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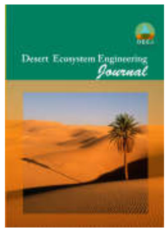

The Effect of Climate Fluctuations on Vegetation Dynamics in West and Northwest of Iran

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Abstract

Vegetation plays an essential role in the ecosystem that its change will alter the ecosystem. This research tried to study temperature and precipitation fluctuations on vegetation conditions in the west and northwest of Iran. For this purpose, the NDVI was determined for June from 2000 to 2016.based on the MOD13Q1 production of the MODIS satellite. Initially, using mean annual temperature and total annual precipitation of 49 stations in the study area, rainfall and temperature maps were prepared in ArcGIS 10.5 software each year and then categorized into five classes by the natural break method. The correlation coefficient was calculated using Pearson correlation between NDVI map with temperature and precipitation maps in the next step. Finally, the correlation was investigated in different temperature and precipitation classes. The results showed that the highest NDVI mean correlation with temperature and precipitation occurred in 8-12 °C with a value of 0.36 and 213-300 mm classes with a value of 0.38, respectively. According to this issue, the northern parts of the study area have a lower temperature, and precipitation responds to climate fluctuations more than other sites. Studying climate fluctuations is recommended for assessing better the temporal and spatial vegetation dynamics. Exploring the human activity's impacts on vegetation changes is proposed to realize vegetation's temporal and spatial dynamics to manage vegetation cover and prevent its degradation.

Keywords: Temperature, Precipitation, NDVI, Correlation Coefficient, Interpolation.

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1. Introduction

One of the main indices for assessing interactions between climate and various ecosystems is vegetation activity (Li et al., 2015). Vegetation dynamics are changeable and climatic factors including precipitation and temperature can affect vegetation growth by influencing seasonal vegetation dynamics (Zhu et al. 2019). These days several models have been developed to evaluate the effect of climate on the vegetation cover.

The results of most predictions of climate change models show that significant changes of spatial and temporal in precipitation and temperature occur worldwide (Hoerling et al., 2012; Behrang Manesh, 2019). So that dry and wet areas in precipitation terms will have been more drought and wetter, respectively. Both of them will have been warmer (Yu et al., 2003; Lioubimtseva et al., 2005; Ndayisaba et al., 2016; Heydari Alamdarloo, 2018).

Although all of the earth's ecosystems are vulnerable to changes in climate (Allen et al., 2010), in drylands, the adverse effects of climate change are much higher (Gregory et al., 2005). Vegetation in dryland ecosystems plays a significant role (Lioubimtseva, 2014), and living organisms' lives depend on them (Tong et al., 2016). On the other hand, vegetation is a direct indicator of the ecosystem's condition and displays local and global environmental changes (Potter et al., 2008).

In each ecosystem, the vegetation cover is very delicate and unstable (De Graff 2018). Generally, vegetation changes are considered as a footprint of climate change and provide an excellent opportunity for studying the climate change effects on the ecosystem in terms of time, location, or both of them (Huntley & Webb., 1988; Whitlock Bartlein, 1997; Bao et al., 2015). It is essential to understand vegetation dynamics and the climate for proper ecosystem management (Zhang et al. 2020). Therefore, studying the relationship between vegetation dynamics and climate change is a significant issue in global change research (Du, 2016; Khosravi et al., 2017b). Measuring and estimating vegetation is very important in studies of vegetation changes. In traditional and field measurements, in addition to time-consuming and cost-effective, obtaining the continuous spatial distribution of vegetation data is difficult (Tong, 2016). One of the best ways to study vegetation changes is utilization of vegetation indices using remote sensing.

Normalized Difference Vegetation Index (NDVI) used to measure plant greenness is one of the best indicators for studying plant growth time changes (Khosravi et al., 2017a; Du, 2016). This index has been widely used since the 1980s to examine the effect of climate change on the global (Potter and Brooks, 1998; Nemani et al., 2003); and regional scale vegetation (Piao et al., 2006). In dry areas, there is a high correlation between precipitation and NDVI, but the interaction between temperature and NDVI is weak and significant (Wang et al., 2001; Li et al., 2004).

Several studies have been done to monitor vegetation changes using the NDVI and its relationship with climatic elements.

Yang et al. (2011) examined the spatial distribution and vegetation dynamics in the Yangtze and Yellow River basins and analyzed the correlation between temperature, precipitation, ground temperature, and NDVI. In this study, the main factor influencing the NDVI was the average temperature.

Hou et al. (2011) examined the relationship between the vegetation dynamics and climatic factors in the natural reserve of a Mountain in China. The effect of climate change on vegetation growth showed that temperature as an indicator of vegetation sensitivity in the study area should be used. Qu et al. (2015) examined the spatial and temporal variations in vegetation cover and factors affecting it during the growing season in China using the NDVI for 1982-2011. They determined that vegetation has a positive trend in the growing season in this region, but the relationship between climate parameters and vegetation is complex and time-consuming.

Jiang et al. (2017) investigated climate change and human activities on the vegetation dynamics in Central Asian regions. In this study, they used the NDVI to study vegetation changes during 1984-2013 and concluded that precipitation and its fluctuation in the vast areas of the study area are the main factors in the growth of vegetation.

Tang et al. (2017) was found the relationship between the NDVI and temperature and precipitation parameters to study the temporal and spatial variations of vegetation in the upper regions of the Shiyang River Basin in China. They found that the climate change effects on plant growth with vegetation types vary in different seasons, and precipitation is a more important factor than temperature affecting annual vegetation variations.

Recently, researches have generally been done on the effect of fluctuations of parameters on climate. Still, in Iran, any comprehensive and accurate spatially analysis has not yet been done, and the researches mostly have been done based on small areas.

In the west and northwest of Iran, dry farming is the most significant activity of inhabitants. Thus, the efficiency of agricultural production and the inhabitant's economy depends on the rainfall. Therefore, this research investigates climate factors (temperature and precipitation) on the vegetation dynamics in this part of Iran.

2. Material and method

2.1. Study Area

The studied area is located from west to northwest of Iran in the range of 32-40 degrees north latitude and 44-51 degrees east longitude, and including ten provinces named Ardabil, East Azerbaijan, West Azerbaijan, Hamedan, Kurdistan, Ilam, Kermanshah, Lorestan, Zanjan, and Qazvin (Fig. 1). There are many climates in Iran, mainly due to the Alborz and Zagros mountains (Nouri et al., 2017). Rainfall masses enter Iran, especially from the west and northwest, and due to the geographic location of the Zagros Mountains, rainfall increases from northwest to west of Iran (Sadeghi et al., 2002). As a result, the semi-arid Mediterranean climate is dominant in the west and northwest of Iran (Nouri et al., 2017). Due to this issue, this area is very rich in vegetation. The minimum height is 14 meters, and the maximum height is 4788 meters above sea level.

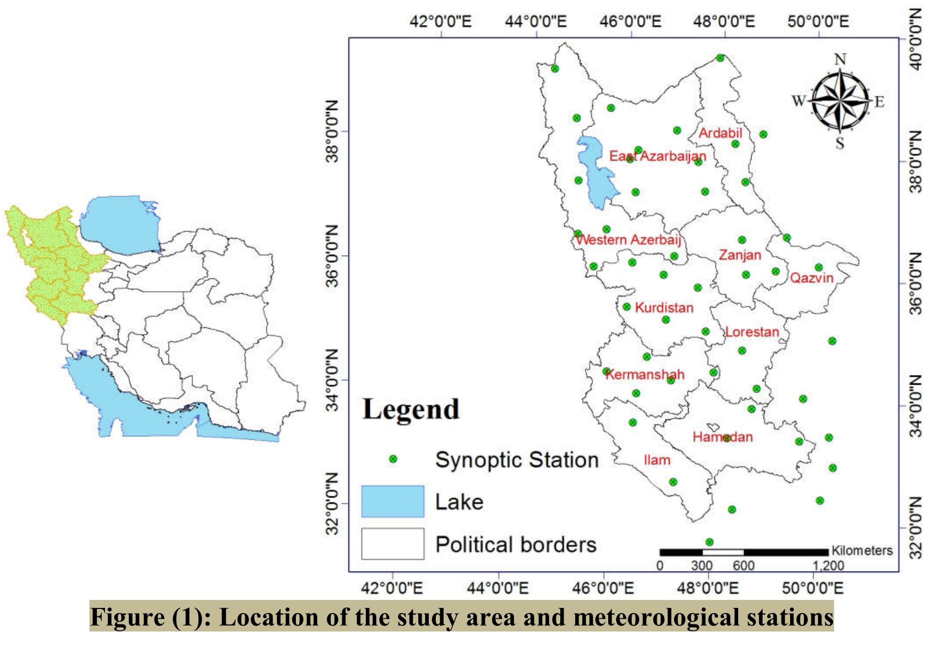

Figure (1): Location of the study area and meteorological stations

2.2. Methodology

In this research, the MOD13Q1 was used to investigate temporal and spatial variations of vegetation. This product has 12 layers of information with a 250 meters spatial resolution. The Normalized Differential Vegetation Index (NDVI) is one of them. The MODIS NDVI product masked for water, heavy aerosols, clouds, and cloud shadows is computed from atmospherically corrected bi-directional surface reflectance. The NDVI is one of the most popular vegetation indices used in many research and satellite surveys to determine the severity and weakness of vegetation (Pôças et al., 2013). The vegetation cover of late spring and early summer was selected in this research. Therefore, the MOD13Q1 product was used on the 25th of June every year from 2000 to 2016.

Also, to investigate the climate fluctuations, the total precipitation and average annual temperature of 49 synoptic stations were used from 2000 to 2016 (Fig. 1), located around the study area. Then, ARC GIS 10.5 software was used for both parameters of temperature and precipitation in each year for interpolation using the co-kriging method. The co-kriging method is a modified kriging method. The general advantage of co-kriging is that it can use more than one variable instead of using only one variable in the estimation process (Adhikary et al., 2017). In the co-kriging method, for increasing accuracy, the interpolation is performed using a second variable associated with the primary variable (Isaaks & Srivastava, 1988). Height is a crucial indicator of precipitation and temperature. Therefore, in this study, rainfall and temperature are the initial variables, and height is the second variable.

It should be noted that the size of the pixels in the maps is 250 m × 250 m (as in NDVI data). After the interpolation, using the temperature and precipitation maps of the study period (2000-2016), the average temperature and average precipitation maps were obtained. Then, the studied period's average temperature and precipitation maps were classified into five classes using the natural break method (Jenks, 1977). This method attempts to minimize the variance between data in each class and maximize the variance between classes based on a computational algorithm. This algorithm uses the average of each range to create the classes to ensure that the distribution of data over each range is more uniform (Jenks, 1977). In the next step, the correlation between vegetation maps and temperature and precipitation maps was calculated using the equation of Pearson correlation (Eq. 1) (Lee Rodgers & Nicewander, 1988) and ArcGIS 10.5 software.

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \qquad (1)$$

Where r is the Pearson correlation coefficient, x_i is the NDVI map for the year and $\bar{x}$ is the average map of the NDVI for the study period. y_i is the maps of temperature and precipitation for the same year and $\bar{y}$ is the mean of these parameters. Pearson's correlation coefficient, also called torque correlation coefficient or zero-order correlation coefficient, is introduced by Carl Pearson. This coefficient is used to determine the relationship between the type and the direction, the relationship between two distances or relative variables, or a distance variable and a relative variable. Evans (1996) presented the following classification for Pearson's correlation (Tab. 1).

Correlation coefficients were obtained according to Evans (1996) and in the ARC GIS software. Finally, the average correlation coefficient between vegetation with temperature and precipitation in different classes was calculated. The methodology is summarized in Fig 2.

Table (1): Classification of Pearson Correlation Coefficient (Evans, 1996)

Class	r	Class	r
Very Weak Positive Correlation	0 - 0.2	Very Weak Negative Correlation	0 - -0.2
Weak Positive Correlation	0.2 - 0.4	Weak Negative Correlation	-0.2 - -0.4
Moderate Positive Correlation	0.4 - 0.6	Moderate Negative Correlation	-0.4 - -0.6
Strong Positive Correlation	0.6 - 0.8	Strong Negative Correlation	-0.6 - -0.8
Very Strong Positive Correlation	0.8 - 1	Very Strong Negative Correlation	-0.8 - -1

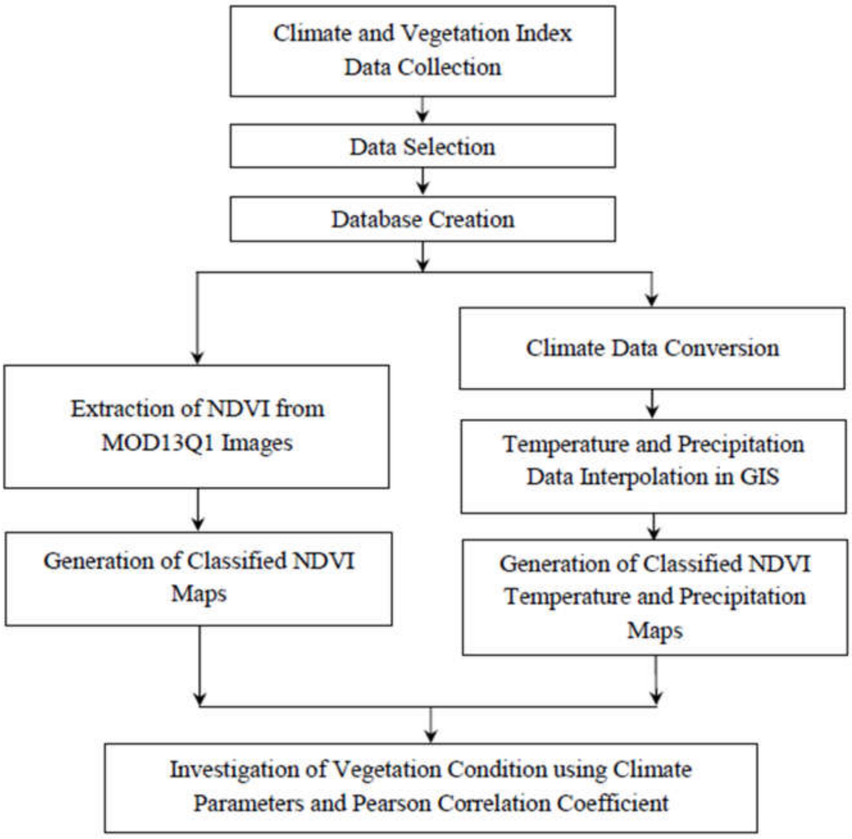

Figure (2): The flowchart of the methodology

3. Results

The average annual temperature and total precipitation maps for the period 2000-2016 and the average of these two parameters were calculated. The results show that the yearly temperature average ranges from 8 to 26 degrees Celsius and the total annual precipitation are between 215 and 811 mm. Then, the map of the average of these two parameters was classified using the natural break method (Fig. 3). The results show that northern regions have lower average temperatures (Zanjan and East Azerbaijan provinces) generally, and Ilam province, located in the southern part of the study area, has the highest temperature average. Also, the annual precipitation average map shows that the most increased precipitation is in the western of the study area, which includes west of Kurdistan province and south of West Azerbaijan province. The lowest rainfall is found in the northern, southern, and eastern regions.

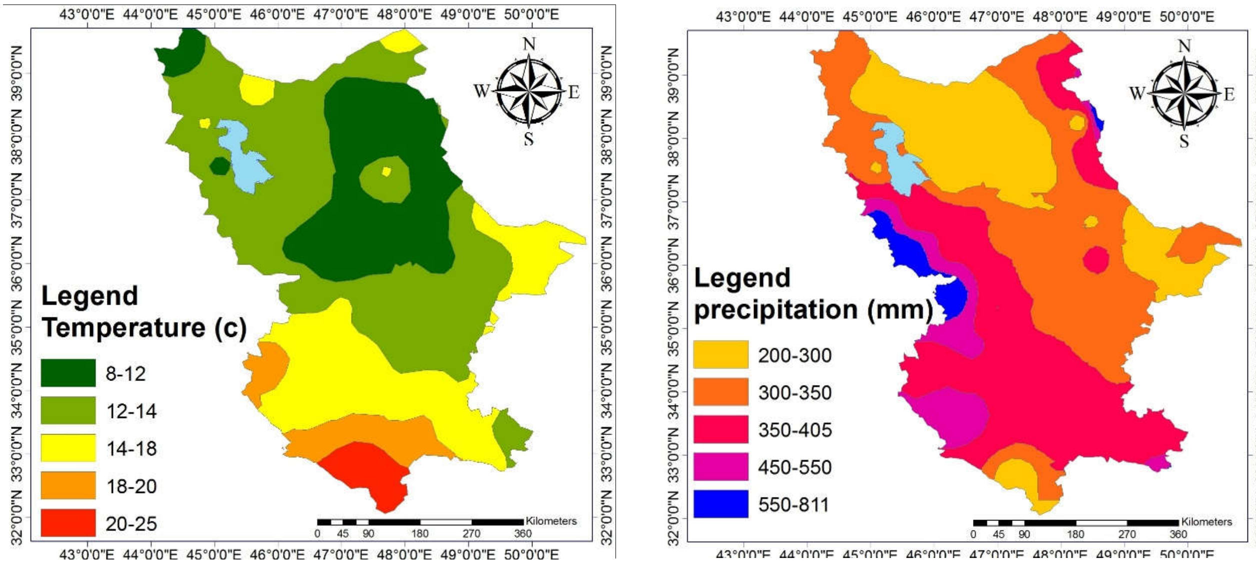

Figure (3): Categorized maps of the average temperature and precipitation of the study area (2000-2016)

The results of the correlation between NDVI and precipitation show that the correlation between NDVI and precipitation has been in the strong positive and very strong positive classes in the northern parts, including most of the East Azerbaijan and Zanjan provinces, northern of West Azerbaijan, Qazvin, and southern Ardebil province (Fig. 4). The highest correlation was found in the northwestern part of the study area (north of West Azerbaijan). The minor correlation was found in the southern parts of the study area and west of Kurdistan province, southwest of West Azerbaijan province, and areas around Urmia Lake.

The results of the correlation between NDVI and temperature indicate that most regions of southern of the study area, especially Hamedan, Lorestan, and northern provinces of Ilam, and around Lake Urmia and west of West Azerbaijan Province, are in the moderate and weak correlations of the positive. Most of the northern and northeastern parts of the study area, including many parts of East Azerbaijan province, south of the Ardebil provinces, West Azerbaijan, and Kurdistan north province, are moderate and weak correlations classes (Fig. 5).

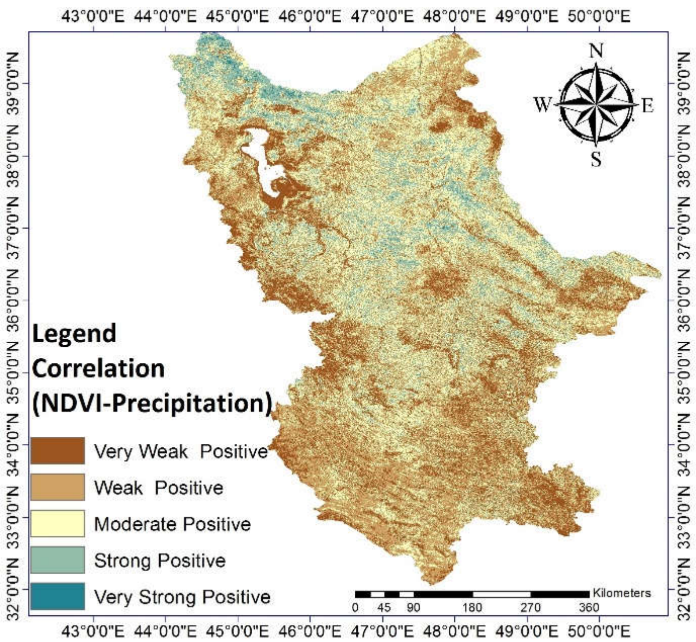

Figure (4): Maps of the Pearson Correlation Coefficients of the NDVI with Precipitation

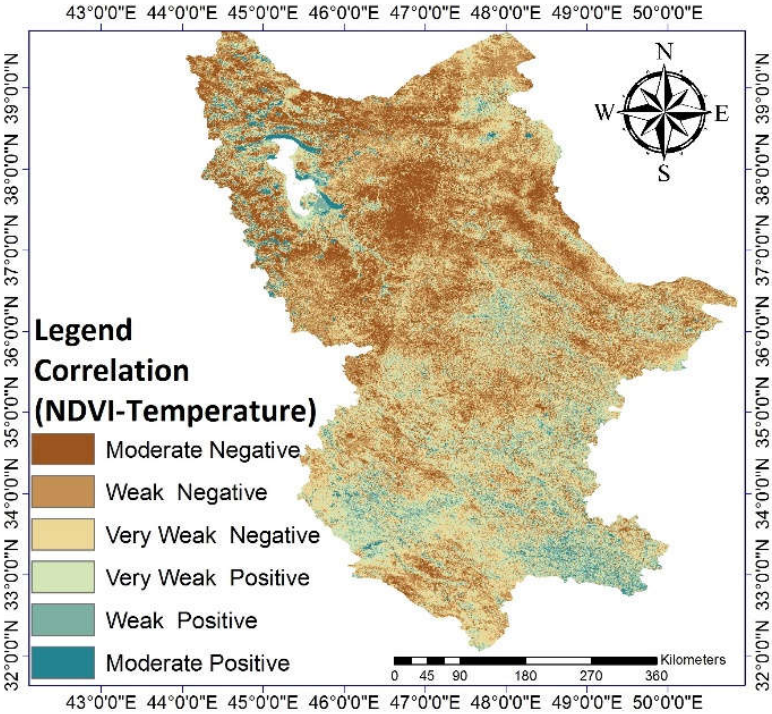

Figure (5): Maps of the Pearson Correlation Coefficients of the NDVI with Temperature

The mean correlation coefficient of NDVI with precipitation and temperature in different temperature classes is given in Table (2). The results show that the highest mean correlation between NDVI and precipitation is in 215-300 mm class, and the average annual temperature is in 8-12 °C class, and the lowest mean correlation is in 850-550 mm class, and the average yearly temperature is in 20- 26 °C class. In general, in the study area, the relationship between NDVI and precipitation in most areas is direct. The correlation between NDVI and rainfall has been increasing while total annual rainfall and average annual temperature decrease. Also, the NDVI moderate correlation and temperature results show that the highest correlation of NDVI means. The temperature is in 550-811 mm class of precipitation classification and 8-12 °C class of temperature classification. The lowest mean correlation is in the 450-550 mm class of precipitation classification, and the average annual temperature is 14-18 °C class of temperature classification. In general, it can be said that in the study area, due to the negative correlation between total NDVI mean with temperature, the relation between NDVI and temperature in most of the regions is inverse.

Table (2): The mean of correlation coefficient in different classes of the mean of temperature and precipitation

Based on Precipitation	**Range of classes**	**Precipitation (mm)**				
		215-300	**300-350**	**350-450**	**450-550**	**550-811**
	Average of correlation coefficient of NDVI and precipitation	0.36	0.32	0.26	0.2	0.1
	Average of correlation coefficient of NDVI and temperature	-0.24	-0.17	-0.1	-0.06	-0.21
Based on Temperature	**Range of classes**	**Temperature ((°C)**				
		8-12	**12-14**	**14-18**	**18-20**	**20-26**
	Average of correlation coefficient of NDVI and precipitation	0.38	0.29	0.24	0.23	0.21
	Average of correlation coefficient of NDVI and temperature	-0.24	-0.19	-0.06	-0.05	-0.16

4. Discussion and Conclusion

Climate changes and fluctuations are some of the most critical factors affecting vegetation growth (Lin et al., 2016). Quantitative measurements and spatial analysis to show the effect of temperature and precipitation on the diversity of plant cover in the region. This issue makes the changes in vegetation and vegetation dynamics better understood in response to climate change (Lin et al., 2016). In this research, the effect of annual temperature and humidity on vegetation cover in different temperature and precipitation classes in the west and northwest of Iran was investigated using the NDVI obtained from the MODIS satellite (MOD13Q1). According to the results, the mean correlation coefficient of precipitation and NDVI were more than the mean correlation coefficient of temperature and NDVI. It indicates that there is a stronger correlation between vegetation and precipitation relative to temperature and vegetation cover in the study area, which this result is consistent with the results of Wang et al. (2001), Li et al. (2004), and Zheng et al. (2017). The results also showed that there is a direct relationship between precipitation and vegetation (Duan et al., 2011; Chuai et al., 2013, Lin et al., 2014) in the study area, while in most areas of the study area there is a negative relationship between temperature and vegetation. Still, in some regions, such as the south, there is a direct relationship. In other words, the type of temperature and precipitation relationship cannot be determined (Lin et al., 2016).

The results showed that the highest correlation between the mean of NDVI and the temperature is in the middle class means the annual temperature of 8-12 °C, and the highest correlation between the mean of NDVI and precipitation is in 215-300 mm class. Due to this, the northern part of the study area (like many parts of East Azerbaijan province, south of Ardebil province), which has low precipitation and temperature, reacts to climate fluctuations compared to other areas.

Although the results of this research indicate that temperature and humidity are effective on vegetation, humans' role in the degradation and reclamation of vegetation should not be ignored. It must be accepted that human activities are also an essential factor for plant growth (Jiang et al., 2017). The difference in the method and scale of human activities will inevitably affect plant growth (Hostert et al., 2011). Therefore, to better understand vegetation's temporal and spatial dynamics and study climate changes and fluctuations, the impact of human activities on vegetation changes should be reviewed to manage vegetation cover better and prevent its degradation.

References

1. Adhikary, S. K., Muttil, N., Yilmaz, A. G., 2017. Cokriging for enhanced spatial interpolation of rainfall in two Australian catchments. Hydrological Processes, 31(12), 2143-2161
2. Allen CD, Macalady AK, Chenchouni H., 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecololgy and Management, 259(5), 660-684.
3. Bao, G., Bao, Y. H., Sanjjava, A., Qin, Z. H., Zhou, Y., Xu, G., 2015. NDVI-indicated long-term vegetation dynamics in Mongolia and their response to climate change at biome scale. International journal of climatology. 35(14), 4293–4306. DOI: 10.1002/joc.4286
4. Behrang Manesh, M., Khosravi, H., Heydari Alamdarloo, E., Sadi Alekasir, M.S., Gholami, A. Singh, V.P., 2019. Linkage of agricultural drought with meteorological drought in different climates of Iran. Theoretical and Applied Climatology, 138, 1025–1033
5. Chuai, X., Huang, X., Wang, W., Bao, G., 2013. NDVI, temperature and precipitation changes and their relationships with different vegetation types during 1998–2007 in Inner Mongolia, China. International journal of

climatology 33(7), 1696-1706

6. De Graff, J.V., 2018. Encyclopedia of Engineering Geology. Bobrowsky, P.T. and Marker, B. (eds), pp. 923-924, Springer International Publishing, Cham
7. Du, J., Zhao, C., Shu, J., Jiaerheng, A., Yuan, X., Yin, J., Fang, S., He, P., 2016. Spatiotemporal changes of vegetation on the Tibetan Plateau and relationship to climatic variables during multiyear periods from 1982–2012. Environmental Earth Sciences, 75, 1–18.
8. Duan, H., Yan, C., Tsunekawa, A., Song, X., Li, S., Xie, J., 2011. Assessing vegetation dynamics in the Three-North Shelter Forest region of China using AVHRR NDVI data. Environmental Earth Sciences 64(4), 1011-1020
9. Evans, J.D., 1996 Straightforward statistics for the behavioral sciences, Thomson Brooks/Cole Publishing Co
10. Gregory, P.J., Ingram, J.S.I., Brklacich, M., 2005. Climate change and food security. Philos T Roy Soc B 360, 2139–2148
11. Heydari Alamdarloo, E., Behrang Manesh, M., Khosravi H., 2018. Probability assessment of vegetation vulnerability to drought based on remote sensing data. Environmental Monitoring Assessment, 190, 702-710.
12. Hoerling, M., Eischeid, J., Perlwitz, J., Quan, X., Zhang, T., Pegion, P., 2012. On the increased frequency of Mediterranean drought. Journal of Climate, 25, 2146–2161.
13. Hostert, P., Kuemmerle, T., Prishchepov, A., Sieber, A., Lambin, E.F., Radeloff, V.C., 2011. Rapid land use change after socio-economic disturbances: the collapse of the Soviet Union versus Chernobyl. Environmental Research Letter, 6, 1-9.
14. Hou, G., Zhang, H., Wang, Y., 2011. Vegetation dynamics and its relationship with climatic factors in the Changbai Mountain Natural Reserve. Journal of Mountain Science 8(6), 865-875
15. Huntley, B.J., Webb, T., 1988. Vegetation History. Kluwer: Dordrecht, the Netherlands
16. Isaaks, E., Srivastava, R.M., 1988. Spatial continuity measures for probabilistic and deterministic geostatistics. Mathematical geology 20(4), 313-341
17. Jenks, G.F., 1977. Optimal data classification for choropleth maps. Department of Geography, University of Kansas: Lawrence, KS
18. Jiang, L., Bao, A., Guo, H., Ndayisaba, F., 2017. Vegetation dynamics and responses to climate change and human activities in Central Asia. Science of the Total Environment, 599, 967-980.
19. Lee Rodgers, J., Nicewander, W. A., 1988. Thirteen ways to look at the correlation coefficient. The American Statistician, 42(1), 59-66
20. Li, Z., Chen, Y., Li, W., Deng, H. and Fang, G., 2015. Potential impacts of climate change on vegetation dynamics in Central Asia. Journal of Geophysical Research: Atmospheres 120(24), 12345-12356
21. Khosravi, H., Zareh, A., Eskandari Dameneh, H., Rafiei Sardoii, E., Eskandari Dameneh, H., 2017a. Assessing the effects of the climate change on land cover changes in different time periods. Journal of Geoscience, 10, 93-103.
22. Khosravi, H., Haydari Alamdarloo, E., Shekoohizadegan, S., Zareie, S., 2017b. Assessment the effect of drought on vegetation in desert area using landsat data. The Egyptian Journal of Remote Sensing and Space Science, 20, S3-S12.
23. Li, J., Lewis, J., Rowland, J., Tappan, G., Tieszen, L.L., 2004. Evaluation of land performance in Senegal using multi-temporal NDVI and rainfall series. J. Arid Environments, 59, 463-480.
24. Lin, X. S., Tang, J., Li, Z. Y., Li, H. Y., 2016. Vegetation greenness modelling in response to inter annual temperature and precipitation changes between 2001 and 2012 in Liao River Basin in Jilin Province, China. Springer Plus, 5(1), 1173.
25. Lioubimtseva, E., 2014. A multi-scale assessment of human vulnerability to climate change in the Aral Sea basin. Environmental Earth Science. 73, 719–729.
26. Lioubimtseva, E., Cole, R., Adams, J.M., Kapustin, G., 2005. Impacts of climate and land cover changes in arid lands of Central Asia. Journal Arid Environment, 62, 285–308.

27. Ndayisaba, F., Guo, H., Bao, A., Guo, H., Karamage, F., Kayiranga, A., 2016. Understanding the spatial temporal vegetation dynamics in Rwanda. Remote Sensing, 8(9), 129.
28. Nemani, R.R., Keeling, C.D., Hashimoto, H., Jolly, W.M., Piper, S.C., Tucker, C.J., Myneni, R.B., Running, S.W., 2003. Climate-driven increases in global terrestrial net primary production from 1982 to 1999. Science, 300, 1560–1563.
29. Nouri, M., Homaee, M., Bannayan, M., 2017. Climate variability impacts on rained cereal yields in west and northwest Iran. International Journal of Biometeorology, 61(9), 1571-1583.
30. Piao, S.L., Mohammat, A., Fang, J.Y., Cai, Q., Feng, J.M., 2006. NDVI based increase in growth of temperate grasslands and its responses to climate changes in China. Global Environmental Change, 16, 340–348.
31. Pôças, I., Cunha, M., Pereira, L.S., Allen, R.G., 2013. Using remote sensing energy balance and evapotranspiration to characterize montane landscape vegetation with focus on grass and pasture lands. International Journal of Applied Earth Observation and Geoinformation, 21, 0159–172.
32. Potter, C., Boriah, S., Steinbach, M., Kumar, V., Klooster, S., 2008. Terrestrial vegetation dynamics and global climate controls. Climate Dynamics, 31(1), 67–78. doi: 10.1007/s00382-007-0339-5.
33. Potter, C.S., Brooks, V., 1998. Global analysis of empirical relations between annual climate and seasonality of NDVI. International Journal of Remote Sensing, 15, 2921–2948.
34. Qu, B. Zhu, W. Jia, S. H., Lv, A., 2015. Spatio-Temporal Changes in Vegetation Activity and Its Driving Factors during the Growing Season in China from 1982 to 2011. Remote Sensing, 7, 13729-13752.
35. Sadeghi, A., Kamgar-Haghighi, A., Sepaskhah, A., Khalili, D., Zand-Parsa, S., 2002. Regional classification for dryland agriculture in southern Iran. Journal of Arid Environment, 50, 333–341. doi:10.1006/jare.2001.0822
36. Tang, Z., Ma, J., Peng, H., Wang, S., Wei, J., 2017. Spatiotemporal changes of vegetation and their responses to temperature and precipitation in upper Shiyang river basin. Advances in Space Research, 60, 969–979.
37. Tong, S., Zhang, J., Ha, S., Lai, Q., Ma, Q., 2016. Dynamics of fractional vegetation coverage and its relationship with climate and human activities in Inner Mongolia, China. Remote Sensing, 8(9), 776-787.
38. Wang, J., Price, K.P. and Rich, P.M., 2001. Spatial patterns of NDVI in response to temperature and precipitation in the central Great Plains. International Journal of Remote Sensing, 22, 3827-3844.
39. Whitlock, C,, Bartlein, P.J., 1997. Vegetation and climate change in northwest America during the past 125 kyr. Nature, 388(6637), 57–61, doi:10.1038/40380.
40. Yang, Z., Gao, J., Zhou, C., Shi, P., Zhao, L., Shen, W., Ouyang, H., 2011. Spatio-temporal changes of NDVI and its relation with climatic variables in the source regions of the Yangtze and Yellow rivers. Journal of Geographical Sciences, 21(6), 979-993.
41. Yu, F., Price, K.P., Ellis, J., Shi, P., 2003. Response of seasonal vegetation development to climatic variations in eastern central Asia. Remote Sensing of Environment, 87, 42–54.
42. Zhang, Y.X., Wang, Y.K., Fu, B., Dixit, A.M., Chaudhary, S. and Wang, S., 2020. Impact of climatic factors on vegetation dynamics in the upper Yangtze River basin in China. Journal of Mountain Science 17, 1235-1250
43. Zheng, Y., Han, J., Huang, Y., Fassnacht, S. R., Xie, S., Lv, E., Chen, M., 2017. Vegetation response to climate conditions based on NDVI simulations using stepwise cluster analysis for the Three-River Headwaters region of China. Ecological Indicators, 92, 18-29.
44. Zhu, X., He, H.S., Zhang, S., Dijak, W.D. and Fu, Y., 2019. Interactive Effects of Climatic Factors on Seasonal Vegetation Dynamics in the Central Loess Plateau, China. Forests 10(12), 1071