REMOTE SENSING MONITORING AND ANALYSIS OF EXPANSION CHARACTERISTICS OF CHONGMING ISLAND IN SHANGHAI, CHINA

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ABSTRACT: Mapping and detecting the landscape pattern change and the expansion features has become an urgent task because of the increasing pressures from rapid urbanization and associated environmental problems in Chongming Island, which has been proposed to become an "ecological" island in the near future. Based on Landsat and ALOS remote sensing imagery and by means of object-oriented classification approach incorporated with vegetation indices (NDVI and NDVSI), a dynamic study was carried out on the island's expansion, vegetation and land use/cover shift patterns for the past 30 years. A different analytical strategy was used for extracting vegetation area and land use types from the various remote sensing images. The NDVSI which was developed in this study was fused with red and infrared bands to improve the resolution and to extract the vegetation information by NN arithmetic for MSS image. The results indicate that the change of vegetation area in Chongming Island does not correspond proportionally with the growth of island, and the change of built-up areas in different periods is highly correlated with the population changes, which reflect the fast development of economy and urbanization.

1. INTRODUCTION

Land use/land cover change has been a key factor for the study of global warming and associated environmental problems. Urban land expansion and reclamations in coastal region constitute the most direct representation forms of land use/land cover change, and refer specifically to the change in land use pattern and urban space distribution resulted from land, social and economic pressure. (Alphan, et al., 2009; Gilliesa, et al., 2003). The expansion of the Chongming Island (121.56°N and 31.75°W) of Shanghai, China and its characteristic land use changes profoundly altered the ecological environment and sustainability of rural development. It is possible to monitor changes in Chongming Island's expansion and its ecosystems in a timely and cost-effective manner by using multi-resolution and multi-temporal remote sensing data, as well as new classification techniques based on the increased availability and improved quality of these data. When coupled with the island's growth monitoring, they can evolve to an efficient tool to analyze the LULC (land use and land cover) changes.

High or medium spatial resolution images (e.g., IKONOS, Quickbird, Landsat Thematic Mapper (TM)/Enhanced Thematic Mapper plus (ETM+), SPOT/High Resolution Visible (HRV)) have been widely employed on regional land use classification. The land use change detection encompasses the quantification of land-cover changes from multi-date imagery commonly acquired by satellite-based multi-spectral sensors (Coppin & Bauer, 1994, 1996). Recent years, different techniques are used to monitor land use dynamics from multi-temporal data. Among them, image classification and vegetation indices-based time series are fundamental to the remote sensing of vegetation phenology and to the extraction of numerical observations related to LULC dynamics (Hall-Beyer, 2003; Pettorelli et al., 2005, Mallinis et al., 2008, Zhou et al. 2009, Lu & Weng, 2007).

The object-oriented classification approach based on per-field classification, involves two stages, namely image segmentation and classification, and has been proven to provide better classification results than per-pixel classification approaches, especially for fine spatial resolution data.On the other hand, vegetation indices are widely used as indicators for analyzing the variations of land cover among vegetation and other factors (Ben-Ze'ev et al., 2006, Morawitz et al., 2006, Tucker et al., 2005). The normalized difference vegetation index (NDVI) is one of the most popular methods for vegetation monitoring (Lee & Yeh, 2009). Meanwhile, additional indices have been applied in other studies, which demonstrated higher correlation with specific vegetation features. Still, very few published studies have been focused on the employment of ALOS image band ratios and index combination for improving the land cover classification accuracy.

The objective of this study is to focus on extraction of vegetation changing dynamics of Chongming Island of Shanghai, China over a 30-year period based on vegetation indices (including NDVI and a new index) and object-oriented classification methods. The paper will present a long time series dynamic monitoring and analytical study on the characteristics of the island's expansion and its land use change based on multiple-sourced remote sensing data. The expansion processes of the built-up area in Chongming Island, together with their influencing factors and driving forces will be revealed by employing Landsat MSS, TM, ETM and ALOS images. The results would be meaningful for the study of the spatiotemporal processes and influencing factors of the expansion of Chongming Island and its further development as an ecological island.

2. STUDY SITE AND DATASET

2.1 Study Site

Chongming Island (121.56°N and 31.75°W) of Shanghai, China, is the world's biggest narrow and long alluvial island, developed from Yangtze River silt (Figure 1). The island extends up to 1411 km^2, and it is 80km long (from east to west) and 13-18 km wide (north to south). More than 90% of the land is elevated between 3.21-4.20m above sea level with a mean annual temperature of 15.2^{o}C. It has various natural soil types including saline-sodic soil, semi-hydromorphic soil and alfisol distributed in the north, the middle north deflection and the south respectively. Chongming Island has been undergoing development for more than 1300 years and its evolution is closely related to the change of Yangtze River estuary. In order to measure urban spatial extent, evaluate its growth trend and monitor the changes of natural ecological environment, vegetation cover was chosen as a key indicator for identifying both spatial and intensity scales of evolution of Chongming Island.

2.2 Data

To monitor the vegetation change dynamics of Chongming island in past 30 years, Landsat MSS(August 1979), TM (August 1989), ETM (November 1999), ETM (August 2002) and ALOS (AVNIR-2, April 2009) images were used in vegetation and land cover change analysis. Imagery selection was driven both from the need for spatial accuracy of the final map, as well from the availability of older remote sensing data, especially for that of 1979, 1989, 1999 and 2002. With the advantage of lower cost and high spatial resolution, ALOS may be a better data source to monitor vegetation change and has been widely used in urban land cover and landscape analysis (Yi & Jiang, 2008).

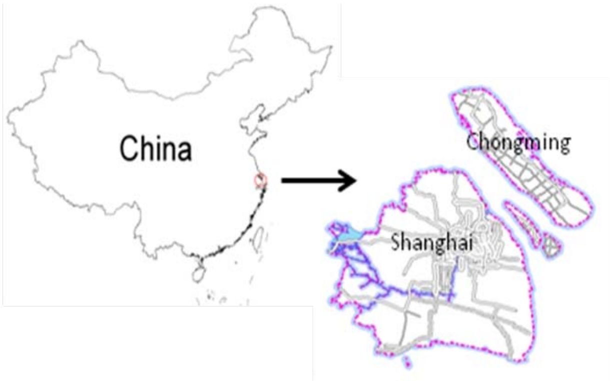

Figure 1. The location of study site: Chongming Island of Shanghai in

3. RESULTS AND ANALYSIS

3.1 Image Segmentation

Segmentation, the primary stage of object-oriented approach, can be realized as an optimization process. eCognition's multi-resolution segmentation is a bottom up region-merging technique starting with one-pixel objects. In particular, eCognition provides segmentation on several scales because the scale parameter is very important for a meaningful analysis and it is the stop criterion in an optimization process. In this paper, the layers used for the segmentation of the different satellite images with corresponding parameters were chosen empirically based on the interactive visual inspection of the results.

3.2 Land Use /Cover Dynamic Changes

Based on the corresponding segmentation of these different satellite images, the hierarchical classification was performed. For ALOS image (2009), vegetation index NDVI was initially computed to discriminate the vegetation related objects with a NDVI threshold larger than 0.1. The NDVI thresholds were 0.1 at the western and middle area Chongming Island and 0-0.4 at the east end of Chongming Island where the main land use type is wetland, pound or paddy field. In the following stage, nearest neighbor classification algorithms were used to eliminate the non-vegetation areas (including the building, road, water body etc.) from the extracted vegetation areas, especially in the eastern district of Chongming Island. The final vegetation polygons in Chongming Island of 2009 were delineated on the subsequent stages that resulted from the fusion procedure described previously. The overall accuracy was 90.36%. In examining producer accuracy, analytical results were satisfied for values above 90.51% and user accuracy was found to be 88.06%. This indicates that the classification scheme for high-resolution sources was feasible for composite vegetation classification and that the method was robust enough to be adopted in Chongming Island.

As mentioned above, MSS image of resolution 57m was used to extract the vegetation area of Chongming Island in 1979. The classification result from the coarse image was affected when NN algorithms were used in eCognition. In this paper, the new vegetation index NDVSI (Normalized difference vegetation structure index - NDVSI=(NIR-(R+G)*0.5)/(NIR+(R+G)*0.5)) was developed in an effort of capturing the vegetation structure which is mainly reflected by NIR band. Therefore, the NDVSI image calculated from MSS image was fused with the MSS6 (infrared wave band) and MSS5 (red band) having a resolution of 14.25m. Then, we performed the NN algorithms on the fused image to extract vegetation area following the corresponding segmentation mentioned above. The classification result is shown in Figure 4 and total accuracy is 88.2%.

TM and ETM images with the resolution of 30m were used to monitor the vegetation change of the study area in 1989 and 2000, respectively. NDVI and RNDVI images were firstly calculated and then added to the eCognition project to take part in the segmentation and NN classification. Based on the analysis and visual inspection of classification processes, the classification strategy is feasible when introducing NDVI and RNDVI images for TM image of 1989 and ETM of 2000. The overall accuracies of the TM image (1979) and ETM image (1989 and 2002) classification were 85.3% and 87.6%, respectively.

Table1 and Figure 4 summarize the main land use types and area distribution including vegetation, built-up and water body and corresponding size of Chongming Island in the past 30 years according to the image classification. Although the island is expanding for the specific period, the change of vegetation area in the island does not correspond proportionally to a ratio of the increasing size of the island. The vegetation cover remains almost the same while there is a little shift for each 10 years time interval. This can be attributed to the expansion of the built-up urban and water body (including fishpond, paddy field, etc.) areas in the different periods reflecting the economic development and the associated fast urbanization of the region. This is obvious if we consider that during the period of 2000 and 2009 the size of island increased by about 56km^2, while in the same period the vegetation area decreased by 32km^2 and the built-up and water body area increased by 87.9 km^2 and 52 km^2, respectively. At the same time, during the same period the associated population has been increased by 170 thousands.

On the other hand, when we turn to the period of 1989 and 2000, the growth of the island (by 81.3km^2) is mainly reflected through the increase of vegetation (by 38.37 km^2) and water body (by 50.7km^2), while there is almost no change in the built-up area and a little decrease in road area, which matches the status of the population decrease by 70.8 thousand during the period. In fact, Chongming Island was paid more attention by local government after 2000 with the economic development and increased demand on protection of ecological environment in China. The primitive ecology is the distinct characteristic of the island before 2000 and some residents left the island for Shanghai downtown to find jobs. This means that the periods of 1989 and 2000 reflect relative stable developing stages of economy and urbanization for Chongming Island.

Table 1. Change of main land use types and growth of Chongming Island

	Types	1979	1989	2000	2009
Island growth	Length (km)	74	81.8	82.4	85.1
	Width (km)	12.9	15.3	15.5	18.6
	Total area(km^2)	1186.76	1407.81	1489.08	1545.11
Main	Vegetation(km^2)	846.56	792.34	830.71	798.15

land use type	Built-up area(km^2)	60.39	167.19	169.92	221.74
	Population		734100	663300 (1999)	842097 (2008)
	Water body(km2)	47.68	171.72	222.42	274.93

* Length : from north to south of island; Width :from east to west of the island

4. CONCLUSION

Understanding the dynamic expansion characteristics of Chongming Island requires the characterization of the land use/cover changes at different temporal scales. The vegetation indices, such NDVI time series, present different frequency components, such as seasonal variations, long-term and short-term fluctuations, which have to be identified. In this study, object-based classification approach with vegetation indices was incorporated to delineate land use/cover change dynamics from the different time satellite imagery in Chongming Island. The adoption of objects instead of pixels as the primary units of classification provided much more information from the assignment of the observations to classes, but also posed the challenge of how to use this information efficiently, especially for images with coarse spatial resolution. In this study, a new vegetation index NDVSI was developed and fused with red and infrared bands to improve the resolution and extract the vegetation and other land use/cover type information by NN arithmetic for MSS images. For ETM images, NDVI and NDVSI products became the basic layers to be added to the project of eCogniton to participate the segmentation and classification process, while NDVI was created as a new arithmetic feature to classify the ALOS image and acquire the different land use type area. The analysis results showed that the classification scheme of different time and resolution images is feasible to monitor the land use/cover change dynamics of Chongming Island and further analyze the corresponding drive causes of it. The advantages of the particular study lay on the synergetic use between object-oriented approach and vegetation indices to explore the rich information contents of land use/cover. The land use pattern shift in Chongming Island for the past 30 years points out that special attention has to be paid to the harmonious development among the environment, ecology and urbanization in order to provide a local sustainable development.

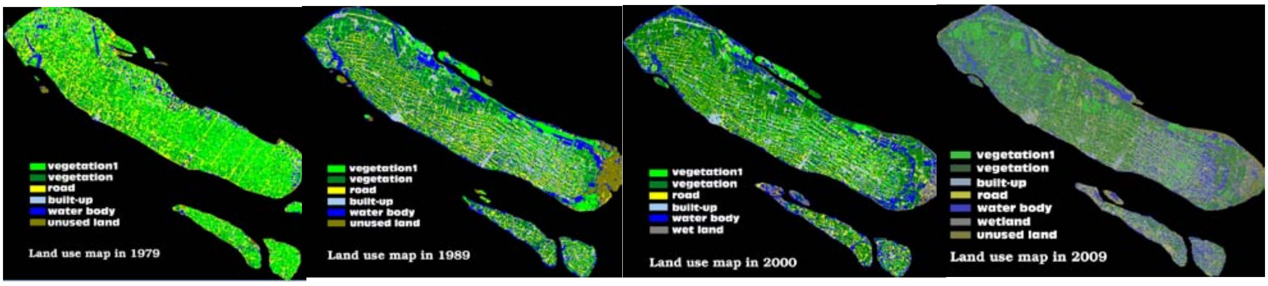

Figure 2. Land use map of Chongming Island, China in 1979,1989,2000 and 2009.

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