URBAN DENSITY AND EXPANSION STUDY USING GIS AND RS METHODS

Gábor MEZÖSI - László MUCSI
University of Szeged, Dept. of Physical Geography, Hungary

ABSTRACT

Szeged, the fourth largest town in Hungary was destroyed in 1879 by the flooding of the Tisza river. In last 100 year new inner structure developed and the border of the town have grown with suburban region being developed and small villages merged with Szeged.

The inner and outer development were investigated by GIS and RS method. Different reference data (topographic maps, old photos and descriptions) and RS data (airphotos, SPOT XS and P images) were used for change detection.

With the help of these data system and methods the topographic maps were renovated and the researchers gave more detailed information for regional planning and decision making.

INTRODUCTION

Two historical events played a great part in the development of Szeged (Fig. 1), the fourth largest town in Hungary. In 1879 about 95 % of the buildings were destroyed by catastrophic flooding of the Tisza river. After the flood, and with the help of larger European cities (Brussels, Berlin, Moscow, etc.), a new structure for the city was planned and built. Avenues and boulevards can now be found in place of ancient streets and buildings.

After the First World War, the area of Hungary was reduced to one third its original size. Before the War, Szeged was relatively central in southern Hungary, approximately 150 km from the southern border. At present the border lies less than 15 km from the town.

The changing inner and outer conditions were investigated utilising GIS methods. With the help of the first maps taken after the flood, the changes in the structure of the town were analyzed, and the direction of the expansion in the last 100 years was determined. One very interesting task was to compare the development of the town, which was based on natural conditions (geomorphology, river, agricultural lands, etc.), before the flood with the past-war development, which was determined by economic and political decisions (socialist planned economy). The most important factors of the past-flood development were the creation of a new road system in a 4 - 6 m higher position, river regulation (Tisza and Maros rivers) and destroying of the main geomorphological forms etc. These effects changed the hydrogeological conditions of the town and created new engineering geological conditions. The industrial and economical importance of the town changed in the country and as a result of inner town development functionally different districts inside the town can be distinguished. The border of the town have grown with suburban regions being developed and small villages merged with Szeged. The inner city preserved its civil aspects, while "modern" blocks of flats were built in the outer residential area.

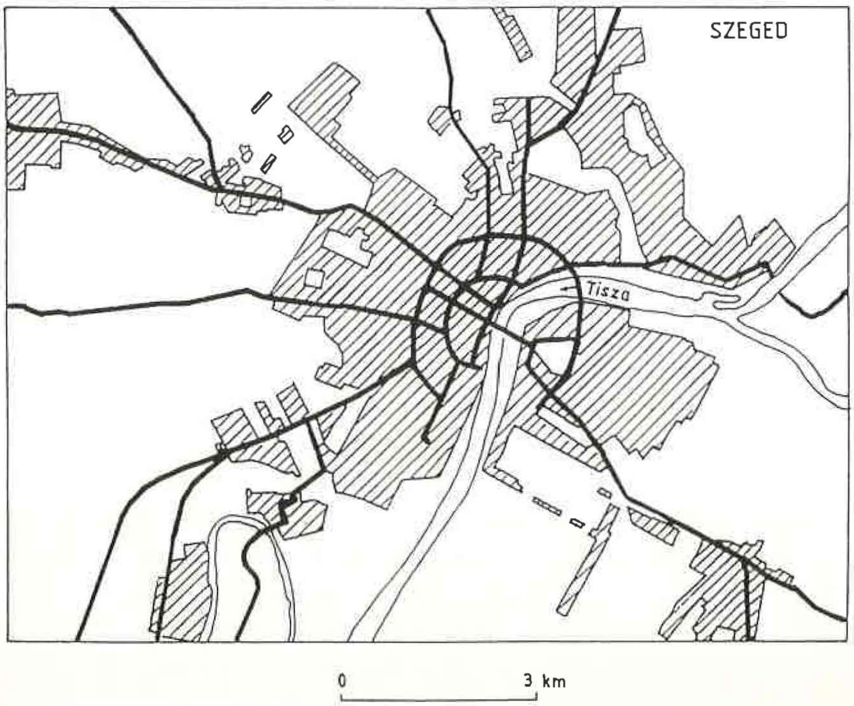

Figure 1 Urban region of Szeged and main highways

SPOT P and XS images was also applied together with airphotos beside topographic maps (1:10.000 and 1:25.000 scale). Vector and raster based GIS were developed on an Intergraph system at the University of Szeged and University of Liege, Laboratory SURFACES. The new direction in the development of Szeged was investigated with the help of gravitational models.

DATA SOURCES

Different data systems were used during the classification and urban fringe monitoring. (Table 1.)

type	date	scale	projection/band
Topographic map	1965 1988	1:10000 1:10000	stereographic projection EOTR*
Airphoto	1972 1981 1992	1:10000 1:10000 1:10000	black&white VIS black&white VIS colour IR
Digital image	29.08.1988 28.06.1990		SPOT XS 1,2,3 bands SPOT P band

* EOTR=Unified National Mapping System

Table 1 Characteristics of data used

RESULTS

The aim of this study was to detect changes in land use from agricultural land to a construction site or housing development.

Structure and development of town Szeged (South Hungary) have been studied to investigate the possibility of remote sensed data for urban monitoring and change detection. This city and its rural surroundings were chosen because we could investigate areas where urban development has been relatively rapid over the last 20-30 years. Applications forming part of this research include urban fringe (an area under constant pressure for change) monitoring, discrimination of urban classes, prediction of residential housing density, estimation of urban quality measures, and population density.

The topographic maps (1965, 1988) were digitized and developed on an Intergraph (Microstation) system at the University of Szeged and University of Liege, Laboratory SURFACES. Vector and Raster GIS were developed on Intergraph and Idrisi to compare the differences between these systems.

Airphotos were scannered and used as a raster base system. The original photos were magnified to the scale 1:10.000 in the photo laboratory of FOMI. The above mentioned topographic maps (image to map) and SPOT panchromatic image (image to image) were utilised for the geometric correction of airphotos. These photos were acquired on 1972, 1981 and 1992.
SPOT XS (1988, 3 bands) and P band (1990) were applied (together with airphotos) for supervised and unsupervised classification and for the investigation of urban change detection. Base problem was that the SPOT images were not acquired on the same time, therefore we were not able to utilize the special XS+P image and different colour composition of XS and P bands (3P1, 32P etc.). We had to apply XS 321 (RGB) colour composition with 20 m resolution and P band independently. Housing density represents a useful input to urban land information systems, and inter-census population change studies, but is not directly observable from spaceborn sensor systems because of their resolution. Even with SPOT's 10 meter resolution P mode data, this is still the case because the average low density housing is about the same size as the pixel, and cannot be positively discriminated without an IFOV nearer to 5 meters. Nevertheless the 10 and 20 m resolution of SPOT offers the potential of using textural variables for housing density studies (Forster 1987). The P band image was used for the geometric correction of XS 321 image and for the identification of different buildings and structures.

Our own principal task was to (1) the detection of changes in the structure and development of the town from the publishing of the latest, most detailed topographic map (published in 1988 but drawn in 1983). With the help of airphotos and digital images (2) we tried to complete and refresh the topographic maps on the scale 1:25000. Beside these aims, we tried to classify the urban, rural and agricultural areas. The range of the investigated area was 16*11 km.

DISCRIMINATION OF HIGHWAYS AND ESTATES

Although the inner structure of the town is clearly arranged, especially on the XS 3 band (infrared 0.79-0.89 μm) because of the different temperature of main streets, buildings and green surfaces and P band (0.51-0.73 μm), the classification is not so easy. On the 20 m resolution XS bands the greater buildings (Opera, Theatre, Stadion, large work-shops, block of flats) can be discriminated, but their form and range cannot. On P band image we have better view from these features, but due to the temporal differences between the XS and P bands, we had to utilize this P band independently. On XS 321 (RGB) colour composite, boulevards and avenues are clearly discriminated visually. The classification of the highways is difficult. These roads are the most popular and good-lying regions from traffic and geographical potential point of view, therefore housing estates and high building can be found along the wider streets. The SPOT 2 HVR XS and P images were acquired at 09 hour 43 minute, consequently long shadow of buildings can be detected due to the low angle of incidence of solar radiation. The effect of this phenomenon is extraordinarily strong along streets of N-S direction. According to the colour composite the classification of the Grand and Outer Boulevards, the Kossuth and Calvaria Avenues is not so difficult (20-30 m width asphalt and concrete pavements). Although, also in this case the shadow effect of higher tower buildings and row houses can disturb the classification, especially along the Outer Boulevard (Fig. 2). These new, ten-storied houses were built in the last two decades. Consequently the main roads can be classified by (1) pixel by pixel method on the XS 321 colour composite, or (2) on the XS 3 black and white image. In the first case more than 20 classes were used with very low standard deviation. Among the older buildings (Tarjan housing estate, Fig. 2) the vegetation have grown stronger which is favourable for living condition, but their shadow increase the standard deviation of pixel values meaning boulevards and avenues. The pixel value of greater green surfaces among the new block of flats are very similar to the pixel values of meadows and pastures on the surrounding agricultural region, therefore a special mask was utilized for

Figure 2a Topographic map (1:10000 scale) of Szeged from 1965

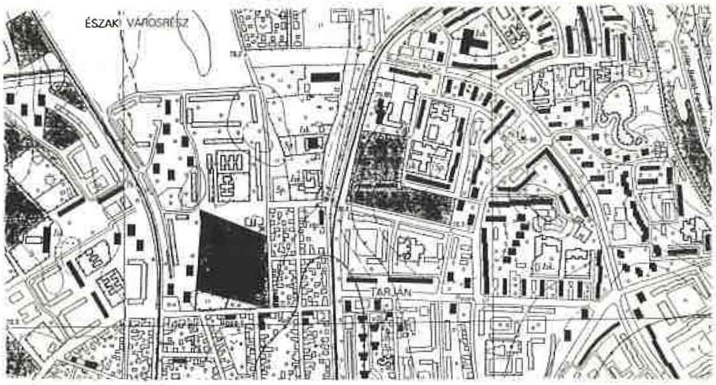

Figure 2b Topographic map (1:10000 scale) of Szeged from 1983

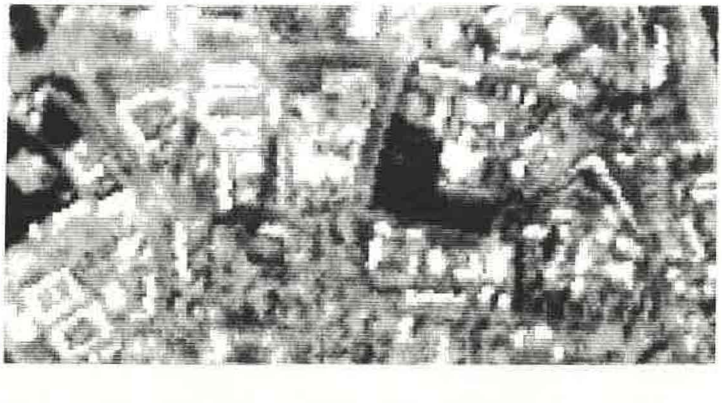

Figure 2c SPOT P scene of Szeged from june 1990

delineation of the urban area from the agricultural land. The shadow effect not only disturbs the classification but also gives a good application for the high building discrimination. Airphotos and SPOT P scene were investigated for the measurement of shadow of different building. Statistically can be proved the simple rule which states that a higher building has longer shadow than a lower house has. On raster base GIS this rule can be expressed that there is greater distance between the centre of a pixel meaning a house and pixel meaning the end of the shadow. This measurement were used for the discrimination of the building of a new estate, which can not be found on the newest topographic maps. This method can be applied for the 5-10 years old settlements, because the gardening is frequently delayed or finally not happen after the finishing of construction.

But the following hypothesis (Froster 1987) is not exactly true: "Low density areas would normally have higher vegetation content than high density areas". It is true only for down town or CBD (Central Business District), in the case of Szeged for the central area delineated by middle or Grand Boulevard.

MONITORING OF OTHER URBAN AND RURAL ENCROACHMENT

Different types of urban land use changes can be detected on the investigated area.

(1) During the last 25 years the most important process was the building up of the open space areas in the inner city. Not only the real open space areas were used but also the old, uncomfortable houses were destroyed especially on the outer ring between the Grand and Outer Boulevards. On Fig. 3a-3b there is an old district near to the Stadion (before 1965), on Fig. 3c this area is already destroyed (1983) and a new estate region can be seen on this area on the SPOT P image (1990. Fig. 3d).

(2) Areal and structural changes can be discriminated on those districts which can be characterized as a rural area inside the town. These types of houses located on the southern part of the town between the Grand and Outer Boulevards (Mora town). The changes can be investigated only on airphotos. On SPOT P image the areal changes were measured, but the inner structure development can not be detected due to the 10 m

Figure 3a 1:10000 scale topographic map 1965 (upper left figure)
3b 1:10000 scale topographic map 1988 (upper right figure)
3c Airphoto from 1972 visible light black and white (lower left)
3d SPOT P (0.51-0.73 μm) image from 1990 black and white (lower right)

resolution. On this region the former network of streets did not change, but new blocks of apartments with 6-8 families replace the old buildings. Similar development occurs outside the circle bank (Petofitelep, Hattyastelep).

(3) On the inner part of the town, which is the oldest part of the town, due to the protection of the ancient-historic buildings, insignificant changes can be detected. During the renovation the material of roofs are being change, consequently also the characteristics of the remote sensed data change. On SPOT P scene the greater blocks can be discriminated, but due to the narrow (width=7-9 m) streets between the blocks, the delineation is not so easy.

SUMMARY

With the help of remote sensed data (airphotos and SPOT XS,P images) in GIS different urban, suburban and rural changes can be investigated. The airphotos were utilised for the detection of structural changes especially on rural regions and XS, P images were used for areal measurement and topographic map correction (1:25000 scale).

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