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

Emre TERCAN¹a, Mehmet Ali DERELI²b

¹General Directorate of Highways, 13th Region, Department of Survey, Project and Environment, Antalya, Turkey
²Giresun University, Faculty of Engineering, Department of Geomatics Engineering, Giresun, Turkey

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

Sure, here is the natural text of your document:

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

Emre TERCAN¹a, Mehmet Ali DERELI²b

¹General Directorate of Highways, 13th Region, Department of Survey, Project and Environment, Antalya, Turkey
²Giresun University, Faculty of Engineering, Department of Geomatics Engineering, Giresun, Turkey

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 Oacıklarının Genişlemesi ve Arazi Örtüsü Değişikliklerinin Uydu Görüntüleri ve CBS Kullanılarak İzlenmesi

Öz: Bu çalışma, 1995-2020 yılları arasında mermer oacıklarının yüzey alanlarındaki artışa dikkat çekmek ve arazi örtüsü 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 oacakları bulunmaktadır. İlgili görüntüler sınıflandırıldktan 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 oacıklarında meydana gelmiştir. Mermer oacıkları % 891,44 oranında çok ciddi bir artış göstermiştir (148,41 hektardan 1577,52 hektara). Mermer oacıklarının 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 oacakları, arazi örtüsü değişimleri, çevresel koruma, arazi kullanım planlaması, CBS, uzaktan algılama

How to cite this article

Tercan, E., Dereli, 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., Dereli, M.A., “Türkiye’nin Burdur ilinin kursal bir yerleşim merkezinde mermer oacaklarının genişlemesi ve arazi örtüsü değişikliklerinin uydu görüntülerle CBS kullanılarak izlenmesi” El-Cezeri Fen ve Mühendislik Dergisi 2021, 8 (2), 741-750.

ORCID ID: *0000-0001-6309-1083; *0000-0003-0575-1316
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.
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               |

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.
\[ D = \ln(a_c) - 0.5 \ln(\text{cov}_c) - 0.5(X - M_c)T(\text{cov}_c - 1)(X - M_c) \]  

(1)

Here, \( c \) is a particular class, \( ac \) is percent probability that any candidate pixel being a member of class \( c \), \( \text{cov}_c \) 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.

| 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  |

Table 2. Accuracy metrics obtained in this study.

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      |

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.](image-url)
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 2015 (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 -0.9                           |
| 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 | 2020 | Total area in 2020 |
|---------|------|------|-------------------|
| AS      | 878.13 | 1387.13 | 4351.68 |
| AA      | 1142.1 | 1584.25 | 13541.40 |
| FSNA    | 657.09 | 766.68 | 23090.84 |
| WS      | 0.54 | 3.33 | 0 |
| MQ      | 96.3 | 160.83 | 750.34 |
| Total area in 1995 | 2774.16 | 13553.73 | 19440.40 |

746
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.

References

[1]. Farahani, H., & Bayazidi, S., Modeling the assessment of socio-economical and environmental impacts of sand mining on local communities: A case study of Villages Tatao River Bank in North-western part of Iran, Resources Policy, 2018, 55, 87-95.
[2]. Amirshenava, S., & Osanloo, M., A hybrid semi-quantitative approach for impact assessment of mining activities on sustainable development indexes, Journal of Cleaner Production, 2019, 218, 823-834.

[3]. Mouflis, G. D., Gitas, I. Z., Iliadou, S., & Mitri, G. H., Assessment of the visual impact of marble quarry expansion (1984–2000) on the landscape of Thasos island, NE Greece, Landscape and Urban Planning, 2008, 86(1), 92-102.

[4]. Ozcelik, M., Environmental pollution and its effect on water sources from marble quarries in western Turkey, Environmental Earth Sciences, 2016, 75(9), 796.

[5]. Atibu, E. K., Lacroix, P., Sivalingam, P., Ray, N., Giuliani, G., Mulaji, C. K., ... & Poté, J., High contamination in the areas surrounding abandoned mines and mining activities: An impact assessment of the Dilala, Luilu and Mpingiri Rivers, Democratic Republic of the Congo, Chemosphere, 2018, 191, 1008-1020.

[6]. Mandal, I., & Pal, S., COVID-19 pandemic persuaded lockdown effects on environment over stone quarrying and crushing areas, Science of the Total Environment, 2020, 732, 139281.

[7]. Afonso, T. F., Demarco, C. F., Pieniz, S., Quadro, M. S., Camargo, F. A., & Andreazza, R., Bioprospection of indigenous flora grown in copper mining tailing area for phytoremediation of metals, Journal of Environmental Management, 2020, 256, 109953.

[8]. Gül, M., Zorlu, K., & Gül, M., Assessment of mining impacts on environment in Muğla-Aydın (SW Turkey) using Landsat and Google Earth imagery, Environmental Monitoring and Assessment, 2019, 191(11), 655.

[9]. Moetetsi, R., & Tesfamichael, S., Quantifying land cover changes caused by granite quarries from 1973-2015 using Landsat data. In GISTAM (pp. 196-204), (2018).

[10]. Chowdhury, M., Hasan, M. E., & Abdullah-Al-Mamun, M. M., Land use/land cover change assessment of Halda watershed using remote sensing and GIS, The Egyptian Journal of Remote Sensing and Space Science, 2020, 23(1), 63-75.

[11]. Uysal, M., Turgut, B., Polat, N., Dereli, M. A., & Yalçın, M., Determination of boron minerals in open pit mines with remote sensing techniques, Afyon Kocatepe University Journal of Science and Engineering, 2017, 17(4), 270-276 (In Turkish).

[12]. Gürsoy, M., & Büyüksağış, İS., Analyze of a sample mining field by remote sensing method, El-Cezeri Journal of Science and Engineering, 2017, 4(3), 518-540 (In Turkish).

[13]. Kabisch, N., Selsam, P., Kirsten, T., Lausch, A., & Bumberger, J., A multi-sensor and multi-temporal remote sensing approach to detect land cover change dynamics in heterogeneous urban landscapes, Ecological Indicators, 2019, 99, 273-282.

[14]. Colkesen, I., & Kavzoglu, T., Ensemble-based canonical correlation forest (CCF) for land use and land cover classification using sentinel-2 and Landsat OLI imagery, Remote Sensing Letters, 2017, 8(11), 1082-1091.

[15]. Temiz, F., Bozdag, A., & Durduran, S. S., Analysis of Land-Use Change in Denizli City Center through Geographical Information Systems, Fresenius Environmental Bulletin, 2018, 27(9), 6129-6136.

[16]. Dereli, M. A., Determination of short-term land cover change by Sentinel-2A satellite imagery for Giresun city center, Afyon Kocatepe University Journal of Science and Engineering, 2019, 19(2), 361-368 (In Turkish).

[17]. Dogru, A. O., Goksel, C., David, R. M., Tolunay, D., Sözen, S., & Orhon, D., Detrimental environmental impact of large scale land use through deforestation and deterioration of carbon balance in Istanbul Northern Forest Area, Environmental Earth Sciences, 2020, 79(270), 270.

[18]. Rudke, A. P., de Souza, V. A. S., dos Santos, A. M., Xavier, A. C. F., Rotunno Filho, O. C., & Martins, J. A., Impact of mining activities on areas of environmental protection in the southwest of the Amazon: A GIS-and remote sensing-based assessment, Journal of Environmental Management, 2020, 263, 110392.
[19]. Elagouz, M. H., Abou-Shleel, S. M., Belal, A. A., & El-Mohandes, M. A. O., Detection of land use/cover change in Egyptian Nile Delta using remote sensing, The Egyptian Journal of Remote Sensing and Space Science, 2020, 23(1), 57-62.

[20]. Dereli, M. A., & Tercan, E., Assessment of shoreline changes using historical satellite images and geospatial analysis along the Lake Salda in Turkey, Earth Science Informatics, 2020, 13, 709-718.

[21]. Ustaoglu, E., & Aydinoglu, A. C., Suitability evaluation of urban construction land in Pendik district of Istanbul, Turkey, Land Use Policy, 2020, 99, 104783.

[22]. Yildirim, V., & Bediroglu, S., A geographic information system-based model for economical and eco-friendly high-speed railway route determination using analytic hierarchy process and least-cost-path analysis, Expert Systems, 2019, 36(3), e12376.

[23]. Orhan, O., Yakar, M., & Ekercin, S., An application on sinkhole susceptibility mapping by integrating remote sensing and geographic information systems, Arabian Journal of Geosciences, 2020, 13(17), 1-17.

[24]. Nyimbili, P. H., & Erden, T., GIS-based fuzzy multi-criteria approach for optimal site selection of fire stations in Istanbul, Turkey, Socio-Economic Planning Sciences, 2020, 71, 100860.

[25]. Tercan, E., & Dereli, M. A., Development of a land suitability model for citrus cultivation using GIS and multi-criteria assessment techniques in Antalya province of Turkey, Ecological Indicators, 2020, 117, 106549.

[26]. Tercan, E., Saracoglu, B. O., Bilgilioğlu, S. S., Eymen, A., & Tapkin, S., Geographic information system-based investment system for photovoltaic power plants location analysis in Turkey, Environmental Monitoring and Assessment, 2020, 192, 297.

[27]. Tercan, E., Tapkin, S., Latinopoulos, D., Dereli, M. A., Tsiroupolou, A., & Ak, M. F., A GIS-based multi-criteria model for offshore wind energy power plants site selection in both sides of the Aegean Sea, Environmental Monitoring and Assessment, 2020, 192, 652.

[28]. Bonifazi, G., Cutaia, L., Massacci, P., & Roselli, I., Monitoring of abandoned quarries by remote sensing and in situ surveying, Ecological Modelling, 2003, 170(2-3), 213-218.

[29]. Malaviya, S., Munsi, M., Oinam, G., & Joshi, P. K., Landscape approach for quantifying land use land cover change (1972–2006) and habitat diversity in a mining area in Central India (Bokaro, Jharkhand), Environmental Monitoring and Assessment, 2010, 170(1-4), 215-229.

[30]. Darwish, T., Khater, C., Jomaa, I., Stehouwer, R., Shaban, A., & Hamzé, M., Environmental impact of quarries on natural resources in Lebanon, Land Degradation & Development, 2011, 22(3), 345-358.

[31]. Ozcan, O., Musaoglu, N., & Seker, D. Z., Environmental impact analysis of quarrying activities established on and near a river bed by using remotely sensed data, Fresenius Environmental Bulletin, 2012, 21(11), 3147-3153.

[32]. Kekovalı, K., & Kalafat, D., Detecting of mining-quarrying activities in Turkey using satellite imagery and its correlation with daytime to nighttime ratio analysis, Journal of the Indian Society of Remote Sensing, 2014, 42(1), 227-232.

[33]. LaJeunesse Connette, K. J., Connette, G., Bernd, A., Phylo, P., Aung, K. H., Tun, Y. L., ... & Songer, M., Assessment of mining extent and expansion in Myanmar based on freely available satellite imagery, Remote Sensing, 2016, 8(11), 912.

[34]. Akanwa, A. O., Okeke, F. I., Nnodu, V. C., & Iortyom, E. T., Quarrying and its effect on vegetation cover for a sustainable development using high-resolution satellite image and GIS, Environmental Earth Sciences, 2017, 76(14), 505.

[35]. Yadav, S. K., & Borana, S. L., Monitoring and temporal study of mining area of Jodhpur City using remote sensing and GIS, Int. Research Journal of Eng and Technology, 2017, 4(10), 2.

[36]. Pericak, A. A., Thomas, C. J., Kroodsma, D. A., Wason, M. F., Ross, M. R., Clinton, N. E., ... & Amos, J. F., Mapping the yearly extent of surface coal mining in Central Appalachia using Landsat and Google Earth Engine, PloS one, 2018, 13(7), e0197758.
[37]. Narin, Ö.G., Yalçın, M., & Akyol, M., Landsat 8 Uydu Verilerinin Kömür Maden Sahası Araştırmalarında Kullanımı, Soma Örneği. 10. Türkiye Ulusal Fotogrametri ve Uzaktan Algılama Birliği Teknik Sempozyumu, 2019, 150-153.

[38]. Bernardo, N., Watanabe, F., Rodrigues, T., & Alcântara, E., Atmospheric correction issues for retrieving total suspended matter concentrations in inland waters using OLI/Landsat-8 image, Advances in Space Research, 2017, 59(9), 2335-2348.

[39]. Lhissou, R., El Harti, A., Maimouni, S., & Adiri, Z., Assessment of the image-based atmospheric correction of multispectral satellite images for geological mapping in arid and semi-arid regions, Remote Sensing Applications: Society and Environment, 2020, 20, 100420.

[40]. Kavzoglu, T., & Colkesen, I., A kernel functions analysis for support vector machines for land cover classification, International Journal of Applied Earth Observation and Geoinformation, 2009, 11(5), 352-359.

[41]. Ali, M. Z., Qazi, W., & Aslam, N., A comparative study of ALOS-2 PALSAR and landsat-8 imagery for land cover classification using maximum likelihood classifier, The Egyptian Journal of Remote Sensing and Space Science, 2018, 21, S29-S35.

[42]. Islam, K., Jashimuddin, M., Nath, B., & Nath, T. K., Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati wildlife sanctuary, Bangladesh, The Egyptian Journal of Remote Sensing and Space Science, 2018, 21(1), 37-47.

[43]. Otukei, J. R., & Blaschke, T., Land cover change assessment using decision trees, support vector machines and maximum likelihood classification algorithms, International Journal of Applied Earth Observation and Geoinformation, 2010, 12, S27-S31.

[44]. Erdas Inc., 1999. Erdas Field Guide. Erdas Inc., Atlanta, Georgia.

[45]. Taati, A., Sarmadian, F., Mousavi, A., Pour, C.T.H., & Shahir, A.H.E., Land use classification using support vector machine and maximum likelihood algorithms by Landsat 5 TM images, Walailak Journal of Science and Technology (WJST), 2015, 12(8), 681-687.

[46]. Maxwell, A. E., Warner, T. A., & Fang, F., Implementation of machine-learning classification in remote sensing: An applied review. International Journal of Remote Sensing, 2018, 39(9), 2784-2817.

[47]. Kangabam, R. D., Selvaraj, M., & Govindaraju, M., Assessment of land use land cover changes in Loktak Lake in Indo-Burma Biodiversity Hotspot using geospatial techniques. The Egyptian Journal of Remote Sensing and Space Science, 2019, 22(2), 137-143.