Investigation of Land Use in Residential Areas of Ulaanbaatar City using Very High Resolution Satellite Images

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Abstract

The aim of this study is to demonstrate the use of very high resolution RS images for a detailed residential urban study in Mongolia. For this purpose, five areas representing the existing residential land use classes are selected in different locations of Ulaanbaatar city. For the analysis, SPOT 5 and Quickbird images are used and different image enhancement techniques are applied. The analysis was carried out using Erdas Imagine 8.6 installed in a PC environment.

Keywords: *Residential land use, Image enhancement, Fusion, Analysis*

1. Introduction

At present, the urbanization and urban expansion are the common problem in both developed and developing countries. Over the past two decades, Ulaanbaatar, the capital city of Mongolia has been significantly expanded due to different development activities as well as migration of people from rural areas. Specifically, since the transition to a market economy the Ulaanbaatar city has experienced much more developments, because it was not possible to pay attention to all of the rapidly changing activities and many things had happened without any control [1,4]. These 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 ger-settlements; the formation of satellite nodes with clusters of commercial functions, and the residential suburbanization in the outer city by single family houses [5].

Now in Ulaanbaatar city one can observe different land use classes, including the most common land use classes such as residential, commercial, industrial and green areas. As the thorough investigation of each of these classes requires a large scale study, in this study we wanted to concentrate only on the residential land use. A residential zone in Ulaanbaatar consists of three basic parts such as apartment quarters, cottage house regions and ger districts. The apartment quarters are divided into a low-rise apartment quarter, a middle-rise apartment region and a high-rise apartment quarter. The low-rise apartment quarter includes the apartment buildings with 2-3 storeys, whereas the middle-rise apartment region includes the buildings with 4-5 storeys. The high-rise apartment quarters usually include the apartment buildings with more than 9 storeys. The cottage house region has emerged during the transition period to a market economy and it represents a new type of urban land use in Mongolia. The ger is Mongolian national dwelling and its history goes back to about

2500-3000 B.C. It is still used as dwelling everywhere in Mongolia and the gers situated in urban areas are surrounded by fences that occupy usually 600m^2-800m^2 [3]. The ger districts in Ulaanbaatar city are separated from the central zone of the capital city by low and middle-rise apartment regions constructed during 1950s and 1960s in the belts of the Small ring and the Big ring areas [4].

Generally, to prevent from the rapid urban expansion, especially from the unplanned urbanization process, urban planners and decision-makers need to regularly evaluate the current development procedures using detailed urban planning maps. However, many city planners specifically from developing world have a lack of the detailed updated maps and often they possess old information which is not relevant for current decision-making [1]. In such a case, RS images with a very high resolution can play a significant role, because the current highest spatial resolution space images are acquired with a few cm accuracy. In the present study, we wanted to demonstrate how very high resolution RS images can be used for a detailed study in urban context. For this purpose, the sites representing apartment quarters which include low-rise, middle-rise and high-rise apartments as well as cottage house regions and ger districts have been selected in different parts of Ulaanbaatar city and for the analysis, SPOT 5 and Quickbird images of 2002 have been used. The analysis was carried out using Erdas Imagine 8.6 installed in a PC environment.

2. The spatial and functional structure changes of Ulaanbaatar city

Generally, the development plan of Ulaanbaatar city before 1990, when the country had a centralized economy represented not only urban construction and physical architectural plan, but it was based on the capital 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 areas, economic and infrastructure sites, residential and dwelling apartments of the country were mainly concentrated in the capital 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. However, when the country entered the market economy, it was not possible to control all of the rapidly changing activities and many things had happened without any control [4].

The main physical expansion of the city and increasing functional complexity of urban life that is the changes of urban internal structure in Ulaanbaatar, have occurred since 1990s. These changes were conditioned by basically transforming politico-economic and social environments in the entire country. The main transformations of the political, economical and social environments [5] were as follows:

1. Since 1990s, the government has implemented different policies step by step to privatize state and collective properties and liberalize the prices. As results of that market principles were established irrevocably, and the private sector became dominant in Mongolian economy. To date, the private economic entities produce 56% of the total industrial products; carry out 42% of construction and erection works, and occupy 76% of total retail turnover. In the case of Ulaanbaatar, there were 13,559 registered businesses and 13,853 licensed businesses operating in 2002.

2. Economic restructuring involves another set of processes, which have determined the contemporary urban changes. Most of the state industrial plants have been closed and privatized due to declining employments in the industry as well as the structural changes of traditional industries. Instead, commercial and service industries have grown rapidly. New private companies operate mostly in trade and advanced services, such as finance, audit, consultancy, real estate, public relations, media, tourism, and compete for profitable locations within the city.

3. The central government and the municipality of the capital city implemented policies to limit a mechanical growth of population (until the early 1980s, rural-to-urban migration was under the strict control of the Government). The population growth of the capital city, however, was continuing during the communist time, and this growth was accelerated even further since the transition period, especially after the new constitution. The new constitution has been in force since 1992 and people had the rights of free circulation and settlement within the country.

4. Privatization processes have created a new class of owners some of whom became wealthy, and since the beginning of the economic reforms there has been a rapid increase of wealth differentiation among people. Furthermore, relating to privatization and liberalization of prices, the price differentiation has occurred also

in the real estate sector and the housing prices became different depending upon the attractiveness and locations of the residences. In the other words, differentiated household incomes and the prices and rent of housing have contributed to the increase of socio-spatial differentiation.

3. The selected sites and data sources

In the present study, low-rise apartment area, middle-rise apartment area, high-rise apartment area, cottage house region and ger district have been slected in 40,000 area, XIX microdistrict, XIII microdistrict, New Cottage area and Khailaast area, respectively. The locations of these sites represented in a SPOT 5 image of 2002 are shown in Figure 1.

As the RS data sources, multispectral SPOT 5 image of 2002 resampled to a pixel resolution of 4m and Quickbird image of 2002 with a spatial resolution of 70cm have been used. In addition, a topographic map of 1984, scale 1:50,000 and a topographic map of 2000, scale 1:5,000 as well as a general urban planning map were available.
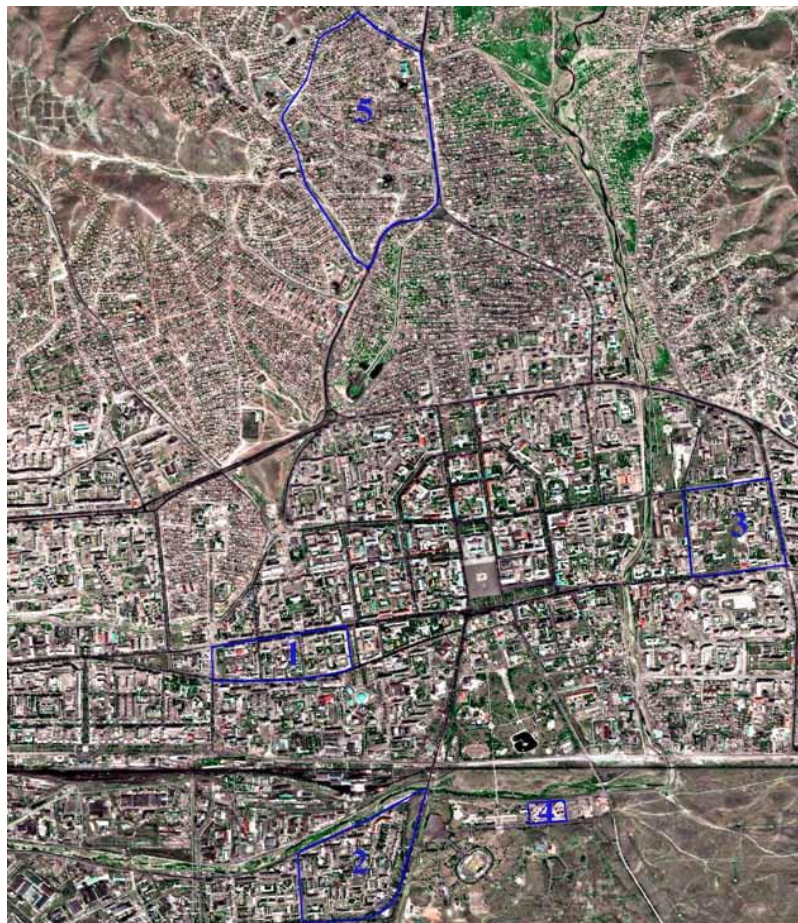

Figure 1. SPOT 5 image of Ulaanbaatar city (Red=band 1, Green=band 3, Blue=ban 2).1- Low-rise apartment area, 2- Middle-rise apartment area, 3- High-rise apartment area, 4- Cottage house region, 5-Ger district.

4. Georeferencing and enhancement of the SPOT 5 and Quickbird images

Initially, the SPOT 5 and Quickbird images have been georeferenced to a Gauss-Kruger map projection, using a topographic map of 2000, scale 1:5,000. The ground control points have been selected on well defined sites and for the transformation, a linear transformation and nearest neighbour resampling approach [7,8] have been applied. In each case of the georeferencing, an image was resampled to a pixel resolution of 70cm.

Then, in order to enhance the spectral and spatial variations of different land use classes as well as to merge the images with different spatial resolutions, different image fusion techniques such as Brovey transform [11],

intensity–hue–saturation (IHS) transformation and principal component analysis (PCA) have been applied and compared. Detailed descriptions of these techniques are given in Richards (1993) and Mather (1999). 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 [2,9]. In the case of this study, the panchromatic image provides more spatial information due to its higher spatial resolution, while the multispectral image provides the information about the spectral variations of the urban classes. Image fusion can be performed at pixel, feature and decision levels [3,9]. In this study, the fusion has been performed at a pixel level. Before applying the fusion techniques, a 5x5 size high pass filtering [6,8,10] has been applied to the panchromatic image in order to enhance the edges.
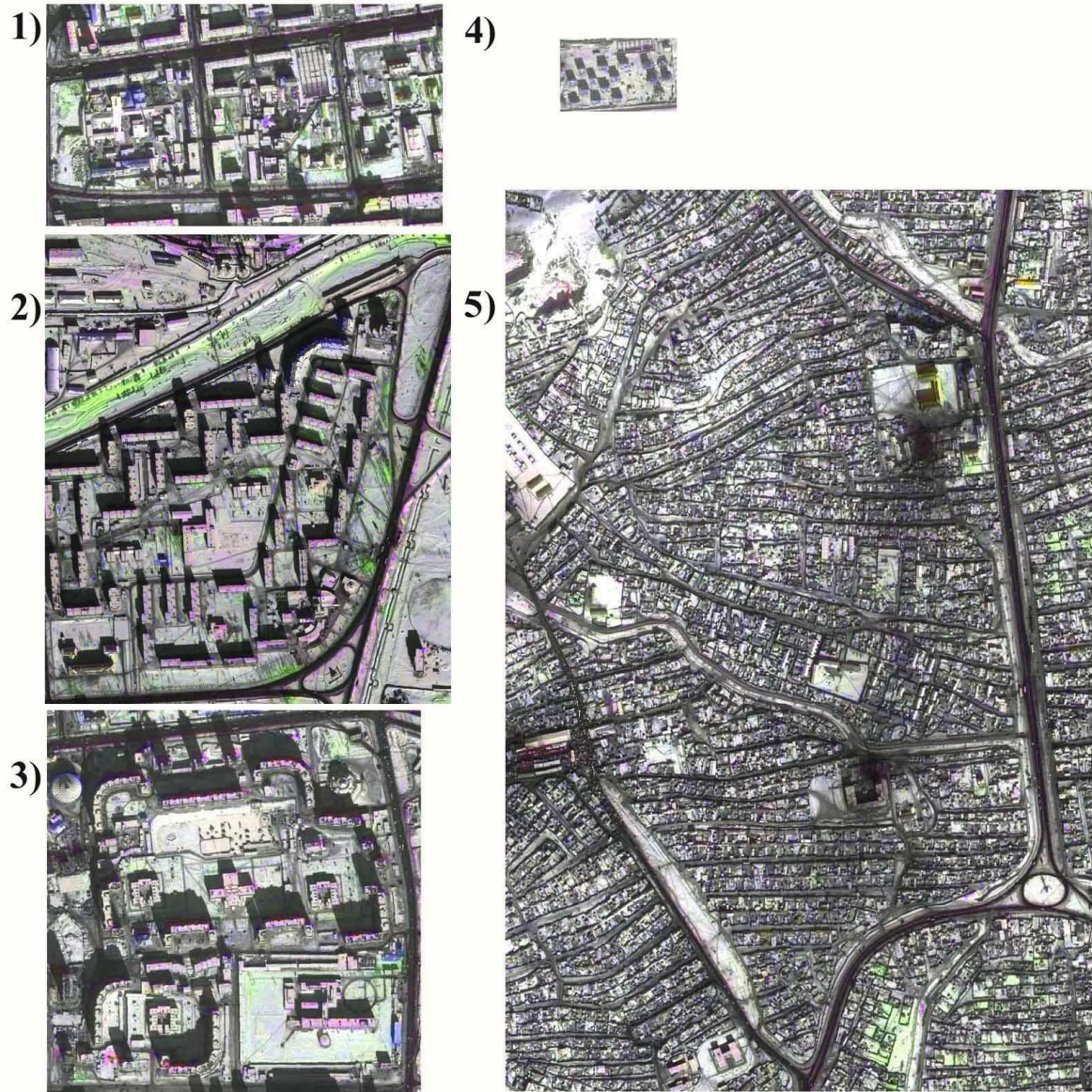

Figure 2. The images created by Brovey transform.
1-Low-rise apartment area, 2-Middle-rise apartment area, 3-High-rise apartment area,
4-Cottage house region, 5-Ger district.

After georeferencing, the images were merged using the above mentioned fusion methods. For the Brovey transform, the bands of SPOT 5 were considered as multispectral bands, while Quickbird image was considered as higher spatial resolution band. For the IHS transformation, the RGB image created by green and near infrared bands of the SPOT 5 data as well as panchromatic band of Quickbird data have been used and the panchromatic band was considered as the I. When the IHS image was transformed back to the RGB colour space, contrast stretching has been performed to the I channel. PCA has been performed using the available panchromatic and multispectral bands. As could be seen from the PCA, the first three PCs contained almost

99% of the total variance. The inspection of the last PC indicated that it contained noise from the total dataset. Therefore, it was excluded from the final analysis.

In order to obtain a reliable color image that can illustrate the spectral and spatial variations in the selected residential land use classes, different band combinations have been used and compared. Although, the images created by the Brovey transform contained some shadows that were present on the panchromatic image, they still illustrated good results in terms of separation of the available land use classes. The images created by the IHS and PCA methods contained less shadows, however, it was very difficult to analyze the final images, because they contained too much color variations of objects belonging to the same class. Therefore, for the interpretation of the selected land use types, the images created by the Brovey transform have been used. The Brovey transformed images of SPOT 5 and Quickbird are shown in Figure 2.

5. Investigation of land use in residential areas

Initially, from the Brovey transformed images, the selected residential land use types have been digitized using a vector module of the Erdas Imagine (Figure 3). Then, for each of the land use types the related analysis has been carried out.

Low-rise residential area in the 40,000 area

As seen from the result of the interpretation, in this region, low-rise residential apartments occupy 3,18 hectares (ha) or 43,7%, the offices and establishments occupy 1,95ha or 27%, trade and services facilities occupy 0,36ha or 5%, general educational school, creche and kindergarten occupy 0,21ha or 3%, printing industry occupies 0,2ha or 2,7%, roads and squares occupy 1,37ha or 18,8% of the entire land use. The coverage density in this region constitutes 41,6% and the average population density is 126 persons per ha. The land designated for offices and establishments, trade and services, production and manufacturing represent new types of the land use which occurred during the transition period. These new types of the land use in the course of their emerging had caused alteration to the primary apartment functions in the given region. In general, the commercialization process in this region has been increased and the trends leading to the deterioration of comfortable living conditions of the residents have been observed. For example, the ground floors of the apartment buildings have been transferred to the ownership of different services such as retail sales, saloons, cafeteria, bars, sauna and karaoke. Moreover, intentional alterations of the building and construction structures cause a negative influence on the comfortable living conditions of the residents in the apartment houses.

Middle-rise residential apartment quarter in the 120,000 area

As could be seen from the result of the interpretation, in this region, the middle-rise residential houses occupy 2,84ha or 30,3%, retail and commercial services occupy 0,42ha or 4,5%, hotels and restaurants occupy 0,39ha or 4,2%, general educational schools, crèches and kindergartens occupy 0,84ha or 8,9% of the land use and the coverage density constitutes 44,1%. The average population density is 143 persons per ha. In this region, 5-6 storey public residential buildings are dominant and from the initial planning the region was constructed with trade and services center, school, crèche and kindergarten complexes. However, during the transition period there had been increased hotels, restaurants, night clubs and entertainment places and other commercial services and they were mainly stationed on the green facilities, thus worsening the living conditions of the local residents.

High-rise residential apartment area in the XIII microdistrict

Actually this region was constructed in 1980s. It is still considered as a new microdistrict of the capital city and the prefabricated block residential houses with more than 9 storeys are dominant here. As seen from the result of the interpretation, in this region high-rise residential houses occupy 2,12ha or 36,5%, general educational school, crèches and kindergartens occupy 1,04ha or 17,9%, the tenure of cultural establishments occupies 0,28 ha or 5,2%, hospitals occupy 0,75ha or 13%, trade and services occupy 0,16 ha or 2.8%, offices occupy 0,28 hectares or 5,0% of the total land use. The building coverage density of this region is about 37% and average population density is 315 person per ha and the average radius of the neighborhood is 500 m.

The Ger district in the Khailaast area

As seen from the result of the interpretation, in this region ger area occupies 70,89ha or 96,5%, the general educational school, crèche and kindergarten occupy 1,11ha or 1,5%, the ownership of the office type establishments occupy 0,17ha or 0,2%, the trade and services organizations occupy 0,46ha or 0,6%, companies and bank owning lands occupy 0,59ha or 0,8%, low-rise apartments occupy 0,18ha or 0,2%, hospital ownership occupies 0,15ha or 0,19% of the entire land use. The average population density is 74 persons per ha and the average radius of the region is 1200m. The average area that occupies a ger household constitutes about 0,05ha.
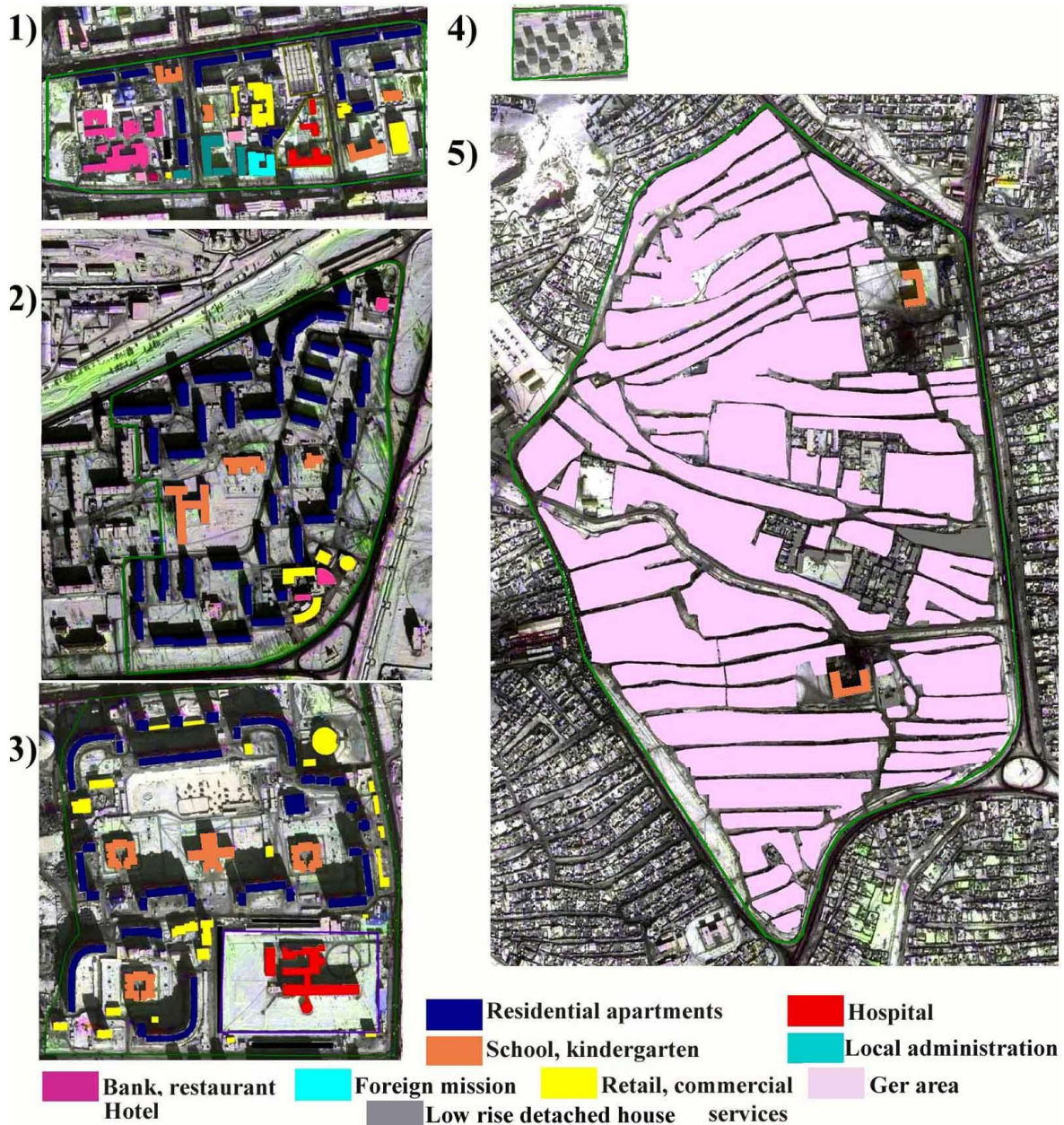

Figure 3. The land use types interpreted from the Brovey transformed images.
1-Low-rise apartment area, 2-Middle-rise apartment area, 3-High-rise apartment area,
4-Cottage house region, 5-Ger district.

Cottage house region

Since the transition period, different western cottage style single family houses with 2-3 storeys have been built in different parts of Ulaanbaatar city. The New Cottage area which contains such single family houses is one on them and is situated in the southern part of the capital city. The houses are privately owned and have modern design and designated for one family or for 2-3 households. As could be seen from the result of the

interpretation, the dominated land use in this region is a single family house and it constitutes about 2.1ha or 32% of the entire land use.

6. Conclusions

The aim of this study was to demonstrate the use of very high resolution RS images for a detailed residential urban study. For this purpose, low-rise apartment area, middle-rise apartment area, high-rise apartment area, cottage house region and ger district were selected in different locations of Ulaanbaatar city and for the analysis, SPOT 5 and Quickbird images were used.

In order to merge the two very high resolution images different image fusion techniques such as Brovey transform, IHS transformation and PCA were used. For the final analysis the results of the Brovey transform were selected, because the images created by this method illustrated good results in terms of separation of the available land use classes in comparison with the other techniques.

As seen from the analysis, since the country entered the market economy, hotels, restaurants, night clubs, entertainment places and other new types of land use became dominant in the low-rise, middle-rise and high-rise apartment areas and they have negative influence on the comfortable living conditions of the residents. Also, it is seen that the ger district has poor development while the people living in the Cottage house region have good living conditions.

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