Investigation of Shoreline Morphometry of Kizilirmak Delta's Lagoons Using Fractal Dimension and Shoreline Development Index

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Abstract
In this study, shoreline morphometry of the Karaboğaz, Balık, Uzun, Cernek, Liman, Gıcı and Tatlı lagoons which are located in the Kızılırmak Delta, was investigated by using fractal dimension and shoreline development index. The shorelines of the lagoons were obtained from Landsat 8 OLI satellite images of June 4, 2017, using remote sensing-image processing techniques including Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Gram-Schmidt pan-sharpening method and Iterative Self Organizing Data Analysis Technique (ISODATA) unsupervised classification method. In order to investigate the relationship between fractal dimension and the environmental conditions, also shoreline development index and the environmental conditions, the vegetation conditions in the surrounding of the lagoons were determined using Normalized Difference Vegetation Index (NDVI) algorithm. The result of the study reveals that the relationship between fractal dimension and NDVI is much stronger than the relationship between shoreline development index and NDVI.
Keywords: Landsat 8 OLI, shoreline morphometry, lagoon, fractal dimension, shoreline development index, NDVI

1. Introduction

Because formations and systems in nature cannot be fully modeled by known geometric algorithms, to examine systems and formations in nature, new methods have been investigated (Korvin 1992; Avasthi 2000; Dimri and Srivastava 2005). Benoit B. Mandelbrot (1967) introduced the fractal geometry for modeling the irregular shape of earth. Formations and systems in nature can be analyzed with fractal geometry and the complexity is expressed in numerically. This numerical expression is referred to as a fractal dimension (D) (Falconer, 2014).

Several methods are used for calculation of fractal dimension. The box-counting is the most preferred method because of its simplicity and practicality. In this approach, the object is covered with grid cells and the number of grids containing at least a part of the object is counted. The process is repeated by using different size of the grids. The fractal dimension is calculated by a logarithmic ratio of the change in the number of grids to the change in the grid size as in Eq.1 (Ediz 2003). In Eq.1, D_B is the fractal dimension, N is the box number, and S refers to the box size.

$$D_B = \frac{\log N_2 - \log N_1}{\log S_2 - \log S_1} \quad (1)$$

In recent years, the use of fractal analysis has been increased with the development of remote sensing and Geographic Information Systems (GIS) technologies in the examination of the spatial patterns (Hamilton et al. 1992; Tarboton 1996; Shen et al. 2011).

In this study, the shorelines of the Kızılırmak Delta's lagoons were extracted using remote sensing techniques and morphometry of the lagoons were examined by fractal analysis and shoreline development index on the GIS environment.

2. Study Area: Kizilirmak Delta

Karaboğaz, Balık, Uzun, Cernek, Liman, Gıcı and Tatlı lagoons are located in the Kızılırmak Delta, which is one of the wetlands in Turkey that are protected by the Ramsar Convention (Figure 1).

Figure 1: Kızılırmak Delta's lagoons

3. Data and Methodology

Landsat 8 OLI satellite image of June 4, 2017 was used to extract the shoreline of the lagoons and to calculate NDVI in the surrounding of the lagoons. Following radiometric calibration and correction, Normalized Difference Water Index (NDWI) and Modified Normalized Difference Water Index (MNDWI) were applied. Using Gram-Schmidt pan-sharpening algorithm 15-m pixel size index data were obtained from 30-m pixel size index images. These index images were classified using Iterative Self Organizing Data Analysis Technique (ISODATA) method and the shorelines of the lagoons were obtained. To perform fractal analysis, classified image is convert to

binary image (Right side of Figure 1).The fractal dimensions based on the box-counting method were calculated for each lagoon using shorelines. Also, shoreline development indexes were calculated for investigation of the morphometry of the lagoons. The environmental characteristics-vegetation conditions of the lagoons were determined using NDVI algorithm. The 100 meters buffers were formed surrounding the lagoons and these buffers were overlapped with the NDVI layer and the mean NDVI values were calculated in the buffer area of each lagoon. At last, the relationship between fractal dimension and NDVI and the relationship between shoreline development index and NDVI were investigated.

4. Results

Calculated fractal dimensions and shoreline development index values are shown in Table 1 and Table 2, respectively. Both in Table 1 and Table 2, higher values indicate more complex morphometric structure. When the fractal dimension values were compared with the shoreline development index values, it was seen that the fractal dimension increased as shoreline development index increased in general.

Table 1. Fractal dimension of the lagoons

Lagoon	D_B	Lagoon	D_B
Karaboğaz	1.3307	Uzun	1.1957
Liman	1.0669	Gıcı	1.0680
Cernek	1.0503	Tatlı	1.1014
Balık	1.0874		

Table 2. Shoreline development index values of the lagoons. (SDI: Shoreline development index)

Lagoon	SDI	Lagoon	SDI
Karaboğaz	0.765	Uzun	0.730
Liman	0.640	Gıcı	0.772
Cernek	0.622	Tatlı	0.785
Balık	0.678		

Table 3 shows the mean NDVI values in the surrounding of the lagoons. To compare the fractal dimension and shoreline development index values with NDVI a graph was plotted (Figure 2).

Table 3. Mean NDVI values in the surrounding of the lagoons

Lagoon	NDVI	Lagoon	NDVI
Karaboğaz	0.765	Uzun	0.730
Liman	0.640	Gıcı	0.772
Cernek	0.622	Tatlı	0.785
Balık	0.678		

This study shows that the relationship between fractal dimension and NDVI is much stronger than the relationship between the shoreline development index and NDVI. In this context, when a comparison is made between the fractal dimension and the shoreline development index, it is seen that the fractal dimension can provide much better information than the shoreline development index on vegetation conditions.

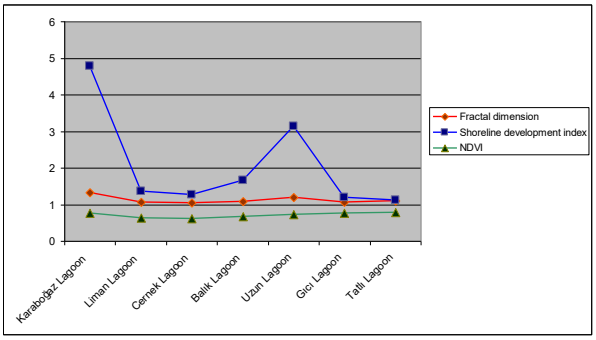

Figure 2: Fractal dimension, shoreline development index and NDVI

5. Conclusion

In this study, shoreline morphometry of Kızılırmak Delta's lagoons was examined by using fractal dimension and shoreline development index, and vegetation conditions in the surrounding of the lagoons were investigated using NDVI. It is concluded that the fractal dimension creates new important information on examination of the shoreline complexity and also provides better perspectives than shoreline development index to investigate of environmental vegetation conditions of the lagoons.

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