University of Tabriz

Journal of Civil and Environmental Engineering
Volume 53 (2023), Issue 1 (Spring), 43-54

EXTENDED ABSTRACT

Relationship between Changes in Water Body and Vegetation in the Eastern of Lake Urmia with the Phenomenon of Dust Storms

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Received: 05 September 2020; **Review:** 15 November 2020; **Accepted:** 19 December 2020

Keywords:
Trend analysis, Dust, Correlation analysis, Water body, Lake Urmia.

1. Introduction

The area of Lake Urmia, as the largest closed lake in the world, has significantly reduced in the last three decades, and this trend has had in-depth effects on environmental characteristics of the areas around the lake. During the last two decades, macro-climatic changes in northwestern Iran, and the involvement of anthropogenic factors such as dam construction caused extensive changes in the volume of water entering the lake and the area of water zone along with increasing salt concentration (Mardi et al., 2018; Sotoudeheian et al., 2016; Alkhayer et al., 2019; Boroughani et al., 2019; Mardi et al., 2018; Delfi et al., 2019). The changes in the area and volume of water of this lake on an annual and seasonal scale have had significant effects on the soil, climate and vegetation quality of the areas around this lake (Tourian et al., 2015; Eimanifar and Mohebbi, 2007). Therefore, the effects of dust due to drying of Lake Urmia can affect air quality around the lake up to a radius of hundreds of kilometers both directly by creating internal dust centers (usually dust from salt deposits) and indirectly by weakening vegetation. Also, emit a wave of salt dust in the air of some cities adjacent to the lake, which has a population of nearly six million persons who are directly and indirectly affected by the consequences of the drying of this lake.

The main objective of this study was to identify the relationship between dust storms in the eastern part of Lake Urmia and the surrounding vegetation due to the annual and long-term variability of this water zone during the statistical period 1999-2019.

2. Methodology

2.1. Study area

The study area includes eastern sub-basins of Lake Urmia, and with an area of 20,292 square kilometers covers a large part of East Azerbaijan Province.

2.2. Data and Modeling

In order to investigate periodic and annual changes in vegetation in the region, Normalized Difference Vegetation Index (NDVI) was used and in order to monitor annual and periodic changes in water body of Lake Urmia, Normalized Difference Water Index (NDWI) was used. Dust data include frequency and intensity of dust. Dust codes from stations around the lake and Dust Storm Index (DSI) were used for dust frequency. MODIS sensor was used to investigate dust intensity of aerosol optical depth (AOD) (Delfi et al., 2019; Tan, 2016). In

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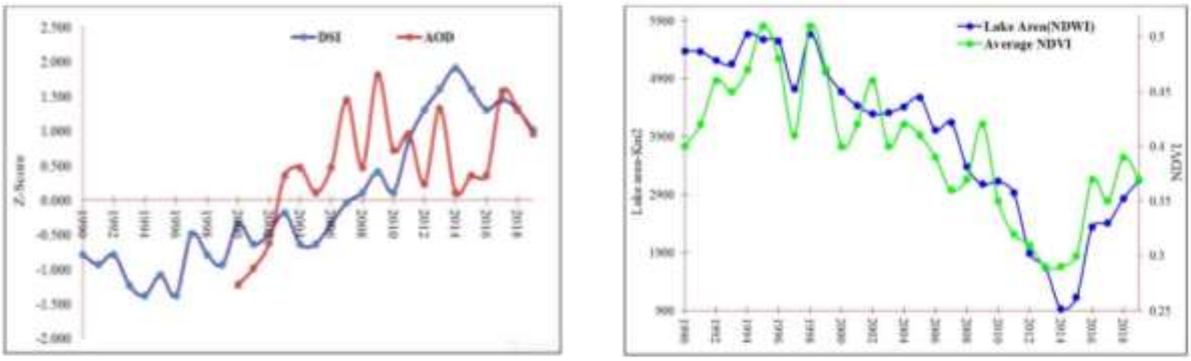
order to investigate whether intensity and frequency of dust in the region as a result of the two main drivers i.e. changes in water body area of the lake and vegetation during the statistical period 1990-2019, significant changes were found in the study area or not, non-parametric analysis Sen's slop estimator and Mann-Kendall test were used (Fernandes and Leblanc, 2005). In order to analyze the correlation between frequency and intensity of dust and changes in the area of water body of the lake and vegetation of the region, Pearson correlation has been used. T-test analysis was used to investigate the relationship between AOD and DSI in relation to annual changes NDWI and NDVI in two time phases.

3. Results and discussion

The study results of 29-year time series trend (1990-2019) of changes in dust intensity and frequency index in the eastern part of Lake showed that during the study period, both DSI and AOD have been significant increasing (Fig. 1-a). Analysis of the time series trend of the two indicators of changes in NDWI and NDVI of the eastern area of Lake Urmia indicates that both of these indicators have a significant decreasing trend during the period 1990-2019 (Fig. 1-b) and vegetation density in the eastern part of the lake has reduced by 0.005 NDVI units per year, which is similar to the decreasing trend of the lake area. This decreasing trend of vegetation in the region has also been significant. The changes in vegetation in the eastern part of Lake Urmia have been such that in addition to reducing the spatial average of vegetation index, its spatial distribution has become more heterogeneous in the study area and the spatial variability coefficient of vegetation index has increased in the region.



(a) (b)

Fig. 1. a) 29-year time series trend of intensity (AOD) and frequency (DSI) of dust storms in the region, b) Time series trend of changes in the area of water zone of Lake Urmia and the average NDVI of the eastern area of Lake Urmia

The area of Lake Urmia has had a continuous decreasing trend during the statistical period, which according to the statistics of Sen's slope estimator has been equal to 142 square kilometers per year. The 6-year period (2011-2016) is in fact the largest reduction in the area of water body of Lake Urmia.

DSI was significantly correlated with AOD, which indicates that while the frequency of dust storms increased in the region, the intensity of dust has also increased in the region. But the two dust indicators, were significantly dependent on changes in water body of Lake Urmia (Table 1). The results of the analysis showed that in the years when the area of water zone of Lake Urmia has reduced and vegetation has been relatively low at the same time, the highest frequency and intensity of dust has been observed, in other words, the simultaneous effect of reducing water zone of the lake and the reduction in the average vegetation index in the region, synergistically, in addition to increasing DSI in the region, has also increased AOD index, which is an indicator of the intensity of dust (Fig. 2).

Table 1. Pearson correlation analysis matrix between two indicators of AOD and DSI and changes in NDWI and NDVI of Urmia Lake water body

Index	Significant level	DSI	AOD	NDVI	NDWI
DSI	R	1	0.75	-0.85	-0.70
	Sig	0.00	0.002	0.00	0.00
AOD	R		1	-0.60	-0.80
	Sig		0.00	0.02	0.014
NDVI	R			1	0.88
	Sig			0.00	0.00
NDWI	R				1
	Sig				0.00

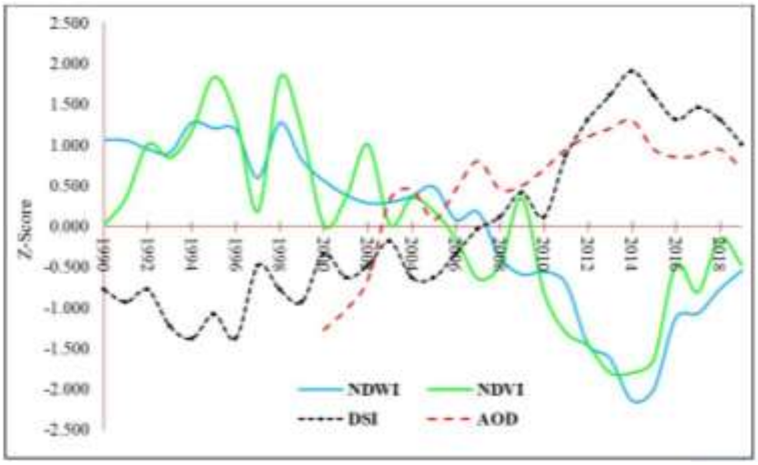


Fig. 2. Relationship between time series of changes in NDWI, NDVI with AOD and DSI in the region

Therefore, reducing the area and drying of the lake both directly (by creating dust centers in the arid areas of the lake) and indirectly (proxy) by weakening soil fertility (due to sequestration of salt aerosols in soil) and weakening of vegetation (closure of leaf pores and disruption of photosynthesis, respiration and transpiration processes), has led to intensification of dust storms in the eastern part of Lake Urmia.

Results showed that the role of changes in the area of water zone of Lake Urmia in frequency of dust storms (DSI) is not direct but indirect and proxy, through change (destruction) in the basin vegetation.

The frequency of dust storms during the 29-year period (1990-2019) has shown more sensitivity to annual changes in vegetation than changes in water zone of Lake Urmia, while the concentration of dust (AOD) is directly related to changes in water body of the lake. The overall outcome of these two indicators i.e. AOD and DSI, has been an increase in intensity and frequency of dust storms in the eastern part of Lake Urmia.

4. Conclusions

The study results led to the revelation that, first, changes in water body of Lake Urmia, which has been reducing over the past three decades, directly and significantly led to an increase in dust concentration (AOD) in the eastern part of Lake Urmia. On the other hand, changes in water level of Lake Urmia have led to a general decreasing trend in vegetation in the region, which has led to an increase in frequency of dust storm index (DSI) in the region. The study model study showed that changes in water body of Lake Urmia as a very powerful driver leads to an increase in intensity and frequency of dust in the eastern part of Lake Urmia and intensifies dust conditions in the region. If the decreasing trend of Lake Urmia intensifies in the study area, more frequent and severe dust storms will occur in the region. Therefore, in addition to management solutions provided, management and conservation of this unique ecosystem should be considered.

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