



Research Paper / Makale

Monitoring of Marble Quarries Expansion and Land Cover Changes Using Satellite Images and GIS on a Rural Settlement of Burdur Province, Turkey

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Received/Geliş: 26.01.2021

Accepted/Kabul: 01.03.2021

Abstract: This study was actualized in Karamanlı district of Burdur province in order to draw attention to the increase in the surface areas of marble quarries and to monitor the changes of land cover types during the period from 1995 to 2020. Geographic information system tools and supervised maximum likelihood classification approach provided a methodological basis for this study. Landsat satellite images used in this study were obtained for 1995, 2000, 2005, 2010, 2015 and 2020. Five land cover classes have been identified, and these classes include artificial surfaces, agricultural areas, forest and semi-natural areas, water surfaces, and marble quarries. Change detection was performed after classifying the relevant images. During 25-year period, an increase of 56.86% in artificial surfaces, a decrease of 0.09% in agricultural areas, a decrease of 13.42% in forest and semi-natural areas and a decrease of 13.76% in water surfaces were designated. The most striking change in the study area occurred in marble quarries. Marble quarries showed a very serious increase of 891.44% (from 148.41 hectares to 1577.52 hectares). It has been observed that the marble quarries are mostly transitioned to forest and semi-natural areas. The findings of this study will provide an important background for the development of environmental protection strategies, and spatial planning studies.

Keywords: Marble quarries; land cover changes; environmental conservation; land use planning; GIS; remote sensing

Türkiye'nin Burdur İlinin Kırsal Bir Yerleşim Merkezinde Mermer Ocaklarının Genişlemesi ve Arazi Örtüsü Değişikliklerinin Uydu Görüntüleri ve CBS Kullanılarak İzlenmesi

Öz: Bu çalışma, 1995-2020 yılları arasında mermer ocaklarının yüzey alanlarındaki artışa dikkat çekmek ve arazi örtüsü tiplerindeki değişiklikleri izlemek amacıyla Burdur ili Karamanlı ilçesinde gerçekleştirilmiştir. Coğrafi bilgi sistemi araçları ve maksimum olabilirlik kontrollü sınıflandırma yaklaşımı bu çalışma için metodolojik bir temel sağlamıştır. Bu çalışmada kullanılan Landsat uydu görüntüleri 1995, 2000, 2005, 2010, 2015 ve 2020 için elde edilmiştir. Beş arazi örtüsü sınıfı belirlenmiştir ve bu sınıflar arasında yapay yüzeyler, tarımsal alanlar, orman ve yarı doğal alanlar, su yüzeyleri ve mermer ocakları bulunmaktadır. İlgili görüntüler sınıflandırıldıktan sonra değişiklik tespiti yapılmıştır. 25 yıllık dönemde yapay yüzeylerde %56,86 artış, tarımsal alanlarda % 0,09 azalma, orman ve yarı doğal alanlarda % 13,42 azalma ve su yüzeylerinde % 13,76 azalma belirlenmiştir. Çalışma alanında en dikkat çekici değişiklik mermer ocaklarında meydana gelmiştir. Mermer ocakları % 891,44 oranında çok ciddi bir artış göstermiştir (148,41 hektardan 1577,52 hektara). Mermer ocaklarının daha çok orman ve yarı doğal alanlara geçiş yaptığı görülmüştür. Bu çalışmanın bulguları, çevre koruma stratejilerinin geliştirilmesi ve mekânsal planlama çalışmaları için önemli bir arka plan sağlayacaktır.

Anahtar Kelimeler: Mermer ocakları, arazi örtüsü değişimleri, çevresel koruma, arazi kullanım planlaması, CBS, uzaktan algılama

How to cite this article

Tercan, E., Derele, M.A., "Monitoring of marble quarries expansion and land cover changes using satellite images and GIS on a rural settlement of Burdur province, Turkey" El-Cezeri Journal of Science and Engineering, 2021, 8 (2); 741-750.

Bu makaleye atıf yapmak için

Tercan, E., Derele, M.A., "Türkiye'nin Burdur ilinin kırsal bir yerleşim merkezinde mermer ocaklarının genişlemesi ve arazi örtüsü değişikliklerinin uydu görüntüleri ve CBS kullanılarak izlenmesi" El-Cezeri Fen ve Mühendislik Dergisi 2021, 8 (2); 741-750.

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1. Introduction

Mining activities trigger not only the increase in employment but also the establishment of infrastructure and superstructure facilities in the regions where the activities are carried out [1,2]. On the other hand, marble quarries, like other mining activities, cause various environmental problems such as pollution of surface water and groundwater, change of geomorphological structure, climatic changes, damage to flora and fauna, visual disturbances, noise pollution, and increase of particulate matter concentration [3-7]. At the same time, significant changes in land cover (e.g. destruction of vegetation) is occurred, depending on the size and scope of their activities [8,9]. It is extremely important to monitor this change process periodically in terms of natural resources management, and development of local/regional planning policies.

Remote sensing (RS) and Geographical Information System (GIS) are two potent approaches for detecting and analyzing land use/land cover (LULC) and its changes over a certain epoch by integrating the temporal and spatial windows of the study region [10]. The use of RS datasets can be an option to provide continuous information a number of research domains such as LULC, mining activities [11-13]. LULC classification with RS images plays an important role in many research domains such as land use management, urban and rural planning, and environmental protection [14-18]. GIS technology provides a flexible background for the storage, analysis and visualization of digital data required for the detection of change and database development [19,20]. It has been frequently utilised in many research domains such as suitability assessment of urban construction land [21], high-speed railway route determination [22], sinkhole susceptibility mapping [23], location selection of fire stations [24], development of citrus cultivation suitability model [25], photovoltaic solar farms location selection [26], and offshore wind farms location selection [27]. The integration of GIS and RS can help generate useful information about the scale and extent of LULC changes. At the same time, these integration presents a useful tool in monitoring land cover changes and environmental impacts associated with mining activities (e.g. marble and granite quarries) [3,8,9,28-36, 37].

The purpose of this research study is to draw attention to the increase in the surface areas of marble quarries and to monitor the changes of land cover types using GIS tools, Landsat satellite images, and supervised maximum likelihood classification approach. These changes are examined for a 25-year period (1995-2020). This study is applied in Karamanlı district of Burdur province, where marble quarry activities are rapidly increasing.

2. Material and Methods

2.1. Study area

Karamanlı district is one of the eleven districts of Burdur with a total area of 410.82 km² (Figure 1). The economy of the district is generally based on agriculture and animal husbandry. In addition, marble quarries have led to an increase in employment in the last 15 years. Due to the widespread of mining activities, significant changes in LULC have occurred and the potential to cause a number of environmental problems has emerged. For these reasons, it was determined as a study area.

2.2. Data set and framework of LULC change detection

In this paper, general framework for the determination of LULC changes includes four stages: i) Satellite image acquisition and image pre-processing: The inter-temporal dimensions of the images (Landsat) vary between 1995 and 2020. Landsat satellite images for Karamanlı district were provided from United States Geological Surveys, Earth Explorer database.

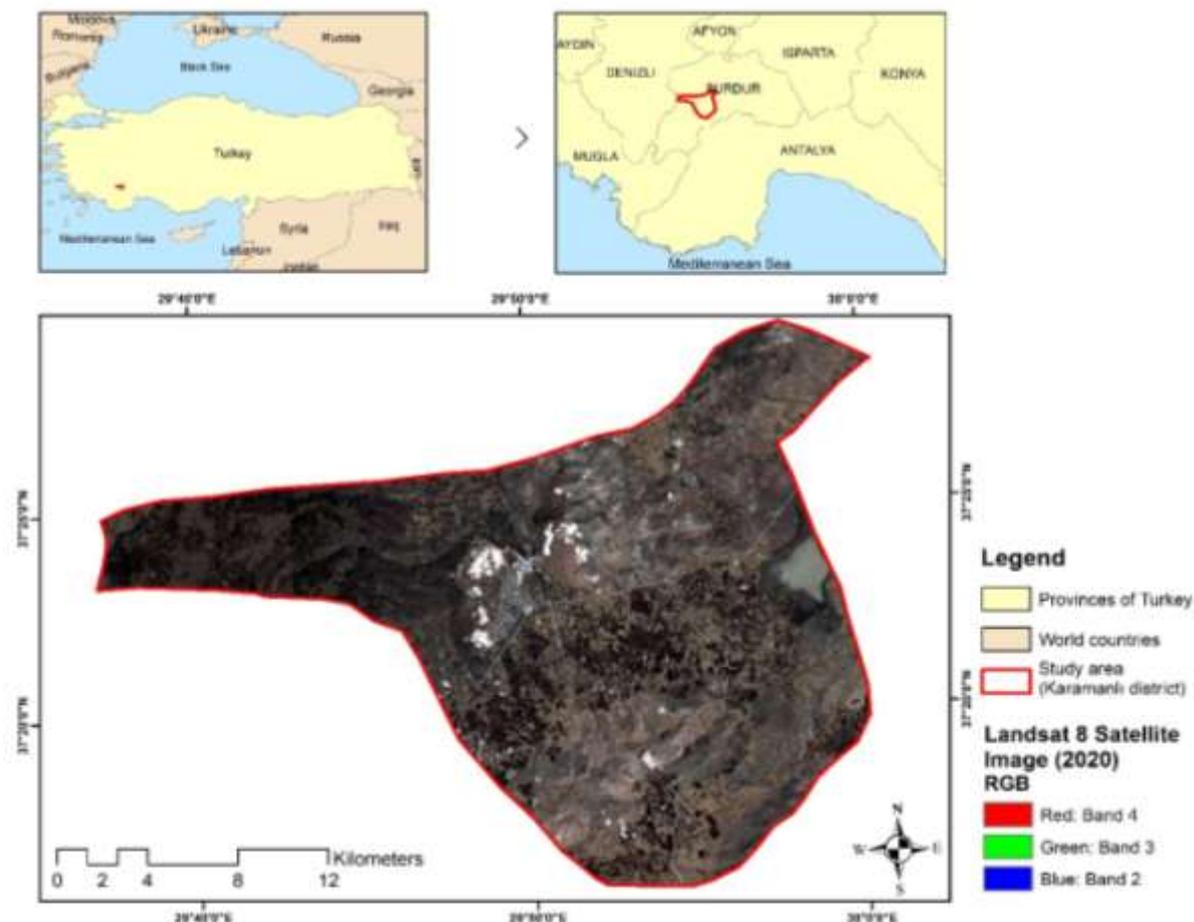


Figure 1. Location map of the study area.

The dates of the images were determined by considering the critical periods/years in which the mining activities accelerated in the study area. The characteristics of the image data are given in Table 1. Atmospheric correction and radiometric correction were implemented to improve the obtained images. These corrections were carried out using the Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) algorithm, which is frequently used in the literature [38,39].

Table 1. Description of the satellite images.

Satellite/sensor	Date	Path/row	Spectral bands	Radiometric resolution (bit)	Resolution (m)	Cloudiness rate (%)
Landsat 5 TM	07/08/1995	179/034	1, 2, 3, 4, 5, 7	8	30	0
Landsat 5 TM	04/08/2000	179/034	1, 2, 3, 4, 5, 7	8	30	0
Landsat 5 TM	01/07/2005	179/034	1, 2, 3, 4, 5, 7	8	30	0
Landsat 5 TM	16/08/2010	179/034	1, 2, 3, 4, 5, 7	8	30	0
Landsat 8 OLI	30/08/2015	179/034	1, 2, 3, 4, 5, 6, 7	12	30	0.10
Landsat 8 OLI	27/08/2020	179/034	1, 2, 3, 4, 5, 6, 7	12	30	0.08

- i. Image classification: Supervised classification was carried out based on the maximum likelihood approach, and classified images were formed. This approach is one of the most preferred supervised classification algorithms in order to monitor LULC changes [40-42]. This approach for calculating the weighted distance or likelihood D of an unknown measurement vector X belonging to one of the known classes M_c is based upon the Bayesian equation.

$$D = \ln(a_c) - [0.5 \ln(|cov_c|)] - [0.5(X - M_c)T(cov_c - 1)(X - M_c)] \tag{1}$$

Here, c is a particular class, a_c is percent probability that any candidate pixel being a member of class c , cov_c is the covariance matrix of the pixels in the sample of class c . The unknown measurement vector is assigned to the class in which it has the highest probability of belonging [43-45]. Field observations and local and/or regional knowledge of the study area were utilised to develop a training set. For each image classification, the training samples represent five land use classes, and the number of training samples differs for different classes, depending on the variability and easiness of identification of each class. In this study, the five land use classes were identified. These classes are artificial surfaces (AS), agricultural areas (AA), forests and semi-natural areas (FSNA), water surfaces (WS), and marble quarries (MQ). Envi 5.3 software was used to accomplish these operations.

- ii. In order to determine the accuracy of the classification process, the control point y for x class was randomly generated. An equalized stratified random sampling approach was used to assess the accuracy of each LULC classification.
- iii. Change detection: Change detection was performed after classifying all images (1995, 2000, 2005, 2010, 2015, and 2015). The classified images were transferred to ArcGIS 10.7 software for vectorization, calculation, and comparison of areas among different dates, and various changes in land use/land cover were identified.

3. Findings and Discussion

In this study, in order to evaluate the classification performance, random sampling points were created for each cell. Then the accuracy analysis was carried out by evaluating whether these points are in which land use class in the real environment. With the equalized stratified random sampling approach, a total of 150 points were generated randomly for each class. This approach randomly divides the point population determined for accuracy analysis into sub-groups homogeneously [46,47]. It is ensured that the sample size of each class or region of interest (ROI) is the same. As a result of the evaluations of randomly generated points, error matrices were produced. The assessments regarding the produced test and control points were carried out by visual interpretation based on the local knowledge of the study area, and utilising historical Google Earth images. The overall accuracy and KAPPA coefficient were used to assess classification accuracy. Table 2 indicates overall classification accuracy and kappa values. There are differences in both evaluation metrics due to the fact that the satellite images obtained in 5-year periods between 1995 and 2020 are not in the same time period and the satellite sensor types differ. The findings indicate that land use classification accuracy is admissible.

Table 2. Accuracy metrics obtained in this study.

Date	Overall Accuracy (%)	Kappa
07/08/1995	93.13	0.86
04/08/2000	89.52	0.81
01/07/2005	91.10	0.85
16/08/2010	88.44	0.82
30/08/2015	89.36	0.81
27/08/2020	89.06	0.80

After pre-processing and supervised classification, the classified thematic land use maps for 1995, 2000, 2005, 2010, 2015, and 2020 are presented in Figure 2. Table 3 and Table 4 present the

summary of the derived land use maps. The areal coverage and transition statistics of each land-use classification from 1995 to 2020 are shown in Table 5.

Table 3. Land use distribution of Karamanlı district from 1995 to 2020.

Classes	Land use in 1995 (F)		Land use in 2000 (E)		Land use in 2005 (D)	
	Area (ha.)	(%)	Area (ha.)	(%)	Area (ha.)	(%)
Artificial surfaces	2774.16	6.75	2922.57	7.11	3957.21	9.63
Agricultural areas	13553.73	32.99	14355.81	34.94	14308.00	34.83
Forests and semi-natural areas	24150.15	58.78	22913.19	55.77	20952.60	51.00
Water surfaces	410.04	1.00	527.04	1.28	1024.47	2.49
Marble quarries	194.40	0.47	363.87	0.89	840.15	2.05
Total	41082.48	100.00	41082.48	100.00	41082.50	100.00
Classes	Land use in 2010 (C)		Land use in 2015 (B)		Land use in 2020 (A)	
	Area (ha.)	(%)	Area (ha.)	(%)	Area (ha.)	(%)
Artificial surfaces	3078.99	7.49	5662.35	13.78	4351.68	10.59
Agricultural areas	10689.66	26.02	15793.56	38.44	13541.40	32.96
Forests and semi-natural areas	25163.82	61.25	16858.53	41.04	20908.40	50.89
Water surfaces	796.05	1.94	804.87	1.96	353.61	0.86
Marble quarries	1353.96	3.30	1963.17	4.78	1927.35	4.69
Total	41082.48	100.00	41082.48	100.00	41082.50	100.00

While the artificial surfaces in the study zone tend to increase in the period intervals of 1995-2000, 2000-2005 and 2010-2015, they tend to decrease in the period between 2005-2010 and 2015-2020. Urban sprawl, establishment of industrial facilities and shore erosion are thought to be the main reasons for the changes in these areas.

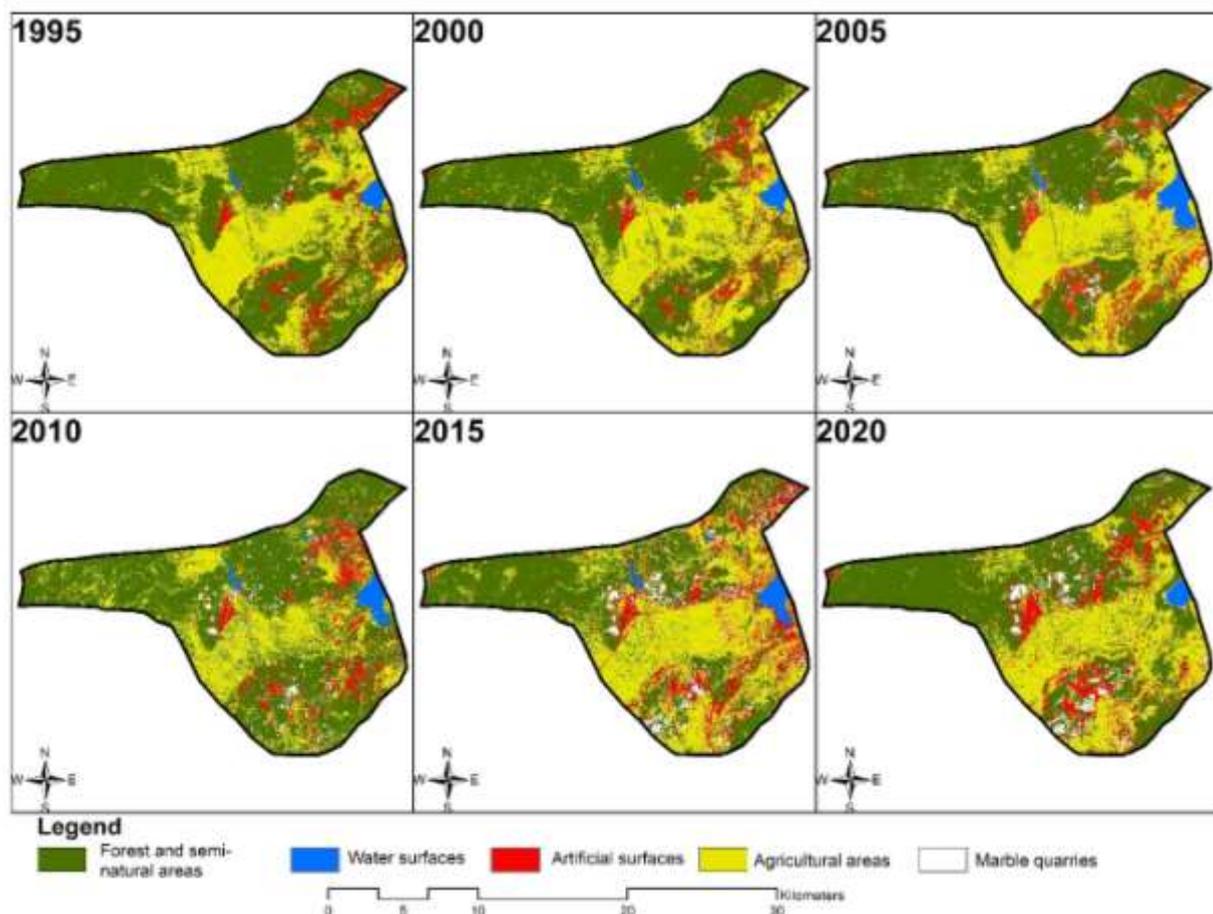


Figure 2. Classification results of Landsat satellite images.

While the agricultural areas in the study zone tend to increase in the period between 1995-2000 and 2010-2015, they tend to decrease in the 2000-2005, 2005-2010 and 2015-2020 period intervals. Depending on the economic conditions, periodic increase or decrease in agricultural activities, change in investment preferences, transformation of agricultural areas into settlements are thought to be the main reasons for the changes in these areas. While forest and semi-natural areas tend to decrease in the period intervals of 1995-2000, 2000-2005, 2010-2015, they tend to increase in the period intervals of 2005-2010 and 2015-2020. The increased mining activities and transformation of forest and semi-natural areas into marble quarries are thought to be the main reasons for the changes in these areas. While the water surfaces tend to increase in the period intervals of 1995-2000, 2000-2005, and 2010-2015, they tend to decrease in the period between 2005-2010 and 2015-2020. It can be said that the main reasons affecting these changes are the dam and pond investments, meteorological factors, and filling the quarries hollows with water. Marble quarries showed an area increase of 87%, 130%, 61%, and 44% in the period between 1995-2000, 2000-2005, 2005-2010, and 2010-2015, respectively. On the other hand, it tends to decrease by 1.82% in the period between 2015-2020. The excessive increase in the area of marble quarries is thought to be due to a prominent incentive for mining activities.

Table 4. Change rate of each land use class during the period from 1995 to 2020.

Classes	Land use change from 1995 to 2000 (E-F)		Land use change from 2000 to 2005 (D-E)		Land use change from 2005 to 2010 (C-D)	
	Area (ha.)	(%)	Area (ha.)	(%)	Area (ha.)	(%)
Artificial surfaces	148.41	5.35	1034.64	35.40	-878.22	-22.19
Agricultural areas	802.08	5.92	-47.81	-0.33	-3618.34	-25.29
Forests and semi-natural areas	-1236.96	-5.12	-1960.59	-8.56	4211.22	20.10
Water surfaces	117.00	28.53	497.43	94.38	-228.42	-22.30
Marble quarries	169.47	87.18	476.28	130.89	513.81	61.16
Classes	Land use change from 2010 to 2015 (B-C)		Land use change from 2015 to 2020 (A-B)		Land use change from 1995 to 2020 (A-F)	
	Area (ha.)	(%)	Area (ha.)	(%)	Area (ha.)	(%)
Artificial surfaces	2583.36	83.90	-1310.67	-23.15	1577.52	56.86
Agricultural areas	5103.90	47.75	-2252.16	-14.26	-12.33	-0.09
Forests and semi-natural areas	-8305.29	-33.00	4049.87	24.02	-3241.75	-13.42
Water surfaces	8.82	1.11	-451.26	-56.07	-56.43	-13.76
Marble quarries	609.21	44.99	-35.82	-1.82	1732.95	891.44

During the 25-year period (1995-2020), it was determined that artificial surfaces increased by 56.86% (from 148.41 hectares to 1577.52 hectares). A decrease of 0.09% in agricultural areas, a decrease of 13.42% in forest and semi-natural areas and a decrease of 13.76% in water surfaces were determined. While the marble quarries were 169.47 hectares in 1995, this area was 1732.95 hectares in 2020. During 25-year period, marble quarries showed a very serious increase of 891.44%. It has been observed that the marble quarries are mostly transitioned to forest and semi-natural areas.

Table 5. Cross tabulation of land use classes between 1995 and 2020.

	Classes	1995					Total area in 2020
		AS	AA	FSNA	WS	MQ	
2020	AS	878.13	1079.64	2302.74	3.6	87.57	4351.68
	AA	1142.1	8543.25	3823.02	21.42	11.61	13541.40
	FSNA	657.09	3766.68	16421.67	24.12	38.88	20908.44
	WS	0.54	3.33	10.89	338.85	0	353.61
	MQ	96.3	160.83	1591.83	22.05	56.34	1927.35
Total area in 1995		2774.16	13553.73	24150.15	410.04	194.40	

4. Conclusions and Recommendations

The presented study aimed to draw attention to the increase in the surface areas of marble quarries and to monitor the changes of land cover types in Karamanlı district of Burdur province. Land cover changes were evaluated over a 25-year period using 6 different Landsat satellite images (1995, 2000, 2005, 2010, 2015, and 2020). GIS tools and the supervised classification-based maximum likelihood approach provided an integrated background in this study. In this context, the changes between the classes (artificial surfaces, agricultural areas, forest and semi-natural areas, water surfaces, and marble quarries) were examined and the problems causing the changes were evaluated. The findings obtained show that there has been a serious change in the areas of marble quarries between 1995-2020. In addition, it is one of the most important findings in this study that forest and semi-natural areas are generally allocated to marble quarries. In other words, it has been determined that the most damaged land cover class is forests and semi-natural areas. The proposed approach has contributed significantly to the detection of land cover changes caused by marble quarries. It also provided an important background for the development of environmental protection strategies.

Mining activities cause permanent changes in land cover. It is extremely important to rehabilitate the degraded lands during and after mining activities in terms of sustainable use of resources. For this reason, as soon as the activities of the marble quarries (open-pit mining), which are increasingly important in the province of Burdur, are completed, planning and design projects should be prepared for the rehabilitation of abandoned marble quarries. This is an extremely important phenomenon for minimizing environmental and social impacts. The participation of different and related occupational groups and the public must be ensured in this rehabilitation process. While conducting spatial planning studies, many parameters such as environmental, geological, topographic, meteorological and geomorphological conditions should be considered in order to determine the purpose of reuse (e.g. recreation area, renewable resource based power plants) of abandoned mining areas.

In future studies, it will be useful to use higher resolution satellite images to comprehensively determine the causes of temporal and spatial changes and to determine the changes by considering more land cover/use classes depending on the purpose and scope of the study. Land cover changes caused by all mining activities (e.g. marble quarries) should be handled comprehensively on a local, regional, national and international scale.

Authors' contributions

ET and MAD were analyzed the data and wrote up the article. Both authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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