Evaluation of Shoreline Dynamics Analyzing Spatial Temporal Data

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ABSTRACT

Shoreline change is considered as one of the most dynamic processes in the coastal regions. Shoreline spatial location mentions to several different features such as vegetation line, high water line, low water line, or the wet/dry line. They can be generated from a variety of spatial temporal data sources, like satellite imagery, digital orthophotos, historical coastal-survey maps and field observed spatial data using Global Positioning System. The undertaken work focuses on analysing shoreline dynamics, using spatial temporal data, by taking advantage of Geographic Information System (GIS) and Remote Sensing (RS). Multi year's shoreline mapping is a valuable method for shoreline monitoring and assessment.

The study area extends from the Port of Shengjin (North), to the delta of Drini river (South), a segment of Drini bay shoreline with a length of about 17 km. The available data used to generate shorelines spatial location include topographic maps at scale 1: 75 000, year 1918 (MGI); topographic maps at scale 1: 50 000, year 1937 (GMIF); topographic maps at scale 1: 25 000, year 1985 (AGMI) ; digital orthophotos of year 2007 and field observed GPS data, year 2014. The net rates of variations NSM (Net Shoreline Movement) of the shoreline position are calculated according to transects inclined perpendicularly to the baseline and spaced equally along the coast using DSAS (Digital Shoreline Analysis System). NSM represents the distance between the oldest and youngest shorelines.

Analyses of the data shows that 35% of coastline of study area is in accretion process meanwhile 65% is in erosion process. Maximum rate of erosion is near to the mouth of Drini river with 10-12m/year in the last years, in average 7.5 m/year in the north side and 4 m/year in the south side of the river delta.

***Keywords**: coastal erosion, shoreline dynamic, spatial temporal data, Net Shoreline Movement.*

INTRODUCTION

Management of coastal zone and its setting require the information about shorelines and their variations through the time. There are several methods to calculate the rates of shoreline. The progress of GIS technology has facilitated the development of some applications for shoreline change analysis. Besides some traditional computation from modelling, GIS also support effective methods for monitoring shoreline position. Using the tools of GIS (Geographic Information System), the rates of shoreline change would be quickly determined for a regional area. Through the input data from extracted shoreline information from historical maps, as well

as by orthoimagery, GIS tool can be used to calculate long-term shoreline change rate. This method is very effective because it would save time and costs [1].
To analyse shoreline evolution and its trends, is necessary to have a definition of the term "shoreline". Having in consideration the dynamic nature of this boundary, the definition should consider the shoreline in two dimension, a spatial dimension and temporal one. In this work, the shoreline position was defined as the water line at the time of the mapping because the study area has been considered to be located in a micro tidal environment [2]. Detection techniques vary depending on the data source and the chosen shoreline definition. With historical shoreline data input, the erosion and deposition rates can be estimated by overlaying using GIS tool. The rate of shoreline change can be calculated by DSAS (Digital Shoreline Analysis System), an extension for ArcGIS. DSAS is a digital shoreline analysis tool that can be used to compute rate-of-change statistics for a time series of historical shoreline data which is developed by United States Geological Survey (USGS) [3]

STUDY AREA

Study area (Figure 1) is part of the Drini Bay, between the 41°41' 34" N to 41° 48' 49" N latitude and 19° 33' 47" E to 19° 36' 09" E longitude. The shoreline segment between port of Shengjin and delta of Drini River is characterized by the presence of the Kenalla lagoon where sand dunes are developed along the beach. The shoreline segment from Cape of Shengjin to the south extreme of the Drini delta has a total length of 17 km, from which 220m is the width of the river delta [4].

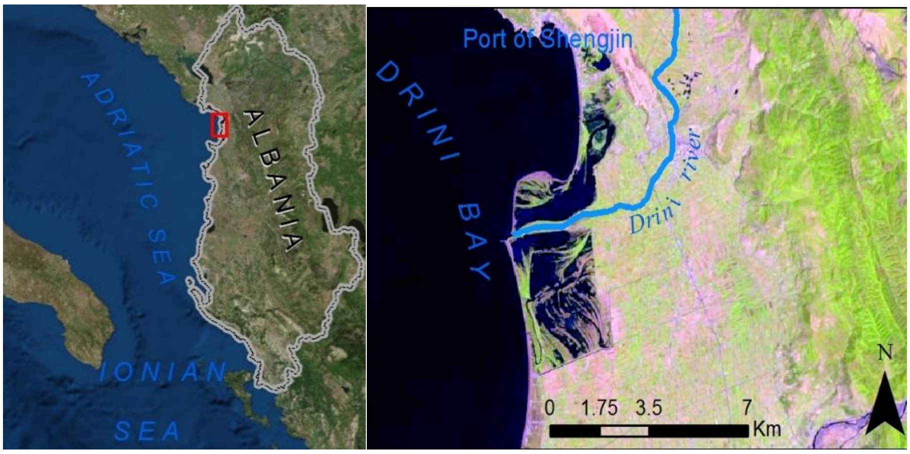


Figure 1 Satellite image of the study area

DATA SOURCE AND METHOD

To map and evaluate shoreline dynamic we have used different type of spatial data source (Table 1);
Topographic maps of year 1918, bassed on Bessel ellipsoid and Gauss-Kryger projection, at scale 1:75 000 with scaning resolution 7.5 m.
Topographic maps of year 1937, bassed on Bessel ellipsoid and Bonne projection, at scale 1:75 000 with scaning resolution 5 m.
Topographic maps of year 1985, based on Krasovsky ellipsoid and Gauss-Kryger projection, at scale 1:25 000 with scaning resolution 2.5 m.
Orthoimagery year 2007, spatial resolution 0.35 m, bassed on WGS 1984 ellipsoid and UTM projection.

Field survey data (GPS data), year 2014.

Table 1 Data Source Used to Evaluate Shoreline Dynamic

Year	Data source	Map scale	Ellipsoid	Projection type	Scanning resolution	RMSE (m)
1918	Topographic Map (MGI)	1:75 000	Bessel 1841	Gauss-Kruger	7.5 m	18.5
1937	Topographic Map(GMIF)	1:50 000	Bessel 1841	Bonne	5 m	11
1985	Topographic Map(AGMI)	1:25 000	Krasovsky 1940	Gauss-Kruger	2.5 m	6
2007	Orthoimagery	1:2 000	WGS 1984	UTM	0.35 m	2
2014	Field survey data	GPS data	WGS 1984	UTM	-	2

GPS=Global Positioning System, RMSE=Root Mean Square Error

All vector files of the shoreline are converted to the same coordinate system and projection: Universal Transverse Mercator (UTM), WGS 84, zone 34N. The rate of evolution of shoreline was then calculated between two successive data, as well as the net rate of erosion over all the time period of the survey. The workflow process of calculation of NSM (Net Shoreline Movement) is completed using DSAS (Digital Shoreline Analysis System) as it is represented on the diagram (Figure 2). NSM represents the distance between the oldest and youngest shorelines (Figure 3). If this distance is divided by the number of years elapsed by two shoreline position between the earliest and latest measurements (i.e, the oldest and the most recent shoreline) the results is EPR (End Point Rate, Figure 3). The EPR parameter shows the mean annual rate of shoreline movement. The major advantage of the EPR is its ease of computation and minimal requirements for shoreline data (two shorelines).

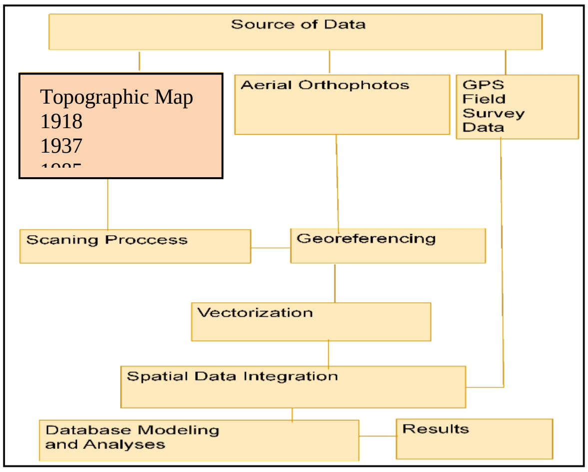


Figure 2 Schematic Workflow Chart

EPR = NSM /(time between the oldest and youngest shoreline) (Figure 3).

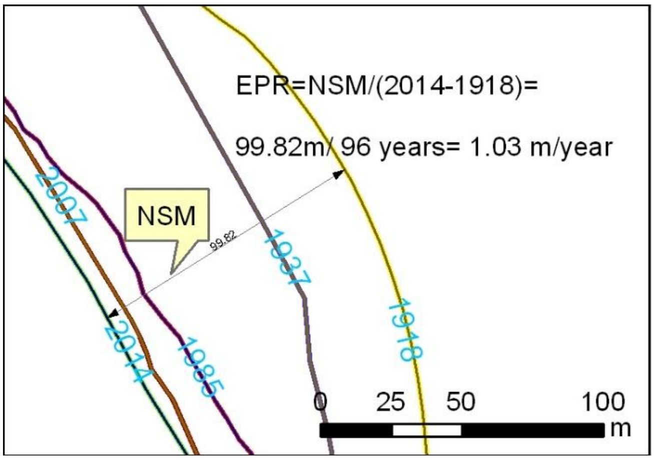


Figure 3 Net Shoreline Movement (NSM) and EPR at selected point.

RESULTS AND DISCUSSION

Evolution of the shoreline shows that solid sediments eroded to the delta of river have been transported and deposited towards the north of the delta (Figure 4, 5, 6, 7). The strong dynamic of sediments during the last years has caused a large advancement of the shoreline, increasing the surface of littorals on the north side of delta. Evolution of this shoreline segment has been influenced by the reduction of sediments transported by the Drini i Lezhes river, as result of deviation of the main stream of Drini river [5,6]

It is evident that, excluding time interval between 1937 and 1985, erosive processes are predominant. For each shoreline extracted, the total area lost by erosion is larger than the area gained to accretion.

For the period of time 1918-1937 (Figure 4) results high rate of erosion, where the area of eroded land is 3.15 ha/ year. The annual rate of erosion varies from 1- 16 m/year. During this period the 63% of shoreline segment is under erosion process.

During the second time interval considered in this study 1937-1985, the results indicate a positive balance in favor of accretion process with 0.53 ha/year (Figure 5).

On the time interval 1985-2014 the results indicate a negative balance in favour of erosion process with 1.6 ha/year. From 1918 up to 2014 the accreted area has a total surface of approximately 160.36 ha and the eroded area has a surface of 240.92 ha, resulting in total with a negative balance of 80.56 ha (Table 2, Figure 6, Figure 13, Figure 14).

Table 2 Rate of Erosion and Accretion

Period	Erosion (ha)	Accretion (ha)	Balance (ha)	**ha/year**
1918-1937	107. 46	47.56	-59.9	**-3.15**
1937-1985	90.09	115.79	+25.7	**+0.53**
1985-2014	89.77	43.62	-46.15	**-1.6**
1918-2014	240.92	160.36	-80.56	**-0.83**

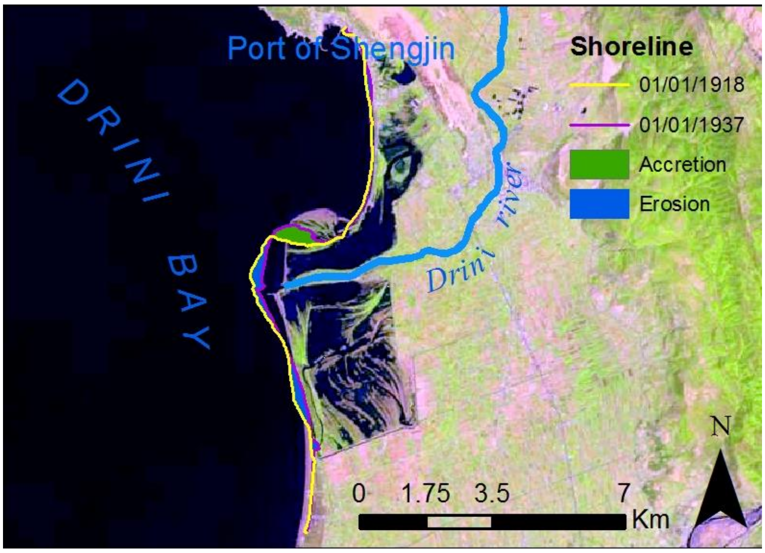


Figure 4 Map of erosion and accretion during period 1918-1937

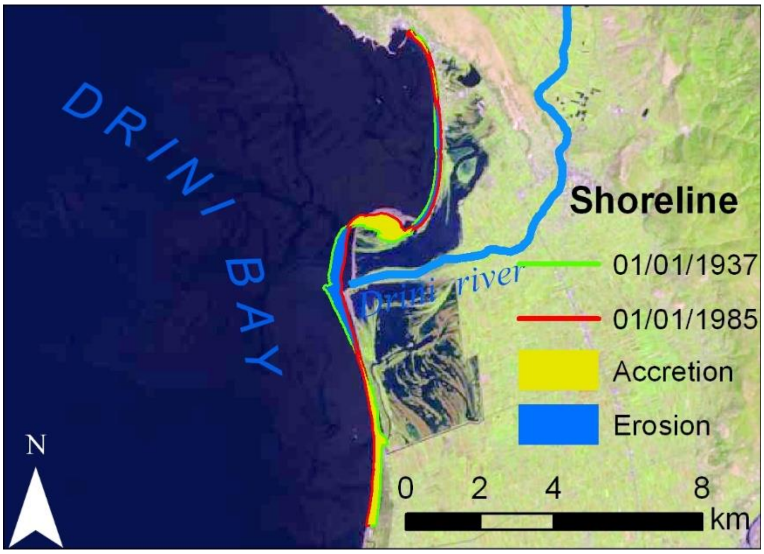


Figure 5 Map of erosion and accretion during the period 1937-1985

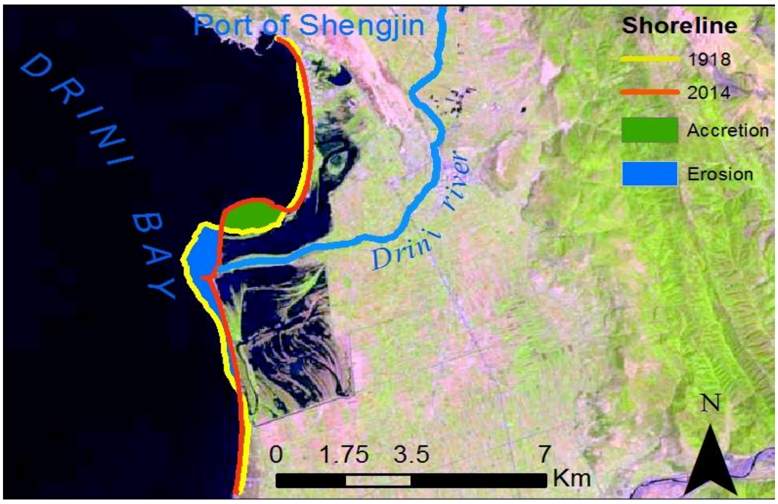
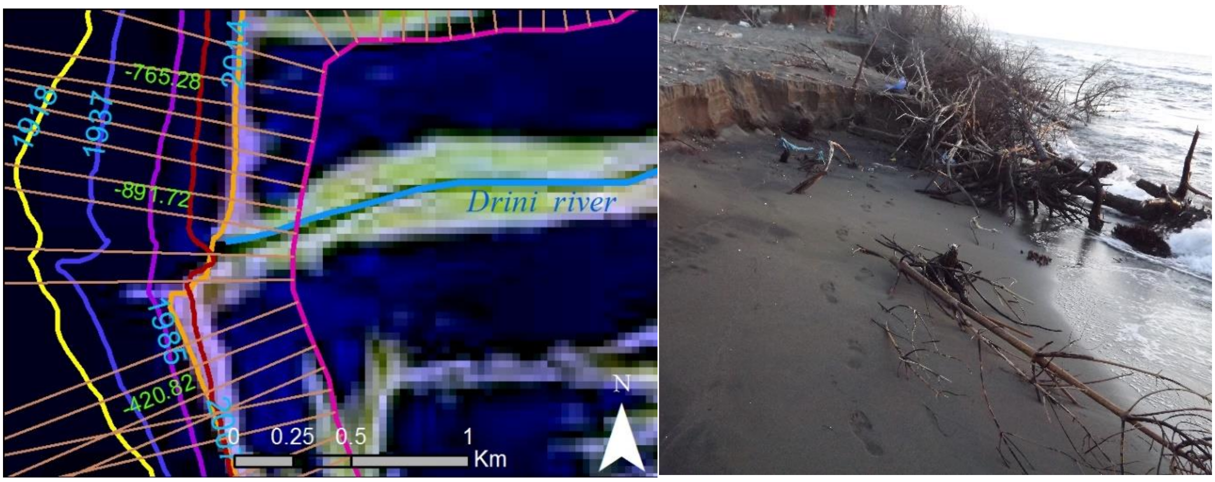


Figure 6 Erosion and accretion during the period 1918-2014

The variation between two successive shorelines in time was calculated as the ratio between the shoreline movements along each of the 160 transects and the time elapsed between them. The main changes in shoreline position (in meters per year) during the four time intervals considered (Figure 8, 9, 10, 11,12, 13) were as follows:
Evaluation of the 1918 and 1937 shorelines (elapsed time 19 year) showed an erosion rate which varies from 1 -16 m/year with a maximum reached in the north side of Drini river's delta (Figure 8). Evaluation of the 1937 and 1985 shorelines (elapsed time 48 year) showed an erosion rate which varies from 0.5-6.5 m/year (Figure 9). Evaluation of the 1985 and 2014 shorelines (elapsed time 29 year) showed an erosion rate which varies from 1-12 m/year (Figure 10). Estimation of shorelines for the entire period considered 1918-2014 (elapsed time 96 year) idicate erosion rate which varies from 1 m-9.5 m/year, with a maximum reached in the north side of the Drini river delta (Figure 11, Figure 14).



A B

Figure 7 A) Evolution of shoreline position at the Drini river's delta for the period 1918-2014; B) Photo (September 2014) of the coast at the North side of the delta

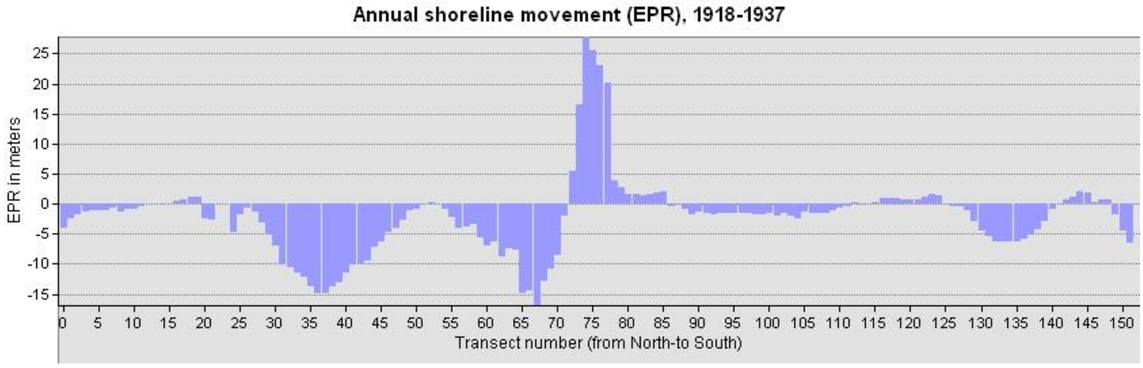


Figure 8 Annual shoreline movement for the period 1918-1937

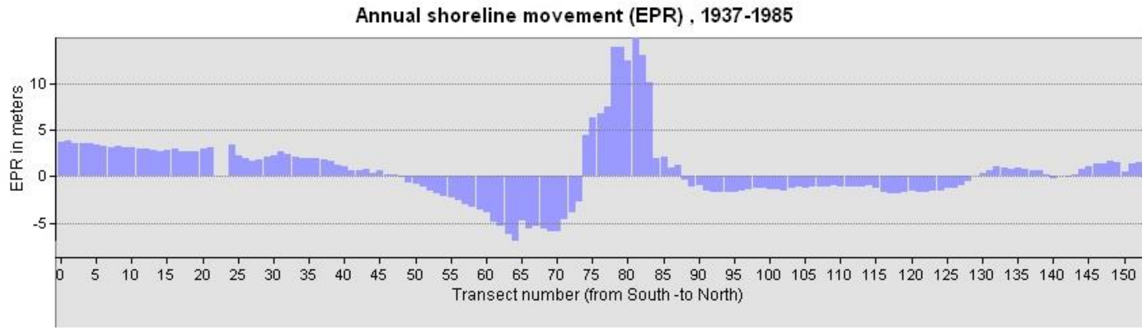


Figure 9 Annual shoreline movement for the period, 1937-1985

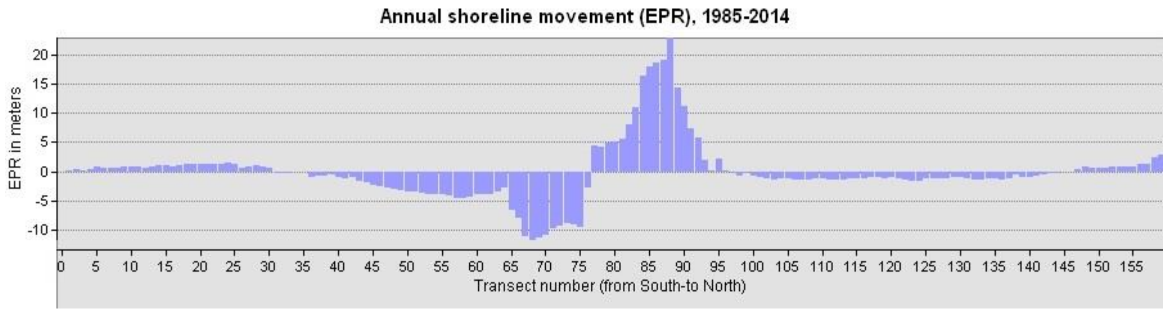


Figure 10 Annual shoreline movement for the period, 1985-2014

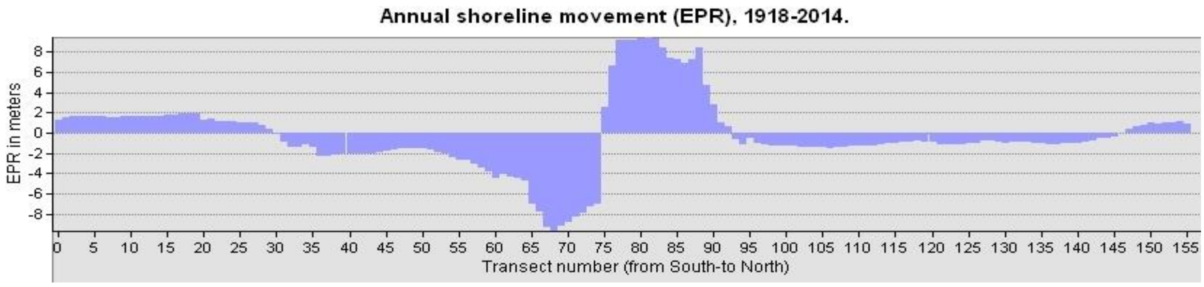


Figure 11 Annual shoreline movement for the entire period, 1918-2014

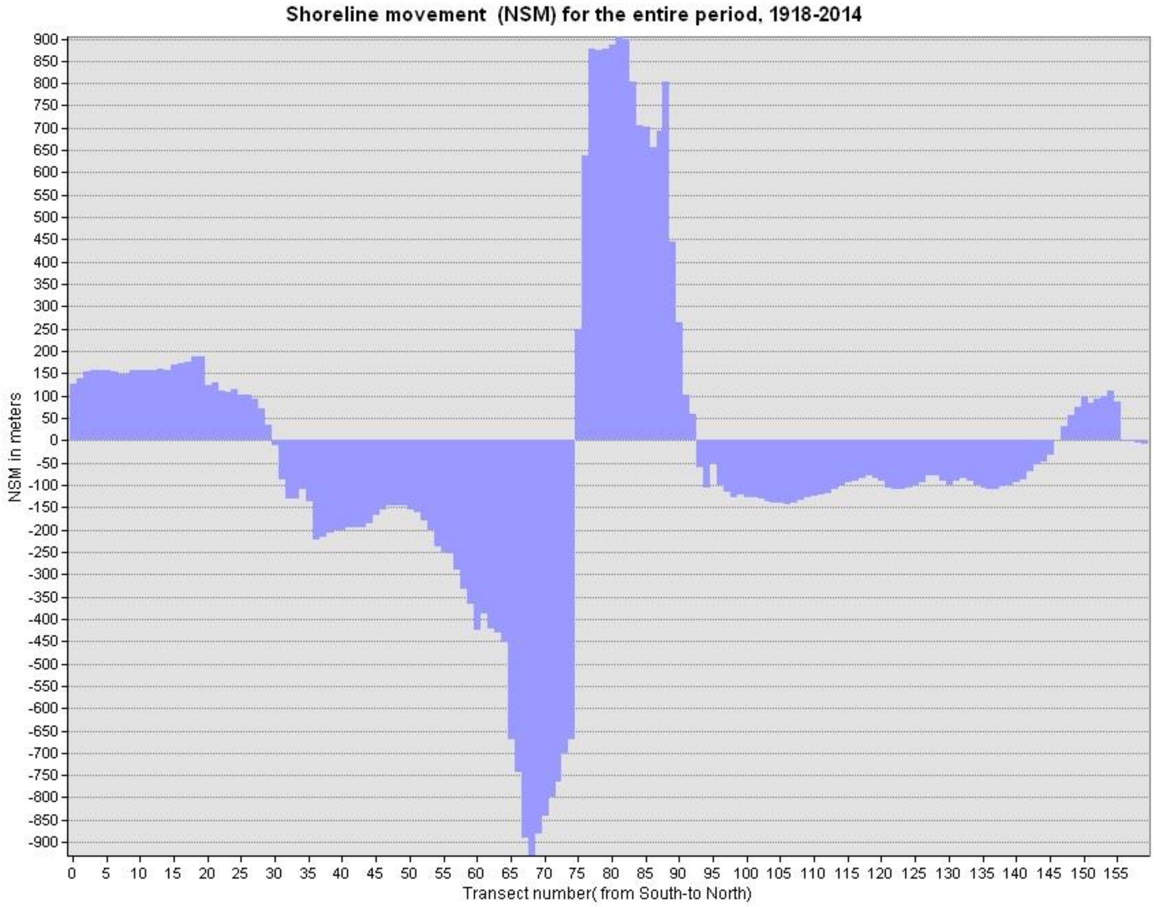


Figure 12 Shoreline dynamics during the period 1918-2014

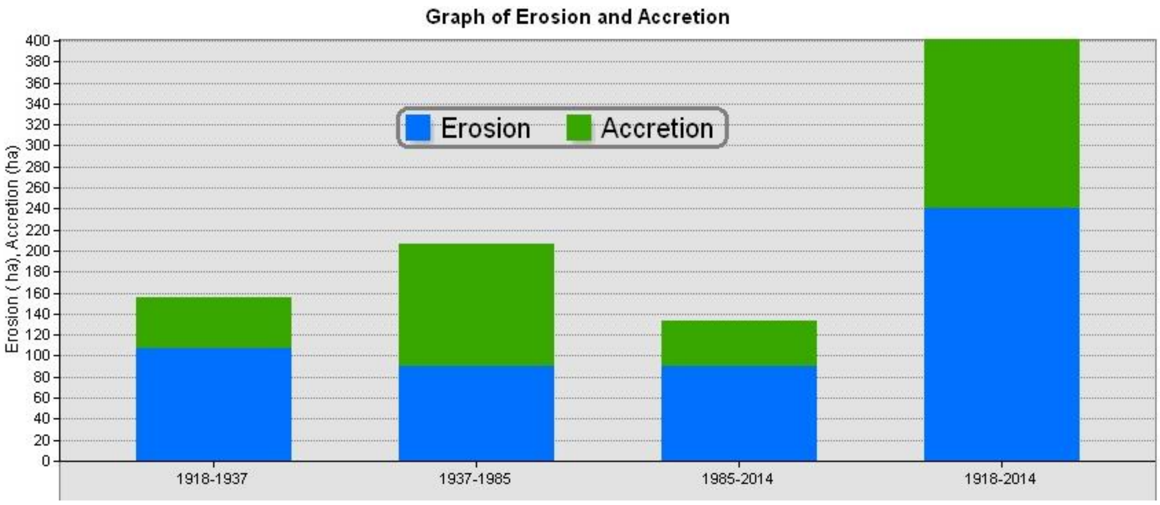


Figure 13 Ratio between erosion and accretion

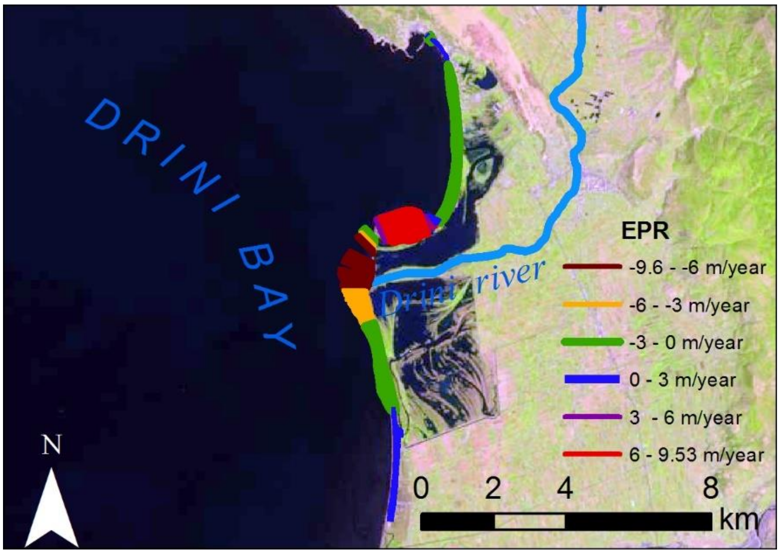


Figure 14, Map of shoreline dynamics

CONCLUSION

In this study the results show that 35% of the coastline of the study area is in accretion process meanwhile 65% is in erosion process. Maximum rate of erosion is near to Drini river's delta ,10-12m/year in the last years and in average 7.5 m/year in the north side and 4 m/year in the south side of the river's delta. The evaluation of shoreline variations occurring in all four investigated time intervals highlighted the variation in the shoreline rate from 1918 to 2014 and the highest rates of coastal erosion were located in the area around Drini river's delta. The rate of erosion peaked (16 m/year at the Drini river's delta) between the time interval 1918-1937, decreasing at 6m/year in subsequent time interval 1937-1985 and 1-12 m/year during the period 1985-2014. The aim of the paper was to produce a quantitative analysis of shoreline changes that can then be used for future multidisciplinary studies on land–coast interaction. Coastal erosion is one of the most important environmental issues that challenge the abilities of scientific institutions, governmental agencies and local authorities. Using spatial data modeling is a potential tool for the evaluation of the past and current changes of the shoreline.

REFERENCES

[1] Pham Thi Phuong Thao; Ho Dinh Duan; Dang Van To, "Integrated remote sensing and GIS for calculating shoreline change in Phan-Thiet coastal area," Int. Symp. Geoinformatics Spat. Infrastruct. Dev. Earth Allied Sci., pp. 1–6, 2008.

[2] Ines Alberico, Vincenzo Amato, Pietro Patrizio Ciro Aucelli, Bruno D'Argenio, Gianluigi Di Paola and Gerardo Pappone, "Historical Shoreline Change of the Sele Plain (Southern Italy): The 1870–2009 Time Window", Journal of Coastal Research, ISSN 0749-0208.

[3] E. R. Thieler, E. A. Himmelstoss, J. . Zichichi, and A. Ergul, "Digital Shoreline Analysis System (DSAS) version 4.0 — An ArcGIS extension for calculating shoreline change," 2009.

[4] Durmishi. Ç, Daja. Sh, Moisiu. L, Alla. B, “Zonimi gjenetik (unitete dhe subunitete) i hapësirës bregdetare shqiptare-bazë për menaxhimin, administrimin dhe planifikimin e qëndrueshëm të zhvillimeve ekonomike, infrastrukturore, urbane dhe turistike”. Konferenca shkencore: Potencialet e burimeve natyrore, baze per nje zhvillim te qendrueshem, pp 235-244, ISBN 978-99956-14-96-6, 2008, Tirane.

[5] Boci. S (1966) “The study of shoreline movement, from topographic point of view”, Bulletin of Natural Science”, Tirane.

[6] Nikolli. P; Idrizi. B; Kabashi. I; Hykollari. R, “ Monitoring of Adriatic coastal erosion using GIS.