

URBAN LAND USE MAPPING AND CHANGE STUDY IN MONGOLIA USING RS AND GIS TECHNIQUES

D.Amarsaikhan^{1*}, Ts.Bat-Erdene²

¹Institute of Informatics, Mongolian Academy of Sciences
av.Enkhtaivan-54B, Ulaanbaatar-51, Mongolia

²Department of Geography and Tourism, Mongolian State University of Education
Ulaanbaatar-46, Mongolia

*Corresponding author: amar64@arvis.ac.mn

ABSTRACT

The aim of this study is to conduct urban mapping and analyze the land use changes of Ulaanbaatar city, Mongolia using very high resolution remote sensing (RS) and geographical information system (GIS) data sets. For the study, the changes that occurred before 1990 are compared with the changes that occurred after 1990 and the socio-economic reasons for the changes are described. For the development of the primary digital database, a large scale topographic map and historical description of the land use elements are used. To generate land use information from the fused RS images, a visual interpretation is applied. Overall, the study demonstrates that during the market economy the central part of the capital city is urbanized very rapidly and became very dense.

Keywords: urban land use, RS image, fusion, mapping, change study

INTRODUCTION

Before 1990, Mongolia had a centrally planned economy. At that time, the development plan of the capital city represented not only urban construction and physical architectural plan, but it was based on the Ulaanbaatar city's investment planning and had a legal power to plan and control the urban internal land utilization. The reason for this was that the prevailing majority of industrial plants, economic and infrastructure sites, residential and dwelling apartments of the country were mainly concentrated in Ulaanbaatar city. On the other hand, everything was based on such a system, where the entire land of the country belonged to the government and was distributed under the tenure of factories and economic establishments of socialist features and the utilization rules and orders were established by the state power and the tenure had been controlled and inspected by the society via state organs (Chinbat *et al.* 2006).

The rapid political changes of 1990 marked the beginning of Mongolia's efforts to develop a market-oriented economy. Since then, Ulaanbaatar city has experienced much more privatized development, which resulted in changes of the spatial and functional structures of the city and the most significant changes have been the increase of commercial functions in the city centre and inner city area, the expansion of the urbanized areas along with the growth of formal and informal settlements, the formation of satellite nodes with clusters of commercial functions, and the residential sub-urbanization in the outer city by western cottage style single family houses (Chinbat *et al.* 2006, Amarsaikhan *et al.* 2011).

The aim of this study is to conduct urban mapping and analyze the land use changes occurred in the central part of Ulaanbaatar city using RS and historical GIS datasets. For the study, the changes that occurred in Ulaanbaatar during the centralized economy were compared with the changes that occurred during the market economy and the socio-economic reasons for the changes have been described. To extract the reliable urban land use information from the RS data sets, very high resolution images of 2012 have been fused. To extract land use information from the fused images, a visual interpretation has been applied.

TEST SITE AND DATA SOURCES

As a test site, Baga toiruu area situated in central part of Ulaanbaatar, the capital city of Mongolia has been selected. The Baga toiruu is the central business district of Ulaanbaatar city where different government, educational, cultural and commercial organizations are located. Besides the Central Government, Parliament and headquarters of major political parties, the Baga toiruu contains

many offices of different ministries, major government organizations, bank headquarters, state universities, diplomatic and international organizations as well as theatres and museums (Chinbat *et al.* 2006). The location of the Baga Toiruu area represented in a Quickbird image is shown in Figure 1.

In the present study, for the urban land use change study, a 1:5000 scale topographic map of 2000, attribute descriptions of the spatial objects, and Quickbird images acquired in May 2012 have been used. The Quickbird data has four multispectral bands (B1: 0.45–0.52 μm , B2: 0.52–0.60 μm , B3: 0.63–0.69 μm , B4: 0.76–0.90 μm) and one panchromatic band (Pan: 0.45–0.9 μm). The spatial resolution is 0.61 m for the panchromatic image, while it is 2.44 m for the multispectral bands. In the current a pan-sharpened image has been selected.



Figure 1. The location of the Baga Toiruu area represented in a Quickbird image of 2012

PRIMARY DIGITAL MAP AND ITS UPDATE

In the beginning, 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 (Torino 2008) using 9 GCPs. For the transformation, a linear transformation and nearest-neighbour resampling approach were applied and the related RMS error was 0.21 pixel. In order to acquire primary digital data, the building 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 covering area of every building was calculated and stored as a new attribute within the database.

In order to include the changes occurred after 2000, it was necessary to update the database created from the topographic map. For this purpose, the pan-sharpened image has been used. For the thorough registration of the GIS and satellite data set, the coordinates of the pan-sharpened image were transformed to the coordinates of the digitized map using 15 ground GCPs. For the transformation, a second order transformation and nearest-neighbour resampling approach were applied and the related RMS error was 0.97 pixel. Then, the digitized map was overlain on top of the georeferenced image, thus creating an updated map that includes the buildings appeared after 2000. Likewise, 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 numbers. As an example of the created database, the digitized original and updated buildings overlain on top of the Quickbird image are shown in Figure 2.

URBAN LAND USE CHANGE ANALYSIS

In the present study, for a detailed study of the central part of Ulaanbaatar city, such land use classes as central government organization, educational institution, academic organization, cultural place, bank and finance organization, trade and public service, international organization, health organization, residential apartment, hotel_restaurant_pub, auto service centre, combination of service, shop and apartments, non-government organization, garage, green area and other land use types have been selected. To analyze the changes occurred before and after 1990, ArcGIS and SPSS Statistics programs were used. After selecting the entities defined for each land use class during the selected time interval, the related number of buildings and their occupying areas were calculated. The number of objects and total areas related to each land use class before and after the market economy are shown in table 1.



Figure 2. The digitized original and updated buildings

Spatial analysis has been carried out mainly using ‘Select by attributes’ function of ArcGIS. As seen from the table 1, for the central government organization, before the year 1990, 18 buildings (28538.9 m² total) were erected, but after 1990, 23 buildings (19381.6 m² total) were built up. Although the number of buildings had increased, the total area occupied by these buildings had not increased. Likewise, for the educational institution, the building area has not been increased at all, despite the addition of 8 new buildings. The bank and finance organization repeats this pattern, for example, there were 5 buildings with an area of 6402.4 m² before 1990 but were increased by 11 buildings occupying only 3967.5 m² following market economy growth after 1990. Since the country entered the market economy, the largest change has occurred in the trade and service. During a whole period of the centralized economy, only 16 buildings occupying 16089.8 m² were belonged to this class, however, after the year 1990, 49 new buildings occupying 21761.6 m² were emerged. As seen during the market economy, buildings were increased by more than three-fold, whereas their occupying areas were increased by only 35.25%. It is interesting to notice that before 1990, 35 residential apartments occupied 38965.5 m², but 21 apartments built up during the market economy occupied only 9417.3 m².

Also it is seen from the table 1 that in comparison with the developments of the centralized economy during the market economy, in this area, only 1 cultural and historical place (953.1 m² total),

1 academic organization (342.9 m²) and 1 international organization (89.4 m²) were emerged. Unlike this case, there were emerged 7 entertainment places (i.e. hotel, restaurant and pub) occupying 4593.9 m² after 1990, compared to 2 entertaining sites (3950.1 m²) of the centralized economy. This was related with the fact that during the market economy, the land parcel in the central part became very expensive and it was extremely difficult to find a piece of land for the state organizations. Moreover, from the table 1, one could observe that after 1990 there were built up 5 buildings for the health organizations (3602.6 m²). However, most of them belong to the private businesses and they mainly use these buildings for the purposes of hospitals and chemists.

Table 1. Total number of buildings (a) and their occupying areas (b) in selected areas before and after 1990

No.	Land use types	Before 1990		After 1990	
		Number of buildings	Total area of buildings (m ²)	Number of buildings	Total area of buildings (m ²)
1	Central government organization	18	28538.9	23	19381.6
2	Educational institution	8	11427.3	8	3250.1
3	Bank and finance organization	5	6402.4	11	3967.5
4	Trade and service	16	16089.8	49	21761.6
5	Residential apartment	35	38965.5	21	9417.3
6	Cultural and historical place	7	17841.5	1	953.1
7	Academic organization	4	4410.3	1	342.9
8	International organization	5	3028.8	1	89.4
9	Hotel, restaurant and pub	2	3950.1	7	4593.9
10	Health organization	3	2783.4	5	3602.6
11	Auto service centre	1	168.6	1	69.5
12	Combination of service, shop and apartment	22	28236.3	20	14388.4
13	Non-government organization	2	1773.7	4	3855.3
14	Garage	16	2334.3	9	1907.8
15	Average storey		3.2		5.2
16	Green area		137616.97		85930

As seen, during the market economy in most land use classes, compared to the number of buildings, the land areas were decreased. The main reason for this was the fact that before 1990, the Mongolian Government built primarily large buildings with a few stories occupying larger areas. However, since the country entered the market economy in 1990, companies and individuals began to replace these large building blocks with independent businesses and houses, typically occupying smaller areas with more stories. For example, during the centralized economy, average story for the buildings was 3.2, while after the year 1990, it became 5.2. Furthermore, it should be mentioned that in many places the ground floors of the residential apartments and some other organizations were changed to small shops, cafeteria and other commercial entities. This process was intensive during the period of the centralized economy (i.e. 22 services occupying 28236.3 m²). However, since the country entered the market economy, people preferred to have their own buildings or houses. Therefore, there were emerged only 20 services below the apartment buildings. In addition, it is seen that the green area was significantly reduced after 1990.

CONCLUSIONS

The overall goal of the study was to conduct urban mapping and analyze the urban land use changes of Central Ulaanbaatar using very high resolution satellite 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 the study area and description of the spatial entities were used. To update the created database, Quickbird image of 2012 was used. To extract land use information from the Quickbird image, a visual interpretation was applied. Overall, the research demonstrated that during the market economy the central part of the capital city was urbanized very rapidly and its planning and management should be reconsidered.

REFERENCES

- [1] Amarsaikhan, D., 2010, A conceptual framework for update of urban GIS by RS data. Proceedings of 4th Annual International Conference on the Application and Development of Geospatial Technologies in Mongolia, pp.12-19.
- [2] Amarsaikhan, D., Battsengel, V., Egshiglen, E., Gantuya, R. and Enkhjargal, D., 2011, Applications of GIS and Very High Resolution RS Data for Urban Land Use Change Studies in Mongolia. International Journal of Navigation and Observation, Vol.2011- Article ID314507, pp.1-9.
- [3] Chinbat, B., Bayantur, M. and Amarsaikhan, D., 2006, Investigation of the internal structure changes of Ulaanbaatar city using RS and GIS. Proceedings of the ISPRS Mid-term Symposium, ITC, Enschede, The Netherlands, pp.wg04_1-6.
- [4] ERDAS, 1999, Field guide, Fifth Edition, ERDAS, Inc. Atlanta, Georgia.
- [5] Mather, P.M. and Koh, M., 2011, Computer Processing of Remotely-Sensed Images: an Introduction. Fourth edition (Wiley-Blackwell).
- [6] Torino, C.E., 2008, Gauss Kruger projection for areas of wide longitudinal extent. International Journal of Geographical Information Science, Vol.22, No.6, pp.703–719.