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Detection of Vegetation Changes in Relation to Normalized Difference Vegetation Index (NDVI) in Semi-Arid Rangeland in Western Iran

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ABSTRACT

This study aimed first to investigate the relationship between Normalized Difference Vegetation Index (NDVI) and vegetation attributes (vegetation cover, bare soil, litter frequency, and the amount of biomass) and, then, evaluating the vegetation changes using NDVI in semi-arid rangeland in western Iran. Ground data were collected to assess the accuracy of *NDVI* index. For this purpose, 14 sampling units were randomly selected for collection of vegetation attributes including biomass, vegetation cover, litter, and bare soil. Then, the correlation between digital pixel values and the sampling units were analyzed. The results showed that NDVI was highly correlated with all vegetation attributes. The maximum correlation was related to vegetation cover (0.84). So, to evaluate the vegetation changes, the NDVI maps were created in 1986, 2001, and 2013. The results showed that the amount of class 1 (very poor vegetation cover) increased from 0.27 km^2 in 1986 to 12.89 km^2 in 2013, and also class 4 and 5 (good and very good vegetation cover, respectively) decreased about 27.8 and 37.7%, respectively. The relationship between precipitation and temperature with NDVI was investigated to assess the sensitivity of NDVI to these parameters. The results showed that the amount of precipitation decreased during the studied time periods. This parameter seems to be one of the most important factors affecting the vegetation in our study area.

Keywords: Precipitation, Satellite imagery, Temperature, **V**egetation cover.

INTRODUCTION

Vegetation cover is one of the renewable resources and the most important element of every ecosystem. This element plays an important role in the lives of all organisms; therefore, it is necessary to monitor it constantly (Kulawarhhana, 1999). Furthermore, appropriate precipitation patterns for dry land farming resulted in many land use and vegetation cover changes in semi-arid rangeland in western Iran (Fathizad *et al*., 2015). Drought vulnerability of recent years drives vegetation cover changes in another way. Conversion of rangeland to cropland (Faramarzi *et al*., 2010; Khormali and Nabiollahi, 2009), deforestation (Fathizad *et al*., 2015), and urban sprawl (Dadras *et al*., 2014 , Jokar Arsanjani *et al*., 2013) are causing changes in land use and vegetation cover in Iran.

Satellite imagery makes it possible for the users to study vegetation cover over large areas, increase the accuracy, and reduce the cost. One of the research techniques for remote sensing of vegetation cover is using the vegetation indices, which allow the user to distinguish vegetation cover from other phenomena (Alavipanah, 2003) and provide

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appropriate equations to achieve the necessary information of the desired area (Ebrahimi *et al.*, 2009). Vegetation indices have been developed to identify biophysical and chemical properties of vegetation, which can be calculated using suitable and useable bands (Boyd, 1996). Near Infrared (NIR) and Red (RED) bands are usually used for classifying vegetation, because the spectral changes in vegetation take place in these two bands (Rangzan, 2004). Several studies have been conducted by application of vegetation indices. Among the various indices of vegetation cover, NDVI has been widely used to monitor the changes in the vegetation cover (Matsushita *et al.*, 2007). To investigate the desertification phenomenon, various indices are used, e.g. drought index, vegetation cover, and land use changes. Yet, nowadays, 90% of the experts use vegetation indices to assess the desertification phenomenon (Hellden, 1986). Ghaemi *et al.* (2010) investigated and compared vegetation indices in a study concerning the vegetation cover in Neishabour. The results showed that the NDVI, as one of the most widely used vegetation indices, is able to provide better differentiation for areas that have a more dense coverage. A number of researchers applied several indices to monitor vegetation cover changes and concluded that the *NDVI* value had more accuracy than other indices (Huang and Wang, 2010; Michener and Houhoulis, 1997; Tahira, 2010). Madanian and Sefyanian (2012) investigated the possibility of monitoring changes in vegetation cover using NDVI, RVI, MNDV, IR, DVI, and TVI indices during the years 1990 to 2001. Their results indicated that the NDVI was more efficient and accurate than other vegetation indices. NDVI had the highest correlation with vegetation cover in comparing with other vegetation attributes such as bare soil (Mokhtari *et al.*, 2000).

In this study, we aimed to investigate the relationship between the *NDVI* value and vegetation cover components in semi-arid rangeland in western Iran, based on the hypotheses that: (1) The vegetation cover can be detected by *NDVI* value and, (2) The *NDVI* value decreases with decreasing precipitation and increasing temperature.

MATERIALS AND METHODS

The Study Area

The study area was Dalab catchment (33° 26' 52" to 33° 18' 43" N and 46° 40' 27" to 46° 15' E), located in Ilam province in western Iran (Figure 1), with a total area of about 39.2 km^2 and the average elevation of about 1385 m. The mean annual precipitation and temperature are 453.4 mm and 15.4C°, respectively.

Ground Sampling

Fourteen units were randomly sampled to investigate the relationship between vegetation attributes and the NDVI (Figure 2). The vegetation data in the sample sites was gathered from June to July, 2013.

A long linear transect of 30 m was used to estimate vegetation attributes including vegetation cover, litter, and bare soil. In each sample unit (transect), the existing plant species, bare soil area, and litter were determined. In the sample units, standing herbaceous vegetation was harvested (cut 1 cm above the ground) in four quadrats of 1×1 m^2. Harvested plants were oven-dried at 80°C for 48 hours before measuring biomass.

Satellite Imagery Data

In order to study the vegetation changes and correlation of vegetation attributes with the NDVI, Landsat TM and ETM+ satellite images of 1986, 2001, and 2013 were used. For these three years, the satellite imagery was acquired during June for further analysis. High resolution Landsat satellite imagery has been used widely for analyses of vegetation cover (Campbell *et al*., 2015;

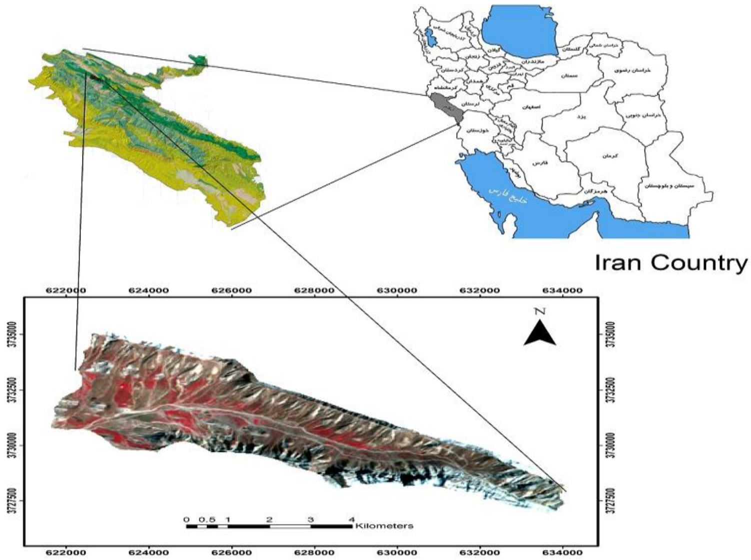

Figure 1. Location of the study area on the map of Iran and Ilam province (RGB combination, extracted from Landsat ETM+, 2013).

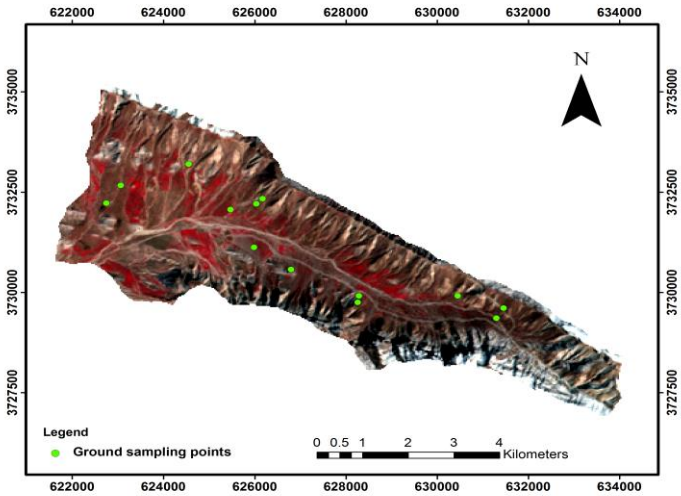

Figure 2. Location of ground sampling units in the study area (RGB map extracted from ETM+ Landsat, 2013).

Fathizad *et al*., 2015; Potter, 2015; Robertson *et al*., 2015) which has a high accuracy for vegetation changes. ArcGIS9.3 and ENVI4.7 software applications were used for analysis of image processing.

NDVI Calculation

The NDVI is one of the most commonly used indices in the world which is used to determine the presence or absence, type, and condition of vegetation. This index has been provided by Rouse et al. (1974). The NDVI formula is calculated based on Equation (1).

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

Where, *NIR* is the reflections in the near-infrared band, and *RED* is the reflections within the range of the red band.

The NDVI provides the possibility of extensive vegetation studies. This index is sensitive to coverage growth conditions (the amount of biomass, the leaf area index, percentage of vegetation cover, etc.), biophysical and biochemical properties (humidity, the chlorophyll in the canopy, etc.), and ecosystem parameters (precipitation, evaporation, transpiration, etc.). The value of this index varies between -1 to $+1$ (Deering, 1978), which tends towards $+1$ in the dense vegetation covers and produces negative values for clouds, snow, and water (Serrano *et al.*, 2000). Bare soil and rock also produce small positive or close to zero negative values. Amount of recognized biomass was considered as a substantial factor which significantly affects the value of NDVI (Tan *et al.*, 2010).

In the present study, infrared and red bands of 1986, 2001, and 2013 satellite imagery were used to calculate the NDVI maps in the study area. To detect the vegetation condition trend, *NDVI* index and greenness levels were used (Soroudi *et al.*, 2011; Abdolahi *et al.*, 2008). To this end and for increasing the accuracy, the *NDVI* values were not assigned to equal classes but, according to the Histogram slopes obtained from applying the *NDVI* index on satellite imagery, values were classified into five classes based on greenness levels. Then, satellite imagery of 2013 was used to find the correlation between the *NDVI* index and field data. This image presented the highest amount of coordination with the data collected in terms of time. After calculating the index, this image was exported into ArcGIS9.3 and ground sampling units were pointed out in the image and, finally, the digital values of the index were calculated for each unit.

RESULTS

A total of 14 units were sampled for ground data collected in our study area. This data was used for assessment of the *NDVI* index accuracy. In the following sections, we will present the results from the correlation between NDVI and ground data and also vegetation changes based on *NDVI* index.

NDVI and Ground Data

Linear regression analysis between the digital values of NDVI (extracted from Landsat ETM+, 2013) and percentage of vegetation cover, biomass, bare soil, and litter showed that vegetation cover had the highest correlation with a coefficient of 0.84, while the lowest correlation with a coefficient of 0.65 was related to litter frequency (Table 1). The correlation between percentage of bare soil and NDVI was negative (Table 1).

Vegetation Changes

After finding a high correlation between NDVI and vegetation cover, the vegetation changes were detected by the *NDVI* values in 1986, 2001, and 2013 (Figures 3, 4, and 5). , The digital values of the NDVI were arranged into five classes: from less than -0.01 to more than +0.38. According to the *NDVI* values, we assumed five vegetation cover classes: those of very good (0.38<),

Table 1. The correlation between vegetation attributes and *NDVI* index (extracted from Landsat ETM+, 2013).

Variable	Biomass	Vegetation cover	Bare Soil	Litter frequency	NDVI [a]
Biomass	1				
Vegetation cover	0.88**	1			
Bare soil	-0.87**	-0.85**	1		
Litter frequency	0.63**	0.71**	-0.77**	1	
NDVI	0.80*	0.84*	-0.75*	0.65*	1

[a] Normalized Difference Vegetation Index * Significant at $\alpha < 0.05$, ** Significant at $\alpha < 0.01$.

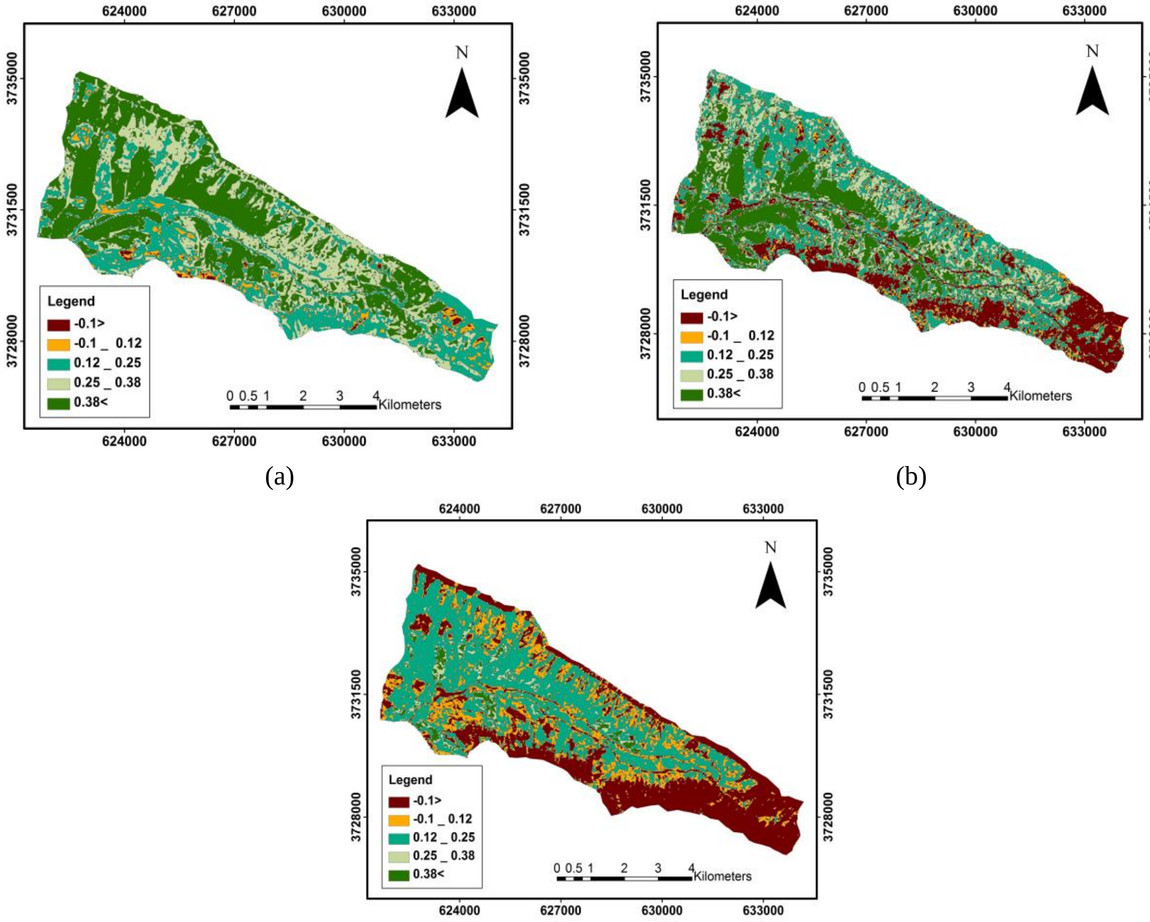

Figure 3. NDVI map of (a) 1986 and (b) 2001, and (c) 2013.

good (0.25–0.38), medium (0.12–0.25), poor (-0.01–0.12), and very poor (-0.01>) (Table 2).

The areas of very poor, poor, and medium classes were increased during 1986–2013, when the *NDVI* values were less than 0.25 (Table 2 and Figure 6). On the other hand, a decreasing trend was found in the good and very good vegetation cover classes, since the *NDVI* values were more than 0.25 (Table 2 and Figure 6).

The area of class 5 was 8.72 km^2 in 1986, which was reduced to 0.96 km^2 in 2013. As previously mentioned, positive digital value represents dense vegetation cover and decrease in this value means a reduction in the vegetation cover for the area. The vegetation changes of NDVI showed a

Table 2. Area and percentage of different NDVI classes for 1986, 2001, and 2013

		1986		2001		2013	
NDVI classes	Condition	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
-0.01>	Very poor	0.27	0.6	8.6	21.93	12.89	32.88
-0.01-0.12	Poor	1.46	3.72	3.79	9.61	8.23	20.99
0.12–0.25	Medium	9.65	24.23	12.45	30.76	16.01	40.28
0.25–0.38	Good	12.25	31.25	9.06	23.11	1.34	3.41
0.38<	Very good	15.77	40.2	9.68	24.59	0.96	2.44

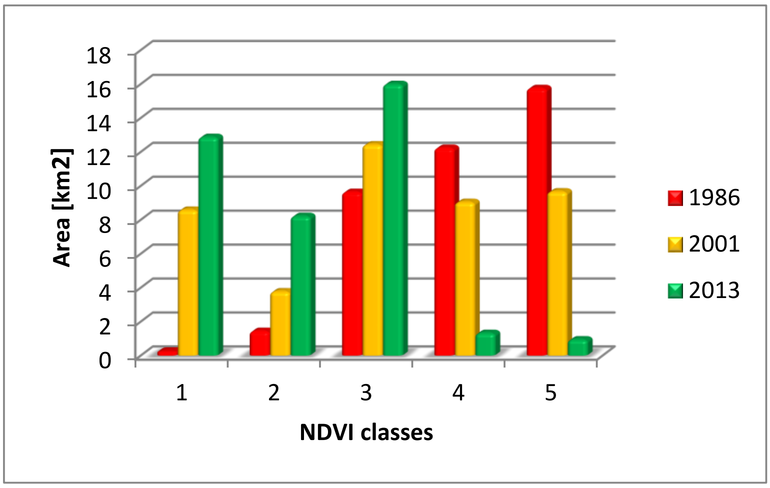

Figure 6. The trend of *NDVI* values changes in different classes during 1986–2013.

decreasing trend of vegetation covers over the period of 27 years.

DISCUSSION

The vegetation cover index of NDVI has been widely used to assess vegetation condition and productivity in different ecosystems (Atzberger, 2013; Jin *et al*., 2013; Lunetta *et al*., 2006; Tan *et al*., 2010). Our study aimed to evaluate the accuracy of NDVI in the estimation of vegetation cover in the semi-arid rangelands of western Iran. The obtained results of correlation between vegetation attributes and the index showed that there was a significant relationship between all of these components and the *NDVI* value. The highest correlation coefficient (0.84) was related to percentage of vegetation cover. Carreiras *et al.* (2006) demonstrated that NDVI vegetation index had a high ability to estimate the forest vegetation cover. *NDVI* value was highly correlated with the percentage of vegetation cover in the grasslands of western China (Barmas, 2013; Mokhtari *et al*., 2000; Zha *et al*., 2003). The NDVI is a ratio of red and infrared bands, and thus shows the highest correlation with the amount of coverage. Our results showed that the *NDVI* value had high accuracy in estimating the amount of vegetation covers in semi-arid rangelands. Furthermore, this index has shown a correlation of 80% with the biomass (Table. 1). Also, there was a high correlation between biomass and vegetation cover (0.88). Johansen and Tømmervik (2014) found a positive correlation between biomass and NDVI. In the current study, the changes of vegetation cover were detected by *NDVI* value during the period of 27 years. The results showed an increase of 32.2% in class 1 (very poor vegetation covers), while classes 4 and 5 (good and very good vegetation covers) decreased by about 27.8 and 37.7%, respectively. The overall results indicated a decline in the vegetation cover in the region. Tan *et al.* (2010) argued that the negative correlation of barren land with NDVI resulted from lower biomass and higher land surface temperature in this area.

Climatic Change

Climatic variables, e.g. precipitation and temperature, are the most important driving forces for vegetation cover changes (Ichii *et al.*, 2002; Sarkar and Kafatos, 2004; Lei and Peter, 2004; Zhou *et al.*, 2003). So, it is essential to investigate the precipitation and temperature changes of the study area.

A significant relationship was found between NDVI and annual precipitation

(Chenar, 2001). In our study, the trend of annual precipitation and temperature for 1986, 2001, and 2013 are shown in Figure 7. The amount of precipitation decreased during these periods of time. Annual temperature in 2001 increased in comparison to 1986, whereas it decreased during 2001-2013. These climate factors seem to be the important factors that influence the NDVI values. The results of our study are closely in line with those of Yang *et al.* (1998) who concluded a high correlation between NDVI and precipitation.

CONCLUSIONS

After finding a significant correlation between vegetation attributes (obtained from the ground data) and the NDVI (extracted from Landsat ETM+ 2013), the vegetation cover was detected successfully during 1986 to 2013 period. Of the vegetation attributes, vegetation cover and biomass had high correlations with NDVI, with the coefficients of 0.84 and 0.8, respectively. These results indicated that the *NDVI* value had a high accuracy in estimating the amount of the vegetation cover in semi-arid rangelands. The area of very poor vegetation cover (class 1) was changed progressively from 0.6% in 1986 to 32.8% in 2013; at the same time, the area of very good vegetation cover (class 5) decreased by about 37.7%.

Overall, in our study area, vegetation condition had a degrading trend in the period of 1986-2013. Climatic conditions in terms of precipitation and temperature have been recognized as the most important driving forces for vegetation cover changes. Climatic data analysis indicated a decreasing trend in precipitation, while temperature increased during this period of time. Our findings suggest that the vegetation cover has to be conserved, and also vegetation condition should be improved by proper techniques.

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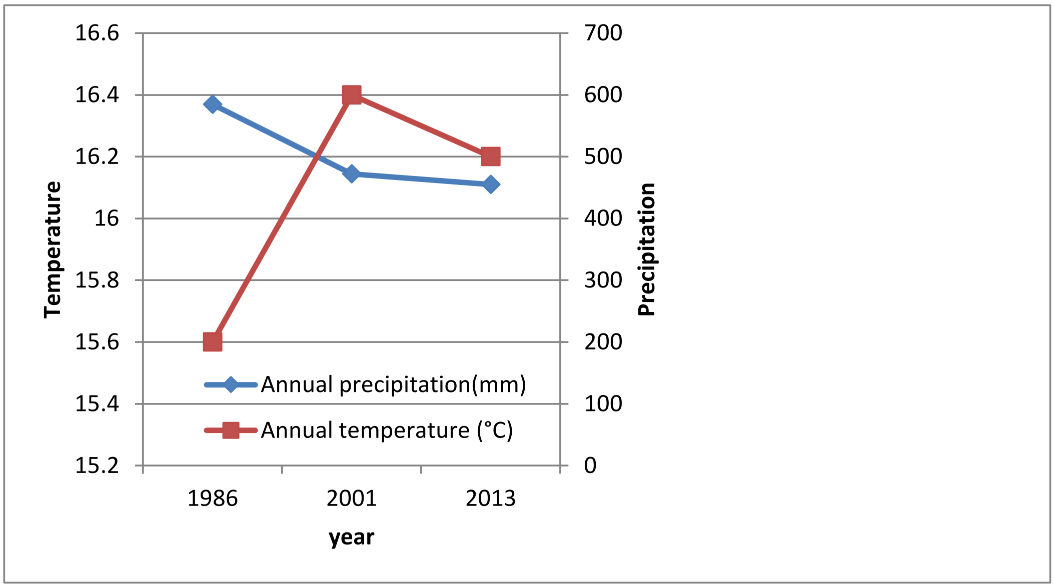

Figure 7. Annual precipitation and temperature in 1986, 2001, and 2013.

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بررسی تغییرات پوشش گیاهی در ارتباط با شاخص تفاضل پوشش گیاهی (NDVI) در مراتع نیمه خشک غرب ایران

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چکیده

هدف از این پژوهش، مطالعه ی رابطه ی شاخص NDVI با مؤلفه های مرتعی (درصد پوشش، خاک لخت، لاش و لاشبرگ، میزان بیومس) و سپس ارزیابی روند تغییرات پوشش با استفاده از شاخص NDVI، در مراتع نیمه خشک غرب ایران است. داده های زمینی به منظور ارزیابی صحت شاخص NDVI جمع آوری گردید. بدین منظور، ۱۴ واحد نمونه برداری برای جمع آوری مؤلفه های مرتعی شامل زیست توده، پوشش گیاهی، لاش و لاشبرگ و خاک لخت به صورت تصادفی انتخاب گردید. سپس، همبستگی بین ارزش های رقومی پیکسل ها با هر واحد نمونه برداری تجزیه و تحلیل گردید. نتایج نشان داد که شاخص NDVI همبستگی بالایی با مؤلفه های پوشش دارد. بیشترین میزان همبستگی مربوط به تراکم پوشش گیاهی بود (۰/۸۴). بنابراین، به منظور بررسی روند تغییرات، نقشه شاخص NDVI در سال های ۱۹۸۶، ۲۰۰۱ و ۲۰۱۳ تهیه شد. نتایج نشان داد که میزان اراضی کلاس ۱ (پوشش گیاهی خیلی ضعیف) از ۰/۲۷ کیلومتر مربع در سال ۱۹۸۶ به ۱۲/۸۹ کیلومتر مربع در سال ۲۰۱۳ افزایش پیدا کرده بود و همچنین مساحت اراضی کلاس ۴ و ۵ (پوشش گیاهی خوب و خیلی خوب) به ترتیب ۲۷/۸ و ۳۷/۸ درصد کاهش داشته اند. روابط بین دما و بارش با شاخص NDVI به منظور بررسی حساسیت این شاخص به این پارامترها مورد ارزیابی قرار گرفت. نتایج نشان داد که میزان بارندگی در طول دوره های زمانی مورد مطالعه، روند کاهشی داشته است. به نظر می رسد که این فاکتور، یکی از عوامل مهم تاثیرگذار بر کاهش میزان پوشش گیاهی منطقه مورد مطالعه بوده است.