APPLICATIONS OF RS AND GIS FOR URBAN LAND USE CHANGE STUDIES

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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 before and after 1990 using spatial data sets. As data sources, large scale topographic maps of 2000 as well as panchromatic and multispectral Quickbird images of 2013 are used. To extract land use information from the Quickbird images, a visual interpretation is applied on the enhanced images. Overall, the study demonstrates that in recent decades, Ulaanbaatar city has urbanized very rapidly.

1. INTRODUCTION

Over the past few decades, 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. At present, the urban growth and urbanization processes are being more strongly observed, especially in the larger towns and cities of the developing world. Due to a lack of thorough planning and managing activities, many of them are facing different urban related problems. Mongolia, as many of these countries has a problem with the urban expansion and the growth of population in the main cities. For example, over the past few years, Ulaanbaatar, the capital city has been significantly expanded (Amarsaikhan *et al.* 2011).

Generally, much of Mongolia's urban growth has taken place since the middle of 1970s, because, at that time, the government encouraged migration to urban areas, specifically to Ulaanbaatar in the belief that this would increase the industrialization and productivity in the country. Although, the government had encouraged the migration, it was under strict control of the state. In 1990, Mongolia entered the market economy and it totally changed the lives in the society. The government had had no more strict control on the migration and many rural families officially and unofficially moved to the capital city, approaching the central market. As a result, the population of Ulaanbaatar had been significantly increased and the city area had significantly expanded (Amarsaikhan *et al.* 2009).

The aim of this study is to analyze urban land use changes occurred in Ulaanbaatar city, Mongolia during a centralized economy and market economy using Remote sensing (RS) and Geographical information system (GIS) data and compare the socio-economic reasons for the changes. 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 2013, land use information extracted from the very high resolution Quickbird images of 2013 and a ground survey have been used. The final analysis was carried using ArcGIS and Erdas Imagine systems and different RS and GIS techniques were applied.

2. TEST SITE AND DATA SOURCES

As a test site, Ikh toiruu area of the Ulaanbaatar city has been selected. Although, the capital city 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 city and has a ring structure (Amarsaikhan *et al.* 2014). 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 building class.

In the present study, for the urban land use change studies, 1:5000 scale topographic (4 sheets) maps of 2000 and Quickbird images of summer 2013 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 0.63 m for the panchromatic image, while it is 2.44 m for the multispectral bands. In this study, the panchromatic band as well as green, red and near infrared bands, have been used. Figure 1 shows a Quickbird image of the test area.

Figure 1. Quickbird image of the Ikh toiruu area.

3. GEOREFERENCING AND ENHANCEMENT OF THE IMAGES

Initially, the panchromatic image has been geo-referenced to a UTM map projection (ERDAS 1999), using 12 ground control points (GCPs) defined from a topographic map of 2000, scale 1:5,000. 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 (Mather and Koh, 2011) were applied and the related root mean square error (RMSE) was 0.46 pixel. Then, the coordinates of the multispectral bands have been transformed to the coordinates of the panchromatic image using the same number of the GCPs and the RMSE was 0.68 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 (Pohl and Van Genderen 1998). 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 (Amarsaikhan *et al.* 2012). In this study, such image fusion techniques as Brovey transform, Intensity-hue-saturation (IHS) transformation, and Gram-Schmidt method and Wavelet-based fusion have been used and compared. Each of these techniques is briefly discussed below.

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).

Wavelet-based fusion: The wavelet transform decomposes the signal based on elementary functions called the wavelets. By using this, an image is decomposed into a set of multi-resolution images with wavelet coefficients. For each level, the coefficients contain spatial differences between two successive resolution levels. Practical implementation of the wavelet transform requires discretization of its translation and scale parameters. In general, a wavelet-based image fusion can be performed by either replacing some wavelet coefficients of the low-resolution image by the corresponding coefficients of the high-resolution image or by adding high resolution coefficients to the low-resolution data (Pajares and Cruz, 2004). In the present study, 'Wavelet Resolution Merge' tool of Erdas Imagine was used and the algorithm behind this tool uses bi-orthogonal transforms.

In order to obtain a good colour image that can illustrate spectral and spatial variations of the available objects in the selected image frame, different band combinations have been used. The applied methods created different images of different qualities. 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 IHS transformation, Brovey transform and Wavelet-based fusion 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. CREATION OF THE DATABASE AND LAND USE CHANGE ANALYSIS

Initially, topographic maps of the study area have been georeferenced to a UTM map projection using 9 GCPs. For the transformation, a linear transformation and nearest-neighbour resampling approach were applied and the related RMSEs were below 0.46 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. Then, for each building entity, the attributes such as "area, polygon, use, built_year, storey, etc." were entered. After creation of the database, it was necessary to update it and for this purpose, the Brovey transformed Quickbird image of 2013 has been used. At the beginning, the coordinates of the Quickbird image were transformed to the coordinates of the topographic map using 15 ground GCPs. For the transformation, a second order transformation and nearest-neighbour resampling approach were applied and the related RMSE was 0.75 pixel. Then, on the georeferenced Quickbird image, the buildings were screen digitized and updated the database of 2000. After that for all new building entities, the attributes such as "area, polygon, use, built_year, storey, etc." were entered. The map that indicates the old and updated information is shown in Figure 2.

Figure 2. The old and updated information of Ikh toiruu.

As could be seen from the interpretation and related analysis, in this area, there were built 1144 buildings occupying 682771,1 sq.m before 1990. However, after 1990 until the year 2013 there had been built 2474 buildings having 1095005,6sq.m. The main reasons for these are as follows:

- Before 1990, the Mongolian Government built primarily large building blocks occupying larger areas.
- 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.
- Since the country entered the market economy, private companies and individuals began to replace the large building blocks with independent businesses and houses, typically occupying smaller areas.

Graphical illustration of the buildings and related areas and their comparisons before and after 1990 are shown in Figure 3.

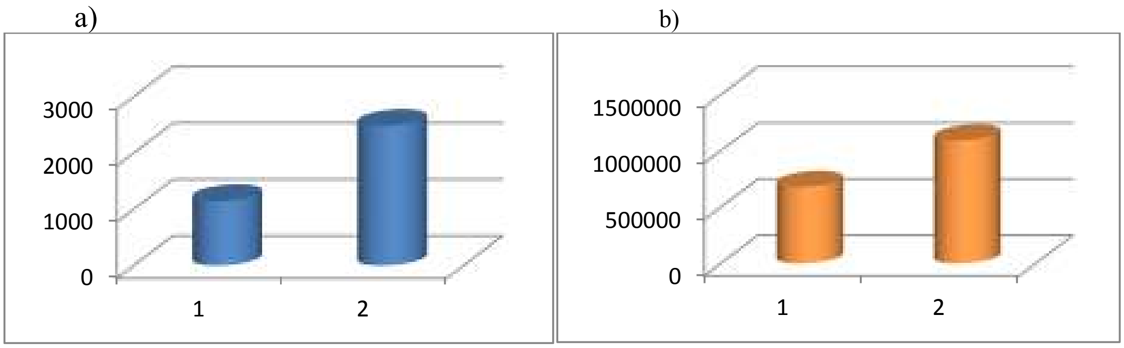

Figure 4. Comparison of the buildings (a) and related areas (b) before and after 1990.

5. CONCLUSIONS

The aim of this study was to analyze urban land use changes occurred in Ikh toiruu area of the capital city of Mongolia before and after 1990 using historical GIS data sets as well as very high resolution panchromatic and multispectral Quickbird images. For the enhancement of the Quickbird images, Brovey transform, IHS transformation, Gram-Schmidt fusion and Wavelet-based 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 image, a visual interpretation was applied. Overall, the study demonstrated that within the last two decades the central part of Ulaanbaatar was urbanized very rapidly and the planners should urgently consider its planning and management.

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