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HUMAN-INDUCED IMPACTS ALONG THE COASTAL ZONE OF BULGARIA. A PRESSURE BOOM VERSUS ENVIRONMENT

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Abstract

Nowadays coastal zones are dynamic areas of various natural changes, but also of accelerated human uses and influences. Despite the coastlines are currently retreating, the increasing trade movements are still attracting people to the coasts and thus causing their occupation. Coastal tourism and development activities such as building of maritime structures, mining, dredging, etc., could adversely affect the functioning of ecosystems, modify morphological processes and reduce coastal zone persistency. As mush the coastal habitation grows as the required measures to protect the infrastructure increase. In this respect, the present research focuses the attention on the pressure boom related to population growth and defence activities performed along the Bulgarian Black Sea coast. In order to delimitate the areas most vulnerable to anthropogenic impacts, the study produces sensitivity classification maps both by population density and human structures at the 14 Bulgarian coastal municipalities. For this purpose data from topographic maps in scale 1 : 25 000 and population Census data were incorporated and analysed into a GIS environment. The results demonstrate that coastal municipalities with high economic and population concentrations or areas prone to erosion/landslide processes correlate to a high degree with most intensively armoured coastline sections. The study is also addressing the key role of the ICZM in decreasing coastal vulnerability, the issues of running process in Bulgaria and still existing gaps for its successful implementation.

Key words: coastal zone, population pressure, human structures, sensitivity map, ICZM

1. Introduction. The coastal areas worldwide have been recognised as most changeable sites between sea and land. At the same time, they are also highly attractive both for settlements and many human activities. Over the past two centuries there has been progressive anthropogenic influence on the geomorphology of the European coast from several perspectives [1]. Since 70s of the past century the Bulgarian Black Sea coastal zone has also experienced significant environmental damages from the increase in economical and recreational uses, and number of developments.

About 60% of the Bulgaria's 412 km coastline, between cape Sivriburun northing and Rezovska river southing (Fig. 1), is presently eroding [2, 3], however, now more than ever people tend to live close to the shorelines [4, 5]. The cliff retreats at an average rate of 0.08 m/y along the Bulgarian coastline: the highest erosion rates of 0.30 m/y was recorded at the loess coast between the capes of Sivriburun and Shabla, whereas at the most southern part the rate reaches at least 0.01 m/y at the volcanic rocks [3]. Thus, the cliff progradation has initially been predetermined by the geological settings of the coast, but as well as by the accelerating sea level rise. The average sea level fluctuations along the Bulgarian Black Sea coast vary from 1.5 to 3 mm/y, however, there would be a case of extreme sea level rise that might cause severe coastline erosion [6, 7].

The high level of shorelines armouring by port or coast-protection structures has arisen as major environmental problem in the coastal zones both at European and national scale. The coastal armouring should not be seen as a local solution and in isolation from other issues since it is closely related to the critical erosion process damaging the stability of coasts of the whole region. For instance, the coastlines of the Mediterranean Sea (almost 30%), the North Sea (20%) and the Black Sea (13%) have the most critical erosion hotspots [8]. Namely the prevalence of erosion/landslide processes along the Bulgarian Black Sea coast had fostered the implementation of many hard defence and stabilisation works over the last decades. In this context, it is important now to consider in what extent the coast-protection structures impact on shoreline and its sustainability [9].

According to the ICZM (Integrated Coastal Zone Management) evaluation report [10], the Black Sea coastal zone has been seeing as highly vulnerable resource due to increasing human population. This results in different conflicts and destruction of the functionality of the coastal system. Erosion, over-urbanisation and unsustainable coastal tourism have been pointed as the most crucial problems. The pressure boom caused by the tourism industry and illegal constructions along the West Black Sea coast has been leading to reduced access to the beaches for the general public, as well as to degradation of natural ecosystems. The bases of these problems are mostly associated with: priority to coastal tourism; lack of law enforcement; poor interactions between coastal scientists and decision-makers; and lack of multidisciplinary monitoring of the coastal zone.

Large sections of Europe's coast are currently dominated by humans as geo-

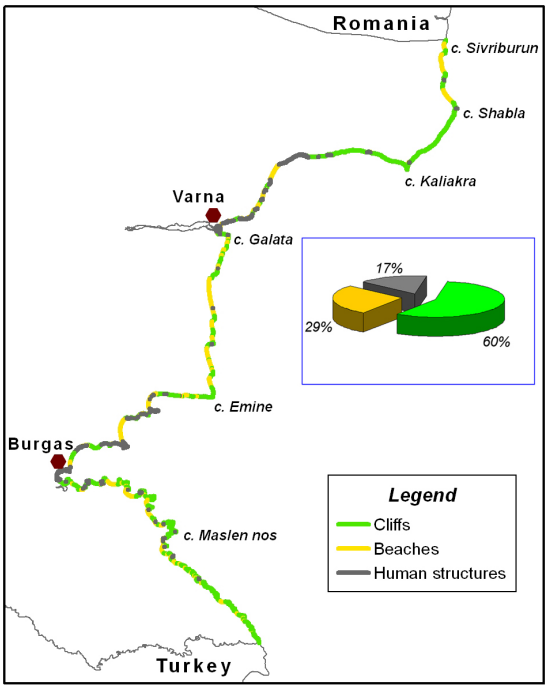

Fig. 1. The Bulgarian Black Sea coast

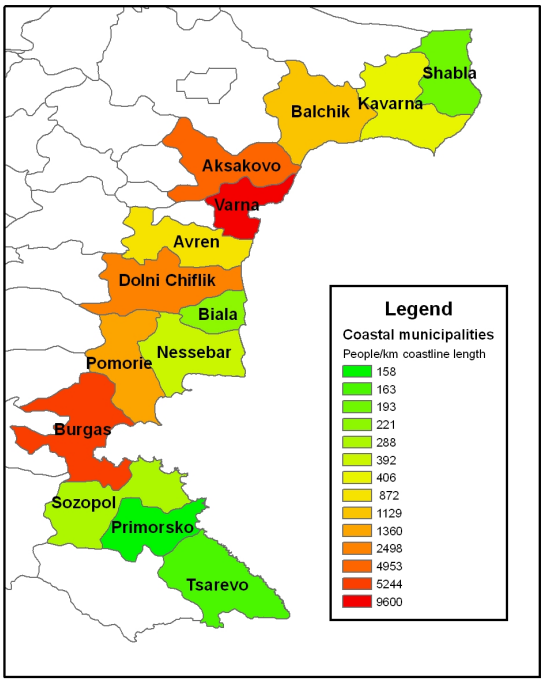

Fig. 2. Sensitivity map by population pressure (at 14 Bulgarian Black Sea municipalities)

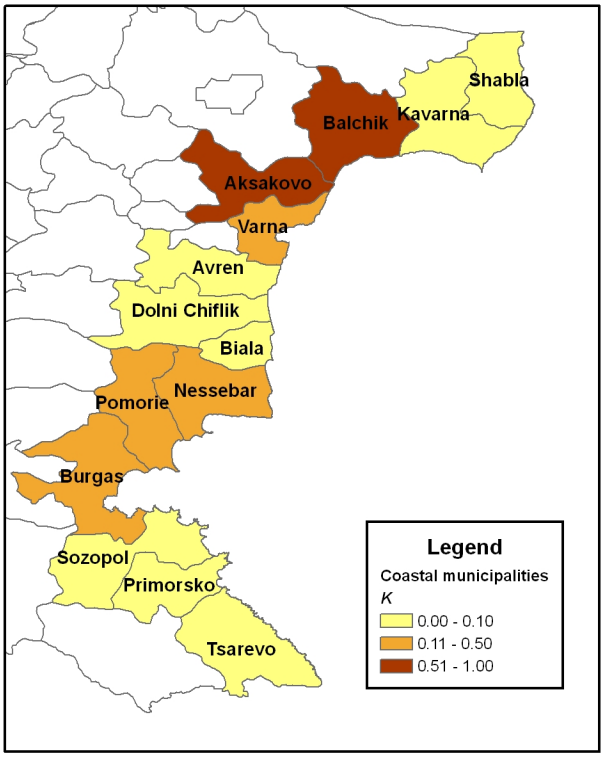

Fig. 3. Sensitivity map by technogenous impact (at 14 Bulgarian Black Sea municipalities)

Fig. 4. Example of dike construction along the Bulgarian coast: a) June 2007; b) May 2009

morphic agents. Under a rising sea level and growing habitation along the coasts, the behaviour and future coastline evolution will become even more influenced by human actions [1]. In recognition of this, the main objectives of present study are to identify the existing risks associated with pressure boom by population and protection activities at the coastal zone of Bulgaria in order to delimitate the most sensitive areas. Such adverse impacts are caused by rapidly increased habitation on one hand and on the other, by coastal defence structures designed to prevent the public/owners properties. At last, some aspects on the attempts towards implementation of the ICZM process in Bulgaria and the still existing gaps for its further progress were also considered.

2. Data used and methodology. Data from topographic maps in scale 1 : 25 000 were used to identify shoreline position, and built harbours and protection structures along the Bulgarian Black Sea coast, and to determine the boundaries of each coastal municipality. The topographic maps were scanned, georeferenced and digitised with help of Geographic Information System (GIS) tools. A number of 379 two major types of segments were indicated along the Bulgarian coast: natural segments (cliffs and beaches) and technogenous segments (ports, navigational channels and defence structures). The information about the location and type of each segment were filled in a separate column in the attribute table of the linear object (for one, the coastline with structures). The linear lengths of the individual segments were estimated with XTools Pro 5.0 GIS extension and the information contained in the attribute table was then exported as an Excel table. After that, the calculations and analyses were performed and the coastline lengths for all 14 Bulgarian Black Sea municipalities were determined.

The basic data for population (number of residents) in the Bulgarian Black Sea municipalities were obtained from the last Census data in 2001 [11], while data for the areas of municipalities were derived from [12]. The different sources data were collected, processed and tabulated. In order to identify the extent of population pressure on the coast, the number of people per linear coastline km for each municipality was used as an indicator. Sensitivity classification maps were produced using ArcGIS Dekstop 9.2. These maps serve to delimitate the most vulnerable areas along the coast that are exposed to the impacts of high population growth, on one hand, and to heavily concentration of human structures, on the other hand.

3. Sensitivity classification by population pressure at the Bulgarian Black Sea coastal municipalities. Coastal areas provide the base for all human activities on the two sides of the coast – land and sea [13]. Thus, the estimates based on the 2001 Census data show that the population living in the 0–10 km coastal zone is 86 million inhabitants or 19 % of the European Union (EU) total population [8]. With the increasing migration of citizens to the coastal zone, however, the character and quality of the shoreline is altering. High population density continually impacts the natural processes and thus affecting stability of

the coastline [8, 14]. As a result, the coastal ecosystems have been threatened of population growth and being now vulnerable to pollution, habitat degradation and loss, overfishing, erosion, etc.

As many other near-shore areas, the Bulgarian Black Sea coastal zone has also recorded higher increase of population compared with the inland areas. This continuous rise is a consequence of natural gain, but as well as of migration trend close to the shore because of existing variety of recreational and economic opportunities. According to the last Census data in Bulgaria [11], it was found that the population density in 10 km zone from the coast reaches 211 people per square km, while in 30 km and 60 km zones, the density is 30 and 28 people per square km respectively [5]. Taking into account that the coastal zone is limited land area, but sensitive to several marine/coastal risks, this high population growth could be considered as one of the major hazard factors that reduces the persistence of the coastal zone.

There are 262 municipalities in Bulgaria, which are the smallest administrative-territorial units. Fourteen of them are classified as coastal municipalities, because they are located entirely or partially within the Black Sea coast [5, 12]. The total area of all 14 coastal municipalities is 5784 square km or they comprise about 5% from the entire country's territory and accommodating almost 9% of national population [5]. By comparison, in 2001 the averaged population density for entire country is 72 people per square km, whereas in all Bulgarian Black Sea municipalities the averaged density value is 122 people per square km.

The sensitivity classification map (Fig. 2) shows the coastal areas with highest population pressure on the coast in terms of how many persons live per linear km of the coastline length at all 14 Bulgarian municipalities. The results obtained vary between the lowest value of 158 persons and the highest value of 9600 inhabitants per km of coastline length. Population concentration is lowest in the coastal municipalities of Shabla and Biala, while the largest sea towns of Varna and Burgas remark the highest population density and thus being the most populous sites along the Bulgarian Black Sea coast. Varna and Burgas are important community centres and regional cores of NUTS II (Nomenclature of Territorial Units for Statistics) regions of Severoiztochen and Yugoiztochen. These two cites are also equipped with largest harbours and they continuously tend to expand due to diverse economic, service and labour opportunities, which are attracting more people to the shore. This population growth had also significant impact on the coastal geomorphology of the two largest Bulgarian Black Sea bays of Burgas and Varna as they comprise larger parts of the heavily developed coastline.

4. Sensitivity classification by human structures at the Bulgarian Black Sea coastal municipalities. A number of defence measures have been applied to solve and manage the erosion/landslide problems along the Bulgarian Black Sea coast. Much of these methods include using of hard stabilisation options such as solid groins, dikes and seawalls [9]. It should be pointed out that building

of protection structures has particularly been increased over the last few decades. As a result, for a 50-year period (1960–2008) the amount of sediment material, incoming from cliff erosion, river solid discharge and wind-blown material has decreased from 4 979 700 Mg/y to 1 221 300 Mg/y. This in turn has provoked a reduction of sediment supply, beach degradation and even generating of new erosion spots. Therefore, the major causes for continuing erosion along the Bulgarian coast at present could be mostly associated with expanding human influence in terms of maritime constructions, dredging works and river corrections [3].

The present study produces a sensitivity classification map of vulnerable areas at the Bulgarian Black Sea shoreline by port/coast-protection structures impacts on the coast (Fig. 3). This classification was made along 14 Bulgarian coastal municipalities using the so-called *coefficient of technogenous impact (K)* which serves for quantitative assessment of the impact of maritime structures on the coastline [15]. This coefficient represents the ratio between the total length of all maritime hydraulic structures/objects (groins, moles, seawalls, dikes, navigational channels and permeable bridges) and the total length of the coastline. According to this classification the extent of technogenous impact is considered as minimal at $K = 0.0001 - 0.1$; average when $K = 0.11 - 0.5$; maximal at $K = 0.51 - 1.0$ and extreme if $K > 1.0$. K was estimated for each municipality along the Bulgarian coast, as it varies between 0.00 (for municipalities of Avren and Dolni Chiflik) and the highest value of 0.70 (for Aksakovo municipality). It is obvious from the classification map that the explored coefficient of technogenous impact is highest for the municipalities of Aksakovo, Balchik, Varna, Nessebar, Pomorie and Burgas, which corresponds to the sensitivity map by population pressure. This means the larger population concentration requires the larger number of measures to be implemented for mitigation of coastal hazards. In fact, the port and stabilisation structures are not regularly constructed along the coast. As a result, there are some parts with largest proportions of armoured coastline: at the northern part of the Bulgarian coast, between cape Ekrene and cape Galata, where 73 various types of maritime structures were identified [16] and at the south part, between the town of Nessebar and cape Foros. These heavily occupied areas include as well as the largest Bulgarian Black Sea bays of Burgas and Varna, where the vast deal of urban/land activities (transport logistics, industries, trades, etc.), coastal infrastructures and tourist developments are concentrated. For example, the highest value of technogenous impact K was identified for Aksakovo municipality, which has the coastline length of 4 km at least. However, the intensive erosion-landslide processes here were solved through 1484 m long dike construction and system of four solid concrete groins with a length between 70–110 m.

Although numerous defence measures taken along the Bulgarian coast, the progress of adverse erosion processes show that the problems related to them have not been solved yet [9]. At present, there are many cases of usefulness and ad-hoc structures along the coast, which are partially broken or being in disrepair

state. Their effects are now resulting in downdrift erosion, reduction of sandy beaches and degradation of natural resources. The needs to protect the coast at most erosion-prone areas have in particular been proclaimed by the increasing habitation in the coastal zone and the needs arisen then to save their properties. Instead of soft protection alternatives, the construction of hard stabilisation structures, such as groins, dikes and seawalls, have been assumed as a common solution to prevent the coastline. In this way, coastal defence in Bulgaria is still poorly planned and often the huge structures are built with many costs and without uses (Fig. 4 a, b). The pictures present a construction of new dike-rubble mound breakwater as a 12 km long road between Albena resort and the town of Balchik. Dikes are onshore structures with the principal functions of protecting low-lying coastal territories against flooding, and they are widely used as defence methods along the Bulgarian coast. Dikes provide effective wave breaking and sufficiently protect the coast against flooding. On the contrary, such structures stop the exchange between land and sea, and vice versa, disrupt sediment supply from the cliff, restrict public access to the water-area and decrease coastline attractiveness. In that case, however the cliff is overgrown and stable, and there is low wave energy reaching the coast. The first picture was taken in June 2007 during the construction and presently (2009) the dike is entirely completed. In this way, 12 km of the natural coast at this section was armoured and the whole coastal ecosystem was forever destroyed. In fact, the shoreline armouring has many impacts that reach far beyond the individual parcels they are designed to protect. As such structures are constructed to protect the coastal infrastructure not to save the beaches the population could be adversely affected by the stabilisation activities in terms of unnatural visual impacts, restricted access to the shoreline and beach reduction [4].

5. Addressing issues of ICZM in Bulgaria. The Integrated Coastal Management (ICM) is defined by [13] as a continuous and dynamic process by which decisions are made for the sustainable use, development and protection of coastal and marine areas and resources. First and foremost, the process is designed to overcome the fragmentation inherent in both the sectoral management approach and the splits in jurisdiction among levels of government at the land-water interface. This is done by ensuring that the decisions of all sectors and all levels of government are harmonised and consistent with the coastal policies of the nation in question.

At present, one of the major tasks for any relevant management strategy is the capability to cope with constantly growing anthropogenic pressures in coastal zones. The main reasons why an integrated approach is needed for managing the oceans and coasts are dual: the effects of ocean and coastal uses can have on oceans and coasts; and (2) ocean and coastal users conflicts [13]. Development activities such as building of structures, mining, dredging, etc. can significantly affect the ecology of the coastal zone and functioning of coastal and marine processes. Two

major types of conflicts related to coastal and ocean resources can be noted: (1) conflicts among users over the use or non-use of particular coastal/ocean areas; and (2) conflicts among government agencies that administer programmes related to coasts and oceans. For example some interactions arising are conflicts related to marine transportation and offshore oil development, coastal land reclamation, coastal tourism, sand mining, commercial fishing etc. In this respect, the integrated concept of adequate ocean and coastal management involves implications of developments, conflicting uses and interrelationships among physical processes and human activities, and it promotes linkages between coastal and ocean activities. As part of ICM, one of the major principles of any ICZM is therefore to take into account all sectoral interests in the coastal zone regarding the process of exploiting and preserving natural resources in the context of sustainable development.

As a whole, ICZM in Bulgaria as an institutional, ongoing and long-term strategy is poorly developed and still needs supporting governmental and public integrated efforts. It was found throughout the evaluation report [10] that in Bulgaria no ICZM equivalent policies are in advanced stages of preparation and fragmented tools are just in place to address coastal issues. The report pointed on the lack of strategy implemented yet and lack of awareness by both the public and state sectors on the importance of ICZM. At this point, the integration of the natural ecosystem in all aspects (physical, coastal, chemical, biological) is not in the field of vision of the public and state policy. This way, the involvement of scientific expertise, public discussions and education programmes on the critical problems have not been conducted and the research results have been rarely taken under the strategies for coastal zone planning and management.

In fact, the development of a Programme for ICZM of the Bulgarian Black Sea coast was started in 1994, however, without an adequate legal framework. This first attempt was funded by a loan from the World Bank, as the land use plans for coastal municipalities elevated above 0.50 m were developed. [17]. Efforts to elaborate a systematic ICZM programme were resumed in 2007, when Bulgaria joined the EU. As a result, the Black Sea Coast Development Act [18], enforced January 1, 2008 was adopted. These activities were enhanced by the need to harmonise the legislation between all EU countries. The main objectives of the Black Sea Coast Development Act are focused on: creation of conditions for protection, sustained integrated progress and development of the Black Sea coast; ensuring free public access to the sea shore; protection, preservation and rational use of natural resources; prevention and reduction of pollution; protection of the sea shore from erosion; and protection of the natural landscape as well as of cultural and historical heritage. At this stage the ICZM process in Bulgaria have not involved all relevant administrative bodies and all decisions are taken by the local, regional and national governments, and due to the state monopoly the coordination between them is missing [10]. In this context, as first attempt

the Black Sea Coast Development Act provides the basis for creation and implementation of an ICZM Programme and for a new strategy to protect the coastal zone against negative natural and anthropogenic impacts in view of the long-term perspective for coastal development [17].

The full implementation of ICZM process in Bulgaria still requires governmental contribution and political will for establishing the legal provisions to regulate many of the existing crucial problems in the coastal zone. Yet, there is no balanced combination of instruments in planning and management and these are the common gaps in the state policy of main directions in the scope of national ICZM. There is no co-ordination and coherency between the main socio-economic activities at national and regional level [10]. The Black Sea Coast Development Act determines only management regulations, but not to the required extent. There is no interaction between coastal scientists, planners and decision-makers, and most of the projects have been authorised without environmental impact assessments. As a result, major areas along the Bulgarian coast were completely urbanised by new developments such as hotels, second homes and other infrastructures, thus causing destruction of the natural resources.

Hence, transparency in decision-making and active public participation are essential for the success of any ICM programme [13] A strong public education that includes outreach efforts to all educational levels and to the general publics could be required in obtaining public understanding of the special character of coastal areas and the need of special ICM strategy.

5. Conclusions. The performed research identifies the existing risks associated with human-induced impacts in order to delimitate the most vulnerable areas along the coastal zone of Bulgaria. The study produces sensitivity classification maps by population density and by technogenous impact at the 14 Bulgarian Black Sea coastal municipalities.

The results demonstrate that the coast is currently exposed to many natural impacts, such as erosion, but also to the boom of increases in economical, development and recreational activities. Population concentration is lowest in the coastal municipalities of Shabla and Biala, while the largest sea towns of Varna and Burgas remark the highest population density and thus being the most populous sites along the Bulgarian Black Sea coast. The highest value of technogenous impact, based on the coefficient K, was found for the municipalities of Aksakovo, Balchik, Varna, Nessebar, Pomorie and Burgas, which corresponds to the sensitivity map by population pressure. This means the larger population concentration requires the larger number of measures to be implemented for mitigation of coastal hazards.

How can we put in place the most adequate coastal management strategy that could help to reduce the vulnerability and control the effects of growing anthropogenic pressure for a long-term preservation of natural resources? Since ICZM is considered as a key to the sustainable planning and development of

densely populated areas, there is an increased demand on expanded efforts by scientists, responsible authorities and general public in Bulgaria to fully realise the coastal zone management process.

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