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Topic (iv): Spatial analysis in a statistical context and disclosure control procedures

**ESTIMATED LAND COVER CHANGE IN THE COMPILED STATISTICAL
LAND COVER/LAND USE GIS OF SLOVENIA: June 1993-June 1997**

Submitted by the Statistical Office of the Republic of Slovenia ¹

Contributed paper

I. INTRODUCTION

1. The data layers of built-up areas and the Statistical Land Cover/Land Use GIS-state '93 of Slovenia were used to estimate the size, location and previous land cover of augmented built-up areas in Slovenia during the period from June 1993 to June 1997. The Statistical Land Cover/Land Use GIS was compiled at the Statistical Office of Republic of Slovenia (SO) using several existing georeferenced data layers. The georeferenced Landsat-TM/93 satellite scanned the data present in the thematic layer. This layer was visually interpreted with the minimum mapping unit of 20 hectares. The augmented built-up areas were obtained from two data layers containing centroids of houses: June 1993 and June 1997. They were buffered and merged, the common areas were eliminated and the remaining areas were overlaid onto the compiled Statistical Land Cover/Land Use GIS of Slovenia-state '93. Thus the land cover categories transformed into built-up areas were determined.

2. It is important to stress that the simultaneous use of land cover and built-up data layers enables a quick and simple (i.e. visual) identification of the location and extent of these kinds of land cover changes. In addition, they can also be used as a correction tool for the producers of these data layers, since certain illogical locations of centroids of houses can be visually detected immediately.

3. Our goal is to analyse the same change for the period from 1997 to 2001, using the Statistical Land Cover/Land Use GIS of Slovenia-state '97 with the minimum mapping unit of 15 hectares with the augmented built-up areas data layer. This, in addition to the centroids of houses, will also include built-up areas of larger industrial objects, warehouses, parking places, etc., as well as the railways and the first three levels of roads.

Key words: GIS, land cover, land use, geocoded data layers, satellite scanned data, centroids of houses, land cover change, quality assessment.

¹ Prepared by E.H. Lojovica, D. Šabica and A. Tretjak.

II. COMPILATION OF THE STATISTICAL LAND COVER/LAND USE GIS OF SLOVENIA

4. In 1997 the first Statistical Land Cover/Land Use GIS of Slovenia-state'93 was compiled merging a number of georeferenced data layers, all from 1993 and covering the whole of Slovenia (2,027,245 ha):

- Landsat-TM satellite scanned data,
- digitised administrative boundaries,
- digitised boundaries of wooded areas,
- digitised boundaries of water bodies,
- digital elevation model: 100 m by 100 m (DEM-100),
- centroids of houses,
- vectors of railways,
- vectors of first level roads.

5. These data were used for the delineation of the five main land cover/land use categories:

- Wooded land cover,
- Agricultural land use,
- Areas under water,
- Bare rocks, i.e. non-vegetated land cover,
- Man-made land use, i.e. houses, roads, railways.

6. The basic data source for the compilation of the Statistical Land Cover/Land use GIS was the georeferenced mosaic of Slovenia, derived from the satellite scanned data with the acquisition date 1993 with a pixel size of 30 m x 30 m. The georeferencing error of the mosaic does not exceed 30 m on the flat areas. These data were used as the base map onto which the rest of the data layers were overlaid (Burrough and McDonnell 19998).

7. Digitised boundaries of wooded area obtained from the Department of Physical Planning of the Ministry of Environment and Physical Planning were used in its draft version for the delineation of this land cover category. The data originated in the 1980s and were delineated from airphotos on a scale of 1:10 000 or 1:17 500. This land cover category comprises forest areas and recreational areas under forest within the larger urban areas.

8. The agriculture category includes all agriculture land use and recreational areas under grass within the larger urban areas. Digitised boundaries of rivers, natural lakes and other water bodies were obtained in a working version from the Hydrometeorology Office. The vectorised data were scanned from topographic maps on a scale of 1:25 000.

9. Using DEM-100 pixels over a defined altitude, reflecting spectral signatures characteristic for open or scarcely vegetated areas with shrubs were classified in the category of bare rocks. In addition, the category "undefined areas" was introduced, comprising 0.01% of the classified territory.

10. The three elements of the 5th land cover category, i.e. houses, roads and railways, were obtained from three separate data layers. The first data layer was acquired from buffered centroids of houses, the procedure of which is described in the next chapter. The central lines of roads' and railways' data layers were buffered according to the official width of corridors of roads and railways respectively. These buffered data layers were merged; crossings and overlapping areas were cleaned and used as one data layer presenting the "man-made" land use category (Šabiæ 1998; Lojoviæ 1999).

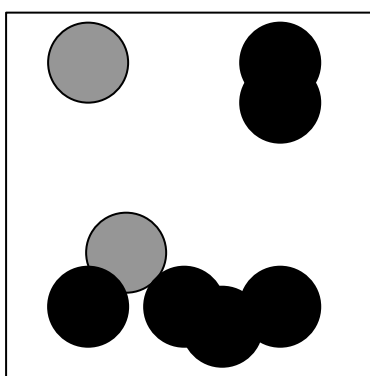
III. ESTIMATION OF AUGMENTED BUILT-UP AREAS

11. In the Register of Territorial Units the records of only those houses that have house numbers are collected. The houses are defined with geographic co-ordinates as: "a unique identification of every residential or commercial building". The geographic coordinates indicate the centre of each house and

are named centroids. The centroids are points which do not bear information on the use of the building or on its area. In order to estimate the area under every building, including the average area of the pertaining yard or garden, the centroids were buffered with a radius of 20 m (Peled 1993). The selection of a 20 m radius was based on a statistical analysis of sampled individual buildings all over Slovenia, and the areas of yards, gardens and auxiliary buildings were measured on airphotos on a scale of 1: 5 000. The average size of the area pertaining to these individual buildings was 0.125 ha. In densely built-up areas these buffers merged into bigger polygons. The contours of individual buffers dissolved in this process and uniform areas of these polygons were taken into account for further elaboration (Fig. 1).

12. The centroids of houses from June 1993 were buffered and the same procedure was repeated with the centroids of houses from June 1997. The built-up areas for these two years were obtained separately. Overlaying the layers with buffered centroids, the locations of demolished houses were identified. Next, the buffers that were common for both layers were removed. What remains represents the augmented built-up areas in Slovenia in the period from June 1993 to June 1997.

13. The calculation of the augmented built-up areas by first subtracting centroids and buffering those which remain would be a much faster method but would not enable the merging of adjacent buffers, thus leading to an overestimation of the augmented built-up areas. In our case the calculated augmentation of built-up area would be greater by 41.5%.



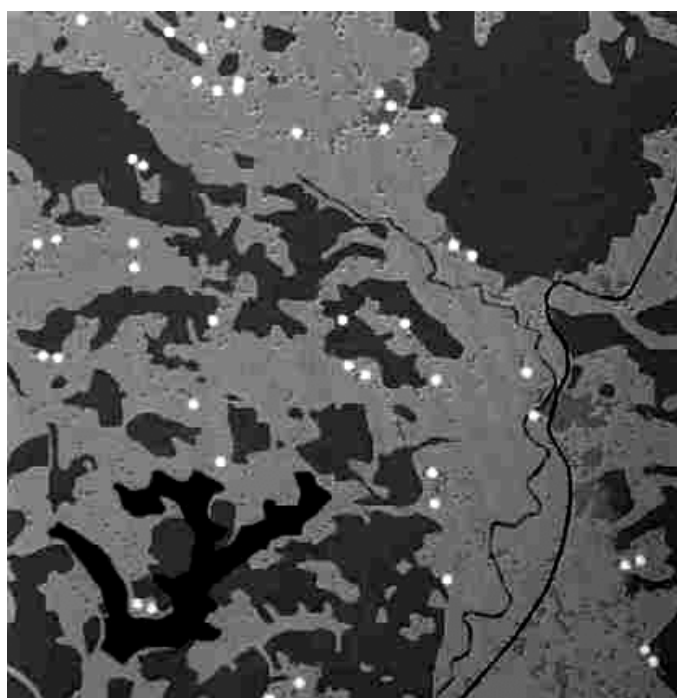
black buffered centroids: **state '93**

gray buffered centroids: **new built-up from '93 to '97**

Figure 1: Schematic presentation of buffered centroids.

IV. ESTIMATION OF LAND COVER CHANGES DUE TO AUGMENTED BUILT-UP AREAS

14. The data layer of augmented built-up areas was overlaid onto the compiled Statistical Land Cover/Land Use GIS of Slovenia-state '93. The areas of wooded and agricultural land cover categories that turned into built-up areas have been determined (Fig. 2). When the new built-up areas were detected within existing built-up areas, they were not considered as land cover/use changes since these buffers did not change the cover/use categories. The buffered centroids that were located with more than 50% of their areas over water, railways or roads were considered as mistakes and removed from the data-layer.



LEGEND:

- dark gray: **forest**
- light gray: **agriculture**
- black: **water and roads**
- medium gray: **built-up**
- highlighted: **augmented built-up**

Figure 2: Cutout from the Statistical Land Cover/Land Use GI highlighted new built-up areas in part of eastern Savinja valley; UL: X = 5510000; Y = 5131000.

15. In the final stage the layer of augmented built-up areas was merged with the layer of administrative boundaries and thus the augmented built-up areas for each statistical region and for the whole of Slovenia were obtained (Tab.1).

16. In Slovenia during the period from June 1993 to June 1997 most augmented built-up areas expanded with the addition of agricultural areas (Fig.3). The statistical regions number 6 and 9 have the highest change of transformation of agricultural to built-up land cover. But it is the graphical presentation of this data that gives us the essential information, i.e. the geographical distribution of the phenomena. As expected, the built-up areas increased mostly around urban centres. However, one exception is the area of Savinja valley where the augmented built-up areas are nearly evenly distributed over the whole valley, which is declared as first quality agriculture land (Fig.4). The geographic distribution of the augmented built-up areas, using a relatively simple and time efficient method, results in new qualitative information which would never have been revealed if these data had been presented only in the classical tabulated form.

Table 1: Land cover change due to augmented built-up areas by statistical regions of Slovenia, June '93 - June '97

Statistical regions	Total area ¹ ha	Agriculture land ² ha	AUGMENTED BUILT-UP AREAS			Share of new built-up areas	
			Total ha	on account of		of total area %	of agriculture %
				Wooded ha	Agriculture ha		
1	133 764	89 874	55.29	0.39	54.9	0.04	0.06
2	216 964	120 159	147.68	2	145.68	0.07	0.12
3	104 060	27 957	21.86	1.6	20.26	0.02	0.08
4	238 417	94 823	124.28	5.15	119.13	0.05	0.13
5	26 354	8 671	20.2	1.6	18.6	0.08	0.23
6	88 503	61 274	66.21	2.33	63.88	0.04	0.11
8	354 609	116 185	244.77	15.52	29.27	0.07	0.21
9	213 655	49 710	62.21	4.85	57.36	0.03	0.13
10	145 632	46 137	21.17	1.3	19.87	0.01	0.05
11	232 472	64 507	58.39	4.22	54.17	0.02	0.09
12	104 429	8 078	45.66	1.22	44.44	0.04	0.1
Slovenia	2 027 277	770 131	895.66	40.71	854.95	0.04	0.11

1. The area of Slovenia (2,027,277 ha) derived by summing up the area of statistical regions differs from the official area (2,027,245 ha) obtained from the Register of Territorial Units by 32 ha or 0.016%. The areas of the statistical regions do not differ from their official areas by more than 0.02%.
2. Agricultural land obtained from the Statistical Land Cover/Land Use GIS-state 1993.

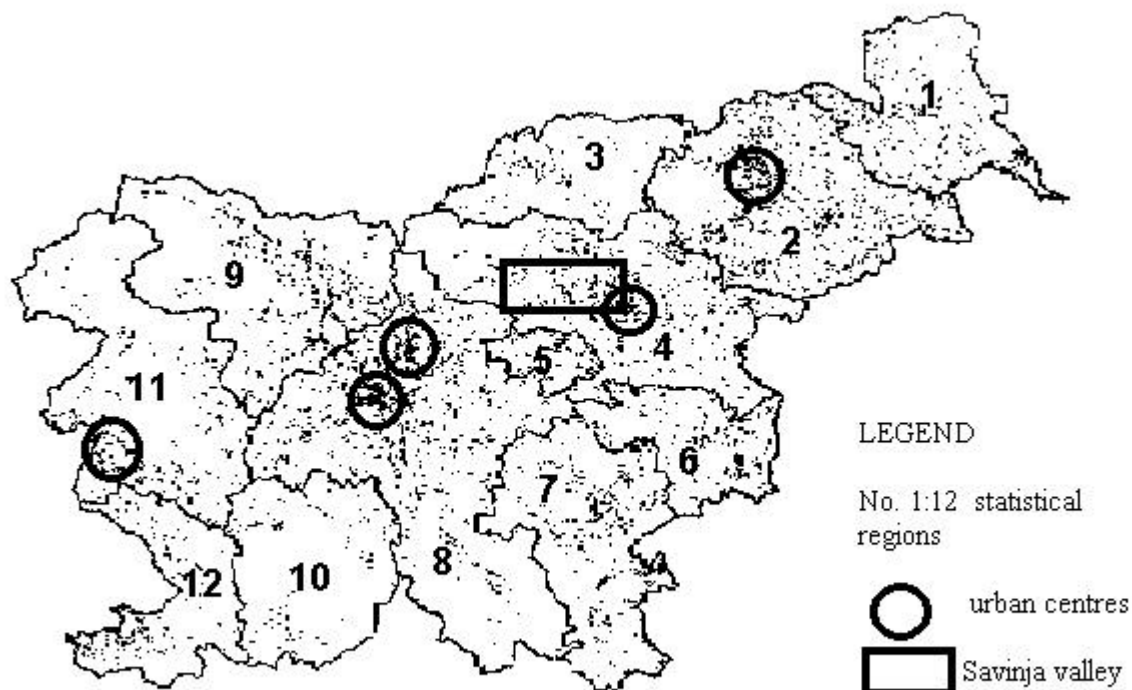


Figure 3: Distribution of augmented built-up areas from June 1993 to June 1997 by statistical regions of Slovenia

V. STATISTICAL LAND COVER/LAND USE GIS OF SLOVENIA-STATE '97 AND QUALITY CONTROL

17. The compilation of the Statistical Land Cover/Land Use GIS of Slovenia-state '97 with the minimum mapping unit of 15 hectares is now under way (Duhamel and Croi 1999; Lojovica et al 1998; Ronconi 1999). For this purpose all the vector data from the state in 1993 were updated to the state in 1997 and the following new data layers were added:

- Landsat TM scanned data from 1997,
- Spot-Pan satellite scanned data from 1996-97,
- georeferenced locations of dumping grounds,
- georeferenced locations of gravel pits and quarries,
- vectors of roads: first three levels.

18. In the compilation process of the new GIS, quality assessment of land cover categories will be performed within each statistical region. As in 1999 the new GIS for the first statistical region was finished; an error matrix for quality assessment was calculated for one randomly selected segment (Congalton 1991). The segment measures 3 000 m x 3 000 m. The photointerpreted and digitised airphotos on a scale of 1:17 500 of the latest Cyclical Aerial Survey (CAS 1996) were used as reference data. The overall accuracy reaches 93% (Table 2).

Table 2: Error matrix of classified polygons from airphotos on a scale of 1:17 500/CAS '96 and from the compiled Statistical Land Cover/Land Use GIS of Slovenia-state '97 on a randomly selected segment of size 3 000 m x 3 000 m on location UL: X = 5590000/Y = 5173000

Statistical GIS '97	Air photos - reference values				TOTAL	% user's accuracy
	agriculture	forest	built-up	Water		
Agriculture	697.99	33.40	21.11	0.43	752.93	93
forest	5.84	89.91	0.02	0.09	95.86	94
built-up	4.16	0.42	46.44	0.05	51.07	91
water	0.03	0.03	0.09	0.15	0
TOTAL	708.02	123.76	67.66	0.57	900.01	
% producer's accuracy	99	73	69	0		Overall accuracy 93

User's accuracy: $(X_j / \sum X_{ij}; j = 1, \dots, 4) \Rightarrow$ commission or inclusion error = type I error
 Producer's accuracy: $(\sum X_{ij} / \sum X_i; i = 1, \dots, 4) \Rightarrow$ omission or exclusion error = type II error
 Overall accuracy: $(\sum X_{ii} / \sum \sum X_{ij}; i = 1, \dots, 4; j = 1, \dots, 4)$.

VI. CONCLUSIONS

19. The Statistical Land Cover/Land Use GIS of Slovenia is the first numerical GIS of Slovenia which comprises a uniform thematic layer of the whole territory. The Statistical Land Cover/Land Use GIS of Slovenia-state '93 officially confirmed that a far greater area of Slovenia is under forest than has been officially reported. The improved resolution of satellite scanned data used in the Statistical Land Cover/Land Use GIS of Slovenia-state '97 will enable a better delineation of land cover categories down to 15 hectares of minimum mapping unit. Since geographical heterogeneity as well as small field sizes are characteristics of Slovenia, this improvement is an important contribution to a more operational use of the compiled Statistical Land Cover/Land Use GIS of Slovenia.

20. The Statistical Land Cover/Land Use GIS of Slovenia-state '97 will enable us to estimate more accurately the land cover/use change during the period from 1997 to 2001 due to augmented built-up areas. In addition, the fourth level of roads will be included as well as the built-up areas of larger industrial objects, warehouses, parking places, etc., which exceed the size of 20 m buffered centroids.

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