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Land use change detection in Denizli City Center using spectral angle mapper method and evaluations in terms of some earth science data

Spektral açı haritalama yöntemi ile Denizli Kent Merkezi arazi kullanım değişim tespiti ve bazı yerbilim verileri açısından değerlendirilmesi

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Abstract

Land use planning is central for a sustainable development processes and should be structured in harmony with geo-environmental constrains. In this study, land use change detection was determined in Denizli residential area between the years 1984 and 2018. In the analyses, Landsat-5TM and Landsat-8 OLI images were used for 1984 and 2018, respectively. The geometric, radiometric calibration and atmospheric corrections were applied to the satellite images in pre-processing stage. Land use change detection was performed using supervised classification -Spectral Angle Mapper- method. Accuracy of the classifications was evaluated by the kappa index, which was 0.80 for 1984 and 0.87 for 2018 image. According to the results, between 1984 and 2018 there was an increase of 155% and 96% in built up and forest areas, while 52% and 40% decrease were observed in agriculture and bare land, respectively. It was also determined that the majority of the settlement areas increased in regions close to active fault zones. Accordingly, the built up areas within the 500 m buffer zone to the active faults were increased by 240% from 1984 to 2018.

Keywords: Land use, Change detection, Remote sensing, Landsat, Denizli

Öz

Arazi kullanım planlaması, sürdürülebilir kalkınma süreclerinin merkezinde yer almakta olup, jeo-çevresel şartlara uyumlu bir şekilde yapılandırılmalıdır. Bu çalışmada, Denizli kent merkezinde 1984 ve 2018 yılları arasında arazi kullanımında meydana gelen değişimler belirlenmiştir. Analizlerde, 1984 ve 2018 yılları için sırasıyla Landsat-5 TM ve Landsat-8 OLI görüntüleri kullanılmıştır. Uydu görüntülerinde ön işlem aşamasında geometrik, radyometrik kalibrasyon ve atmosferik düzeltmeler uygulanmıştır. Arazi kullanımı değişim tespiti, kontrollü sınıflandırmalardan, Spektral Açı Haritalama yöntemi kullanılarak gerçekleştirilmiştir. Sınıflandırmanın doğruluğu kappa indeksi ile değerlendirilmiş olup 1984 yılı için 0.80, 2018 yılı için 0.87 olarak bulunmuştur. Elde edilen sonuçlara göre 1984 ile 2018 yılları arasında yerleşim ve orman alanlarında sırasıyla %155 ve %96'lık artış meydana gelirken, tarım ve çıplak arazilerde ise %52 ve %40'lık oranlar da azalma gözlenmiştir. Yerleşim alanlarının büyük çoğunluğunun, aktif fay zonlarına yakın bölgelerde arttığı belirlenmiştir. Buna göre, çalışma alanında yer alan aktif faylara 500 m'lik zonlar içerisinde, 1984 ile 2018 yılları arasında yapılaşma alanlarındaki artış, %240 olarak tespit edilmiştir.

Anahtar kelimeler: Arazi kullanımı, Değişim tespiti, Uzaktan algılama, Landsat, Denizli.

1 Introduction

The exponential growth of the human population in the past two hundred years has led to significant changes in natural and built environments. Although urbanization is regarded as a positive process related to population growth, industrialization, and global integration, it is economically benefited only by the minority of the urban population [1]. Land use change is a complex and dynamic processes associated with the political, economic, cultural, technological and natural driving forces and the respective factors [2],[3]. The last spatial planning construction regulation came into force in 2014 in Turkey. The aim of the regulation is to protect and develop physical, natural, historical and cultural values, to ensure the balance of protection and use, to support sustainable development at the country, region and city level, to create healthy and safe environments with high quality of life. In the regulation, the planning stages, from the upper level to the lower level are represented by Spatial Strategy Plan, Environmental Plan, Master development, and Implementation development Plan. In all plans, among others, the natural disaster and geological data is included in the general planning principles. In spatial strategy planning covering the national and regional level and in the environmental plans made at the region, basin or province level, it is necessary to analyze and identify natural hazards and risks for reducing the losses and take measures to decrease disaster risks. In master development and implementation development plans, geological-geotechnical or micro-zoning studies, geological, geomorphological, hydrological and hydrogeological structure, potential hazards of natural disasters, settlement suitability, risk management and mitigation plans should also be evaluated.

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Denizli is one of the most important cities of the Aegean region in terms of geothermal energy, marble, agriculture, tourism, textile and other industrial capacity. Denizli city, which was founded under the name of Laodikeia in the third century BC, has been severely suffered from major earthquakes that caused loss of life and property [4]. The city center and its surroundings are surrounded by Denizli and Babadağ fault zones [5], so it has high seismic activity today as it was in history. It is known that many ancient cities in and around Denizli were destroyed as a result of historical earthquakes [6]. Land use planning is a systematic procedure in order to create more desirable social and environmental conditions also reducing risks from natural hazards. In the early 2000s, geological, geotechnical and hydrogeological investigations in Denizli Municipality urban settlement area were carried out by Pamukkale University [7] and a geological-geotechnical urban information system for Denizli [8]-[10] was first time developed by GEOUKS computer program written by [11] in C++ programming language. However, the urbanization has extended rapidly to the western part of the Municipality after the settlement suitability map of Denizli was first published by [7]. In this study land use change processes were carried out in the region of 206 km², covering the central district of Denizli (Figure 1). It has identified that urbanization has extended mainly on agriculture and bare lands without taking into consideration of active fault zones.

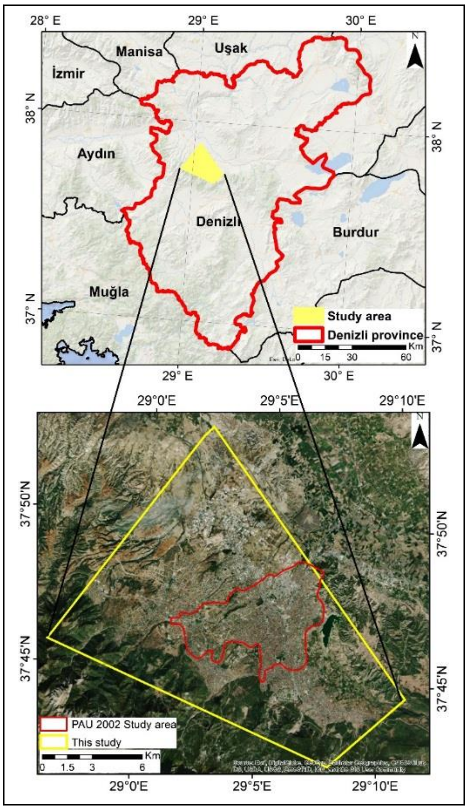


Figure 1. Location map of the study area.

2 Geological and morphological settings

The study area is geologically located in Denizli basin/graben. The oldest geological units exposed in the area are Paleozoic schist-quarzites (Ortaköy formation) and marbles (Paşapınar formation) of the Menderes massif. The Tavas nappe, the lowermost unit of Lycian nappes, overlie the Menderes massif units with Jurassic-Cretaceous limestones and calciturbidites (Babadağ formation) [12] followed by mainly Upper Paleocene to Eocene limestones and clastics (Faralya formation) [17],[13]. The Neogene cover units in the study area is represented by Kolonkaya formation of Late Miocene- Pliocene consisting of limestones and clastic sediments [14]. Quaternary deposits are mainly represented by lake, coastal plain, floodplain, terrace and alluvial fan deposits. Pre Neogene units are located within footwall whereas Neogene-Quaternary units are located within the hanging wall of the Denizli and Babadag fault zones of the Denizli Graben [15] (Figure 2).

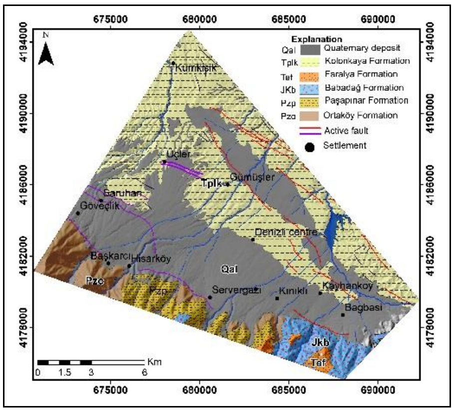


Figure 2. The active faults [5] and simplified geological map [12], [16] of the study area.

The 35 km long Babadağ fault zone is located in the southwestern parts of the study area, with Quaternary activity, Generally, it trends at N60°E, and dips 55-70° to northeast. The 25 km long Denizli fault zone, trending N45°W and dipping 55-70° to northeast, is located in the central parts of the study area with Holocene activity [5]. Figure 3 represents the historical and instrumental earthquakes recorded around the region. It is known that the city center and villages caused by strong earthquakes occurred in magnitude of 6.6 in 1702 and 6.5 in 1717 were damaged, almost the city was rebuilt and nearly 6,000 loss of life were recorded by the earthquakes [6].

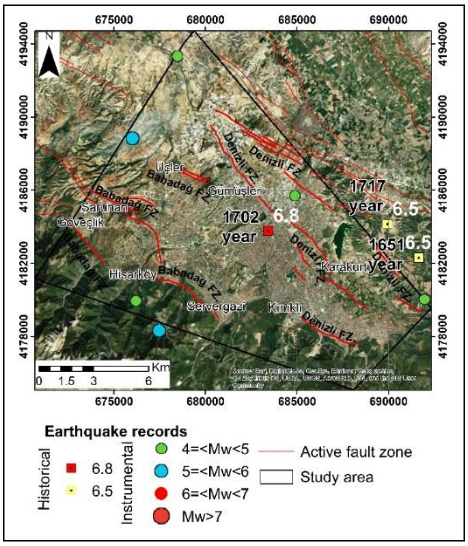


Figure 3. Spatial distribution of Active faults in the study area [4], Historical earthquake record [17], and Instrumental earthquake records of the study area and its vicinity [18].

The elevation ranges between 166 and 2288 m and is gradually decreasing from south to north (Figure 4). The southern parts of the study area where basements units exposed through the Babadağ and Honaz mountains is represented by steep slopes up to 67 degrees. The slopes of less than 10 degrees corresponding 62 % of the study area located around the Denizli city center and its surroundings (Figure 5).

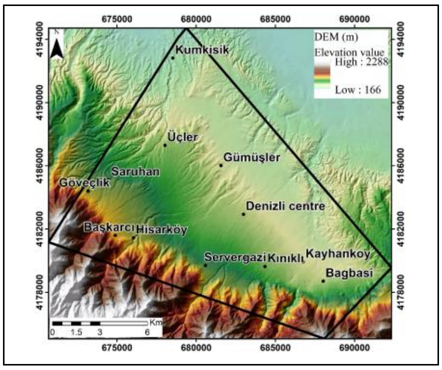


Figure 4. Digital elevation model of the study area.

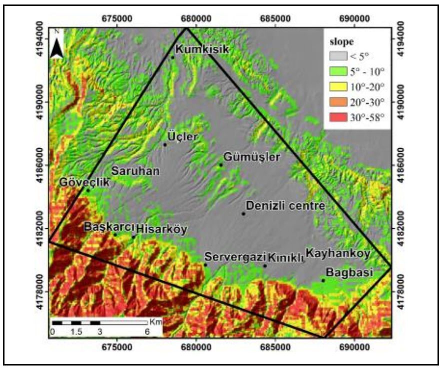


Figure 5. Slope map of the study area.

3 Method

Land use change is mainly based on the comparison of the state of features, using at least two images that are taken at different times. In preprocessing stage, firstly, geometrical distortions between the two images are harmonized with each other using certain control points. Secondly, radiometric corrections were carried out in order to eliminate the atmospheric effects causing irregular and false sensations in the images and to correct the reflections that did not fully represent objects from the radiation detected by the sensors. Then, atmospheric correction and image enhancement processes were performed to eliminate the spectral effect of water vapor and aerosols.

Spectral Angle Mapper (SAM) method was used for change detection. SAM is a supervised classification based spectral of band that uses an angle to match pixels to reference spectra (training sets). The algorithm assigns the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in a space with dimensionality equal to the number of bands [19] (Figure 6).

Small angles between the two spectrums indicate high similarity and vice versa. Repressing the influence of shading effects to accentuate the target reflectance characteristics is another advantage of the method [20]. This technique functions well in the face of scaling noise. The mathematical formulation of SAM was given by equation 1:

$$= \cos^{-1}\frac{\sum XY}{\sqrt{\sum X^2 \sum Y^2}} \tag{1}$$

Where:

α : Angle formed between reference spectrum and image spectrum
X : Image spectrum
Y : Reference spectrum

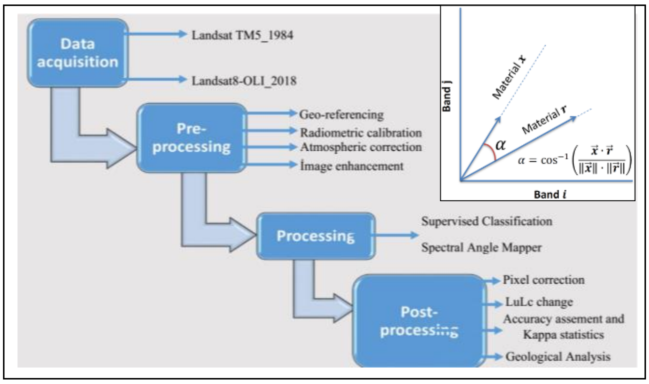
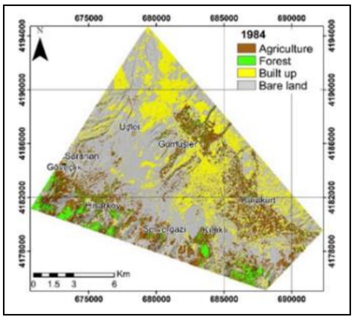


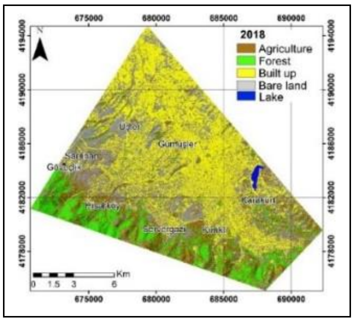
Figure 6. The stages of the methods applied in this study.

4 Results

Denizli city center is growing fast due to rapid population growth and migration from rural areas. In this study, land use changes in Denizli city center were determined using remote sensing techniques and Landsat satellite images between 1984 and 2018. Four land use classes namely, agricultural areas, forest, settlement, and bare lands were used in the classification made on the image dated 1984. In the classification for 2018, in addition to 1984, the water body class was also included. Land use classes for 1984 and 2018 are given in Figure 7.



(a)



(b)

Figure 7. Land use classification map for 1984 (a), 2018 (b).

Performance evaluation of classifications was made using confusion matrix for general accuracy, and statistical differences between classifications using Kappa coefficient. Kappa statistics is a measurement mechanism between reference data and user-defined classified data [21],[22]. When the classification error matrices are examined, the total Kappa value of the classes is determined as 0.80 for 1984 and 0.87 for 2018 (Table 1).

Table 1. The results of the accuracy assessment and the kappa statistics.

Class Names	1984		2018	
	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy
Unclassified	0	0	0	0
Agriculture	92.86	86.67	84.62	91.67
Forest	81.25	86.67	91.67	91.67
Built Up	81.25	86.67	83.33	83.33
Water			100.00	100.00
Bare soil/Rock	85.71	80.00	90.91	83.33
Accuracy	% 85.00		% 90.00	
Kappa	0.8000		0.8750	

Accordingly, it was determined that the highest classes in the study area consisted of bare lands in 1984 and 2018 with 64.15% and 38.69%, respectively (Figure 8). On the relevant dates, it was determined that there was a decrease in agriculture and bare areas from land change classes, while an increase occurred in forest and built up areas (Figure 9).

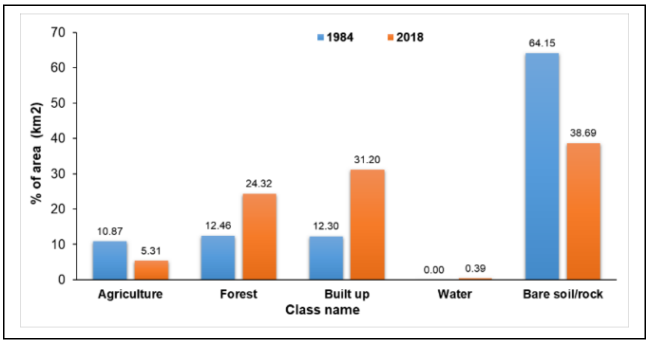


Figure 8. Distribution of land use class percentages for 1984 and 2018.

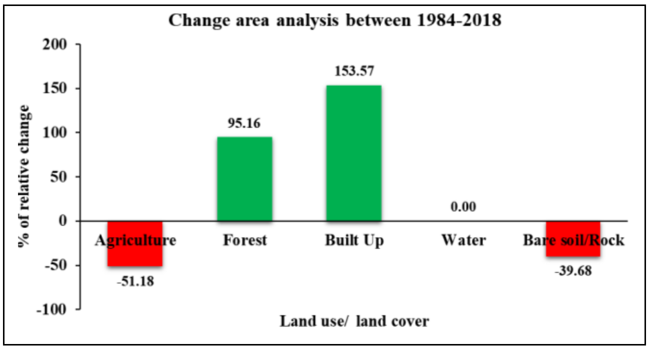
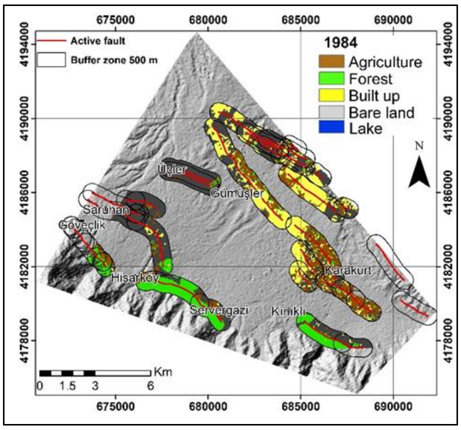
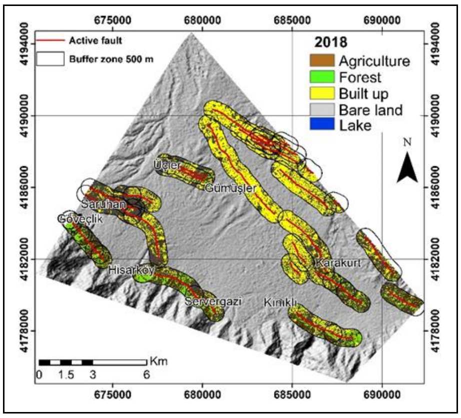


Figure 9. Overall land use changes between 1984-2018.

It has been determined that 36 % of the settlements are located on the Quaternary units, which are sensitive to seismic hazards. In addition, the built up areas in 500 m buffer zones around the active faults has increased 240% between 1984 and 2018 (Figure 10).



(a)



(b)

Figure 10. Changes in regions close to active fault lines for 1984 (a) and 2018 (b).

5 Conclusions

Denizli city is one of the leading cities in Turkey in terms of agriculture, industry, culture and tourism. The city is located in seismically high hazard zone. According to the results obtained, an increase of 153.57 % was observed in built up areas between 1984 and 2018. It has been also determined that most of the settlements are located on the Quaternary units and around the active fault zones, which are geologically sensitive to strong ground shaking, liquefaction and other ground deformations. Turkey earthquake hazard maps and earthquake building regulations came into force on 1 January 2019. In order to eliminate the adverse effects of possible earthquake hazards on urbanized areas, effective land use planning strategies should be evaluate in large scales with detailed micro zonation studies considering site specific geological, seismological and geotechnical characteristics.

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