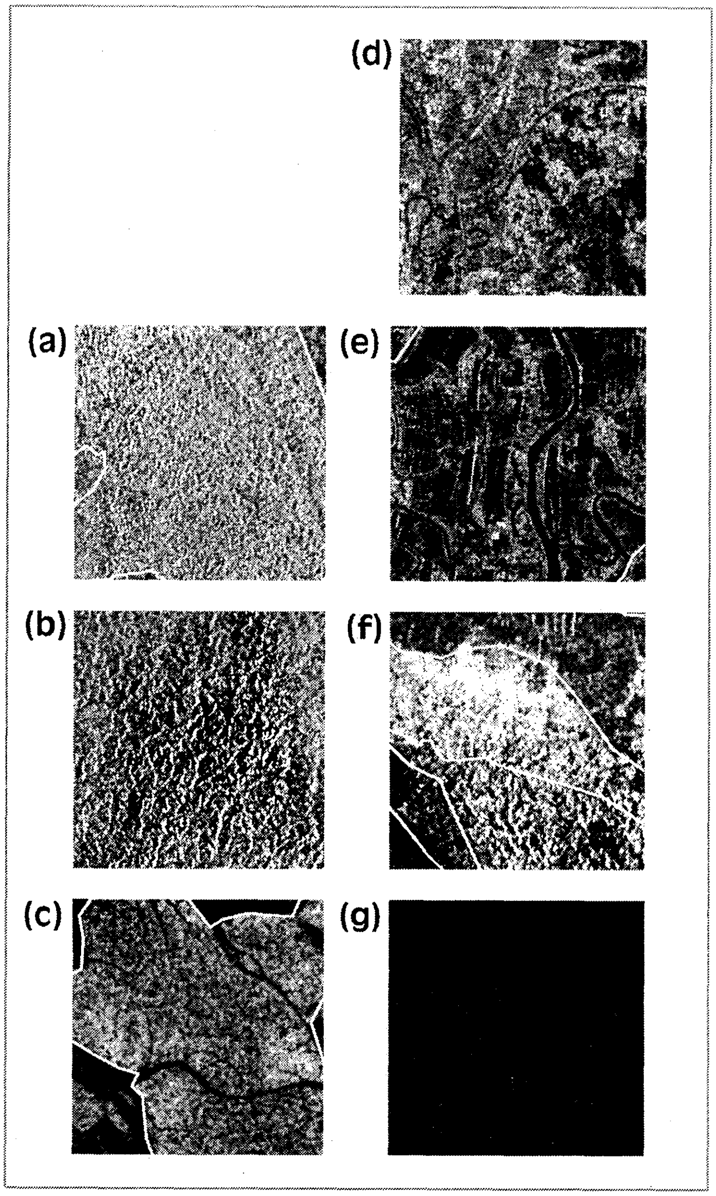

Figure 4. Visual interpretation of JERS-1 SAR image (a) forest (b) degraded forest (c) coastal plantation (d) agriculture (e) shrimp farms (f) urban (g) water

Forest cover map prepared from visual interpretation and on-screen digitizing is presented in Figure 5. The land cover and landuse on the map is separated from west to east direction. The western area is covered by sea, at the middle agriculture and eastern-side is forest; north-eastern part is degraded forest and south-eastern is forest. Statistics shows that forest area is distributed on 27 054 ha of area (9.2%).

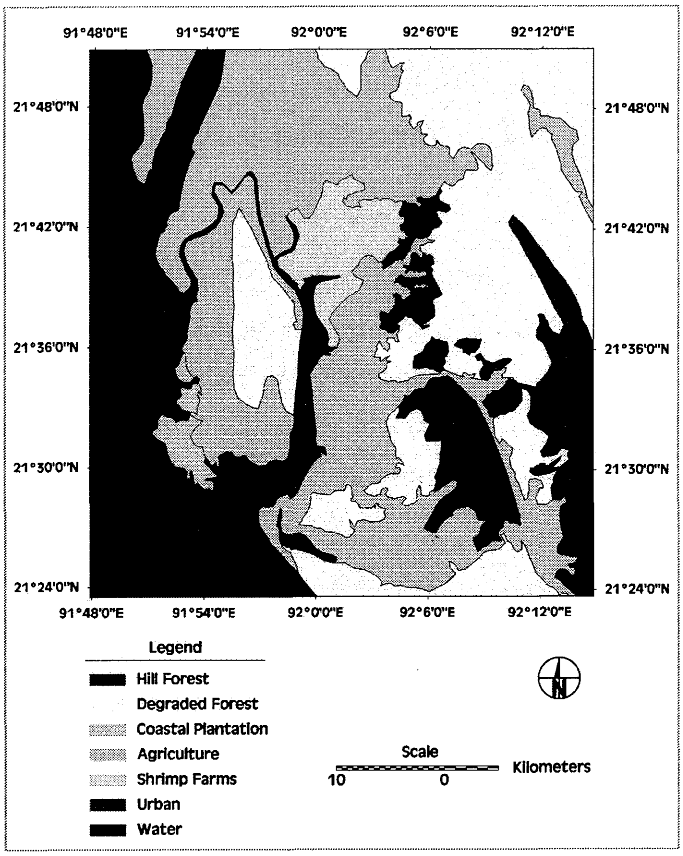

Figure 5. Forest (land) cover map of southern Chittagong using JERS-1 SAR data

Table 5. Land cover and landuse type in the study area

Landcover / Landuse	Area (ha)	Percentage
Forest	27 054	9.2
Degraded forest	95 364	32.6
Coastal plantation	2 558	0.9
Agriculture	89 454	30.6
Urban	625	0.2
Water	69 549	23.8
Shrimp farms	8 086	2.8

Radar image is suitable to separate forest from non-forest class. Forest can be separated based on the intensity and texture image. Degraded forest is also distinguishable from well-stocked forest in most of the cases. However, multispectral optical image (i.e. Landsat ETM+) could separate eight different vegetation types (primary and secondary forest, bamboo, shrubs, plantation with indigenous species, Teak, Rubber and Acacia) in the study area (Rahman *et al.* 2004). In contrast, further distinction of different forest types is not possible on the radar image.

Terrain features and urban classes are more separable on SAR image in compare with optical images (i.e. Landsat). Topographic feature is more vivid on the SAR image in compare with the optical images. The topographic features and slopes are easy to detect on the SAR image. SAR has a high intensity on the urban areas because of corner reflection, when two smooth surfaces form a right angle facing the radar beam, the beam bounces twice off the surface and most of the radar energy is reflected back to the radar sensor and appear in very bright tone on a radar image.

This study has developed an interpretation key for tropical landscape using SAR data. Such a key is available in the other regions of the world (i.e., Jiyuan *et al.* 1986) but not in this study region. However, interpretation key for vegetation of the study region has been developed using optical sensors (see Rahman *et al.* 2004).

6. Conclusion

This study has developed (i) forest cover map in southern Chittagong, Bangladesh and (ii) interpretation key to identify and delineate forest coverage in the study region. The investigation has failed to prepare a forest cover map based on digital classification with the assistance from intensity and texture-based forest classification because it often inter-mixed with many other classes. Further study should be carried out to overcome this problem.

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