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THE CHANGE MODEL OF THE RELIEF WITHIN THE SCOPE OF ANTHROPOGENIC GEOMORPHOLOGY USING GEOGRAPHICAL INFORMATION SYSTEMS AND REMOTE SENSING TECHNIQUES ON THE COASTS OF IZMIT GULF AND ITS SURROUNDINGS

İzmit Körfezi Kıyıları ve Yakın Çevresinde Coğrafi Bilgi Sistemleri ve Uzaktan Algılama Teknikleri Kullanılarak Antropojenik Jeomorfoloji Kapsamında Rölyefin Değişim Modeli

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Abstract

Internal and external factors shape geomorphological elements and processes and vary temporally and spatially. However, today, geomorphological conditions and topographic surfaces are being changed and reshaped by many anthropogenic factors such as settlement, industry, transportation, mining, and tourism. This situation, which leads to the emergence of anthropogenic geomorphological conditions, can be examined with different methods and techniques. This study used Geographical Information Systems (GIS) and Remote Sensing (RS) techniques to determine the intensity of relief change within the scope of anthropogenic geomorphology on the coasts of the Gulf of Izmıt and its immediate vicinity. The anthropogenic relief change model used in the study consists of 6 steps. The model includes the preliminary estimation findings of the factor maps with the weighted overlay method, Landsat satellite image analyses, photo analyses, and measurement-observation data on land and satellite images. In the study, preliminary finding data for relief change were produced from the slope, topographic relief, land use, distance to the main road, and road density data of the study area. Then, satellite images of 1980, 1990, 2000, 2010, and 2020 were analyzed, and a relief change intensity map of anthropogenic origin was obtained by making measurements at 60,000 points through field studies and satellite images. The applied model determined that the intensity of relief change due to anthropogenic origin is high in 22% of the Gulf of Izmit coasts and its immediate surroundings. The findings determined a high density of relief change in transport, industrial and residential areas, and coastal filling areas in areas with high slope values.

Keywords: Anthropogenic Geomorphology, The Gulf of Izmıt Coasts, Change Model of the Relief, Geographic Information Systems (GIS), Remote Sensing (RS).

Öz

Jeomorfolojik unsurlar, süreçler iç ve dış etkenlerle şekillenmekte, zamansal ve mekânsal olarak çeşitlilikler arz etmektedir. Ancak günümüzde jeomorfolojik koşullar ve topografik yüzey, yerleşim, sanayi, ulaşım, madencilik ve turizm gibi birçok antropojenik etkenle değiştirilmekte ve yeniden şekillendirilmektedir. Antropojenik jeomorfoloji koşullarının ortaya çıkmasını sağlayan bu durum farklı yöntem ve tekniklerle incelenebilmektedir. Bu çalışmada, İzmit Körfezi kıyıları ve yakın çevresinde antropojenik jeomorfoloji kapsamında rölyef değişim yoğunluğunun tespiti için Coğrafi Bilgi Sitemleri (CBS) ve Uzaktan Algılama (UA) tekniklerinin kullanıldığı model üzerinden incelemeler yapılmıştır. Çalışmada kullanılan antropojenik kökenli rölyef değişim modeli 6 basamaktan oluşmaktadır. Model, faktör haritalarının ağırlıklı bindirme yöntemi ile ön tahmin bulgularını, Landsat uydu görüntüsü analizlerini, fotoğraf analizlerini, arazi ve uydu görüntüsü üzerinden ölçüm-gözlem verilerini içermektedir. Araştırmada ilk olarak inceleme sahasının eğim, topografik rölyef, arazi kullanımı, ana yola mesafe ve yol yoğunluğu verilerinden rölyef değişimi için ön bulgu verisi üretilmiştir. Daha sonra 1980, 1990, 2000, 2010 ve 2020 yılı uydu görüntüleri analiz edilmiş, 60.000 noktada arazi çalışmaları ve uydu görüntüleri üzerinden ölçümler yapılarak antropojenik kökenli rölyef değişim yoğunluğu haritası elde edilmiştir. Uygulanan model üzerinden İzmit Körfezi kıyıları ve yakın çevresinin %22'sinde antropojenik kökenli rölyef değişim yoğunluğunun yüksek değerde olduğu saptanmıştır. Elde edilen bulgulardan, yüksek eğim değerlerinin olduğu alanlardaki ulaşım, sanayi ve yerleşim alanları ile kıyı dolgu alanlarında yüksek yoğunluklu rölyef değişiminin olduğu saptanmıştır.

Anahtar Kelimeler: Antropojenik Jeomorfoloji, İzmit Körfezi Kıyıları, Rölyef Değişim Modeli, Coğrafi Bilgi Sistemleri (CBS), Uzaktan Algılama (UA).

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INTRODUCTION

There is always a mutual interaction between natural environment conditions and human beings. From the past to the present, many activities of humankind have been shaped according to the region's natural conditions. However, the industrial revolution and technological developments have increased human beings' urge to change nature due to their demands (Ellis & Ramankutty, 2007; Brown et al., 2017). This situation has led to changes in natural conditions and discussions on naming it as a new geological period (Zalasiewicz et al., 2010; Harden et al., 2014; Knitter et al., 2019; Larsen & Harrington, 2020; Kurucu Sipahi & Bağcı, 2024). Today, this period in which human beings are active is called the Anthropocene (Crutzen & Stoermer, 2000; Steffen et al., 2011; Castree, 2014; Hoelle & Kawa, 2021). The changes in the hydrosphere, lithosphere, atmosphere, and biosphere due to anthropogenic factors have also been reflected in geomorphological conditions (Gregory & Walling, 1979; Ellis et al., 2010; Ellis, 2017; Werther et al., 2021). Geomorphological conditions developed by internal and external factors are subjected to human intervention for different reasons and reshaped (Brown, 1970; Goudie, 1993; Hooke, 2000; Church, 2010; Ellis & Haff, 2009; Goudie, 2020; Henselowsky et al., 2021). Geomorphological changes of anthropogenic origin first occurred on a small scale with the use of mining ages, ancient structures, agricultural revolution, and trade processes (Price et al., 2011; Anthony et al., 2014; Migon & Latocha, 2018; Brandolini et al., 2019; Rick et al., 2020). The increase in population with the industrial revolution has led to greater use of nature and changes in geomorphological conditions based on many factors (Rózsa, 2007; Jefferson, 2013; Jordan et al., 2014; Goudie & Viles, 2016; Aguilar et al., 2020). Especially with the developing technology, settlement, industry, transportation, mining, agriculture, and tourism activities have changed geomorphological elements and processes in certain areas and caused the relief to be redesigned (Cooke, 1976; Szabó et al., 2010; Lóczy & Süto, 2011; Tarolli, 2016). Changing geomorphological conditions under human influence, the emergence of artificial landforms, and the different effects of the changing topographic surface have led to the scientific development of anthropogenic geomorphology (Glomb & Eder, 1964; Goudie, 1993; Cuff, 2008; Szabó, 2010; Rózsa, 2010; Brown et al., 2013; Ertek, 2017; Li et al., 2017; Tarolli et al., 2019; Uzun, 2020a).

The first examples of anthropogenic geomorphology studies, which emerged as a sub-discipline of geomorphology, were observed in Europe and America in the 19th century. Marsh's research, in which he examined the changes in the natural environment and geomorphological conditions of humans, is considered the first study on anthropogenic geomorphology (Marsh, 1864). In addition, scientists named A. Stoppani and A. Pavlov played a significant role in the first emergence of the concept of Anthropocene. In the studies that became more widespread in the 1900s, Shaler, Gilbert, and Sherlock focused on geomorphological changes during soil erosion, mining, and colonial activities (Shaler, 1912; Gilbert, 1917; Sherlock, 1922). After the 1980s, studies on relief changes, models based on morphometric analyses, the effect of transportation networks on geomorphological conditions, and anthropogenic geomorphology classification are essential studies in the discipline (Golomb & Eder, 1964; Brown, 1970; Nelson & Outcalt, 1982; Nir, 1983; Erlich, 1990; Goudie, 1993). As of the 2000s, technological developments such as Geographic Information Systems (GIS) and Remote Sensing (RS) techniques have enabled the diversification of methods in anthropogenic geomorphology studies and the increase in the number of researchers (Remondo et al., 2005; Ertek & Erginal, 2006; Szabo et al., 2010; Manea et al., 2011; Rózsa & Novak, 2011; Ursu, 2011; James et al., 2012; Byizigiro et al., 2015; Sofia et al., 2016; Tarolli & Sofia, 2016; Verstraeten et al., 2017; Migon & Latocha, 2018; Zentai, 2018; Brandolini et al., 2019; Downs & Piegay, 2019; Pröschel & Lehmkuhl, 2019; Rocatti et al., 2019; Tarolli et al., 2019; Turoğlu, 2019; Xiang et al., 2019; Cao et al., 2020; Chirico, et al., 2020; Rózsa, et al., 2020; Uzun, 2020b; Henselowsky et al., 2021; Pierik, 2021; Uzun, 2021a).

This study aims to create a model by using Geographical Information Systems (GIS) and Remote Sensing (RS) techniques to determine the distribution and intensity of human-induced relief or topographic change within the scope of anthropogenic geomorphology in the sample area of Izmit Bay coasts and its immediate surroundings. The study is based on the morphometric change of the relief due to erosion, deposition, leveling-smoothing, and mixing processes on the surface as anthropogenic geomorphological changes. The selection of the coastal area of Izmit Bay as the sample area in the study was influenced by the fact that it contains various geomorphological features, the topography is exposed to anthropogenic factors in the origin of dense population, settlement, industry and transportation, and changes in different dimensions (in terms of relief) have been experienced on the surface from past to present.

The Gulf of Izmit's coasts are located east of the Marmara Sea in northwestern Turkey. There is the Kocaeli plateau in the north, the Samanlı Mountains in the south, the Samanlı Mountains and the overcoat area in this area, and the Izmit-Sapanca alluvial trough in the east of the Gulf of Izmit coasts and its immediate surroundings. Yelkenkaya Cape forms the western border of the study area in the north and the Lale Stream delta area west of Çatal Cape in the south. The study area is between 40040'-40048' north latitude and 29022'-29058' east longitude (Figure 1). The Gulf of Izmit, which extends in the east-west direction for 50 km from the Marmara Sea into the land, has a coastal length of 190 km. The coasts of the Gulf of Izmit are within the borders of 11 different districts, 9 of which are located in Kocaeli province and 2 of which are located in Yalova province. There are dense residential areas and industrial establishments in different sectors on the northern (Dilovası, Körfez) and eastern (Derince, İzmit, Gölcük, Başiskele) coasts of the Gulf of Izmit. In the north part, the D-100 highway, Istanbul-Ankara motorway (O-4), railway, and many industrial ports constitute the area where transportation is concentrated (Figure 1). In the south-southeast coasts, agriculture, tourism, industry in some areas, and transport (D-130 motorway).

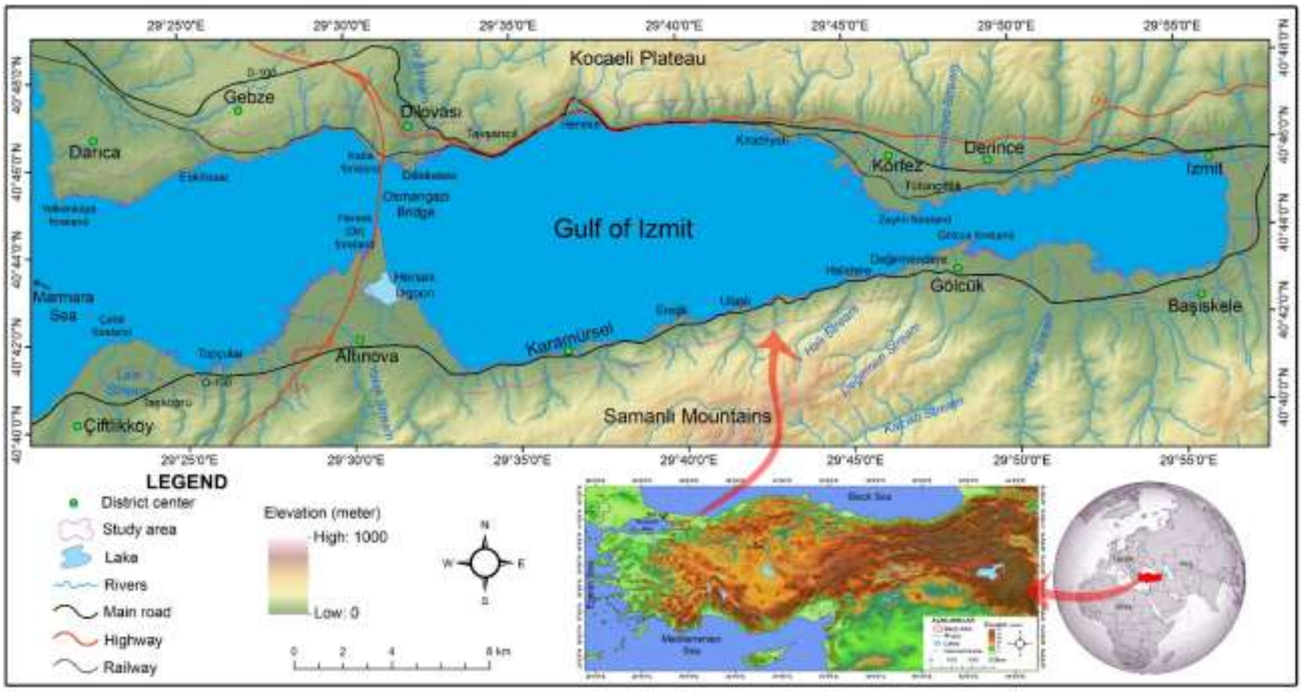

Figure 1: Location Map of The Study Area

MATERIAL AND METHOD

In the research, 12 1:25.000 scale topography sheets, historical aerial photographs, Landsat MSS dated 23.07.1975 and 10.08.1980 from United States Geological Survey (USGS), Landsat TM dated 24.07.1990, Landsat ETM dated 25.06.2000 and 26.07.2010, Landsat OLI data dated 08.05. 2020 dated Landsat OLI data, high-resolution orthophoto of 2022 from Google Earth Pro, 500 aerial photographs downloaded from tripinview, road data from OpenStreetMap, past period photographs from municipalities, observation, measurement data, and photographs obtained from field studies, and past period cartographic data were used.

Firstly, a digital elevation model was created from the topography sheets using ArcGIS software. Then, slope, topographic relief, and drainage network data were obtained from the digital elevation model. 30 high resolution (4800x2966 and 400 DPI) orthophotos downloaded from Google Erath Pro for the year 2022 were merged with Photoshop software and then coordinated with ArcGIS. The coastline of Izmit Bay in 2020 was drawn from the high-resolution satellite image obtained. The boundaries of the study area were established with a 1000-meter buffer area based on the coastline of 2022. Land use data was created by classifying the high-resolution satellite image and edited by checking with field studies. Road data downloaded from the OpenStreetMap application were reduced to the boundaries of the study area, and a road density map was created using kernel density analysis. From the road data, the main road routes, D-100, D-130 highway, O-4 and O-5 motorway, and railway line were redrawn, and then the distance map to the roads was produced. Landsat satellite images (1975, 1980, 1990, 2000, 2010, and 2020), old and new photographs, aerial photographs, cartographic data, and observation-measurement data in field studies were analyzed to create and apply the model. The anthropogenic geomorphology map of the research area was also produced as a result of the findings obtained after the creation of the model and the analysis of previous studies on the field and the subject.

2.1. Stages of Creation of Relief Change Model of Anthropogenic Origin

The model created to distribute the intensity of relief change due to anthropogenic origin consists of 6 steps. In the first step, the boundaries of the study area were determined after analyzing the related studies (Figure 2).

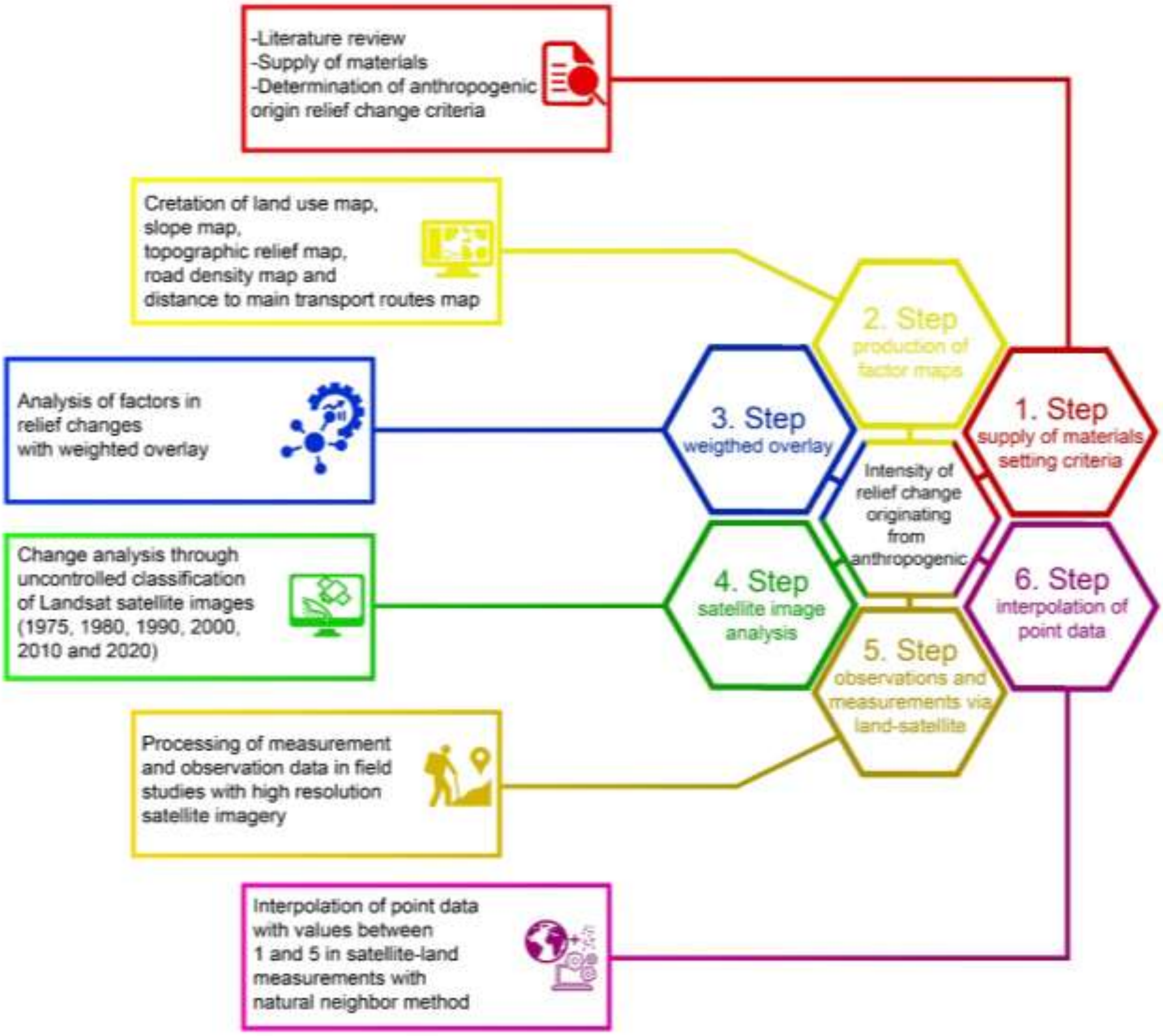

Figure 2: Work-Flow Chart of Model of Relief Change Originating From Anthropogenic

The most crucial stage of the first part of the model is the determination of the criteria required to determine the intensity of anthropogenic relief change in the field (Figure 2). The criteria include features with a coefficient value between 1-5, morphometrically classifying anthropogenic relief changes, and indicating different impact types and geomorphological processes. In determining the criteria, many studies on anthropogenic geomorphology were utilized (Nelson & Outcalt, 1982; Nir, 1983; Goudie, 1993; Rózsa, 2007; Cuff, 2008; Rózsa & Novak 2011; Jefferson et al., 2013; Sofia et al., 2016; Tarolli & Sofia, 2016; Brown et al., 2017; Migon & Latocha, 2018; Xiang et al., 2019; Cao et al., 2020; Rózsa et al., 2020; Uzun, 2020a). In this context, based on the studies of Szabó (2010) and Tarolli et al. (2019), among others, qualitative and quantitative parameters were made site-specific, and the characteristics of the criteria steps were determined in detail (Szabó, 2010; Price et al., 2011; Migon & Latocha, 2018; Brandolini et al., 2019; Tarolli et al., 2019) (Table 1).

In the second stage of the model, the factor data required to create a preliminary map of the distribution of anthropogenic-induced relief change are generated to determine in which areas field studies, measurements, and observations will be concentrated. Geomorphological factors are slope and topographic relief, anthropogenic factors are land use, road density, and distance maps to main transport routes. Slope and topographic relief data were produced from DEM and divided into 5 categorical classes. A land use map was created by analyzing satellite images and field studies, while road data were produced from road line data obtained from OpenStreetMap.

Table 1: Criteria Used ın Field Observations And Measurements of Anthropogenic Origin Relief Changes*

Coefficient	The Intensity of Geomorphological Change	Morphometric observation and measurement criteria	Types of anthropogenic influence	Processes and elements of anthropogenic geomorphology
1	No change or too low	No observed change or 0-0.5 m vertical-horizontal, small size change with narrow space	Forest areas, other vegetation types, unused land, agricultural land, pasture land, rural or secondary residential areas	Natural geomorphological processes or small-scale relief arrangement, mixed processes
2	Low	Small size change between 0.5-1 m vertically, with narrow or wide areas	Residential areas, secondary roads, commercial areas, socio-cultural areas, parking areas, other anthropogenic uses	Minor relief erosion, leveling-flattening, mixed processes, indirect shore change
3	Medium	Changes between 1-3 m vertically and in medium width area	Industrial area, residential area, primary and secondary roads, socio-cultural areas, parking area, recreation area	Leveling-flattening, mixed processes, coastal erosion, marine terrace deformation, artificial hills, artificial terraces
4	High	Large-scale change in vertical-horizontal dimension with a large area between 3-10 m	Main access roads, residential area, railway, main road underpasses, industrial area, road junctions, recreation area	Relief erosion, slope arrangement, artificial terraces, leveling-flattening, drainage change, mixed processes, coastal accumulation and erosion, dead cliffs,
5	Too high	More than 10 meters of vertical-horizontal and wide-area exchange	Mine, sand processing area, main transportation lines, highway, railway, main road, tunnel, coastal embankment areas, industrial ports	Large-scale relief erosion, coastal fill areas, coastal erosion, delta deformation, drainage change, artificial valley-trough, artificial terrace, tunnel, artificial pit-lake

*The studies of Szabó (2010), Price et al., (2011) and Tarolli et al. (2019) were used to determine the criteria sources.

In the third stage of the model, 5 different main factors and their 28 sub-criteria are analysed with the weighted overlay in the Multi-Criteria Decision Making Method (MCDM) based on certain assumptions and preliminary estimation data are produced (Table 2). This is based on the assumption that anthropogenic processes cause more considerable relief changes in geomorphologically more unfavorable areas (e.g., high slopes). In this context, the impact percentages of the main criteria and the impact coefficients of the sub-criteria were determined through the matrix created. These values were analyzed with ArcGIS software, and preliminary estimation findings were presented for the distribution of relief change intensity of anthropogenic origin. The preliminary prediction map's findings also reveal the areas where relief change will be concentrated.

In the fourth stage of the study model, Landsat satellite images are analyzed in addition to the findings of the preliminary prediction maps. The 1975 Landsat satellite image was only used to determine the shoreline and coastal fill areas due to the difference in resolution. Landsat satellite images of 1980, 1990, 2000, 2010, and 2020 of the research area were brought to the appropriate band combinations and analyzed by controlled classification method, and land change areas were determined. Then, the morphometric characteristics of relief changes were determined by analyzing the change areas on high-resolution satellite images.

The fifth stage of the study is the most important and intensive part of the model. In this stage, the preliminary prediction map and satellite images are analyzed. Along with the mentioned analyses, the current change is determined through old photographs of the study area. After all analyses, measurements, and observations are made using the criteria of the intensity of relief change due to anthropogenic origin. The data whose coordinates (x, y data) are determined by the measurements and whose criterion value is determined are assigned as points to the high-resolution satellite image. In field studies, morphometric measurements were made on the surface or by photograph scaling. In the areas that cannot be reached in the field studies, points with appropriate criterion values are assigned on the satellite image. Data with a coefficient value between 1 and 5 were entered at more than 60,000 points, where field studies and satellite images determined the relief change dimension.

In the sixth and last step of the model, points with coefficient values between 1 and 5 were interpolated from field studies and satellite images. Coefficient point values were interpolated with the natural neighbor method to determine the distribution of relief change intensity of anthropogenic origin and a map was produced. The natural neighbor method was preferred because it provides simple, accurate, and more continuous data than other interpolation methods.

Table 2: Impact Values of The Criteria Used in The Weighted Overlay Analysis For The Forecast Map

Main Criteria	Sub Criteria	Impact percentage	Impact coefficient	Main Criteria	Sub Criteria	Impact percentage	Impact coefficient
Land Use	Residential area	25	4	Topographic relief	0 – 5 m	20	1
	Transportation		5		5 – 15 m		2
	Coastal fill areas		5		15 – 30 m		3
	Sand processing		5		30 – 60 m		4
	Industrial area		3		10 – 161 m		5
	Agriculture		1	Road Density	2,6 – 19,7	15	1
	Other usage areas		2		19,8 – 39,5		2
	Unused lands		1		39,6 – 59		3
	Forest vegetation		1		59,1 – 88,2		4
Slope	0^0 - 2^0	25	1		88,3 – 129		5
	2^0 - 5^0		2	Main Transport	50 m	15	5
	5^0 – 10^0		3		100 m		4
	10^0 – 15^0		4		500 m		2
	15^0 - 52^0		5		5000 m		1

Natural Neighbour method is an interpolation method introduced by Sibson (1981) (Sibson, 1981; Belikov et al., 1997). The method is applied by finding a set of points with known values closest to this area to calculate the value of unknown areas over irregularly distributed sample points and calculating the surface values based on areas proportional to their weights to these points (Bobach, 2008). It uses Voronoi tessellation in its working principle, and this system makes the calculations workable. The advantages of this interpolation method are that it is a more accurate and smoother approach to unknown points. The basic equation of the natural neighbor method and the equation of Sibson weights, Voronoi diagram, and Laplace weights are included in this formula.

$$G\ (x) = \sum_{i=1}^{n} \mathrm{Wi(x)\ f(xi)} \qquad\qquad Wi(x) = \frac{A(xi)}{A(x)}$$

In the basic equation, G(x) is the point, area, x, and Wi weight values to be estimated, and f(xi) is the point data with a known value. In the tessellation equation Wi(x), A(x) is the volume center of each area in the Voronoi polygons, and A(xi) is the center at the intersection of a new polygon (Sibson, 1981).

FINDINGS

3.1. Preliminary Estimation of Relief Change Areas with Multi-Criteria Decision Making Management in the Gulf of Izmit Coast and its Surroundings

In the research, slope, topographic relief (geomorphological criteria), land use, road density and distance to main roads (anthropogenic criteria) data were created for the preliminary prediction map. These data were used in the study because they have common effects on relief change, include both anthropogenic and geomorphological conditions and provide a better analysis of the site. All of the factor maps were analyzed in detail, and a matrix of the percentage and coefficient values of the main factor and sub-criteria on anthropogenic relief changes specific to the site was created (Figure 3).

When the slope and topographic data are analyzed, the uplift areas developed under the influence of tectonic directions in the north and south of the coasts of the central basin of the Gulf of Izmit have caused sudden elevation level changes (Figure 4). This has resulted in high slope and topographic relief values, especially on the coasts between the Dilovası-Tavşancıl-Hereke line in the north and Gölcük-Karamürsel line in the south. Apart from these areas, slope values are pretty high in the coastal hinterland of Darıca-Gebze-Dilovası and the area northwards from the Izmit coast and southwards from Karamürsel.

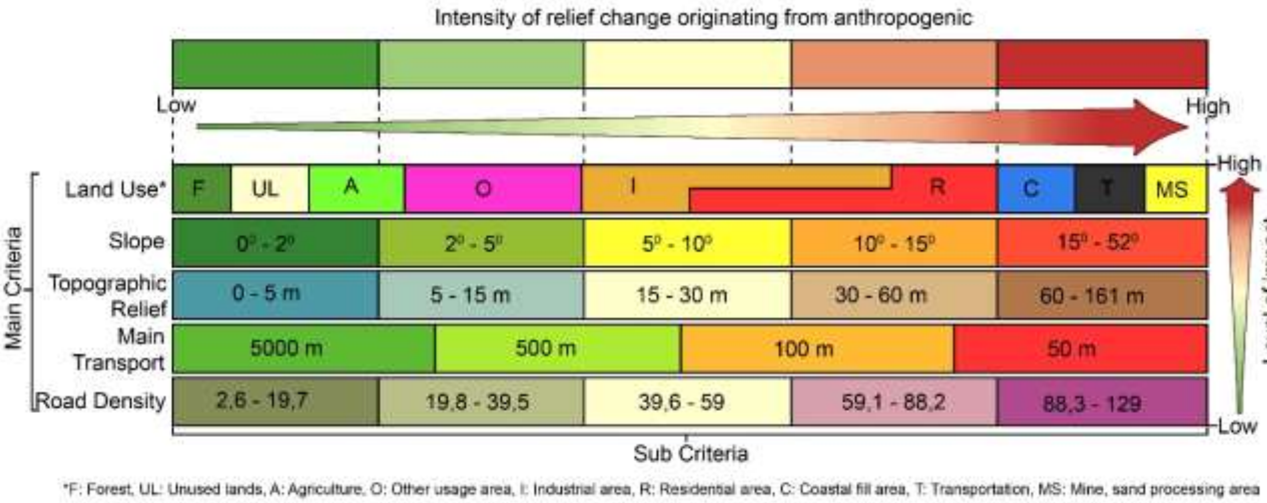

Figure 3: Impact and Comparison Matrix of Main and Sub-Criteria Used For Anthropogenic Origin Relief Change Density Preliminary Forecast Data

When the land use distribution of the Gulf of Izmit coastal area in 2020 is examined, it is understood that the eastern basin coasts, including Körfez, Derince, İzmit, Başiskele, and Gölcük are intensively used for settlement, industry, and transport. Settlement areas in Darıca and Karamürsel coastal areas attract attention. Diliskelesi, western coasts of the Hersek delta, Gölcük, İzmit, Derince, and Körfez coasts have large areas of coastal filling areas (Figure 4). Most coastal filling areas are industrial, harbor, and recreation areas. In the central basin coastal hinterland, there are forest areas. The land use in the southwestern coastal area (Altınova and west) is agricultural.

It is seen that the road density in the research area is parallel to the population and settlement affecting the coastal area. Izmit coast is the coastal area with the highest road density (Figure 4). Gölcük, Körfez, Derince and Karamürsel are the other areas with high road density. The east-west oriented D-100 highway, O-4 motorway, and railway line passing through the northern coastal area and the O-5 motorway in Dilovası reveal the preliminary finding that transport-induced relief changes will be intense on these coasts in terms of distance. The main transport routes on the southern shores of the Gulf of Izmit are the east-west oriented D-130 highway and the O-5 motorway in the Hersek delta.

The impact percentage and impact coefficient values of 5 main criteria and 28 sub-criteria, which reveal the geomorphological and anthropogenic characteristics of the research area, were calculated through the matrix (Figures 3 and 4). The creation of the matrix is based on the assumption that large-scale human activities, parallel to areas with less favorable geomorphological conditions for human activities, lead to more significant and wider changes in relief. The impact values of anthropogenic and geomorphological factors were calculated over the matrix, and the weighted overlay method produced a preliminary prediction map of the anthropogenic-induced relief change intensity of the site.

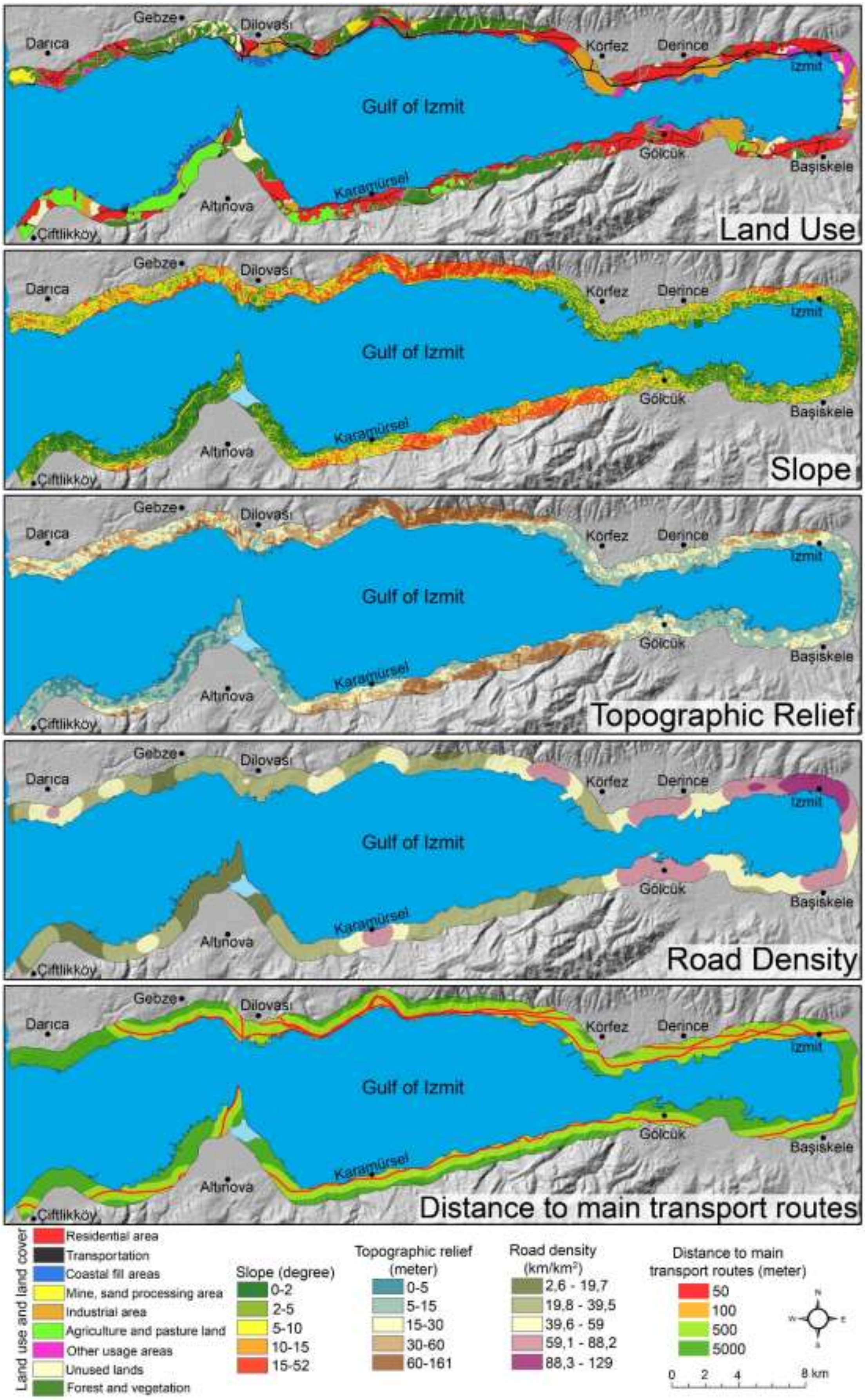

Figure 4: Geomorphological and Anthropogenic Factors Used For Forecast-Finding Analysis

According to the preliminary prediction map, the data reveal that the intensity of relief change may be high in the coastal areas of Dilovası-Hereke-Kirazlıyalı coasts, İzmit, Gölcük and Karamürsel (Figure 5). The main reason for the intensity of relief change in these areas is related to the fact that anthropogenic activities such as settlement, industry, and transport coincide with high-slope and topographic relief areas. It is understood that the coastal areas of Çiftlikköy, Altınova, Darıca, and Gebze may have the lowest density. The fact that human activities are less in these areas and geomorphological conditions are more favorable for human activities has caused no change in the relief. Apart from these areas, the areas with forest areas, coastal filling areas, and sandstone processing areas in terms of land use in the preliminary prediction map could not be predicted correctly over the average impact values (Figure 5). This situation was caused by the fact that the average data of slope, topographic data values, and anthropogenic impact values were in the medium intensity class instead of the low-high class in terms of impact value in the specified areas. The preliminary prediction map model revealed the relief change areas by the assumptions in certain areas, but some faulty situations were observed in some areas. For the mentioned reason, it is aimed to produce a map of relief change intensity with a high accuracy rate with other process steps of the mode.

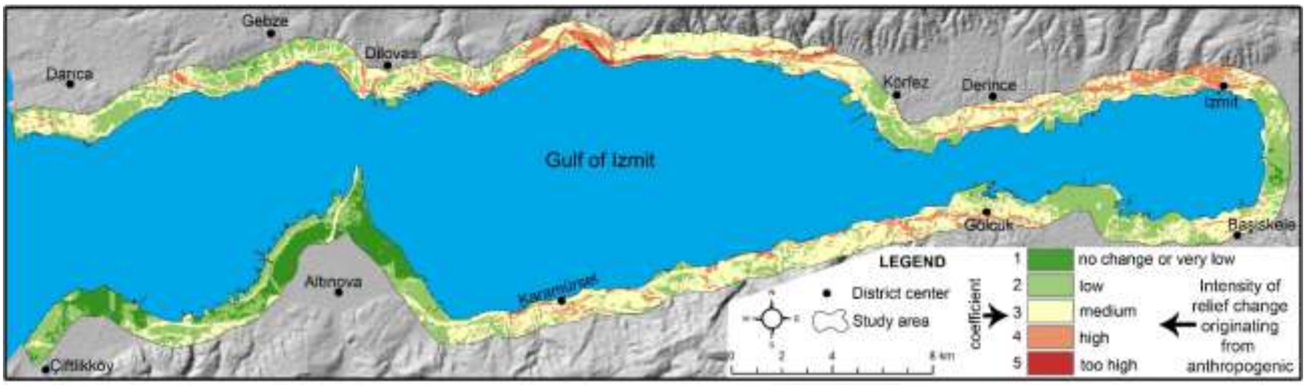

Figure 5: Density Of Relief Change Originating From Anthropogenic Preliminary Estimation Map Of The Research Area

3.2. Relief Change Intensity Distribution Model of Anthropogenic Origin on the Gulf of Izmıt Coasts and Its Surroundings

The preliminary estimation data's findings were first analyzed to accurately reveal the distribution and intensity of anthropogenic relief changes based on many factors. Then, Landsat satellite images were analyzed to determine the effect of land use changes on geomorphological conditions in the study area over the last 40 years (Figure 6). The periodically changing areas of the satellite images analyzed by controlled classification were determined through ArcGIS software. These areas were also diagnosed with high-resolution satellite images to determine the relief change. After the preliminary estimation findings and satellite image analyses, the old photographs and cartographic data of the areas where the change is concentrated, as well as the current land and aerial photographs, were examined comparatively (Figure 7). Finally, within the scope of the findings in all analyses, the changes measured and observed in situ with the field study were given a coefficient value according to the criteria between 1 and 5. The areas not measured in situ in the field studies were given a coefficient value according to the relief change criteria via high-resolution satellite imagery (Figure 8). More than 60.000 data points were obtained by measurements and observations in the field, and satellite images were interpolated by the natural neighbor method. The processes revealed the distribution and intensity of anthropogenic relief change in the study area (Figure 9).

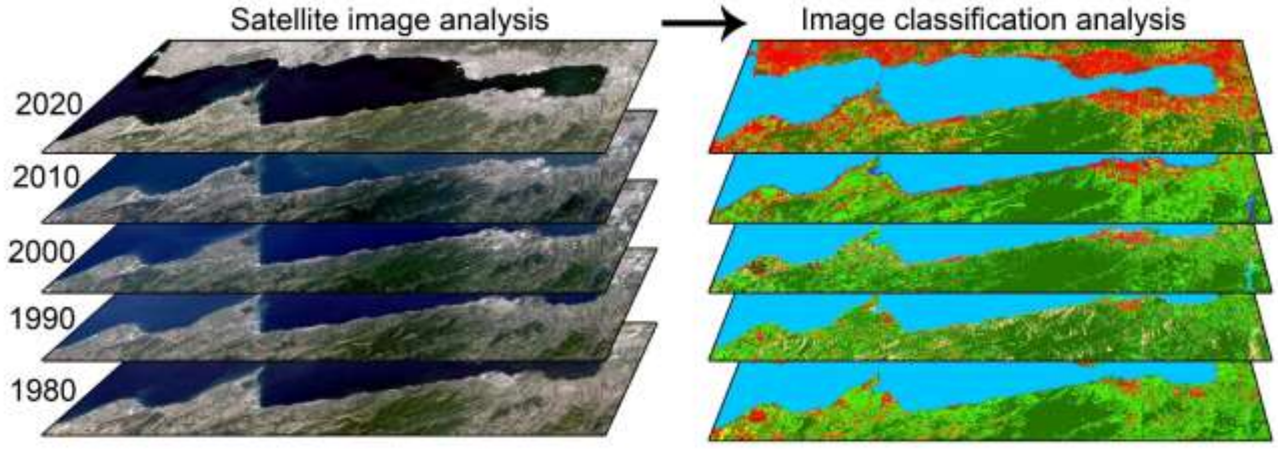

Figure 6: Landsat Satellite İmages and Controlled Classification Analysis Of The Research Area

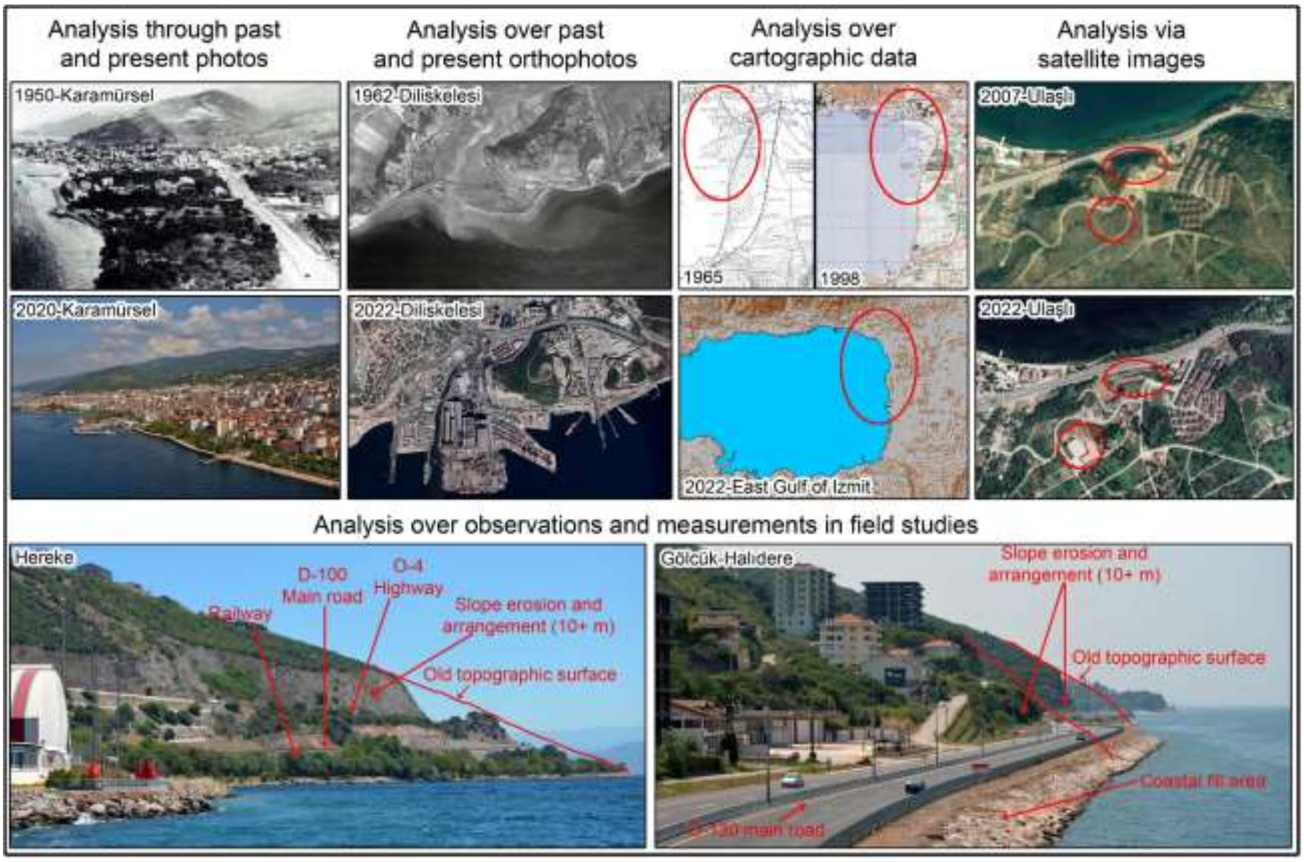

Figure 7: Relief Change Analysis Via Photographs, Cartographic Data And Satellite Images

Figure 8: Distribution and Coefficient Example Of Relief Change Points Determined On Land And Satellite Images

It was determined that the intensity of anthropogenic geomorphological change in the coastal area of Izmit Bay is 40 % deficient or no change, 16 % low, 22 % medium, 12 % high, and 10 % very high. According to the map of relief change intensity of anthropogenic origin, the cement industry area and sand processing area in the coastal hinterland of Darıca and Hereke constitute the first areas with the highest relief change intensity (Figure 9 and Photo 1). The coastal landfill sites in Altınova, Diliskelesi, Körfez, Derince, İzmit, Gölcük, and Başiskele are the other areas with high intensity. Coinciding with the areas with high slope values, the railway on the Gebze coast, the motorway and D-100 highway from Dilovası to İzmit, and the D-130 highway between Karamürsel, Ulaşlı, Halıdere, Değirmendere are the other areas where relief change is intense (Figure 9). Apart from the very high-intensity anthropogenic-induced relief change areas, the presence of high-intensity changes in the settlements of Hereke, İzmit, Gölcük, Değirmendere, and Karamürsel, especially with the process of redevelopment on the slopes, draws attention (Photo 1). The use of plains and alluvial plains for agricultural purposes in the southwest of the study area has caused very little geomorphological change. In the settlement areas on the coastal plains of Gölcük, Darıca, Körfez, and Derince districts, a moderate relief change was found. Drainage and shoreline changes due to anthropogenic factors in the wetland on the eastern shore of Izmit Bay caused reasonable changes. Forested areas forming the land cover in the steep areas in the northern and southern coastal hinterland of the central part of the Gulf of Izmit and unused lands between Gebze-Darıca constitute the areas where no change is observed. The anthropogenic-induced geomorphological change intensity model applied within the scope of the Gulf of Izmit sample area shows relief changes in various morphometric characteristics caused by different factors in the study area.

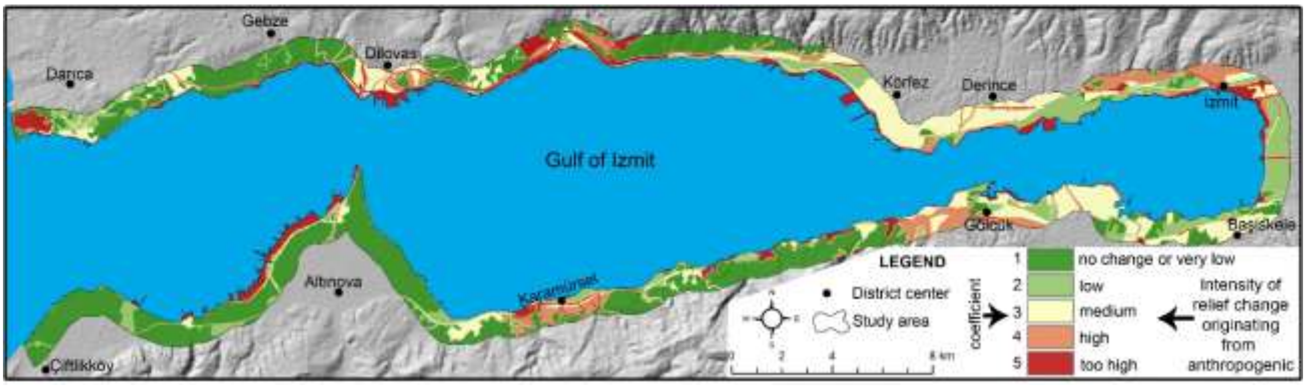

Figure 9: Anthropogenic Origin Relief Change Model Of The Gulf Of Izmit Coasts And Its Surroundings

Many geomorphological elements are formed by different factors and processes on the shores of Izmit Bay and its immediate vicinity. However, the relief change findings revealed by the applied model show that anthropogenic geomorphological units have replaced natural geomorphological units in many areas (Photo 1). These are examples of artificial coasts, anthropogenic slope erosion, artificial terrestrial deposits, direct and induced anthropogenic coastal erosion areas, and delta and drainage changes.

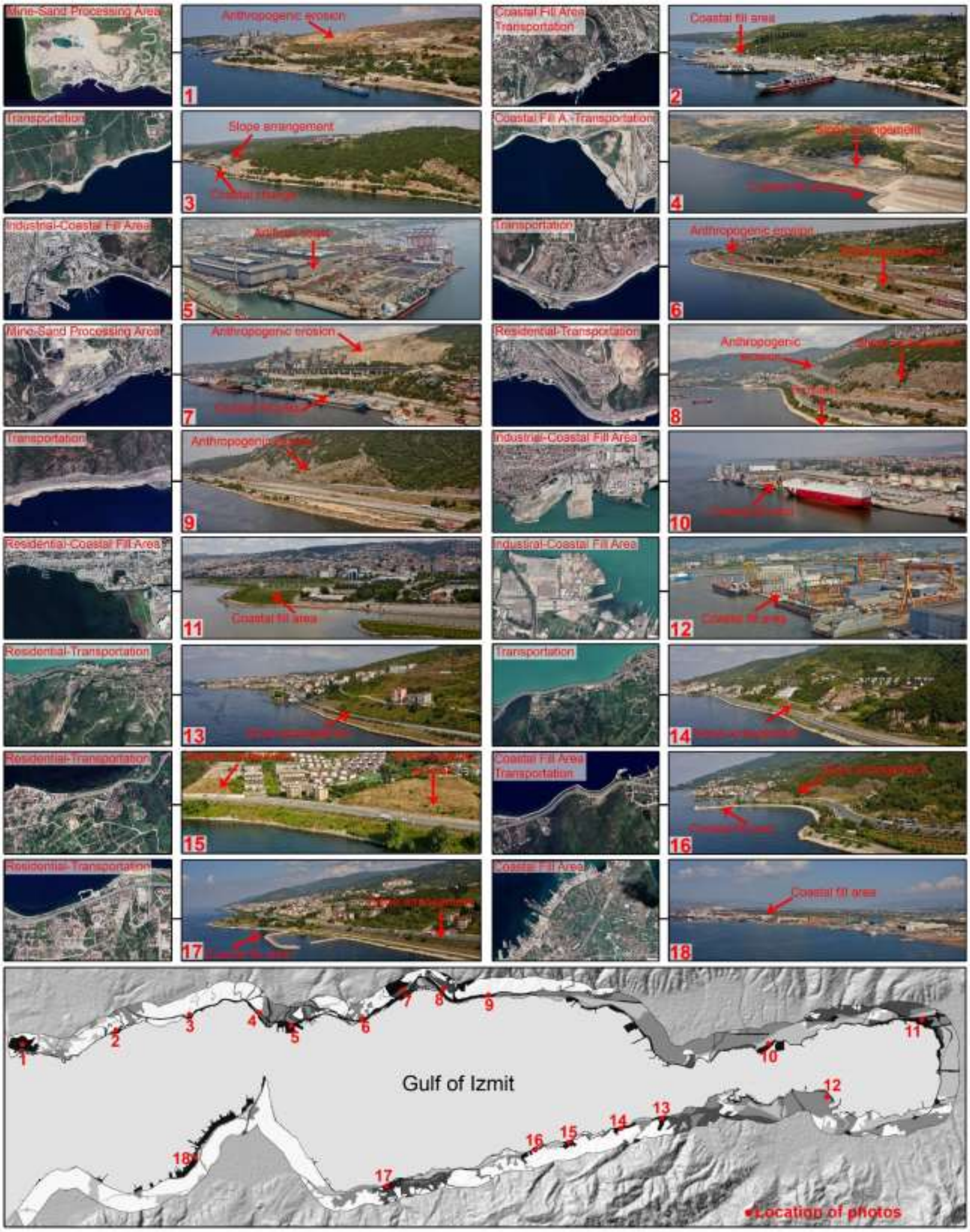

Photo 1: Satellite Images and Photographs of Anthropogenic Origin Relief Change Samples in The Research Area (aerial photos taken from tripinview)

DISCUSSION

The models put forward in anthropogenic geomorphology studies can reveal the global, regional and local relief change status with different results by applying various methods (Nelson ve Outcalt, 1982; Nir, 1983; Rózsa, 2007; Szabó, 2010; Manea et al., 2011; Rózsa & Novák, 2011; Ursu et al., 2011; Jefferson, 2013; Sofia et al., 2016; Tarolli, 2016; Tarolli & Sofia, 2016; Rocatti et al., 2019; Tarolli et al., 2019; Xiang et al., 2019; Cao vet al., 2020; Chirico et al., 2020; Rózsa et al., 2020). At this point, it is seen that some of the morphometric models cannot fully reveal the distribution of relief change and the intensity of anthropogenic geomorphology (Nir, 1983; Erlich, 1990). Another situation is that the analyses-parameters in studies conducted with different methods are questioned, criticized, or there are doubts about the correct presentation of scientific information (Rózsa & Novák, 2011). The potential anthropogenic geomorphology index, one of the first models, is a morphometric model and includes different parameters (Nir, 1983). However, it is stated that this model does not provide accurate data and has relational and geographical inaccuracies in its parameters. The analyses made on the model, which was revised later, cannot fully reveal the local anthropogenic geomorphology data (Rózsa & Novák, 2011). In particular, studies, where basic geomorphological units such as plateau, mountain, plain, climate characteristics, and literacy rate are used as criteria cannot accurately analyze anthropogenic relief changes that may occur, and regional studies cannot go into detail. In this respect, the model proposed in this study considers a region's slope and topographic relief characteristics as a parameter rather than plateau or plain characteristics. It is known that humankind does not need to interfere with geomorphological conditions, especially when using flatter areas, but in areas with steep slopes, transportation, settlement, industry, etc. It is known that it necessarily leads to the relief arrangement for reasons (Tarolli, 2016; Tarolli et al., 2019). The high level of influence of the slope, topographic relief, and land use parameters among the criteria in the model used in the study is due to this situation. In the model map, the high-intensity relief change area between Diliskelesi-Hereke-Kirazlıyalı due to transport proves that the model provides accurate data. At the same time, the models should be made site-specific because the socio-cultural structures are different locally in many parts of the world, and the type and size of anthropogenic intervention varies. The fact that the criteria of anthropogenic relief change intensity of the model used in the study can be changed and can be made site-specific enables the presentation of scientifically accurate data. Many parameters are used with various variations in different anthropogenic geomorphological modeling (Tarolli & Sofia, 2016; Rózsa et al., 2020). The most important feature of the proposed and applied model is that it can reveal the joint effect of anthropogenic and geomorphological factors using GIS, remote sensing techniques, preliminary prediction maps, and analysis findings from different databases. In addition, the transport distribution underlying anthropogeomorphological changes, revealed in many studies, is used as one of the basic parameters of the model Sofia et al., 2016; Downs & Piagey, 2019; Xiang et al., 2019). Another situation is that the model presents both temporal and spatial change data. The fact that morphometric models provide general data shortens the extent of material change. However, analyses with long-term orthophotos, cartographic data, and satellite images show the distribution and temporal period of change more accurately (Xiang et al., 2019; Chrico et al., 2020). UAV and LIDAR data used in many studies provide very high-resolution anthropogeomorphological change data. At the same time, morphometric calculations of anthropogeomorphological changes can be made over these data, as in the SLLAC example (Sofia et al., 2016). However, due to the short history of the use of LIDAR and UAV in land modeling in the world, past changes cannot be detected. It has been determined that the changes in the shores of the Gulf of Izmit, which is the sampling area, and its immediate surroundings can go up to 80 years based on the coast and its hinterland and reveal long-term temporal data. The anthropogenic-induced relief change model has given essential results in using the distribution and intensity of long-term changes in local-regional field studies. The model's criterion steps and the ability to make morphometric data site-specific enable the data to be reorganized in future changes.

CONCLUSION

This study created a model consisting of 6 steps using GIS, remote sensing techniques, and various methods to reveal the intensity and distribution of anthropogenic relief change in the Gulf of Izmit and its immediate vicinity. In the model used in the study, anthropogenic relief change criteria were determined first. Then, 5 main criteria, namely slope, topographic relief, land use, distance to main roads and road density, and 28 sub-parameters of these data were analysed with the weighted overlay method in the MCDM and a preliminary finding-prediction map was created. In the other part of the model, 1980, 1990, 2000, 2010, and 2020 satellite images were analyzed with the preliminary prediction map data. Afterward, cartographic data and photographs were analyzed comparatively, and point data with coefficient values between 1-5 were generated with measurement and observation data from field studies and high-resolution satellite images. As a result of interpolating the obtained data with the natural neighbor method, a model of the intensity of relief change of anthropogenic origin was presented.

In the preliminary prediction map, it was observed that the changes from the past to the present, coastal filling areas and micro-sized relief changes were not reflected in the result map and the model was incomplete at this point. Due to this situation, it has been determined that the observations and morphometric values assigned pointwise in the basic model produce more useful, accurate results and produce results that will fully reflect the relief change. As a result, in addition to using geomorphological and anthropogenic factors in the preliminary prediction data of the model, the use of observation and measurement data obtained from field studies and satellite imagery data has been found to provide very accurate and usable model maps.

According to the model data, it was determined that the intensity of anthropogenic-induced geomorphological change in the coastal area of Izmit Bay is 40% deficient or no change, 16% low, 22% medium, 12% high, and 10% very high. It has been determined that relief change is intensified significantly in the cement industry and sand processing area in Darıca and Hereke, on the main road routes between Dilovası-Hereke-Körfez, in the coastal hinterland of İzmit, Gölcük-Karamürsel, and coastal filling areas. Relief change is shallow in areas used as forest and agricultural areas, alluvial plains, and lowlands. It has been determined through the applied model that the intense anthropogenic pressure changes the geomorphological elements and processes, especially in the eastern basin of the Gulf of Izmit coast. It was also seen that the model applied in the study has a structure that can be used for different purposes in anthropogenic geomorphological studies with its analytical features, querying from many parameters, and its developable and adjustable features.

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