Monitoring topographical changes of island in the outlet of the Dongting Lake from 2000 to 2010 using time series of Landsat images

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Abstract—Natural evolution and anthropogenic disturbance have influenced the river-lake relationship in the middle Yangtze River and the impact is deeper and deeper during the last ten years with the Three Gorges Dam putting into use. An analysis of the island located at the outlet spillway of the Dongting Lake draining into Yangtze River topography change between pre-dam and post-dam period was conducted based on twelve Landsat TM and ETM+ images acquired during the last ten years. Remote sensing data and in-situ water level data are combined for analysis. Results of this study show that the island has experienced a little erosion process after post-dam period. Different direction of the island has different topography change trend. Along transect 1 the gradient slope was getting flatter, and along transect 2 and transect 4 the gradient slope was getting steeper, while along transect 3 there was little change occurred.

INTRODUCTION

The Three Gorges Project (TGP) is the largest water conservancy project ever undertaken in China, and indeed the world. The TGP is expected to control flooding not only in the area along the Yangtze river mainstream but also in the area surrounding Dongting Lake, which connects directly with the Yangtze river[1].The Three Gorge Project intercepts a large volume of silt and regulated the runoff of the Yangtze River[2], which will result ecological environment changes in the Yangtze river area. People are more and more concerning about the relationship between the river and lakes under the influence of the Three Gorges Project impacts. Recently, a project on Chenglingji sluice construction goes on to propose, while the lake ecological environment was more vulnerable affected by increasingly natural and human activities.

The lake bottom topography has changed greatly in the middle Yangtze River under various natural and anthropogenic activities. In this research, an island located at the outlet spillway of Dongting Lake to Yangtze River near chenglingji chose as an example. The island morphology change can reflect topography changes in the outlet spillway area of Dongting Lake. Various methods getting the topography change have been developed, Sedimentology[3,4,5], sonar measuring technique[6], underwater survey, and geophysical methods[7]. However, these methods tend to be long and costly, and sometimes impossible for high disturbance area like the outlet spillway of Dongting Lake. Remotely sensed satellite data can provide valuable information of highly frequent change environment, and it has been widely used in lake researches. M.Ma et al. observed Ebinur lake area change between 1998 and 2005 applying the remote sensing based technique[8], Lian Feng et al. derived Poyang lake bottom topography using MODIS data[9].

Water level can indirectly reflect the lake bottom topography. In this research, water lever and island area and water/land boundary change distance are joined up to reflect morphology changes of the island, which will contribute to outlet spillway management and protection.

STUDY AREA

The island in this research is located at the outlet spillway of Dongting Lake draining to Yangtze River(113.03° E-113.08° E，29.2° N-29.5° N)(Fig.1). It is located in northeast part of the Dongting Lake, where there is water and sediment exchange bond between Dongting Lake and Yangtze river and experiences frequent and complex hydrologic change process. In dry season, water come from Dongting Lake drain to Yangtze river through there, while in flooded season, water come from Yangtze river may backflow into Dongting Lake also through there.

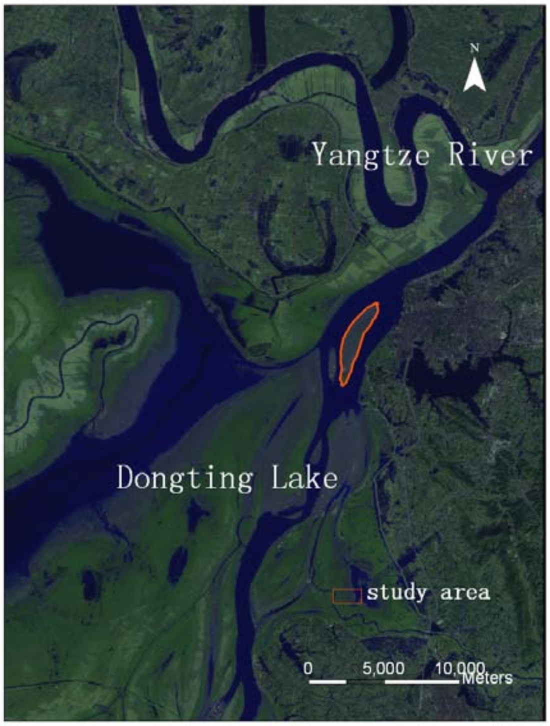


Figure 1. Location of the study area

DATA AND METHODS

Twelve Landsat Thematic Mapper(TM) and Enhanced Thematic Mapper(ETM+) images （Tab. 1） between 2000 and 2010 were acquired from USGS website [http://earthexplorer.usgs.gov/]. All the images were rectified using image to image rectification with more than 30 ground control points (GCPs) in each image ensuring that root mean square error (RMS) less than 0.5 pixels. The water/land boundary was got through unsupervised classification and human-computer interactive interpretation. Then the classification result was converted to vector format in ARCGIS software. The Digital Shoreline Analysis System (DSAS) was employed to calculate the rate of island boundary line change. DSAS computes rate-of-change statistics for a time series of shoreline vector data initially applied to the seashore change research. DSAS generates transects that are cast perpendicular to the baseline at a user-specified spacing alongshore[10]. The transect and shoreline intersections along this baseline are then used to calculate the rate-of-change statistics. In this study, baseline was constructed landward in elliptical shape with a point never submerged in water in the center of the island as ellipse center. Then shoreline change envelope (SCE) was calculated, which is the distance between the shoreline farthest from and closet to the baseline at each transect. The calculated change distance was comparative analyzed with the in-situ water level data from nearby chenglingji hydrologic station which is the representative and control station of Dongting Lake.

Table 1. Date of the remote sensing data used and water level at Chenglingji station

Date	Water level(m)
2000-02-26	21.06
2001-01-11	21.88
2001-12-29	20.98
2002-03-19	23.79
2003-01-17	22
2003-02-02	22.23
2006-12-19	21.07
2007-05-20	23.2
2007-10-27	23.48
2007-12-14	20.74
2009-10-24	21.74
2010-03-09	21.88

RESULTS

This paper takes the operation of the Three Gorges Dam as a transition point and illustrate the island, lying at the outlet of the Dongting Lake, topography change in pre-dam and post-dam periods based on twelve LANDSAT TM/ETM+ images from 2000 to 2010, six before the Three Gorges Dam operation and six after that. All the results below are based on the assumption that there is a same gradient around the island.

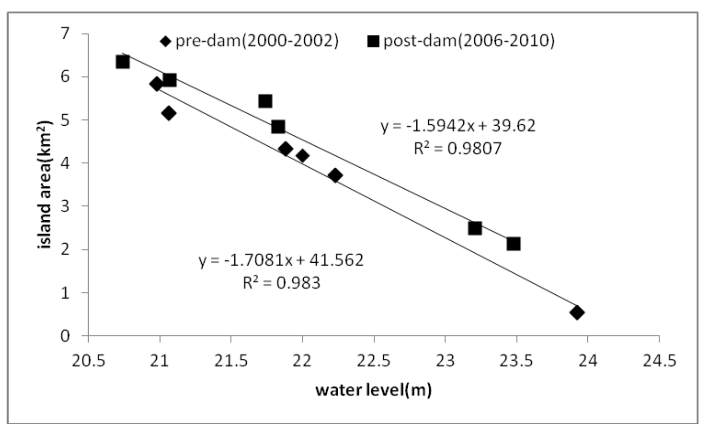


Figure 2. Relationship between exposure area of the island and chenglingji hydrologic station water level before and after the Three Gorges Dam putting into use.

Results of this research show that the emerged island area has strong correlation with water level of the nearby chenglingji hydrological station (Fig.2). During the period 2000-2002, there was 1.7km^2 or more land area expected to be submerged as each meter rise in water level, while after the Three Gorges Dam went into operation for three years, from 2006 to 2010, as water level rise 1 meter, the submerged land area was approximately 1.6km^2. The different submerged area change indicates that island topography have changed after the Three Gorges Dam put into use. It revealed that a little erosion was occurred in the island area at the elevation between 20.5 meter and 24 meter.

To assess the spatial change of the island topography, four representative transects were selected to quantify pre-dam and post-dam change rate differences (Fig.3). The distance island boundary and the baseline during each period was calculated in DSAS, and then be correlated analyzed with water level measured from nearby chenglingji hydrologic station.

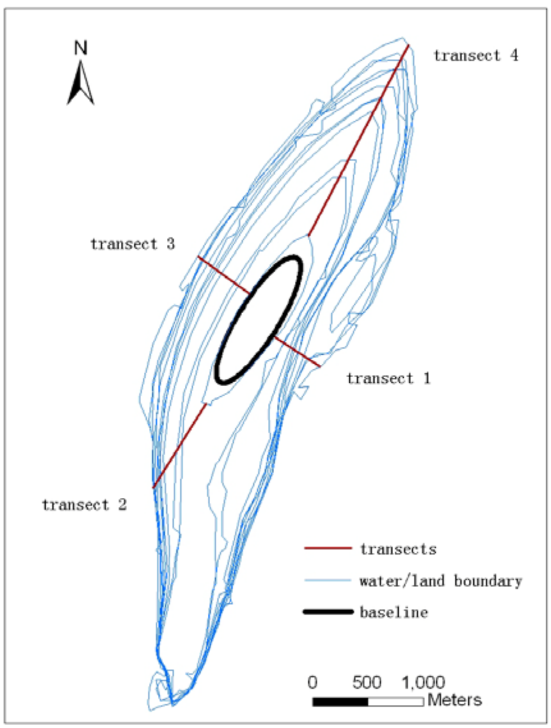
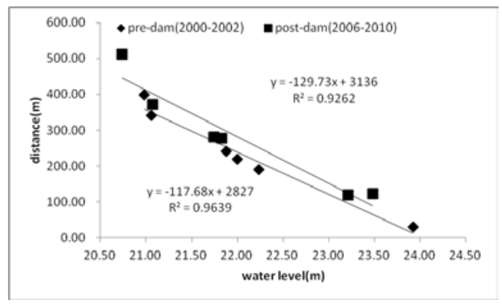


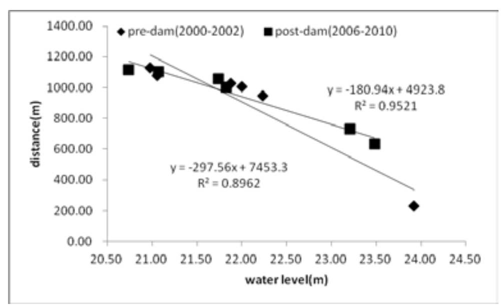
Figure 3. The island boundary position derived from remote sensing data. Four representative transects were generated to intersect all boundaries and the proposed baseline based on DSAS software.

The figure (Fig.4) shows the topography change varied with different direction of the island. In general, the larger change in distance between the island boundary and baseline over a certain range of water level, the relatively flatter island topography there is. Among the four transects, there is the steepest gradient along transect 1, steeper are along transect 3, transect2, and along transect 4 the topography is the flattest. When it comes to the change along the four transects following the Three Gorges Dam construction, along the transect 1 direction the topography became flatter in the post-dam period, along the transect 2 and transect 4 direction the topography became steeper, along the transect 3 the topography barely changed.

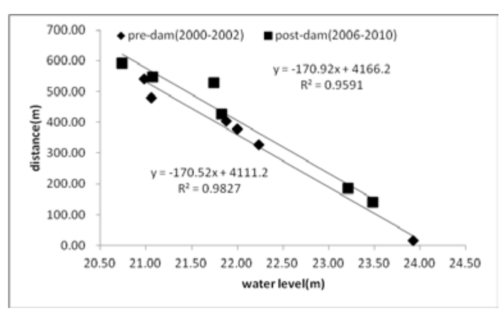
(A)



(B)



(C)



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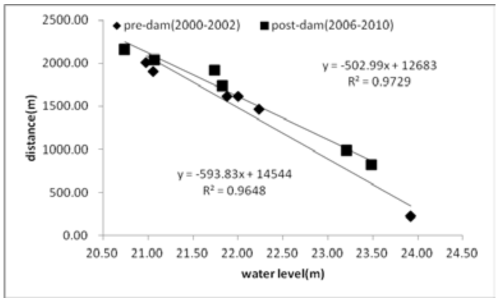

Figure 4. The correlation between island boundary change deriving from the remote sensing data and in-situ water level change of chenglingji along four transects. (A) Transect 1, (B) Transect 2, (C) Transect 3, (D) Transect 4. Note that the distance is each period island boundary to the baseline along the transect.

CONCLUSIONS

The results of this research demonstrate that it is possible to detect the island topography change with remote sensing data and in-situ water level data. The combination use of remote sensing and ARCGIS software provide a strong tool for assessing spatial and temporal change of the island topography in a frequent change environment.

Further studies are needed to applying this method in lake bottom topography change mapping and quantifying changes in different section of island beach but not a transect. Besides, many other remote sensing data can be used to get more period images for more detailed topography change

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