Analyzing the time series changes trend of the Aerosol Optical Depth (AOD) index of Terra satellite's MODIS sensor for Jazmorian basin in the southeast of Iran during 2000-2018

Peyman Mahmoudi[1], Allahbakhsh Rigi Chahi[2]
1- Department of Physical Geography, Faculty of Geography and Environmental Planning, University of Sistan and Baluchestan, Zahedan, Iran
2- Sistan and Baluchestsn Province Meteorological Administration, Zahedan, Iran

Corresponding Author's E-mail: p_mahmoudi@gep.usb.ac.ir

Abstract

The present study aimed at investigating the time series changes of aerosols optical depth (AOD) index on a monthly basis in Jazmorian Basin in the southeast of Iran using remotely sensed satellite data. To this end, the monthly data of aerosol optical depth (AOD) index from MODIS sensor of Terra Satellite were applied for an 18-year period (2000-2017). After preparing the monthly time series of AOD index, classical linear regression was employed for examining the changes' trend of this index. The study results indicated that AOD index changes' trend has been significant in α=0.05 probability level only for January during which an ascending trend has been documented. The changes' trends were also found significant for February, April and May, whose probability level was α=0.1. The changes' trends of AOD was also found ascending during these three months alike January. Disregarding these four months, no significant trends were observed in the other studied months in terms of the changes' trends of aerosol optical depth (AOD) in Jazmorian Basin.

Keywords: Jazmorian Basin, Dust, Trend, Classical Linear Regression, AOD

1. INTRODUCTION

As inseparable parts of the earth system, dust cycles cause the generation of about 2000 tons of dust and aerosol every year. Out of this amount, 75% settles down on earth surface and the remaining 25% settles down on oceans' surface [1]. The frequency of the dust storms' occurrence in a region depends on factors like the high wind speed, soil with no vegetative cover [2], dry climatic conditions [3], soil moisture, local and external weather system, short-term rainfalls, extents of deforestations, long-term droughts, land use changes and human activities [4].

Iran is constantly exposed to numerous local and regional dust systems for its being located on an arid and semi-arid belt in the world [5]. Raeispour [6] and Tavousi et al. [7] investigated the dust storms in Khuzestan province in synoptic and statistical methods and reported an ascending trend for them. The statistical examination of the dust phenomenon by Mehrshahi [8] in Sabzevar County showed that the dust phenomenon has had an ascending trend in this country in the northeast of Iran and it has taken place during afternoon hours in 71% of the cases. In a study under the title of tracking dust phenomenon in the western half of Iran, Azizi [9], analyzed the annual and monthly time series trends of this phenomenon and introduced Dezful and Bushehr as the two critical centers of dust in this region. He concluded that the border region between Syria and Iraq and between the west and southwest of Iraq were respectively two primary centers of dust generation in the studied region. Montazeri [10] investigated the changes' trend of the days with dust in Bushehr's synoptic station using Mann-Kendall non-parametric test and proved the existence of an ascending trend in all of the months except June and even in a yearly scale. Babayi Fini et al. [11] investigated the dust occurrence in the west of Iran in spatial and temporal terms and showed in a 95% confidence level that there was an ascending trend in some stations (Arak and Khorramabad) and descending trend in some other stations (Ghazvin and Khorram Dareh). Yarahmadi [12] proved the precipitation reduction as well as increase in temperature, wind speed and dusty days in the western half and southwest of Iran in a research entitled the effect of climatic fluctuations on the occurrence of dust phenomena.

Jazmorian Basin is situated in the southeast of Iran between Kerman and Sistan and Baluchestan Provinces, which has currently become completely dried and transformed into a desert due to the drought and not being allocating a water right from the upstream dams [13, 14]. In terms of accuracy in detection and temporal and spatial extent, aerosol optical depth (AOD) enables the time- and space-based monitoring in a vast extent of land. Various studies have been conducted using this method, including the researches by Rashki et al. [15, 16], Namdari et al. [17], Alam et al. [18] and Kaskaoutis et al. [19].

Within the format of a comprehensive study, the current research intended to investigate the changes trend of aerosol optical depth (AOD) time series based on a monthly scale in Jazmorian Basin in the southeast of Iran using the remotely sensed satellite data. According to which, a better knowledge could be acquired regarding the environmental changes in this section of Iran.

2. STUDY REGION

Jazmorian Basin is stretched in a land about 69600 square kilometers in the southeast of Iran between 26º 28' and 29º 30' of the northern latitude and between 56º 15' and 61º 23' of the eastern longitude. The western half of this basin is some 35600 square kilometers in area and it is positioned in Kerman Province and its eastern half is 34000 square kilometers in area and is located in Sistan and Baluchestan Province [20].

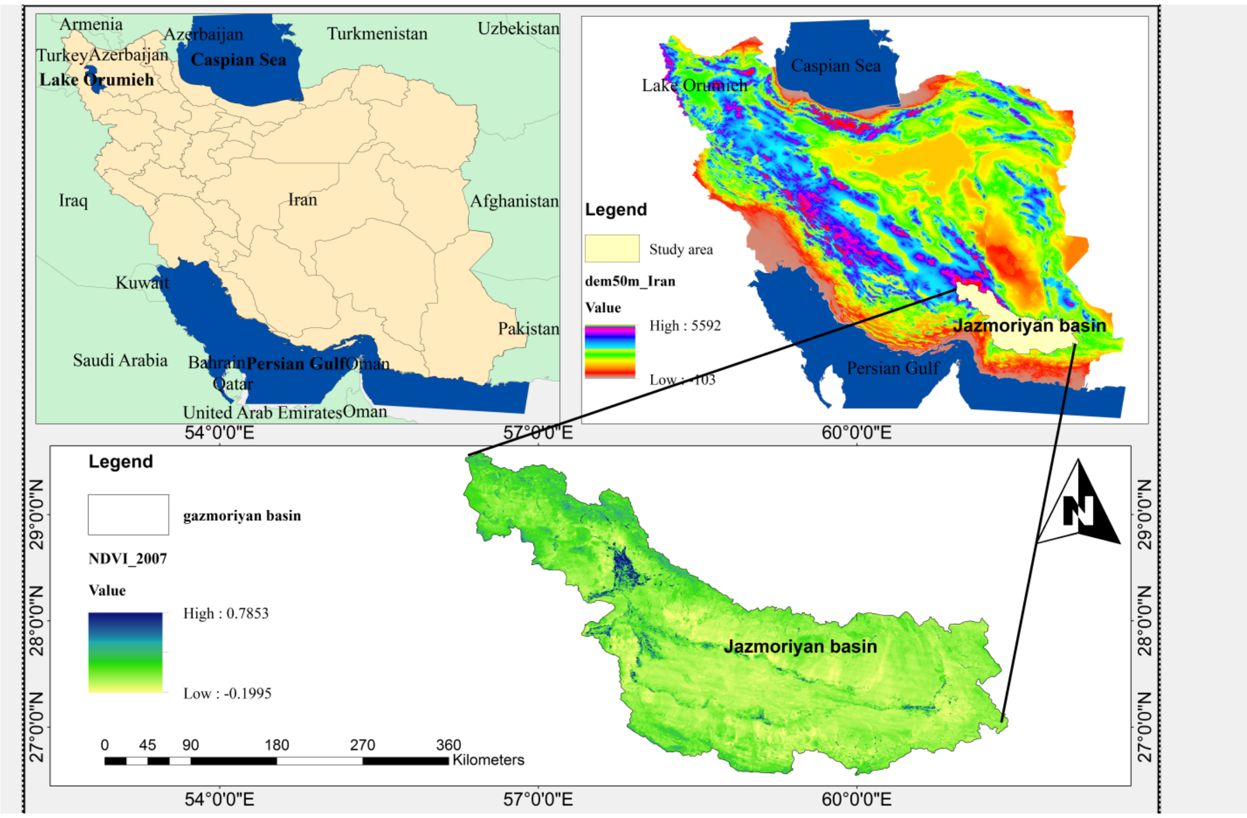


Figure 1. Geographical position of Jazmorian Basin in Southeast of Iran

The water from all the rivers and dry rivers in this basin pours entirely into Jazmorian wetland (Lake) in the center of the basin. Two permanent rivers of Halil River and Bampour perform a large part of the basin's drainage. In addition to these two rivers, there are several floodways, as well, the water of which directly flows into Wetland Jazmorian.

Although Jazmorian Basin is hydrologically considered as a part of Iran's central watershed area, it climatically features exceptional conditions different from Iran's central regions for its reception of a massive deal of its relative humidity from Oman Sea. Due to the same reason, the basin possesses appropriate facilities in terms of repair, reconstruction and exploitation of renewable natural resources. It is not at all comparable with the other basins in central Iran due to its limited reception of atmospheric precipitations and intolerable heat and very high annual evaporation (over 4500mm in some regions).

Based on the latest census estimations in 2006, Jazmorian Basin accommodates a population of 933514 people out of whom 38.4%, 358528 individuals live in urban regions and 61.6%, 574986 individuals live in rural districts [20].

3. DATA AND METHODOLOGY

Due to having access to the entire spots in a region, the dust data obtained from satellite images are important scales for investigating the spatial and temporal distribution of the dust [21]. For the same reason, monthly aerosol optical depth (AOD) data from MODIS sensor of Terra Satellite was used for the region between 28º and 30º of the northern latitude and between 56º and 62º of the eastern longitude for an 18-year period (2000-2017). These data are downloadable from Google Earth Engine database at https://earthengine.google.com. This index is one of the most important parameters for studying the dust phenomena. In fact, aerosol optical depth (AOD) refers to the distribution of aerosols existent in atmosphere. This quantity depends on wavelength and is defined in the form of light reduction per every unit length on a given path. The optical depth amount can differ with the density of the aerosols and the properties of the particles. The optical depth changes range from 0.1 to 0.2 for clear continental air and from 0.1 to 0.5 for clear oceanic air. The AOD values above the aforesaid amounts are reflective of the density of suspended particles along the vertical air columns [21].

After preparing the monthly time series of aerosol optical depth (AOD) in separate for all the twelve studied months of the studied region, classical linear regression [22] was utilized for investigating the changes trend of aerosol optical depth (AOD).

The general form of the classical linear regression equation is the relation (1) in which y is the output variable, $x_1, x_2, \ldots, x_n$ are the input variables, and $a_0, a_1, \ldots, a_n$ are the coefficients of the equation.

$$y = a_0 + a_1 x_1 + \ldots + a_n x_n \tag{1}$$

Relationship (2) is a univariate mode of classical linear regression that is used in this study.

$$y = a_0 + a_1 x \tag{2}$$

Suppose a set of pairs of observational variables is available in the form of $(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)$. Generally, by minimizing the sum of squares errors between observational and computational data which relation is in the form of $\sum_{i=1}^{n}[y_i - (a_0 + a_x x_1)]$, the equation coefficients (i.e., a_0 and a_1) are calculated as follows.

$$a_1 = \frac{m\sum_{i=1}^{m} x_i y_i - \sum_{i=1}^{m} x_i \sum_{i=1}^{m} y_i}{m\sum_{i=1}^{m} x_i^2 - \left(\sum_{i=1}^{m} x_i\right)^2} \tag{3}$$

$$a_0 = \frac{\sum_{i=1}^{m} y_i - a_1 \sum_{i=1}^{m} x_i}{m} \tag{4}$$

3. RESULTS

The monthly mean aerosol optical depth (AOD) was calculated based on the data of MODIS sensor of Terra Satellite for an 18-year period from 2000 to 2017 for Jazmorian Basin (figure 2). The results indicated in seasonal scale that the lowest and the highest AOD values have been documented for winter and summer, respectively. In monthly scale, as well, the lowest and the highest AOD values belonged to December and July with values respectively equal to 0.33 and 0.6 (figure 2). Thus, summer and July were the dustiest season and month in comparison to the other seasons and months. Normally, the reasons for the high rate of AOD during the hot half of the year could be attributed to the dry nature of climate, high temperature and severe precipitation shortage.

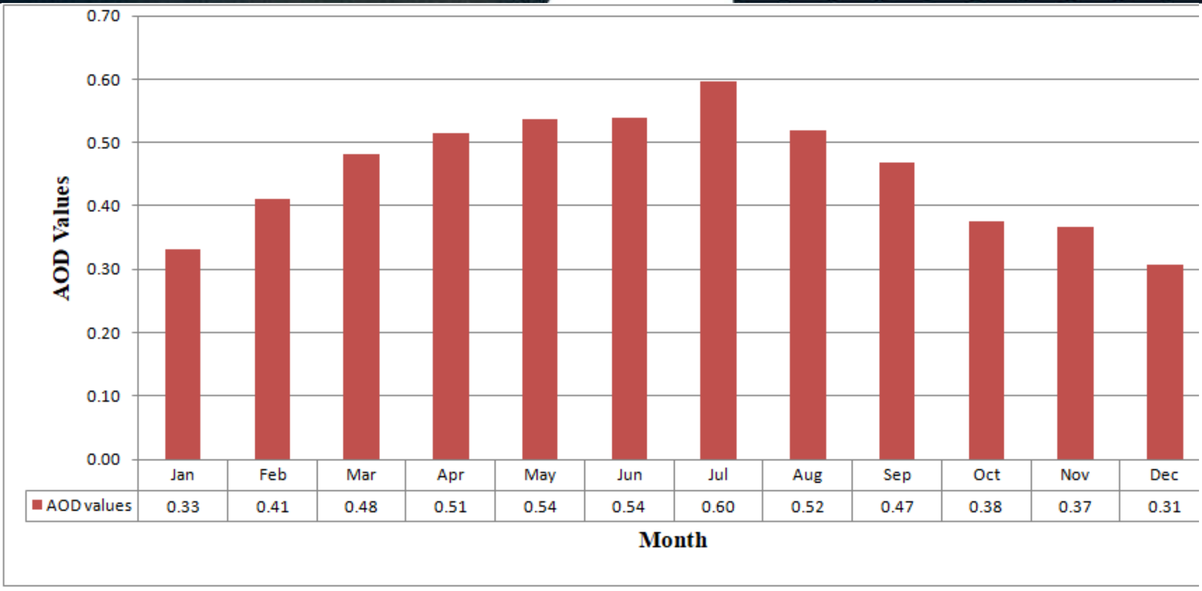


Figure 2. The diagram of the monthly mean changes of aerosol optical depth (AOD) in Jazmorian Basin (2000-2017)

Figure (3) displays the year-to-year time series data of AOD changes for the entire study period. As it is observed in this diagram, the values of this index highly differed from a month to another in such a way that the highest and the lowest amounts of this index had been recorded for March, 2012, and January, 2002, with values respectively equal to 0.792 and 0.16. Furthermore, a very mild ascending trend could also be visually sensed in the time series data obtained for this index.

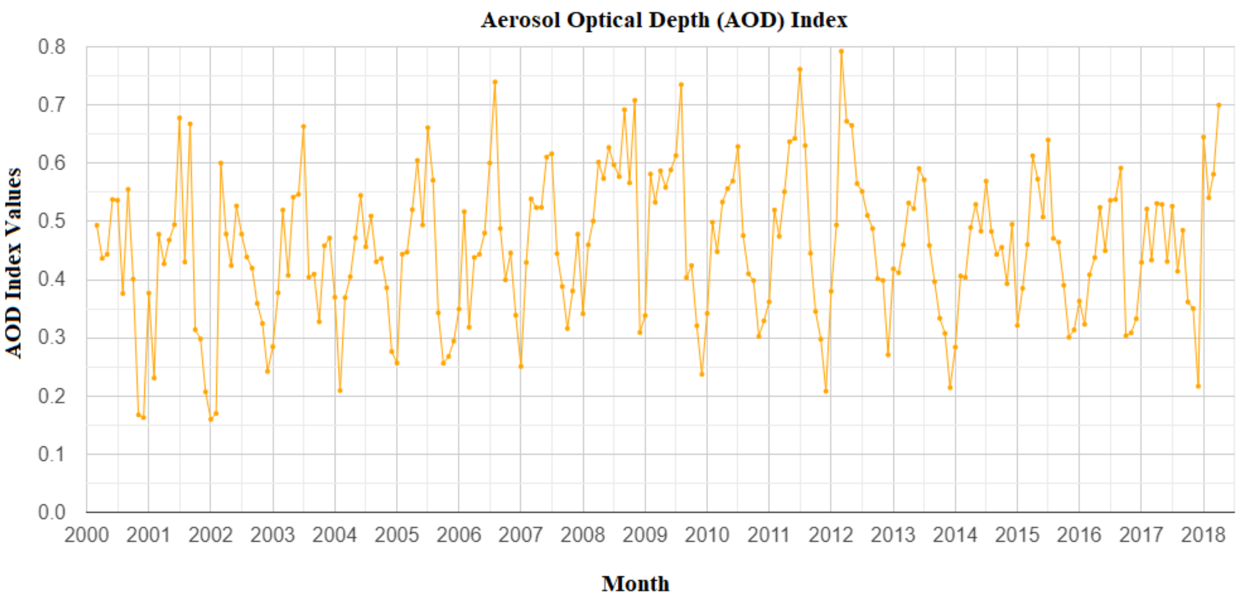


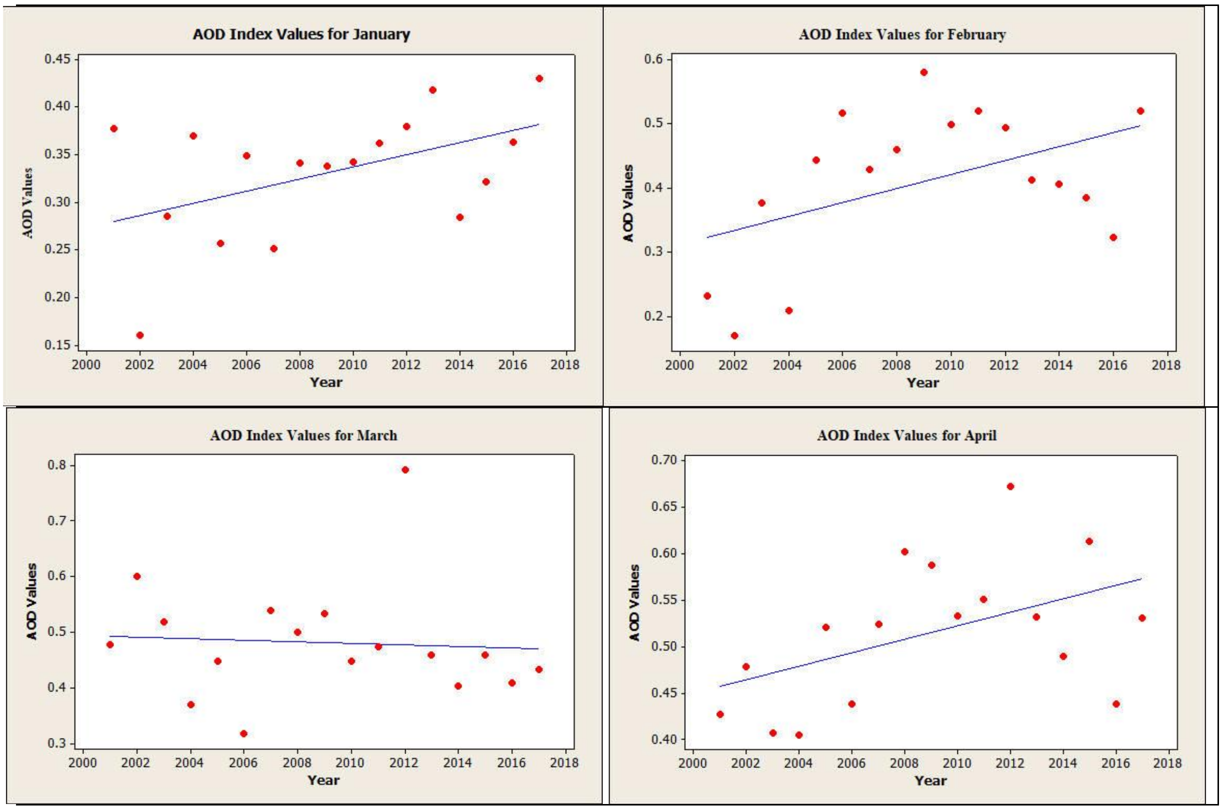
Figure 3. Monthly time series of aerosol optical depth (AOD) for Jazmorian Basin (2000-2017)

To perform a more precise investigation of the long-term changes' trends of aerosol optical depth (AOD) in Jazmorian Basin, time series data were prepared in separate and the corresponding changes' trends were examined using classical linear regression. The regression equations of each month and their significance levels have been summarized in table (1). As it can be seen in the table, the aerosol optical depth (AOD) changes' trend has only been significant in the probability level of α=0.05 in January, whose progress was ascending. In addition, the AOD changes' trends were also found significant for February, April and May, whose probability level was α=0.1. The AOD changes of these three months are also reflective of ascending trends. Disregarding these four months, no significant trends were evidenced for Jazmorian Basin in terms of AOD in the other studied months.

Table 1. Equations of change trends of aerosol optical depth (AOD) index along with their significant level

Month	Regression equation	Significant level
January		**0.05**
February		**0.06**
March		**0.79**
April		**0.06**
May		**0.09**
June		**0.47**
July		**0.72**
August		**0.99**
September		**0.93**
October		**0.66**
November		**0.60**
December		**0.93**

After determining the ascending or descending trends of the monthly time series data of AOD index for all the twelve studied months, it was made clear that the steepest slopes of changes with values equal to 0.0109, 0.00721 and 0.00635, respectively, belonged to February, April and January (table 1 and figure 4). The reason for this ascending trend, as documented in the results of the studies by Arjmand et al. [21], can be the drying of Jazmorian Lake as a result of the construction of numerous dams, including Jiroft Dam on Halil River and Bampour on Bampour River. August, December and September were also the three months during which the changes' gradient was very trivial. Figure (4) vividly illustrates the diagrams related to these three months.



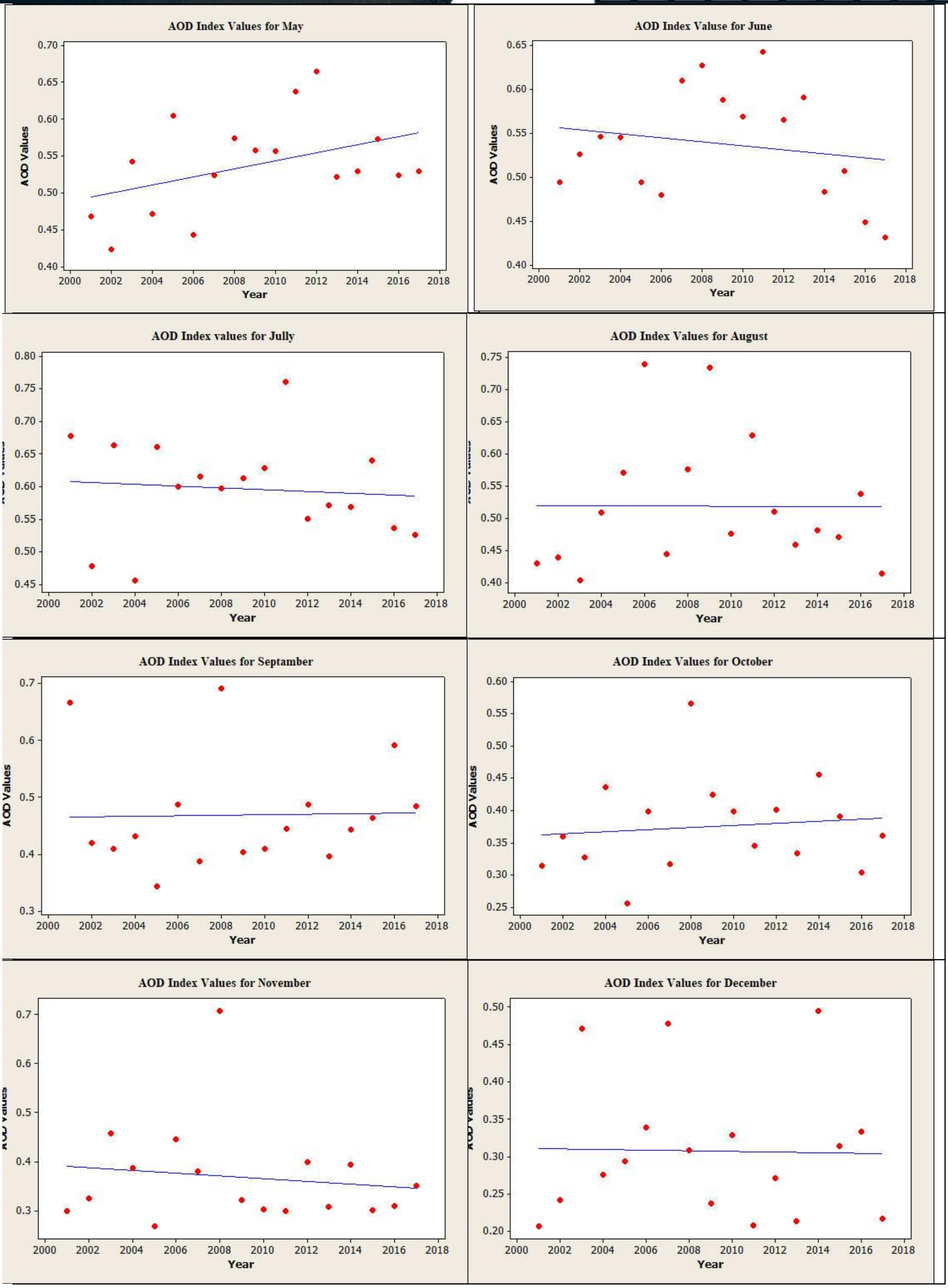


Figure 4. The slopes of aerosol optical depth (AOD) changes' trends in separate for all twelve months of the year (2000-2017)

4. Conclusions

In the present study, the time series changes' trend of aerosol optical depth (AOD) was investigated in a monthly scale for Jazmorian Basin in the southeast of Iran using the remotely sensed satellite data. The study results indicated that on a monthly basis, the AOD values have been ascending and significant only for January in the probability level of α=0.05. Additionally, the AOD values were also found ascending for February, April and May, but in a probability level of α=0.1. Putting these four months aside, no significant trend was found for the other studied months in terms of aerosol optical depth (AOD).

The changes' trend of AOD values for cold months of the year can be a sign of severe environmental changes in Jazmorian Basin. Desertification and land degradation as a result of long-lasting droughts, drying of Jazmorian lagoon, improper water resources management and construction of numerous dams without paying attention to the ecological needs of the basin and climate change can be the possible reasons for this ascending trend of AOD during the cold seasons of the year. Thus, it is necessary to exactly and comprehensively study land degradation and desertification in this basin in line with its recreation and renovation.

6. References

1. Huang, M., G. Peng., J. Zhang., and Sh. Zhang, Application of artificial neural networks to the prediction of dust storms in Northwest China. Global and Planetary Change, 2006. 52(1-4).
2. Mei, D., L. Xiushan., S. Lin., and W. Ping, A Dust-Storm Process Dynamic Monitoring With Multi-Temporal MODIS Data. Proc. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2008. XXXVII (Part B7).
3. Qu, J. J., X. Hao., M. Kafatos., and L. Wang, Asian dust storm monitoring combining Terra and Aqua MODIS SRB measurements. IEEE Geosciences and Remote Sensing letters, 2006. 3(4).
4. Shao, Y., K. H. Wyrwoll., A. Chappell., J. Huang., Z. Lin., G. H. McTainsh., Mikami, M., T. Y. Tanaka., X. Wang., S. Yoon, Dust cycle: An emerging core theme in Earth system science. Aeolian Research, 2011. 2(4).
5. Rashki, A., D. G. Kaskaoutis., A. S. Goudie., and R. A. Khan, Dryness of ephemeral lakes and consequences for dust activity: The case of the Hamoun drainage basin, southeastern Iran. Science of The Total Environment, 2014. 463(1).
6. Raispoor, K, Statistical and synoptical analysis of dust phenomena in Khouzistan province. Msc thasis, University of Sistan and Baluchestan, 2008. (In Persian)
7. Tavousi, T., M. Khosravi., and K. Raispoor, Statistical Analysis of Dust Phenomenon in Khuzestan Province In During Period (1996- 2005). NIVAR, 2012. 74-75. (In Persian)
8. Mehrshahi, D., and Z. Nekounam, Statistical survey dust storms and analysis of windinduced dust regimes in Sabzevar. Geography, 2009. 7(22). (In Persian).
9. Azizi, G., M. Miri., and S. O. Nabavi, Detection of dust phenomena in the westwen half of Iran. Arid Regions Geographic Studies, 2012. 7(2). (In Persian)
10. Montazeri, M., and L. Dadkhah, Change of days with dust in the synoptic station in Bushehr. Geographical Data (SEPEHR), 2013. 22(86). (In Persian)
11. babaee Fini, O., T. Safarrad., and M. Karimi, Spatial-Temporal Analysis of Dust Storm Occurrence in West of Iran. Journal of Environmental Studies, 2014. 40(70). (In Persian)
12. Yarahmadi, D., A. Khoshkish, Zoning dust phenomena in west Iran The period from 1990 to 2009. Journal of Applied Researches in Geographical Sciences, 2014. 13(31). (In Persian)
13. Mohammadi, A., Sedimentology and sedimentary geochemistry of Jazmurian playa. Arid Biome, 2010. 1(1). (In Persian)
14. Kardan, R., G. Azizi., P. Zawar-Reza., and H. Mohammadi, Modeling the Influence of Water Body in Surrounding Areas (Case Study: Climatic Modeling of Jazmoorian Watershed by Creation of Assumptive lake). Iranian Journal of Watershed Management Science, 2009. 3 (7). (In Persian)
15. Rashki, A., D. G. Kaskaoutis., P. G. Eriksson., C. D. W. Rautenbach., C. Flamant., and F. A. Vishkaee., Spatio-temporal variability of dust aerosols over the Sistan region in Iran based on satellite observations. Natural hazards, 2014. 71(1).

16. Rashki, A., D. G. Kaskaoutis., P. Francois., P. G. Kosmopoulos., and M. Legrand., Dust-storm dynamics over Sistan region, Iran: seasonality, transport characteristics and affected areas. Aeolian Research, 2015.16.
17. Namdari, S., K. K. Valizade., A. A. Rasuly., and B. S. Sarraf, B. S., Spatio-temporal analysis of MODIS AOD over western part of Iran.Arabian Journal of Geosciences, 2016. 9(3).
18. Alam, K., S. Qureshi., and T. Blaschke., Monitoring spatio-temporal aerosol patterns over Pakistan based on MODIS, TOMS and MISR satellite data and a HYSPLIT model. Atmospheric Environment, 2011. 45(27).
19. Kaskaoutis, D. G., P. Kosmopoulos., H. D. Kambezidis., and P. T. Nastos., Aerosol climatology and discrimination of different types over Athens, Greece, based on MODIS data. Atmospheric Environment, 2007. 41(34).
20. https://fa.wikipedia.org/wiki/%D9%87%D8%A7%D9%85%D9%88%D9%86_%D8%AC%D8%A7%D8%B2%D9%85%D9%88%D8%B1%DB%8C%D8%A7%D9%86
21. Arjmand, M., A. Rashki., H. Sargazi., Monitoring of spatial and temporal variability of desert dust over the Hamoun e Jazmurian, Southeast of Iran based on the Satellite Data. Geographical Data, 2017. 27(106).
22. Mahmoudi, P., M. Mohammadi., and H. Daneshmand., Investigating the trend of average changes of annual temperatures in Iran. International Journal of Environmental Science and Technology, 2019. 16(2).