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APPLICATIONS OF GIS AND RS FOR DETAILED URBAN LAND USE CHANGE STUDIES IN MONGOLIA

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ABSTRACT: The aim of this study is to analyze urban land use changes occurred in central part of Ulaanbaatar, the capital city of Mongolia from 1930 to 2008 with a 10 year interval using GIS and RS data sets. As data sources, large scale topographic maps of 2000 as well as panchromatic and multispectral Quickbird images of 2006 are used. To extract land use information from the Quickbird images, a visual interpretation is applied on the enhanced images. For the database development, spatial analysis and image processing ArcGIS and Erdas Imagine systems installed in a PC environment are used.

KEY WORDS: Urban land use, Change study, Topographic maps, Quickbird images

1. INTRODUCTION

In recent years, cities all over the world have experienced rapid growth because of the rapid increase in world population and the irreversible flow of people from rural to urban areas. Specifically, in the larger towns and cities of the developing world the rate of population increase has been constant and nowadays, many of them are facing unplanned and uncontrolled settlements at the densely populated sites or fringes (Amarsaikhan *et al.* 2001). To prevent from the rapid urban expansion, urban planners and decision-makers need to regularly evaluate the current development procedures using updated urban planning maps (Amarsaikhan *et al.* 2009).

Over the past few years, RS platforms, techniques and technologies have been evolutionized. System capabilities have been greatly improved (Amarsaikhan and Sato 2003). Now the highest spatial resolution image can be acquired with a few cm-accuracy, while the ordinary high resolution images can be acquired with a few meter accuracy. It means that it is possible to extract from RS images, different thematic information of varying scales depending on the resolution of the image elements and integrate the extracted information with other historical data sets stored in a GIS and conduct sophisticated analyses (Amarsaikhan *et al.* 2007).

The aim of this study is to analyze urban land use changes occurred in central part of Ulaanbaatar city, Mongolia from 1930 to 2008 with a 10 year interval using RS and GIS data sets. For the basic preparation of spatial and attribute databases 1:5000 scale topographic maps of 2000 have been used. To update the database of 2000 up to the year of 2008, very high resolution Quickbird images of 2006 and a ground survey have been used. To extract land use information from the Quickbird images of 2006, a visual interpretation has been applied on the enhanced RS images. The final analysis was carried using ArcGIS and Erdas Imagine systems and different techniques were applied.

2. TEST SITE AND DATA SOURCES

As a test site, Ikh toiruu area of Ulaanbaatar, the capital city of Mongolia has been selected. Although, Ulaanbaatar is extended from the west to the east about 30km and from the north to the south about 20km, the study area chosen for the present study covers the central part of the capital city and has a ring structure. In the selected image frame, it is possible to define such classes as buildings, pedestrian walking area, road, bare soil, green area and central squire. However, the main aim of the study is to concentrate on the changes of the buildings.

Figure 1. Quickbird image of Ikh toiruu area.

In the present study, for the urban land use change studies, 1:5000 scale topographic maps of 2000 and Quickbird images of March 2006 have been used. The Quickbird data has four multispectral bands (B1: 0.45–0.52μm, B2: 0.52–0.60μm, B3: 0.63–0.69μm, B4: 0.76–0.90μm) and one panchromatic band (Pan: 0.45-0.9μm). The spatial resolution is 0.61 m for the panchromatic image, while it is 2.4 m for the multispectral bands. In the current study, the panchromatic band as well as the green, red and near infrared bands have been used.

3. INTEGRATION OF PANCHROMATIC AND MULTISPECTRAL BANDS

There should be needed a high geometric accuracy and good geometric correlation between the images in order to successfully integrate them. At the beginning, the coordinates of the multispectral bands have been transformed to the coordinates of the of the panchromatic image using 9 ground control points (GCPs) defined from a topograpic map of the study area. The GCPs have been selected on clearly delineated crossings of roads, streets and city building corners. For the transformation, a linear transformation and nearest-neighbour resampling approach were applied and the related root mean square error (RMSE) was 0.86 pixel.

Then, the integrated image was enhanced using different image fusion methods. The concept of image fusion refers to a process, which integrates different images from different sources to obtain more information from a single and more complete image, considering a minimum loss or distortion of the original data. In other words, the image fusion is the integration of different digital images in order to create a new image and obtain more information than can be separately derived from any of them (Pohl and Van Genderen 1998, Ricchetti 2001, Amarsaikhan *et al.* 2009). In this study, such image fusion techniques as multiplicative method, Brovey transform, Intensity-hue-saturation (IHS) transformation, and Gram-Schmidt fusion have been used and compared. Each of these techniques is briefly discussed below.

Multiplicative Method: This is the most simple image fusion technique. It takes two digital images, for example, high resolution panchromatic and low resolution multispectral data, and multiplies them pixel by pixel to get a new image (Seetha *et al.* 2007).

Brovey transform: This is a simple numerical method used to merge different digital data sets. The algorithm based on a Brovey transform uses a formula that normalises multispectral bands used for a red, green, blue colour display and multiplies the result by high resolution data to add the intensity or brightness component of the image (Vrabel 1996). For the Brovey transform, the 2,3,4 bands of Quickbird data were considered as the multispectral bands, while the panchromatic image was considered as the multiplying panchromatic band.

IHS transformation: It is defined by three separate and orthogonal attributes, namely intensity, hue, and saturation. Intensity represents the total energy or brightness in an image and defines the vertical axis of the cylinder. Hue is the dominant wavelength of the colour inputs and defines the circumferential angle of the cylinder. Saturation is the purity of a colour or the amount of white light in the image and defines the radius of the cylinder (Harris et al., 1990). In the HIS each pixel is represented by a three-dimensional coordinate position within a colour cube. Pixels having equal components of red, green and blue lie on the grey line, a line from the cube to the opposite corner.

Gram-Schmidt fusion method: Gram-Schmidt process is a procedure which takes a non-orthogonal set of linearly independent functions and constructs an orthogonal basis over an arbitrary interval with respect to an arbitrary weighting function. In other words, this method creates from the correlated components non- or less correlated components by applying orthogonalization process. Generally, orthogonalization is important in diverse applications in mathematics and other applied sciences because it can often simplify calculations or computations by making it possible, for instance, to do the calculation in a recursive manner (Karathanassi *et al.* 2008).

In order to obtain a good colour image that can illustrate spectral and spatial variations of the classes in the selected image frame, different band combinations have been used. Most of the methods created good images on the basis of visual interpretation. The image created by the Gram-Schmidt fusion method was very difficult to analyze, because it contained too much color variations of objects belonging to the same class. The images created by the multiplicative method, IHS transformation and Brovey transform looked similar to the original Quickbird image. Although, these images looked very similar to one another, detailed analysis of each image revealed that the Brovey transformed image gave a superior image in terms of the spatial separation between different objects and classes. Therefore, for the interpretation of the building class, the image created by the Brovey transform has been used.

4. DATABASE DEVELOPMENT AND LAND USE CHANGE ANALYSIS

Initially, topographic maps of the study area have been georeferenced to a Gauss-Kruger map projection using 9 GCPs. For the transformation, a linear transformation and nearest-neighbour resampling approach were applied and the related RMSEs were below 0.5 pixel. In order to acquire primary digital data, the buildings were digitized from the georeferenced topographic maps of 2000, scale 1:5000 using ArcGIS system. The digitized map is shown in Figure 2. Then, for each building entity, the attributes such as “area, polygon, use, built_year, storey, etc.” were entered.

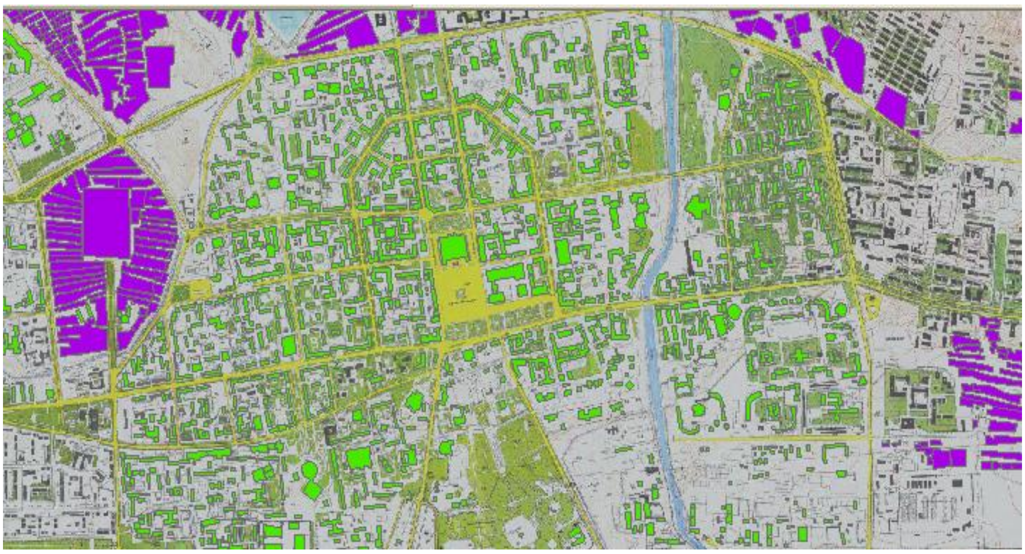

Figure 2. A digitized map of Ikh toiruu, 2000.

After creation of the database, it was necessary to update it and for this purpose, the Brovey transformed Quickbird image of 2006 has been used. At the beginning, the coordinates of the Quickbird image were transformed to the coordinates of the topographic map using 12 ground GCPs. For the transformation, a second order transformation and nearest-neighbour resampling approach were applied and the related RMSE was 0.82 pixel. Then, on the georeferenced Quickbird image, the buildings were screen digitized and updated the database of 2000. For further update of the database, new buildings built in between 2006 and 2008 defined from a ground survey, were entered. After that for all new building entities, the attributes such as “area, polygon, use, built_year, storey, etc.” were entered. The updated map is shown in Figure 3.

Figure 3. The updated map of Ikh toiruu, 2008.

As could be seen from the interpretation, in this area, there were built 13 buildings having 18916,46м^{2} in 1930-1940, 19 buildings having 27394,71м^{2} in 1940-1950, 104 buildings having140528,68м^{2} in 1950-1960, 163 buildings having 162058,82м^{2} in 1960-1970, 147 buildings having 171924,19м^{2} in 1970-1980, 114 buildings having 144194,84м^{2} in 1980-1990, 276 buildings having 206863,12м^{2} in 1990-2000, 287 buildings having 268406,61м^{2} in 2000-2008, respectively. The rapid increase of the buildings after 1990 is due to a fact that the people wanted to have a piece of land in areas having good infrastructure and build something on it.

5. CONCLUSIONS

The aim of this study was to analyze urban land use changes occurred in Ikh toiruu area of Ulaanbaatar, the capital city of Mongolia from 1930 to 2008 with a 10 year interval using historical GIS data sets as well as very high resolution panchromatic and multispectral Quickbird images. For the enhancement of the Quickbird images, multiplicative method, Brovey transform, IHS transformation, and Gram-Schmidt fusion were compared and the best image was obtained by the use of the Brovey transform. To extract land use information from the enhanced Quickbird images, a visual interpretation was applied. Overall, the study demonstrated that within the last few decades the central part of Ulaanbaatar was urbanized very rapidly and became very dense.

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