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EVALUATION OF URBANIZATION PROCESS IN ULAANBAATAR CITY USING MULTITEMPORAL RS IMAGES

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ABSTRACT: The aim of this study is to evaluate the urbanization process of Ulaanbaatar, the capital city of Mongolia using multitemporal satellite remote sensing (RS) data sets. To extract urban land cover information from the selected RS data sets, a refined supervised classification method based on maximum likelihood classification that uses spatial thresholds defined from the local knowledge is applied. Overall the research indicated that in recent decades Ulaanbaatar city has faced very rapid urbanization process.

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 process are being more strongly observed, especially in the larger towns and cities of the developing world and because of a lack of thorough planning and management many of them are facing different urban related problems [1,4]. As it is known, when the urban areas are expanded, some important natural resources such as forest, natural vegetation and water resources as well as some agricultural lands are transformed into land for housing, industry and infrastructure. Also, rapid urbanization processes followed by an industrialization process cause other environmental problems such as urban heat island, torrential rainfall, water and air pollution [10].

Mongolia, as many countries of the developing world has a problem with the urban expansion and the growth of population in the main cities, specifically in the capital city. 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 Ulaanbaatar, approaching the central market. As a result, the population of Ulaanbaatar had been significantly increased and the city area had significantly expanded [3].

In this study, we wanted evaluate the urbanization process of Ulaanbaatar city using multitemporal RS images. As RS data sources, Landsat MSS, SPOT XS, Landsat TM and Landsat ETM (+) data were used. To extract the urban land cover information from the selected RS data sets, a maximum likelihood classification that uses spatial thresholds defined from the local knowledge was applied.

2. TEST AREA AND DATA SOURCES

As a test site Ulaanbaatar, the capital city of Mongolia has been selected. Ulaanbaatar is situated in the central part of Mongolia, on the Tuul River, at an average height of 1350m above sea level and currently has nearly 1 million inhabitants [8]. The selected part of the capital city is about 24kmx18km. It covers the majority of the area belonging to the capital city, although there are some areas extending outside of the selected image frame.

As the data sources, Landsat MSS data of January 1974 with a spatial resolution of 79m, SPOT XS data of May 1986 and June 1997 with a spatial resolution of 20m, Landsat TM data of October 1990 with a spatial resolution of 30m, and Landsat ETM (+) data of August 2001 with a spatial resolution of 28m were used. In addition, topographic maps of 1969 and 1984, scale 1:50,000, and a general urban planning map were available. Figure 1 shows the test area in some of the selected RS images.

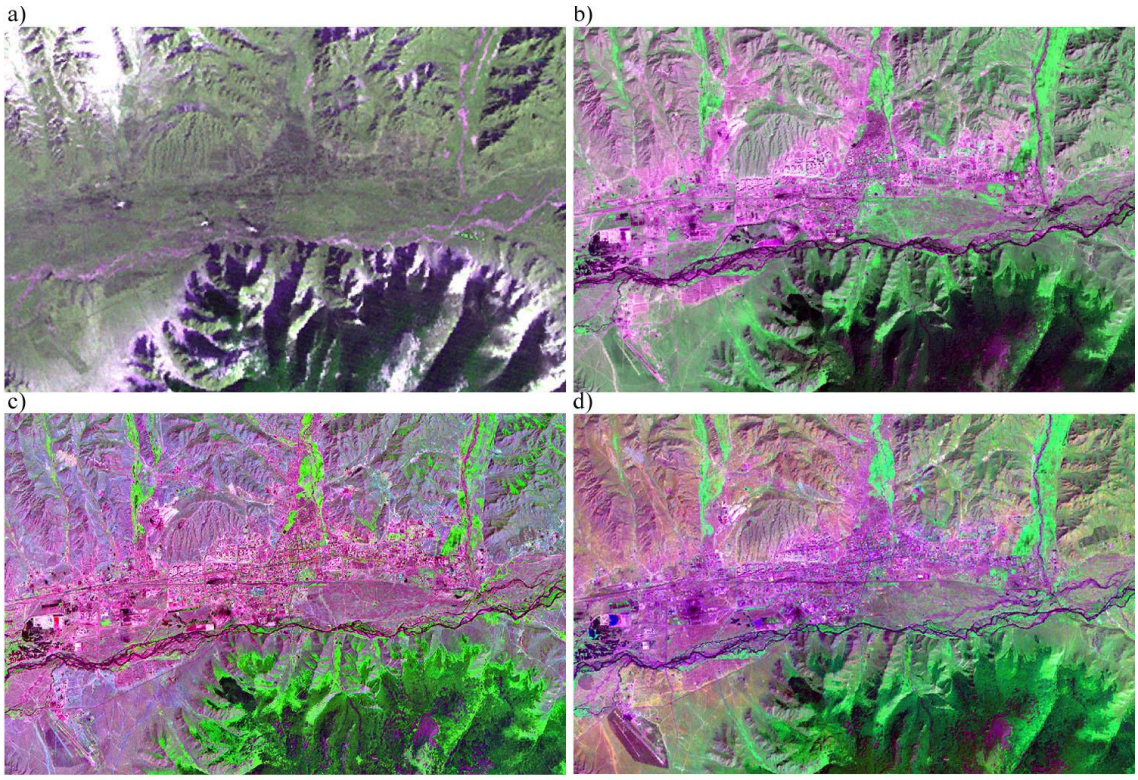

Figure 1. RS images of Ulaanbaatar area. a) MSS image of 1974, b) TM image of 1990, c) SPOT XS image of 1997, d) ETM+ image of 2001.

3. RADIOMETRIC CORRECTION AND GEOREFERENCING OF THE MULTISPECTRAL IMAGES

At the beginning, all images were thoroughly analyzed in terms of radiometric quality and geometric distortion. The Landsat MSS data had a destriping effect and it was corrected by applying a destripe removing function followed by a 3x3 size average filtering [6]. Then, the 1986 SPOT XS image was georeferenced to a Gauss-Kruger map projection using a topographic map of 1984, scale 1:50,000. The ground control points (GCP) have been selected on well defined cross sections of roads, streets and other clearly delineated sites. In total, 12 regularly distributed points were selected. For the transformation, a linear transformation and nearest neighbour resampling approach [5] have been applied and the related root mean square (RMS) error was 0.78 pixel. In order to georeference other images, 12-16 more regularly distributed GCPs were selected on each image comparing the locations of the selected points with other information such as the already georeferenced SPOT XS and the selected topographic maps. Then, the images were successively georeferenced to the Gauss-Kruger map projection using the topographic map of 1984. For the actual transformations, a second order transformation and nearest neighbour resampling approach were applied. The RMS errors of the image transformations were 1.2 pixel for the MSS, 0.92 pixel for the TM, 0.65 pixel for the 1997 SPOT XS and 0.84 pixel for the ETM, respectively. In all cases of the georeferencing, an image was resampled to a pixel resolution of 30m.

4. CLASSIFICATION OF THE IMAGES AND EVALUATION OF THE URBANIZATION

In this study, to extract the reliable urban land cover information from the selected RS data sets, a refined maximum likelihood classification that uses spatial thresholds defined from the local knowledge has been used. As the features for the classification, for all data sets green, red and infrared bands have been selected. To define the sites for the training signature selection, from the images, several areas of interest (AOI) have been selected for the available classes such as building area, ger (Mongolian national dwelling) area, green vegetation, soil and water using the local knowledge. Then, the separability of the selected training signatures was evaluated using Jeffries–Matusita distance [7,9] and the samples which demonstrated the best possible separability were chosen to form the final signatures. The final signatures included about 86-512 pixels.

For the actual classification, a maximum likelihood classification has been used. The maximum likelihood classification is the most widely used supervised classification technique, because a pixel classified by this method has the maximum probability of correct assignment [9]. Initially, in order to check the performance of the standard method, the selected bands were classified, however, on the classified images there were different mixed classes and it was not possible to correctly evaluate the urbanization process. To separate the statistically mixed classes, the class specific features as well as spatial thresholds can be applied. The class specific features can be determined through the feature extraction process, however, the application of this approach would become difficult if there is a fewer number of bands. The spatial thresholds can be defined from the knowledge about the test area or historical GIS data sets. The idea of the spatial threshold is that it uses a polygon boundary to separate the overlapping classes and only the pixels falling within the threshold boundary are used for the classification. In that case, the likelihood of the pixels to be correctly classified

will significantly increase, because the pixels belonging to the class that overlaps with the class to be classified using the threshold boundary are temporarily excluded from the decision making process. In such a way, the image can be classified several times using different threshold boundaries and the results can be merged [2].

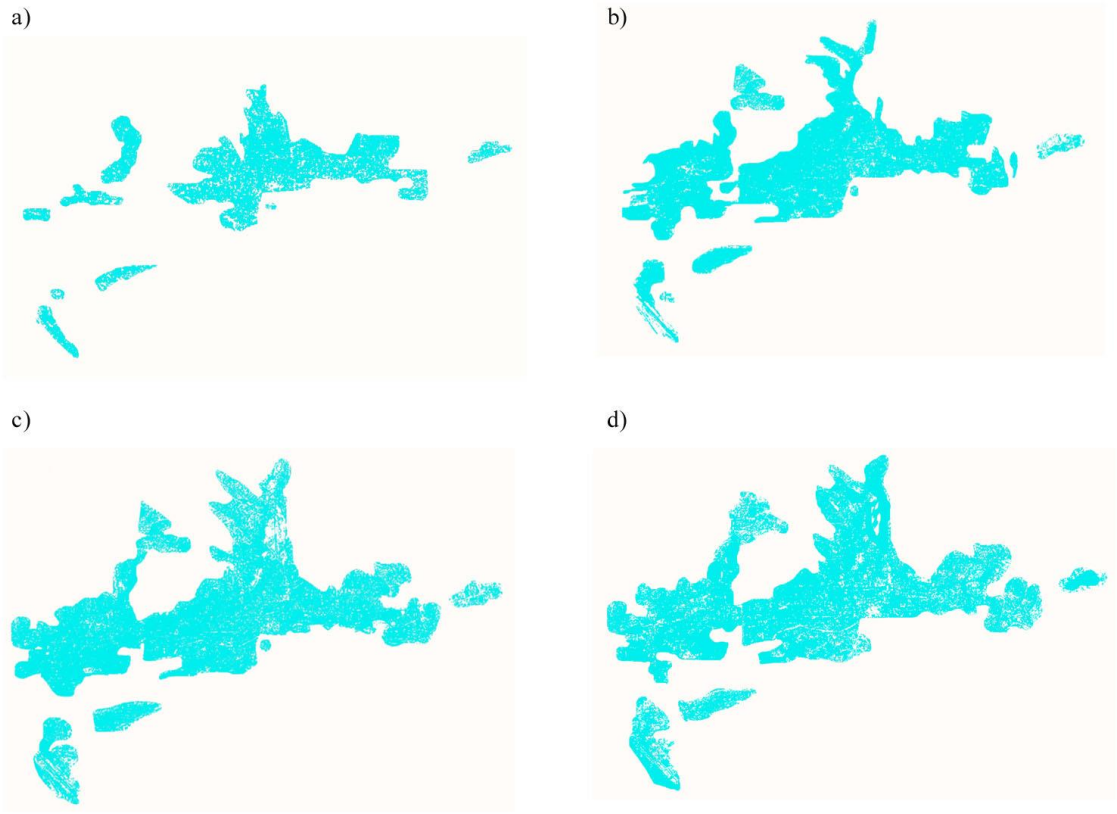

Figure 2. The results of the classifications of a) MSS image of 1974, b) TM image of 1990, c) SPOT XS image of 1997, d) ETM+ image of 2001.

In the present study, to separate the statistically overlapping classes, different spatial thresholds determined on the basis of the local knowledge have been used. The local knowledge was based on the knowledge about the site as well as the historical GIS data sets. The results of the classifications (except 1986 data) using the defined spatial thresholds are shown in figure 2. For the accuracy assessment of the classification results, the overall performance has been used and as ground truth information, different AOIs containing the purest pixels have been selected. The confusion matrices produced for the refined classification method indicated overall accuracies of 87.2% for the 1974 data, 90.1% for the 1986 data, 90.9% for 1990 data, 93.2% for the 1997 data and 91.5% for 2001 data, respectively.

In order to define the areas related to urban expansion, initially, the total areas related to each class was defined by calculating statistical parameters of the classified multitemporal RS images. Then, the classes were merged into two classes: urban and non-urban. The urban class included building area and ger area, whereas non-urban class included all other classes. The areas related to urban class evaluated from RS images obtained at different years are shown in table 1. As seen from table 1, in recent decades Ulaanbaatar city has faced very rapid urbanization process and its size has been almost doubled since 1974.

Table 1. The total areas for urban class in different years, evaluated from multitemporal RS data sets.

RS images	Total areas in hectares (ha)
Landsat MSS (1974)	5217.1
SPOT XS (1986)	7324.6
Landsat TM (1990)	9033.1
SPOT XS (1997)	9497.3
Landsat ETM+ (2001)	9687.8

5. CONCLUSIONS

The overall idea of the research was to evaluate the urbanization process of the capital city of Mongolia using multitemporal satellite RS images. To extract urban land cover information from the selected RS data sets, a refined classification algorithm based on the maximum likelihood classifier that uses spatial thresholds defined from the local knowledge was applied. After the classification, the defined classes were merged into either urban or non-urban class. As seen from the result of the evaluation process, in recent decades Ulaanbaatar city has faced very rapid urbanization process.

REFERENCES

1. AMARSAIKHAN, D. GANZORIG, M. and SAANDAR, M., 2001, Urban Change Study Using RS and GIS, *Asian Journal of Geoinformatics*, December 2001, No2, Vol2. pp. 73-79.

2. AMARSAIKHAN, D. and SATO, M., 2003, The role of high resolution satellite images for urban area mapping in Mongolia. In *'Reviewed Papers' part of Proceedings of the Computers for Urban Planning and Urban Management (CUPUM)'03 International Conference*, Sendai, Japan, pp.1-12, May 2003.

3. Amarsaikhan, D., Ganzorig, M. and Moon, T.H., 2005, Application of multitemporal RS and GIS data for urban change studies, Proceedings of the Korean GIS Conference, Busan, Korea, pp.190-215.

4. BOLT, D., 1996, An Urban Community Strategy For Implementing Decentralization And Devolution Policies. *ITC Journal*, 1, pp. 18-28.

5. ERDAS, 1999, Field guide, Fifth Edition, ERDAS, Inc. Atlanta, Georgia.

6. GONZALEZ, R. C. and WOODS, R. E., 2002, Digital Image Processing, Second Edition, Upper Saddle River, (New Jersey: Prentice-Hall).

7. MATHER, P.M., 1999, Computer Processing of Remotely-Sensed Images: An Introduction, Second Edition, (Wiley, John & Sons).

8. MONGOLIAN STATISTICAL YEAR BOOK, 2006, National Statistical Office of Mongolia, Ulaanbaatar, Mongolia.

9. RICHARDS, J.A., and JIA, X., 1999, Remote Sensing Digital Image Analysis-An Introduction, Third Edition, (Berlin: Springer-Verlag).

10. TACHIZUKA, SH., HUNG, T., OCHI, SH. and YASUOKA, Y., 2002, Monitoring of Long-term Urban Expansion by the use of Remote Sensing Images from Different Sensors. Available online at: www.gisdevelopment.net/aars/acrs/2002/urb.