

Urban Change Mapping of the Black Sea coastal zone in Bulgaria Using Remote Sensing Data

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Abstract. The Black Sea coastal zone in Bulgaria is an area of substantial importance due to its significant natural and economic resources, as well as to its sensitivity with respect to unfavorable ecological impacts. In this study mapping of urban areas change in coastal zone of Bulgaria based on satellite imagery is presented. The survey covers the period 1990 – 2006 of the transition from planned economy to market economy in Bulgaria. The remotely sensed data used include multispectral images from Landsat TM of 1990s, Landsat ETM+ of 2000, IRS-P6, SPOT 4 and SPOT 5 of 2006 and 2007. Visual interpretation of multispectral satellite images was applied for urban areas change detection. The results indicate that the urban area expanded substantially in the two-kilometer strip of land along the Black Sea coast in Bulgaria during the period 2000 – 2006, mostly to the detriment of arable land and woodland. The observed types of urban change identified were urban expansion or densification. Besides, the results provide an estimate of the extent, pattern and direction of urban dynamics in the study area.

Keywords: Urban change, Bulgarian coastal zone, Remote Sensing

1. Introduction

The Bulgarian Black Sea coastal zone is a vulnerable region, which is very sensitive to the diverse natural and anthropogenic impacts on the environment. At the same time, this is one of the areas, which has endured the most sizeable and rapid urban change in recent years. The urban pattern has undergone a considerable change as a result of the growth of built-up areas mainly related to tourism industry. Urban development is critical for biodiversity, environmental protection and natural resource management of this territory.

Remote sensing proves to be a basic component of urban monitoring and mapping. Remotely sensed data are widely used to provide information on urban land cover characteristics and their change (Shackelford & Davis, 2003; Gamba et al., 2005; Maktav et al., 2005; Netzband et al., 2007; Chen et al., 2009; Seifert, 2009; Esch et al., 2010; Taubenböck et al., 2010; Wurm et all., 2011). Direct observation of urban change with satellite imagery provides a uniform approach to mapping and assessing the urban development at various spatial and temporal scales. Both, remote sensing and geographic information systems (GIS) are a powerful tool for monitoring, mapping and analysis of urban dynamics as well as for identifying trends of urban change pattern.

The causes and consequences of urban development mostly have a reference to space. Thus, for mapping of urban pattern, not only spatial information on the current status is required, but also continuous knowledge on changes. In this study mapping of urban areas change in the Bulgarian Black Sea coastal zone based on satellite imagery is presented. The survey covers the period 1990 – 2006 of the transition from planned economy to market economy in Bulgaria.

2. Materials and Methods

2.1. Study Area

The study area is located in East Bulgaria and is approximately bounded by the coordinates $41^{\circ}56' - 43^{\circ}44'N$ and $27^{\circ}17' - 28^{\circ}36'E$ (Figure 1). The coastline has a length of 378 km and covers the entire eastern bound of Bulgaria stretching from Romania in the north to Turkey in the south. The study area includes all of the 14 coastal municipalities in Bulgaria. This land strip with an area of 5,756 km² is 10 to 40 km wide. The region is characterized by both well preserved natural landscapes and strong anthropogenized areas. The northern part features plain and karst relief, while the southern is predominantly lowland with forested hills, lakes, wetlands, and coastal lagoons. The sandy beaches occupy approximately 130 km of the coast. The climate is formed under the influence of the Black Sea. It is moderate-continental in the north and transitional-Mediterranean in the south. The summer is relatively warm and the winter is mild, the average annual precipitation is 440-900 mm. The region is an important center of tourism during the summer season from May to October.

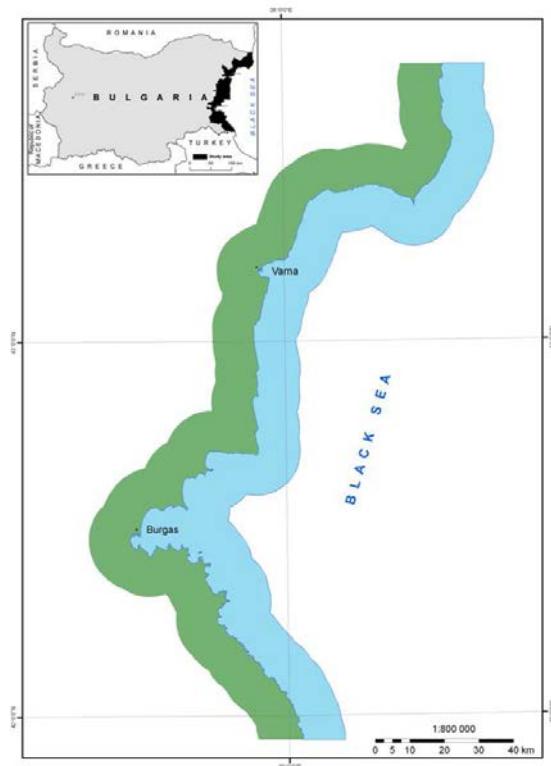


Figure 1. Study area of the Black Sea coastal zone in Bulgaria.

2.2. Data and Methodology

The remotely sensed data used include multispectral images from Landsat TM of 1991 and 1992, Landsat ETM+ of 2000, IRS-P6, SPOT 4 and SPOT 5 of 2006 and 2007. A wide variety of ancillary data was used, such as digital topographic and thematic maps, orthophotos, statistics, and in-situ data from multi-year field observations.

An integrated approach of remote sensing and GIS was applied to detect, map and analyze the urban dynamics in coastal zone. Urban change data was obtained by visual interpretation of satellite imagery in GIS environment applying the methodology and nomenclature of the CORINE Land Cover (CLC) project (Heymann et al., 1994; Perdigao and Annoni, 1997; Bossard et al., 2000; Feranec et al., 2006; EEA, 2007; Büttner and Kosztra, 2007; Steenmans and Büttner, 2007). The following geometric criteria for urban change mapping were used: a minimum area of 1 ha and a minimum width of 50 m.

3. Results and Discussion

Mapping of urban areas change in the Bulgarian Black Sea coastal zone for the period 1990 - 2006 took place according to the land cover and land use in 1990, 2000 and 2006. The produced maps (Figure 2) show the structure and spatial distribution of land use/cover in the study area.

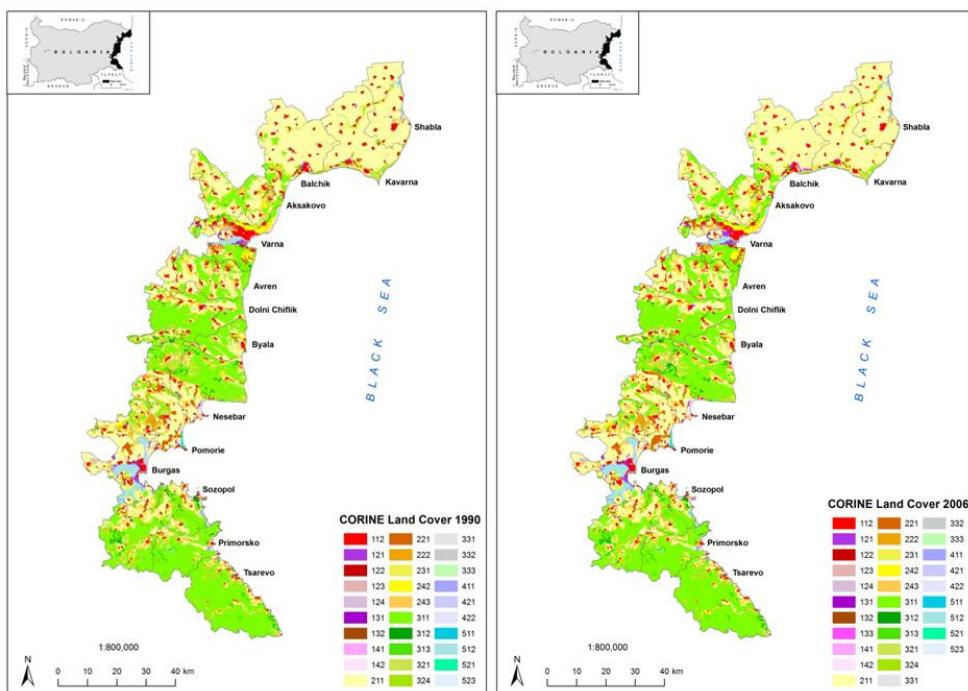


Figure 2. Land cover and land use in the Bulgarian Black Sea coastal zone for 1990 and 2006.

The statistics of land use/cover in coastal zone in Bulgaria (Table 1) represents the distribution in 2006 of artificial surfaces (5.93%), agricultural areas (51.89%), forest and semi-natural areas (40.06%), wetlands (0.53%), and water bodies (1.58%).

The total area of land use and cover change in the Black Sea coast municipalities was 6682.9 ha in 1990-2000 and 3754.7 ha for the period 2000 – 2006 (Table 2).

CLC class	1990		2000		2006	
	Area (km ²)	%	Area (km ²)	%	Area (km ²)	%
Artificial surfaces	331.28	5.75	333.52	5.79	341.19	5.93
Arable land	3004.18	52.19	2992.13	51.99	2985.29	51.89
Forest and semi-natural areas	2296.06	39.88	2305.52	40.05	2304.7	40.06
Wetlands	32.05	0.56	30.57	0.53	30.57	0.53
Water bodies	93.04	1.62	94.61	1.64	90.95	1.58
TOTAL:	5756.35	100.00	5756.35	100.00	5756.35	100.00

Table 1. Land cover and land use in the Black Sea coastal zone in Bulgaria for 1990 - 2006.

Land use/cover change type	1990-2000 (ha)	1990-2000 (%)	2000-2006 (ha)	2000-2006 (%)
Enlargement of urban fabric	28.9	0.43	63.7	1.70
Enlargement of construction sites	-	-	417.9	11.13
Enlargement of sport & leisure areas	-	-	289.0	7.70
Enlargement of industrial & transport units	-	-	96.5	2.57
Enlargement of mineral extraction sites	55.9	0.84	18.8	0.50
Intensification of agriculture	1025.1	15.34	228.3	6.08
Extensification of agriculture	2275.8	34.05	377.4	10.05
Afforestation	2005.5	30.01	599.5	15.97
Deforestation	1291.7	19.33	1663.5	44.30
TOTAL:	6682.9	100.00	3754.7	100.00

Table 2. Land use/cover change in the Bulgarian Black Sea coastal zone.

Mapping of urban change in Bulgarian coastal zone shows that the urban area expanded substantially along the Black Sea coast during the period 2000-2006, mostly to the detriment of arable land and woodland. Urban

changes are mainly located in the two-kilometer strip of land along the coast, where they cover 20.1% (757.7 ha) of the total changed area. Most of urban changes are situated in the southern part of the coastal zone. The areas of the towns of Nesebar (with the Sunny Beach Resort and the village of Ravda), Sozopol, Primorsko and Tsarevo (with the villages of Lozenets and Sinemorets) experience the greatest urbanization pressure. This is in close connection with tourism development and includes construction of hotels, second homes, sport and leisure facilities areas, including golf courses, and a small airport for charter planes (Table 3).

Municipality	Enlarge- ment of urban fabric (ha)	Enlargement of construction sites (ha)	Enlargement of sport & leisure areas (ha)	Enlargement of transport units (ha)	TOTAL (ha)
Kavarna	-	18.7	-	-	18.7
Balchik	-	214.0	-	-	214.0
Nesebar	-	164.8	121.8	-	286.6
Pomorie	5.1	-	-	-	5.1
Sozopol	-	-	119.6	-	119.6
Primorsko	21.4	-	-	27.7*	49.1
Tsarevo	17.1	-	47.5	-	64.6
TOTAL (ha):	43.6	397.5	288.9	27.7	757.7

Table 3. Urban changes 2000 – 2006 in the two-kilometer strip of land along the Black sea.

4. Conclusion

This study presents the results obtained from the spatio-temporal analysis and mapping of urban dynamics in the Black Sea coastal zone in Bulgaria. The results provide the basic spatial characteristics of identified urban changes concerning area, patch distribution, and land use processes related to relevant socio-economic processes.

The urban pattern expands substantially and it is mostly located in the two-kilometer strip of land along the Black Sea. The towns of Nesebar, Sozopol, Burgas, and Primorsko are identified as “hot spots” due to the greatest urbanization pressure. Tourism development is the main driving force for urban development in all “hot spots”, but for Burgas the leading driving forces are industry and transport.

Results are essential for exploiting the growing potential of remote sensing technologies for effective monitoring of dynamic urban areas to support

decision making with spatial, quantitative, consistent and comparable data needed for sustainable development of coastal zones.

Acknowledgements

The study was funded by FP7-PEOPLE-2009-IRSES (Grant No.247608) IGIT- Integrated geo-spatial information technology and its application to resource and environmental management towards the GEOSS.

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