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Geohazard evaluation based on GIS and remote sensing in the context of cliff/bluff erosion vulnerability along the Bulgarian coast

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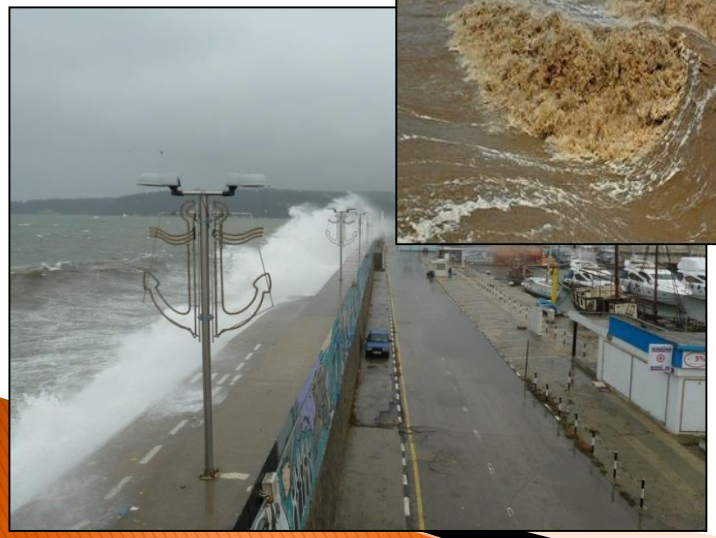
INTRODUCTION: what are coastal geohazards?

Coastal hazards in Bulgaria:

- **Cliff erosion**
- **Landslides**
- **Floods**



INTRODUCTION: Landslides

- Landslides amount to 79 and cover 12% of Bulgarian coast (about 45 km) on an area of 37 km^2
- In the northern portion of the coast (86% of the length and 97% of the area of all landslides), Peychev et al., 2014
- Erosion and impact of surface and groundwater are main exogenous processes affecting the landslides
- Increased role of technogenous factors: undermining and overloading of slopes, flooding by water supply and sewage networks, dynamic loads, especially in the urban, industrial, resort and villa areas along the coast.

INTRODUCTION: Floods

- 20% (83 km) of Bulgarian coast is at low enough elevation to be at risk to local storm surges
- Sites at risk to flooding at projected sea level rise up to 5 m:

  Cities - 14

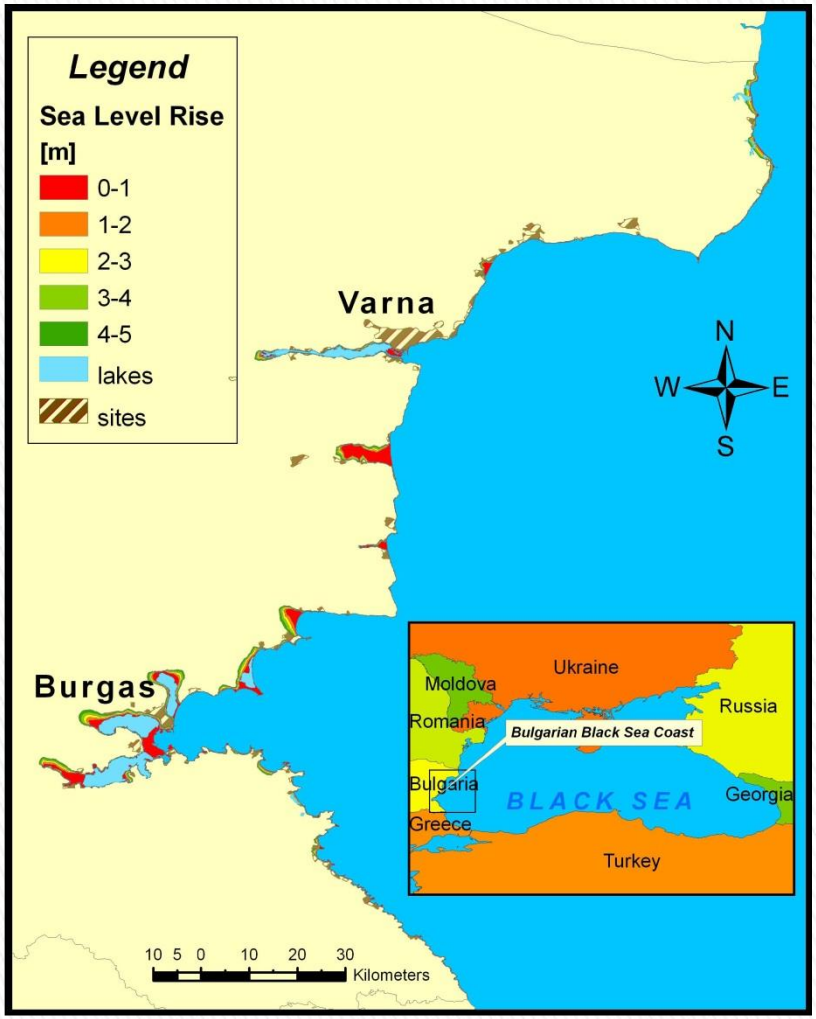
  Villages - 17

  Resorts - 13

  Campsites – 8

- Number of residents affected at 5 m SLR

  About 100 000 from all 549 765 citizens at these sites



Low-laying territories along Bulgarian coast

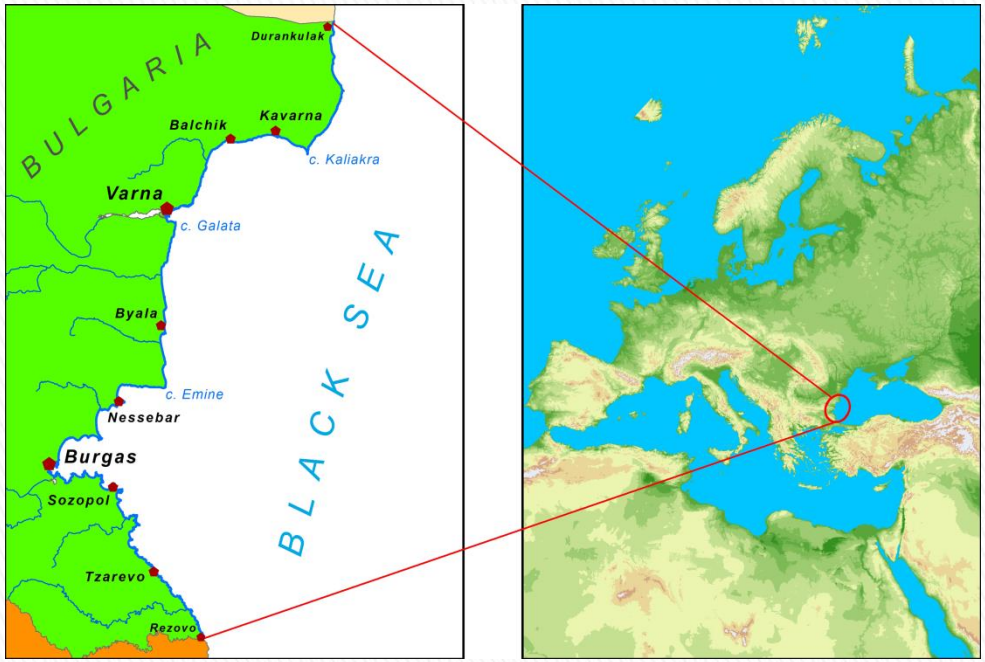
STUDY FOCUS

- **A modern, geomorphic GIS-based classification of the Bulgarian coast has been developed to provide the basis for identifying and evaluating those areas most prone to various coastal hazards.**

- **As an example, a sensitivity map of the Bulgarian coastline to one geohazard, coastal erosion/cliff retreat, was produced from the geomorphic classification, and this predictive map was tested with existing field data.**

STUDY AREA

Erosion and cliff retreat, both natural and human-induced, is one of the main hazards affecting the coast



Bulgarian Black Sea coast

- 60% of 432 km long Bulgarian Black Sea coastline comprises an eroding cliff with mean erosion rate of 0.08 m/y.
- The highest erosion rates of 0.30 m/y is in the north part at the loess coast, while at the volcanic rocks at the south part, the rate reaches 0.01 m/y at least.

(*Peychev and Stancheva, 2009; Stanchev et al., 2013*)

What affects the extent of coastal erosion?

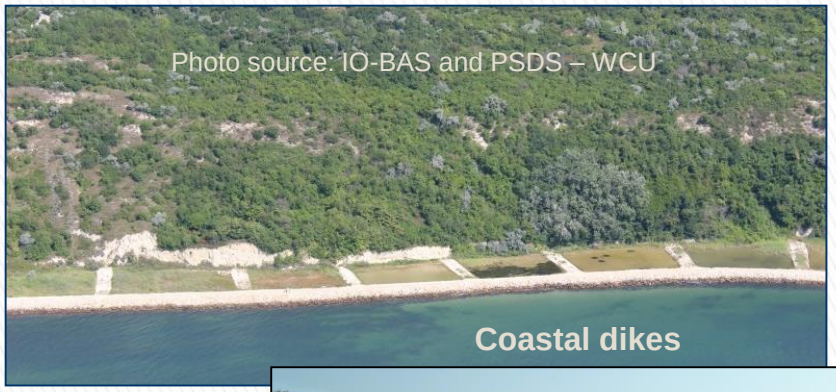
1) environmental factors:

- ✓ geological settings of the coast
- ✓ shortage in sediment supply
- ✓ sea level rise, intensive waves and storm surges etc.

2) factors related to human activities:

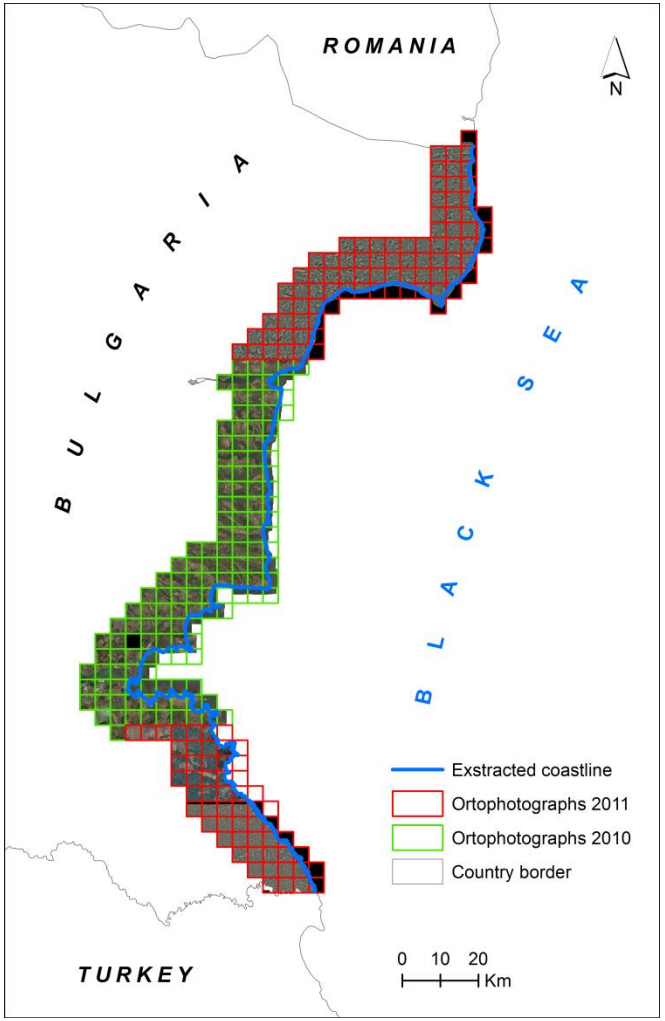
- ✓ coastal urbanization and expanded developments
- ✓ armouring the coastline by hard engineering structures (dikes, seawalls and solid groins)

Attempts to control coastal erosion or coastal protection



The continuing cliff erosion along the Bulgarian coast is being accelerated by extensive human influence in terms of maritime constructions, dredging works and river corrections

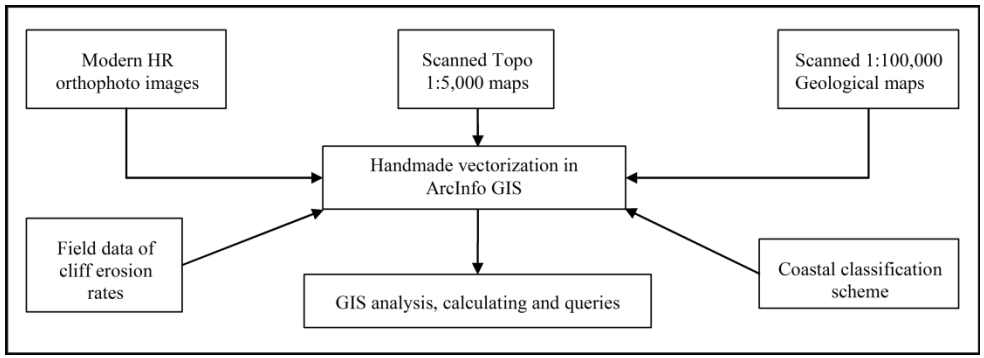
DATA USED AND GIS METHODS



107 orthophoto images cover entire Bulgarian coast

Data of three different sources:

- Topographic maps in 1:5,000 scale from 1983;
- High Resolution (HR) colour orthophoto images from 2010 and 2011;
- Geological maps from 1991/92 in 1:100,000 scale



RESULTS

Geomorphic GIS-based classification of Bulgarian coast

- Geomorphic classification utilized both geomorphological and engineering criteria.

✓ A total of 867 segments were delineated along the coast:

➢ 465 are natural landforms (cliffs, beaches, river mouths) having a length of 362,62 km;

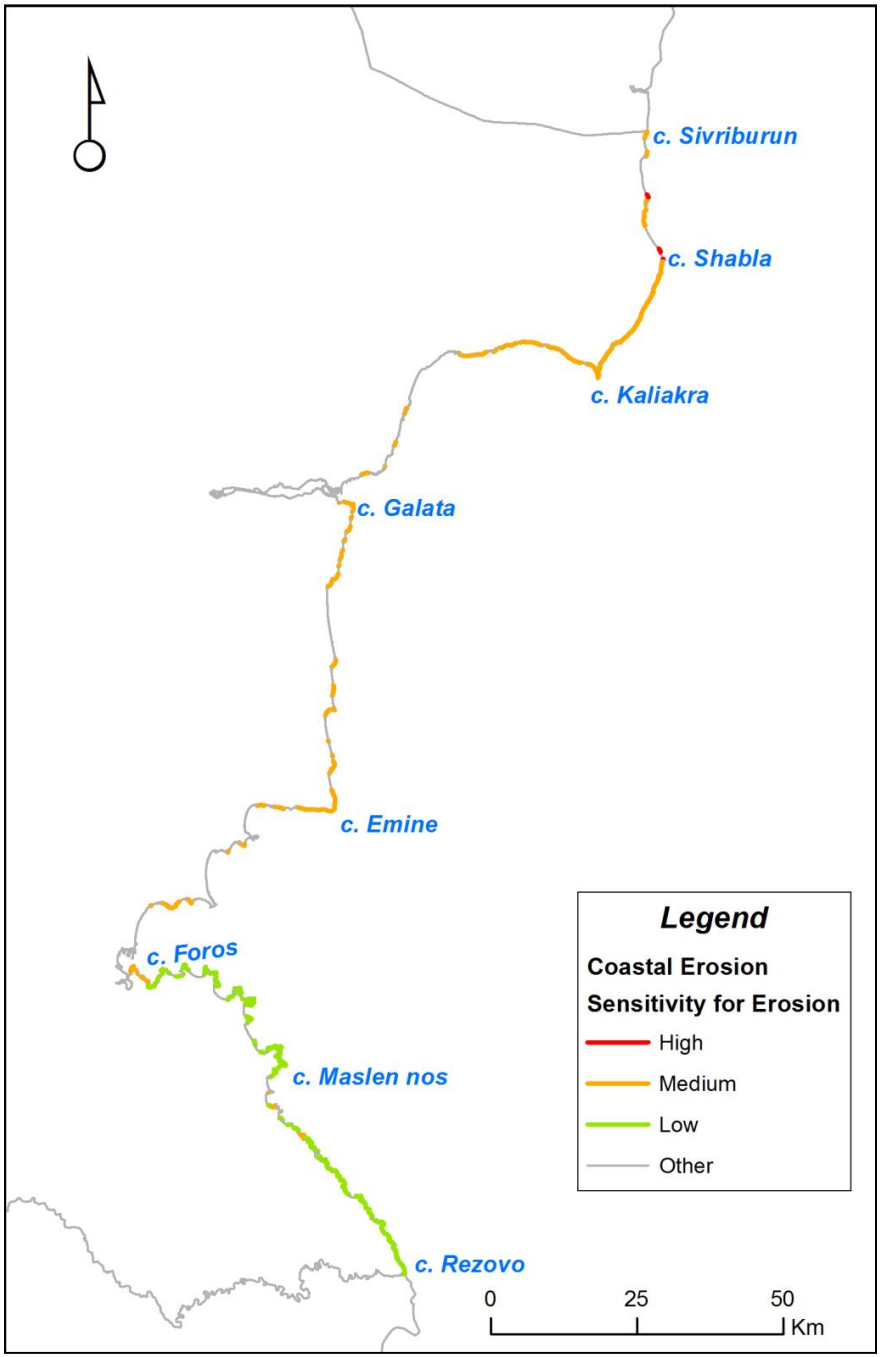
➢ 402 are technogenous segments (port and coast-protection structures, artificial beaches) with a total length of 70 km.

Predictive map of cliff erosion vulnerability

i) **low hazard**: coastal sections made up of volcanic type cliff along the southernmost coast between Capes Foros and Rezovo;

ii) **moderate hazard**: coastal sections made up of limestone type cliff. This includes the coast between Capes Shabla and Foros in the middle part of the Bulgarian coastline;

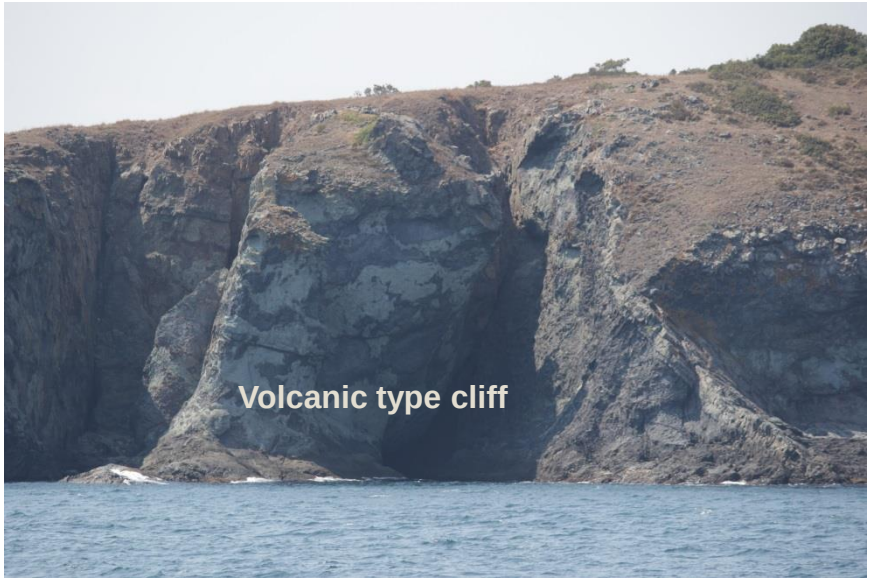
iii) high hazard: coastal sections of loess and clayey type cliff, between Capes Sivriburun and Shabla, and at the area between Capes Emine and Foros.



- The total length of cliff coast is 213 km, with the loess type cliff comprising 1.0% and clayey type cliff 2.5% of the eroding coast.
- Limestone type cliff is dominant and spreads along 107 km or 50.4% of the coastline, and volcanic type cliff occupies 98 km or 46.1 % of the coast.

This classification of cliff vulnerability is supported by field measurements of cliff erosion rates. **According to Peychev and Stancheva (2009), the average rate of erosion of loess sediments is quite high: 0.30 m/y. At certain sites (e.g. Cape Krapetz and Cape Shabla), the erosion rate reaches 1.2-1.6 m/y.**

It is quite high as well as in coastal sections built by clays and sandy clays. The average rate of erosion ranges from 0.19 to 0.29 m/y. The average rate of erosion in limestone type cliff varies between 0.05 and 0.30 m/y. Volcanic type cliff is resistant to erosion and respectively the average rate of erosion is low: 0.01 m/y.



CONCLUSIONS

- A modern, detailed GIS-based segmentation of the Bulgarian coast has been created to provide the basis for identifying and assessing those areas most vulnerable to coastal geohazards.

- The study used HR orthophotos and geologic maps to classify the Bulgarian Black Sea coast into segments based on geomorphic type. These data were then used to develop a predictive model for cliff erosion vulnerability based primarily on the structure and geologic make up of the cliff/bluff sections of shore.

- The predicted erosion susceptibility was verified for a representative number of segments using field data collected previously. Therefore, we assume that map of cliff vulnerability to erosion is valid for all segments identified.

- As the erosion rate and vulnerability of the coastline is constantly changing due to natural and anthropogenic factors, the erosion sensitivity map supported by HR digital orthophotos and GIS methods is very useful in identifying cliff locations along the coast that may be most susceptible to erosion. These areas, especially when coincide with human occupied areas, should be closely monitored.

- Such information will help to guide development planning in coastal areas that might potentially be subject to erosion, storm surge flooding and other coastal geohazards both at the present time, and increasingly in the future in response to projected sea level rise.

THANK YOU FOR YOUR ATTENTION

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