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VISUALIZATION URBAN SPATIAL GROWTH OF DESERT CITIES FROM SATELLITE IMAGERY: A PRELIMINARY STUDY

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ABSTRACT

Desert cities, particularly those in Asia, are the home of ever-increasing population and emerging production centers. These areas are facing different problems and challenges, such as urbanization, land degradation, water shortage, and climate changes. Mapping and visualizing the spatial growth of urban settlements are a prerequisite to formulate and implement various planning and management activities. In this preliminary study, we discuss a remote sensing-based method to visualize the spatial growth of urban settlements of desert cites from satellite imagery. The case study site is located at the southern rim of the Taklamakan Desert, China. Our preliminary research comprised several major procedures. Firstly, we acquired two predominately cloud-free Landsat images for 2000 and 2010, respectively. Secondly, we conducted image preprocessing that included a procedure of relative radiometric normalization. Thirdly, we derived a normalized differenced vegetation index (NDVI) image from each of the normalized images. Fourthly, we used the two NDVI images to analyze the spatial growth of the oasis. Lastly, we visualized the spatial growth of urban settlements of the desert cities by comparing both the normalized images and the two NDVI images. Our ongoing research will focus on the production of land use/cover maps that will form the basis for a temporal analysis of the urban spatial distribution.

Key Words: Urban spatial growth, desert cities, satellite imagery, visualization, relative radiometric normalization, normalized differenced vegetation index (NDVI), oasis growth, change analysis

INTRODUCTION

Desert cities, particularly those in Asia, are the home of ever-increasing population and emerging production centers. These areas are facing different problems and challenges, such as urbanization, land degradation, water shortage, and climate changes (Belaid 2010). Accurate mapping and visualizing of the spatial growth of urban settlements are a prerequisite to formulate and implement various planning and management activities (Yang, 2002, 2007, 2010, 2011b; Alberti et al., 2004; Auch et al. 2004).

In this paper, we discuss a remote sensing-based method to visualize the spatial growth of urban settlements of desert cites from satellite imagery. Our purpose is to demonstrate how satellite imagery can be useful for this type of applications. Central to our method is the acquisition of two satellite images with different years that can allow examining the spatial growth of urban settlements of desert cities through the use of appropriate digital image processing procedures. The following sections will describe the study area, discuss our research methodology, and present our preliminary results. Since this paper reports part of our preliminary study for an on-going project, we will also outline some of our further work.

STUDY SITE

The case study area covers part of Hotian Prefecture, which is located along the southern rim of the Taklamakan Desert in the Uyghur Autonomous Region of the People's Republic of China (Figure 1). The Taklamakan Desert is one of the world’s major sandy deserts, and the oasis of Hetian is strategically located along the southern branch of the famous “Silk Road” transferring goods, technologies, and cultures between ancient China and the West. With a population of more than 271,900 (2007), Hetian has been highly depending upon several major rivers derived from the Kunlun Mountain that provide the water and irrigation for the towns and oasis. There are some other cities that are located within the Hetian oasis (Figure 2).

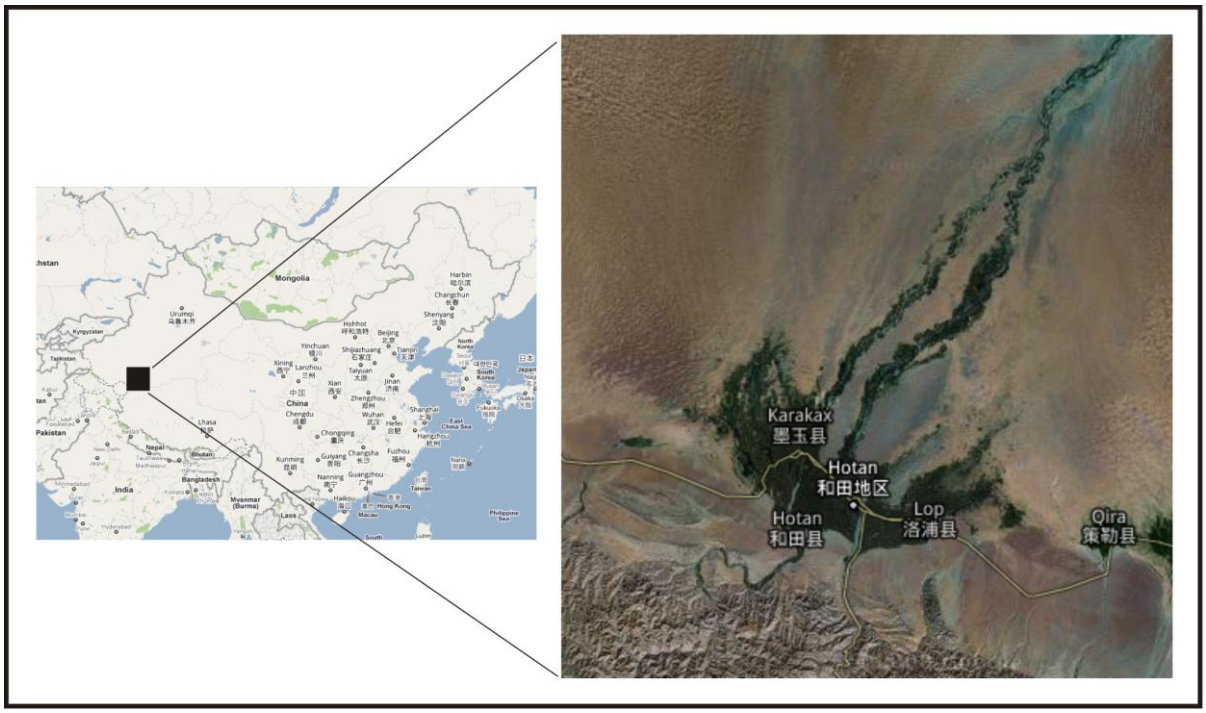

Figure 1: Location of the study site. The left is a map for the People's Republic of China, and the small solid square is the study site that is enlarged in the right-side figure. Note that the study site is located in the north of the Kunlun Mountains and along the southern rim of the Taklamakan Desert in the Uyghur Autonomous Region of China. Several cities and numerous small villages are distributed within the large oasis (in green) that is fed by two large river systems originating from the Kunlun Mountains. Sources: Google Map and Google Earth.

Figure 2: Three major cities in the study site: Moyu (Upper; image date: 19 September 2005), Hetian (Middle; image date: 31 March 2006), and Luopu (Lower: image date: 30 April 2010). Sources: Google Earth.

RESEARCH METHODOLOGY

In order to visualize urban spatial growth, we have carefully designed a method comprising primary and secondary data acquisition, image processing of remote sensor data, change analysis, and interpretation and analysis. The primary data we use were two predominately cloud-free satellite images acquired from Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) for 2000 and 2010, respectively (Figure 3).

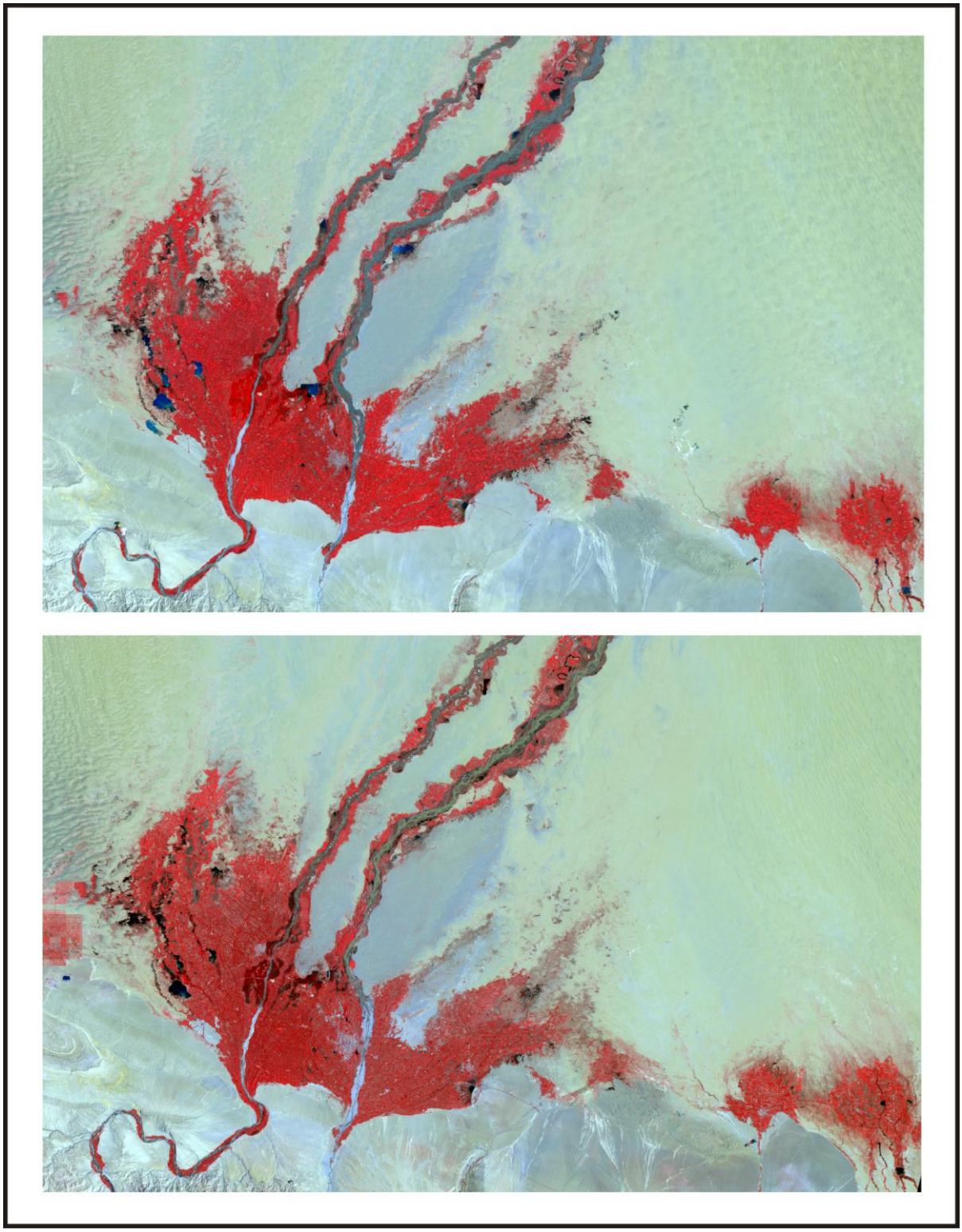

Figure 3: The two Landsat images used in this study. The upper image is part of a Landsat Enhanced Thematic Mapper Plus (ETM+) scene dated on 5 August 2000, and the lower one is a Thematic Mapper (TM) scene acquired on 8 July 2010. Both are displayed in false color composite. Note that the large oasis mass is in reddish color.

In addition to the satellite images, we collected diverse geospatial datasets including administrative and hydrological boundaries, digital elevation model (DEM) data derived from the Shuttle Radar Topography

Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), socio-economic data, and so on. These geographically referenced data were used to facilitate satellite-based urban mapping at different stages. We also conducted a GPS-guided field survey to collect ground reference data essential for the processing and interpretation of the satellite images.

Both geometric and radiometric rectifications were conducted before some further processing procedures. For this purpose, the relative radiometric normalization (RRN) is preferred over the absolute radiometric correction method because no in situ atmospheric data at the time of satellite overpasses are necessary. Based on the comparative research done by Yang and Lo (2000), the RRN procedure proposed by Hall et al. (1991) was applied to the two images in order to suppress their radiometric differences caused by the variations among atmospheric conditions, sensor-target-viewing geometry, vegetation growing seasons, and phenological characteristics. The 2000 ETM+ image was used as the reference and the 2010 TM image was radiometrically rectified by using the radiometric control sets.

During the preliminary study stage, we focus on visual analysis of urban spatial growth. For this purpose, we derived a normalized differenced vegetation index (NDVI) image from each of the normalized images. Then, we used the two NDVI images to analyze the spatial growth of the oasis. Lastly, we visualized the spatial growth of urban settlements of the desert cities by comparing both the normalized images and the two NDVI images.

RESULTS AND CONCLUSIONS

In our study area, we found that urban growth has been achieved along the development of the oasis. By using the two NDVI images, we are able to visualize the spatial growth of the Hetian oasis (Figure 4). Note that most of the newly oasis additions were located along the northern part, predominately along the two major river systems and the major road system.

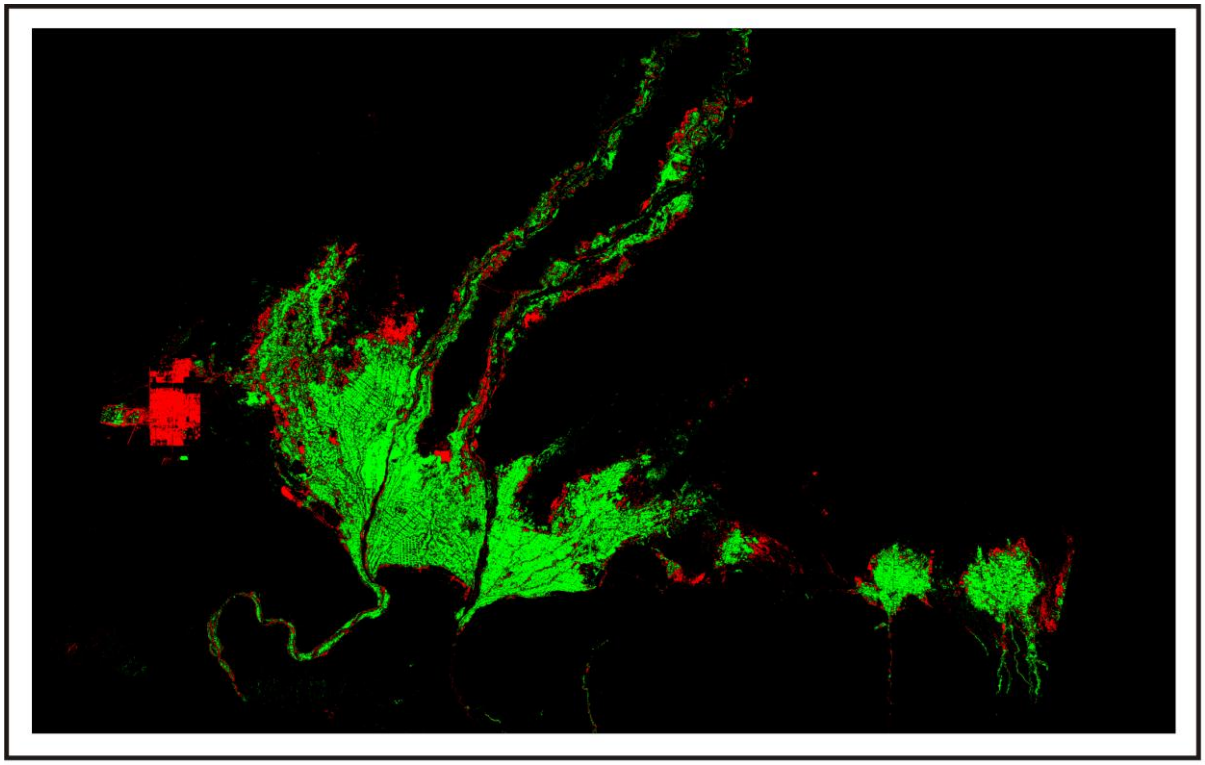

Figure 4: Spatial growth of oasis between 2000 and 2010 detected from the two Landsat images. Note that the green area indicates the oasis distribution in 2000, and the red area was the newly developed oasis between 2000 and 2010.

By comparing the two images, we are able to visualize the urban spatial growth of desert cities between 2000 and 2010. We found that the new additions of urban settlements were largely from the conversions of farmland and grassland. In addition, we found that these new additions were mostly distributed along major highways and rivers, suggesting the importance of accessibility of transportation and water resources in the urban development (Figure 5). Interestingly, we also found that the oasis area increased, which allowed sustaining a large population in the study area. This study demonstrates the utilities of satellite imagery and digital mapping techniques for the study of urbanization in a desert area.

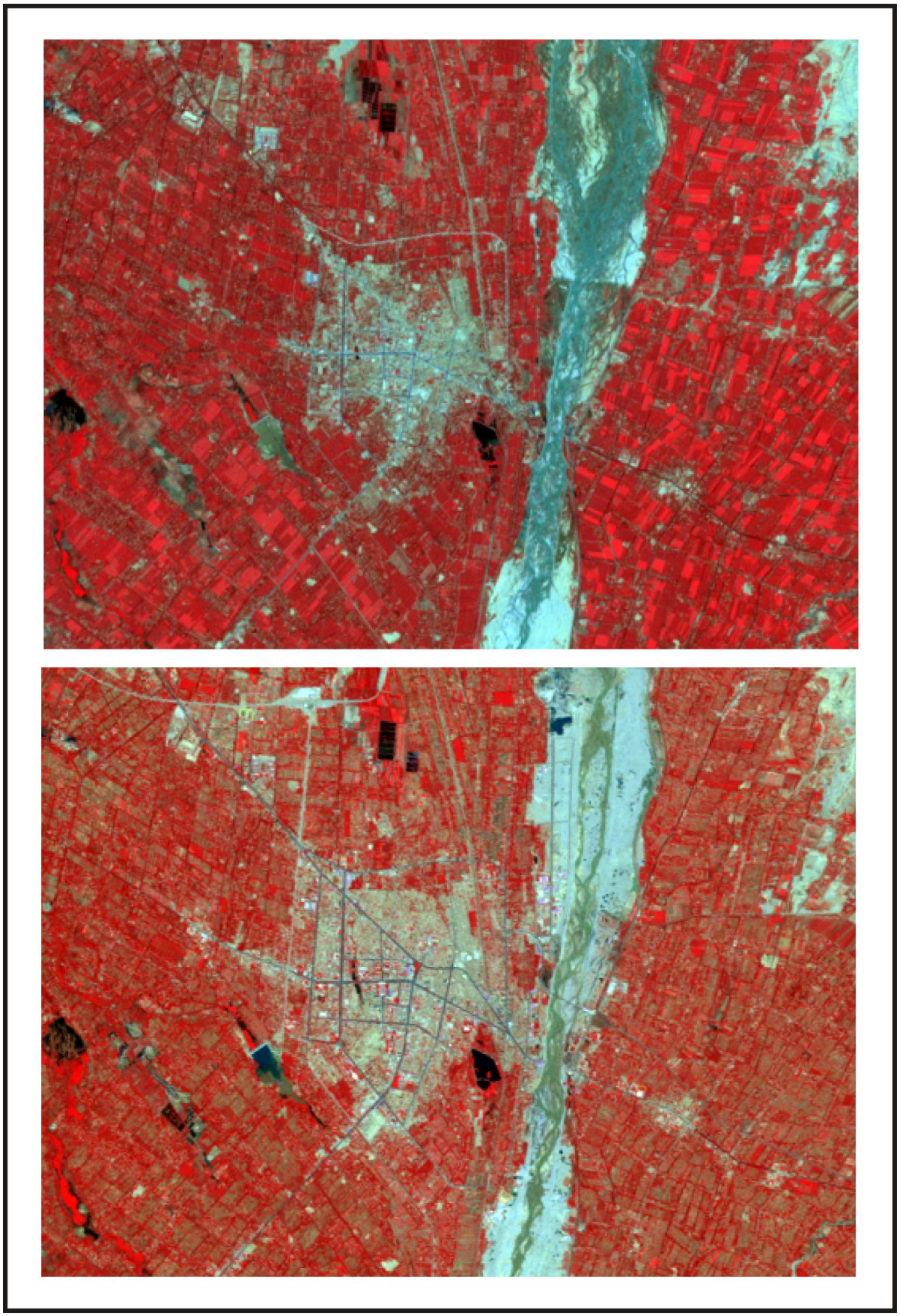

Figure 5: Urban spatial growth of the city of Hetian, Xingjiang, China. The upper image is a Landsat Enhanced Thematic Mapper Plus (ETM+) scene dated on 5 August 2000, and the lower one is a Thematic Mapper (TM) scene acquired on 8 July 2010. Both are displayed in false color composite. Note that the spatial growth of the Hetian city is clearly visible by comparing these two images.

It should be noted that this paper only reports our preliminary research results. Our on-going research focuses on the production of land use/cover maps from the two satellite images by using advanced pattern recognition method such as the one discussed by Yang (2010a). This type of information can be used to quantitatively assess the spatial growth of urban settlements by using a method described by Yang and Lo (2002). We will also conduct thematic accuracy assessment and use the GIS minimum dominate overlay

and matrix analysis to visualize the progressive growth of urban built-up land and to quantify the urban dynamics.

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REFERENCES

Alberti, M., Weeks, R., and Coe, S. (2004) Urban land-cover change analysis in Central Puget Sound. Photogrammetric Engineering and Remote Sensing, 70, 1043-1052.

Auch, R., Taylor, J. and Acededo, W. (2004) Urban Growth in American Cities: Glimpses of U.S. Urbanization. USGS Circular 1252. http://pubs.usgs.gov/circ/2004/circ1252/ (Last access: 15 Feb. 2011).

Belaid, M. A. (2010) Remote sensing of desert cities in developing countries, in Remote Sensing of Urban and Suburban Areas (eds R. Tarek and J. Carsten), Springer, Netherlands.

Hall, F. G., Strebel, D. E., Nickeson, J. E., and Goetz, S. J. (1991) Radiometric rectification - toward a common radiometric response among multidate, multisensor images, Remote Sensing of Environment, 1, 11-27.

Yang, X. (2002) Satellite monitoring of urban spatial growth in the Atlanta metropolitan region. Photogrammetrical Engineering and Remote Sensing, 68, 725-734.

Yang, X. (2007) Integrating remote sensing, GIS and dynamic modeling for sustainable urban growth management, in Integration of GIS and Remote Sensing (ed V. Mesev), John Wiley, New York.

Yang, X. (2010) Integration of remote sensing with GIS for urban growth characterization, in Geospatial Analysis and Modeling of Urban Structure and Dynamics (eds B. Jiang and X. Yao), Springer, Dordrecht.

Yang, X. (2011a) Parameterizing support vector machines for land cover classification. Photogrammetric Engineering and Remote Sensing, 77, 27-37

Yang, X. (2011b) Use of archival Landsat data to monitor urban spatial growth, in Urban Remote Sensing: Monitoring, Synthesis and Modeling in the Urban Environment (ed X, Yang), Wiley-Blackwell.

Yang, X. and Lo, C. P. (2000) Relative radiometric normalization performance for change detection from multi-date satellite images. Photogrammetric Engineering and Remote Sensing, 66, 967-980.

Yang, X. and Lo, C. P. (2002) Using a time series of normalized satellite imagery to detect land use/cover change in the Atlanta, Georgia metropolitan area. International Journal of Remote Sensing, 23,1775-1798