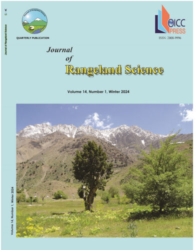

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Application of Land Measurements for Detection of Climate Change Impact on Vegetation Dynamics, Kermanshah Province, Iran

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Abstract:

Vegetation is an important component of terrestrial ecosystems whose changes are controlled by climate changes and human activities. In order to detect the climate change impact on vegetation dynamics of Kermanshah province, Iran, this study was conducted using multi-time images of NDVI and EVI regarded as vegetation indices taken by MODIS sensors. Also, the trend of changes in climatic parameters such as temperature and precipitation were used by Mann-Kendall test over 15 years (2006 – 2020). Finally, the correlation between vegetation and climatic parameters was examined. The result of 15-year changes in vegetation using two indicators of NDVI and EVI showed that the trend of vegetation in more than 59 % of Kermanshah province has been decreasing. The trend of precipitation in more than 88 % had decreased and the trend of temperature in the 98 % area had increased. The correlation between vegetation obtained from NDVI and EVI indices with the climatic parameter showed a positive correlation between precipitation and vegetation and a negative correlation between temperature and vegetation in more than 80 % and 59 % of this province, respectively. The results of the correlation analysis of different land-uses showed that in the barren lands and shrub lands, the positive correlations between precipitation and vegetation were stronger than the negative correlation between temperature and vegetation. In contrast, in grasslands and savannahs, the relationship between vegetation and temperature was stronger than that for precipitation. According to the results of this study, the climate changes and human activities are effective in controlling the trend of vegetation in different areas, which can be well demonstrated using the information obtained from remote sensing data.

Keywords: Climate change; Distribution pattern; Mann-Kendall; MODIS sensor; Vegetation

1. Introduction

Vegetation has a basic role in terrestrial ecosystems and is regarded as a link between the atmosphere, soil, and biosphere (Ekrami et al., 2021) while transferring materials and exchanging energy (Potter et al., 2008). Location and time changes of vegetation at various scales are considerably under the effect of climate changes (Cai et al., 2014; Li et al., 2019b). Understanding the effective mechanisms of plant ecosystem growth, monitoring time and location changes, evaluating vegetation quantitatively (Asadian et al., 2016) and plant effectiveness are necessary climate variables at regional and world scales (Rezai and Zerehi, 2022). Climate changes lead to the increased vegetation and a prolonged growing season in the damaged regions (Fouladi et al., 2020). As a result, climate changes and human activities are more likely to control the degradation and restoration of vegetation (Wang et al., 2015). Thus, understanding the reaction of terrestrial ecosystems to climate changes in fragile ecological zones contributes to develop consistent and

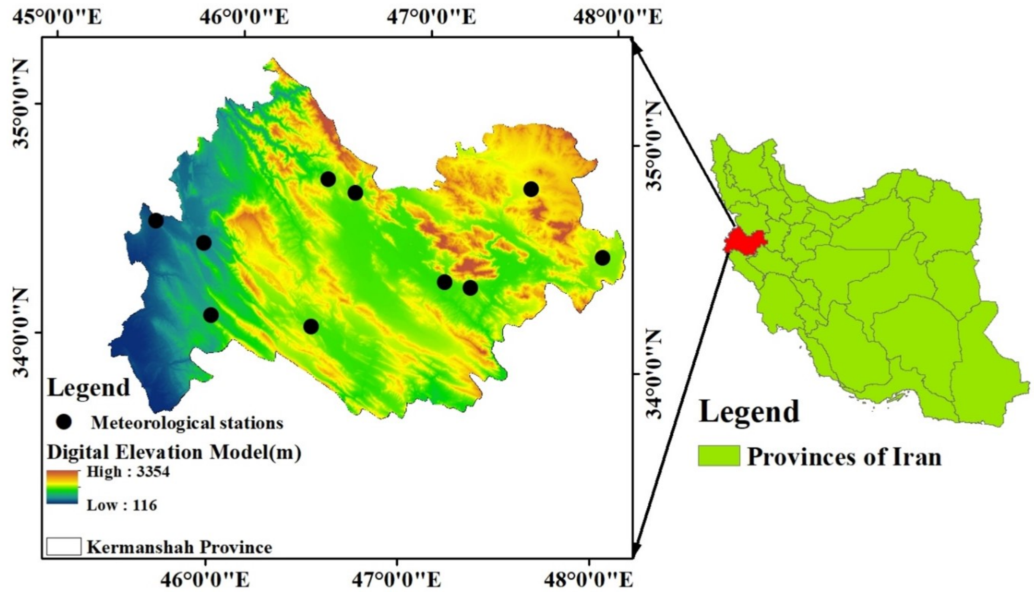

Figure 1. Map of Kermanshah province in Iran and the maps of Elevations and Meteorological stations in the province

stable strategies and policies for ecosystem management (Li et al., 2018). Therefore, vegetation has a critical role in regulating the world cycle of materials and exchanging energy as one of the key components of terrestrial ecosystems (Piao et al., 2011; Eskandari Damaneh et al., 2021b). Time and location changes and varieties in relation to the vegetation indicate the effectiveness of terrestrial biochemical processes (Piao et al., 2011). In this regard, monitoring the systematic dynamics of vegetation seems to be essential in order to understand biochemical processes and potential feedback related to climate cycles (Arneth et al., 2010). Consequently, the ability to predict vegetation consistency with future climate changes will be increased (Zhang et al., 2017; Zhao et al., 2017).

Remote sensing as an approach is highly efficient in monitoring the desired dynamics considering such features as wide area vegetation (Zerehi and Rezai, 2022), long-term time series data, and suitable, timely and available time and location separation. Plant index has been resulted from the spectral difference of two or more bands, which are achieved by remote sensing data (Huete et al., 2002); it can be used as a strong and simple criterion to describe the photosynthetic activity of vegetation and the structural variety of canopy cover (Rezai, 2020). One of the most effective ways to monitor and describe the ground surface dynamics and analyze the time series of vegetation is to use vegetation indices including the enhanced vegetation index (EVI) and the normalized difference vegetation index (NDVI) (Eskandari Damaneh et al., 2021a). These two indices have been used as strong tools for investigating the ecosystem's degradation and health using information obtained by the reflection difference and infrared and red band spectral absorption (Gurung et al., 2009; Qu et al., 2020). Many studies have used satellite data to investigate the trend of vegetation changes and relationships with climate elements (Zou et al., 2020). In this regard, studies have indicated that growth dynamics of vegetation during 1982 – 2011 in central and southern China were of a considerable positive increasing trend (Xu et al., 2014), and a positive correction has been observed between temperature and vegetation in the north-eastern region of Guangdong province (Wang et al., 2015). However, few studies focused on the relationships between vegetation products and climate variables such as temperature, precipitation, and solar radiation (Li et al., 2019a). In this respect, Wu et al. (2015) found that delay time duration is different among different types of vegetation. Then, they pointed out that delayed monthly precipitation is effective in vegetation growth in the agroecological region. It is obvious that the relationship between vegetation and climate elements indicates significant time and location heterogeneities. Vegetation changes in the Alps match the temperature variations during 2000 – 2016; also, the effect of altitude changes has been positive on vegetation growth and the temperature has been regarded as one of the main determinants in terms of vegetation (Knapp et al., 2015). This effect is most obvious in cold regions (Prevéy et al., 2017). In addition, the studies indicated that the impact of such climate variables changes as temperature and precipitation is more obvious in the highlands (Pepin et al., 2015; Prevéy et al., 2017). However, the relationship between vegetation and climate change has not been addressed completely. Therefore, the current study aims to investigate the vegetation changes trend in Kermanshah province, Iran and the relationship between vegetation changes and climate variables including precipitation and temperature during 2006 – 2020.

2. Materials and methods

2.1 Study area

Kermanshah province with an area of 24,434 km^2 is located at northern latitude of 33°41′ to 35°17′ and eastern longitude of 45°24′ to 48°6′ in the west of Iran (Fig. 1). Mean precipitation is almost 445 mm and mean temperature is

Table 1. Satellite and climatic data

Data	Spatial separation power	Time periods	Sources
MOD13A2	1,000 m	2006 – 2020	https://lpdaacsvc.cr.usgs.gov/
MCD12Q1	500 m	2006 – 2020	https://lpdaacsvc.cr.usgs.gov/
Precipitation		2006 – 2020	https://data.irimo.ir/
Temperature		2006 – 2020	https://data.irimo.ir/
Digital Elevation Model	30 m		https://lpdaacsvc.cr.usgs.gov/

almost 14.3 °C. The minimum and maximum height is approximately 116 and 3,354 m above sea level (Nemati Paykani and Jalilian, 2012; Karam et al., 2014).

2.2 Research methodology

2.2.1 Satellite data and processing

In this research, two indices of NDVI and EVI were prepared by MODIS sensors MOD13A3 to investigate monthly vegetation changes trend with spatial separation of 1 km (see https://lpdaacsvc.cr.usgs.gov/). Data related to annual precipitation and temperature have been taken from monthly precipitation data in Kermanshah province on the website of the Iranian Meteorology Organization (https://data.irimo.ir/) during 2006 – 2020. Details related to the desired data have been presented in Table 1.

In this paper, to prepare and classify the maps of vegetation images, ArcMap v.10.8 and ENV15.3 software were used. After drawing the desired maps, all the images were cut at the border of Kermanshah province, and the images were analyzed by the desired software. MODIS sensors MCD12Q1 with a resolution of 500 m were used to investigate land use and vegetation changes.

2.2.2 Climatic data

Climatic data of temperature and precipitation in the monthly time frame for 10 stations in the study area (Fig. 1) that had a common time base and suitable dispersion were prepared from the Iranian Meteorological website for the years 2006 – 2020. Then, using the IDW interpolation method, temperature and precipitation raster maps were prepared in ArcGIS 10.8 software.

2.2.3 Vegetation indices

Two vegetation indices including NDVI (equation 1) and EVI (equation 2) were considered to monitor the vegetation changes based on blue (B) and red bands and near infrared (NIR) and the amounts of G and L are given as 2.5 and 0.5, respectively (Qu et al., 2020; Eskandari Damaneh et al., 2020) in Table 2.

2.2.4 Annual means of climate parameters and vegetation

To compute the annual mean, the monthly means of time series were used during 2006 – 2020. The equation (3) has been used for the computation of every 15-year pixel means;

$$MI = \frac{1}{n}\sum_{1}^{2} Mm \tag{3}$$

Where:
MI refers to the arithmetic mean,
n is the number of years and
Mm demonstrates the monthly mean.

To compute the annual changes trend of climate parameters and vegetation indices in the case study, Mann-Kendall test was conducted and the achieved statistic has been computed by the equations (4–7).

$$S = \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \operatorname{sgn}(x_j - x_i) \tag{4}$$

Where:
S is the statistic of Mann-Kendall test,
x_i is the value of ith data,
n is the number of data and
$\operatorname{sgn}(x_j - x_i)$ refers to the sign function, which is computed by the equation (5).

$$\operatorname{sgn}(x_j - x_i) = \begin{cases} +1 & if \quad (x_j - x_i) > 0 \\ 0 & if \quad (x_j - x_i) = 0 \\ -1 & if \quad (x_j - x_i) < 0 \end{cases} \tag{5}$$

Mann-Kendall statistic variance is computed by the equation

Table 2. Research Vegetation indices

Vegetation indices	Equation		Sources
NDVI	$\mathrm{NDVI} = \dfrac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}}$	(1)	https://lpdaacsvc.cr.usgs.gov/
EVI	$\mathrm{EVI} = \mathrm{G} \times \dfrac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{L} + \mathrm{NIR} + 6 \times \mathrm{RED} - 7.5 - \mathrm{B}}$	(2)	https://lpdaacsvc.cr.usgs.gov/

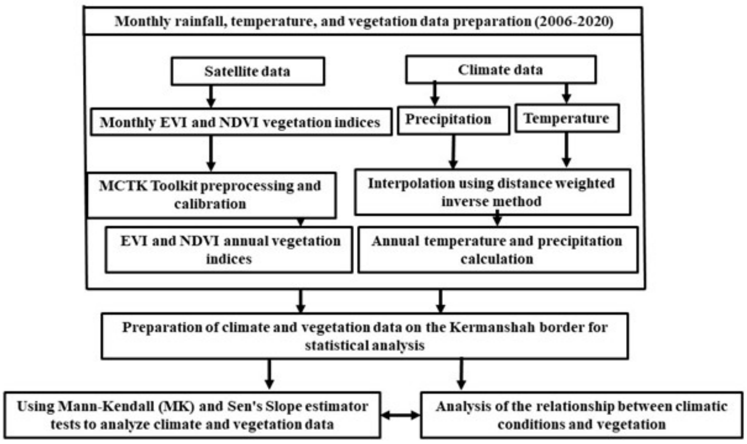

Figure 2. Flowchart of study steps

(6).

$$\mathrm{Var}(S) = \frac{1}{18}\left[N(N-1)(2N+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t+5)\right] \tag{6}$$

Where:
N is the number of observational data,
m is the number of sequences,
t_i is the number of sequences for the ith value and
t refers to the amounts of sequences.

The second component in the above-mentioned equation is an adjustment for the sequence or sensitive data. The standardized statistic of Z test is achieved by the equation (7).

$$Z = \begin{cases} (S-1)/\sqrt{\mathrm{Var}(S)} & if \quad S>0 \\ 0 & if \quad S=0 \\ (S+1)/\sqrt{\mathrm{Var}(S)} & if \quad S<0 \end{cases} \tag{7}$$

The positive and negative values of Z demonstrate the increasing and decreasing trend of time series.

2.2.5 Correlation between vegetation indices and climate parameters

To investigate the effectiveness of climate parameters on vegetation, the relationship between NDVI, EVI and climate indices including temperature and precipitation was used (Pei et al., 2019). In Fig. 2, we show the steps of the current study in brief.

3. Results

3.1 Land use and land cover

The survey of land use in Kermanshah province using the Modis meter showed that there were 6 major land uses in this area as shown in Fig. 3, which include Built-Up, Bare lands, Agricultural, Grasslands, Shrub lands, and Savannas, which covered about 0.47, 1.79, 24.41, 48.47, 24.58, and 0.01 %, the area of the province, respectively.

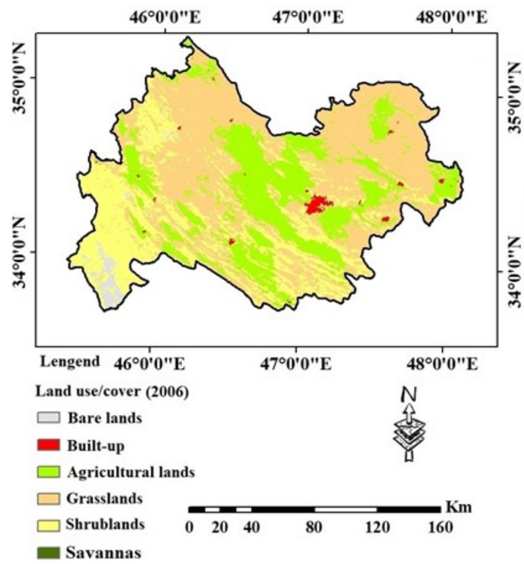

Figure 3. Land use and land cover map of Kermanshah province in 2006

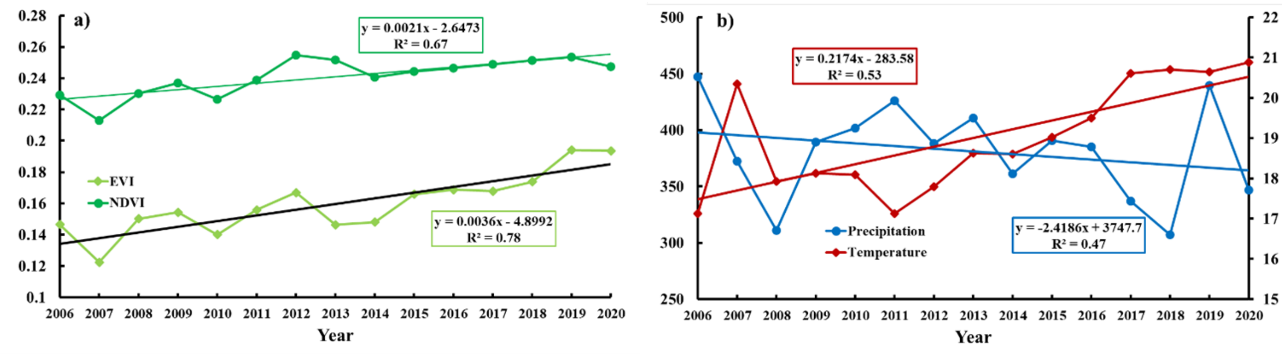

Figure 4. a) Time variations trend of two vegetation indices over 2006 – 2020. b) Time variations trend of precipitation and temperature over 2016 – 2020

3.2 Trends of vegetation indices and trends of climate parameters during 2006 – 2020

Trends of NDVI and EVI vegetation indices during 2006 – 2020 are presented in Fig. 4a, it has been indicated that the values of the two indices were increasing over years with the slopes of 0.002 and 0.003, respectively, with range of EVI given as 0.122 and 0.194 related to the years 2007 and 2019. For NDVI, the maximum and minimum amounts were 0.212 and 0.254 for the years 2012 and 2019, respectively.

Based on Fig. 4b, the trend of precipitation and temperature variations was decreasing and increasing with slopes of −2.42 and 0.21 over 15-year period. Furthermore, the maximum and minimum precipitation estimated as 447.43 and 307.21 mm was related to the years 2006 and 2018, respectively; on the other hand, the minimum and maximum amounts of temperature were estimated as 17.11 and 20.89 °C for the years 2006 and 2020, respectively.

3.3 Classification of province area based on vegetation indices and climate parameters

Investigating the location changes of vegetation indices including NDVI and EVI demonstrated the lowest values in northeastern, southwestern and western regions and the highest ones in northern and northwestern regions in Kermanshah province (Figs. 5 & 6).

The highest amounts of precipitation were related to the least temperature in central and northern regions and the least precipitation was related to the maximum temperature mainly in the western and southwestern areas (Figs. 7 & 8).

3.4 Impact of climate changes on the spatiotemporal evolution of vegetation indices

Investigating the trend of vegetation indices and climate parameters (precipitation and temperature) over 2006 – 2020 is presented in Fig. 9. According to Fig. 9a, the trend of variation of NDVI was decreasing up to 62.86 area; almost 34.88 % was significant while approximately 37.14 % of the province area had an increasing index with 8.46 % significance.

The trend of variation of EVI index (Fig. 9b) showed that the index was decreasing up to 59.72 % of the area and 28.06 % was significant. Moreover, the index increased to 40.28 % of the area and almost 12.74 % was significant.

Investigating the trend of precipitation variations in Fig. 9c indicated that the precipitation was decreasing at

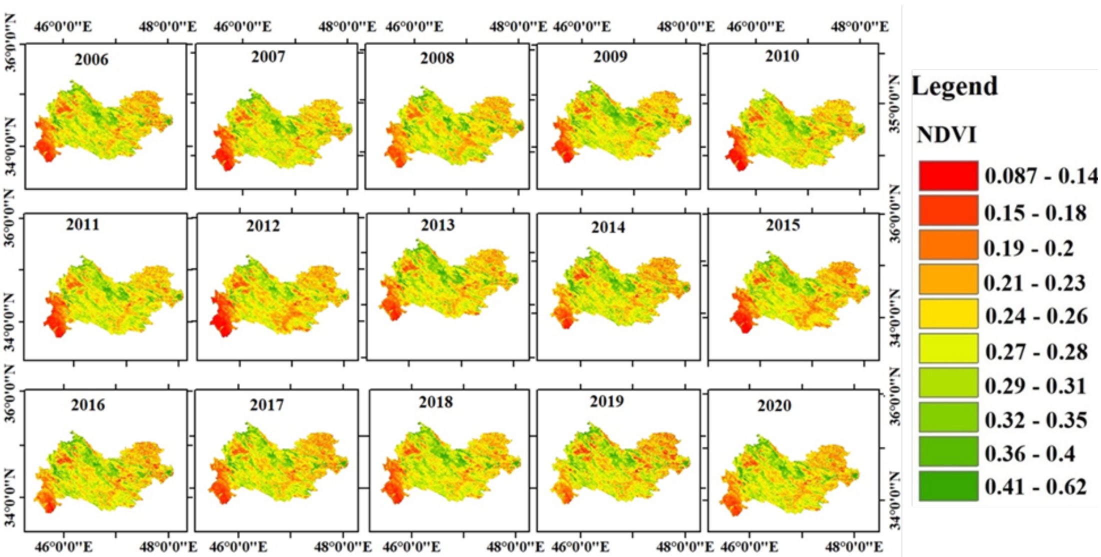

Figure 5. Spatial variations of NDVI during 2006 – 2020

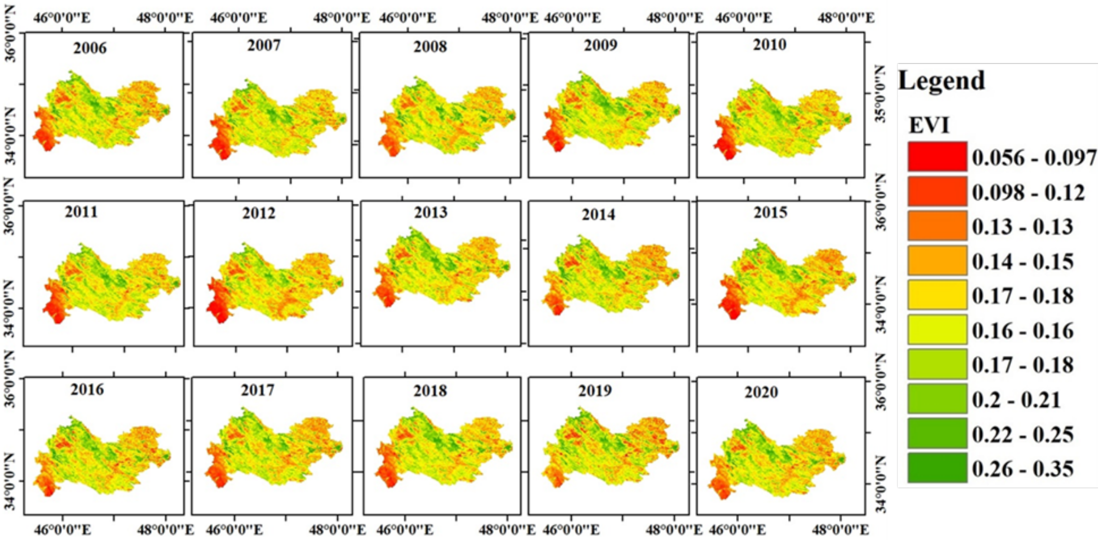

Figure 6. Spatial variations of EVI during 2006 – 2020

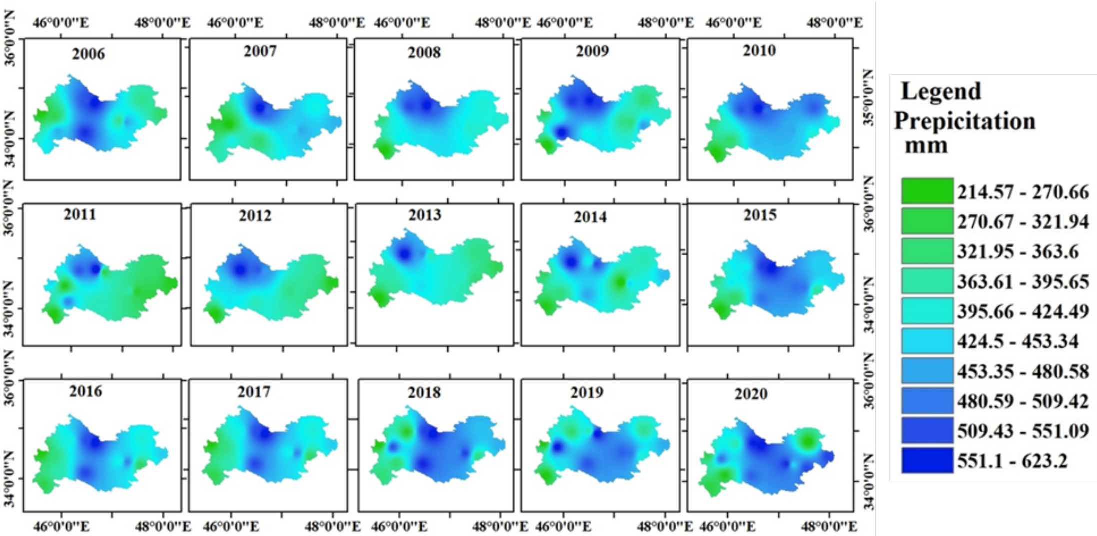

Figure 7. Spatial variation of precipitation in 2006 – 2020

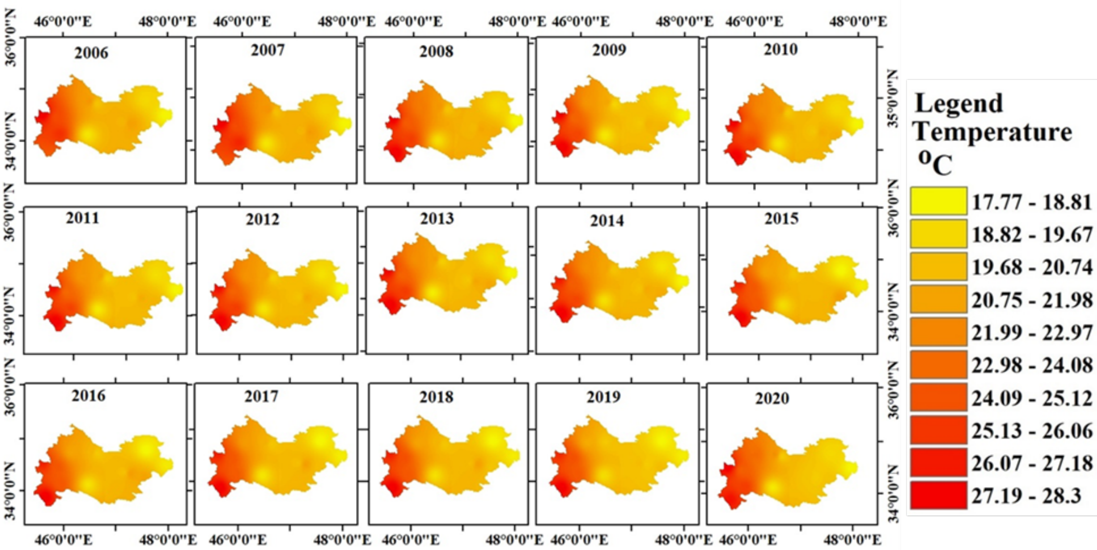

Figure 8. Spatial variation of temperature in 2006 – 2020

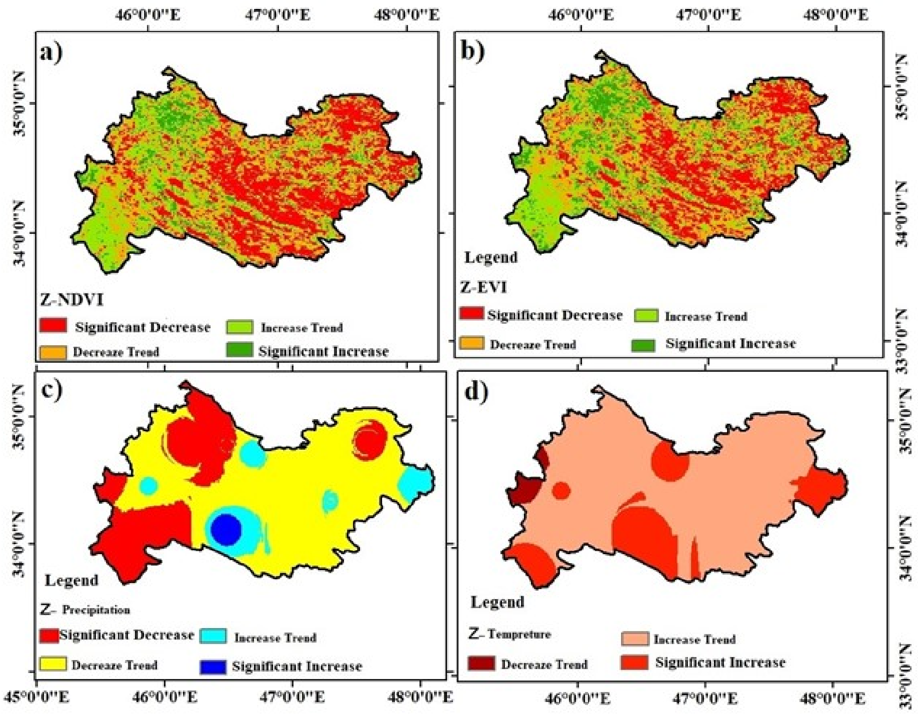

Figure 9. Trend of NDVI, EVI, precipitation and temperature in a, b, c and d, respectively, during 2006 – 2020

88.84 % area and the 27.33 % was significant. The precipitation increased at 11.16 % of the area and almost 1.95 % was significant.

The trend of temperature variations in Fig. 9d indicated that almost 97.67 % of the area was increasing and approximately 20.31 % was significant. As well, 2.33 % of the area was of decreasing temperature.

3.5 Correlation between vegetation indices and climate parameters

The correlation between EVI and NDVI indices and both temperature and precipitation are presented in Figs. 10 & 11. The correlation between the EVI and precipitation was positive with value of 81.52 % of areas in the province and 11.48 % of the total value was significant. Also, the correlation between EVI and precipitation was negative at 18.48 % of the total area and 12.85 % of the total value was significant (Fig. 10a). The correlation between EVI and

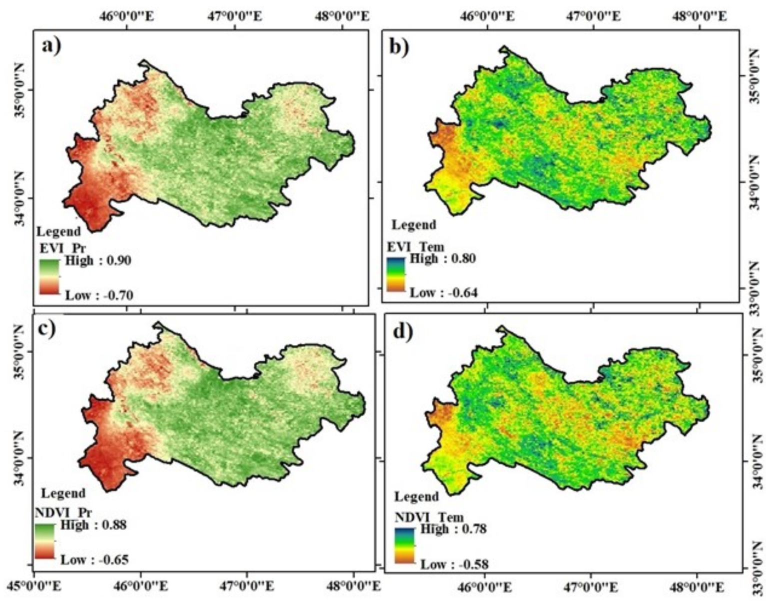

Figure 10. Correlation between EVI vs. precipitation and temperature (Fig a and b), Correlation between NDVI vs. precipitation and temperature (Fig c and d)

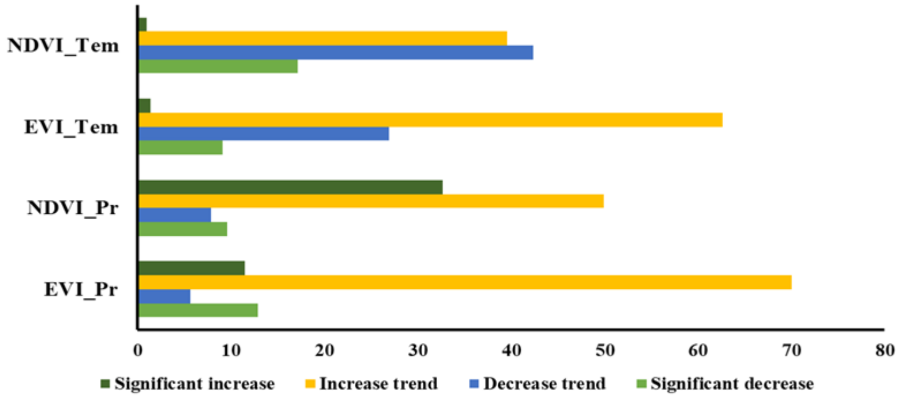

Figure 11. Correlation between NDVI and EVI with precipitation (Pr) and temperature (Tem).

temperature was positive at 63.99 % of the total area and 1.37 % of the total value was significant (Fig. 10b and 11).

The correlation between NDVI and precipitation was positive at 82.59 % of the total area and 32.70 % of it was significant; moreover, the correlation between NDVI and precipitation was negative at 17.41 % of the total area 9.57 % of the total value was significant (Fig. 10c and 11). The correlation between NDVI and temperature was positive at 40.48 % of the total area and 0.95 % of the total value was significant whereas the correlation between NDVI and temperature was negative at 59.52 % of the area and 17.19 % of the total value was significant (Figs. 10d and 11).

3.6 The relative contribution of climate change to vegetation in different land uses

The correlation between NDVI and EVI indices vs. both precipitation and temperature in different land uses are presented in Table 3.

For Barren land use, there were positive correlations between both NDVI and EVI indices with precipitation with values of 93.45 and 91.82 % of the region, respectively, and about 84.78 and 89.20 % of these values were significant. While there were negative relationships between both indices with precipitation and the decreasing values of 6.55 % and 8.18 %, respectively, the values of 0.16 % and 0.16 % were significant.

The correlation between both NDVI and EVI indices with temperature in this land use were negative with val-

Table 3. Relationship between NDVI and EVI and precipitation and temperature in different land uses

Land use	Trends	NDVI		EVI	
		Precipitation	Temperature	Precipitation	Temperature
Barren land	Significant increase	84.78	0.16	89.20	48.45
	Increase trend	8.67	16.69	2.62	0.00
	Decrease trend	6.38	80.03	8.02	50.90
	Significant decrease	0.16	3.11	0.16	0.65
Agricultural lands	Significant increase	44.65	0.29	15.95	8.28
	Increase trend	50.32	31.69	77.19	29.71
	Decrease trend	3.60	43.95	3.64	60.99
	Significant decrease	1.43	24.07	3.22	1.02
Grasslands	Significant increase	32.60	1.44	11.79	5.86
	Increase trend	57.91	44.64	77.04	22.20
	Decrease trend	7.09	39.88	5.81	70.05
	Significant decrease	2.40	14.04	5.37	1.88
Shrublands	Significant increase	23.11	0.48	7.19	16.96
	Increase trend	36.23	38.57	52.93	32.33
	Decrease trend	13.64	43.33	7.98	50.04
	Significant decrease	27.02	17.63	31.90	0.68

ues of 83.14 and 51.55 %, respectively and about 3.11 and 0.65 % of them were significant. Also, there were positive correlations of 16.86 and 48.45 % between both indices and temperature; the values of 0.16 % and 0.16 % were significant.

The correlations between vegetation indices of NDVI and EVI with precipitation in agricultural land use were positive with the values of 94.96 and 93.14 %, respectively, of which 44.65 and 15.95 % were significant. Meanwhile, the relationship between NDVI and EVI indices with precipitation was negative in 5.04 and 6.86 % of this region, of which 1.43 and 3.64 % were significant.

The correlations between NDVI and EVI indices with temperature in this land were negative with the values of 68.02 and 62.01 % of the area, respectively; the values of 24.07 and 1.02 % were significant. Also, positive correlations were observed between both indices and temperature with the values of 31.98 and 37.99 %, respectively, of which 0.29 and 8.28 % were significant.

The positive correlations were observed between vegetation indices NDVI and EVI with precipitation in grassland use with the values of 90.51 and 88.83 % of the region, respectively and about 32.60 and 11.79 % were significant. Meanwhile, negative relationships were observed between these indices with the values of 9.49 and 11.17 % of this region, of which 2.40 and 5.37 % were significant.

The negative relationships between NDVI and EVI indices with temperature were observed in this land use with the values of 53.92 and 71.94 %, respectively, of which 14.04 and 1.88 % were significant. Also, positive correlations were observed between indices and temperature with the values 46.08 and 28.06 %, respectively, of which 1.44 and 5.86 % were significant.

The correlations between vegetation indices NDVI and EVI with precipitation in Shrub lands use were positive with the values of 59.34 and 60.12 %, respectively and of these values, about 23.11 and 7.19 % were significant.

There were negative relationships between indices and precipitation with the values of 40.66 and 39.88 %, respectively, which 27.02 and 31.90 % were significant. The correlations between NDVI and EVI index with temperature were negative with values 60.95 and 50.72 % and about 17.63 and 0.68 % are significant. Also, the correlations between NDVI and EVI index and temperature were positive with the values of 39.05 and 49.28 %, respectively, of which about 0.48 and 16.96 % were significant.

In savannah, the correlation between NDVI, EVI and rainfall was positive for all the land uses while the correlation between vegetation indices and the temperature was negative.

4. Discussion and conclusion

Vegetation as one of the main terrestrial ecosystem components plays an important role in regulating the world cycle of materials and the exchange of energy (Askarizadeh and Arzani, 2018). Therefore, in this study, to exactly evaluate the vegetation of Kermanshah province, multi-time images of NDVI and EVI achieved by MODIS sensors have been applied and also, the variations of climate parameters such as temperature and precipitation have been addressed using Mann-Kendall test during 2006 – 2020. Finally, the correlation between vegetation and climate parameters has been regarded.

Investigating the trend of 15-year vegetation variations using two desired indices indicated that the vegetation has been decreasing in more than 95 % of the total area. The decreasing trend of vegetation can be caused by human elements including land use changes from natural grasslands, shrublands, etc. into agricultural ones (Shabanipoor et al., 2019). A study conducted by Emadodin et al. (2020) demonstrated that the population growth in Kermanshah province has increased and land use changes have been done to supply food and housing. Other elements were the livestock imbalance and early livestock entrance to jungles and rangelands (Ggeitury et al., 2007). On the other hand, the results indicated that the increasing trend of vegetation has been observed in more than 37 % of the total area. According to the results reported by Bai (2021), the increase can be led by the increased changes of natural lands such as rangelands and jungles into agricultural ones as well as protection activities such as enclosure and tree planting. Results have shown that the trend of precipitation variations is decreasing at 88 % of the total area while the temperature has been increased in 98 % of the total area in Kermanshah province. Saymohammadi et al. (2017) stated that the increasing trend of temperature and the decreasing trend of precipitation had been observed while reviewing the observational climate data and the desired model and the trends will be repeated in future. Investigating the correlation between vegetation indices including NDVI and EVI and climate parameters such as precipitation indicated that vegetation and precipitation are correlated positively at 80 % of the total area but the vegetation is negatively related to temperature at 59 % of the area in Kermanshah province. Karimi et al. (2018) studied the trend of vegetation variations in Kermanshah province and pointed out that the vegetation is decreasing in the case study, which has been caused by the decreased precipitation and the increased temperature as well as several droughts in the region. Investigating the impact of climate parameters on vegetation in a variety of land uses demonstrated that the impact varies in various land uses. According to the results, in barren lands and shrublands, there is a strong correlation between precipitation and vegetation as compared to the temperature while the relationship between vegetation and temperature is stronger in grasslands and savannah. Mo et al. (2019) stated that in dry and semi dry regions, the main controlling element of vegetation is precipitation whereas temperature is a limiting factor to the plant's growth. Kim et al. (2021) in a study concluded that in the highlands, the temperature is more effective than precipitation. Considering the results, it can be concluded that climate variations and human activities may control the trend of vegetation expansion in a variety of regions and its impact can be shown using remote sensing information and data. Human activities and climate change playing a major role in vegetation growth are promoted. Good hydrothermal conditions play a crucial role in vegetation growth. Studies have shown that climate warming prolongs the growth period of vegetation, which promotes vegetation growth (Ren et al., 2022).

It was concluded that estimating and analyzing the trend of EVI and NDVI changes and their relationship with climatic factors can provide researchers with a set of valuable information about the mechanisms of terrestrial ecosystems, which can be obtained by analyzing the relationship between vegetation and climate changes. Different ecosystems can be examined properly. The long-term study of natural and human factors provides the basis for studying the temporal and spatial changes in vegetation cover. Climatic factors such as long-term droughts and increasing temperatures may increase the destruction of natural and artificial vegetation in different regions. According to the existing limitations, the framework presented in this study can be used in the overall evaluation and identification of ecosystem changes and their creating potential in wide geographical scales. Since changes in vegetation and effective ecosystems are controlled by multiple biophysical processes and socioeconomic factors, it is suggested that other effective factors in estimating vegetation such as the CO_2 cycle, soil conditions factors, and changes in solar radiation, which were not studied in this study, should be considered. We suggest to use satellite data with better spatial and temporal resolution such as Landsat and Sentinel satellite data to estimate the vegetation cover of the study area and then, to evaluate its changes with other climatic factors.

Ethical approval:
This manuscript does not report on or involve the use of any animal or human data or tissue. So the ethical approval does not applicable.

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Authors Contributions:
All authors have contributed equally to prepare the paper.

Availability of data and materials:
The data that support the findings of this study are available on request from the corresponding author.

Conflict of Interests:
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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