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A SPATIAL MODEL TO EVALUATE MAN-INDUCED TRANSFORMATION USING GEOINFORMATION TECHNOLOGIES

Eugenia Roumenina, Georgi Jelev, Roumen Nedkov, Vanya Naydenova, Georgi Kanev

Space Research Institute - Bulgarian Academy of Sciences
e-mail: roumenina@space.bas.bg

Abstract

The sustainable use of municipal territory, complying with ecological and social-economic features, is among the top-ranking directions of modern regional policy. A key problem here is the evaluation and control of the territories subject to intensive anthropogenic activity. The paper presents a methodology for performing such type of study. Using conventional-source data and satellite imagery integrated in a data base, a spatial model to evaluate the man-induced transformation of the land of Novi Iskar, Sofia Municipality, was designed. The ranking of land-use categories and the maps of the man-induced transformation distribution index were created after Goffmann's methods adapted for Bulgarian territory by Iliev-Ilieva. As a result of the dynamic urbanization process and the intensive agricultural and industrial-transport activity, the landscape structure of the studied land has experienced material changes. The calculated regional man-induced transformation index (Ual = 554) is close to the index of Sofia Municipality, which is the highest for the country. It is strongly affected by the high values of the index of fields that were utilized for residential and industrial

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purposes. Based on the generated digital terrain model, a series of derivative morphometric cartographic models was created, which reveal the nature and features of the relationships between the relief's plastics and the spatial distribution of the individual land-use categories. The created geodata base provides for express retrieval of thematic information from multi-channel satellite images for the purpose of monitoring the examined territory's man-induced transformation. Obtaining regular unbiased information is of great importance for the Municipality's adequate policy formation and funding.

Keywords: *man-induced transformation, remote sensing, geographic information systems, spatial modeling.*

1. Introduction

The sustainable use of municipal territory, complying with ecological and social-economic features, is among the top-ranking directions of modern regional policy. A key problem here is the evaluation and control of the territories subject to intensive anthropogenic activity. The Town of Novi Iskar is one of the four towns located on the territory of Sofia Municipality. It was proclaimed a town in 1974, as a result of merging the Villages of Kourilo, Koumaritsa, Slavovtsi, and Gnilyane. The Town of Novi Iskar falls within the Municipality's northern industrial area which incorporates as well the industrial settlements of Svetovrachane and Kremikovtzi.

The main objective of the study is the design of a spatial model to evaluate the man-induced transformation of the territory of the Town of Novi Iskar, Sofia Municipality. To achieve it, three interrelated tasks must be solved, namely: 1. To create a geodata base for the territory of the Town of Novi Iskar containing information on land-use; 2. To generate digital terrain model (DTM) and to create a series of derivative morphometric cartographic models, revealing the nature and features of the relationships between the relief's plastics and the spatial distribution of the individual land-use categories. 3. To identify and analyze the man-induced transformation of the examined territory.

2. Methods and information background of the study

In implementing the specified tasks, the basic technologies used were geoinformation technologies (Burrough A., 1996, Lillesand T., Kilfer R., 2000, Тикунов В., 2004), involving geoinformation systems and data processing technologies applied in remote sensing of the Earth. The work methods comprise eight major stages, which are shown in Fig. 1.

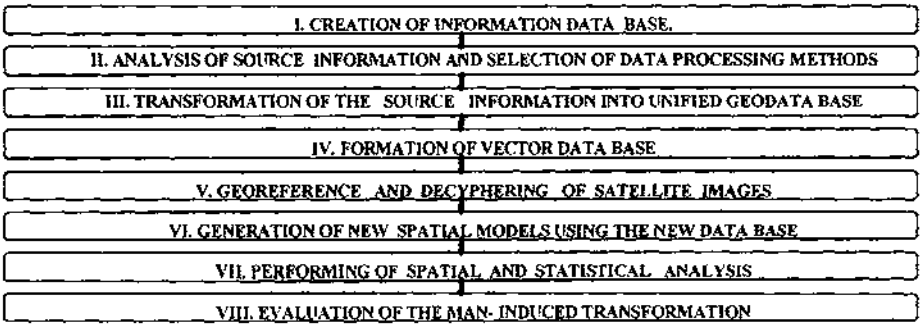

Fig. 1. Work stages

To achieve the objective of the study, the following information sources were used: large-scale topographic maps in scale M 1:10,000; satellite images from Landsat ETM$^+$ and IKONOS taken in 2000 and 2005, accordingly, and data from the National Institute of Statistics. The topographic maps and satellite images were georeferenced to a unified coordinate system (Bulgarian coordinate system, 1970) into a geodata base. By digitizing the topographic maps and visual computer-aided interpretation and photo-revision of the satellite images, vector layers were created. The vector data base was used to generate a digital terrain model and its derivative cartographic models of topographic surface slope and aspect. The performed modelling using GIS tools helps to reveal the relation between the man-induced transformation and the morphographic features of the land of the Town of Novi Iskar. As a result of the performed operations related to information input and preliminary processing, layers of geodata bases were created, required by the subsequent spatial analyses (Table 1). A series of derivative morphometric cartographic models was created, describing the relation between man-induced transformation attributes and relief characteristics. Upon analysis and generalization, the obtained spatial quantitative evaluations were presented in the form of maps (Figs. 2), graphs and tables.

Table 1. Data distribution by layers in the data base

Name of layer	Type of layer
Satellite images from Landsat ETM and IKONOS	Raster
Large-scale topographic maps	Raster
Land boundary	Vector-polygon
Boundary of the quarters' territory	Vector-polygon
Triangulation points	Vector-Points
Ground control points measured by GPS	Vector-Points
Relief isolines	Vector-Line
Forest territories	Vector-Polygon
Natural meadows	Vector-Polygon
Pastures	Vector-Polygon
Perennial plants (vineyards, orchards)	Vector-Polygon
Fields	Vector-Polygon
Water areas, streams, and hydro-melioration equipment (rivers, dams, gullies, canals, etc.)	Vector-Polygon
Transport and infrastructure territories	Vector-Polygon
Built-up lands for residential and industrial purposes	Vector-Polygon
Disturbed lands (mines, quarries, landfills etc.)	Vector-Polygon
Ground measurements 2006–2008	Vector-Points
Digital terrain model	Raster
Slope	Raster
Aspect	Raster
Man-induced transformation	Raster

3. Major results

The spatial analysis and evaluation of man-induced transformation was performed after Goffmann's methods adapted for Bulgarian territory by Iliev-Ilieva (Илиев Ил., М. Илиева 1998). In it, the number of land-use categories is reduced to 10, and each category is assigned an appropriate man-induced transformation rank (r). The values of the man-induced transformation ranks (r) for the respective land-use categories are as follows: Protected territories (protected natural territories, archaeological sites, sanitary-protected areas etc.) – 1; Forest territories – 2; Natural meadows – 3; Pastures – 4; Perennial

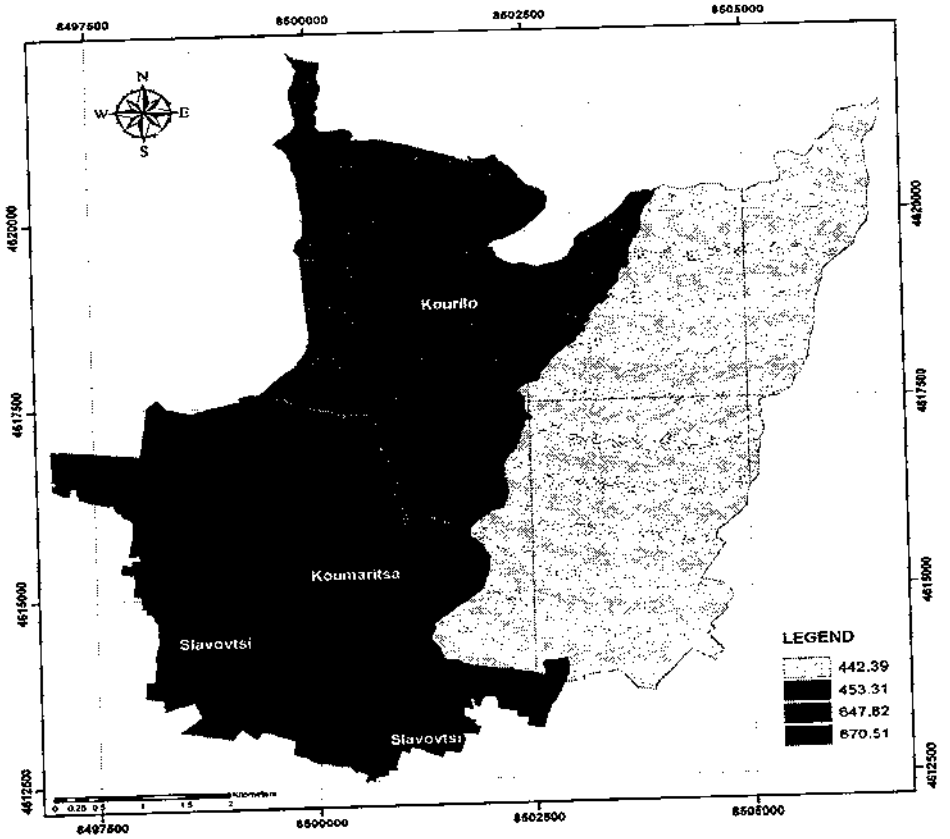

Fig.2. Distribution of man-induced transformation index (Ual) on the territory of the town of Novi Iskar by quarters

plants (vineyards, orchards) – 5; Fields – 6; Water areas (rivers, dams, gullies, canals, etc.) – 7; Transport and infrastructure territories – 8; Built-up lands for residential and industrial purposes – 9; Disturbed lands (mines, quarries, landfills etc.) – 10. The proposed man-induced transformation index (Uam) is equal to the product of the man-induced transformation rank (r) of the respective land-use category and its portion of the overall territory in %. The sum of the man-induced transformation indices of the individual categories represents the local index (Ual).

Within the boundaries of the examined territory, 9 land-use categories were identified, whereas only protected territories (Fig. 2) were not identified. These categories have been formed under the influence of both natural and social-economic factors.

Forest territories

Forest territories are of great ecological importance as a factor maintaining natural equilibrium. The greater portion of mountain lands in the northern part of the region accounts for a greater portion of forest-occupied territories compared to the plane southern part. This land-use category occupies 30.2 % of the region's territory. It is lacking in the Koumaritsa and Slavovtsi quarters. The forests are located mostly in the low mountainous area (altitude of 600 - 1,000 m), along southern slopes with inclination from 10^0 to 30^0 (Table 2). The man-induced transformation index is 60.32, which is close to the average value for Sofia Municipality (58.4). Its relative share ranks third in significance to the formation of Ual.

Natural meadows

The relative portion of natural meadows is 5.52 %, whereas in the Slavovtsi quarter it is less than 1%. They are located mostly in plane territories with altitude of 500 - 600 m (Table 2). Part of the natural meadows is located on the flooded terrace of the Iskar River, which creates marshes at spring water maximum. Another reason for the marshes, particularly in the Gnilyane area, is the high level of underground water.

The man-induced transformation index is 16.56, which is higher than the average for Sofia Municipality (11.7). This relatively high index evidences of available favourable conditions for development of pasture stock-breeding.

Table. 2. Percentage of the area distribution by land-use categories conformity with the relief characteristics on the land of the town of Novi Iskar

Relief characteristics		Land-Use Categories								
		Forest territories	Natural meadows	Pastures	Perennial plants	Fields	Water areas, streams and hidromelio-rative equipment	Transport and infrastructure territories	Built-up lands for residential and industrial purposes	Disturbed lands
Elevation levels	200 m - 600 m	21.3	99.5	66.1	32.9	96.7	99.5	96	95.3	66.7
	600 m - 1000 m	78.6	0.5	33.9	67.1	3.3	0.5	4.0	4.7	33.3
	1000 m - 1600 m	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Slope(°)	0 ° - 1°	9.5	85.5	43.3	14.3	60.4	83.1	56.8	50.4	25.4
	1 ° - 3 °	4.1	8.4	15.2	3.7	24.0	10.2	35.6	25.7	37.4
	3 ° - 7 °	10.0	3.6	18.0	20.4	11.8	5.4	3.5	13.7	33.7
	7° -10°	10.1	2.0	9.9	30.0	3.0	1.0	0.7	5.6	0.6
	10 ° - 15 °	23.7	0.4	9.5	24.0	0.7	0.2	1.1	3.5	0.6
	15 ° - 20 °	20.2	0.1	2.4	5.7	0.1	0.1	0.9	0.9	0.8
	20 ° - 30 °	19.1	0.0	1.4	1.5	0.0	0.0	1.0	0.3	1.4
	>30 °	3.4	0.0	0.2	0.4	0.0	0.0	0.4	0.0	0.1
Aspect	Flat	8.6	75.1	24.6	12.9	36.8	62.4	29.3	13.7	9.5
	North	3.1	0.9	1.8	0.1	0.6	0.1	1.2	0.5	0.6
	Northeast	4.6	6.6	1.4	0.4	1.8	0.9	2.1	3.7	9.4
	East	10.6	3.1	5.8	1.7	2.7	2.5	4.9	13.2	9.5
	Southeast	16.0	0.3	12.3	13.7	16.0	1.3	11.7	31.2	38.0
	South	16.2	2.6	23.4	28.0	21.6	6.0	38.9	13.1	30.6
	Southwest	17.9	7.8	10.3	18.1	10.0	11.8	5.7	10.8	2.3
	West	14.8	3.4	9.4	14.6	8.1	12.4	5.1	10.8	0.1
	Northwest	8.4	0.2	11.0	10.4	2.4	2.7	1.1	3.1	0.0

Pastures

This category occupies 3.44 % off the overall area, whereas most of the pasture territories are located in areas featuring altitude of 500 - 600 m and inclination of 0^0 to 3^0 (Table 2). The man-induced transformation index is 13.76, which is by 24 points less than the average for Sofia Municipality. The relative share in Ual formation is among the lowest ones - 3 %.

Perennial plants

The land-use category of perennial plants on the territory of the Town of Novi Iskar occupies only 1.4 % of the overall area. The greater part of these is located on the territory of the Gnilyane Quarter, at altitude of 600 to 1,000 m, along slopes of southern exposure featuring inclination of 3^0 to 15^0 (Table 2). A look-up into old topographic maps in scale M 1:10,000 issued in 1970 reveals that its territory used to be occupied by vineyards and orchards. The relative share of this category's Uam in the formation of Ual is only 1 %, notwithstanding the value of Uam (6.95) for the examined territory which is nearly threefold greater compared to the respective value for Sofia Municipality (2.5).

Fields

The greatest relative share in the territory's structure is occupied by the field category - 33.94 %. The man-induced transformation index (203.64) for the considered land-use category is substantially higher than the average value for Sofia Municipality (152.4). Its relative share in Ual formation is highest – an overall of 38 % for the whole land of the Novi Iskar region. This tendency is not uniform for the lands of the individual quarters, varying from 30.36 for the Kourilo Quarter to 422.04 for the Slavovtsi Quarter (Table 3). The fields are located in plane areas with altitude of 510 - 600 m.

Currently, the structure of arable land shows that the greatest part of them is occupied by fields planted with grain crops: maize, barley, wheat, and fodder – mainly alfalfa. Vegetable-planted areas rank second.

Water areas, streams, and hydro-ameliorative equipment

Water areas occupy 3.4 % of the overall area, which points to a relatively well organized irrigation system. This parameter is strongly affected by the Iskar River, which flows through the lands of the Quarters of Koumaritsa, Kourilo, and Gnilyane. Notwithstanding the erected protective embankments, part of these quarters' territory was damaged by the floods of June 2005 (Fig. 3). The man-induced transformation index is 23.73, which is close to the average for Sofia Municipality (23.1).

Table 3. Man-induced transformation index (Uam) on the territory of the Town of Novi Iskar

Land-Use Categories	Town of Novi Iskar	Koumaritsa Quarter	Gnilyane Quarter	Slavovtsi Quarter	Kourilo Quarter
Forest territories	60.32		82.68		105
Natural meadows	16.74	22.23	16.56	2.22	19.68
Pastures	13.76	13.32	13.92	14.44	13.52
Perennial plants	6.95	0.5	17.65	0.55	
Fields	203.64	316.8	189.42	422.04	30.36
Water areas, streams, and hydromeliorative equipment	23.73	33.53	22.19	4.27	27.65
Transport and infrastructure territories	40.64	36.24	20.32	137.52	26
Built-up lands for residential and industrial purposes	136.17	202.59	79.65	66.78	197.1
Disturbed lands	18.9	45.3			34

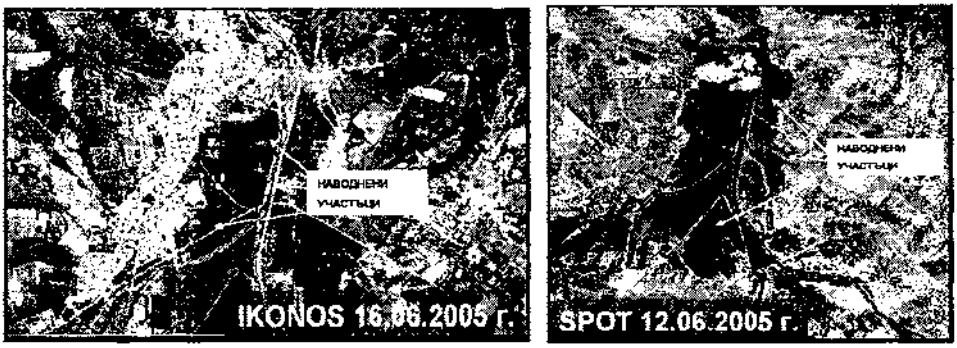

Fig. 3. Satellite images from IKONOS and SPOT on which the areas flooded in June 2005 may be seen

Transport and infrastructure territories

The infrastructure type of land use includes the areas occupied by the transport network elements (inclusive of field and forest roads) outside the populated areas and the pertaining infrastructure. It occupies 5.1 % of the territory's overall area. The man-induced transformation index (40.84) is twice as big as the index of Sofia Municipality (12.0). It is greatly influenced by the lands occupied by the Airport of Dobroslavtsi, part of which is located on the land of the Slavovtsi Quarter. Currently, the airport is not used according to its destination. The relative share of the considered category's Uam in the formation of the local index is 8 %. The transport network on the plane territory is well organized, field roads constituting an important part thereof.

Built-up lands for residential and industrial purposes

The territory's building up is associated with some of the gravest damages during man-induced transformation, occupying 15.1 % of the overall area forming the structure of the examined territory's land use. A number of industrial and service sites and equipments have been erected on the region's territory. The relative share of this category's Uam in the formation of Ual is 26 %, which ranks it second in significance to the formation of the local index, after the field category. The man-induced transformation index is 136.17 which is less than the average for Sofia Municipality (163.8). This tendency is not uniform for the lands of the individual quarters, varying from 66.78 for the Slavovtsi Quarter to 202.59 for the Koumaritsa Quarter (Table 3).

Disturbed lands

The greatest changes in the territory's natural status and regime have occurred in the north-west part of the region as a result of the development of mining and quarry activity. The relatively low stage of development of industrial technologies, the insufficient or lacking depth selection, and last but not least, the deposits' low useful content called for exploitation of large fields. The highest values of the index of the disturbed lands' category are associated with the Quarters of Koumaritsa and Kourilo where Uam is equal to 45.3 and 34, accordingly.

Disturbed lands occupy 1.9 % of the overall area. The land hosts one deserted uranium mine, one deserted open-extraction coal mine and clay-extraction quarries. Despite that these sites feature the highest man-induced transformation rank their share in Ual formation is insignificant – 4 %. The Uam index for this category is 18.9, which is much less than the average for Sofia Municipality (51). This tendency varies with the individual quarters, whereas Gnilyane and Slavovtsi have no disturbed lands (Table 3).

4. Conclusion

As a result of the dynamic urbanization process and the intensive agricultural and industrial-transport activity, the landscape structure of the studied land has experienced material changes. The calculated local man-induced transformation index (Ual = 554) is greater than the value of this index for Sofia Municipality, which is the highest for the country. It is strongly affected by the great values of Ual for fields and built-up lands for residential and industrial purposes. This tendency is characteristic of the Koumaritsa and Slavovtsi Quarters, while the values of Ual for the other two quarters are close to the average value for the country (448.1).

The plane relief in the southern part of the territory, the soil and agro-climatic conditions and resources favour the development of agricultural land use. Despite the relatively favourable agro-climatic conditions, few perennial plants are grown in the region.

The created geodata base provides for express retrieval of thematic information from multi-channel satellite images for the purpose of monitoring the examined territory's man-induced transformation. Obtaining regular unbiased information is of great importance for the Municipality's adequate policy formation and funding.

References

1. Burrough, A. (1996). Principles of Geographical Information Systems for Land Resources Assessment. Clarendon Press, Oxford, 210 p.

2. Lillesand T., R. Kilfer (2000). Remote Sensing and Image Interpretation, John Wiley & Sons , 721.

3. Основы Геоинформатики, под ред. Тикунова В. (2004) ACADEMA, Москва, т. 1, 345, т. 2, 477.
4. И л и е в И л., М. И л и е в а, (1998). Оценка на антропогенната преобразуваност на територията на България, Сборник "100 години география в Софийския университет", И-во "Св.Кл.Охридски", С, стр. 523 – 531.
5. Брой на населението по области, общини и населени места, (2005). Национален статистически институт, София.

ПРОСТРАНСТВЕН МОДЕЛ ЗА ОЦЕНКА НА АНТРОПОГЕННАТА ПРЕОБРАЗУВАНОСТ С ИЗПОЛЗВАНЕ НА ГЕОИНФОРМАЦИОННИ ТЕХНОЛОГИИ

Е. Руменина, Г. Желев, Р.Недков, В. Найденова, Г. Кънев

Резюме

Устойчивото използване на територията на общините, съобразено с екологичните и социално-икономически особености, е едно от приоритетните направления на съвременната регионална политика. Един от ключовите проблеми е оценката и контролът на териториите, подложени на интензивна антропогенна дейност. В статията е представена методология за провеждане на такъв тип изследване. С използване на данни, получени от конвенционални източници и спътникови изображения, интегрирани в геобаза данни, е съставен пространствен модел за оценка на антропогенната преобразуваност на землището на гр. Нови Искър, Столична община. Градацията на категориите земеползване и картите за разпределението на индекса на антропогенна преобразуваност са съставени по адаптираната за територията на

България от Илиев–Илиева методика на Гофман. Под въздействието на динамично протичащия урбанистичен процес, както и в резултат на интензивната селскостопанска и промишлено–транспортна дейност ландшафтната структура в изследваното землище е претърпяла съществени изменения. Изчисленият регионален индекс на антропогенна преобразуваност (Ual = 554) е близък до този на Столична община, който е най-високият за страната. Силно влияние върху неговото формиране оказват високите стойности на индекса от ниви и застроени земи от населените места и промишлеността. На базата на генериран цифров модел на релефа са съставени серия от производни морфометрични картографски модели. Те разкриват характера и особеностите на взаимовръзките между пластиката на релефа и пространственото разпределение на отделните категории земеползване. Създадената геобаза данни дава възможност за експресно извличане на тематична информация от многоканални спътникови изображения за извършване на мониторинг на антропогенната преобразуваност на изследваната територия. Получаването на регулярна обективна информация има изключително значение както за формиране на адекватна политика на общината, така и за финансовото й осигуряване.