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# Analysis of shoreline changes and cliff retreat to support Marine Spatial Planning in Shabla Municipality, Northeast Bulgaria

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ABSTRACT

Measuring historical shoreline change and cliff retreat is an essential aspect of understanding the long-term geomorphic evolution of any coastal system. These data are also critical for predicting future changes and incorporating that data into proper coastal management. In recent years, Marine Spatial Planning (MSP) has increasingly been recognized as an important tool in the sustainable management of marine space across Europe and worldwide, including also issues of coastal zone management and land-sea interactions (Directive 2014/89/EU for MSP). This paper deals with investigation of the shoreline changes and cliff retreat along the 34 km section of the Black Sea coast at Shabla Municipality (Northeast Bulgaria). The study area has a low density of development and comprises large sand beaches, dunes and rapidly retreating loess cliffs. The present research was formulated under the European Union (EU) Directive for MSP in the Black Sea Basin (MARSPLAN-BS) Project. The goal was to provide reliable data and useful information in support of the development of a pilot marine spatial plan for Shabla Municipality. The study was focused on the analysis of shoreline movement (at sand beaches – erosion/accretion) and cliff retreat (at rocky coasts) utilizing a Geographic Information System (GIS). Primary data sources include topographic maps in scale 1:5,000, tachometry survey and modern Very High Resolution (VHR) orthophoto images. Change rates were determined using the Digital Shoreline Analysis System (DSAS), an ArcGIS extension for calculating shoreline change (Version 4.3), and rate-of-change statistical method. Management of coastal erosion, hard engineering methods and lack of required setbacks were discussed. Results for rates of shoreline change and cliff retreat were verified with preliminary field measurement studies and cross-checked with existing hydrodynamics, geology and geomorphology of the coast of Shabla Municipality.



## 1. Introduction

Coastlines are dynamic features that change shape and position at different timescales in response to both natural processes (sea level change, waves, tides and currents) and human activities (mainly port construction and coast-protection structures). Beach erosion and coastal cliff retreat are chronic issues along many open shore and rocky coastlines all over the world. With the continued growth of population in coastal zones and increased threat by erosion to human developments and infrastructure, there is also an increased demand for accurate information for the examination of trends in coastline position over different timescales (Moore and Griggs, 2002; EUROSION Project, 2004; Morton et al., 2004; Morton and Miller, 2005; Hapke and Reid, 2007; Williams and Micallef, 2009; Hapke et al., 2010; Anfuso et al., 2012; Carrasco et al., 2012; Perez-Alberti et al., 2012; Hapke et al., 2013; Pranzini and Williams, 2013; Oyedotun, 2014; Semeoshenkova and Newton, 2015; Burningham and French, 2017).

According to Stanchev et al. (2013), 213 km (49.3%) of the entire 432 km Bulgarian coast consists of eroding cliffs. At certain sections, the retreat of cliff results in land loss and damages to private and public properties and infrastructure. These shoreline changes and coastal erosion have been studied in many previous works using different methodological approaches (Shuisky and Schwartz, 1988; Peychev, 1998; Trifonova and Stancheva, 2001; Peychev, 2004; Dachev et al., 2005; Trifonova and Stancheva, 2005; Keremedchiev and Stancheva, 2006; Stancheva and Marinski,

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2007; Stancheva et al., 2008, 2011; Peychev and Stancheva, 2009; Stanchev et al., 2013).

The measurement and prediction of shoreline change and cliff retreat is essential for proper coastal management (Hapke and Reid, 2007; Hapke et al., 2010; Perez-Alberti et al., 2012; Prukpitikul et al., 2012; Hapke et al., 2013; Oyedotun, 2014; Gould et al., 2015). This paper deals with investigation of the shoreline changes and cliff retreat along the 34 km section of the Black Sea coast at Shabla Municipality (Northeast Bulgaria). The study area has a low density of development and comprises large sand beaches, dunes and rapidly retreating loess cliffs.

The loess cliffs of Shabla Municipality study area have some of the highest cliff erosion rates along the Bulgarian coast (Peychev, 2004; Peychev and Stancheva, 2009). This is the greatest coastal zone management challenge of Shabla Municipality - balancing the need for mitigation measures and an integrated management approach that considers both protecting coastal ecosystems and threatened infrastructure (Cooper et al., 2016). Therefore, a detailed understanding of these change rates is critical for the development of coastal setbacks, mapping coastal erosion hazards, erosion–accretion studies, and conceptual or predictive modelling of coastal morphodynamics (Perez-Alberti et al., 2012).

In recent years, Marine Spatial Planning (MSP) has increasingly emerged as an important tool in the sustainable management of marine areas across Europe and worldwide, including also issues of coastal zone management as to Directive 2014/89/EU for MSP (Directive, 2014/89/EU; Zaucha, 2014; Ramieri et al., 2014). "*Marine spatial planning is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process*" (Ehler and Douvere, 2009). The use of spatial planning for marine areas still lags behind that for the terrestrial environment, but recent initiatives in both the United States and the EU show the increasing focus on spatial planning of both coastal and marine areas (Granit et al., 2014). Coastal areas are interdependent with the sea in both human uses and nature conditions and thus most human marine activities are functionally connected to the shore and vice versa. The Directive 2014/89/EU sets up the need for establishing a framework for MSP including Integrated Coastal Management (ICM).

## 2. Theme of the paper

The present research was carried out under the European Commission (DG-MARE) MARSPLAN-BS Project to provide reliable data and useful information in support of development of a pilot marine spatial plan for Shabla Municipality. The study was focused on the analysis of shoreline movement (at sandy beaches – erosion/accretion) and cliff retreat (at rocky coasts) using the Digital Shoreline Analysis System (DSAS) (Thieler et al., 2009). This is a first attempt to apply such an analysis of shoreline changes and cliff erosion along the Bulgarian coast. The DSAS rates of shoreline change and cliff retreat were verified with preliminary field measurements and cross-checked with the existing hydrodynamics, coastal geology and geomorphology. The most erosion-prone coastal segments along the cliff shorelines in the study area were identified. Through this analysis we aimed to increase the knowledge and understanding of coastal erosion issues in Shabla Municipality and to utilize the best obtained results in mitigation measures of erosion impacts.

## 3. Study area of Shabla Municipality

The study area includes the coastline of the Municipality of Shabla, located along the northern Bulgarian Black Sea coast from Cape Sivriburun on the border with Romania in the north to Cape Shabla in south (Fig. 1). The municipality of Shabla has an area of 329.6 $km^2$ (Kopralev, 2004). It comprises 0.30% of the country's territory. It is bordered by Romania to the north, the Black Sea to the east, Kavarna Municipality to the south and General Toshevo Municipality to the west. The coastal length of the municipality, derived from orthophoto images from 2011, is 33.75 km. The area is rural with a low density of development compared to the southern part of the Bulgarian coast.

The Shabla area is a low plateau, slightly elevated and inclined towards the sea. The area is flat, uniform, gently sloping to the E-SE with an elevation up to 100 m above the sea level. The territory is part of Eastern Danube plain. There are two major geomorphic zones along this coast. The coastline between the Capes of Sivriburun and Shabla is relatively straight and low, with eastern exposure. The coast is generally composed of Upper Sarmatian limestones covered by loess sediments (Philipov, 1991; Cheshitev et al., 1992; Peychev and Stancheva, 2009). The Upper Sarmatian limestones are cut at sea level and below (Peychev, 2004). In this area, cliffed sections at the capes are separated by vast sand beaches bounded inland by few lakes (a type of lagoon): Durankulak (with area of 3.4 $km^2$ and maximal depth 4 m), Ezerets (area of 0.7 $km^2$ and maximal depth of 12 m) and Shabla (area of 0.8 $km^2$ and maximal depth - 9 m), (Popov and Mishev, 1974). Four kilometers east of Shabla town is the Shablenska Tuzla lagoon. These lakes are protected sites under national legislation and the Natura 2000 ecological network, and they are also important bird and Ramsar wetland areas (Stancheva et al., 2016).

The regional coastline is made up of sandy beaches covering 14.43 km and coastal cliffs comprising 17.94 km (9.31 km of loess type cliff and 8.63 km of limestone type cliff) (Fig. 2). In the present study we did not investigate the entire coastline of Shabla Municipality. Five representative sectors were selected, including 3 sectors of large sand beaches and 2 sectors of loess type cliff, that are most prone to erosion (Fig. 1). Coastal defense structures (groins, coastal dikes/rip-raps and seawalls) are few, comprising a total length of 1.38 km. In the most eastern part of Shabla Municipality, at Cape Shabla, a permeable structure (pier) was installed in 1960s and it is currently under renovation (Fig. 2).

South of Cape Shabla, the coast is rocky, composed of shelly, oolitic Middle Sarmatian limestones (Cheshitev et al., 1992). From Cape Shabla to Kavarna town, the coast is high with an active vertical cliff. The height of the cliff gradually increases from 5 to 6 m at Cape Shabla to 60 m by Cape Kaliakra, and then up to 120 m by the town of Kavarna (Peychev, 2004) (Fig. 1).

Much of the territory of Shabla Municipality is occupied by farmland, as the soils are very suitable for growing any crops. The lack of industrial manufacturing, large cities and large tourist resorts near the sea are the reason for relatively low environmental pollution of beaches and nearshore waters.

Four large beaches are located in the study area: Durankulak-North, Durankulak-Krapets, Krapets and Shabla (Fig. 2). Beaches are characterized by calcareous medium sands with high content of $CaCO_3$ (up to 80–90%) due to the supply with fragmented shells from the large mussel fields found in the nearshore (Popov and Mishev, 1974; Trifonova and Stancheva, 2001; Peychev, 2004; Dachev et al., 2005). The nearshore (2 km seaward) underwater slope varies between 0.007 at Cape Sivriburun and 0.023 at Cape Shabla (Stancheva et al., 2016). Large dune systems are developed at the coast between Capes of Sivriburun and Shabla, and in particular near the beach of Durankulak, north from Cape Krapets along the sandy beach and at the coastal area of Shabla-Ezerets. Trifonova and Stancheva (2001) found that generally these four sandy beaches in the study area were stable to accreting, although the cliff sections separating them have been distinguished with the

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