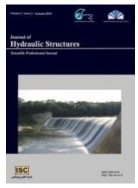
Journal of Hydraulic Structures
J. Hydraul. Struct., 2021; 7(2):60-71
DOI: 10.22055/jhs.2021.38382.1190



OPEN ACCESS

Examining the Effect of Salt Dust Storms of Lake Urmia on Vegetation

Fariba Golreyhan [1]
Khalil Valizadeh Kamran [2]
Davood Mokhtari [3]
Ali-Akbar Rasouli [3]

Abstract

Urmia Lake is one of the largest saline lakes in the world, which has greatly decreased in recent years. It has created many dangers and concerns especially concerning salt dust in its arid areas. Therefore, this research aimed to investigate the relationship between vegetation and dust in the cities around Lake Urmia. For this purpose, first, using MODIS images and NDVI index, changes in the vegetation of the region in 2010 to 2020 were determined, and then, using the MERRA-2 database, the dust concentration was extracted for the mentioned years. The results showed that the mean NDVI in the study area follows a steady trend with a total mean of 0.2957 and sometimes increases or decreases due to the influence of external factors such as dust. Accordingly, the highest rate (0.3495) of the average NDVI is related to 2018 and the lowest rate (0.2579) is related to 2013. Furthermore, to investigate the relationship between vegetation and dust, two methods of linear and logarithmic regression were used. Based on linear regression (0.7703) and logarithmic (0.7153), the findings showed that the highest determination coefficient between the two indicators was in May.

Keywords: Salt Dust, Vegetation, MODIS, MERRA-2, Lake Urmia.

Received: 28 August 2021; Accepted: 12 September 2021

1. Introduction

Mismanagement of groundwater resources, overdevelopment of commercial land, and construction of dams in arid and semi-arid regions have led to enhancement of land erosion and exposed lakebeds due to extensive drying. As a result, areas around the surface water have dried up and wetlands experience more sandstorms and dust storms in areas such as the Aral Sea in Central Asia [1 - 4], Owens Lake, Albert and Yellow in North America [5 - 7], Kati Thanda-Lake Eyre in Australia [8] and Hamun Lake in Iran [9 - 11]. Another lake in which the vegetation of the surrounding basins has recently changed and the amount of salt storms has increased is Lake

[1] Department of Geography, Marand Branch, Islamic Azad University, Marand, Iran.
[2] Faculty of Planning and Environmental Sciences , University of Tabriz, Tabriz, Iran Email: valizadeh@tabrizu.ac.ir (**Corresponding author**)
[3] Faculty of Planning and Environmental Sciences, University of Tabriz, Tabriz, Iran.

Urmia, which is the second salt lake in the world and its water level has decreased from 1276 meters in 1999 to 1270 meters in 2019 [12]. So far, a lot of research has been done on dust and salt storms in Iran and the world, some of which are mentioned below.

Yan et al., 2011 in North China evaluated the effect of vegetation on dust accumulation in a semi-arid steppe. The results showed that areas with more vegetation could obtain more nutrients by trapping dust in the air in semi-arid steppes [13]. Fan et al., 2014 evaluated the relationship between vegetation and dust storms in early vegetation emergence using MODIS sensor images and NDVI index. The results showed that there was a moderate correlation (0.55) between dust storms and vegetation in the spring in Mongolia [14]. Tan., 2016 in China examined the relationship between vegetation and dust intensity. The results of multiple regression analysis showed that the relationship between vegetation and dust intensity variance below the wet temperate zone to the dry temperate zone is weaker due to the decrease in the mean NDVI at four study points [15]. Sofue et al., 2018 used AVHRR sensor images to monitor vegetation performance against rainfall and dust storm prevalence in the Gobi Desert. In this study, correlation analysis between precipitation and NDVI anomalies was performed and the results of data analysis showed that the changes of NDVI anomalies in the eastern part of the Gobi Desert are consistent with precipitation anomalies in this period. However, in the southwestern region of the Gobi Desert, NDVI has declined, especially since 2010, regardless of rainfall. This result shows that the vegetation in this area is more degraded than in other areas [16]. Khosfi et al., 2019 in the arid regions of Central Iran investigated the relationship between dust storm index, climatic parameters, and NDVI index using the logistic regression method. The results showed that most wind erosion and dust storms occurred in spring [17]. Khosfi et al., 2020 investigated the spatial and seasonal changes of sandstorm events and their relationship with weather conditions and vegetation in the semi-arid regions of central Iran. In this study, they used Modis images and highlighted vegetation index (EVI) to investigate the relationship between vegetation and sandstorms, which showed that except in spring, there is a strong negative relationship between vegetation and dust (correlation -70). In other seasons, there is a strong positive relationship between vegetation and dust [18]. Bahrami et al., 2013 in Khuzestan modeled the temporal-spatial occurrence of dust storms. In this study, they calculated the NDVI index between 2000 and 2008 using MODIS images and concluded that the destruction of vegetation has effectively affected the frequency of dust storms of domestic origin in Khuzestan province, and saline and alkaline soils are more susceptible to the release of dust particles into the atmosphere than other soils [19]. Poor Hashemi et al., 2015 in Khorasan Razavi province evaluated the relationship between vegetation and the number of dust storms using geographic information systems and remote sensing. The results showed that there is a close relationship between vegetation changes and the number of dust occurrences in Khorasan Razavi province and with the increase and decrease of vegetation, the number of dust occurrences decreases too. The results also showed that the amount of dust has increased compared to the past and among the years studied, 2008 had the highest and 2005 had the lowest incidence of dust [20]. Sohrabi et al., 2015 in Isfahan province evaluated the effects of vegetation on the occurrence of dust in ecosystems of arid regions. The results of regression analysis showed that the number of occurrences of dust is closely related to the distribution of vegetation and with the decrease of vegetation the number of dust increases [21]. Ghadimi et al., 2017 in Ahvaz evaluated the effects of dust on the spectral behavior of plants using remote sensing data. In this study, non-parametric spectral analysis methods such as periodogram, Welch, and multiplier were used to evaluate the effect of dust [22]. Therefore, according to the research background and the issues raised in this study, we intend to evaluate the impact of salt storms and vegetation on each other in Lake Urmia using MODIS images and the NDVI index.

2. The Study Area

The study area includes the catchment basin of Lake Urmia in the northwest of Iran, which is located at 36 11' to 39 26' north latitude and 44 10' to 48 21' minutes east longitude of the prime meridian. This region is limited to Azerbaijan and Armenia from the north, Ardabil province from the east, Zanjan and Kurdistan provinces from the south, and Turkey from the east.

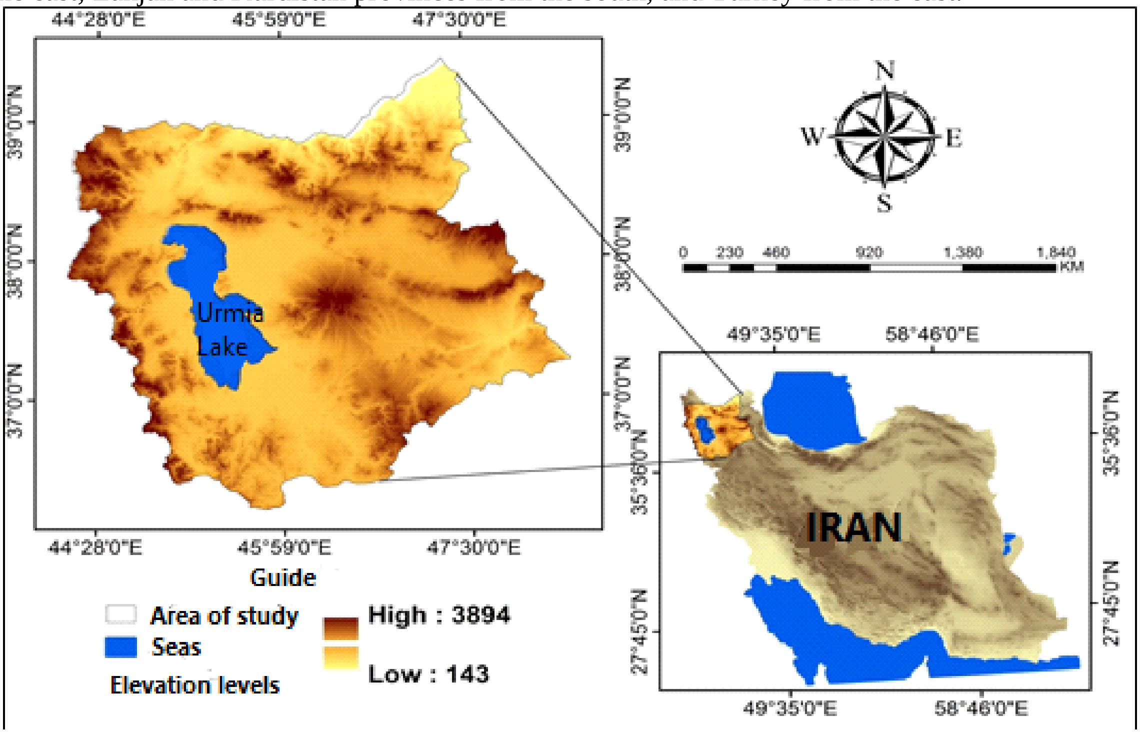


Figure 1. The study area

3. Materials and Methods

In the present study, Modis satellite images (HYPERLINK) of TERRA sensor in 11 years from 2010 to 2020 were used to calculate the NDVI. PMER.5 data of MERRA-2 database in the period 2010 to 2020 were used to check the dust concentration. To do this, PM2.5 data for each year were first obtained from the database five months before the NDVI calculation, which was reviewed for a total of 55 months and then analyzed using ArcGIS software. Then, using linear and logarithmic regressions, the determination coefficient between the vegetation and the months before the vegetation study was calculated.

3.1. NDVI index

Tucker as an indicator for assessing vegetation health first introduced the Normalized Difference Vegetation Index (NDVI) in 1979. This indicator is the most common indicator for vegetation surveillance, which normally reflects infrared band waves well. The range of variation of each pixel varies between +1 and -1. Typically, its value is 0.1 for areas with sparse vegetation and 0.8 for areas with dense vegetation . In general, this index reflects vegetation potential [23], percentage of green vegetation, percentage of leafy areas, and vegetation densities [24] and is expressed as Equation 1.

$$\mathrm{NDVI} = \frac{\mathrm{R_{NIR}} - \mathrm{R_{red}}}{\mathrm{R_{NIR}} + \mathrm{R_{red}}} \tag{1}$$

Where the infrared spectral reflection is near and the spectral reflection is red.

3.2. MERRA Database

NASA's Center for Modern Analysis for Research and Applications is a set of atmospheric reanalysis data [25] created by NASA's Global Modeling and Assimilation Office (GMAO). This re-analysis database uses version 5 Goddard Earth Observation System (GEOS-5) which is a public atmospheric circulation model and the Data Assimilation System (DAS) [26]. It stimulates and optimizes observations and, by combining the model data used and irregular spatial and temporal observations, generates a network of data with appropriate accuracy and establishes a system for analyzing historical data. The second version of this model and data set was released in 2014. This version uses new short-wavelength and infrared information and has advantages over the previous version, which include numerous improvements and updates to data simulation, making aerosol, sulfate, and dust observations available [3,5,27 – 29, 33]. In the present study, PM2.5 data were re-analyzed for 5 months before the date of the NDVI index survey (June 3, 2010, to 2020) of the MERRA 2 database with an accuracy of 0.56 * 0.525 in the cities around Lake Urmia in the form of NC. Finally, the determination coefficient was used to investigate the relationship between dust and vegetation, which is expressed as Equation 2.

$$R^2 = \frac{[\sum_{i-1}^{n}(x_i - \bar{x})(Y_i - \bar{Y})]^2}{\sum_{i-1}^{n}(x_i - \bar{x})^2 \sum_{i-1}^{n}(Y_i - \bar{Y})^2} \tag{2}$$

Where the data are real and simulated by the model, respectively. And the total average is the data of the statistical population and the evaluated numbers of samples [30].

4. Results and Discussion

Finally, to understand the distribution of vegetation in the study area, the NDVI vegetation map for 2010 to 2020 was drawn (Figure 2). As it can be seen in the above images, vegetation distributions do not follow a trend distribution and, depending on other environmental factors, have undergone changes in their distribution levels in the years under study. To better understand the minimum, maximum and average values of NDVI were extracted for the studied years (Table 1). Accordingly, the year 2013 with 0.2579 has the lowest, and 2018 with an average of 0.3495 has the highest average vegetation in the study area. Furthermore, in studying the range of NDVI changes (difference between the minimum and maximum values), it was found that 2019 is the year with the lowest range of changes (between -0.224 to 0.2262) and 2012 has the lowest rate of change (between -0.0906 and 0.8986) (Table 1).

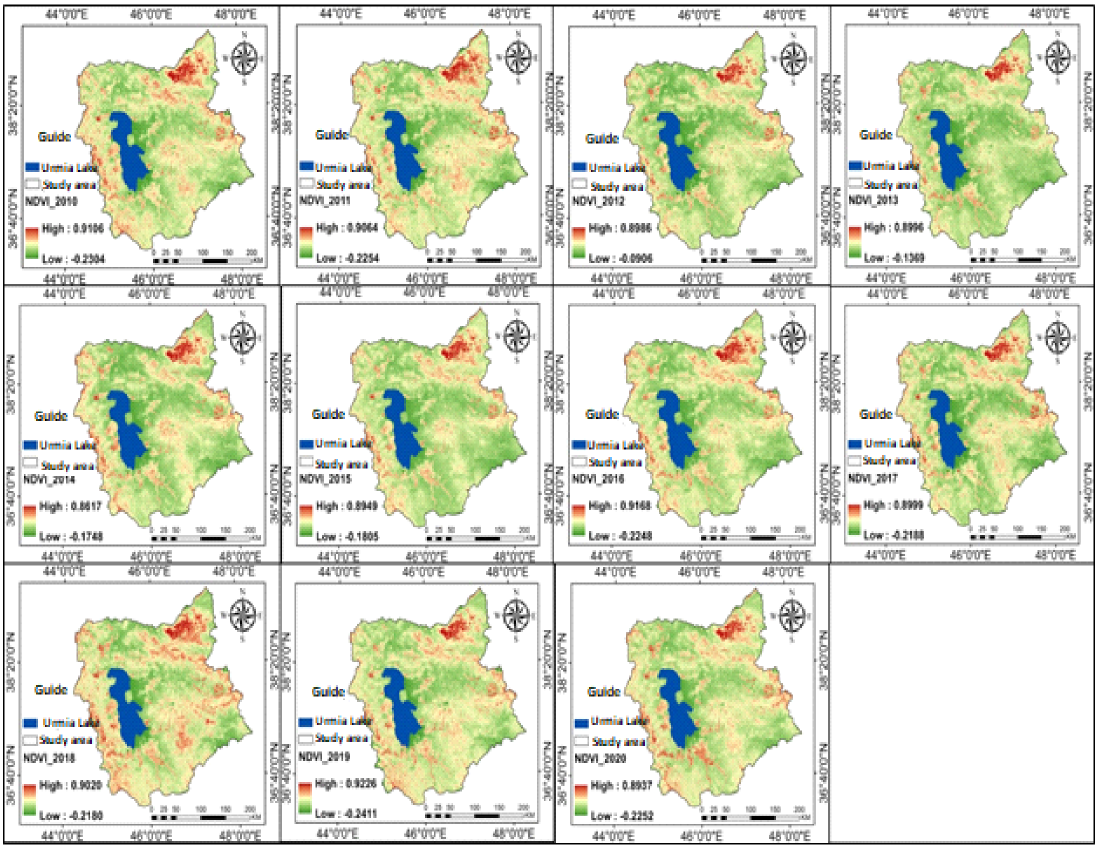


Figure 2. Vegetation Distribution in the Study Area based on the NDVI Index in 2010 to 2020

Table 1. Minimum, Maximum, and Average Values of NDVI in 2010 to 2020

Date	Minimum	Maximum	Average
03/06/2010	-0.2304	0.9106	0.3138
03/06/2011	-0.2254	0.9064	0.3126
03/06/2012	-0.0906	0.8986	0.2718
03/06/2013	-0.2188	0.8999	0.2579
03/06/2014	-0.1748	0.8617	0.2783
03/06/2015	-0.1805	0.8949	0.2827
03/06/2016	-0.2248	0.9168	0.2934
03/06/2017	-0.1369	0.8996	0.2677
03/06/2018	-0.2180	0.9020	0.3495
03/06/2019	-0.2411	0.9226	0.3190
03/06/2020	-0.2252	0.8937	0.3056

Then, to evaluate the effect or relationship of dust with the vegetation area of the region, dust concentration values were extracted through MERRA 2 sensor for 5 months before NDVI analysis. Accordingly, as we move from winter (average dust concentration in January is 16.3628 kg / m3) to spring (average dust concentration in May is 27.0414 kg / m3), the amount of dust concentration has increased, which is true in most the years under study (Table 2). Concerning the increase in humidity in winter and its decrease in spring and the increase in the effectiveness of other parameters such as wind, etc., it seems normal. The results of this part are highly consistent with the results of Dadashi et al., (2020) in which the seasonal distribution of dust particles in Iran was studied using the data of the MERRA 2 database [31]. The surveys also showed that the lowest dust concentration is related to 2018 in January, i.e., 5 months before the vegetation survey, and the highest amount of dust is related to 2013 and May, which is one month before the vegetation survey of the region. As can be seen in Table 2, based on the results of 2013, the increase in dust concentration is exactly in line with the decrease in vegetation (Table 1) and the decrease in dust concentration in 2018 is exactly in line with the increase in vegetation.

Table 2. Total Dust Concentration (Kg/m^3)

Date	1 Month before (May)	2 Month before (April)	3 Month before (March)	4 Month before (February)	5 Month before (January)
03/06/2010	26.4137	26.8290	18.9050	16.9643	15.7755
03/06/2011	26.2342	26.6174	18.4087	16.4874	15.5449
03/06/2012	27.2250	27.4741	19.3920	17.3064	16.4253
03/06/2013	29.1273	26.4198	23.6135	20.5083	19.2363
03/06/2014	27.3597	26.5377	18.5209	17.1905	16.4803
03/06/2015	27.1133	27.2842	19.0483	17.1413	16.2706
03/06/2016	26.3868	26.9387	18.7081	16.9618	15.8068
03/06/2017	28.5998	25.9531	22.5538	20.1614	19.0075
03/06/2018	25.5868	22.4482	16.6006	14.6790	14.4496
03/06/2019	26.2356	26.5414	18.5790	16.3734	15.3268
03/06/2020	27.1735	26.9965	18.7917	17.7640	15.6668

Table 3 shows the determination coefficients of linear and logarithmic regression for one, two, three, four, and five months ago. Accordingly, most of the correlations based on logarithmic regression between NDVI values and the amount of dust in one month before (May) of the NDVI index was 0.715 and the lowest correlation in two months ago (April) was 0.3132. These conditions were similar for linear regression and in the previous month (May) the correlation was 0.7703 and two months ago (April) the correlation was 0.3534 which includes the highest and lowest correlations between NDVI index and dust concentration is based on linear regression.

Table 3. Determination Coefficient of NDVI Average with Dust Level

Correlation with	Logarithmic equation	r^2	Liner equation	r^2
1 month before (May)	y = -10.34ln(x) + 14.399	0.7915	y = -34.086x + 37.119	0.7703
2 month before (April)	y = -8.406ln(x) + 16.093	0.3132	y = -29.828x + 35.186	0.3534
3 month before (March)	y = -17.54ln(x) - 2.0676	0.6496	y = -57.683x + 36.429	0.6293
4 month before (February)	y = -15.25ln(x) - 1.2258	0.7066	y = -50.552x + 32.359	0.6959
5 month before (January)	y = -14.05ln(x) - 0.8079	0.7479	y = -46.175x + 30.015	0.7241

In the following, the correlation between NDVI average and dust concentration in Figures 3 and 4 is also presented schematically based on logarithmic and linear regressions, which except for April, the distribution of data has a positive and significant trend and its determination coefficients are mostly above 0.6, which is almost an acceptable correlation.

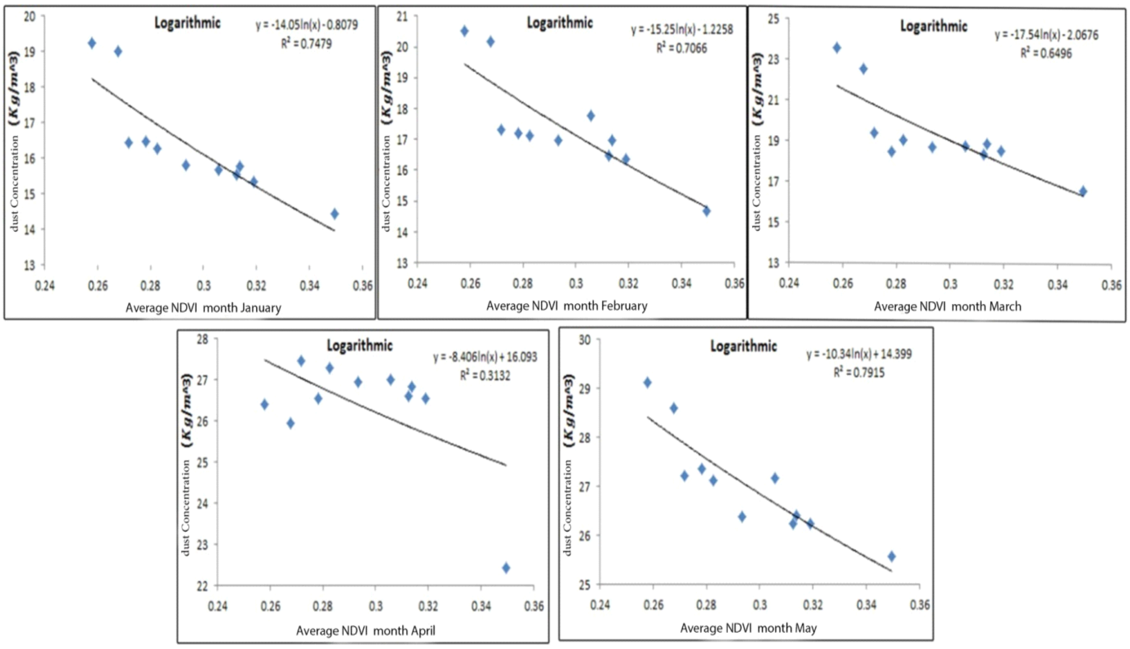


Figure 3. Average Changes of NDVI Index and Dust Concentration based on Logarithmic Regression

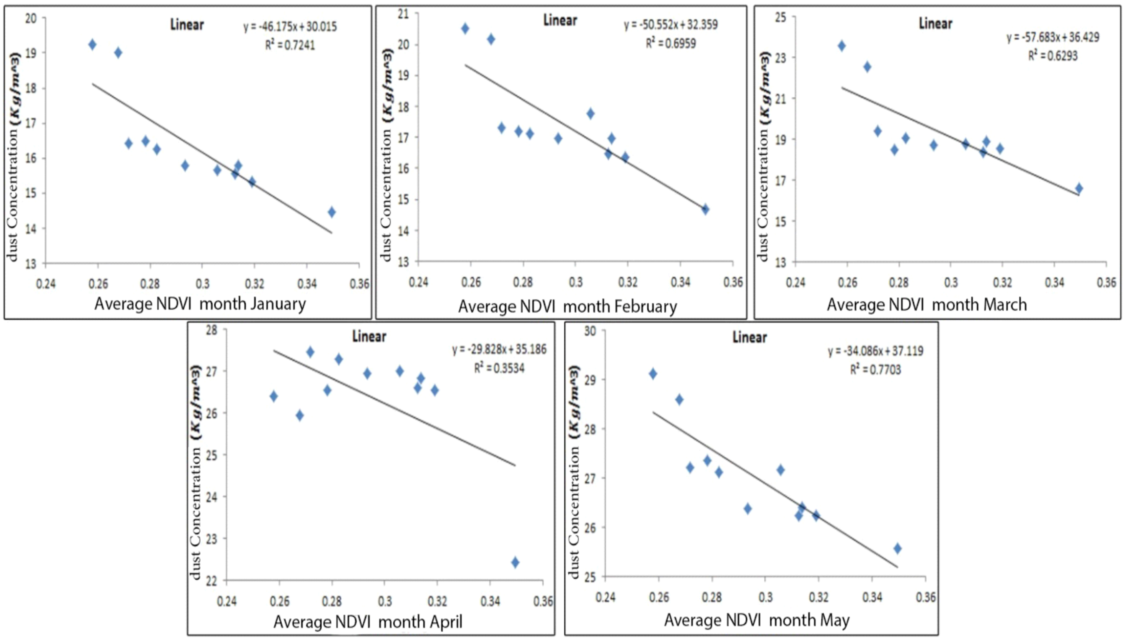


Figure 4. Average Changes of NDVI Index and Dust Concentration based on Linear Regression

5. Conclusion

The results of the NDVI index showed that the highest average of NDVI in 2018 with a numerical value of 0.3495 and the lowest NDVI in 2013 with a numerical value of 0.2579, which is a difference of approximately 9% between different years, indicating that the other factors are involved in the distribution of vegetation. However, as mentioned, the NDVI index follows a steady trend in the study area, the average of which for the whole years is 0.2957, which is consistent with the results of Nabipour et al., 2016. In a study, they evaluated the changes in vegetation and groundwater pollution in the cities around Lake Urmia and expressed the average NDVI index of 0.3045 between 1994 and 2016 [32]. Moreover, the average minimum and maximum of NDVI in the region are -0.1956 and 0.9006, respectively, which indicates the range of differences between vegetated areas and areas without vegetation. In addition, dust concentration values were extracted through the MERRA-2 sensor 5 months ago (January, February, March, April, and May) to investigate the relationship between dust and vegetation area. Accordingly, the average concentration of dust in winter (January, February, and March) is 17.7166 kg / m3 and in spring (April and May) is 26.7043 kg / m3. In other words, as we move from winter to spring, the concentration of dust has increased, which is true for most of the years under study. The results of this part of the study are consistent with the results of Raeespour and Khosravi., 2019 who studied and analyzed the long-term optical depth of aerosol (AOD) behavior in Sistan plain using the MERRA-2 model [33]. Because based on the results, the highest amount of dust occurs in spring and the least amount of dust occurs in winter. Finally, logarithmic and linear regression methods and coefficient of determination were used to investigate the relationship between vegetation distribution and dust concentration. Therefore, according to the logarithmic regression method, the highest correlation between vegetation index and dust concentration is related to May with a numerical value of 0.715 and the lowest correlation is related to April with a numerical value of 0.3132. Furthermore, in the linear regression study, it was found that the highest correlation between vegetation index and dust concentration was related to May with a numerical value of 0.7703 and the lowest correlation was related to April with a numerical value of 0.3534. The results of this part are consistent with the research of Bayat et al., 2016 in which the determination coefficients of vegetation and dust based on linear regression is 0.82 [34]. According to the above, and research results, as well as following the reduction of water and vegetation around Lake Urmia and the emergence of bare lands on its shores, and the occurrence of dust removal in these areas, there is a great risk to the lake's inhabitants and the entire population around to about 10 kilometers because of the dust threat and respiratory problems, as well as the threat of salt dust and the destruction of agricultural lands and natural life in general. Therefore, officials must make timely decisions to prevent further crises in the region.

References

1. Xi, X., Sokolik, I.N., 2016. Quantifying the anthropogenic dust emission from agricultural land use and desiccation of the Aral Sea in Central Asia. J. Geophys. Res. 121, 12–270.
2. Indoitu, R., Kozhoridze, G., Batyrbaeva, M., Vitkovskaya, I., Orlovsky, N., Blumberg, D., Orlovsky, L., 2015. Dust emission and environmental changes in the dried bottom of the Aral Sea. Aeolian Res. 17, 101–115.
3. Issanova, G., Abuduwaili, J., Galayeva, O., Semenov, O., Bazarbayeva, T., 2015. Aeolian transportation of sand and dust in the Aral Sea region. Int. J. Environ. Sci. Technol. 12, 3213–3224.
4. Löw, F., Navratil, P., Kotte, K., Schöler, H.F., Bubenzer, O., 2013. Remote-sensing-based analysis of landscape change in the desiccated seabed of the Aral Sea—a potential tool for assessing the hazard degree of dust and salt storms. Environ. Monit. Assess. 185, 8303–8319.
5. Borlina, C.S., Rennó, N.O., 2017. The Impact of a Severe Drought on Dust Lifting in California's Owens Lake Area. Sci. Rep. 7, 1784.
6. Moore, J.N., 2016. Recent desiccation of western Great Basin saline lakes: lessons from Lake Abert, Oregon, USA. Sci. Total Environ. 554, 142–154.
7. Sweeney, M.R., Zlotnik, V.A., Joeckel, R.M., Stout, J.E., 2016. Geomorphic and hydrologic controls of dust emissions during drought from Yellow Lake playa, West Texas, USA. J. Arid Environ. 133, 37–46.
8. Strong, C.L., Parsons, K., McTainsh, G.H., Sheehan, A., 2011. Dust transporting wind systems in the lower Lake Eyre Basin, Australia: a preliminary study. Aeolian Res. 2, 205–214.
9. Behrooz, R.D., Esmaili-Sari, A., Bahramifar, N., Kaskaoutis, D.G., Saeb, K., Rajaei, F., 2017. Trace-element concentrations and water-soluble ions in size-segregated dustborne and soil samples in Sistan, Southeast Iran. Aeolian Res. 25, 87–105.
10. Rashki, A., Eriksson, P.G., Rautenbach, C.D.W., Kaskaoutis, D.G., Grote, W., Dykstra, J., 2013. Assessment of chemical and mineralogical characteristics of airborne dust in the Sistan region, Iran. Chemosphere. 90, 227–236.
11. Rashki, A., Kaskaoutis, D.G., Eriksson, P.G., Qiang, M., Gupta, P., 2012. Dust storms and their horizontal dust loading in the Sistan region, Iran. Aeolian Res. 5, 51–62.
12. Ahmady-Birgani, H., Ravan, P., Schlosser, J. S., Cuevas-Robles, A., AzadiAghdam, M., & Sorooshian, A. (2020). On the chemical nature of wet deposition over a major desiccated lake: Case study for Lake Urmia basin. *Atmospheric Research*, *234*, 104762.
13. Yan, Y., Xu, X., Xin, X., Yang, G., Wang, X., Yan, R., & Chen, B. (2011). Effect of vegetation coverage on aeolian dust accumulation in a semiarid steppe of northern China. *Catena*, *87*(3), 351-356.

14. Fan, B., Guo, L., Li, N., Chen, J., Lin, H., Zhang, X., Shen, M., Rao, Y., Wang, C. and Ma, L., (2014). Earlier vegetation green-up has reduced spring dust storms. *Scientific reports*, *4*, 6749.
15. Tan, M. (2016). Exploring the relationship between vegetation and dust-storm intensity (DSI) in China. *Journal of Geographical Sciences*, *26*(4), 387-396.
16. Sofue, Y., Hoshino, B., Demura, Y., Kai, K., Baba, K., Nduati, E., Kondoh, A. and Sternberg, T., (2018). Satellite monitoring of vegetation response to precipitation and dust storm outbreaks in Gobi Desert Regions. *Land*, *7*(1), p.19.
17. Khusfi, Z.E., Roustaei, F., Ebrahimi Khusfi, M., & Naghavi, S. (2019). Investigation of the relationship between dust storm index, climatic parameters, and normalized difference vegetation index using the ridge regression method in arid regions of Central Iran. *Arid land research and management*, 1-25.
18. Khusfi, Z. E., Khosroshahi, M., Roustaei, F., & Mirakbari, M. (2020). Spatial and seasonal variations of sand-dust events and their relation to atmospheric conditions and vegetation cover in semi-arid regions of central Iran. *Geoderma*, *365*, 114225.
19. Bahrami, Hossein Ali; Jalali, Mahboubeh; Darvishi Blourani, Ali; Azizi, Rasoul (2013), Spatial-temporal modeling of occurrence of dust storms in Khuzestan province, Remote Sensing and GIS of Iran, Volume 5, Number 2, 95-114.
20. Pourhashemi, Sima; Boroughni, Mehdi; Zanganeh Asadi, Mohammad Ali; Amira Ahmadi, Abolghasem, (2015), Analysis of vegetation relationship on the occurrence of dust in Khorasan Razavi province using GIS and remote sensing, remote sensing and GIS in natural resources, Year 6, Number 4, 33-45.
21. Sohrabi, Tayebeh Sadat; Wali, Abbas Ali; Ranjbar Fardavi, Abolfazl; Mousavi, Seyed Hojjat, (2015), Quantitative Analysis of Vegetation Feedback on Dust Occurrence in Arid Ecosystems (Case Study: Isfahan Province), Rangeland and Watershed Management, Iranian Journal of Natural Resources, Volume 71, Number 41, 973-985.
22. Ghadimi, Mehrnoosh; Zare, Amin; Maqbal, Masoumeh; Sahebi, Mahmoud Reza, (1398), Evaluation of the effects of dust on the spectral behavior of plants using remote sensing data, Journal of Surveying Science and Technology, Volume 8, Number 4, 163-176.
23. Teillet, P. M., Staenz, K., Willams, D. J., 1997, Effects of spectral, spatial, and radiometric characteristics on remote sensing vegetation indices of forested regions, Remote Sensing of Environment 61: pp. 139–149.
24. Thenkabail, P. S., Gamage, M. S. D. N., Samakhtin, V, U., 2002, Evaluation of narrowband and broadband vegetation indices for determining optimal hyperspectral wavebands for agricultural crop characterization, Photogrammetric Engineering and Remote Sensing 68: pp.607–621.
25. Rienecker, M. M., Suarez, M. J., Gelaro, R., Todling, R., Bacmeister, J. T., Liu, E., Bosilovich, M. G., and Woollen, J., 2011, MERRA: NASA’s modern-era retrospective analysis for research and applications: Journal of Climate, 24, 3624–3648.
26. Molod, A., L. Takacs, M. Suarez, J. Bacmeister, 2015, Development of the GEOS-5 atmospheric general circulation model: Evolution from MERRA to MERRA2. Geoscientific Model Development, 8; 1339-1356.
27. Real-Rangel, R., Pedrozo-Acuña, A., Breña-Naranjo, J. A., and Alcocer-Yamanaka, V., 2017, Evaluation of the hydroclimatological variables derived from GLDAS-1, GLDAS-2 and MERRA-2 in Mexico: E-proceedings of the 37th IAHR World Congress August 13–18, Kuala Lumpur, Malaysia.

28. Abbaszadeh Mazraji, Zahra; Sadeghi, Suleiman; And Hosseinzadeh, Seyed Reza (2013), Assessing the Accuracy of Common Methods of Estimating Climatic Data in the Study Area: Temperature and Precipitation in Kashfarud Basin of Mashhad, First National Conference on Meteorology, Kerman, Graduate University of Industrial and Advanced Technology. Kerman.
29. Yasemi, Hadith, (2017), Assessing the Accuracy of Estimating Outdoor Temperatures of Global Temperature Bases on Iran, Master Thesis, Supervisor Mohammad Darand, University of Kurdistan.
30. Osinowo A.A., E C. Okogbue, E.O. Eresanya, O.S. Akande, 2017, Evaluation of wind potential and its trends in the mid-Atlantic, Modeling Earth Systems and Environment, 3(4); 45.
31. Dadashi-Roudbari, A., Ahmadi, M., & Shakiba, A. (2020). Seasonal Study of Dust Deposition and Fine Particles (PM 2.5) in Iran Using MERRA-2 Data. *Iranian Journal of Geophysics*, 43-59.
32. Nabipour, Yusuf; Arianfar, Ali and Samadian, Morteza 2016, Investigation of vegetation changes on groundwater pollution in Urmia plain using RS and GIS, Sixth National Conference on Water Resources Management of Iran, Kurdistan, University of Kurdistan.
33. Raeespour, Kouhzad; And Khosravi, Mahmoud, 2019, Analysis of long-term behavior of aerosol optical depth (AOD) in Sistan plain using MERRA-2 model, International Dust Conference in Southwest Asia, Zabol, Zabol University.
34. Bayat, Reza; Jafari, Somayeh; Red spring, Baqer; Charkhabi, Amir Hossein. (1395). Study of the effect of fine dust on vegetation changes (Case study: Shadegan wetland, Khuzestan), Remote sensing and GIS in natural resources, 7 (2): 17-32.