Change Detection of Land Use and Riverbank in Mekong Delta, Vietnam Using Time Series Remotely Sensed Data

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Abstract: By taking the advantages of remote sensing technology, changes of land cover in Ca Mau Peninsular (the Southern part of the Mekong delta) and erosion of riverbank of the Mekong River have been defined. Change detection using time-series optical and radar satellite images (Landsat, SPOT and Radarsat) is the main approach in this study. Typical land cover in Ca Mau Peninsular is mangrove; its changes are observable by analysing imageries from 1973 to 2008. The results showed that more than half of the mangrove area was converted into shrimp farms. This made forest cover severely declined. Riverbank of the Mekong River also was detected to be eroded and accreted in a complicated form. Locations along the left and right banks of Tien and Hau river are defined as hot spots that are seriously suffered erosions. Topographic maps in 1966–1968 were taken into account as base line data, which was analyzed along with satellite images from 1989 to 2009. In addition, the Digital Shoreline Analysis System (DSAS) package was taken to analyze trend of changes in terms of changing prediction.

Key words: remote sensing; change detection; land use; riverbank; erosion

1 Introduction

Traditional methodologies in study of land cover and riverbank changes require conventional surveys, repeated measurements to identify and to evaluate changes. Recent studies in the Mekong Delta have been focused on erosion processes of riverbanks at hot spots (Southern Institute of Water Resources Research 2001) and conversion of mangrove into shrimp farms. Remote sensing techniques offer another approach to these issues - the use of satellite imagery combined with other digital data to extract information and derive certain measurements, as in an assessment of channel migration of Thu Bon River using scanned data- aerial photos and satellite imagery (Remote sensing and Geomatic Center 1999). A typical study of channel migration in Yellow river (China) made use both analog and digital data with a time sequential imageries of 19 dates from 1976 to 1994 (Yang et al. 1999).

There have been studies on utilization of remote sensing technology for mangrove mapping or identification of mangrove changes, such as production of an cartographic assessment of mangrove ecosystem from West Bengal in India to Ho Chi Minh City in Vietnam by using SPOT imageries (Blasco et al. 2001) or Landsat data and aerial photographs in Malaysia (Sulong et al. 2001). A primary assessment of mangrove changes in Ca Mau Province by using old map in 1966 and SPOT in 1995 and 2001 had been done (Phan 2006).

This paper presents applications of time-series satellite digital data of different sources composed of optical and radar imageries in riverbank and land use change detection and to demonstrate a capability of remotely sensed data with digital processing and GIS analysis for studies in a large area.

The main objective of land cover change study was to initial identify types of land cover and their changes over the period of 1973–2008. Test site consisted of Nam Can and Ngoc Hien districts, part of Ca Mau peninsular, Mekong Delta. The study area, South of the Cua Lon river was included a half of mangrove area which was destroyed by herbicides during the period of 1961–1971, and then recovered by reforestation. Afterward, the recovered mangrove was converted into shrimp ponds and rice fields.

For riverbank monitoring, the aim was to use remote sensing data which is known as an effective and fast technology to analyze the phenomenal hazard in the
For this purpose, multi-temporal optical and radar satellite images from 1989 to 2009 have been used. In addition to this topographical maps of the area were also used to provide the base map from 1966 to 1968 before the advent of remote sensing technique. Sa Dec Town and Hong Ngu District are presented as hot spots. The forecasted result showed that the speed of erosion into the land in Sa Dec is up to 50 m per year in next 10 years.

2 Methods

2.1 Remote sensing data used
Remote sensing data mainly used for land use monitoring at the test site of Ca Mau peninsular showed in Table 1. The data used for riverbank monitoring were acquired by Landsat, SPOT, and Radarsat satellites from the time period of 1989 to 2009. Besides this, a topographic map in 1966 was also used as base map.

2.2 Data processing
First, land use / land cover types were classified by using combination of supervised classification (Maximum likelihood classifier) and unsupervised classification (ISODATA) methods. The extent area and image data for analysis were indicated as in Fig. 1.

Second, riverbanks were extracted from topographic maps and satellite images by digitizing. From the topographic map, it was digitized follow the rivers shown in the map. For the satellite data, the composite image R-G-B by band 5-4-2 was used to enhance the objects and distinguish clearly between soil, vegetated land, mud clay soil and water and to be easily digitized. The files of riverbanks digitized were in shape format. Then all the shape files in different times were input data for DSAS module and linear regression function with weight of Matlab programming to predict effectively the riverbanks in next five and ten years.

3 Results

3.1 Land use monitoring
There are four main types of land use with forest, water bodies of aquatic farms, built-up, and annuals of cultivated land. Typical land cover at this area is mangrove, which has changed over time by various human activities. General changes at this area could be observed through three periods as the follows: (i) before the year of 1973, (ii) after 1973 to early 1990s, and (iii) from 1990s until 2008. Before 1961, mangrove at Ca Mau covered over 150 000 hectares, which had been strongly decreased, particularly many times by suffering defoliants during the war time. In addition to these direct human impacts, the postwar period was marked by a large destruction of the remaining mangrove due to massive construction of shrimp farms.

Table 1 List of remote sensing data used for land use monitoring.

<table>
<thead>
<tr>
<th>No.</th>
<th>Path/ Row</th>
<th>Province</th>
<th>Date</th>
<th>Satellite – Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>135/ 054</td>
<td>Ca Mau</td>
<td>03 Jan 1973</td>
<td>Landsat MSS – 80 m</td>
</tr>
<tr>
<td>2</td>
<td>274/ 333</td>
<td>Ca Mau</td>
<td>06 Apr 2000</td>
<td>SPOT* – 20 m</td>
</tr>
<tr>
<td>3</td>
<td>274/ 333</td>
<td>Ca Mau</td>
<td>10 Mar 2008</td>
<td>SPOT*- 2.5 m</td>
</tr>
</tbody>
</table>

* Data providing source: Planet Action – Spot Image.

Fig. 1 Satellite data (left) and land cover classified images (right) in 1973, 2000 and 2008. Image source: Planet Action–Spot Image. Images analysed by GIRS
During 1961–1971, this area was suffered a mass destruction by defoliants in summer of 1962 and later in 1966–1970 (Hatfield Consultants LTD. 1998), consequently making large bare areas covering as much 43% of the area, which were easily detectable on the Landsat MSS satellite image acquired in 1973, showing strips of non forest (Fig. 1).

After the war in 1975 until 1979, mangrove was partly recovered (Le et al. 2003). However, at this time, conversion of mangrove into cultivated land for rice growing also had been took place. This removed almost ten thousand hectares of mangrove. During 1989 and 1996 recovered mangrove was encroached by landless local people to develop aquaculture (Benthem et al. 2003).

From 1995 to 2000 and 2008, mangrove was strongly fragmented by conversion of forest into shrimp ponds with various tree cover rates. In the satellite image of 2008, at the tip that is the land belonging to protected area, shrimp ponds were removed out and forest have been restored again. Bare land of non forest at the previous period became water bodies of aquaculture ponds. At the rest part of the area, a farming system in the pattern type of mosaicked forest and aqua-cultural farms.

Conversion of mangrove into shrimp farms was more than half of the area (54%), forest covered only 42% from the analysis of satellite data in 2000. This kept losing until 2008, showed the area of mangrove was estimated approximately 76%. However, about 50% out of this area is shrimp ponds and forest mixed together with various cover rates, ranging from 10% to 60% (Fig. 1). For the whole Ca Mau Peninsular (a large area outside the data), forest cover rate could be much lower than this figure.

Conversion of mangrove into shrimp farms made forest area severely declined. Having recovered in early 1980s, the area of mangrove reached nearly 120 000 ha has been quickly decreased 60 000 ha in 2007. There were about 60 000 ha lost during 25 years from 1983 to 2007; corresponding to that period, shrimp farms had increased from about 20 000 ha in 1977 to 60 000 ha in 1992 nearly 60 000 ha in 2005 (Nguyen et al. 2009).

This is a trade-off status of mangrove in the Mekong Delta, which is increasing shrimp farms and consequently area of mangrove is decreased. Trends of mangrove decline and shrimp farm increase would be not stable yet.

Processes of mangrove changes over time can be observable following patterns of lost by war – recovery – mass conversion to shrimp farms – replanted to increase cover rate (still shrimp farms), illustrated by satellite images from 1973 to 2008 (Fig. 2a–d).

3.2 Riverbank monitoring

Along riverbanks, there are two phenomena as erosion and accretion happening. Erosion mainly occurred in Tien River from Tan Chau area to lower stream My Thuan, while in Hau river the phenomenon was less severe from Can Tho upwards Chau Doc. Great changes were distributed in Tien River extended from 4 to 10 km in length, eroded into land from 100 to 1000 meters. The eroded areas are presented in Table 2 (Pham et al. 2002).

Erosion is happened in the Tien River such as in sites 1, 2, 3 and 4 where happening strongly in Sa Dec (Site 1) (Fig.3) and in upstream of Thuong Phuoc Cape (Site 2) with forecasted rate of up to 50 and 33 m per year, respectively. The remainders, site 3 and 4 have maximum eroded rate of 15 and 18 m per year, respectively. The accretion phenomenon has happened in downstream of Thuong Phuoc Cape (Site 2) has a rate of 11 m per year (Lam et al. 2010).
At Sa Dec town (Site 1), there were 38 transects create with the distance of 100 m (Fig. 4). Riverbanks of Tien River in Sa Dec Town have eroded seriously. Especially in the curved riverbanks in Tan Quy Dong, Tan Quy Tay, An Hiep commune of Sa Dec, 850 m in width was eroded in southerly from 1989 to 2009. Forecasting for riverbanks of Tien River in 2015 and 2020 was done by using DSAS tool. In 2015 and 2020 the eroded width will be 137 m and 254 m in average which some places will be over 200 m and 400 m, respectively, such as transect 14 to 22.

Thuong Phuoc Cape (Site 2) was divided into two sides as left side and right side. At left side area, the riverbanks of Tien River are predicted to be eroded with maximum width of 184 m in 2015 and 330 m in 2020, while at the right side to be accreted to 108 m in 2015 and 171 m in 2020.

Besides Long Khanh A islet (Site 3) was divided into two parts as upper side and lower side to analysis. In both side, the erosion phenomenon has been happening which made land surface become reducing. The heaviest erosion area is at the cape of islet with the rate 15 m per year. From year 1966 to 2009, the riverbanks of upper side have

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**Table 2 Location of erosion areas in the Mekong River within period of 1966–1999.**

<table>
<thead>
<tr>
<th>River branch</th>
<th>Areas</th>
<th>Length (km)</th>
<th>Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tien river</td>
<td>- Left bank</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thuong Phuoc-</td>
<td>6</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Thuong Thoi Tien</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hong Ngu</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>An Phong</td>
<td>4</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Tan Thanh</td>
<td>4</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>My Xuong</td>
<td>9</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Chau Thanh-Sa</td>
<td>6</td>
<td>100–350</td>
</tr>
<tr>
<td></td>
<td>Dec-My Thuan</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cho Lach-Ben Tre</td>
<td>3.5–4.5</td>
<td>250–400</td>
</tr>
<tr>
<td></td>
<td>- Right bank</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>My Luong</td>
<td>4</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Long Dien</td>
<td>4</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Sa Dec</td>
<td>10</td>
<td>1100</td>
</tr>
<tr>
<td>Hau river</td>
<td>- Left bank</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nhon Hoa-An Chau</td>
<td>4.5</td>
<td>200–800</td>
</tr>
<tr>
<td></td>
<td>- Right bank</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>An Chau-Long Xuyen</td>
<td>2.6</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Binh Thuy-Can Tho</td>
<td>2.8</td>
<td>150</td>
</tr>
</tbody>
</table>

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**Fig. 3 Mekong River with severe eroded sites in Hong Ngu District and Sa Dec Town.**

**Fig. 4 Eroded riverbank in Sa Dec (Site 1)**
eroded regularly and are predicted to go into mainland 106 m in 2015 and 167 m in 2020 while the rate of lower side is lower. However, in recent years from 2007 to 2009, the riverbank of lower side had erosion rate increasing and is supposed to be lost reach to 91 m in 2015 and 170 m in 2020.

In Chau Ma cape (Site 4) located in Hong Ngu District, Dong Thap Province which has also erosion phenomenon as the other site in both left and right riverbanks with rate up to 20 m per year. Therefore, they were predicted to be eroded 100 m in 2015 and 200 m in 2020.

Coefficients of correlation having the value over 80% in almost transect of site 1 to 4 means these are strongly related to the historical phenomenon. However, some values under 30% mean the phenomenon is local and not regular such as in some transects of left side riverbanks of Thuong Phuoc Cape and of right side riverbanks of Chau Ma cape.

4 Conclusions

Remote sensing techniques provide a useful tool and satellite data gives an objective view when they are applied at large scale. It allows a synoptic viewing to predict changes in large region.

Multi-temporal optical and radar satellite images acquired from 1989 to 2009 have been used. As the results, Tien riverbanks in Sa Dec town were predicted to be eroded the highest rate as 50 m per year and until 2015 and 2020. The other riverbanks such as Cape of Chau Ma islet were predicted to be eroded up to 100 m in 2015 and 200 m in 2020. Beside the erosion is the main phenomenon in Tien River, accretion has also happened in Cape of Thuong Phuoc right side of Tien riverbanks with predicted accretion of 110 m in 2015 and 170 m in 2020.

Mangrove destruction to develop shrimp farming causes crucial decline of cover rate of forest at the Ca Mau area. The naturally protective barriers of mangrove for coastal zone is breaking that could harm the inland area on environment and economic activities.

The current projects have been implementing in the Mekong Delta in order to monitor the changes of mangrove forest in coastal zone and of Mekong River banks and shorelines more frequently. The software tools have also been developing to support for management of mangrove and riverbanks in the Delta.

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References


基于越南遥感时间序列数据的湄公河三角洲土地利用及河岸变化检测研究

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摘要：通过采用先进的遥感技术，基于光学和雷达时间序列卫星影像（陆地卫星, SPOT和雷达卫星），本文对金瓯半岛的多时段光学和雷达卫星影像（陆地卫星, SPOT和雷达卫星）,本文对金瓯半岛的多时段光学和雷达卫星影像（陆地卫星, SPOT和雷达卫星）,本文对金瓯半岛的多时段光学和雷达卫星影像（陆地卫星, SPOT和雷达卫星）,本文对金瓯半岛的多时段光学和雷达卫星影像（陆地卫星, SPOT和雷达卫星）,本文对金瓯半岛的多时段光学和雷达卫星影像（陆地卫星, SPOT和雷达卫星）,本文对金瓯半岛的多时段光学和雷达卫星影像（陆地卫星, SPOT和雷达卫星）...

关键词：遥感；变化检测；土地利用；河岸；侵蚀

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