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AN ANALYSIS OF THE DYNAMICS OF THE ENVIRONMENTAL PARAMETERS IN THE ROMANIAN NEARSHORE OF THE BLACK SEA

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ABSTRACT

Due to the global climate change the strong storms that occur in the Romanian coastal environment are more powerful and, although, somehow shorter in time, they have a higher frequency of recurrence. The changes in the vulnerability characteristics of natural habitats and touristic coastal areas were analyzed together with the impact of the coastal protection infrastructures. Most of the above mentioned changes are caused by extreme anthropogenic / natural factors that occur at different intervals in time. The main modelling factors of the coastline are the waves and they depend on the meteorological factors and on the local topography of the Black Sea bottom. The present work is based on the analysis of the data acquired from multiple data collection campaigns that span for a fifty year period, from 1962 to 2012. After the data processing, the results show that the erosion process is greater than the accretion phenomenon. Another conclusion is that the climate change induces a more active dynamics in the coastal environment and it seems that the western side of the Black Sea is the most affected part of the sea basin. The work is still ongoing and further analyses and correlations with other data sources are currently made.

Keywords:: Black Sea, Romanian nearshore, wind, waves, currents, coastal dynamics

1. INTRODUCTION

One of the most important environmental parameters, having the biggest negative impact on the Black Sea coastal infrastructure, is the erosion process. In the recent decades, this process has affected the Romanian shore, by slowly diminishing large areas of sandy beaches. In the last 50 years, between 1962 and 2012, in the northern part, the Danube Delta shoreline has changed due to the coastal processes that are showing a great increase in erosion. This is linked to an unbalanced sediment budget caused by the construction of two hydroelectical dams along the Danube river and the river navigation infrastructure that ends in the Black Sea, at Sulina.

The environmental parameters that leave their mark along the 244 km of Romanian Black Sea shore, which is about 6% of the Black sea coastline, do not have always natural causes. The causes for the erosion process are induced by anthropogenic factors and they cannot be solved easily or right now. One way to deal with this problem is to nourish with sand and build different coastal structures (submerged dikes or groins) to keep the sand nearshore. The cause of this problem cannot be dealt with right now as the sediments that were usually supplied by the Danube river are stopped by the two dams (Portile de Fier I and II).

The Romanian coast is split into two geographical sectors: the Northern Sector and the Southern Sector.

The Northern Sector has a length of approximately 170 km and it is characterized by the Danube Delta, which is a major part of the coast line, it stretches from the Ukrainian border to the Midia Port. Because the Danube Delta encompasses so much of the Northern Sector, the sector is characterized by lagoons and low lands that, in general, do not exceed the height of 2 m [1], [2].

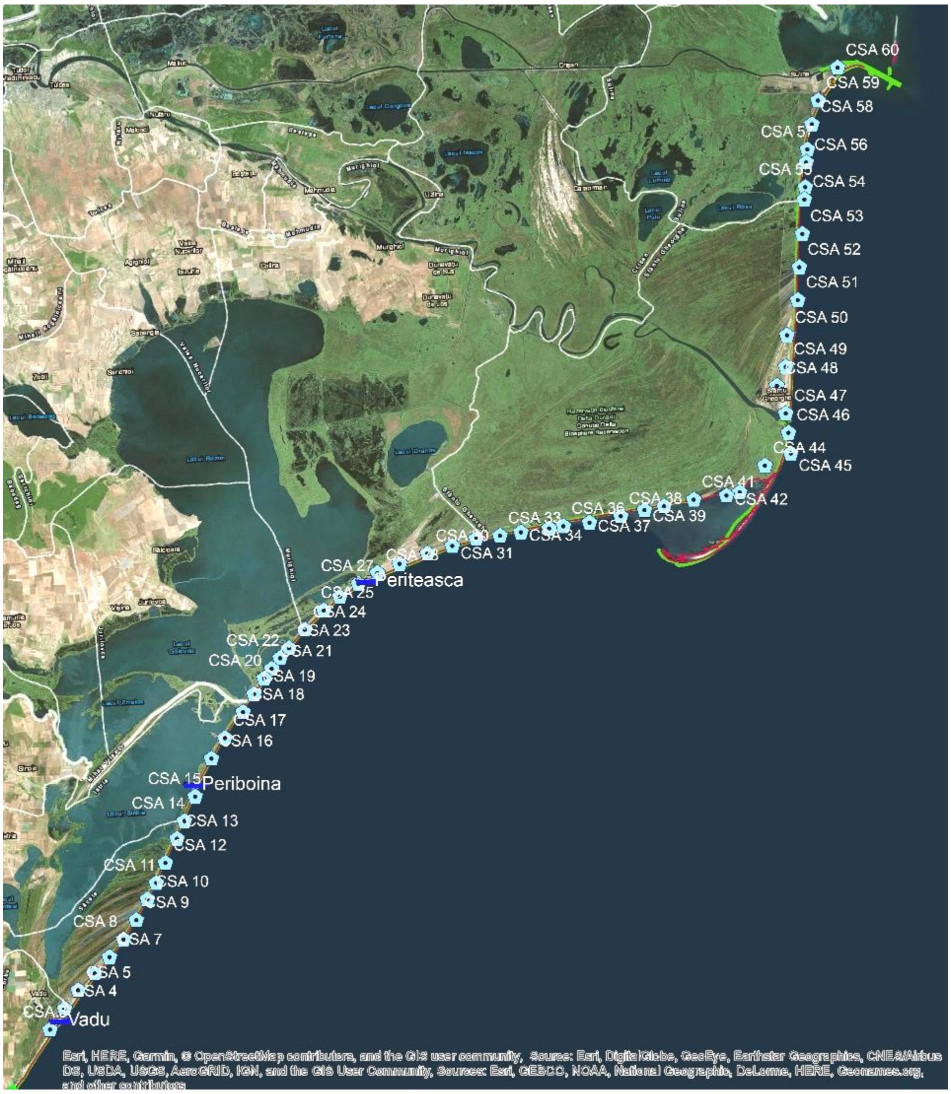


Fig. 1. The landmark topographic system on the Northern Romanian Littoral, as installed in 1961

The Southern Sector has a length of approximately 74 km and it stretches from Midia Port to the boarder with Bulgaria. This sector is characterized by high terrains, with cliffs that have a maximum height of 80 m in the region of Constanta Harbour. As comparing to the Northern Sector, the Southern Sector has small beaches with a lot of coastal protections, as in some parts the beach completely eroded and the waves smash directly at the bottom of the cliffs.

The erosion processes and its extension along the Romanian Black Sea coast have been observed since 1962 The study is based on a topographic network of concrete landmarks, which span about 140 km in length and were distributed along the shore in the Northern Sector in the Danube Delta Biosphere Reservation, in 1961 (Fig. 1). In the Southern Sector, the monitoring started in 1980, after the first topographic network was installed in this area [3].

Due to the ample erosion process in this northern sector, many landmarks were lost but, based on the geographical coordinates of the network, some of them were installed and are still in use today, for coastal monitoring.

Due to the ample erosion that affected a large part of the northern sector (about 115 km), numerous protection measures have been taken to combat this process since 1962, action that was driven by the State Water Board at that time.

As for the Southern Sector, because of the geological structure, the geomorphological processes are quite stable and the hydrotechnical constructions are preventing the erosion processes.

In the past, the State Water Board implemented many projects to protect the shore from eroding away. The first project was implemented in 1936 - 1940 and it continued several years later in an effort to protect the coast, in 1956-1960, 1967-1970, 1981-1985 and 1989-1999.

In the present day, the Masterplan has been implemented along the Romanian shore by building and rebuilding breakwaters and dikes, beach nourishment and cliff consolidations [4], [5].

Fig. 2. The Landmark topographic system on the Northern Romanian Littoral, installed in 1980

Fig. 3. Old dike system before the Masterplan

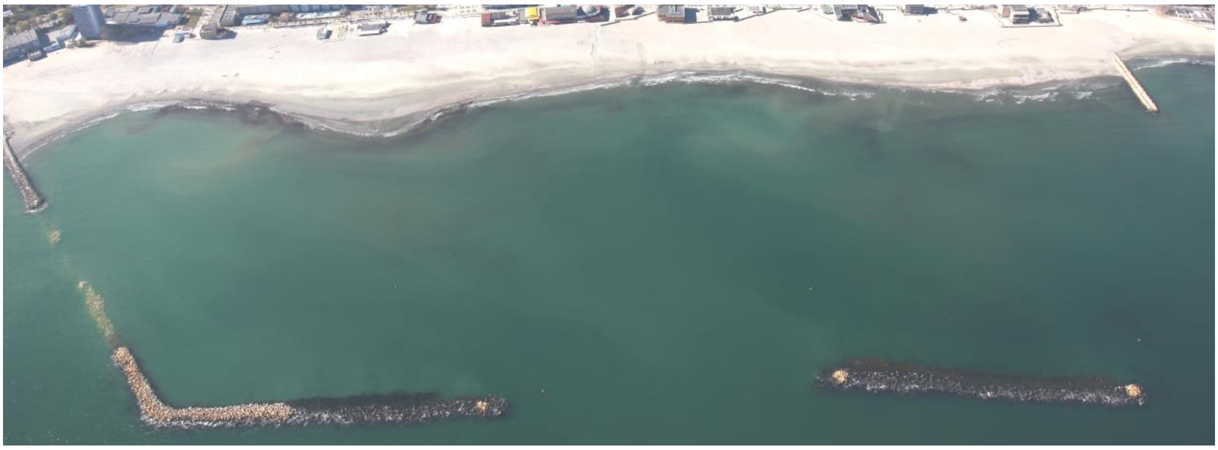


Fig. 4. Dike reconstruction and beach nourishment in the south of Mamaia resort

Fig. 5. Dike reconstruction and enlargement alongside with beach nourishment in Eforie North

In the erosion process, an important role is played by the wind that generates the waves and, if the wind would blow in a certain direction for a long period of time, it can change the surface current direction [6], [7]. Several studies have been done on the subject of coastal protection by modelling wind, waves, currents and sediment transport along the coast, in order to provide a better understanding in what spots should the protective dikes be built and what would there impact be on the coastline [8], [9], [10], [11]. The new dike system and sand nourishment were implemented in 2015, in several spots along the Romanian coast, like South Mamaia Resort (Fig. 4), Constanta coastline (Fig. 5) and Eforie Nord coastline (Fig. 6).

Fig. 5. New dike system constructed and beach nourishment at Constanta

Even if the Black Sea is not so large, the storms that hit the coast are strong and they can disrupt the nearshore navigation and stop the activity of the ports along the coast [12], [13]. The risk is considerable when it comes to such storms because they can cause marine and coastal hazards [14], [15]. For future innovative coastal protection measures, some marine energy farms could be considered as they can absorb/decrease/dissipate the wave energy that causes the erosion [16], [17]. These wave energy farms can be installed in particular spots that are in need of a protection scheme and, by doing so, the outcome could be also beneficial form a socio-economic point of view [18], [19]. The wind-wave interaction could also affect the high waves, and thus, offshore wind energy farms effects – directly or mediated by the implied support structures – are to be considered.

2. METHODOLOGY

Due to the fact that the long term morphology data were in the shape of maps, they had to be geo-referenced to compare the changes between the new measured shoreline data and the old shoreline ones that resulted from the historical maps.

The data sources for the new shoreline measurements are from satellite images and GPS measurements to show the trends, either long term or short term. To map the collected data, a mapping software was used, having high precision. Because the topographic landmark system is digitized, new data or shoreline changes can be monitored solely on this, making transects from the landmarks to the new shoreline, tracking its morphological progress through time. This, in turn, provides the basis for a shoreline vulnerability classification and future trends if no action would be taken when it comes to erosion.

The measurements for the study were processed in a systematic way. The geo-referenced maps were obtained using ArcGIS 10 software with the help of different spatial analysis tools to digitize the data in a referenced environment. That permitted the assessment of the shoreline geo-morphological changes when comparing the new shore line measurements with the historical map. The map of the State Water Committee was referenced in the projection Stereo 70 National Grid.

The shoreline measurements/mapping are done annually if possible with GPS instruments that are in a GIS class, but for the maps in this paper only three shorelines were used, from 2012 for the one in Fig. 7 a) and 2007 with 2016 Fig. 7 b).

3. RESULTS

As the shoreline morphology changes it affects the socioeconomic activities due to the damage induced to the national heritage and different buildings. Because the coastal infrastructure (fisheries and restaurants) is always growing it has an important role in how the coastal ecosystems or marine protected areas are affected.

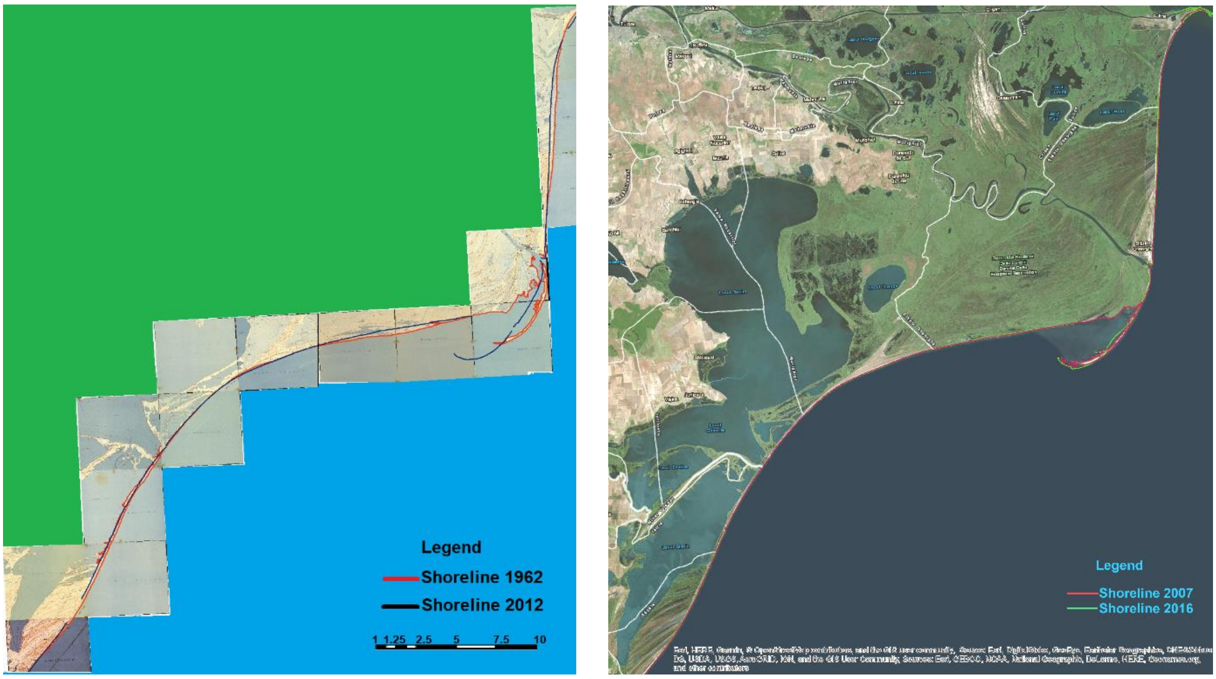
In the Northern Sector, the shoreline lost the biggest amount of land which is equivalent to 2600 hectares that is approximately 50ha/year. Whereas the accretion record sums only 350 hectares, approximately 7 ha/year. The result is a loss in sediment of 2250 hectares.

When considering sub sectors, between Sulina and Sf. Gheorghe the loss was of about 790 hectares, Ciotica and Perisor lost 730 hectares, Perisor and Periteasca lost 12 hectares and Periteasca and Grindul Chituc lost 360 hectares.

The result of this coastal monitoring showed that the most active area to erosion/accretion is in the northern sector between Sulina and Sf. Gheorghe. Here the interface between the land and the sea fluctuates the most, approximately 500m. The shoreline where the accretion persists is between Perisor and Periteasca.

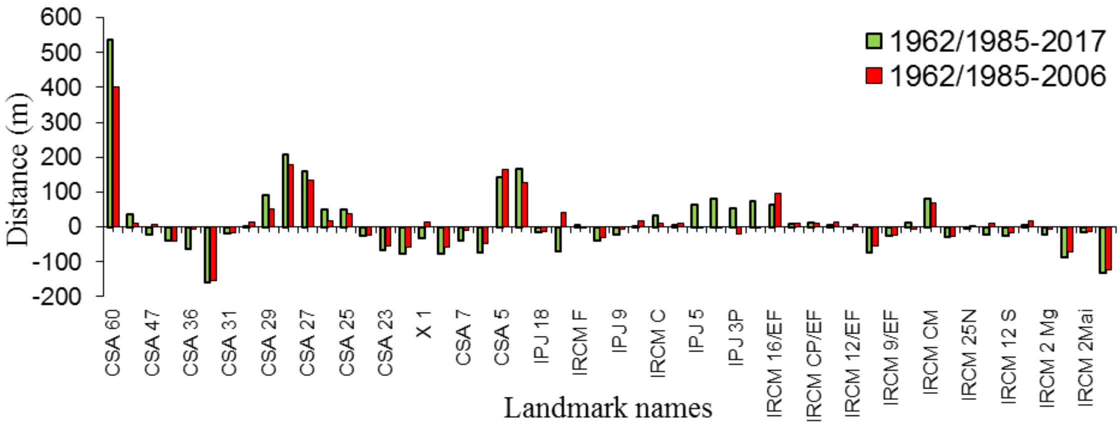
The northern topographical landmark system has seen better days, as only 18 remain and are still in use today, from all 60 that were installed. Many landmarks have been lost due to the intense erosion process that had engulfed them alongside with a portion of the shore. In the south part of the Northern Sector two landmarks (CSA 1 and 2) are off access as they were installed in a militarized with no access. Therefore, no measurements were made using the two landmarks. Even so the remaining network sustains the monitorization process at a yearly interval or in some cases seasonally in order to catch the geo-morphological changes after a big storm that can impact the coast at high level.

A comparison between the shorelines from 1962/1985 to 2006 and 2017 shows the rhythm of evolution between the two periods (Fig. 7). This also gives some visual information about how the shore looks. In general the difference is small as the period between the two shorelines are not for apart only 11 years. Because the Masterplan was finalized during this period the regions where the sand nourishment was done are significantly greater (IPJ 5 to IPJ 2) from the normal shoreline evolution.

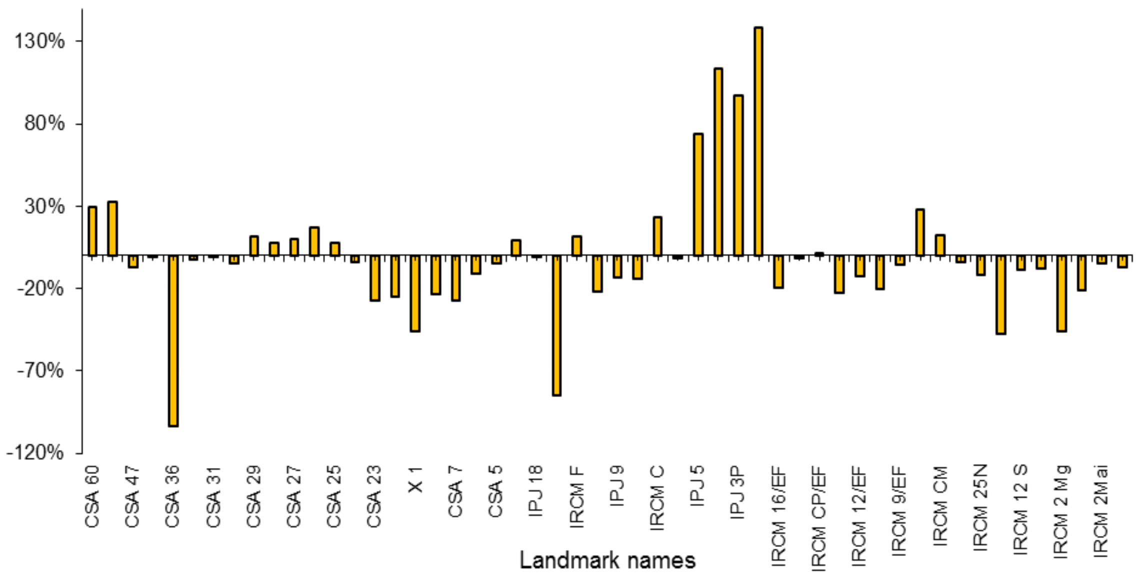


a) b)

Fig. 6. Shoreline modifications between 1962 -2012 a) and 2007 – 2016 b)



Graph 1 – Accretion and erosion values along topographic network for two time periods



Graph 2 – Percentage result between the two time periods

Fig. 8. Evolution of the shoreline

In the second graph (Fig. 8), the percentage difference reflects, as an even better perspective, the natural evolution of the shoreline, from the artificial sand nourishment. In the northern part the first two topographic references, a 30% accretion have been seen, which is equivalent to 135.3 m or approximately 12 m/year, for the first one and 24.7 m or 2.2 m/year for the second one. There are also two extreme cases where the shoreline retreated 104% (CSA36 or Ciotica – Perisor sector) and 85% (IPJ 15 or northern part of Mamaia) in these 11 years. The rest of the coastline was subjected to natural conditions.

The greatest accretion process has been in the northern part of the Danube Delta because of the Sulina jetties, the shoreline has moved in the detriment of the sea by 172 m, in the past 50 years, whereas the shoreline on the northern part of the Sf. Gheorghe channel has remained almost the same. An explanation could be that, due to the higher current velocity from North to South, the sediment is pushed along the shore, forming the Sacalin Island. By assessing the evolution of the coast in this region as it forms a parabolic shape, and by analyzing the structure of the Danube Delta, the Sacalin Island will be, most likely, connected with the shore, in the future, creating a new lake.

Due to the fact that the general direction of the current is from north to south and that after it passes the Sacalin Island the current velocity slows down, it gives a chance to sediments to deposit on the bottom, elongating the island more but, because of the way that the island is forming farther south, the shoreline is eroding. The coastline reacts to this phenomenon as it retreats in some cases by 200 m to 350 m, in the Ciotica- Perisor sector. Going further south, the erosion is slowly decreasing as, between Pariteasca and Chituc, the shoreline eroded by approximately 180 m.

The CSA 51 landmark in the photo is taken in 1983, 11 years after it was installed, nowadays the landmark is not in use because is in the sea (Fig. 9).

Fig. 9. CSA 51 landmark in the surf zone

4. CONCLUDING REMARKS

In conclusion, the sand deficiency in some areas (Mamaia and the South Sector of the coast) is caused by the low sand budget, as a considerable amount is captured by the hydroelectric dams that are built on the Danube River, the port constructions and their lengthened outer protective dikes (Midia, Constanta) cause the sediments to be pushed offshore, stopping the natural transit of the sedimentary stream along the shore to the south.

Furthermore, due to the construction of the Sulina jetties, the current circulation has been affected the region, thus slowing down the current velocity, allowing the accretion to take place and creating an island that can disappear under the sea or get smaller and reappear with a different shape, depending on intensity or severity of storm waves.

The highest recorded accretion value is about 600 m and it was determined by analyzing the differences that resulted from multiple shoreline measurements. This value was obtained in front of CAS 50 landmark, which is near Casla Vadanei.

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