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Land Use and Cover Change Study in Overall Ulaanbaatar City using RS and GIS

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Abstract: The aim of this study is to analyze the urban land use and cover changes of Ulaanbaatar city using very high resolution remote sensing (RS) and geographical information system (GIS) data sets. For the study, the changes that occurred in Ulaanbaatar before 1990 are compared with the changes that occurred after 1990 and the socio-economic reasons for the changes are described. Overall, the study demonstrates that in recent decades Ulaanbaatar city is urbanized very rapidly and there is a need to reconsider its planning and management.

1. Introduction

Over the last 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 (Amarsaikhan *et al.* 2009a). In the coming decades, the world's rapid urbanization will be one of the greatest challenges to ensure human welfare and global environment. According to recent estimates, cities occupy about four percent of the world's terrestrial surface, yet they are home to almost half the global population, consume close to three-quarters of the overall natural resources, and generate three-quarters of its pollution and wastes. The UN estimates that virtually all net global population and economic growth over the next 30 years will occur in cities, leading to a doubling of current population (Redman and Jones).

In general, the developed countries have a higher percentage of urban people than the developing countries. However, rapid urbanization process is mainly occurring in less developed countries, and it is expected that in future most urban expansions will occur in developing countries. Mongolia, as many countries of the developing world has problems with the urban expansion and the growth of population in the main cities.

For example, over the last two decades Ulaanbaatar, the capital city of Mongolia has experienced different urban related problems. In the city, various problems had been previously accumulated during the centralized economy and they have been intensified by the reforms of the entire political and economic systems, unregulated market development and the rapid population growth caused mainly by migration from rural areas (Amarsaikhan *et al.* 2005, Amarsaikhan *et al.* 2009a).

To analyze the current changes, urban planners and decision-makers need to regularly evaluate development procedures using updated urban planning maps. However, many city planners in developing countries lack access to updated maps and often rely on old data that are not relevant. One of the possible solutions could be the use of RS images with different spatial and spectral resolutions. As the present RS is so advanced, it is now possible to extract different thematic information at various scales, to integrate the extracted information with other historical data sets stored in a GIS and to conduct sophisticated analyses (Amarsaikhan *et al.* 2009b).

The aim of this study is to analyze the urban land use changes of Ulaanbaatar city using RS and GIS data sets. For the study, the changes that occurred in Ulaanbaatar before 1990 were compared with the changes that occurred after 1990 and the socio-economic reasons for the changes have been described. For the basic preparation of spatial and attribute databases, a large scale topographic map of 2000 and historical description of the entities have been used. To update the database of 2000 up to the year of 2008, very high resolution panchromatic and multispectral Quickbird images of 2008 have been fused using a Brovey transform. To extract land use information from the fused images, a visual interpretation has been applied.

2. Test site and data sources

As a test site, Ulaanbaatar, the capital city of Mongolia has been selected. Ulaanbaatar is extended from the west to the east about 30km and from the north to the south about 20km. The present study covers almost whole infrastructure of the city and it is shown in a Quickbird image of 2008 (Figure 1).

Figure 1. Quickbird image of Ulaanbaatar, 2008.

In the present study, for the urban land use change study, 1:5000 scale topographic map of 2000 and Quickbird images of 2008 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, panchromatic, red and near infrared bands have been used.

3. Co-registration of Quickbird images

There should be needed a high geometric accuracy and good geometric correlation between the images in order to perform successful data fusion. Initially, the panchromatic Quickbird image has been georeferenced to a Gauss-Kruger map projection using a topographic map of 2000, scale 1:5000. The ground control points (GCP) have been selected on well defined cross sections of roads, streets and building corners and in total, 15 regularly distributed points were selected. For the transformation, a second order transformation and nearest neighbour resampling approach (Richards and Jia 1999) have been applied and the related root mean square (RMS) error was 1.12 pixel. Likewise, the multispectral Quickbird image has been georeferenced to a Gauss-Kruger map projection using the same topographic map of the test area. For the transformation the same number of GCPs has been used and the related RMS error was 1.05 pixel. In each case of the georeferencing, an image was resampled to a pixel resolution of 1m.

4. Image fusion using Brovey transform

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 (Zhang, 2010). 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.* 2009a). In this study, to fuse very high resolution panchromatic and multispectral Quickbird images, a Brovey transform has been performed. This is a 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). The formulae used for the Brovey transform can be described as follows:

$$\mathrm{Red} = \frac{\mathrm{Band}_1}{\sum_{i=1}^{n} \mathrm{Band}_n} * \mathrm{High\ Resolution\ Band} \quad (1a)$$

$$\mathrm{Green} = \frac{\mathrm{Band}_2}{\sum_{i=1}^{n} \mathrm{Band}_n} * \mathrm{High\ Resolution\ Band} \quad (1b)$$

$$\mathrm{Blue} = \frac{\mathrm{Band}_3}{\sum_{i=1}^{n} \mathrm{Band}_n} * \mathrm{High\ Resolution\ Band} \quad (1c)$$

5. Database development and its update

Initially, a digital topographic map of the study area of scale 1:5000 represented in a raster format, has been georeferenced to a Gauss-Kruger map projection using 12 GCPs. For the transformation, a linear transformation and nearest-neighbour resampling approach were applied and the related RMS error was 0.28 pixel. In order to acquire primary digital data, the building and ger areas were digitized from the georeferenced topographic map of 2000 using ArcGIS system. Then, for each defined entity, the attributes such as address, built_year, use, condition and storey_number were entered and the entities were uniquely identified by their registration number. Moreover, the area of every building was calculated and stored as a new attribute within the database.

In order to analyse the changes occurred in between 2000 and 2008, it was necessary to update the created from the topographic map, database. For this purpose, the image obtained by the Brovey transform has been used. For the thorough registration of the GIS and fused satellite data sets, the coordinates of the fused image were transformed to the coordinates of the digitized map using 24 ground GCPs. For the transformation, a second order transformation and nearest-neighbour resampling approach were applied and the related RMS error was 0.93 pixel.

Then, the digitized map was overlain on top of the georeferenced fused image thus highlighting the buildings and ger areas appeared after 2000. After this, on the georeferenced image, the buildings and ger areas were screen digitized and updated the previously created database. After that for all new entities, the attributes such as address, built_year, use, condition and storey_number were entered and they were uniquely identified by their registration number. As an example of the created database, the digitized original and updated buildings and ger area are shown in Figure 2.

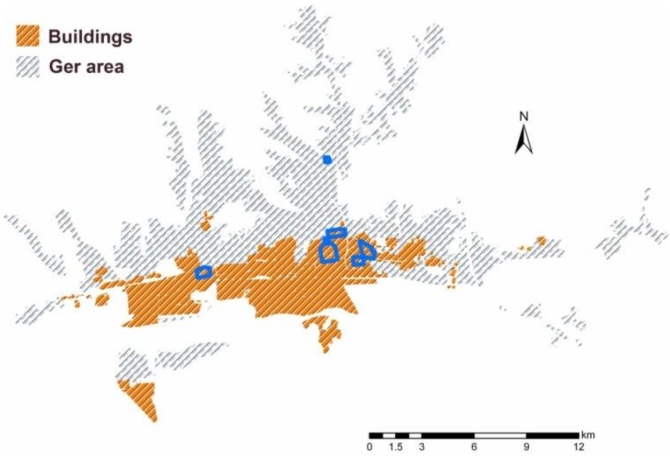

Figure 2. The digitized original and updated buildings and ger area.

6. Urban land use and cover change in Ulaanbaatar city

At present, in Ulaanbaatar city, agricultural land, urban district and settlement areas, roads and network, forest resource, water area and special protected area occupy 274478 ha, 33116 ha, 5668.3 ha, 76383 ha, 4143 ha, 76656 ha of the total land, respectively. However, until 1990 agricultural land, urban district and settlement areas, roads and network, forest resource and water area occupied 256164 ha, 19599 ha, 7136 ha, 67267 ha, 4108 ha of the total land, accordingly, and there was no land allocated for special protection. As seen, during the market economy, agricultural land, urban district and settlement areas, and forest resource have been increased by 7.1%, 68.9% and 13.6%, respectively. Meanwhile, roads and network have been decreased by 20.6% and there was a very little change in water class. Comparison of these classes before and after 1990 is shown in Figure 3. As could be seen that the most significant change had occurred in urban district and settlement areas. This has been connected with a fact that during the free market economy, many rural families moved to the people preferred to live in settlement areas having good infrastructure.

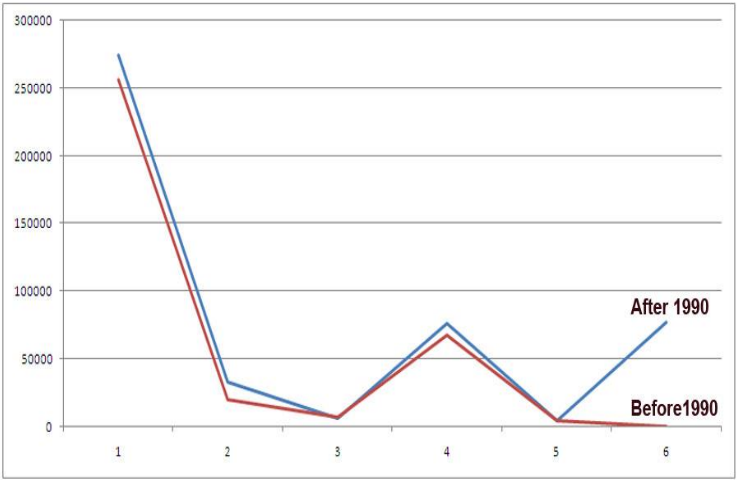

Figure 3. Comparison of land use classes of Ulaanbaatar city before 1990 and after 1990. 1-agricultural land, 2-urban district and settlement areas, 3-roads and network, 4-forest resource, 5-water area, 6-special protected area.

No.	**Land use class**	**Before 1990 (м²)**	**After 1990 (м²)**	**Changes (м²)**
1	Houses	7120	5214	- 1906
2	Ger districts	82729.6	147862	+ 65132.4
3	Commercial area	1772	21241	+ 19468
4	Central government and public organizations	3850	5107	+1257
5	Warehouse area	1920	55667.6	+ 53747.6
6	Roads	9520.5	19508	- 9988
7	Dams	18000	16000	- 2000
8	Water area	23758	20758	- 3000
9	Free area	231000.5	54520	+176480.5
	Overall area:	380885.6	380885.6	-

Table 1. Land use changes occurred in ger districts of Ulaanbaatar city before and after 1990.

Among the available land use classes, the major role plays the land use type: urban district and settlement areas. Of this land use type, 51% is occupied by the builtup areas and 22% is occupied by the ger districts. Generally, in Ulaanbaatar city, the most changing land use class was the ger area. In the ger districts of the capital city, one could define such land use classes as the houses, ger area, commercial area, central government and public organizations, warehouse area, roads, dams, water area and free area. The total areas related to each class defined from the digitized map as well as the RS images are shown in table 1.

As seen from table 1, before 1990, in Ulaanbaatar city, the land for houses, ger districts, commercial area, central government and public organizations, warehouse area, roads, dams, water area and free area occupied 7120 sq.m, 82729.6 sq.m, 1772 sq.m, 3850 sq.m, 1920 sq.m, 9520.5 sq.m, 18000 sq.m, 23758 sq.m, 231000.5 sq.m, respectively. However, after 1990, theses land use classes have been changed to 5214 sq.m, 147862 sq.m, 21241 sq.m, 5107 sq.m, 55667.6 sq.m, 19508 sq.m, 16000 sq.m, 20758 sq.m, 54520 sq.m, respectively. It is seen that the most significant increase occurred in ger districts, commercial and warehouse areas, while some decrease occurred in housing area, dams and water area. As could be seen from the analysis, during the market economy there have been some noticeable changes occurred in Ulaanbaatar city.

7. Conclusions

The idea of the research was to analyze the urban land use and cover changes of Ulaanbaatar city using very high resolution optical images and some GIS data sets. For the study, the changes that occurred in Ulaanbaatar before 1990 were compared with the changes that occurred after 1990 and the socio-economic reasons for the changes were described. For the basic preparation of spatial and attribute databases, a large scale topographic map of 2000 and description of the spatial entities were used. To update the database of 2000 up to the year of 2008, Quickbird images of 2008 were fused. To extract reliable land use information from the fused RS image, a visual interpretation was applied. Overall, the study demonstrated that during the market economy Ulaanbaatar city was urbanized very rapidly and its planning and management should be reconsidered.

8. References

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