APPLICATION OF RS FOR URBAN LAND COVER CHANGE STUDY

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ABSTRACT: The aim of this study is to conduct urban land cover change study in Ulaanbaatar city, Mongolia using multi-temporal satellite remote sensing (RS) and geographical information system (GIS) data sets. To extract reliable urban land cover information from the selected RS data sets, a refined supervised classification method based on maximum likelihood classification (MLC) that uses spectral thresholds defined from the local knowledge is applied. Overall, the research indicated that in recent decades Ulaanbaatar city has been significantly expanded.

1. INTRODUCTION

At present, because of the rapid increase in world population and the irreversible flow of people from rural to urban areas, the urbanization and urban sprawl have become the common problem of governments and decision-makers in both developed and developing countries (Amarsaikhan *et al.* 2009a). As it is known, the developed countries have a higher percentage of urban inhabitants 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 the developing world (Amarsaikhan *et al.* 2011).

As it is known from a city planning record of Mongolia, much of its urban growth has taken place since the middle of 1970s, because, at that time, the government encouraged migration to urban areas, specifically to Ulaanbaatar. Although, this encouragement was based on the belief to increase the industrialization and productivity, the government made a strict control over migration, and only those who found jobs could move to Ulaanbaatar city. To accommodate the growing population in the capital city, the government mainly constructed high-rise apartment blocks (Amarsaikhan, 2011). However, the number of apartments fell well short of satisfying the demands of the growing population. Therefore, when rural people migrated to Ulaanbaatar, set up gers (Mongolian national dwellings) for their accommodation.

The rapid political changes of 1990 marked the beginning of Mongolia's efforts to develop market economy. It started to change the lives in the society very rapidly and the government stopped controlling of many things (Chinbat *et al.* 2006). For the isolated rural people, it had become very difficult to reach the central market. Meanwhile, many things started to centralize in the capital city and Ulaanbaatar had become a dream location for many rural people (Amarsaikhan *et al.* 2014). Therefore, many rural families moved officially and unofficially to Ulaanbaatar. As a result, the population of Ulaanbaatar increased significantly and the city area expanded drastically (Amarsaikhan and Bat-Erdene, 2013).

In this study, the changes occurred in Ulaanbaatar between 1969 and 1990 have been compared with the changes occurred between 1990 and 2016 using historical GIS data as well as RS images. Such comparisons could be helpful for the planners to consider directions of the urbanization process in the city. To extract the reliable urban land cover information from the selected RS data sets, a refined MLC algorithm that uses spectral thresholds defined from the local knowledge was used.

2. TEST SITE 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, in the Tuul River valley, at an average height of 1350m above sea level. By 2016 statistics, population of the city was counted at about 1,400,000 inhabitants (Mongolian Statistical Year Book, 2016). Today's Ulaanbaatar is the main political, economic, business, scientific and cultural center of the country. In addition, the city is home to the central government and its bureaucratic structure, and the most prominent public and private institutions of higher learning and best medical services (Amarsaikhan *et al.* 2009b).
The study area chosen for the present study covers an area of 28kmx20km. It covers the majority of the area belonging to the capital city, although there are some areas extending outside of the selected image frame. For the selected area, it is possible to define such classes as built-up area, ger area (Mongolian traditional dwelling), forest, grass, soil and water.

As the data sources, Landsat TM data of September 1990 with a spatial resolution of 30m, Landsat 8 data of September 2016 with a spatial resolution of 30m 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 recent outlook of the test area in the Landsat 8 image.

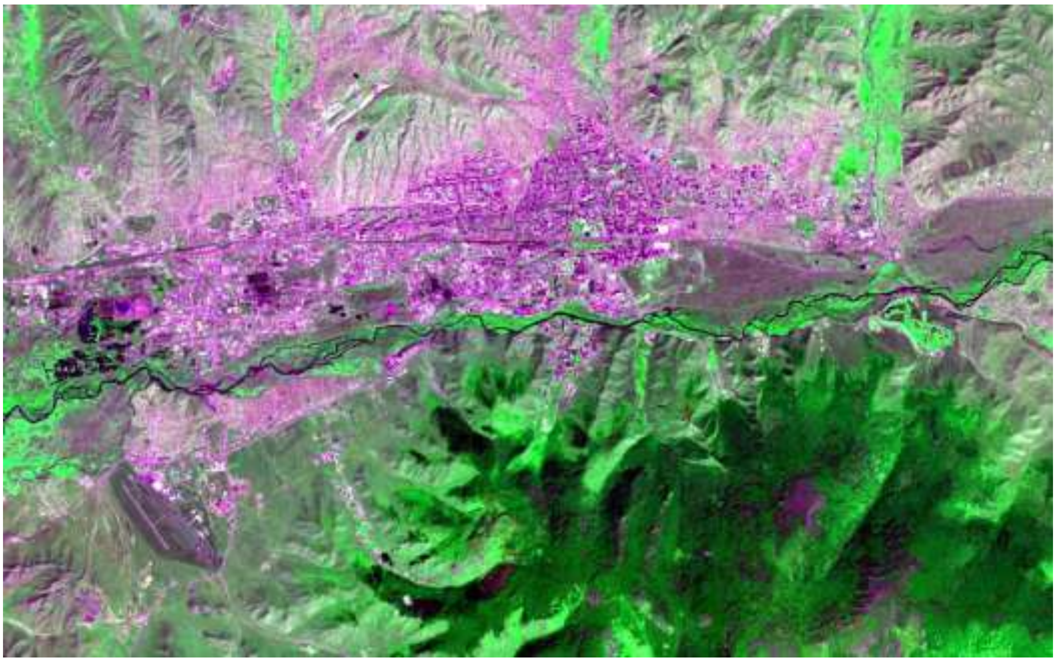

Figure 1. 2016 Landsat 8 image of the selected part of Ulaanbaatar city.

3. RADIOMETRIC CORRECTION AND GEOREFERENCING OF THE RS IMAGES

At the beginning, both images were thoroughly analyzed in terms of radiometric quality and geometric distortion. Band 1 (i.e., blue band) of Landsat TM data had noise from the atmosphere and it was difficult to correlate its radiometric values with other bands. Therefore, it was excluded from the analysis. Moreover, thermal bands of both images were excluded from the further analysis, too.

Initially, the Landsat TM image of 1990 was georeferenced to a UTM map projection using a topographic map of 1984, scale 1:50 000. The ground control points (GCPs) have been selected on well defined cross sections of roads, streets and other clearly defined sites. In total, 15 more regularly distributed points were selected. For the transformation, a second order transformation and nearest neighbor resampling approach have been applied. The root mean square (RMS) error was 0.96 pixel. Then, the Landsat 8 data of 2016 were georeferenced to a UTM map projection using the same topographic map of 1984. The transformation was conducted by the use of a second order transformation and nearest neighbour resampling approach and again 15 more regularly distributed GCPs were selected. The RMS errors were 0.91 pixel.

4. CLASSIFICATION OF THE IMAGES

In recent years, rapid and timely mapping of urban areas, specifically at regional and global scales has become an important task for many urban planners. This is associated with the rapid urbanization process, because the planners and decision-makers need to evaluation the related environmental and social problems (Cao *et al.* 2009). However, in most cases urban areas are complex and diverse in nature and many features have similar spectral characteristics and it is not easy to separate them by the use of common feature combinations or by applying ordinary techniques (Amarsaikhan *et al.* 2015). For the successful extraction of the urban land cover classes, reliable features and an efficient classification technique should be used. In the present study, for the classification of urban land cover types, a refined statistical MLC algorithm has been constructed. The method can be successfully used for separation of classes in both images.

4.1. Evaluation of the training signatures

Generally, in the classification process, it is desirable to include only the features in which the signatures of the selected classes are highly separable from each other in a multidimensional feature space. In case of the present study, as the features, the green, red and near infrared bands from RS data sets of both 1990 and 2016 have been selected.

To define the sites for the training signature selection, several areas of interest (AOI) have been selected for each available class (i.e., building area, ger area, forest, grass land, soil and water) using the local knowledge. The local knowledge was based on the basis of the spectral variations of the land surface features as well as the texture information delineated on the false color images. The separability of the selected training signatures was firstly checked in feature space and then evaluated using Jeffries–Matusita distance (Amarsaikhan *et al.* 2007). Then, the samples which demonstrated the best possible separability were chosen to form the final signatures. The final signatures included about 123-458 pixels.

4.2. The refined MLC method

The MLC is the most widely used classification technique, because a pixel classified by this method has the maximum probability of correct assignment (Erbek *et al.* 2004). The decision rule assuming Bayes' rule can be written as follows:

$$P(Ci|x) = P(x|Ci)*P(Ci)/P(x) \quad (1)$$

where P(Ci|x)-posterior probability, P(x|Ci)-conditional probability, P(Ci)-prior probability, P(x)-probability of finding a pixel from any class. The actual classification is performed according to P(Ci|x) > P(Cj|x) for all j#i.

Within the framework of this study, for all classes equal prior probabilities have been assigned. To conduct a classification decision rule, for each class label a conditional probability that is approximated by a multivariate probability density function, should be evaluated. For this purpose, the sample mean vectors, determinants and variance-covariance matrices for each class are estimated from the selected training signatures. Then, every pixel in the digital image is evaluated using the maximum likelihood and the class label is assigned to the pixel that has the maximum probability (Mather and Koh, 2011).

At the beginning, in order to check the performance of the standard method, the selected bands were classified using the statistical MLC. As could be seen from the results, on the classified images there were different mixed classes between the classes: building area and ger area. This should be apparent, because the previous signature analysis indicated that the signature distributions of these classes had significant overlaps in the multidimensional feature space. To separate the statistically mixed classes, the class specific features as well as spectral thresholds can be applied. The class specific features can be determined through a feature extraction process, however, the application of this approach would become difficult if there is a fewer number of bands. The spectral thresholds can be determined on the basis of DN values of data sets.

In order to improve the traditional MLC, the constructed classification algorithm uses spectral thresholds defined from the local knowledge. The local knowledge is based on the spectral and textural variations of the selected classes in different parts of the selected images and the thresholds are applied to separate the statistically overlapping classes. It is obvious that a spectral classifier will be ineffective if applied to the statistically overlapping urban classes, because they have very similar spectral characteristics. For such spectrally mixed classes, classification accuracies should be improved if spectral properties of the classes of objects could be incorporated into the classification process.

When thresholds apply only the pixels falling within the threshold limits 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 limits. After the process finishes, all ancillary results are merged, thus creating a new land cover image.

For the accuracy assessment of the classification results, the overall performance has been used. This approach creates a confusion matrix in which the selected reference pixels are compared with the classes in the classified image and as a result, an accuracy report is generated indicating the percentages of the correspondence (Amarsaikhan and Douglas, 2004). In this study, as ground truth information, different AOIs containing the purest pixels (i.e. 7959 pixels for both classification results) have been selected. The confusion matrices produced for the refined MLC classification method indicated overall accuracy of 92.12% for the 1990 data set, while for the 2016 data set it was 91.83%. As the classification accuracies exceed 90%, these results can be confidently used for further analysis or update of a land cover layer within a GIS. A flowchart for the constructed refined MLC method is shown is Figure 2.

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 Landsat 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, in recent decades Ulaanbaatar city has faced very rapid urbanization process and its size has been significantly increased since 1990.

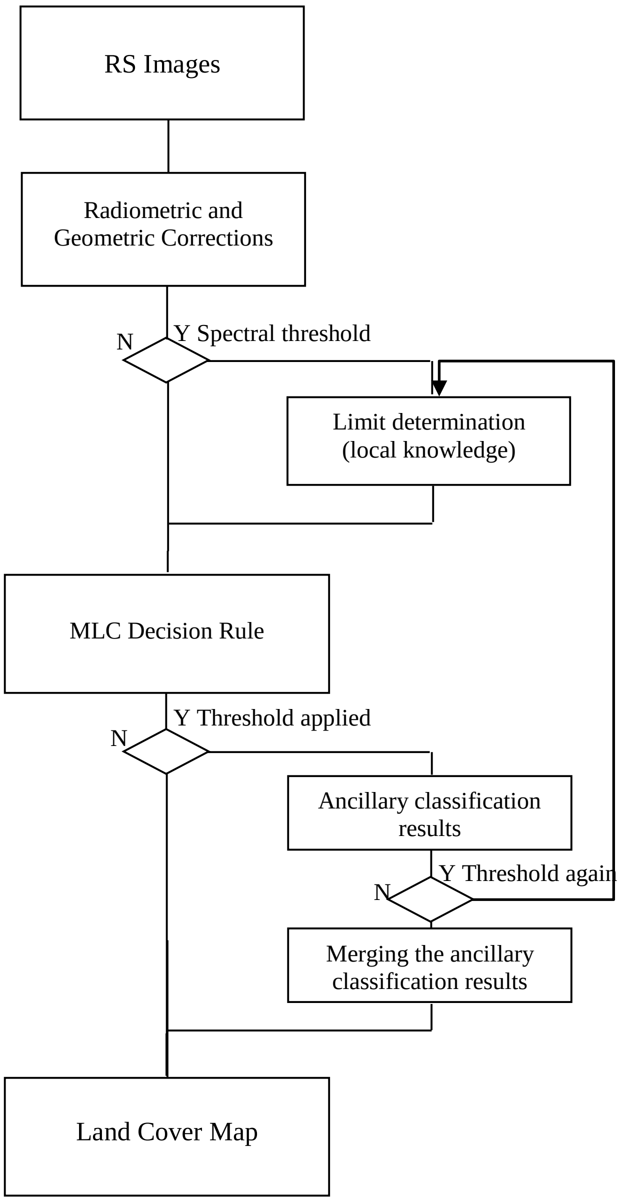

Figure 2. A general diagram for the refined MLC method.

5. LAND COVER CHANGE STUDY

The current study aimed to compare the changes of Ulaanbaatar area in between 1969 and 1990 with the changes occurred in between 1990 and 2016 using multi-temporal RS and GIS data sets. To create the primary historical GIS data, the classes: building area, ger area, forest and water were digitized in a UTM map projection from a topographic map of 1969, scale 1:50 000 using ArcGIS. The apartments, residential houses, industrial buildings and all other building areas were included in the building area class, because on the selected satellite images it was not possible to distinguish among these classes, due to their very similar spectral characteristics. However, using ground truth data and knowledge about some local areas one can observe that the main industrial areas are mainly distributed in the southern part of the city and some are located in the western part.

Table 1. The total areas for each class in different years, evaluated from GIS and multi-temporal RS data sets.

Time period	The total areas for each class in hectares	
	Building area	Ger area
1969	2498.92	978.86
1990	3996.71	2719.65
2016	5753.12	10834.93

To define the total area of each class on the digitized vector map, the areas have been automatically calculated using ArcGIS. The total areas related to the classes defined from the digitized map are shown in Table 1. Although, we have census data of Ulaanbaatar city, it is not possible to directly relate it to the current analysis, because our study area does not cover all the areas from where the final census data is collected. However, as the test area covers the majority of the area belonging to the capital city, it is possible to use the census data for a comparison of the general population increase with the actual urban expansion process.

As seen from Table 1, in 1969 in Ulaanbaatar city, the building area and ger area covered 2498.92ha and 978.86ha, respectively, whereas in 1990 these two urban classes covered 3996.71ha and 2719.65ha, respectively. The available census data indicated that in 1969 the population of the capital city was 267 400, while in 1990 it had become 574 900. As seen, within the 21 year period of the centralized economy, the building areas were increased by only 59.94%, whereas the ger areas were increased by more than two-fold. Meanwhile, the population increased by more than 2 times (Amarsaikhan *et al.* 2009a).

Moreover, as seen from Table 1, within 26 years, since the country entered the market economy, the building areas were increased by 43.9%, while the ger areas were increased by more than almost four fold. Thus, this study has revealed that over recent years, the ger areas in the capital city have been significantly expanded, specifically in the urban fringes.

6. CONCLUSIONS

The overall objective of the study was to conduct urban land cover change study in the Mongolian capital city using multi-temporal Landsat images and GIS data. As could be seen from the analysis, during the periods of both centralized and market-based economies significant changes occurred in the ger area of the city and ger districts mainly extended in northern and eastern parts of the Ulaanbaatar city. Furthermore, it was seen that a spatial resolution of the used RS data sets allowed to conduct the analysis at a regional scale and the results could be useful for the planners and decision-makers to consider directions of the urbanization process in the capital city.

To extract reliable urban land cover information from the selected Landsat images, a refined supervised classification method based on the parametric classification that uses spectral thresholds defined from the local knowledge was applied. It was seen from the classification results that the spectral thresholds defined from the local knowledge could considerably improve the performance of the classification and for the accurate classification, proper limits should be applied.

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