SATELLITE DATA APPLICATION FOR MANGROVE MANAGEMENT

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ABSTRACT

It is well-known that the mangrove ecosystem plays important roles in coastal regions by its functions including, inter alia, supplying food and fuel wood for humans and natural protection against erosion. Moreover mangrove ecosystem has become one of the key factors in considering the global warming issue and thus mangrove ecosystem is becoming increasingly important. However, mangrove management is quite a complex undertaking because of its geographic conditions. Satellite remote sensing will provide basic data for these purposes. In this paper, effectiveness of satellite data for classification and mapping of mangrove forests is reported as an example of their application for mangrove management.

Can Gio Mangrove Biosphere Reserve of Ho Chi Minh City in Vietnam was selected for the study because well-developed mangrove habitats are currently widely observed in spite of the serious damage suffered during the Vietnam War.

For classifying mangrove species, analysis of Band 1 to Band 9 spectra of ASTER was carried out for the study area. ASTER VNIR and SWIR data acquired on 8th August, 2002, 9th February, 2003 and 25th February, 2003 were used. Mangrove's digital number (DN) values in SWIR are generally lower than non-mangrove vegetation such as wild grass and rice paddy. Different mangrove species such as Avicennia alba, Rhizophora apiculata and Phoenix paludosa have different specific DN values. These spectral variations enable us to separate mangroves and classify mangrove species. In particular, different spectral pattern was observed in different mangroves.

For mapping mangrove forests, Landsat/TM, ETM+ and JERS-1/OPS were utilized. In order to accurately determine the changes of the mangrove front, which is the boundary between mangrove forest and the river, four images (1989, 1994, 1997, 2001) were compared using NDVI and DN values. Having defined the thresholds, each mangrove front was occurred to the west of Can Gio Forest Park. The mangrove front changed in irregular patterns with advancing and retreating zones. The maximum advance of the front was about 250m and the maximum retreat was about 70m along the river bank. The different behavior of the front was caused by different conditions of mangrove growth.

1. Introduction

Mangrove forests have decreased considerably throughout the world in spite of the recognition of the importance of its sustainable use and conservation in recent years. From global mangrove statistics, it is seen that recent estimate of mangrove area declined significantly from 19.8 million hectares in 1980 to 14.7 million hectares in 2000 (FAO). However, this figure depends on the accuracy of information provided by each country, and the currently most reliable estimate is that of the early 1990s. Therefore, mangrove area estimate is difficult and reliable estimate is now urgently needed for both local and global level.

Currently various satellite data are available to assist mangrove area estimate throughout the world. In this paper, effectiveness of satellite data for mapping and classification for mangrove is reported as an example of applying satellite data for mangrove management in Vietnam (Hang et al., 2003, Hirose et al., 2004). In Vietnam, mangrove forests are believed to have declined from 227, 000ha in 1980 to 104,000 ha in 2000, but the most reliable area estimate is 252,500ha in 1983.

2. Study area

The study area, Can Gio mangrove forest is located 50km south of Ho Chi Minh City in southern Vietnam (Figure 1). Most of the study area is flat alluvial plain with a basement composed of Neogene to Quaternary sediments below 3m depth. The Can Gio area has a complicated, networked river system that is influenced by the tidal regimes (maximum amplitude of around 4m). Although mangrove was seriously destroyed during the Vietnam War, current dense mangrove forest is estimated to cover more than 38,750ha (Hong, 2000). As a result, UNESCO registered it as the first Biosphere Reserve in Vietnam.

3. Data used

The satellite data set used in this study is laid out in Table 1. False color composite images (01 Jan. 1973- 08 Aug. 2002) are shown in Figure 2. The upper three images are Landsat/MSS, TM and ETM. The lower three images are JERS-1/OPS and Terra/ASTER. All six images are chronologically numbered. A topographic map and a land use map and a vegetation map (1:10,000) were used to obtain the precise Ground Control Points. Registration errors of each image were under 0.5 pixels.

Table 1. Data used in this study

Satellite/Sensor	Acquisition Date
Landsat/MSS	01st Jan., 1973
Landsat/TM	06th Mar., 1989
JERS-1/OPS	16th Nov., 1994
	16th Jan., 1997
Landsat/ETM	02nd Jan., 2001
Terra/ASTER	08th Aug., 2002
Terra/ASTER	09th Feb., 2003
Terra/ASTER	25th Feb., 2003

Fig.1 Location map of study

4. Analysis and results

4.1. Comparison of false color and NDVI images

False color composite images and Normalized Difference Vegetation Index (NDVI) images were calculated to compare the sequence of mangrove changes in the study area (Figs. 2 and 3). Since NDVI values represent a normalized ratio of reflected visible and near-infrared energy as expressed by the following equation, it is used for analysis of terrestrial vegetation monitoring.

$$NDVI=(NIR - RED)/(NIR + RED) \quad (1)$$

NIR represents near-infrared energy and RED represents visible energy here. Although the lands damaged by bombs and sprays during the war are characterized in grayish color in Figure 2-1, Figure 2-2 shows good recovery of mangrove. And good results of the mangrove replanting program are demonstrated by the images of JERS-1, Landsat/ETM and ASTER. The NDVI values also indicate good recovery and high values of NDVI concentrated in two areas: in the center and the lower part of the image (Figure 3). The determination of the southern front of mangrove growth will be reported in the next section.

4.2. Mangrove species in the study area

In the southern part of the area, three dominant species are observed, namely *Avicennia alba* (M), *Rhizophora apiculata* (D) and *Phoenix paludosa* (CL) (Kitaya et al., 2002). M is a pioneering species and often occupies the interface between land and sea in areas of high salinity due to its ability to grow on weak, unconsolidated sediments and higher saline tolerance capability. D is the most common mangrove tree species found in the study area. This mangrove species has high commercial timber value and was widely replanted after the war. D is widespread in the intermediate zone between M and CL. Stands of CL are often found in elevated ground, forming mixed communities with other mangrove species such as *Acrostitum aureum* and *Nypa fruticans*.

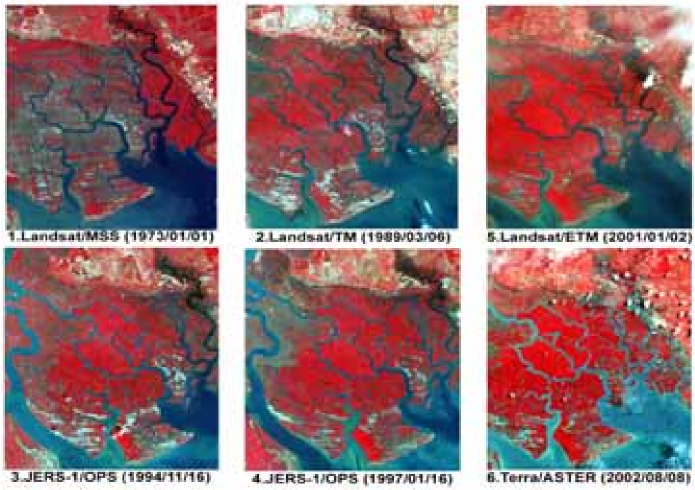

Fig.2 False color images of Can Gio

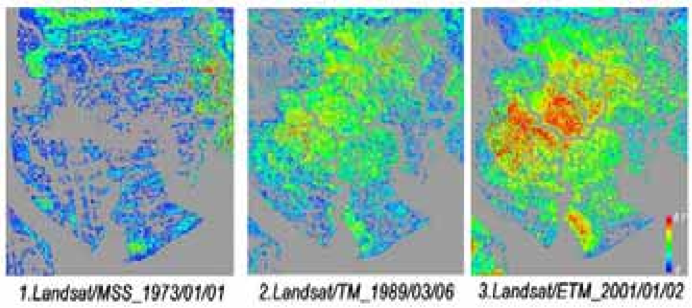

Fig.3 NDVI images of Can Gio mangrove forest

4.3. Mangrove classification

Spectral features of vegetation are closely related to physical properties of leaves and stems of trees. Those features give strong spectral reflectance and absorption in VNIR and SWIR regions. Some researchers have reported the possibilities of mangrove mapping by using those spectral features derived from satellite data (Kotera et al., 1997).

NDVI values were examined to separate vegetative areas from barren areas. As a result, it was concluded that vegetative areas can be separated from non-vegetative areas by using threshold value of NDVI 0.3 for this study area.

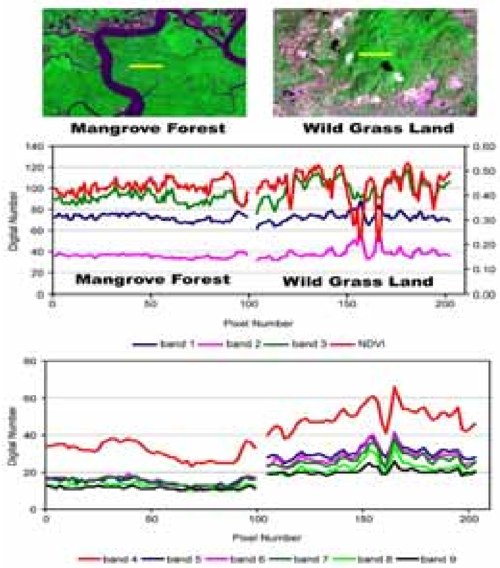

Fig.4 Histograms of DN values in VNIR and SWIR

Figure 4 shows comparison of DN values

between mangrove forest and wild grass areas. In SWIR bands, mangrove forests show clearly lower DN values than wild grass areas. Comparison of DN values in rice paddy areas also showed the same relationship in other areas. Thus mangrove forests can be separated from non-mangrove woods using ASTER data.

After delineating mangrove forests from non-mangrove areas, DN values were examined for different mangrove species such as M, D and CL. Then level slicing and PCA were applied. The result of PCA shows the significant distribution pattern in the study area. And maximum likelihood classification method was applied using training areas which were selected from the vegetation map. Finally, a mangrove classification map was prepared as shown in Figure 5. Field survey was conducted in September 2003 to verify the results of mangrove mapping by this study. Delineated mangrove areas in the map agreed well with field observations. Moreover, small channels which cannot be seen on the images were detected from the mangrove classification map.

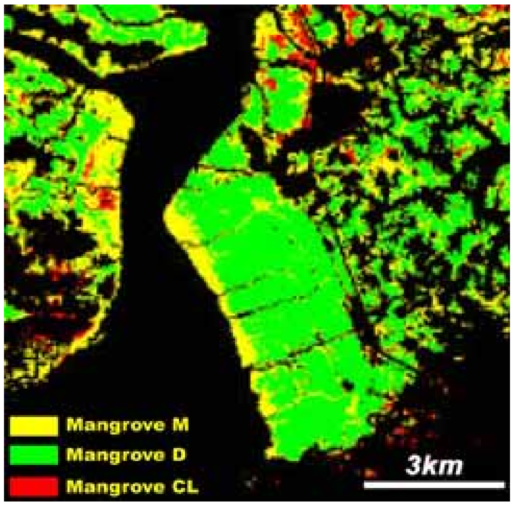

Fig.5 Mangrove classification map

4.4. Mangrove mapping

Mangrove mapping was carried out to determine the extent of mangrove forest coverage at the margin of Forest Park. Mangrove front, which is the boundary between mangrove forest and the river of the four images (1989, 1994, 1997, 2001) was compared using specific values of NDVI and DN.

Having defined the thresholds, each mangrove front was drawn as in Figure 6 for the areas A, B, and C. The changes of these lines vary from approximately 20 to 250m advance and approximately 70m retreat with irregular pattern. Those changes were presumably caused by various natural conditions such as “sedimentary changes” and “water currents” because sedimentation and erosion mechanism in the river mouth zone are complicated and changeable under the strong tidal current conditions.

The retreat of mangrove front occurs significantly in the southern part of area C. This area was strongly affected by the river flow and the tidal current. Moreover, there were three shrimp ponds. Before the shrimp ponds, river flow and tidal currents were balanced under natural conditions. But after the shrimp ponds were built, water fills in more easily than other river channels during rising tide. And water, in the meantime, has been strongly drained off to

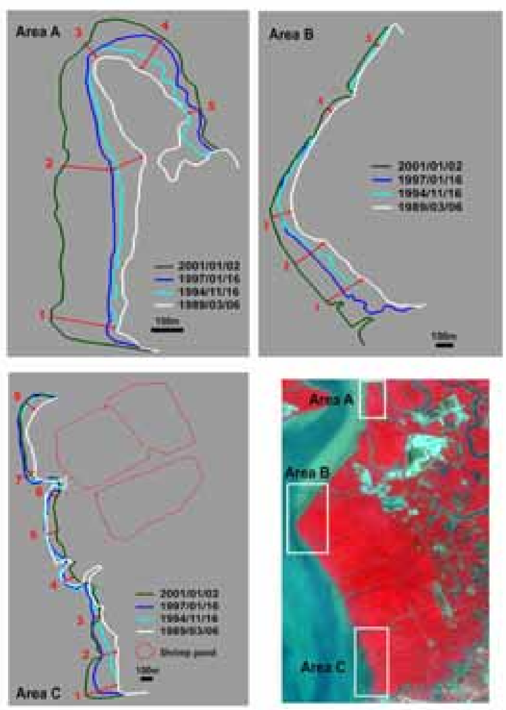

Fig.6 Changes of mangrove front

the river during ebbing tide. This phenomenon was reported by field measurement and experimental data (Mazda et al., 2002). After every high tide, a typical eddy caused by strong ebb flow was observed. The amplitude of this tidal current is more than 70cm/s. It is enough to carry the sediment materials at the bottom. Thus coastal erosion occurred in the southern part of the study area due to large and strong tidal flows. Therefore retreating mangrove front was observed on line 3 to 7 related to the eddy flow at drain mouths of shrimp ponds.

5. Conclusion

In this paper, two examples were presented namely mapping and classification for mangrove management. It was shown that multi-temporal data and multi-spectral data provide useful information for mangrove management. In particular, different spectral patterns were observed from different mangrove species. These results encourage us to further study mangrove areas in the world as well as to acquire information on local distribution of different mangrove species. The results are summarized as follows.

(1) Mangrove in the study area can be divided into three dominant species using nine spectral bands of ASTER/ VNIR and SWIR. And small channels which cannot be seen on the images were detected from the classification map.

(2) Mangrove forest front changed significantly between 1989 and 2001. The maximum advance of the distance of the front was about 250m and the maximum retreat was about 70m along the shoreline of Forest Park. Possible causes of retreating mangrove fronts are related to strong water current at drain mouths of shrimp pond.

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