The role of GIS and Very High Resolution Image Data as Planning Support Tools – Case Study of Belgrade

Christian HOFFMANN, Klaus STEINNOCHER, Marjo KASANKO, Radmila GRUBIŠIC

Dr. Christian Hoffmann, GeoVille Information Systems GmbH, Museumstr. 11, 6020 Innsbruck, Austria, hoffmann@geoville.com
Dr. Klaus Steinnocher, ARC Seibersdorf research, Systems Research Division, Environmental Planning Dept., 2444 Seibersdorf, Austria, klaus.steinnocher@arcs.ac.at klaus.steinnocher@arcs.ac.at
Ph.Lic. Marjo Kasanko, European Commission - DG Joint Research Centre, Institute for Environment and Sustainability, Unit: Landuse – Land Cover, 21020 Ispra, Italy, marjo.kasanko@jrc.it
Ms. Radmila Grubisic, Town Planning Institute of the City of Belgrade, Palmoticeva 30, Belgrade, Yugoslavia, Urbel1@Eunet.yu

1. INTRODUCTION

In September 1999 the IKONOS satellite was successfully launched providing the highest resolution images currently available for public use. The satellite's sensor can generate one-metre panchromatic and four-metre multispectral images with off-nadir viewing of up to 60º in any azimuth for a better revisit rate and stereo capabilities. The high-resolution imagery provided by IKONOS offers a wide range of applications for city planners.

This paper describes the generation of land cover/land use databases for the city of Belgrade in the framework of the MOLAND program of the European Commission. Visual interpretation of image data was used to derive the databases, a technique already applied successfully for the analysis of urban development of different cities (Petrini-Monteferri et al. 2001). Among the image data sets the newly available IKONOS images are of particular interest as they offer an excellent basis for image interpretation of urban areas (Hoffmann et al. 2001).

2. CASE STUDY OF BELGRADE

2.1 The City of Belgrade

Belgrade is located on the tangent line of Central Europe and the Balkans, actually half-way between West and Southeast Europe at the merger of the Save and Danube rivers (N44º 48', E20º 28') (http://www.beograd.org.yu/geography/index.html). It is the capital of the Federal Republic of Yugoslavia and its largest city. Belgrade's microregion comprises portions of the Srem, Banat and Sumadija regions, and consists of 16 city communities (Perovic & Zegarac 2000)

Both the Danube, which separates the city from Vojvodina, and the Save River, which flows along the city and separates the old city from the New Belgrade development of the Tito times, are essential elements of the city landscape and organization (http://copernico.dm.unipi.it/~milani/belgrado/node12.html).

After World War I Belgrade became the capital of newly founded Yugoslavia, and it remained the capital also after World War II during which it was occupied by the Germans. The city was devastated during repeated air raids by the Germans, as well as by the Allies. After 1945, it was once more rebuilt, before emerging today as an important multinational and multifunctional metropolis. In spring 1999, the fifth bombing of the century took place with a number of destruction on infrastructure and on public and private buildings.

The area of investigation in the present study comprised the built-up area of Belgrade plus a peri-urban buffer zone. Sub-urbanization zones (e.g. Pancevo, Batajnica etc.), which were heavily bombed during the NATO air strikes, are also included in the area of interest. The extended total area of investigation amounted to approximately 900 sqkm (Figure 1).

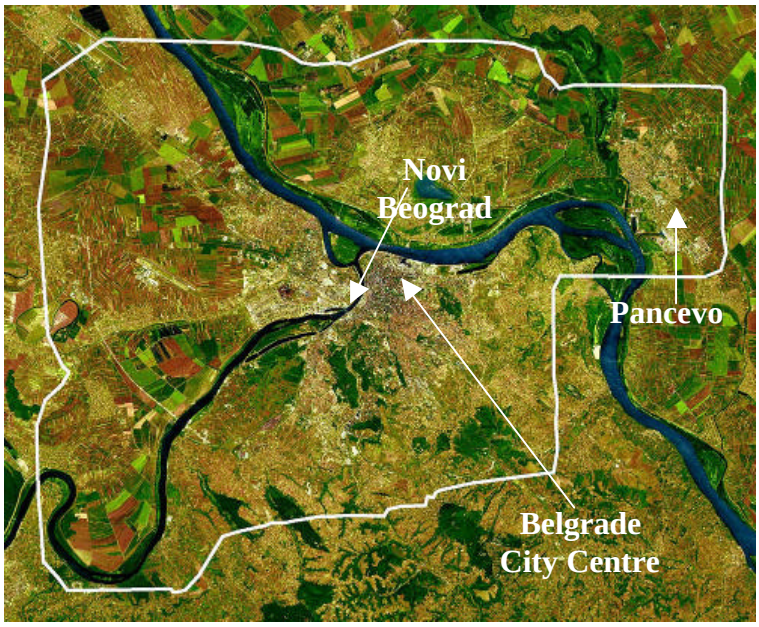

Fig. 1: Area of investigation – Belgrade and surroundings superimposed to the IRS image.

2.2 Activities in the frame of the MOLAND project

MOLAND (Monitoring Land cover/use Dynamics) is a research project carried out by the Institute for Environment and Sustainability of the Joint Research Centre of the European Commission. The aim of the project is to provide a spatial planning tool that can be used for assessing, monitoring and modelling urban and regional development. MOLAND allows quantitative and qualitative comparisons at European level between areas subject to changes due to policy interventions. The MOLAND methodology simultaneously addresses the European Union (EU) perspective on the one hand, and the regional/local dimension on the other. To date, the MOLAND methodology has been applied to an extensive network of cities and regions, for an approximate total coverage in Europe of 50,000 sq. km (http://moland.jrc.it). Belgrade was choosen as a site due to the destructions caused in the most recent war and the status of the FRY as one of the potential Accession Countries to the EC.

The main activities of the project comprised the creation of detailed GIS databases representing land use and transport networks for the City of Belgrade at four points of time (1967, 1987, 1997, 2000). Visual interpretation of IKONOS satellite images lead to the so called reference land use database for the year 2000. The "historical" databases were derived from IRS images (5.8m resolution), Russian KFA-1000 images (7m resolution) and American CORONA images (3m resolution) acquired 1997, 1987 and 1969 respectively (see Table 1).

Sensor	Platform	Channels	Spatial resolution	Launch
Carterra	IKONOS2	PAN	1m	Sep 1999
PAN	IRS-1C	PAN	5.8m	Dec 1995
LISS-III	IRS-1C	VIS	23.5m	Dec 1995
KFA-1000 Photocamera	Resurse F1M Priroda-5	PAN & VIS	6 – 8m	recurrent since 1979
KH-4A Photocamera	CORONA	Black & White	2.75m (best)	recurrent between 1963 and 1969

Table 1: Overview on the image data used

Before image interpretation could take place the image data had to be geometrically rectified in order to allow comparison of the four different acquisition dates. Root mean square (RMS) errors on the average of 2.8(X) and 3.2 (Y) meter were achieved for the four IKONOS-scenes (see Table 2) and validated against 1:10.000 Serbian and Russian maps.

Scene	**RMS**		**Maximum Residual**	
	X	**Y**	**X**	**Y**
Western	4.8	4.4	7.7	4.2
Centre	2.6	3.8	3.6	5.6
Eastern	2.1	2.3	3.1	2.5
Panchevo	1.8	2.4	2.5	3.0

Table 2: Comparison of IKONOS to 1:10.000 map data

Visual photo interpretation was used for development of the land use data bases. The minimum mapping unit for land use polygons was one hectare for artificial surfaces, and three hectares for non-artificial surfaces. In addition to the polygon databases rivers, canals, road and rail networks were digitized as linear features and stored in a vector database. An extended CORINE land cover nomenclature modified for the purposes of MOLAND was used for attributing the vector and polygon layers (http://etc.satellus.se/the_data/index.htm). The resulting databases represent land use in scale 1:25.000 in an ArcInfo compatible format. Independent validation of each data set guaranteed for a high quality of the land use products.

The reference database for the year 2000 was derived from visual interpretation of the IKONOS imagery. In addition to the polygon and vector databases bombed areas were digitised in a separate layer. The historical databases were derived from visual interpretation of the 1997, 1987 and 1969 image databases. The downdating of the databases started with 1997, continued with 1969 and finally the database for the year 1987 was generated. This approach ensured the preparation of a homogenous database allowing for continuos comparison with respect to the two best image resolutions (i.e. CORONA, IKONOS). For this the CORONA-image information was compared with the polygons of the data set for 1997 and a stepwise downdating of the IRS-derived database to the 1969 situation took place. Subsequently an intersection of the final polygon-data sets of 1997 and 1969 served as a basis for generating the polygons of the data set of 1987.

Reference and historical databases were supplemented with ancillary data such as demographic, socio-economic, transport or environmental (pollution etc.) data.

2.3 Collaboration with the Town Planning Institute of Belgrade

In the frame of the project a collaboration with the Town Planning Institute of the city of Belgrade has been established. The main activitiy of the Institute is the production and implementation of urban development plans, including general plans for the territory of Belgrade and plans for regulation of particular parts of the city's territory (mostly reconstruction of already built areas, restoration and legalization, specific-purpose plans, development plans for traffic and public utility infrastructure etc.) Further the Institute defines urban-planning and technical conditions for the construction of individual buildings and carries out expert studies as well as urban development analyses (http://www.beograd.org.yu/english/grad/predustan/ostala/urbanist/). The institute is also responsible for the creation of the new Master Plan of Belgrade. A draft Plan is scheduled for April 2002, based - among other data sets - on the rectified IKONOS imagery and the reference database established during the presented project.

3. PROJECT RESULTS

The final products of the project were four harmonised databases, representing the land use of the metropolitan area of Belgrade at four points of time. Figure 2 shows the IKONOS image and the corresponding reference database of the City Centre of Belgrade. Figure 3 gives an overview of all four databases.

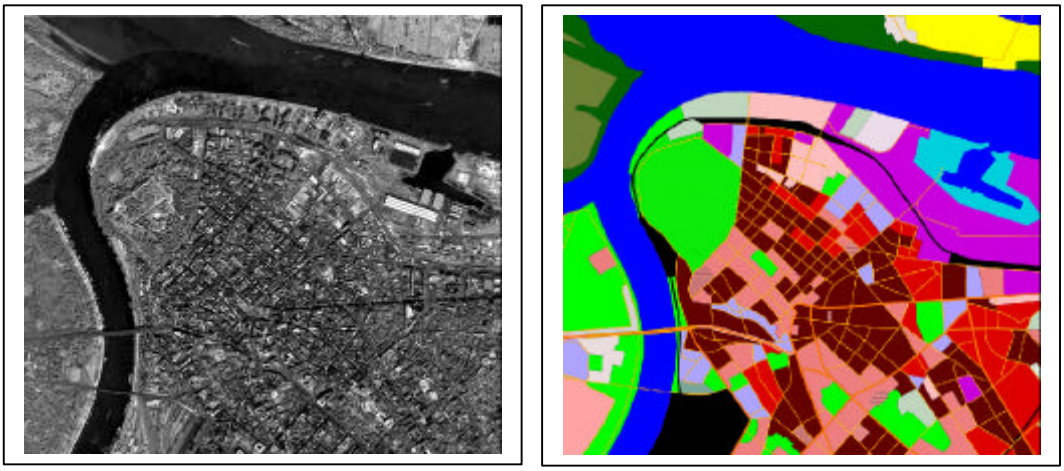

Fig. 2: IKONOS-image of the City Centre of Belgrade and the derived land use interpretaion

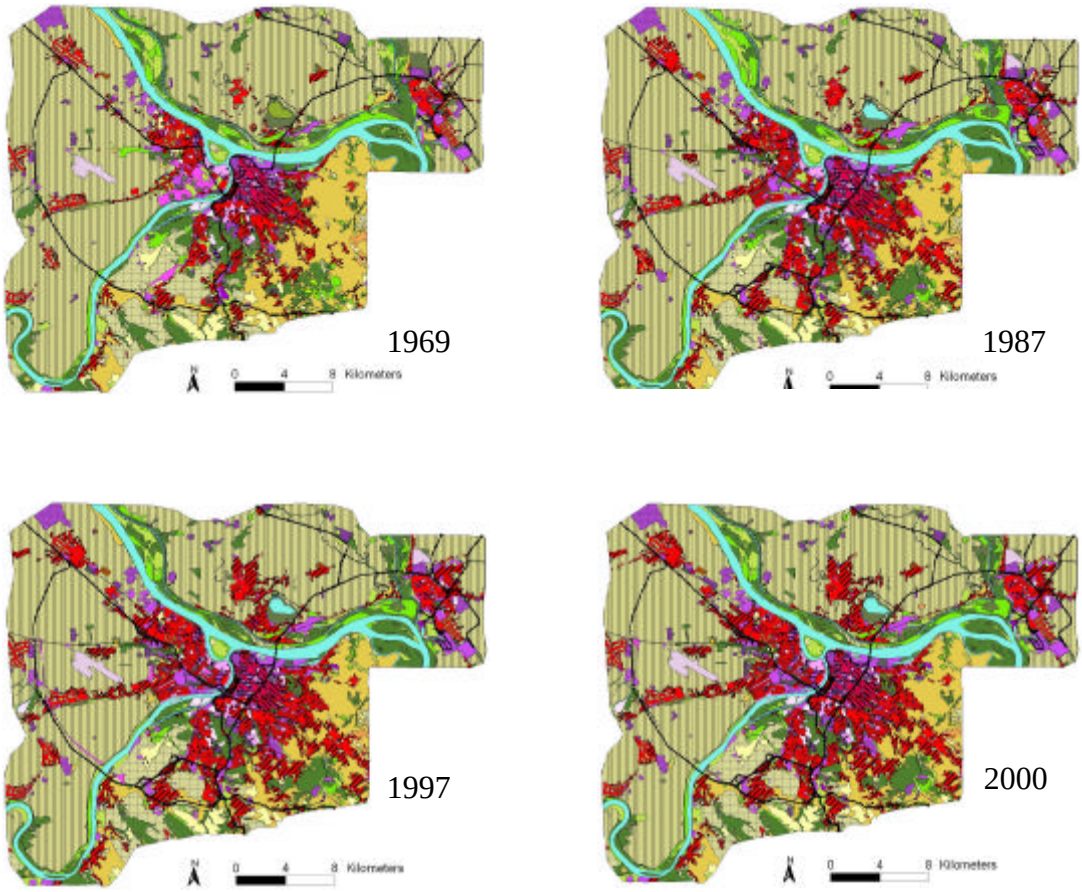

Figure 3: GIS vector and polygon datasets for the City of Belgrade (1969 – 2000)

Based on the reference and historic databases statistics of land use and land use changes were computed. Table 3 shows the increase and decrease of aggregated land use classes for the four investigated years.

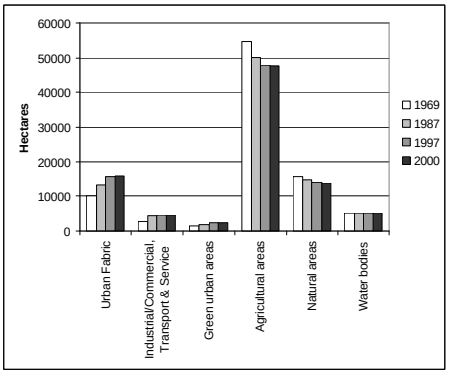

Table 3: Graph of land use changes in the area of investigation

It can be clearly seen that the increase of built-up areas happend at the expense of agricultural areas. An ongoing expansion of residential areas from the core urban area to the suburban regions was also recognised. Major construction activities were noticed in the south-eastern part of the area of investigation.

The derived land use information is currently being used by the Town Planning Institute of the City of Belgrade as one input for the devolopment of the new Master Plan but also for issues such as the regulation of about 100.000 illegally constructed dwelling units (Figure 4).

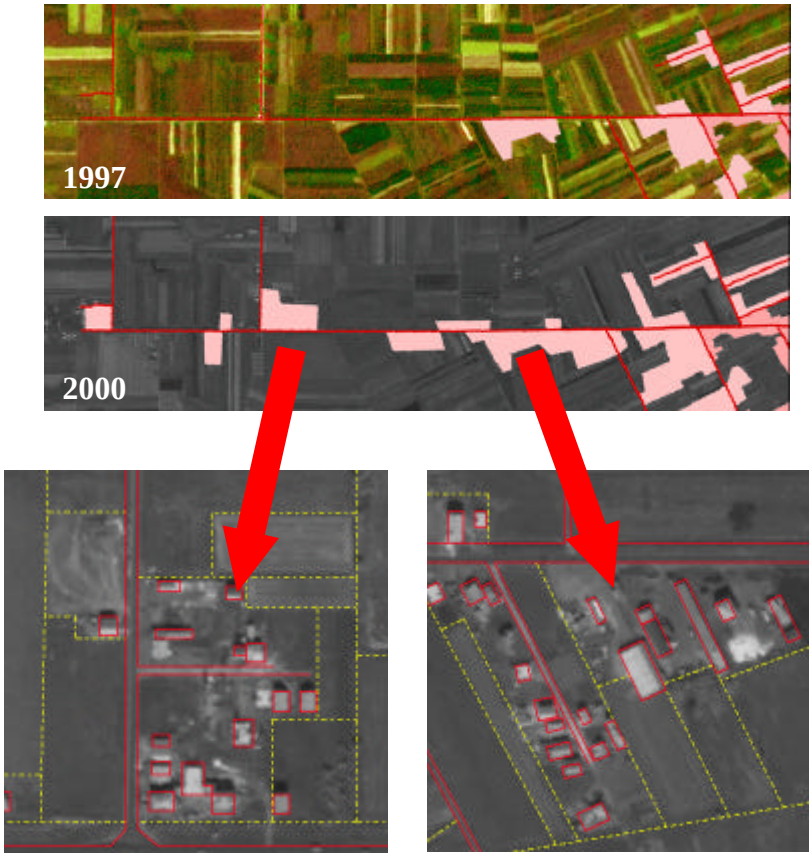

Fig. 4: Illegal constructed dwelling units

In combination with socio-economic data sets of the metropolitan the results will further be used by the Joint Research Centre of the European Commission to identify urban and environmental indicators that will help in providing a synthetic assessment of urban and peri-urban landscapes. The development of scenarios of growth for urban and peri-urban areas is another application based on the combination of EO and non-spatial data. These scenarios can subsequently serve as major input to formulate and evaluate long term strategy for sustainable urban development.

REFERENCES

http://www.beograd.org.yu/geography/index.html : City Government
http://www.beograd.org.yu/english/grad/predustan/ostala/urbanist/ : Town Planning Institute of the City of Belgrade
http://copernico.dm.unipi.it/~milani/belgrado/node12.html : Danube and Sava
http://moland.jrc.it : JRC, SAI, SSSA: Towards Sustainable Urban and Regional Development
http://etc.satellus.se/the_data/index.htm : CORINE Land Cover information
Hoffmann, C.; Steinnocher, K.; Kasanko, M.; Toutin, T.; Cheng, P. (2001): Urban Mapping with High Resolution Satellite Imagery. In: GeoInformatics Magazine, Volume 4, December 2001, pp 34-37.
Perovic, M.R.; Zegarac, Z. (2000) The Destruction of an Architectural Culture: The 1999 Bombing of Belgrade. Cities, Vol. 17, No. 6, pp. 395-408
Petrini-Monteferri, F.; Steinnocher, K.; Gangkofner, U.; Wasserrab, F. (2001): Mapping the development of urban areas from space – case studies of Vienna, Belgrade and Shanghai. In (Jürgens C. Edt.) Remote Sensing of Urban Areas, Issue 35, Regensburg ISBN 3-88246-222-1, pp 241-245, June 22-23