EFFECTS OF GLOBAL SEA LEVEL RISE ON THE ADRIATIC COASTS OF ALBANIA

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Abstract

Global climate change causes sea level rise, and especially is affecting low lying coastal areas of the world. In the next century, it is estimated that climate change will raise the sea level approximately 1 meter. Gradually increasing impact of this event will cause especially the lower coastlines to retreat back to the land. Meanwhile, many coastal settlements will be invaded by the waves and beaches will face erosion. Residential areas of the western coasts of the Albania, is usually on low coast areas. A probable sea level rise scenario will have serious impacts on coasts of Adriatic Sea of Albania. This paper focuses on sea level rise and its impacts on the coastal areas and coastline of the western coasts of the Albania. For this purpose, satellite images for the years 1985 and 2011 the coastal lines were obtained using Geographic Information Systems and Remote Sensing Techniques and change is determined for a period of 27 years.

Keywords: *Global climate change, Coastal areas, Adriatic Sea of Albania, Geographic Information Systems and Remote Sensing.*

Introduction

Sea level and coast lines are changing for millions of years due to expanding or melting of continental ice covers. Sea level rise causes changes on coastlines especially on low coastal zones and the sea expand towards to inlands. Sea level had changed in geological times due to eustatic, isostatic, and tectonic factors. Also it has often changed in Quaternary when the climate changes happened in high frequency and high amplitude (Jordan and Maschner, 2000). The climate changes at the end of Pliocene and beginning of Quaternary had significant effect to dwindle of continental ice covers and sea level changes. For instance, the ice in the ocean

melted approximately 3000 years ago from present and that caused sea level rise and coastline changes towards to inlands. In the Quaternary which is time climate changes often happened, the deposited sediments during glacial times in river valleys along the coasts caused partially decrease of sea level. Thus, sea level decreased 120-125 m below than present day level during the Last Glacial Maximum which is happened 30000 and 19000 years ago. As a result of sea level decrease, the continental shelf areas have appeared as land and the rivers reached the sea kilometers far away from their present estuaries (Vellanoweth and Erlandson, 2004; Atalay, 2005).

The global sea level is identified that is close to present day level because the temperatures were higher for 2°C to 3°C than present day temperatures in the period between Last Interglacial and beginning of Holocene for 120 thousand years (Suursaar et al., 2008; Houghton et al., 2001; Lambeck, 1996). The sea level is increased more than 100 meters in the time between present day and the beginning of Holocene which is the last period of Quaternary (Atalay, 2001). It is estimated that the sea level rise is stopped approximately 6000 years ago from the present day. According to tide and sea level measurement records, the global sea level increased approximately 10 cm to 25 cm (1-2,5 mm/y) in 100 years from the end of 19th century (Sterr, 2008; Türkeş and Çetiner, 2000).

By the recent researches it is clear that the effects of sea level rise due to global climate change continue on the coastal areas and coastline changes. For instance; the global average temperature has increased for 0,5°C after the end of 19th century and between 1900 - 1940 years. After this increase of temperature, a cooling period has happened for 25 years. The global average temperatures increased again in 1970s, 1980s and 1990s. The hottest 8 years happened in 1990s after the year of 1978. The year of 1998 was the hottest year for both the north and the south hemispheres since 1860. In addition it is the hottest year of the global temperature records for approximately 140 years, many natural hazards, which were powerful and in number of never counted before, happened in 1998. According to tide and sea level measurement records, it is identified that the sea level is increasing 2 mm per year since the end of 19th century (Sterr, 2008; Türkeş et al., 2000; Öztürk, 2002; Aksay et al., 2005).

The climate changes in geological times have an important impact on the change of landscapes. Also they caused permanent changes on ecological systems on coastal areas by glacial movements and the changes in sea level (Türkeş et al., 2000; Gesch, 2009; Douglas, 2001). The major effects could be counted as; permanent inundation in coastal regions, beach and seaside erosions, salination of underground and surface waters, high water level observations on the lands, and increase in storm and flood destruction (Leatherman, 2001). According to recent researches, the sea level is estimated to rise approximately 1 meter in next 100 years. This event will have increasing effects especially on delta plain coasts and will cause decline of coastline towards the land. At the same time, there will be an increasing erosion event on the

beaches. Thus, many coastal settlements damaged by the sea waves (Vafeidis et al., 2008; Sterr, 2008; Erol, 2003).

Sea level has increased 10 cm to 20 cm on the Mediterranean coasts in last 100 years (Piervitali, 1997; Türkeş et al., 2000). The sea level of the Mediterranean will increase for 18 cm to 20 cm until 2025 and it should be assessed that the sea level rise will be at least 100 cm until 2100. It is mentioned that any changes in the water level of Mediterranean will affect low coasts of Albania which are consisted of Holocene depositions (Nieuwland, 2001; Türkeş et al., 2000; IPCC 2001). Climate change and sea level rise according to climate change are assessed in IPCC 2001 reports with the scenarios prepared by the new information. According to the report, the sea level rise is estimated to happen between 0.2 m and 0.85 m until 2100.

In this study, the effects of sea level changes in Quaternary on formation of Adriatic coasts and coastal settlements in Albania which has 557 km long coastline.

Study Area

Albania is a small and mountainous country on the southwestern part of the Balkan Peninsula and has coasts along Adriatic and Ionian seas. The country is located between 40°-42° latitudes and 19°-20° longitudes. Its neighbor countries by land borders are Montenegro, Serbia, The Former Yugoslav Republic of Macedonia (FYROM), and Greece. The length of the coastline of Albania is measured as 557 km. The south part of the Albanian coastal region is mountainous and consisted of Mesozoic and Tertiary aged sedimentary and volcanic rocks. The north part of Albanian coastal region is consisted of approximately 40 km wide plains which are formed by Holocene depositions. In some parts of coastal strip, there are some small hills in verity heights between 200 m and 300 m (Matherstt et al, 1999; Ciavola et al., 1999; Figure 1).

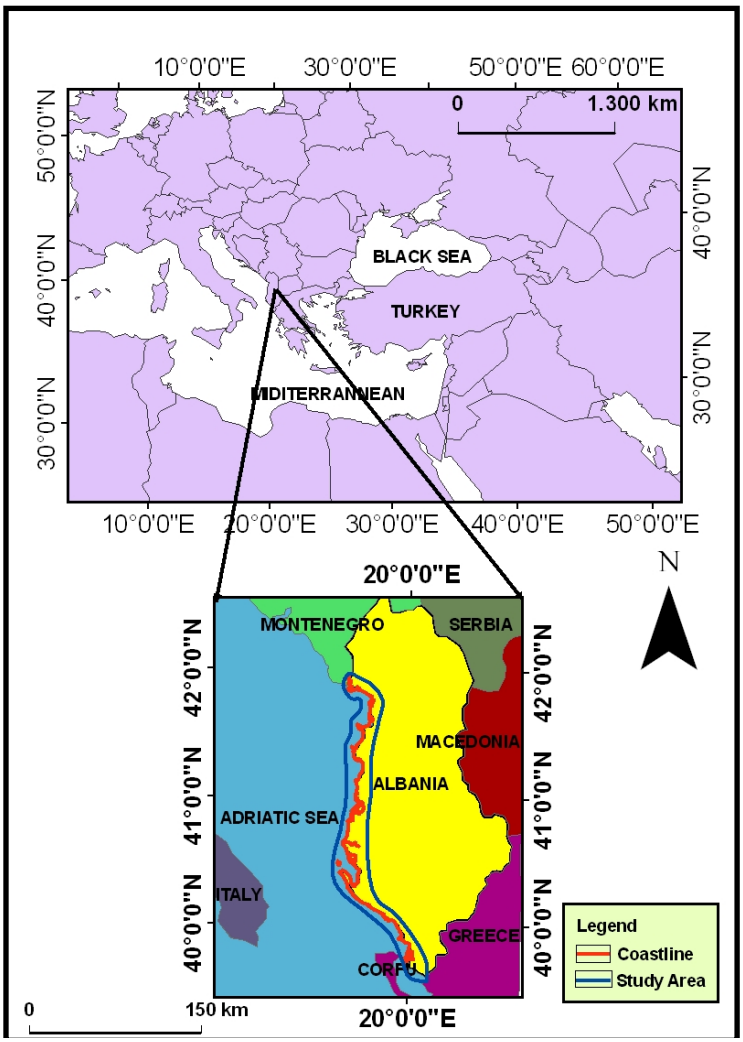

Figure 1: Study Area

Methods

There are many different methods which are prevalently used to determine the land use of coastal regions and coastline changes with the help of advancing technology. Aerophotogrammetry, Remote sensing (RS), Laser Imaging Detection and Ranging (LIDAR), Global Positioning System (GPS), and Geographic Information Systems (GIS) are some of them (Maiti and Bhattacharya, 2009; Gesch, 2009; Demirci, 2008). The system that elderly counted techniques are used for coastal areas is called as Coastal Geographic Information System.

It is possible to determine the reserves and potentials of natural resources and to observe the changes in time and update by comparing historical data and actual data. Comparing the aerial photographs and satellite images which are gathered in different times for a randomly selected region is very important to determine the changes correctly, faster, and cheaper. GIS and RS techniques, which are have important usage potential especially in applications about geosciences, are very important two techniques providing the easiness to the user for coastal region researches and analysis (Mausel et al., 2004; Richards, 1995 Şeker and Kabdaşlı, 2002, Çölkesen, 2007). Storing, analyzing, processing, and visualizing the spatial changes in time is easier with the help of GIS. Thus, it is used as an effective method to determine coastal land use, coastline changes, and coastal geomorphology changes for coastal management (Turoğlu, 2000; Tecim, 1999). GIS is a technique that helps to control and take early precautions for environmental degradations by determining the changes (Mousavil et al., 2007). RS techniques are used for sensation of the energy reflecting from the earth surface, processing to gather information about the material, and analyzing the information (Prabaharan et al., 2010). The changes in a selected coastal region could be determined with the help of RS by comparing old and new dated aerial or satellite images (Ciavola et al., 1999; Akar, 2007; Kurt et al., 2010).

In this study, GIS and RS techniques are used to identify the changes of sea level and coastline in time. Coastline and sea level changes are determined using RS technique on satellite images which are received from USGS Global Visualization Viewer. The satellite images are captured by Landsat TM (Thematic Mapper) with the resolution of 30 meters in 12 August 1985 and 19 July 2011. In this technique, the images in pieces are combined. After geometric corrections (UTM, WGS 84, Zone 34N), the images are improved by using the Normalized Difference Vegetation Index (NDVI) tool in ERDAS 9.3 software. The image, which is elderly produced after the RS application, is added to ArcMap and coastlines are produced using Spatial Analyst toolset. The images of sea level changes for 1 m and 5 m rise are received from Global Sea Level Rise Map page of geology.com internet site. Firstly, the received images, which show Albanian coasts, converged to JPEG format. Then, their coordinates are addressed using the coastline which is produced from satellite image captured in 2011. On the second phase, polygons are produced to visualize the sea shore that thought to be under water after 1 m and 5 m sea level rise. Lastly, the required maps are produced by using polygons and visualization techniques.

Results

Although Albania is a small country with 28748 km^2 total area, it has three different climate types as a result of verity of landscapes. The inner north parts of the country have humid climate and northeastern parts have alpine climate that has warm and rainy summers, cold and dry winters. The coastal region of Albania along Adriatic Sea has characteristics of the Mediterranean climate that has warm, rainy winters

and hot, dry summers. This part of the country, which is our study area, has annual precipitation average of 930 mm to 2200 mm, and annual temperature average of 15°C to 16.5°C. The rainiest period of the coastal region is time between October and March (Cıavola, 1999).

The settlements on the coastal region of Albania are accumulated on the areas which have very low gradient, low coast characteristics, and high earthquake risk. Thus, it increases the risk of inundation after a possible sea level rise (Nieuwland, 2001). In addition, strong storms sometimes cause more than 1 m sea level rise or decrease even in certain conditions. These prove that a potential sea level rise on the Adriatic coasts of Albania will affect the settlements and the economic and social life on the surroundings dramatically. The part of the total population (3002859 people, CIA, 2012) which is settled on coastal region will suffer significantly as result of sea water invasion towards the inlands. In addition, the delta plains of Albania's longest rivers (Bune, Drina, Vjose, Shkumbin, Semanit, and Erzen) will be under sea water after sea level rise and agriculture and economic life will be damaged.

If the sea level rises 1 m, 332,7 km^2 area of the 45 km long coastal region, which is located between Bune river mouth and Rodonit bay, will be under sea water. On the same location, 588,7 km^2 area will be covered by sea water if the sea level rises 5 m (Figure 2). Eventually, Kenata lagoon on the east of Bune delta plain, the part of Velipoje beach until Shengjin, and Shengjin port will be totally under the sea. Also, 15 km long beaches between Velipoje and Shengjin will be under sea water after a potential sea level rise. The sea water will reach 2 km close to Laç and invade many roads, houses, and stores so, will affect the life adversely. At the same time salty sea water will invade the Drina river bed for kilometers and cause salination of the water in river bed. Drina delta plain and Blu lagoon will be covered by sea water, so the agricultural lands will be out of use as a result. The transportation also will be affected badly by sea water cover on E762 numbered motorway which is located between Shengjin and Drina River (Figure 2).

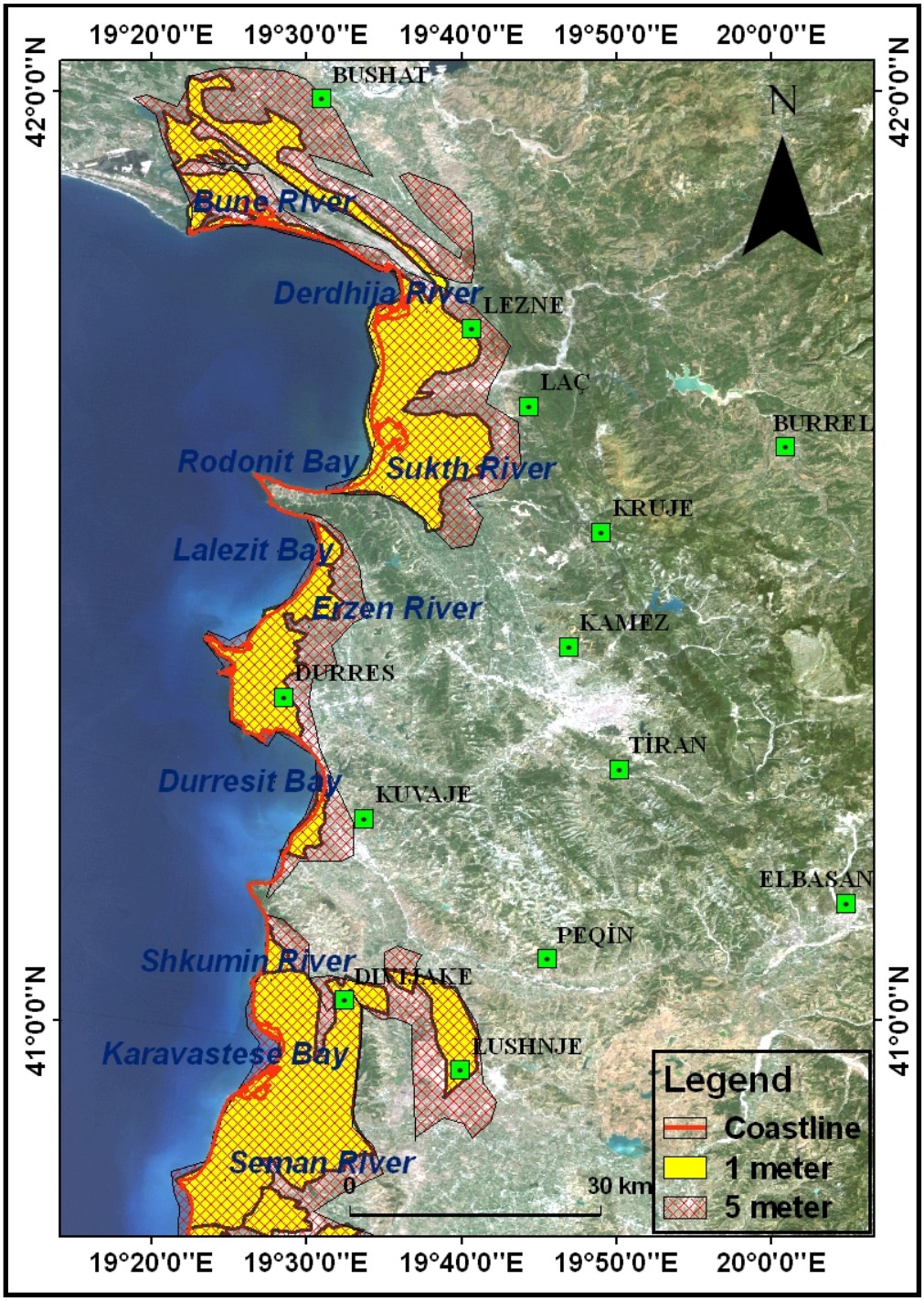

Figure 2: Sea level changes on Adriatic coasts of Albania

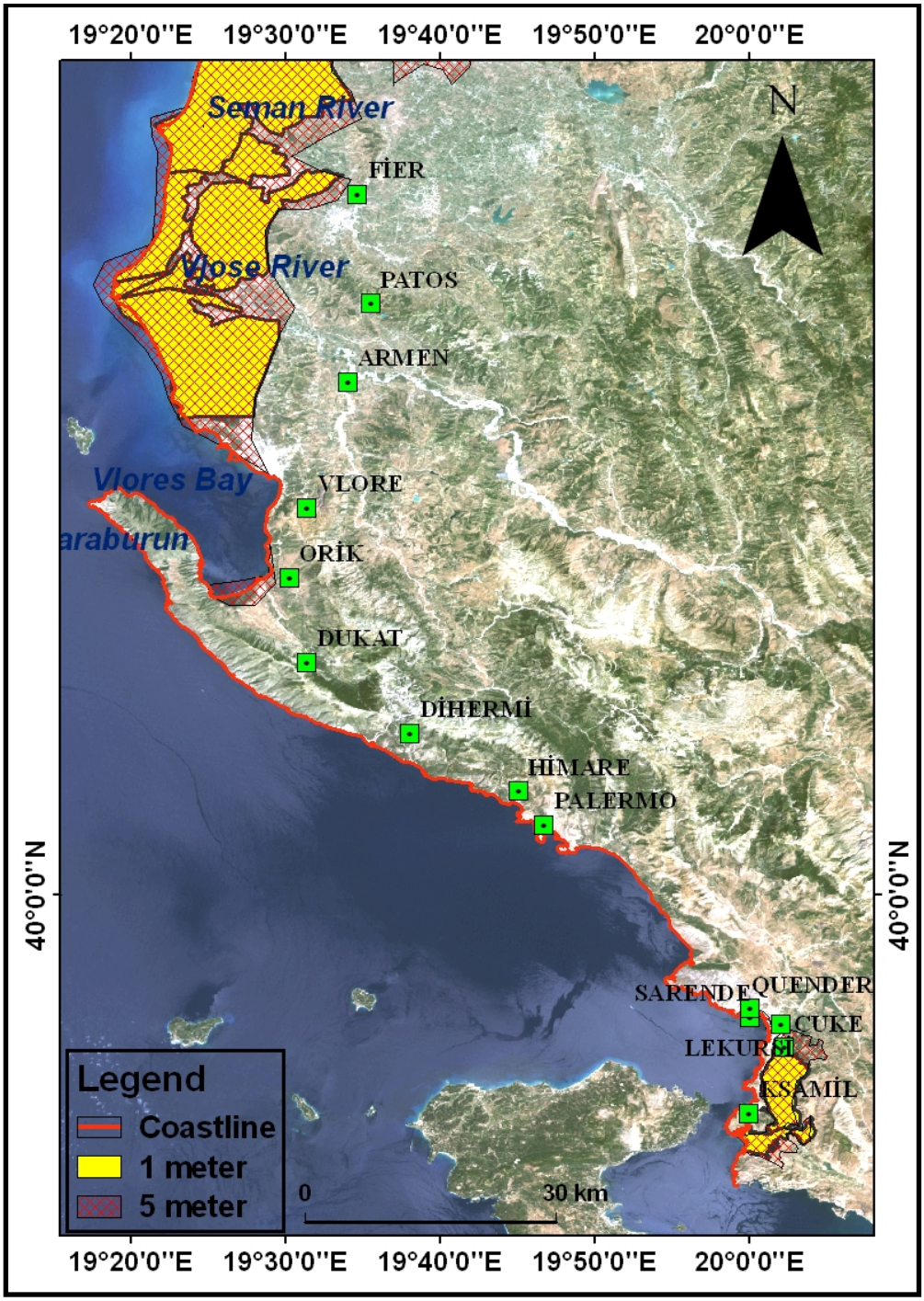

Figure 3: Sea level changes on Adriatic coasts of Albania

On the other side, if the sea level rises 1 m, 119,9 km^2 area of the sea shore between Lalezit and Durresit bays, 737,4 km^2 area between Durresit bay and Karaburun, and 40,2 km^2 area of Sarende coast, which is located on the south of Albania, will be covered by sea waters. If the sea level rises 5 m, 243,3 km^2, 941,2 km^2, and 56,8 km^2 areas on the previously mentioned locations will be under sea level respectively (Figure 2 and Figure 3). As a result of salty sea water invasion to delta plains and the mouths of Vjose, Mati, Drina, Shkumbin, Semanit and Erzen rivers, the lands will lose agricultural importance. Pataku, Vilunit, Karavasta, Narta, Blu, and Paşa Liman lagoons will be destroyed by sea water invasion. The tourism and natural life will be affected adversely because the coasts and roads between Lalezit and Durresit for 9 km and between Draç and Kavaje for 13 km will be below the sea level. 9 km long coast between Semani and Vjose rivers and the delta plains of those rivers will be covered totally by sea water. The water of the rivers, which will be mixed with salty sea water, will not be suitable for drinking water supply of people (Figure 2 and Figure 3). The least damaged parts of the Albanian coasts from a potential sea level rise are the area between Karaburun and Sarende which is has cliffs along the coastline.

The coasts of Albania are one of the most important recreation areas for Albanians. Nevertheless, it is identified that there have been important changes on the coastline in 27 years between 1985 and 2011 because of sea level changes and urbanization. Also, taking sand from the beaches, port and pier constructions on the coasts and forming new beaches by man hand are the other factors for coastline changes. As a result of these changes, the total length of Albanian coasts has changed generally towards to the land and towards to the sea from place to place. The results of coast line measurements of Albania for 1985 and 2011 are different. The total coastline length of Albania was 535 km in 1985 and it was 557 km in 2011. Thus, it is identified that the coastline is lengthened for 22 km because of the coastline changes which are elderly mentioned (Figure 4).

Albanian coastline has changed significantly along the delta plain areas of Bune, Vjose, Mati, Drina, Shkumbin, Semanit, and Erzen rivers in 27 years period between 1985 and 2011. In addition, there have been important changes along the coasts of Vlores, Karavastase, and Lalezit bays and in lagoons (Kenata, Pataku, Vilunit, Karavasta, Narta, Blu, Paşa Liman) behind the coastline (Figure 4).

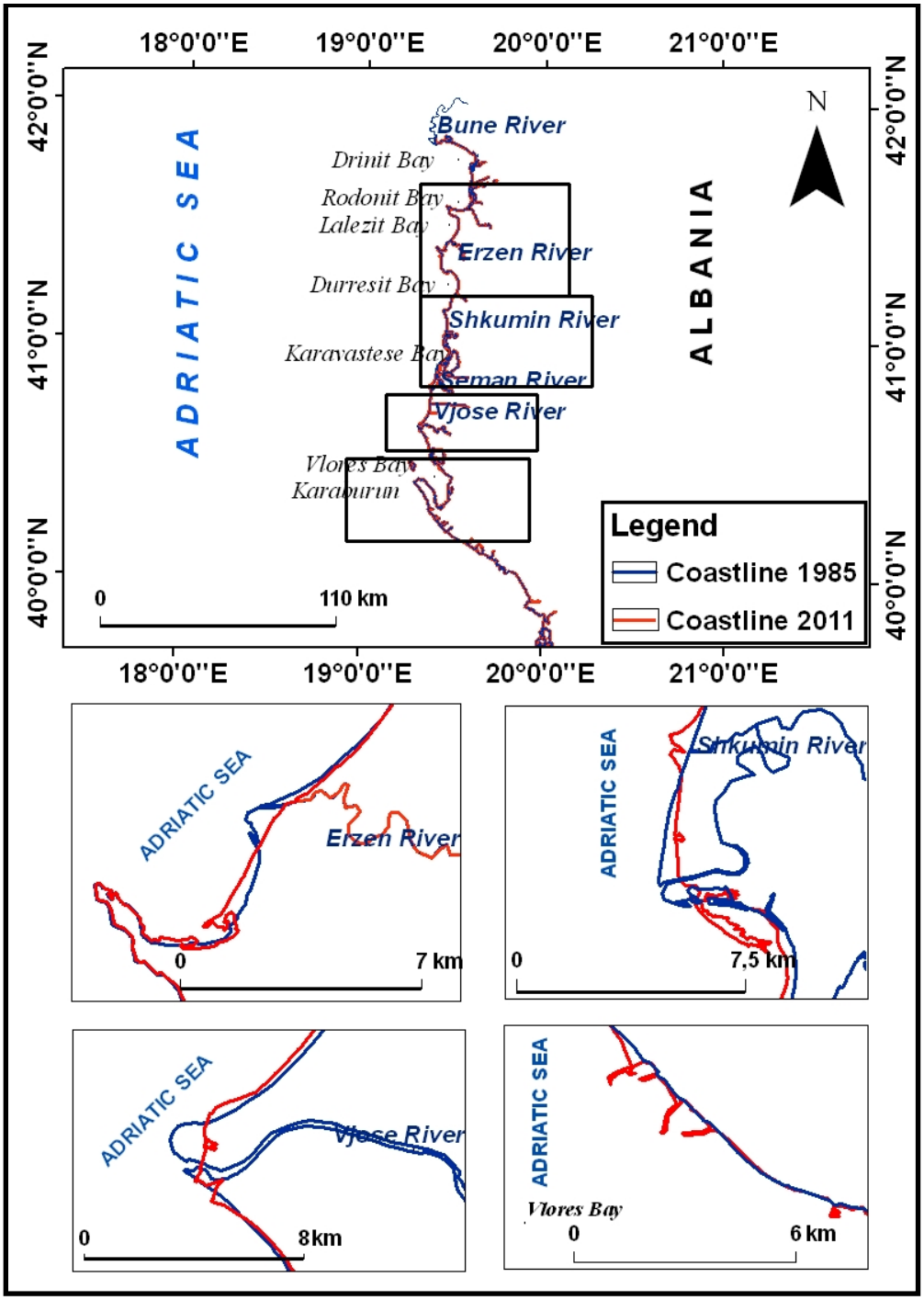

Figure 4: Coastline changes along Adriatic coasts of Albania (1985-2011)

Conclusion

The Adriatic coasts of Albania have changed for 22 km in past 27 years between 1985 and 2011. The coastline was 535 km in 1985 and it was 557 km in 2011 according to the calculations which are applied on the satellite images.

If the sea level rises 1 m or 5 m, the total 1230,1 km² or 1830 km² area will be under sea level respectively. This will affect social and economic life adversely. Besides, sea level rise will cause loss of terrestrial area; it will cause salt water intrusion to fresh water resources close to sea. In this case, agricultural and drinking water demand will increase. The frequency of forest fires and their impact area and duration will also increase depending on the increase of the duration and severity of hot and dry season. Thereby, terrestrial ecosystems and agricultural production systems could be damaged. The delta plains, coastal plains, and beaches which are the locations of intense settlement, agricultural, and touristic places of Albania, will be under the sea level.

The events would have been occurred as a result of a potential sea level rise should be considered in coastal land use planning of Albania. The existed buildings on the settlement areas on coastal regions should be used until the end of their useful economic life. At the same time, the arrangements for land use planning should be made according to possible sea level changes depending on climate change.

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