MONITORING THE RED RIVER USING DIGITAL SATELLITE IMAGERY

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ABSTRACT

The Red River is known as a large international river basin in Asia covering three countries of China, Vietnam and Laos. This paper deals with the use of digital satellite imagery taken on different dates to derive useful information on the dynamics of the Red River section in Vietnam. The results of detecting and quantifying river changes by digital image processing and GIS analysis proved the feasibility and utility of using multi-resolution, multi-temporal satellite imagery and integrated GIS and image processing software as an effective monitoring tool for better river management for regional sustainable development.

1. INTRODUCTION

In Vietnam, the Red River forms a large ecosystem with recognized national and international importance. It can be considered both resource, environment and hazard. The river, therefore, needs to be properly monitored and managed for sustainable development. To this end, systematic and continuous collection, analysis and use of monitoring information should be carried out using both traditional and advanced methods.

Besides ground-based methods that are limited in spatial and temporal coverage, satellite images with the advantages of being synoptic and repetitive data have been increasingly used for monitoring purposes in different parts of the world. This is strongly supported by recent developments in satellite remote sensing in particular and information and communication technology in general.

This paper describes the use of some public and commercial multi-temporal, multi-resolution digital satellite imagery, image processing and GIS techniques to extract useful information on the Red River ecosystem in Vietnam. The highlighted feasibility and utility of using such data and analysis techniques for resource and environmental monitoring forms a strong basis for further applications to support future regional development management and decision making.

2. THE RED RIVER IN VIETNAM

The Red River stems from Yunnam Province, China. Its gross catchment area is 169000 km^2, of which 86 660 km^2 lies in Vietnam (accounting for 51% of the total basin area), 81 240 km2 (accounting for 48%) in China, while 1100 km^2 (making up 0.6 %) lies in Laos PDR. The Red River Basin is dominated by the tropical, monsoon climate and is subject to other climatic disturbances, such as typhoons, tropical depressions and storms. The average annual rainfall varies from 1500mm to 4800 mm. Because of the abundant rainfall, the flow in the Red River is rather high. In the dry season, due to the operation of Hoa Binh and Thac Ba reservoirs, the flow rate of the Red River downstream rises from 300 to 700m^3/s which constitutes a significant flow rate for salt intrusion prevention, water supply and navigation, especially in the low flow season from March to April (Water Resources Consulting Services, 2001).

The Red River flows into the land of Vietnam at the mountainous province of Laocai and into the Gulf of Bacbo through Balat estuary in the NW-SE direction. There are ten provinces located along the river on a total length of more than 500km covered by 5 Landsat TM/ETM+ scenes. Overall, the study area is characterized by varying topography, tropical humid climatic conditions and mixture of land use and land cover. These natural and socio-economic conditions certainly influence the successful use of satellite imagery to derive relevant information for river management purposes.

3. MATERIALS AND METHODS

To study feasibility and utility of digital satellite images for the Red River monitoring tasks in the regional and local conditions of Vietnam, three kinds of satellite imagery were selected based on image resolution, price and availability. These include moderate resolution (MODIS), high resolution (Landsat TM/ETM+, SPOT HRV), and very high resolution (IKONOS) images.

Terra MODIS is a relatively new satellite sensor launched by NASA in 1999. It collects multispectral, moderate spatial resolution and high temporal resolution images. MODIS data are better than NOAA AVHRR in spatial resolution. They can be accessed freely via the internet (MODIS Land Team, 2003). Thus, with this sensor, daily and regional coverage of the Red River in Vietnam from Laocai to the Gulf of Bacbo can be achieved.

Landsat TM/ETM+ and SPOT HRV are resource satellite sensors managed by NASA and SPOT company respectively. The data with high spatial resolution collected by these sensors are suitable for monitoring selected reaches of the Red River.

IKONOS is the first commercial very high-resolution satellite managed by Space Imaging company. Its products have spatial resolution of 1 m black and white, 4 m multispectral, and 1 m color (pan-sharpened) available as natural color (RGB) or color infrared (NIR,R,G). The revisit time of IKONOS data is between 1 and 3 days (Space Imaging, 2000). This kind of images can be used for high detailed monitoring of Red River at the local scale.

The specific datasets collected for analysis in this study, are presented in Table 1. The collected MODIS images are 500m 32-day “monthly” composites available from the Global Land Cover Facility with 7 bands covering all seasons of 2002.

Table 1. Collected digital satellite data for the Red River monitoring study

Satellite	Sensor	Date of acquisition	No. of bands	Area
Terra	MODIS	2002	7	Laocai-Balat
Landsat	ETM+	29/12/1999	8	Laocai
Landsat	ETM+	08/05/2001	8	Balat
Lansat 5	TM	30/09/96	7	Sontay
SPOT 1	HRV	21/06/86	3	Hanoi
SPOT 3	HRV	22/10/94	3	Sontay
SPOT 2	HRV	24/10/94	3	Hanoi
SPOT 3	HRV	26/10/95	3	Hanoi
SPOT 3	HRV	30/09/96	3	Sontay
IKONOS	IKONOS	30/03/2000	4	Hanoi

The digital satellite images for the Red River area were analyzed for detection, mapping and quantifying changes in and along the river using image processing and GIS software (ENVI, IDRISIW and MAPINFO) and reference data including topomaps, thematic maps and ground truth.

The data were reprojected (MODIS data) or geometrically corrected using GCP taken from the topomap sheets. The sub-images were extracted to cover the area of interest and then were further analyzed using different established image processing and GIS techniques (Eastman, 1997; Jensen, 1996; Lillesand and Kiefer, 1994; Mather, 1999). As image enhancement, natural and false color composites (NCC and FCC) were created for visual interpretation and training sample selection for image classification. Image transformations were applied to produce index images such as Normalized Difference Vegetation Index (NDVI) from red and near infrared bands. Single-band and multi-band classifications were performed using thresholding, supervised and unsupervised algorithms respectively. For quantification and digital comparison, statistical, geometrical and overlay analysis operations were carried out.

4. RESULTS AND DISCUSSION

The Terra MODIS images including NIR, NDVI, NCC and FCC provide a general picture of the Red River. The river can be seen as a line that widens downstream in NIR images (Figure 1).

MODIS NDVI, NCC and FCC images reveal broad seasonal changes in landuse and landcover along the Red River from mountainous to coastal areas. These changes affect river water quality. Ten landuse and landcover types such as evergreen forest, closed shrublands, open shrubland, savannas, perennial crops, rice and cash crops, rice, urban land, barren land and water bodies were mapped according to IGBP land cover system for the provinces along the Red River by multitemporal supervised classification of MODIS 500m monthly composites of 2002.

Thus, with moderate spatial resolution and high temporal resolution, MODIS imagery can be used for quick geographical stratification of the Red River into large and small water areas. This operation is useful for detailed monitoring with higher spatial resolution sensors.

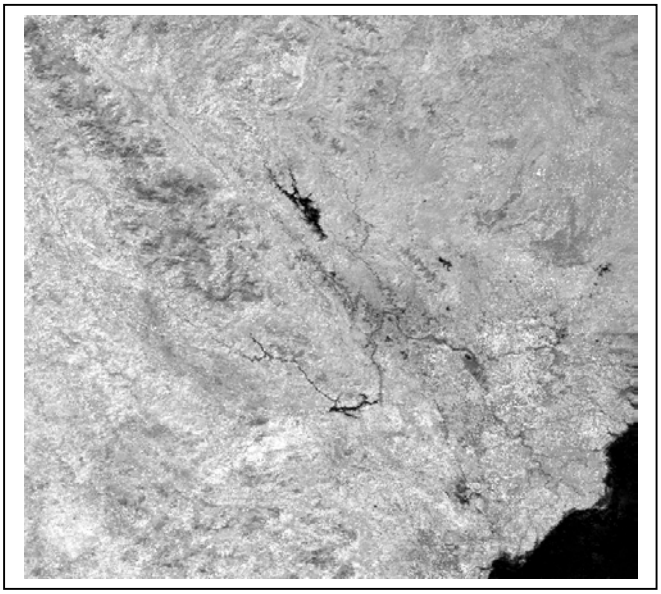

Figure 1. MODIS NIR image of the Red River area, 10/2002

In the mountainous area of Laocai, where the Red River enters Vietnam, the river water can be well observed during the dry season with 30m resolution NIR and other data derived from Landsat ETM+ image taken on 29/12/1999.

In the coastal area, the Red River mouth known as Balat estuary is well represented in Landsat ETM+image taken in summer on 8 May 2001. Different band and enhancement combinations help identify different landuse and landcover types in the area such as rice and other crops, rural settlement, salt field, sand and mud, mangrove, aquaculture, turbid and clear waters.

In the localities of the Red River delta such as Sontay and Hanoi, the existing Red River channel can be seen clearly with oxbow lakes as abandoned channels on both sides in SPOT and Landsat TM NIR, NDVI, NCC and FCC images.

The area of the Red River channel in Sontay separated from background using NIR images is given in Table 2 that shows slight differences in absolute value of the Red River extent between two dates and two sensors.

Table 2. Estimated area of the Red River channel in Sontay based on NIR images

Date	Sensor	Estimated area	
		Ha	%
24/10/94	HRV	1157.12	6.86
30/09/96	HRV	1143.75	6.77
30/09/96	TM	1137.19	6.74

In Hanoi, the emergence of a large sand bar in the Red River area could be detected looking at multitemporal SPOT NIR images of 1994 and 1995.

In both localities, the river channel and other landuse and landcover on the flood plain are emphasized in characteristic colors on FCC images. These images created from combinations of SPOT and Landsat TM bands provide a tool for quick assessment of river water turbidity (Chopra *et al.*, 2001). Different shades of green, light and milky blue of the Red River water correspond with its varying levels of medium and high turbidity.

A comparison of FCC images of the Sontay and Hanoi areas derived from SPOT XS images taken only two days apart (24/10/94 and 22/10/94) shows that the Red River water turbidity in the Sontay area is higher than in the Hanoi area. This information is supported by recorded suspended sediment concentrations at Sontay and Hanoi stations.

The statistics of landuse and landcover classes in Sontay using SPOT and TM data are given in Table 3.

Table 3. Area of land use/land cover (LULC) based on supervised classification, ha

No.	LULC type	Classified image		
		SPOT , 24/10/94	SPOT, 30/09/96	TM, 30/09/96
1	Red River	1320.20	1016.95	1061.37
2	Pond, lake, swamp	1144.98	1274.89	1201.37
3	Sand	51.95	379.98	376.62
4	Built up area	3785.64	2744.34	1530.81
5	Village with plantation	6062.41	50015.42	7592.69
6	Rice field	3887.91	5915.56	3915.56
7	Dense vegetation	621.91	534.84	1196.56

This table shows a decrease in the area of the Red River channel and an increase in the area of pond, lake, swamp and sand bar in the study area between 24/10/94 and 30/09/96 and similar results for classified SPOT and Landsat TM images of the same date (30/09/96).

The use of very high spatial resolution satellite imagery is illustrated in Figure 2. This 1-meter resolution (pan-sharpened) color image collected during Spring 2000 features the Red River and landuse in the urban and suburban areas of Hanoi. The river dike is highly visible on both sides. Outside the dike, is the flood prone area occupied by uncontrolled mixed landuse. This accurate information obtained with IKONOS data is important for floodplain management. IKONOS data, therefore, can be used for detailed mapping and temporally extended change analysis in the Red River area in combination with air photos.

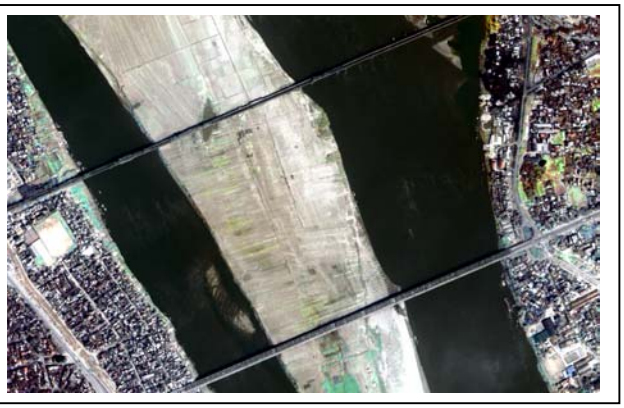

Figure 2. IKONOS Pan+XS image showing the Red River in Hanoi, March 30, 2000

5. CONCLUSIONS AND RECOMMENDATIONS

For effective monitoring of the Red River in Vietnam, multisensor approach should be applied ranging from moderate to high and very high spatial resolution sensors such as MODIS, Landsat TM/ETM+, SPOT HRV and IKONOS.

In monitoring the Red River, major changes that can be detected and quantified effectively with digital satellite imagery are those related to river channel, water turbidity, environmental greenness and extent of land use/land cover types on the flood plain of the Red River.

The monitoring information obtained from satellite images for the Red River area can be used for direct analysis of land use changes, flood prone areas or further used for modeling studies to support management and decision making.

With rapid technological advances, satellite-based monitoring of the Red River can be easily standardized and become more objective and cost effective than the traditional method. However, further research activities are required for operational use of digital satellite imagery in monitoring and understanding processes in the Red River ecosystem in Vietnam.

6. REFERENCES

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