VERIFICATION OF TEMPORAL ANALYSIS OF COASTLINE USING OBJECT-BASED IMAGE CLASSIFICATION DERIVED FROM LANDSAT-5 IMAGES OF KARASU, SAKARYA – TURKEY

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The most vulnerable part of the Black Sea Coast in Turkey is located within the Sakarya City. The 50 kilometers long coastal line in this basin has been formed with the sediments carried by the Sakarya River for thousands of the year.

In 1996, a fishing port was constructed at approximately 1 km east of the Sakarya River nearby Karasu district. In the following stages, the project was turned out to a harbor extending its breakwater to 1.5 km, and the construction was completed in 2008. During the construction, it was discovered that the coastal line progressively moved into inland towards the houses on the coastal area. Indeed, the coastal erosion increased gradually in time, and at last the houses in forefront of the coastal line were destructed by a storm on January 2010.

In this study, temporal analysis of changes in coastline of Karasu was studied on the basis of the classification results acquired using object-based image analysis approaches. For this purpose, Landsat imagery with multispectral bands of 1987, 2001, 2006 and 2010 test area were used. These images were handled by the eCognition v4.0.6 software with the main steps of segmentation and classification. Thus, vectors of coastline were obtained from object-based classifications. On the other hand, these vector results were compared with reference vector and on-screen digitizing results. From the classification results mentioned above, the accuracy assessments were presented and interpreted. Based on the extracted results, it was seen that, temporal analysis of coastline of Karasu can be successfully undertaken and integrated to the GIS environment.

1. INTRODUCTION

The most sensitive part of the southern Black Sea coast is located in boundaries of the Sakarya province of Turkey. This 40 kilometers long coastal line were formed in the thousands of the year with the sediments carried by the Sakarya River. The width of this coastal area reaches to 1 km in some parts. The largest settlement on the area is the Karasu District of the Sakarya Province. It is an imharborant summer resort city and the tourism is the main economical income of the city (Figure 1) (Kutoğlu et al., 2010)

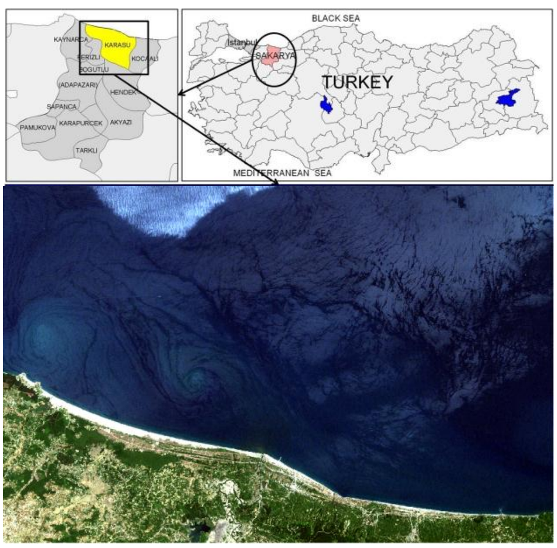

Figure 1. Karasu testfield from Landsat imagery

The Sakarya River is the largest river of the western Anatolia and it reaches to the Black Sea just nearby the Karasu. In 1996, approximately 1 km east of this point a construction of a fishing port was started. In the following stages of the project, harbor breakwater was extended to 1.5 km and then the project turned to a harbor and the construction was completed in 2008.

While construction of the harbor, citizen who has the houses located on the coastal area observed the coastal line changed over time toward the direction of land. Indeed, the coastal line has been reached to the nearby the houses built up close to the sea shore and the storm occurred on the January 2010 caused serious destruction on these houses (Kutoğlu et al., 2010).

In this study, temporal analyses of changes in coastline were tested using object-based classification approach from low-resolution Landsat dataset of Karasu testfield. Firstly, images were geo-referenced to be defined in a common coordinate system. Then these images were integrated to eCognition software to test the performance object-based classification. A few tests were carried out to match with the successful segmentation and then the classification by entering membership functions to the used software. Thus, vectors of coastline were obtained from object-based classifications. At the end, these vector results were compared with reference vector maps and on-screen digitizing results to investigate the beginning time, reasons and temporal speed of this erosion and revealing a risk perspective. Authors, finally comment on the pros and cons of the object-based classification of the low-resolution images with the detailed explanation of the reasons of the erosion.

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2. DATASETS AND METHODOLOGY

Due to harbor construction in Karasu was began in 1996, using archive data were required before and after this date to evaluate the temporal changes occurred in the testfield. Data which can be used for this purpose is evaluated only satellite sensor data. After checking the archives, it is figured out that only Landsat-5 TM data achieve contains the satellite sensor data belongs to the region dating back to 90s and present period. When the level of the erosion considered in the region as 100s meters, Landsat-5 TM and Landsat-7 ETM data was evaluated as the suitable data set. Then in the archive of the 1987, 2001, 2006 and 2010 data were obtained to be used in the study (Fig. 2) (Kutoğlu et al., 2010).

Ground Sampling Distance (GSD) of used satellite images are 30 meters, which can be evaluated as too much for the detailed studies related to coastal erosion and coastal change detection line, when the magnitudes of the changes were examined, it utilizable of these images were accepted. On the other hand, GNSS measurements belongs to the coastal line were done in January 2010 were also used to verify the accuracy of the satellite imageries. Besides, vector results were obtained using manual on-screen digitizing results from used images (Marangoz et al., 2006).

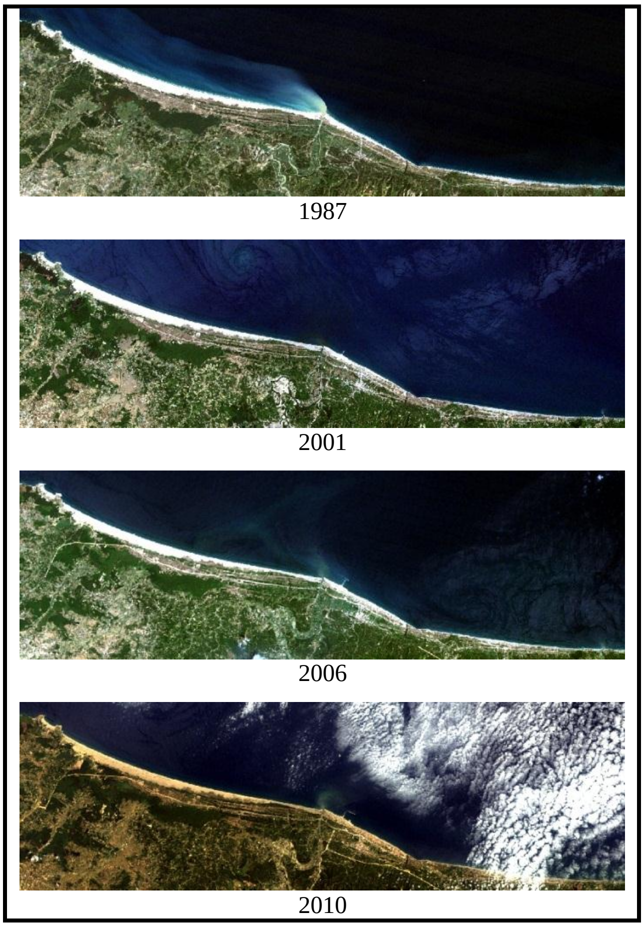


Figure 2. Used images of Karasu testfield

Aim of this study was testing performance of temporal changes in coastline using object-based classification results of low-resolution images, so Landsat imagery which have same GSD were used.

Before the image classification processes, geometric correction of the images was completed and results of geometric correction of Landsat imagery has been given in detail in Oruç et al., 2004. At the all processing phase, all spectral bands of these images except thermal ones were investigated.

The developments in the remote sensing technologies have certainly provided an opportunity of using satellite images for many applications. In terms of digital photogrammetry, this has also caused to being used of different image processing techniques. Classification relies on the pixel-based approaches is limited at present. Typically, they have considerable difficulties dealing with the rich information content of high-resolution data e.g. QuickBird and Ikonos images, they produce inconsistent classification results and they are far beyond the expectations in extracting the object of interest. From this point, comparing with the object-based approaches gained by pixel-based image analysis; much more positive results can be obtained. Besides, low-resolution images can be undertaken using this approach. Therefore, the object-based image analysis has become necessary especially for image classification.

In object- based classification, not only pixel grey values but also spatial and contextual information, which provide distinguishing of the segments formed by pixels having relations with each other, from the image have been used. Due to mentioned nature of classical methods, eCognition object-based image analysis software can be used. Its classification phase starts with the crucial initial step of grouping neighbouring pixels into meaningful areas, which can be handled in the later step of classification. Such segmentation and topology generation must be set according to the resolution and the scale of the expected objects. By this method, not single pixels are classified but homogenous image objects are extracted during a previous segmentation step. This segmentation can be done in multiple resolutions, thus allowing differentiating several levels of object categories. As known, object- based image analysis approaches can reveal satisfied classification results using very high resolution images (Marangoz, 2005).

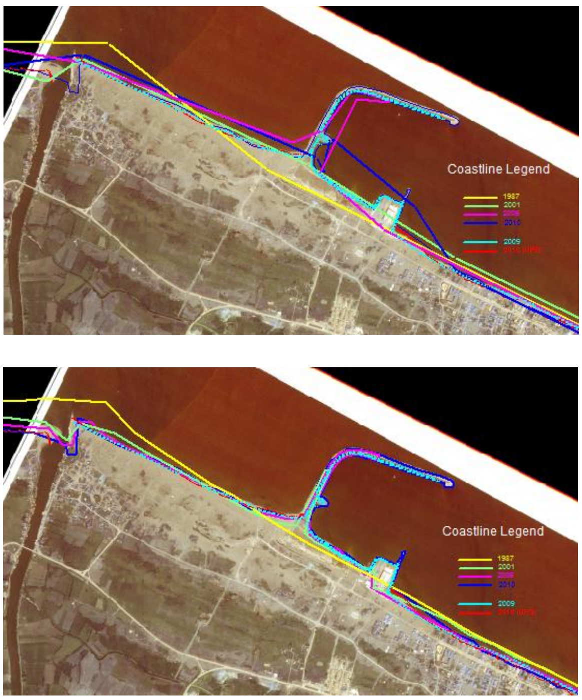
3. OBJECT-BASED IMAGE ANALYSES AND MANUAL ON-SCREEN DIGITISING RESULTS

In this study, image segmentation and object-oriented classification phase were derived by using eCognition v 4.0.6 software. This software offers a relatively segmentation technique called Multiresolution Segmentation (MS). Because of the MS is a bottom-up region-merging technique; it is regarded as a region-based algorithm. MS starts by considering each pixel as a separate object. Subsequently, pairs of image objects are merged to form bigger segments (Darwish et al., 2003). The merging decision is based on local homogeneity criterion, describing the similarity between adjacent image objects. The pair of image objects with the smallest increase in the defined criterion is merged. The process terminates when the smallest increase of homogeneity exceeds a userdefined threshold (the so called Scale Parameter – SP). Therefore a higher SP will allow more merging and consequently bigger objects, and vice versa. The homogeneity criterion is a combination of color (spectral values) and shape properties (shape splits up in smoothness and compactness). Applying different SPs and color/shape combinations, the user is able to create a hierarchical network of image objects. (eCognition User Guide 4, 2004).

Image segmentation phase is followed by the classification of the images. eCognition software offers two basic classifiers: a nearest neighbour classifier and fuzzy membership functions. Both act as class descriptors. While the nearest neighbour classifier describes the classes to detect by sample objects for each class which the user has to determine, fuzzy membership functions describe intervals of feature characteristics wherein the objects do belong to a certain class or not by a certain degree.

Thereby each feature offered by eCognition can be used either to describe fuzzy membership functions or to determine the feature space for the nearest neighbour classifier. A class then is described by combining one or more class descriptors by means of fuzzy-logic operators or by means of inheritance or a combination of both. As the class hierarchy should reflect the image content with respect to scale the creation of level classes is very useful. These classes represent the generated levels derived from the image segmentation and are simply described by formulating their belonging to a certain level. Classes which only occur within these levels inherit this property from the level classes. This technique usually helps to clearly structure the class hierarchy (Marangoz et al., 2004).

In segmentation phase, two classes titled sea and land were generated and then, classification phase were started with suitable levels and membership functions. At the end of classification analyses, accuracy statistics which includes overall accuracy (%80-83 for all images) and Kappa statistics (0.80-0.83 for all images) for each image was given by eCognition software. After these phases in eCognition, .dxf coastline vectors derived from object-based classification results were obtained using exporting features of software. On the other hand, coastline vectors were obtained using manual on-screen digitizing methods from images in CAD software. These vectors and vector from Karasu reference map are also shown onto 2010 Ikonos image of fishing port in Figure 3.



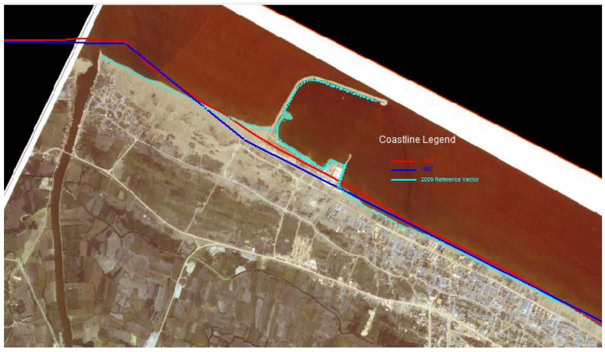
a

b

Figure 3. Vectors derived from feature extraction methods; a: object-based classification, b: manual on-screen digitizing

4. COMPARISON OF FEATURE EXTRACTION VECTORS WITH REFERENCE VECTORS

Object-based vector results and manual on-screen digitizing vector results were compared year by year with reference vector from 1/5000 scale topographic maps using GIS software (Fig. 4).



1987

2001

2006

2010

Figure 4. Comparison of vectors; **blue**: object-based results, **red**: manuel on-screen digitizing, **cyan**: reference vector

For the areal changes the 5 km coastal line where the most serious erosions occurred was investigated in three sections. First section covers the eastern part of the Sakarya River, second section covers western part of the river till the breakwater of the harbor and the last section covers the other 3 km part correspond to the city center. These three transections were determined on special places which coastal erosion was occurred using all images. Figure 5 only shows these transections using 1987 Landsat image.

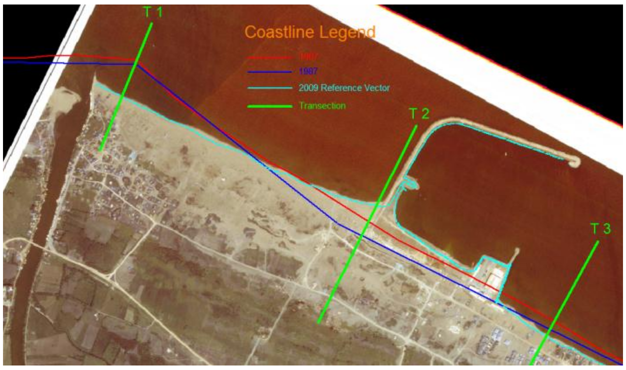
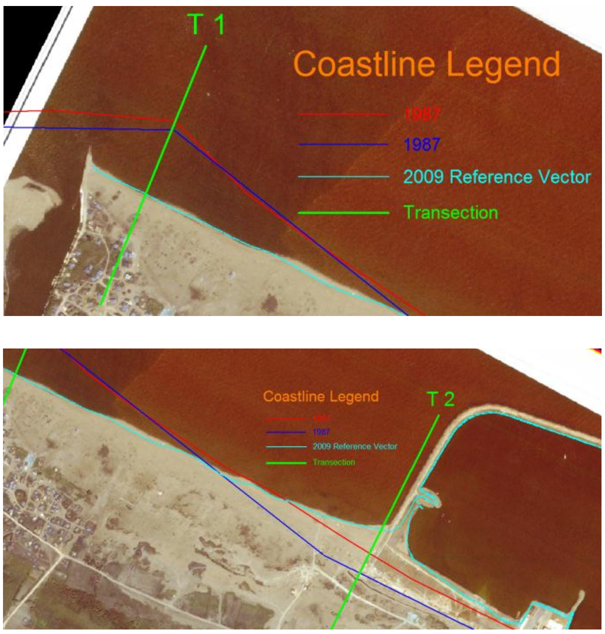


Figure 5. Comparison of object-based vector results, manual on-screen digitising vector results and reference vector; **blue**: object-based results, **red**: manuel on-screen digitizing, cyan: reference vector, **green**: transections

Detailed explanation mentioned above is shown in Figure 6a and 6b. Figure 6a shows that, coastal erosion is clearly determined near the Sakarya River. By the comparison of vectors, object-based vector results and manual on-screen digitizing vector results show this situation. On the other hand, Transection 2 in Figure 6b shows that, by the construction of fish port, cumulated sediments from Sakarya River were placed to the port area.



a

b

Figure 6. Transection 1 and 2, Comparison of vectors; **blue**: object-based results, **red**: manuel on-screen digitizing, cyan: reference vector, **green**: transections

In Figure 7, a photograph taken in the year of 2010 summer season in a sunny day from the glider for the Karasu Municipality. In this photograph the estuary and direction of sediments distribution carried by the Sakarya River can be seen clearly. When the photographs examined, it is very clear that the sediment spread around the coastline in the western part of the port, and the sediment transharboration to the eastern part of the port is obviously prevented by the harbor. Besides, Transections T1 and T2 are shown in this photograph.

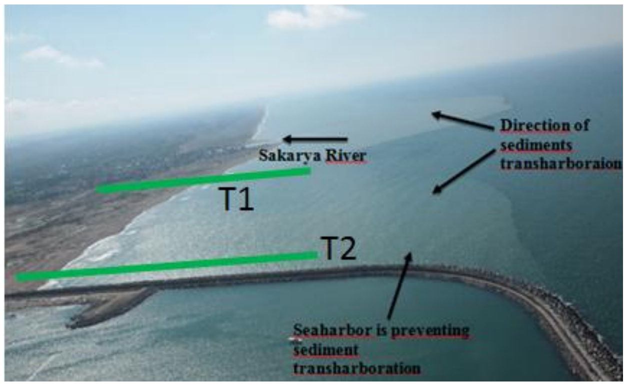


Figure 7. Photograph of Coastline of Karasu

Based on the comparison of vectors which is shown in Figure 4, object-based vector results and manual on-screen digitising vector results are nearly similar to each other. Determined differences between two approaches were arisen from the segmentation and classification phase in eCognition and digitising mistakes during manual on-screen digitising. Also, coastal erosion was determined derived two approaches using T1, T2 and T3 transections from all Landsat images and metric information of coastal erosion is shown in Table 1.

Comparison	T1 (m)	T2 (m)	T3 (m)
Landsat 1987 (OBIA) – Reference Vector	201	-207	41
Landsat 1987 (Manual) – Reference Vector	230	-114	95
Landsat 2001 (OBIA) – Reference Vector	15	-45	89
Landsat 2001 (Manual) – Reference Vector	30	-67	67
Landsat 2006 (OBIA) – Reference Vector	0	149	24
Landsat 2006 (Manual) – Reference Vector	33	-18	14
Landsat 2010 (OBIA) – Reference Vector	50	32	104
Landsat 2010 (Manual) – Reference Vector	-9	-13	47

Table 1. Metric information of coastal erosion

As shown in the table, looking at metric information of three transections, two approaches were outcome similar results in T1 transection. Here, only object-based approach cannot determine the coastal erosion in 2010 Landsat image. T2 transection shows that, by the construction of fish port, cumulated sediments from Sakarya River were clearly determined using two approaches. Here, only object-based approach cannot determine the coastal erosion in 2006 Landsat image. In T3 transection, two approaches were outcome similar results for coastal erosion.

5. CONCLUSION

In this study, temporal analysis of changes in coastline of Karasu was studied on the basis of the classification results acquired using object-based image analysis approaches. For this purpose, Landsat imagery with multispectral bands of 1987, 2001, 2006 and 2010 test area were used. These images were handled by the eCognition v4.0.6 software with the main steps of segmentation and classification. Thus, vectors of coastline were obtained from object-based classifications. On the other hand, these vector results were compared with reference vector and on-screen digitizing results.

Based on the results, following conclusions could be drawn:

- Although Landsat images are suitable for temporal analysis, these images should not be used for high precision analyses.
- Object-based feature extraction process is very fast and feasible on coastline extraction, because it has close results as manual digitizing.
- Manual on-screen digitizing method process is slower than the other one but it has more close results as reference vector results.
- eCognition software has low extraction capability of linear objects. Therefore, wrong extracted results were occurred about coastal erosion. Some sample errors were appeared from 2010 Landsat image at T1 transection and 2006 Landsat image at T2 transection
- Operator knowledge was used for manual digitizing. On the other hand, fuzzy membership functions were used to extract features in the object-based image analysis.
- Making GIS-based analysis and comparisons with raster and vector data of the test area has crucial importance in terms of putting forth the recent situation.

6. ACKNOWLEDGEMENTS

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