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Monitoring the change of coastline with remote sensing and GIS: a case study from Izmit and Gemlik Gulfs, Turkey

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ABSTRACT

Humanity has preferred to settle down in coastal areas since its existence. This situation brings socioeconomic and cultural benefits, as well as a better quality of life for the development of civilizations. Although coastal areas are of great benefit to the population and economy, they can be affected by natural or artificial disasters such as erosion, tsunami, and flooding. Nowadays, it is necessary to monitor the change of the coastline to better manage coastal areas and take precautions against disasters. In recent years, instead of traditional measurement methods, changes in coastal areas can be more accurately determined by remote sensing methods and satellite imagery. In this study, an analyzes was conducted to detect the change in coast of Sea of Marmara, Gemlik and Izmit Gulf using Landsat-5 and Landsat-8 satellite imagery from 1985-2020. First, using the object-based classification method, rule sets were developed, and the coastal class was generated. During the segmentation and classification stages, parameter analyses were performed to create corresponding rules, and accuracy analyses were conducted. In the second stage of the study, the target classes were exported to the geographic information system environment and a coastal change detection analyzes was performed.

1. Introduction

It is vital to monitor the change of coastlines in in terms of sustainable development and environmental protection. In particular, global climate change, which is one of the most important environmental problems of our time caused as a result of human activities that directly or indirectly affect the composition of the atmosphere should be monitored over specific time periods and anticipating and modeling possible negative consequences of global climate change and taking precautions are among the priority issues at the national and international levels.

Coastal areas are one of the most vulnerable regions in the world affected by human impacts such as natural disasters and climate change. Erosion, flooding, rise of water level and unusual weather conditions are the most common natural disasters in these regions (Paravolidakis et al. 2018). However, a large part of the human population lives in coastal regions. On the coasts of the countries that belong to the European Union, this percentage reaches up to 20% of the total population (Koroglu et al. 2019). Because of coastal areas are so vulnerable to damage and are home to much of the human population, it is important to identify coastal areas and coastlines and monitor the changes of them. In addition, it is necessary to monitor the natural or artificial changes on the coast to create city models, prepare urban and regional plans, plan the use of natural resources in the region, thus protecting the environment.

When examining the studies conducted in recent years, it was found that the analyses of coastal changes are carried out using remote sensing methods. Sahin et al. 2021 used image processing techniques to determine the change in coastal settlements in the Izmit Gulf. Wang et al. 2017 observed coastal changes using Landsat imagery for the Ningbo coast. Hossain et al. 2021 derived the coastline of the southeast coast of Bangladesh and automatically detected the coastal change using NDWI. Abualtayef et al. 2021 used GIS and remote sensing techniques to determine the changes in the Gaza coast. Yan et al. 2021 observed coastal changes on the Yangcheng coast using the Digital Shoreline Analyzes System. In this study, within the framework of Gemlik and Izmit Gulfs of the Marmara region, coastal changes between 1985 and 2020 were monitored and the target classes are created using remote sensing methods and

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coastal change analyses were performed by exporting them to the GIS environment.

2. Method

In this study, object-oriented rule-based classification method was used. In order to detect the coastal change, 4 different target classes have been created as land, water, island and lake. Digital image processing techniques and automated water extraction index were used in the development of rule set and classification. With the object-based classification method, the class assignment process is carried out by determining the appropriate parameter analyzes of the segmentation and classification stages. In addition, digital image processing techniques and appropriate indexes are used in the rule set created for automatic target classes extraction. In particular, the Automated water extraction index, which helps to distinguish between land and water classes, was used in the creation of the land class. This index, which is used for the separation of surface waters, was published by Feyisa et al, 2014. According to Feyisa et al, it consists of two equations. In this study, these two equations and difference of these equations is used.

$$AWEInsh = 4 * (Band2 - Band5) - 0.25 * Band4 + 2.75 * Band7 \quad (1)$$

$$AWEIsh = Band1 + 2.5 * Band2 - 1.5 * (Band4 + Band5) - 0.25 * Band7 \quad (2)$$

$$AWEIDiff = AWEInsh - AWEIsh \quad (3)$$

2.1. Study area and dataset

One of the most important factors in choosing the Izmit and Gemlik Bays as the study area is the rapid industrialization and urbanization in the coastal areas with the increase in human population density in this region in recent years. It is important for local and private administrations to determine the social, economic, and cultural effects of the coastal formations in this region.

Landsat Collection 2 Level 2 satellite images were used in the application. 2 Landsat-5 satellite images of 1985 and 2 Landsat-8 satellite images of 2020 were used. The features of the satellite images used are given in Table 1.

Table 1. Features of the satellites

	Landsat-5	Landsat-8
Spatial Resolution	30m	30m
Radiometric Resolution	16bit	16bit
Temporal Resolution	16 days	16 days
Year	1985	2020

In order to apply the same rule, set during classification in satellite images, bands with the same or close spectral range are used. The spectral ranges of the bands and the band aliases used during classification are shown in Table 2. In addition, the emissivity band in level-2 products is also used to increase the classification accuracy with EMIS alias.

Table 2. Bands and their respective spectral ranges.

Landsat-5 Bands	Landsat-5 Spectral Range(μm)	Landsat-8 Bands	Landsat-8 Spectral Range(μm)	Band Alias
SR_B1	0.45 – 0.52	SR_B2	0.452 – 0.512	BLUE
SR_B2	0.52 – 0.60	SR_B3	0.533 – 0.590	GREEN
SR_B3	0.63 – 0.69	SR_B4	0.636 – 0.673	RED
SR_B4	0.76 – 0.90	SR_B5	0.851 – 0.879	NIR
SR_B5	1.55 – 1.75	SR_B6	1.566 – 1.651	SWIR1
SR_B7	2.08 – 2.35	SR_B7	2.107 – 2.294	SWIR2

2.2. Process and analyzes

In this study, the workflow steps given in Fig. 1 were applied to perform shore extraction and change. In the proposed method, firstly, satellite images were normalized according to Landsat 4-7 Collection 2 Level 2 Science Product Guide and Landsat 8 Collection 2 Level 2 Science Product Guide. In the second step, the image is segmented with multiresolution segmentation. As a result of parameter analyzes for multiresolution segmentation, the most suitable parameters were found. The parameters used are given in Table 3.

Table 3. Multiresolution segmentation parameters.

Parameter		Value
Image Layer Weights		
	BLUE	0.25
	GREEN	0.25
	RED	0.25
	NIR	0.75
	SWIR1	0.50
	SWIR2	0.50
	EMIS	0.50
Scale		40
Shape/Color		0.3
Compactness		0.5

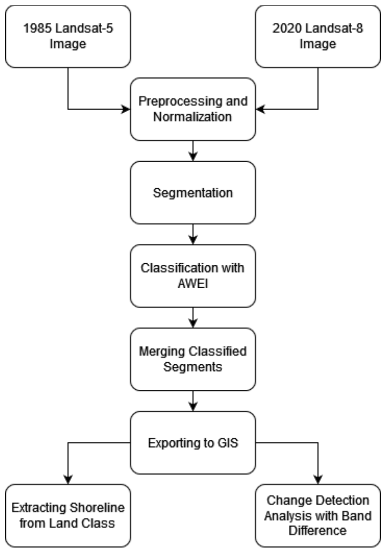

Figure 1. Workflow of study.

In the third step, the generated segments were classified using the Automated Water Extraction Index. The parameters used during this classification were calculated with the help of Equations 1 and 2. The land class was classified with the help of the difference (Equation 3) between the two obtained parameters. Pixels that do not have any value defined as out of classification are classified according to NIR < 0 value.

Land class assignments are made for values that meet the conditions of AWEIsh <-0.002 and AWEInsh – AWEIsh> 0.098. As a result of these two processes, unclassified pixels are assigned to the Sea class. Sea class clusters within the land class were assigned as lakes, and land class clusters within the sea class were assigned as islands. Results are given for 1985 in Fig.2, 2020 in Fig. 3.

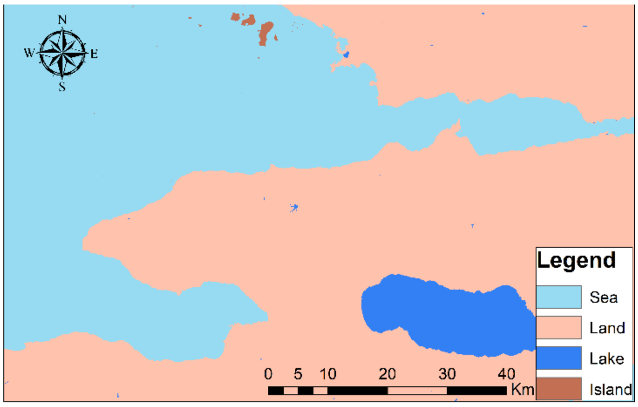

Figure 2. Classification results for 1985

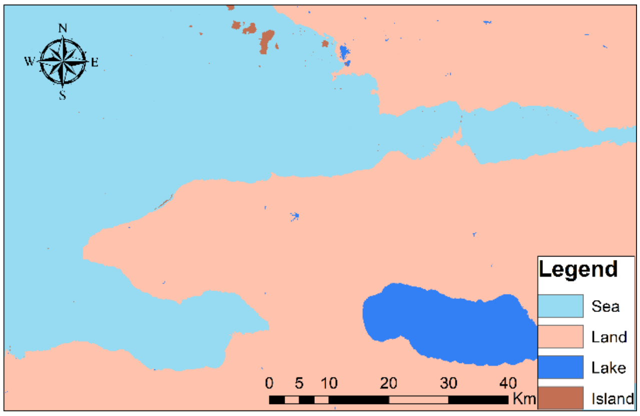

Figure 3. Classification results for 2020

In the fourth step, segments belonging to the same class were exported to the GIS environment as shapefiles using the merging algorithm. In the last step, the coastline was extracted using the vector data belonging to the Land class. Class files, which are vector data, were converted to raster data and the spatial variation in the coastal areas was determined by subtracting the two images from each other. The accuracy of the classification was calculated with error matrix based on TTA (train and test area) mask.

3. Results

In this study, 4 target classes, namely water, land, lake, and island, were created and the accuracy analyzes of these classes were carried out separately for every image used. Error matrices and overall accuracies is calculated with TTA Mask method. Accuracy analyzes result for 1985 images can be seen in Table 4. and Table 5., accuracy analyzes result for 2020 images can be seen in Table 6. and Table 7. Classification accuracies were 84% for Gulf of Izmit and 83% for Gulf of Gemlik in 1985, and 79% for Gulf of Izmit and 82% for Gulf of Gemlik in 2020. Kappa was calculated as 75% for Gulf of Izmit and 74% for Gulf of Gemlik in 1985, and 79% for Gulf of Izmit and 73% for Gulf of Gemlik in 2020.

Table 4. Error matrix based on TTA mask 1985-1

Class	Sea	Land	Lake	Island	Sum	User
Sea	386	46	23	10	465	0,830
Land	12	158	20	0	190	0,832
Lake	23	0	283	0	306	0,925
Island	33	3	0	32	68	0,471
Sum	454	207	326	42	1029	
Producer	0,850	0,763	0,868	0,762		
Overall Accuracy	0,835		Kappa	0.752		

Table 5. Error matrix based on TTA mask 1985-2

Class	Sea	Land	Lake	Island	Sum	User
Sea	286	33	13	12	344	0,831
Land	15	144	4	0	163	0,883
Lake	14	0	123	0	137	0,898
Island	22	12	0	44	78	0,564
Sum	337	189	140	56	722	
Producer	0,849	0,762	0,879	0,786		
Overall Accuracy	0,827		Kappa	0.743		

Table 6. Error matrix based on TTA mask 2020-1

Class	Sea	Land	Lake	Island	Sum	User
Sea	231	55	12	33	331	0,698
Land	12	273	20	0	305	0,895
Lake	9	1	91	0	101	0,901
Island	23	12	0	89	124	0,718
Sum	275	341	123	122	861	
Producer	0,840	0,801	0,740	0,730		
Overall Accuracy	0,794		Kappa	0.794		

Table 7. Error matrix based on TTA mask 2020-2

Class	Sea	Land	Lake	Island	Sum	User
Sea	309	55	21	9	394	0,784
Land	25	287	4	0	316	0,908
Lake	4	0	123	0	127	0,969
Island	40	14	0	55	109	0,505
Sum	378	356	148	64	946	
Producer.	0,817	0,806	0,831	0,859		
Overall Accuracy	0,818		Kappa	0.732		

After the classification process, the changes in the coastal areas were determined by the Band difference change analyzes. As a result of the analyzes, a total of 6.4 km^2 of landfill was detected in the coastal areas between 1985 and 2020.

4. Discussion

As a result of analyzes and evaluation, it was observed that majority of coastal change in the Gulf of Izmit was man made landfills. While it has been determined that there are landfill areas in the Gulf of Gemlik, it is seen that it does not cover as wide an area as the Gulf of Izmit. As seen in Fig. 5, new shipyards have been added to the existing shipyards. As a result of this addition, landfill of 1.72km^2 is made in Gulf of Izmit. Constructed ports on a landfill area of 1.3 km^2 can be seen in Fig.4 and Fig. 7. In Fig. 6, a filling of approximately 1 km^2 was made for the construction of the marina. When these changes in coastal region observed, it could be seen that these areas of landfill could become vulnerable to earthquakes, sea-level rise, and unusual weather effects. For this reason, coastal vulnerability of these regions for sea level rise and natural hazards should be investigated. Data obtained from this study are important data source in terms of settlement and infrastructure planning in the region. By evaluating this data, it can be prevented that the changes made on the coast further deteriorate the integrity of the coast and increase its vulnerability.

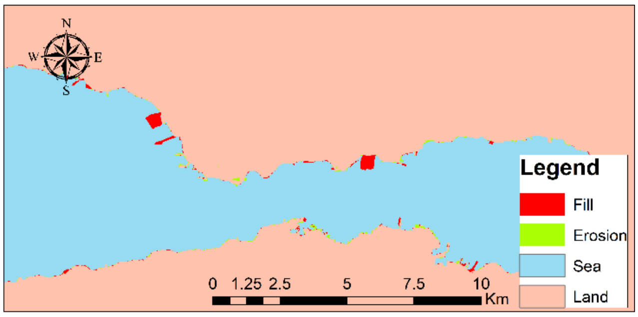

Figure 4. Change detection results for Gulf of Izmit.

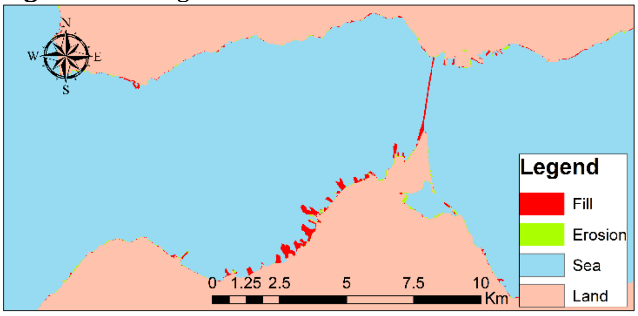

Figure 5. Change detection results for Gulf of Izmit.

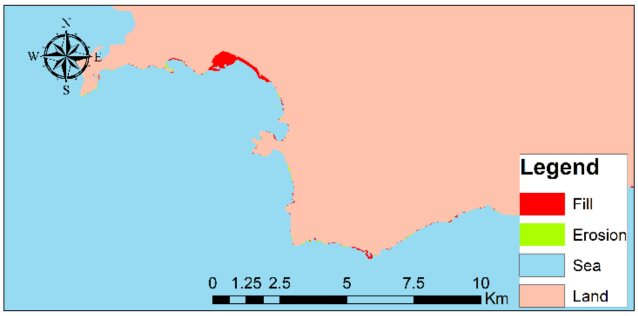

Figure 6. Change detection results for Gulf of Izmit.

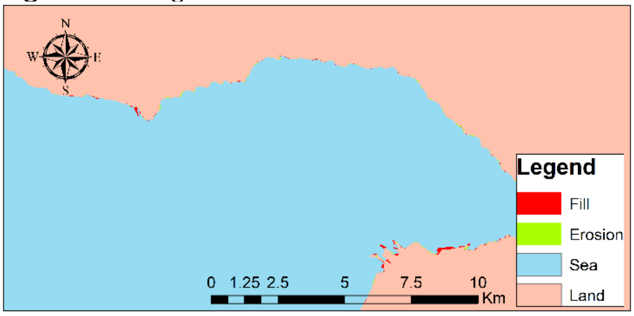

Figure 7. Change detection results for Gulf of Gemlik.

5. Conclusion

This paper presented an efficient workflow for monitoring the change of coastline with remote sensing and GIS. The proposed method in this study, based on object-based image analyzes, includes segmentation, analyzes and classification steps for the automatic shoreline extraction using Landsat data. The model parameters were determined with the analyses from the segmentation and classification steps to find the optimum strategy for extraction of shoreline and change detection analyzes. Accuracy analyzes was performed on the automatically extracted target classes of sea, land, lake, and island with kappa values 75% and 74% for 1985, and 79% and 73% for 2020. As a result of the change detection analyzes a total of 6.4 km² of landfill was detected in all study area between 1985 and 2020.

As a result of this study, it could be seen that identifying and monitoring the change of coastal areas and coastlines are important. In addition, it is necessary to monitor the natural or artificial changes on the coast to create city models, control of natural disasters, and crisis management, as well as for the tracking and prevention of unorganized urbanization and planning the use of natural resources in the region, thus protecting the environment. In future studies, rule set can be improved for better accuracy. With the usage of vulnerability indices, coastal vulnerability can be determined. In the next study, studies on coastal vulnerability will be conducted based on this study.

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