



Determining anthropogenic pressure on the Southern Black Sea blue flag beaches

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Abstract

Coasts are settlement areas that attract human for many years. Türkiye, geographically located on Mediterranean Basin and Asian Continent passage with unique climate regime, has a great coastal zone. The mid-latitude geographic setting makes possible to experience coastal recreation and tourism activities for almost all year along. Among all activities sun, sea and sand tourism can be placed on the first stage. Recent changes in local climate of the Black Sea such as rising mean atmospheric temperatures and increasing number of sunny days have triggered touristic beach activities in the region. In the literature, there are different techniques for grading and classifying coastal beaches. In this study, as an integral part of coastal landscape formation Land Use/Land Cover (LULC) structure is linked to landscape value and regarded as cover changes that determines landscape pattern of the area under investigation. The research rationale of this study is based on an assumption of Southern Black Sea coastal blue flag beaches are under severe anthropogenic pressure. For this purpose, 15 blue flag beaches which are located on the Black Sea coast of Türkiye were selected based on their morphological dimensions. To determine landscape changes and potential human induced effects on selected beaches for the last 35–40 years period, georeferenced, atmospherically corrected Landsat 5 TM and Landsat 8 OLI-TIRS satellite images were used. Furthermore, carrying capacities for all researched beaches were calculated and documented in order to find the actual human usage frequencies during the high season. According to results of the study, it is clearly observed that all beach areas are under anthropogenic pressure. The most important evidence of this situation is the proportional increases in the IS (Impervious Surface) cover class in the classified images between 1984 and 1985 and 2021 in all 15 beaches. Moreover, these increases have reached up to 5–6 times for some beaches. As inferred, from the field surveys, beach carrying capacities were also exceeded for the most of the beaches under investigation. This means the blue flag beaches of Southern Black Sea are not only affected by construction and urbanization but also under intense pressure of overuse during the high seasons. It is revealed that these areas should be carefully managed with state-of-the-art techniques that prioritize adaptive planning that takes into account all stakeholders participation. Moreover, the activities, authorization and attitudes of municipalities regarding the coastal zones must be limited and inspected by a higher organization.

Keywords Coastal Change · Remote sensing · Blue flag · Beach · Black Sea

Introduction

Coastal areas with variable hinterland zone widths have become extremely important areas of interest for humanity with their length exceeding 450,000 km on a global scale. Human civilization actually owes its current shape and level of development to some extent to the existence of coasts. So that, even in ancient times, the idea of how to reach point “B” from point “A” on any coastal land was transformed into the practice of discovering new regions by using sea and wind energy. Coasts have thus become very important

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areas for human settlement, transportation, trade, nutrition, defense and recreation activities for thousands of years. Considering many types of coastal activities, the most important usage for coastal stakeholders in sustainable, economic and ecological terms are undoubtedly recreational activities and coastal tourism that develops accordingly. This type of tourism, which is seen as a sun, sand and sea activity, can certainly have both positive and negative effects on the coasts. In general, its positive effects can be explained particularly as economic development, employment opportunities and better environmental design. Negative effects include exceeding of carrying capacity and overuse with all side effects on environment. In particular, uses that exceed the carrying capacity put the environment under pressure in the medium- and long-term scales and reduce the overall value of the area. Moreover, coasts are extremely valuable areas from an ecological perspective and are described as ecotones of terrestrial and marine ecosystems. Anthropogenic pressure and overuse on the coasts have resulted in the destruction of these valuable transitional ecosystems over time. (Peña-Alonso et al. 2018). Services such as urbanization, tourism and transportation have always been at the forefront of these pressures (Antrop 2006). Natural land cover changed under anthropogenic influence has made coastal areas unsustainable and triggered the emergence of catastrophic environmental problems on both the sea and land sides of the coasts (Cengiz 2012). The most important of these effects are the fragmentation of green areas and the decrease in biodiversity and quality of provided ecosystem services (Ahern 1995; Boström et al. 2011; Guneroglu et al. 2013, 2015; Guneroglu 2015). These coastal problems are observed not only in Türkiye but also in many other coastal countries. For this reason, as in the rest of the world, coastal projects to be included in national development plans must be ecosystem-based, adaptive and sustainable. In parallel with the increase in environmental awareness and concern, coastal environmental designs should be aimed to improve the relevant area, not disrupt it. It is clear that especially in the last 20–25 years, people have become closer to the concepts of returning to nature. Therefore, it is obvious that this issue should be taken seriously in new designs and projects concerning coastal ecosystems. Moreover, ecologically based designs, which will be realized by taking into account the concepts and principles of coastal areas management and landscape ecology, are expected to be more useful and sustainable in the long term. Thus, it is inevitable for ecosystem-based landscape planning approaches to take into account not only natural elements but also sociological and cultural parameters (Cengiz 2012). Although changing environmental conditions and cultural influences have made the change of landscapes inevitable (Antrop 2006), this change must be improving and developing the ecosystem,

not disrupting it. For this reason, it would be appropriate to design elements that do not disrupt ecological integrity, especially in urban transformation projects or new designs. From this perspective, landscape changes are expected to be positive rather than being negative.

Preservation and development of existing landscapes is only possible by understanding landscape values. The protection of landscapes is also an issue that the European Landscape Convention (ELC) emphasizes. According to the European Landscape Convention, “*Landscape is defined as the way people perceive areas whose character is shaped by the interaction of nature and human activities*” (Council of Europe 2000). In addition, the convention, which includes the protection and development of the landscapes of the countries, has brought to the agenda many issues such as raising awareness, reward system and monitoring for the protection and development of the landscape areas, including seas and coasts. The aim here is to provide ecological landscape solutions that are applicable, measurable and traceable on a continental scale. Certainly, it is important that such an approach can be applied to coastal landscape areas in order to leave healthy environments to future generations. Ecosystem-based coastal landscape planning must be adaptive, that is, evolvable, to keep up with changing and developing culture, geography and norms, as well as the continuation of the services offered by the ecosystem (Katsenavakis et al. 2011). However, it seems that many coastal zones, especially in the last quarter century, are inadequate in terms of basic planning principles, let alone their ecological protection. The decreasing coastal green cover, the destroyed natural structure and the increasing impervious surface rates confirm this situation. The current status is not environmentally sustainable. Because every process made on the coasts without the necessary planning and analysis has led to negative, undesirable consequences. This has become a problem in almost many coastal regions of the world, except coastal planning in some developed countries. Regulations and decisions regarding the coast must be planned by applying bottom-up strategy in which all stakeholders participate. This approach is very important for the sustainability of coastal planning. Humanity, which has realized that natural resources are limited in the last 25–30 years, and the resulting increasing environmental awareness necessitate such a solution. So much so that even decision makers now include the opinions of all other users and stakeholders in such projects and want to predict the problems that may arise. The technological infrastructure and simulation capabilities available today make it possible to predict the results of coastal projects. The most obvious modifications in coastal areas are undoubtedly the changes in land use and cover. How and in what direction these changes affect the coastal zone mirrors what consequences they may have

in the long term. For example, renovation of an old village beach road connection to double lane highway may at first glance be beneficial. It may even provide economic benefit for that area and make other stakeholders happy. However, after a while, inadequate infrastructure problems, pollution and some other social problems that may be caused by the exceeded capacity in the relevant beach area are often ignored. For this reason, the participation of all stakeholders is important in the plans, projects and measures to be taken for the coastal zones. This situation becomes even more important especially for beaches that have received the blue flag award, which is extremely valuable in terms of tourism activity. It is necessary both economically and ecologically for these areas to maintain their blue flag certifications.

Undoubtedly, the studies required by this certification and monitored on a scale of 33 criteria are primarily a matter of concern for decision makers, users and managers, as well as for all stakeholders. The continuity of the quality of the ecosystem services offered by a blue flag beach depends on the actions of continuous monitoring and inspection of these areas. Türkiye is one of the leading geographical locations in Europe in terms of blue flag beaches. As of 2023, the number of blue flag beaches on the coast of Turkey is 551 (URL 1). 33 of these beaches are located in the Black Sea coastal zone, which is the Northern Anatolian coast of the country. In recent years, with the impact of global climate change, the increase in average temperatures and the number of sunny days observed on the Black Sea coast has increased the available beach activities in this region. However, in recent years, the region has become an important tourism destination that can offer multiple opportunities such as “plateau” with its green texture, “culture and belief” with its historical background, and “sea tourism” with its coasts. Making this situation sustainable definitely depends on scientific coastal management approaches. Creating inventories of these areas is necessary for both current and future planning. Today, the most important factor facing these unique coastal regions is human-induced pressures. This situation has manifested itself in the form of changes in land use and cover, and in a character that is increasingly approaching the shoreline. Many countries experience the negative effects of land cover or landscape changes occurring in the coastal zone (Yagoub and Kolan 2006; Freire et al. 2009; Cui et al. 2023). Turkey appears as one of these countries (Guneroglu 2015). It is extremely important to periodically monitor these changes occurring on the coasts. The best technique that can be used today for this purpose is undoubtedly remote sensing. It has become easier to follow LULC changes thanks to satellites that can take multispectral images with high ground resolution. In the literature, the blue flag certification is based on 4 basic concepts as explained by FEE (Foundation for Environmental

Education). These are subjects such as environmental education, water quality, safety services and environmental management. However, when the landscape is considered as a whole, although it is not specifically included in the 33 criteria, LULC and the perceived environmental quality associated with it may be necessary to be included for effective management of the beaches and coastal areas. Therefore, the aim of this study is to compare the LULC changes in the immediate adjacent area of some important blue flag beaches selected on the Black Sea coast between 1984 and 1985 and 2021 using appropriate land cover classes. Thus, urbanization and the increasing impervious surface rate for the last 35–40 years have been demonstrated quantitatively. This will reveal which of the Black Sea coast beaches in question are more at risk and exposed to human pressure.

Material and method

Study area

The study area is the Black Sea southern coastal periphery and surrounded by the Black Sea bordered countries such as Bulgaria and Georgia. The west of the study area is characterized by the geomorphological structures of the Danube Delta consisting of swamps, lakes and islets. It is accepted that this delta was a gulf indentation of the Black Sea 6500 years ago and that over time, it took its current form with sediment transport of river waters. It is known that the delta moves towards the sea by approximately 30 m every year. In the study area, there are deltas of medium and long rivers such as Sakarya, Yeşilırmak, Kızılırmak and Çoruh. Apart from these rivers, there are many small wild streams flowing into the Black Sea. These are veins that transfer precipitation from the high mountain formations on the northern slopes to the Black Sea (Report 2002). These wild streams are also extremely important for beach areas. Because the sediment carried by the streams nourishes the beaches and stabilizes them. This region has been an area that different nations have wanted to use as a settlement for many years (Kosyan and Velikova 2016). The countries bordering the Black Sea (Turkey, Bulgaria, Ukraine, Russian Federation, Georgia and Romania) have an important historical past and civilization adventure. It is known that the coasts are used intensively in almost all of these countries that surround this water basin (Antonidze 2010). While the Black Sea maintained its character as a virgin and natural basin until the 20th century, this situation began to change in the last century with the presence of anthropogenic pressures to the detriment of the region (Kosyan and Velikova 2016). This situation has reached levels that may threaten the existence and health of the beaches. This area exhibits

a heterogeneous topographic structure, in the east it has a narrow coastal structure with the mountains extending parallel to the coast, in the middle part topography is less rugged with wide coastal background. The western side of the study area is similar to eastern side. Especially in the eastern part, due to reasons arising from structural geomorphology, the settlement shows a linear pattern in the coastal zone, as in the entire region. For this reason, it has a limited number of wide beach areas due to the topographic pattern. In the Black Sea region, coastal sandy areas are generally in the form of narrow beaches with a length of 100–300 m. For this reason, it is aimed that the beaches that will be the subject of the study should have a certain level of tourism potential with a blue flag and an average width of 35 m and a length around 500 m. Thus, by focusing on areas where tourism potential can be developed, areas suitable for practical research and planning have been identified. The Black Sea coast, which is the subject of the study, covers the area defined by the geographical coordinates of 41° 54' 27" N, 28° 03' 07" E, and 41° 33' 49" N, 41° 34' 21" E, extending from Bulgaria in the West to Georgia in the East. There are 16 provinces on the Black Sea coast in this defined zone. These are, from west to east, Kırklareli, Tekirdağ, İstanbul, Kocaeli, Sakarya, Düzce, Zonguldak, Bartın, Kastamonu, Sinop, Samsun, Ordu, Giresun, Trabzon, Rize and Artvin. Even though the city centers of some of these provinces are far from the coast, they definitely have a district and beach that are connected to the sea. Some of them are from provinces that have coasts to both the Marmara Sea and the Black Sea (Karlı et al. 2011). The study area has a topographically steep, difficult and rugged structure, with the Istrancalar in the west, the Küre Mountains in the middle west, the Canik in the middle and the Eastern Black Sea mountains ranges rising right on the coast in the east. Since the central part has a moderate roughness, it shows climatic differences from the western and eastern parts. The rainiest part was the Eastern part with an average annual rainfall of 1800 mm. The Black Sea coastal zone, which has natural beauties where blue and green meet, has a rich vegetation, especially in the Western and Eastern parts. The slopes facing the sea are covered with dense forests because they receive a lot of rainfall. It is also a very important area in terms of natural and endemic plant diversity (Anşin 1980; Var 1992). The Black Sea coastal climate type is "C" according to the Köppen-Geiger classification, meaning it is a mid-latitude type with mild humidity in winters. This rainy climate type, where evaporation is low, is observed as the "Cfa" sub-climate type along the Black Sea coastal zone (Öztürk et al. 2017). Apart from sun, sand and sea tourism, there are also many alternative tourism resources in the region such as health, mountains, faith and plateaus. It is known that the Black Sea coasts are an alternative to the negative climatic

conditions that may be experienced on the Aegean and Mediterranean coasts in parallel with the effects of global climate change (Karadeniz et al. 2018). Carrying out studies to preserve the unique cultural and natural texture of this area is important for the sustainability of the region. The studied beaches are listed by TÜRÇEV (Turkish Environmental Education Foundation) as "Blue Flag" beaches in the Black Sea for 2020. They are selected according to their dimensions which are 500 m in length and over 30 m in width. The 500 m limit is accepted in the literature as a sufficient length in terms of the beach carrying capacity and tourism infrastructure. Similar dimensional limit assumptions have been made in the literature in studies on beach quality, user satisfaction or beach morphology (Botero et al. 2014; Ballesteros et al. 2018). Considering the coastal structure of the Black Sea coast, the determined study area including blue flag awarded beaches was given below. These are; İğneada Resort Beach, Şile Resort Beach, Palm Beach, Bağıranlı Beach, Kumcağız Beach, Cebeci Beach, Sahil Park Beach, Çuhallı Beach, Akevler Beach, İncesu Beach, Omtel Beach, Denizkızı Beach, İnci Beach, Deniz Evleri Beach and Miliç Beach (Fig. 1).

Methodology

The methodology of the study consists of two sections in accordance with the aim of the study. The first stage explains calculating of beach carrying capacity and the second one is on quantifying long term LULC changes by using remote sensing and GIS techniques. The study was also supported by two period field surveys carried out by the project team.

Calculating beach carrying capacity

Beach carrying capacity calculations are based on physical and morphological settings of coastal area under investigation. First of all, dimensions of the available space should be considered for calculating physical carrying capacity (PCC) which is built on minimum comfortable ergonomic recreational space needed for a beach user as documented very well in literature. As a step forward, the calculated PCC is mostly limited by many factors that involved in beach usage that means in reality PCC should be downscaled according to those limiting factors. There many studies on beach carrying capacity downscaling techniques, this limited capacity is called either actual or real carrying capacity (ACC). In this study, number of windy days, temperature and precipitation data were used for downscaling PCC. The available data compiled from Turkish Meteorological State Agency and Meteoblue web service by considering relevant limiting factors for a specific beach, ACC can be calculated according to equation given below (Eq. 1) according to Khodkar

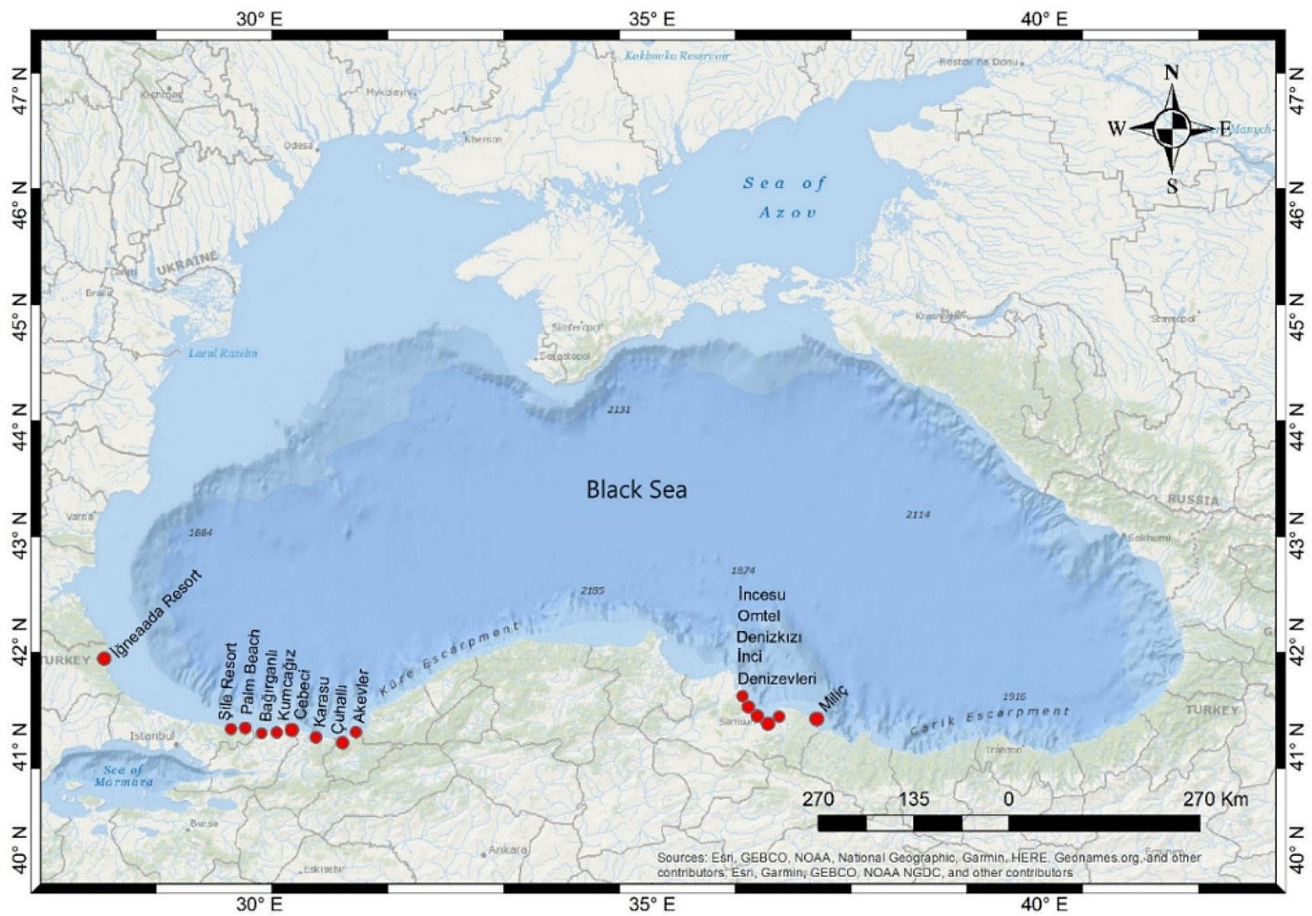


Fig. 1 Study area and blue flag beaches

and Özyurt Tarakçıoğlu (2018), Rodella et al. (2020) and Fredy et al. (2021).

$$PCC = (T_a/P_a)xR_f \quad (1)$$

$$R_f = DL_s/TL_v \quad (2)$$

$$ACC = PCCx(S_{f1}xS_{f2}xS_{f3} \dots xS_{fn}) \quad (3)$$

$$S_{fn} = 1 - (L_n/T_n) \quad (4)$$

where,

T_a : Total recreational beach area (m^2).

P_a : Comfortable beach area per user (m^2).

ACC : Actual Carrying Capacity (#).

PCC : Physical Carrying Capacity (#).

DL_s : Total day length suitable for swimming.

TL_v : Total time length spent per visit.

R_f : Rotation factor.

S_{fn} : Scaling factor.

L_n : Limiting value of variable “n” for a specific beach.

T_n : Total value of variable “n” for a specific beach

Rotation Factor (R_f) is a coefficient that is used to approximate revisit rate of a beach in a regular sunny day. It is important for estimation of PCC and calculate the final carrying capacity in beaches. In this study, some parameters were set as following, $P_a=10 \text{ m}^2$, $DL_s=10 \text{ h}$, $TL_v=5 \text{ h}$ and $R_f=2$ based on available literature and field observations.

Satellite image processing and GIS (geographic information system) analysis

Georeferenced, atmospherically corrected Landsat 5 TM and Landsat 8 OLI-TIRS satellite images were used to reveal the landscape change that occurred in 15 beaches within the scope of the study area over the last 35–40 years. Landsat satellite data are frequently used in environmental remote sensing applications, especially in terms of monitoring land cover changes (Guneroglu 2015). Satellite images of the data in Table 1 below, covering the study area, were downloaded from the archives on NASA Global Land Cover Facility (GLCF) servers by filtering quality parameters to observe the landscape change.

Table 1 Landsat satellite images descriptive information related to study area

Sensor Type	Path/Row	Image Date	Ground Resolution (m)	Image Format	Source	Data Type
Landsat 5 (TM)	175/031	1985-06-28	30	GeoTiff	GLCF	Standart (SR)
	179/031	1984-06-05				
	181/031	1985-07-24				
Landsat 8 (OLI-TIRS)	175/031	2021-05-14	30	GeoTiff	GLCF	Standart (SR)
	179/031	2021-07-29				
	181/031	2021-07-27				

The Landsat satellite images are selected by taking in to account summer high season time, study area spatial extend, cloud cover rate and the closest date for corresponding two periods (1984-85/2021) image pairs of the same path and row. These multispectral data is atmospherically corrected Level 2 surface reflectance (SR) images which are flagged with quality range between “0–9” by the GLCF distribution archive. This archive provides atmospherically corrected surface reflectance images for free. Considering the maximum ground resolution (30 m) during the image classification stage, four classes vegetation, impervious surface, sand & soil, and water were defined and produced using Support Vector Machines (SVM).

SVM has been used in many LULC change, coastline extraction and bathymetry detection studies with satisfactory results (Pal and Mather 2005; Yin and He 2011; Lin et al. 2018; Misra et al. 2018). SVM algorithm has been proved as very successful in separating between remotely sensed LULC classes using optimum hyperplanes and robust generalization capabilities (Vapnik 2000; Pal and Mather 2005). SVM is also advantageous as it allows to use less training data by focusing on an individual class using support vectors and define extreme cases to separate classes from each other (Sanchez-Hernandez et al. 2007). Clustered sampling technique was used for selection training and testing dataset by avoiding autocorrelation (Tso and Mather 2009; Dihkan et al. 2013; Guneroglu 2015). In this study, the Radial Based Kernel (RBF) function was used with SVM algorithm. The RBF kernel is widely preferred in such classification problems due to the fact that a small number of predefined parameters are determined by the user and the effect of these parameters on the classification result is less than other kernel functions (Mathur and Foody 2008; Kavzoglu and Colkesen 2009). Consequently, the sampling strategy described by Mather (2004) was used. At this stage, regarding predefined 4 LULC classes, for each Landsat 5 TM and Landsat 8 OLI-TIRS images minimum sample size were set as 1200 and 1400 respectively. From this point of view, 60% of the total sample number was selected as training and 40% as test data.

The classification accuracy after image processing stage, was based on error matrices for all periods. Necessary metrics such as Overall Accuracy (OA), Kappa (K), User Accuracy (UA) and Producer accuracy (PA) were calculated

according to Tso and Mather (2009). It is revealed that the classification results were accurate and successful for representation of the problem (Table 2).

Classified image data was imported in to geospatial database for further analysis. All beaches included in the study were specifically differentiated according to previously defined layers or classes such as Impervious Surface (IS), Vegetation (V), Sand & Soil (S) and Water (W). In order to obtain proportional changes occurred in the last 35–36 years' time span, the areal extend of each beach class produced from 1984 to 1985 image data was compared to same one in 2021. Details on proportional change rates for each blue flag beach were analyzed in results section of the manuscript.

Results

The Black Sea coasts have been exposed to more tourism pressure in recent years due to changing environmental and climate conditions. For this reason, these important coastal areas of Turkey need an adaptive coastal management plan that is strategically accepted and regulated by scientific principles. When evaluated from this perspective, this study carried out on the important blue flag beaches of the Black Sea clearly demonstrated how important the coastal management plan for the region under investigation. Beach carrying capacity calculation and analysis of LULC change, carried out within the scope of the study, were considered as indicators of direct human-induced pressure. Determining beach carrying capacity is extremely important for policy makers, especially in terms of coastal management. Because, decision makers can ensure more effective management of beach areas within the framework of these numerical limits. Similarly, revealing the direction in which coastal land cover change is evolving is necessary to mitigate anthropogenic pressures on beaches. In this respect, the results obtained within the scope of this study can be used directly in coastal management application decision processes. Because both data sets obtained aim to reveal quantitative anthropogenic pressure. For this purpose, the studies carried out in the field and the results obtained from remotely sensed data were combined to evaluate temporal changes and associated reasons in the region. The results are summarized and presented below. This study, in which

Table 2 Classification accuracy of Landsat TM/OLI-TIRS images of the study area

Beach Name	Landsat 5 TM (Image Set I) (1984*-1985**)						Landsat 8 OLI-TIRS (Image Set II) (2021)						Classification Accuracy			
	(IS) UA/PA	(V) UA/PA	(S) UA/PA	(W) UA/PA	(IS) UA/PA	(V) UA/PA	(S) UA/PA	(W) UA/PA	(S) UA/PA	(W) UA/PA	(V) UA/PA	(S) UA/PA	Kappa		OA	
													Set I	Set II	Set I	Set II
Miliç**	90.74–80.99	100–100	88.38–94.59	100–100	84.50–89.34	100–100	89.38–83.47	99.21–100	89.38–83.47	99.21–100	100–100	89.38–83.47	0.92	0.91	94.14	93.31
Denizveher**	90.74–80.99	100–100	88.38–94.59	100–100	84.50–89.34	100–100	89.38–83.47	99.21–100	89.38–83.47	99.21–100	100–100	89.38–83.47	0.92	0.91	94.14	93.31
İnci**	90.74–80.99	100–100	88.38–94.59	100–100	84.50–89.34	100–100	89.38–83.47	99.21–100	89.38–83.47	99.21–100	100–100	89.38–83.47	0.92	0.91	94.14	93.31
Denizkızı**	90.74–80.99	100–100	88.38–94.59	100–100	84.50–89.34	100–100	89.38–83.47	99.21–100	89.38–83.47	99.21–100	100–100	89.38–83.47	0.92	0.91	94.14	93.31
Omtel**	90.74–80.99	100–100	88.38–94.59	100–100	84.50–89.34	100–100	89.38–83.47	99.21–100	89.38–83.47	99.21–100	100–100	89.38–83.47	0.92	0.91	94.14	93.31
İncesu**	90.74–80.99	100–100	88.38–94.59	100–100	84.50–89.34	100–100	89.38–83.47	99.21–100	89.38–83.47	99.21–100	100–100	89.38–83.47	0.92	0.91	94.14	93.31
Akevler*	98.91–74.59	100–100	79.61–99.18	100–100	90.09–81.30	100–100	83.33–90.91	99.19–100	83.33–90.91	99.19–100	100–100	83.33–90.91	0.91	0.91	93.52	92.84
Çuhallı*	98.91–74.59	100–100	79.61–99.18	100–100	90.09–81.30	100–100	83.33–90.91	99.19–100	83.33–90.91	99.19–100	100–100	83.33–90.91	0.91	0.91	93.52	92.84
Sahil Park*	98.91–74.59	100–100	79.61–99.18	100–100	90.09–81.30	100–100	83.33–90.91	99.19–100	83.33–90.91	99.19–100	100–100	83.33–90.91	0.91	0.91	93.52	92.84
Cebeci*	98.91–74.59	100–100	79.61–99.18	100–100	90.09–81.30	100–100	83.33–90.91	99.19–100	83.33–90.91	99.19–100	100–100	83.33–90.91	0.91	0.91	93.52	92.84
Kumcağız*	98.91–74.59	100–100	79.61–99.18	100–100	90.09–81.30	100–100	83.33–90.91	99.19–100	83.33–90.91	99.19–100	100–100	83.33–90.91	0.91	0.91	93.52	92.84
Bağrganlı*	98.91–74.59	100–100	79.61–99.18	100–100	90.09–81.30	100–100	83.33–90.91	99.19–100	83.33–90.91	99.19–100	100–100	83.33–90.91	0.91	0.91	93.52	92.84
PalmBeach*	98.91–74.59	100–100	79.61–99.18	100–100	90.09–81.30	100–100	83.33–90.91	99.19–100	83.33–90.91	99.19–100	100–100	83.33–90.91	0.91	0.91	93.52	92.84
Şile Resort*	98.91–74.59	100–100	79.61–99.18	100–100	90.09–81.30	100–100	83.33–90.91	99.19–100	83.33–90.91	99.19–100	100–100	83.33–90.91	0.91	0.91	93.52	92.84
İğneada**	84.96–92.62	100–100	91.96–83.74	100–100	97.47–95.07	100–100	96.14–98.03	97.98–100	96.14–98.03	97.98–100	100–100	96.14–98.03	0.92	0.97	94.14	97.78

comparisons are made on the basis of each blue flag beach area, is the most comprehensive study to date in terms of its spatial extent and content. When the carrying capacity of the 15 blue flag beaches of the study area is evaluated, it is revealed that temperature, precipitation and wind parameters can be considered as limiting factors (Table 3). Data obtained from the General Directorate of Meteorology and the Meteoblue database also support these claims. Moreover, climatic characteristics and geographical location of the study area are main causes of the aforementioned problem. Despite to seasonally changing conditions, the Black Sea coastal zone is one of the windiest regions in Turkey with relatively high precipitation and cloudy days through the year. For this reason, during the high season between June and September (122 days), these parameters affect the carrying capacity of the beaches in the region. Among all beaches under investigation, due to its spatial dimensions, Sahil Park has the highest carrying capacity with $R_f=2$, this blue flag beach is known with high tourism pressure in summer high season. The daily beach visitor number can easily exceed the calculated actual carrying capacity (ACC) which is 7850 person/day as both domestic and foreign tourist population coming from densely populated cities such as Ankara, İstanbul and Kocaeli especially on national holidays and weekends. Similarly, Cebeci Beach from Kandıra, Kocaeli is another recreational area with high carrying capacity as indicated in Table 3. Generally, public beaches with free of charge entrance policy and relatively high R_f factor have high carrying capacity compared to paid private beaches such as Miliç, Palm Beach, Şile Resort and İğneada. The lowest carrying capacity per user day was calculated around 308 for Şile Resort blue flag beach in İstanbul. Şile Resort is a private beach with paid entrance policy and low R_f factor. Similarly, İğneada and Palm Beach areas are at the second stage in terms of associated ACC value, which is respectively around 1063 and 954 person/day.

Detailed information on ACC load for each beach is given in Table 3. Considering limiting factors of the study area, temperature and precipitation found to be the most influential variables affecting overall ACC rate. Comparative analyzes carried out in the study area revealed the effects of human-induced anthropogenic pressure both visually and quantitatively on the 15 beaches that are the subject of the study. According to data obtained for the last 35–40 years, these areas have been exposed to extreme human pressure. Table 4 below gives landscape change rates in the context of LULC for these beach areas. As inferred from remote sensing analyses and field observations, it is clear that all beach areas are under anthropogenic pressure. The most important evidence of this situation is the proportional increase in the IS (Impervious Surface) cover class. Moreover, these increases have reached up to 5–6 times for some

Table 3 Beach carrying capacity for Southern Black Sea blue flag beaches

Beach Name	Season	Temperature	Precipitation	Wind	PCC	R_f	ACC
	Days (#)	$S_{in}(T)$ ($T > 25^\circ\text{C}$)	$S_{in}(P)$ Days (#)	$S_{in}(W)$ ($W > 28 \text{ km/h}$)	Person / Day (#)	Rotation Factor	Person / Day (#)
Miliç	122	0.82	0.76	0.97	4283	1	2584
Denizevler	122	0.82	0.76	0.97	4319	2	5212
İnci	122	0.82	0.76	0.97	3099	2	3739
Denizkızı	122	0.82	0.76	0.97	2539	2	3063
Omtel	122	0.82	0.76	0.97	3187	2	3846
İncesu	122	0.82	0.76	0.97	3155	2	3807
Akevler	122	0.73	0.75	0.99	1514	2	1645
Çuhallı	122	0.73	0.75	0.99	2677	2	2909
Sahil Park	122	0.66	0.77	0.98	7899	2	7850
Cebeci	122	0.66	0.78	0.94	7368	2	7163
Kumcağız	122	0.66	0.78	0.94	3710	2	3607
Bağırçanlı	122	0.66	0.78	0.94	4196	2	4079
PalmBeach	122	0.62	0.83	0.89	2091	1	954
Şile Resort	122	0.62	0.83	0.89	675	1	308
İğneada	122	0.68	0.81	0.78	2487	1	1063

beaches. The highest IS proportional increase was observed for Akevler beach in Düzce-Akçakoca district. It has been confirmed by on-site observations that the area has been under the influence of intense summer house construction in the last 35 years. Furthermore, another beach area with 558% IS cover increase was Kırklareli-İğneada beach. The LULC changes and associated landscape formation for Akevler and İğneada beach were given below in Fig. 2. This situation shows a similar pattern for other beaches.

In addition to the increase in the rate of impervious surfaces, the decrease in vegetation cover will bring about the risk of deterioration of green cover and therefore natural landscapes in the long term. This situation is undesirable in terms of the sustainability of coastal areas. Considering the entire study area under investigation, the least changes in IS cover was observed in Sahil Park and İncesu beaches. The change ratios were calculated around 92% for Sahil Park and 102% for the İncesu beach. This can be attributed to the relatively limited empty space for new building and constructions as these areas are already densely inhabited compared to other beaches.

Discussion

The presented study aims to facilitate adaptive coastal zone management by identifying and measuring human-beach interactions based on field surveys and remote sensing techniques in particular by focusing on registered blue flag beaches of the Southern Black Sea. Human-induced pressure on Southern Black Sea blue flag beaches is not a stand-alone problem that can be evaluated and solved following simple approximations. On the contrary, this problem causes many other environmental troubles to occur or become evident.

Among these problems, it is possible to count side effects such as air, water, noise and plastic pollution. Plastic pollution is one of the most important environmental problems in today's world. The high amount of microplastic found in measurements made on beaches is an indication that these areas are under anthropogenic pressure (Portman and Brennan 2017; Simeonova et al. 2017; Pervez and Wang 2022). While plastic pollution visually affects beaches and shores, it also deteriorates the quality of ecosystems and aquatic life through ecological cycles. Similarly, it is known that the increase in the impervious surface rate and the resulting overpopulation negatively affects coastal ecosystem services (Aktürk and Güneröglü 2021) the visual quality and recreational water quality (Torres-Bejarano et al. 2018) on the coasts by degradation of coastal landscape value. Furthermore, the increasing rate of hard structures and buildings in the vicinity of the beach zones reduces coastal sedimentation and interrupt beach nourishments (Pagán et al. 2016). Coastal urbanization is especially stressed by Güneröglü et al. (2019) as one of the most important environmental problems of the Black Sea basin. In fact, it is clear that human pressure is the most effective parameter in the emergence of all the undesirable environmental effects mentioned above. For this reason, with the analyzes carried out in this study, it has been quantitatively revealed how the blue flag beaches, which are extremely important for Türkiye and the Southern Black Sea, have been subjected to changes in the long term.

Quantitative results of the last 35 years comparisons of the beach environments revealed that vegetation (V) and soil (S) land use covers are mostly converted to impervious surfaces. This problem can also be easily observed by visual interpretation of the classified multispectral images of the beaches (Fig. 2). Therefore, it is clearly the 15 blue flag beaches of the southern Black Sea region are under

Table 4 Landscape change rates as revealed from LULC analyses

Beach_Name	1984-85 (Area/ha)				2021 (Area/ha)				Change Ratio (%)			
	IS	V	S	W	IS	V	S	W	IS	V	S	W
	***	***	***	***	***	***	***	***	***	***	***	***
Miliç	2.6	142.5	86.4	147.9	6.3	132.2	91.6	149.2	+141	-7	+6	+1
Denizveleri	76.1	85.6	171.4	236.8	249.8	13.9	73.9	232.4	+228	-84	-57	-2
İnci	44.1	48.2	87.8	196.1	147.1	5.2	27.4	196.5	+234	-89	-69	0
Denizkızı	49.9	66.4	81	184.4	146.1	10.6	38.1	186.9	+193	-84	-53	+1
Omtel	31	92.8	66.2	103	70.3	67.1	57.2	98	+127	-28	-14	-4
İncesu	22.3	69.2	54.6	135.4	45.1	60.1	41.9	134.4	+102	-13	-23	0
Akevler	13.1	164.2	54.6	175.4	88.3	84.1	21.2	173.8	+577	-49	-61	0
Çuhallı	23.4	133	19.4	132.8	90.9	67.2	17.5	123.9	+289	-50	-10	0
Sahil Park	54.4	19.4	131.8	230.9	104.1	11.4	83.9	237.1	+92	-41	-36	+3
Cebeci	21.1	96.1	44.3	150.4	54.5	71.2	31.8	154.4	+159	-26	-28	+3
Kumcağz	57.1	290.8	44.4	208.4	130.5	246.2	12.9	211.1	+129	-15	-71	+1
Bağırçanlı	27.2	282.5	19.4	108.6	59.9	222.1	40.7	107.8	+121	-21	+109	0
Palm Beach	16.5	100	17.6	131.5	48.9	78.8	18	129.9	+197	-21	+3	-1
Şile Resort	16.5	100	17.6	131.5	48.9	78.8	18	129.9	+197	-21	+3	-1
İğneada	12.8	268.4	81.1	454.8	84.1	202.4	76.1	454.4	+558	-25	-6	0

*** IS (Impervious Surface), V (Vegetation), S (Soil and Agriculture), W (Water)

impact of severe anthropogenic pressure. Mitigation of this environmentally unsustainable anthropogenic pressure is an issue of high priority for southern coast of the Black Sea. Similarly, Foti et al. (2022), based on approximately 50 years data, conducted a study in Calabria, Italy to monitor intense anthropogenic pressure on dune systems. This shows that the problem affects not only the Black Sea region but also other coastal areas of the Mediterranean basin. As it is well-known by coastal management community and scientific groups, high numbers or simply “growth” does not mean “improvement”. Scientific initiatives should be firstly focus on sustainability and convince all stake holders to take action on ecologically balanced coastal environments. Human induced pressure is not only reflected as changing LULC structure but also bring forth traffic jam, lack of infrastructure and solid waste problems that worsening the situation. It is obvious that for the last 35 years, the composition of “blue-yellow-green” is neither protected nor prioritized by coastal stake holders in the region. Thus, in guidance with European Landscape Convention (ELC), in order to protect our landscapes, we should first define what we have and quantify their landscape values in the region.

As suggested in ELC, the protection of natural landscapes can only be achieved by limiting development planning and new building construction activities in coastal areas. However, as given in Table 4 above, the increase in soil class observed at Bağırçanlı beach shows that these infrastructure and construction activities are continuing. This situation was clearly observed during field surveys in other blue flag beach areas as well. Considering the studied 15 blue flag beaches, no problems were observed in terms of “blue flag” management within the framework of the current blue flag criteria. Moreover, responsible organizations such as TÜRÇEV and municipalities are found to be very keen and active in monitoring blue flags. However, the increasing number of buildings in areas close to beach zones and the exceeding of the carrying capacity of the beaches, especially on holidays, create pressure on these areas and affect their sustainability. It is extremely necessary to resolve this situation by taking into account the tourism sector and the environment in order to preserve the quality of these beaches and the blue flag award in the long term.

Considering, Southern Black Sea blue flag beaches the first remedy can be designation of special “no-construction” areas by the responsible coastal authority. This action can be planned as a “bottom-up” approach by taking in to account and convince all stake holders. Such a simple effort can largely inhibit alteration of the LULC structure or at least protect the current state. Apart from this, managing the number of beach visitors, especially on free public beaches, by taking into account the carrying capacity limits can be considered as another practical solution. In this context,

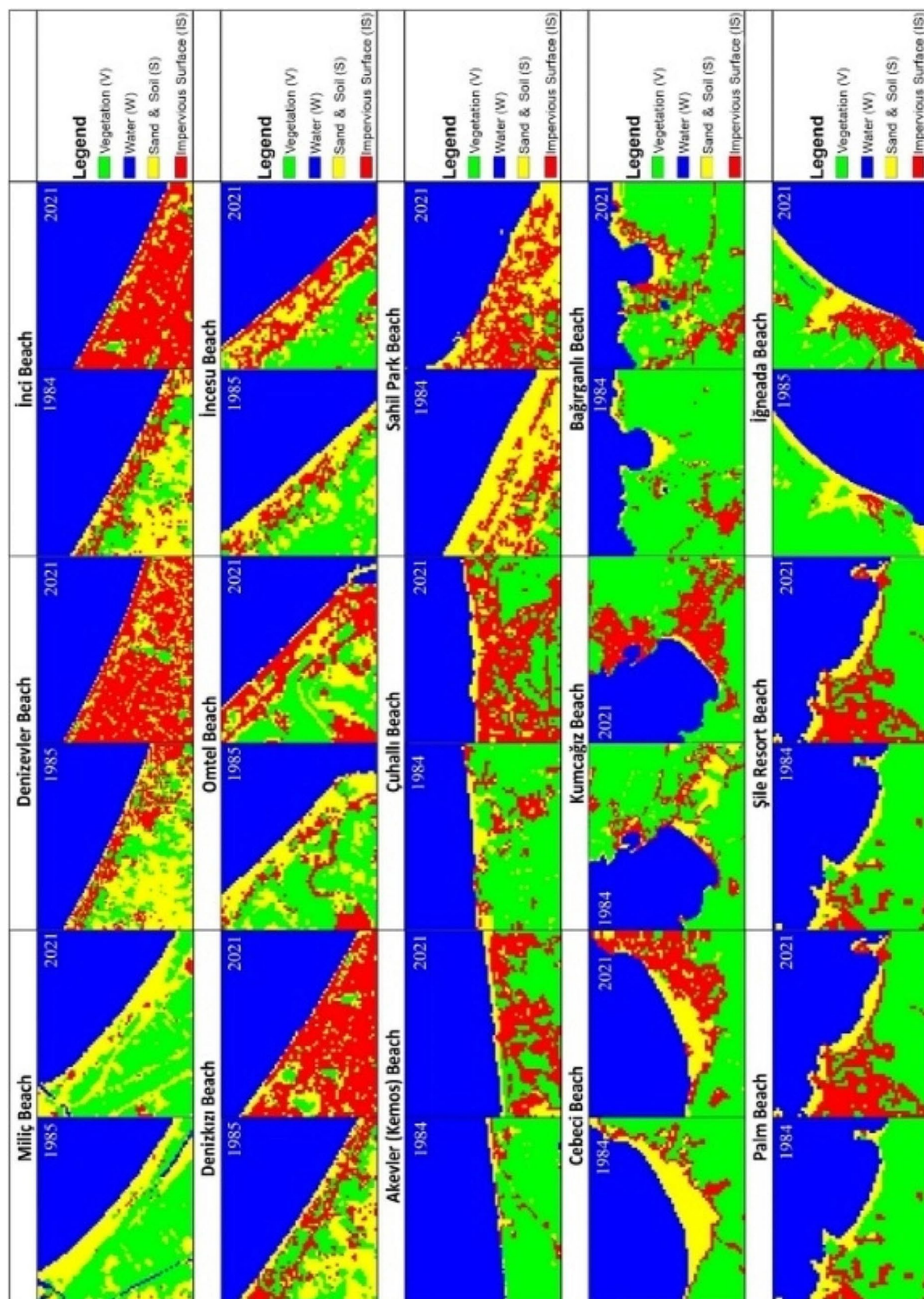


Fig. 2 Temporal LULC changes of blue flag beaches

operating the “user pays” principle in a way that appeals to all income levels may be another solution for blue flag public beaches. Another long-term and relatively difficult way to reduce human-induced pressure on blue flag beaches could be to educate and raise the awareness of the people living in these beach areas, that is, the local people and the beach visitors. Of course, although this solution is difficult to achieve in very short periods of time, it has the potential to ensure that blue flag areas and other coastal management plans can be carried out more effectively. In fact, although the necessary information about the beach area and its surroundings is prepared for visitors at each blue flag beach board, most people do not pay attention to these boards or are content to just read them. Implementing this information for blue flag beaches and their close vicinity is another requirement determined and noted during the field observations.

As a result, it has revealed that these areas should be carefully managed with state-of-the-art techniques that prioritize adaptive planning that takes into account all stakeholders participation. Moreover, the activities, authorization and attitudes of municipalities regarding the coastal zones must be limited and inspected by a higher organization. Unfortunately, the current situation has not been a good example in terms of sustainable environment and transfer of natural heritage to other generations. The increasing domestic and international tourism demand on the Black Sea coast should be seen as an opportunity for better management of these areas.

Conclusion

Coastal zones are unique areas in terms of their ecological and spatial formations that should be managed by appropriate scientific techniques. These techniques should be somehow establishing a robust “protection and use” balance to ensure the sustainability of the valuable coastal zones. Such an initiative can be started by valuing these areas. The same actions are also necessary for the Southern Black Sea coastal region as it is documented above. Increasing world population and relatively higher incomes are considered as root causes that direct human to live by the sea or very close to sea. In reality, living by the sea is indeed comfortable compared to other settlement types. However, the anthropogenic pressure on coastal regions reached to such a level that cannot be sustained anymore. Therefore, taking an action to mitigate severe impacts of this problem it is an issue of high priority. The study determined that the blue flag beaches on the southern Black Sea coast are under human pressure and these pressures negatively affect the carrying capacity of the beaches, animal and plant diversity, sedimentation rate and general environmental quality. The results obtained have the

potential to reveal new research topics for future beach studies. In fact, issues such as the coastal vegetation diversity, beach users’ profile and expectations, and research on new parameters to improve the blue flag certification are among the issues that may come to the fore in this field. Therefore, there is a need to collect all kinds of geographical, social and economic data for better management of this coastal phenomena. It can be concluded that for a long-term benefit of all stakeholders field campaigns can be initiated to establish coastal inventories including blue flag beaches and surrounding settlements in their close buffer zones.

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