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Application of Data Envelopment Analysis Method to Study the Dust Phenomenon in Lorestan Province

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Abstract
Dust storm is one of the environmental threats in arid and semi-arid regions of the world like Iran which causes serious damages in these areas. Lorestan province is one of the most vulnerable western provinces exposed to dust storm. In this study, climatic parameters includes precipitation, temperature, the maximum wind speed and predominant wind direction were collected from 5 meteorological stations (Khorramabad, Borujerd, Aligudarz, Nurabad and Pol dokhtar) on the basis of monthly and annually scale during 10 years (2001-2010) and thirty dust storm systems were selected as indicator. Then, the correlation between climatic parameters and dust storms was analyzed by Data Envelopment Analysis (DEA) method. The results showed that the maximum and minimum numbers of dusty days in the study area were in 2008 and 2003, respectively. Also, Peak of dust storm frequency was recorded in July which is highly related to temperature in semi-arid climate including Lorestan province. The DEA method along with the window analysis showed that at some of the stations examined, over time the viewing angle was lower with the passage of time and in some other places was more, the viewing angles had not changed in some stations. It was also found that the average temperature index was the most sensitive index. It is concluded that by moving from the western to the eastern parts of Lorestan province by increasing distance from neighbor countries, local dust sources has become more important than foreign sources and dust storm intensity decreased.

Keywords: Dust storm; Climatic parameters; Data Envelopment Analysis; Iran; Lorestan Province.

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Introduction

Nowadays dust storm is one of the most important environmental threats in arid and semi-arid regions of world. People have been naturally affected by airborne dust during previous years and have adapted themselves to it but the intensity of this problem as an environmental hazard has increased dramatically for residents of cities and villages during two recent decades [1]. Dust generally consists of 0.05-0.1 mm atmospheric particles can be transported thousands of kilometers at high altitude from surface ground and even effects on all cities of a country or even all countries of a continent [2]. Dust storms impact on animals and plants as severe as humans. For instant, hardening of stones, coral reefs devastating, plant growth inhibition and fruit set disorder, decreasing agricultural yield and livestock products also, reduction of sunny hours per day are environmental consequences of dust. The most serious anthropogenic impacts of dust includes air pollution, asthma occurrence and other respiration disorder, business failures, machinery problems, water pollution and digestive diseases [3]; [4]. Sahara desert, the vast desert area that covers the western parts of Mali, southern part of Algeria and eastern part of Mauritania are the main dust hotspots [5]. The western and southwestern provinces of Iran like Khuzestan, Ilam, Kermanshah and Lorestan have been largely affected by dust transported from deserts located in the northwest of Iraq, the west of Syria and the east and southeast of Saudi Arabia. Dried parts of Huge Lagoon (Huralazim) near Iran-Iraq border and lagoons of Khuzestan are indoor sources of dust in Iran [6]. Dust storms mainly occur in spring and summer and sometimes with less intense in fall and winter. The main factor in dust borne is wind speed. As wind speed increases over erosion threshold speed, significant amount of particles arise from deserts and arid regions to the atmosphere and cause lots of problems for adjust areas [7]. For example, in 2011, it was estimated that beekeepers were damaged more than 140 million Rials in Lorestan province by dust impacts [6]. Occurrence of dust storm is closely related to the climatic conditions of the area such as precipitation, temperature and also vegetative coverage and soil texture [8]. Therefore, it is necessary to investigate the relationship between climatic conditions and dust storm occurrence as an important environmental threat. Environmental assessment by Data Envelopment Analysis (DEA) as non-parametric method is used to evaluate date functions in most procedures. The DEA method was originally introduced by Charnes et al. [9] then developed by Banker et al. [10]. This method has been widely used in assessing the relative efficiency of industrial departments. The advantage of the DEA method is that the input and output variables can have large dimensions and there is no need to know the relationship between the variables in the model. However, an important hypothesis in the traditional DEA model is that the output variables should have a positive profit index and very strong attributes [11]. Huan et al. [12] used the three-step DEA model to evaluate the performance of CO_2 in each region in China country. Hernandez et al. [13] used the non-radial DEA method to analyze energy efficiency indices for sampling wastewater treatment machines in Spain and potential savings in economic conditions and carbon emission to improve its efficiency and Zhu et al. [14] in their research, studied DEA along with the environmental effects of products for environmental assessment, and found that the network DEA method could show the environmental productivity differences of products in different stages. If dust borne and transport processes and find out the factors eliminating its impacts. Some researchers illustrated that high temperature, low precipitation, poor vegetation and high speed winds provide substrate for happening dust storm [15]; [16] found that dust borne is affected by climatic conditions, ground vegetation and soil moisture [16]. Cheng and Feng. [17] in the research regarding "numerical simulation and synoptic analysis of dust emission and transport in East Asia" showed that a dust storm may develop when a synoptic system moves to deserts of the northeast Asia with a surface wind speed exceeding 6 m s^{-1}. Liu and Park [18] studied impacts of dust storms on air pollution in large cities like China. Meshat and Avad [19] by studying effects of synoptic patterns on numbers of dusty days identified two different meteorological systems (high and low pressure) in the western and southern parts of Saudi Arabia. Sang et al. [20] by surveying the temporal and spatial changes of springtime dust storm in the northern China found that the maximum numbers of dust storms occur in deserts of study area. They also showed that dust diffusion decreased in spring. Alijani [21] expressed Khuzestan has more than fifty dusty days annually by plotting the temporal and spatial maps of dust in Iran. Studies of Farajzadeh and Alizadeh [22] showed that Zabol station had the maximum numbers of dusty days. They reported that the maximum and minimum numbers of dusty days were recorded in June and December, respectively. Ansari Renani [2] investigated the correlation of dust storm with different climatic parameters and found that the maximum and minimum correlation of dust borne were observed with wind speed and humidity, respectively. Yarahmadi et al. [23] studied the effects of meteorological changes on dust storm in the western and southern parts of Iran and found that numbers of dusty days increase in recent years by decreasing precipitation and enhancing temperature and wind speed by studying on chronological changes of dust storms in Khorramabad reported that of dust storm is increasing dramatically at Khorramabad station and happening in nearly all months of year and all seasons except winter [24]. Considering the importance of dust storm phenomenon and also limited studies about it in Lorestan province, the present study was conducted to investigate the relationship between climatic parameters and dust occurrence by DEA method in Lorestan province as one of the most susceptible provinces to dust borne.

Materials and Methods (Study area)

The study area located in Lorestan province (east of 46° 51′ to 50° 30′ longitude and north of 32° 37′ to 34° 22′ latitude), situated in the western part of Iran with a total area of 28559 km^2 (Fig. 1). Lorestan has 4 different seasons meteorologically, diversity in seasons is observed from the north to the south and the west to the east as cold snowy weather in north and mild rainy weather in south happen simultaneously. Recorded difference of the maximum and minimum absolute temperature in different cities of Lorestan reaches more than 80 ºC. The maximum and minimum absolute temperature in Lorestan were recorded 47.4 ºC and -36 ºC, respectively. Lorestan has the third place after Gilan and Mazandaran in annual precipitation with 550 mm of rainfall equivalent annually. The population of Lorestan was estimated at 1,754,243 people in 9 cities in 2011 (www.amar.org.ir).

Fig 1. Situation of Lorestan province

Meteorological stations

Four different climatic parameters including precipitation, temperature, the maximum wind speed and predominant wind direction were selected from 5 synoptic meteorological stations due to their most important role in causing dust phenomenon. The stations were selected based on covering the entire province. The geographical characteristics of the meteorological stations was shown in Table 1.

Data analysis

Considering the fact that decreasing precipitation and enhancing temperature increase susceptibility of dust particles to lift from dried soils by wind. After selecting the station and obtaining climatic parameters information from the General Meteorological Office of Iran, the annual and seasonal trends of four parameters of temperature, precipitation, the maximum wind speed and predominant wind direction were investigated using Excell 2016 software. Then DoMarton dryness coefficient was calculated using Formula 1 and annual climate was determined based on Table 2 for each station. Eventually, final model for dust storm analysis was presented using DEA method.

$$I = \frac{P}{T+10} \qquad (1)$$

Formula 1 as:
Where I = dryness coefficient, P = annual precipitation, and T = annual temperature.

The DEA model

The data envelopment analysis method is a non-parametric method for calculating the performance of the data. The Data envelopment analysis models are divided into two categories input-oriented or output-oriented. In this research, the output-oriented multiple BCC model was used to evaluate the performance of Decision-Making Units (DMU). The calculation process is as follows:

$$\begin{aligned} & Min\ \sum_{i=1}^{m} v_i x_{io} - v_o \\ & \text{S.T}\ \ \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + v_o \le 0 \quad \forall j \qquad \text{(Model 1)} \\ & \sum_{r=1}^{s} u_r y_{ro} = 1 \end{aligned}$$

Table 1. The longitude and latitude of synoptic stations in the study area

Station	Longitude (degree)	Latitude (degree)	Altitude (meter)
Khorramabad	48.17	33.26	1147
Borujerd	48.45	33.55	1629
Aligudarz	49.42	33.24	2022
Nurabad	48.00	34.30	1851
Pol dokhtar	47.43	33.90	713

Table 2. Climate classification based on DoMarton method

DoMarton dryness coefficient	Climate
<10	Dry
10-19.9	Semi-arid
20-23.9	Mediterranean
24-27.9	Sub-humid
28-34.9	Wet
>35	Very wet

Where n is the number of DMUs whose performance is computed (j = 1, 2, ..., n), x_{ij} are inputs and y_{rj} are outputs of the model. It should be noted that the BCC model used in this study was accompanied by a window analysis. A window analysis examines the efficiency changes of the units under evaluation over a given time period. This kind of analysis is useful when the number of evaluation units is low compared to the number of indicators. In a window analysis, each DMU in each year is assumed as one DMU. This analysis is as follows:

$$W = k-p + 1, np \quad (2)$$

Where n is the number of DMUs, p, the length of the window (p≤k), np the number of units under evaluation in each window, k the number of periods of time examined and w represents the number of windows.

Results and Discussion

Investigation periodic changes of dust occurrence in the study area

To investigate the state of dust all around the province, statistics of dusty days were collected from Iran Meteorological Organization during the 10-year period. Dusty day mean the day abounding with dust as horizontal visibility becomes below 10 km and wind speed reaches to 15 m s^{-1} or even more [8]. Accordingly, thirty effective dust systems with less horizontal visibility is brought in Table 3. Collected data in Table 3 illustrated that numbers of dusty days dramatically increased during 2006-2008 and reached to the maximum days (70 days per year) in 2008. A decreasing trend in the numbers of dusty days was observed during 2008-2010. During 2001-2005, the numbers of dusty days was negligible and the minimum days with dust phenomenon (3 days per year) was recorded in 2003. Also, the maximum and minimum numbers of dust occurrence were recorded in June and February, respectively. Actually, soil particles become more susceptible to suspend in the atmosphere as air humidity and soil moisture decrease and wind speed increases in summer [6]. Because of instability conditions of the north deserts of Sahara in Saudi Arabia, the southern parts of Iraq and the western parts of Syria, main dust hotspots are located in Iraq, Kuwait, Syria, the northeast of Persian gulf, and the north of Saudi Arabia which cause dust particles to lift and transfer to the southwestern provinces of Iran like Lorestan [8]. Therefore, Pol dokhtar in the west and Aligudarz in the east part of Lorestan had the highest and lowest dust occurrence, respectively. Due to the geographic characteristics of the stations (Table 1), it seems that with increasing altitude, the numbers of dust occurrence has decreased.

Table 3. Predominant dust systems in Lorestan province during a 10-year period

Number	Year	Month	Horizontal view (meter)	Number of days
1	2001	May	4000	2
2	2001	July	3000	3
3	2002	June	5000	3
4	2002	July	4000	5
5	2003	May	600	3
6	2004	August	1500	5
7	2004	July	4000	3
8	2005	March	4000	2
9	2005	April	300	2
10	2006	May	5000	3
11	2006	July	2500	9
12	2006	July	2000	8
13	2007	March	2000	4
14	2007	April	2500	4
15	2007	June	4000	4
16	2007	July	1000	4
17	2007	July	3000	۵5
18	2008	February	400	4
19	2008	March	2000	6
20	2008	April	300	8
21	2008	May	4000	7
22	2008	June	500	15
23	2008	July	200	15
24	2008	July	1000	15
25	2009	August	5000	10
26	2009	September	2000	7
27	2009	July	1000	8
28	2010	September	2000	9
29	2010	June	2500	4
30	2010	August	5000	4

Average annual amount of climatic parameters at the study stations

Average amount of climatic parameters (precipitation, temperature, the maximum wind speed and predominant wind direction) recorded during 10 years at five meteorological stations (including Khorramabad, Borujerd, Aligudarz, Nurabad, and Pol dokhtar) are shown in Fig 2. Data illustrated that while temperature trend was uniform at all study stations, precipitation trend had fluctuation during 10 years. It is observed that the minimum precipitation and the maximum dusty days were recorded in 2008. Abdoveis et al. [27] by investigating effects of precipitation on dust borne in Khuzestan province indicated that dust occurred in longer period of time during years with the lowest recorded precipitation. Mehrabi et al. [8] found the same results in research in Khuzestan province. Statistical data showed that predominant wind direction during 10 years at Khorramabad, Borujerd, Aligudarz, Nurabad, and Pol dokhtar stations were recorded 216, 189, 170, 189, and 155 degree, respectively. Therefore, wind direction changed from 130 to 250 degree [Average wind directions in Fig 2 divided on 10 based on results showed by Mehrabi et al. [8]]. Average wind direction in 2008 with the maximum numbers of dusty days was 188 degree which representing that dust hotspot was indoor, mainly came from

Khuzestan province (The South). Average wind speeds during 10 years were 23, 34, 30, 35, and 26 m s^{-1} at Khorramabad, Borujerd, Aligudarz, Nurabad, and Pol dokhtar stations, respectively which were upper the threshold speed (15 m s^{-1}) at all study stations. Average wind speed in 2008 with the maximum numbers of dusty days during a 10-year period was recorded 31 m s^{-1} which was upper the threshold speed.

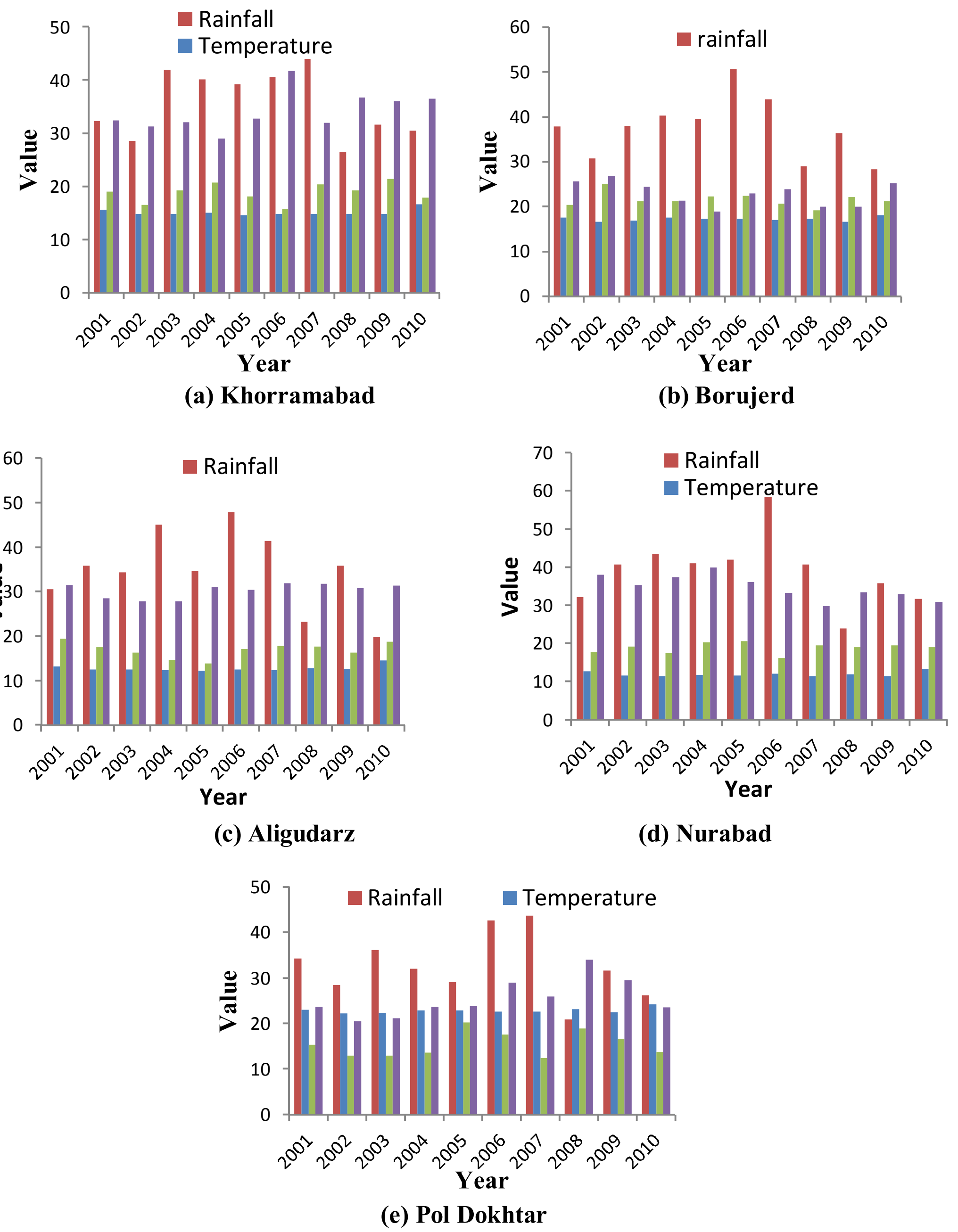

Fig 2. Average annual climatic parameters at a) Khorramabad, b) Borujerd, c) Aligudarz, d) Nurabad, and e) Pol dokhtar stations

Average amount of climatic parameters during season at the study stations

Average amount of climatic parameters including precipitation, temperature, the maximum wind speed and direction of predominant wind during season at the study stations are shown in Fig 3. The minimum precipitations at all stations were recorded in summer that showed significant difference with other seasons. It is concluded that the minimum precipitation and the maximum temperature had positive correlation with the maximum numbers of dusty days. Therefore, inner parts of Lorestan and near provinces like Khuzestan were defined as dust hotspots in summer because of decreasing soil moisture enhances ability of soil particles to transfer [8]. So dust storms entered into Khuzestan province, located in the southwest of Lorestan province, intensified in dried lagoons of Khuzestan and the western and eastern parts of Karkhe River and moved indoor dust particles to other regions [7]. Average wind directions at Khorramabad station during a 10-year period were recorded 213, 245, 198, and 201 degree in spring, summer, fall and winter, respectively. The direction of predominant wind at Khorramabad station was the southwest. Average wind directions in spring, summer, fall and winter were 213, 153, 195, and 191 degree, respectively at Borujerd and 187, 122, 194, and 174 degree at Aligudarz stations. Average wind direction were 188 degree (with the south direction) at Borujerd and 169 degree (with the southeast direction) at Aligudarz stations for all seasons. Average wind directions measured in spring, summer, fall and winter were 196, 206, 178, and 179 degree at Nurabad and 162, 229, 112, and 117 degree at Pol dokhtar stations, respectively. Average wind directions were 190 (the southwest) and 155 (the southeast) degree for all season at Nurabad and Pol dokhtar stations, respectively. Direction of predominant wind in summer (with the maximum numbers of dusty days) was 191 degree representing the wind blew toward the southwest. The maximum wind speed were recorded at Khorramabad (26 m s^{-1}), Borujerd (34 m s^{-1}), Aligudarz (33 m s^{-1}), Nurabad (40 m s^{-1}), and Pol dokhtar (27 m s^{-1}) in spring, spring, winter, winter and spring, respectively. It is highly important that seasons with the maximum wind speed (spring and winter) were not the same as season with the maximum numbers of dusty days (summer) in Lorestan province. Farajzadeh and Razi [25] by investigating spatial and temporal distribution of storms and severe winds in Iran showed that there was not significant correlation between average wind speed and numbers of dust storm occurrence. So stations with high numbers of dust storm occurrence did not have high wind speed. There are different methods for determining climate [26]. DoMarton method is one of the most valid ones based on annual average precipitation and temperature (Formula 1). DoMarton believed that as the amount of evaporation relates to average temperature, climate can be determined by calculating dryness coefficient (Table 2). Climate classification during a 10-year period based on DoMarten is brought in Table 4.

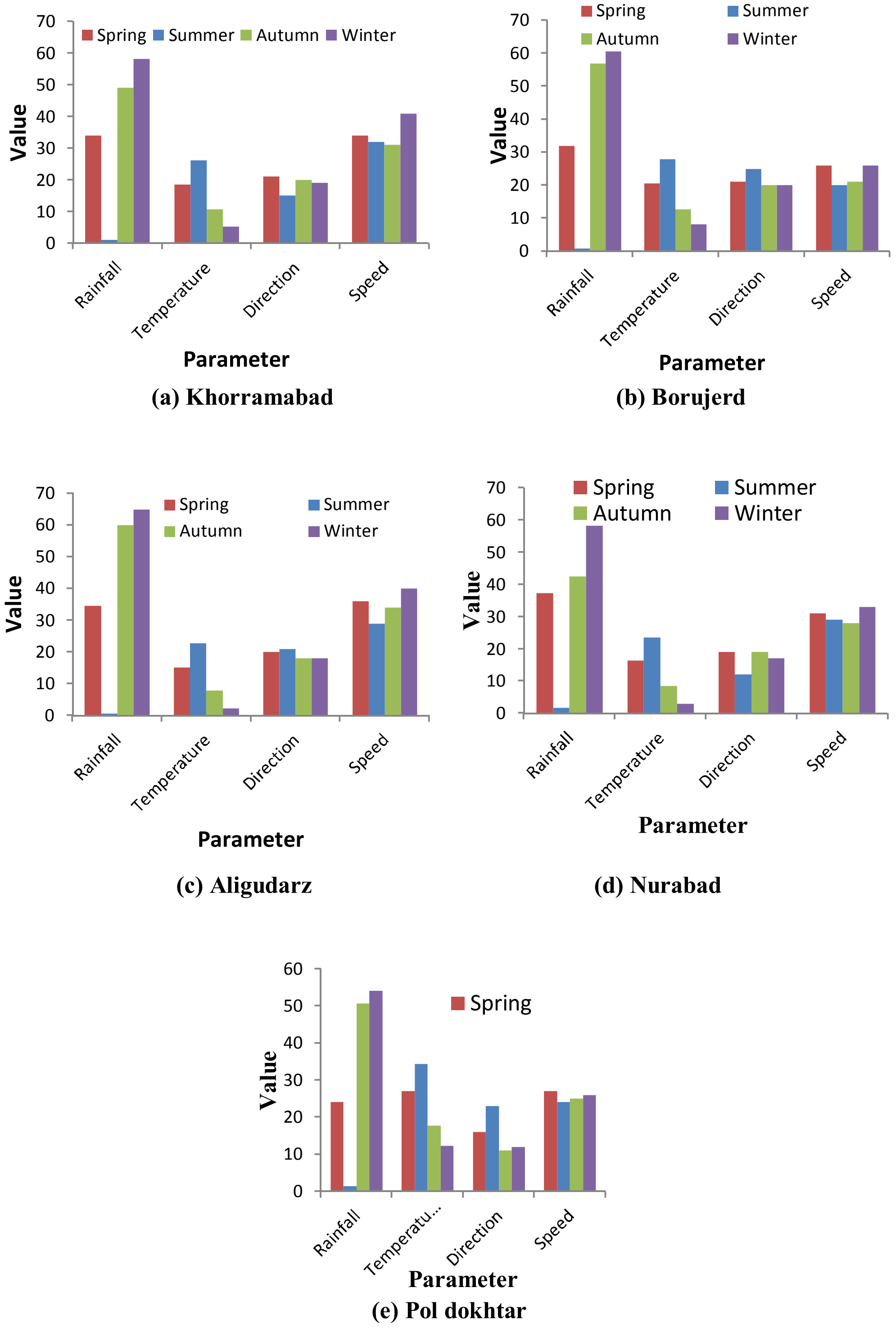

Fig 3. Average amount of climatic parameters during season at a) Khorramabad, b) Borujerd, c) Aligudarz, d) Nurabad, and e) Pol dokhtar

Table 4. Climate determination at different meteorological stations in the study area during a 10-year period

Year	Khorramabad	Borujerd	Aligudarz	Nurabad	Pol dokhtar
2001	Semi-arid	Semi-arid	Semi-arid	Semi-arid	Semi-arid
2002	Semi-arid	Semi-arid	Sub-humid	Mediterranean	Semi-arid
2003	Semi-arid	Mediterranean	Semi-arid	Sub-humid	Semi-arid
2004	Semi-arid	Semi-arid	Sub-humid	Mediterranean	Semi-arid
2005	Semi-arid	Semi-arid	Mediterranean	Mediterranean	Semi-arid
2006	Semi-arid	Semi-arid	Semi-arid	Wet	Semi-arid
2007	Mediterranean	Mediterranean	Mediterranean	Mediterranean	Semi-arid
2008	Semi-arid	Semi-arid	Semi-arid	Semi-arid	dry
2009	Semi-arid	Semi-arid	Semi-arid	Mediterranean	Semi-arid
2010	Semi-arid	Semi-arid	dry	Semi-arid	dry

Semi-arid climate is the predominant climate in Lorestan province. But Mediterranean and humid climates were observed at Aligudarz and Nurabad stations in some years. Table 4 illustrated that the maximum and minimum dryness coefficients were calculated at Nurabad (in 2006) and Pol dokhtar (in 2008) stations. The lower dryness coefficient became, climate tend to become dryer as arid and semiarid climates showed the lower dryness coefficients and humid and wet climates were observed in stations with higher dryness coefficients. Generally, by moving from the southern and the western parts of the province to north and east parts, humidity increased and temperature decreased in consequence of mountains and going through higher longitude. Zandi [28] found the same results by climate determination in Khorasan Razavi province using DoMarten method.

Investigation of the relationship between dust phenomena and climatic parameters using DEA

The research community in this applied study was the 5 meteorological stations in Lorestan province. Information was compiled through library documentation, Internet sites, statistics management and information technology of the meteorological organization of the province during the period from 2001 to 2010. Using the Analytical Hierarchy Process (AHP), the indexes were selected to determine the selected meteorological stations in the province. The input for the stations is a constant number, one, because the purpose examines the output effects for 1 unit of change in inputs. For the output indexes, the mean of temperature, mean of rainfall, mean of wind direction, mean of wind speed and drought factor were selected to survey the performance of stations. For each meteorological station, the data were collected during the period from 2001 to 2010. (Table 5) In window analysis, the length of windows was considered the five years, and as a result the model was executed for 6 periods of 5 years. The courses provided are as follows: The results of the model implementation are presented in Table 6, the interpretation of the obtaining numbers indicates the angle of view of the meteorological stations, if a number is near to one indicating that the angle of view is bad at the station under study. According to the mean column obtained in this table, Khorramabad weather stations (in 2002, 2006 and 2007), Borujerd (in 2008 and 2009), Nurabad (in 2004, 2005 and 2006), Pol dokhtar (in Years 2001, 2005, 2006, 2007, 2008, and 2010) have a bad viewing angle in the years mentioned. (Fig 4) Fig 5 shows the viewing angle of the station studied at a period of 10 years. According to this form, the positive slope of the diagram shows that the good viewing angle, fixed slope, indicating that the viewing angle do not change and the negative slope of diagram indicates that the viewing angle is bad at the station under study. As you can see, the Nurabad station has a slope of ascension during the period from 2006 to 2008, indicating that the viewing angle is increasing. Pol dokhtar Station has a constant slope during the years 2006 to 2008 indicating that the viewing angle of the station has not changed during the mentioned time period. Also, Khorramabad Station has a slope of descending in the years 2003 to 2006, which indicates that the viewing angle of the station is decreasing in the mentioned years. In order to achieve this goal, which indicator is more critical at each station, that means this indicator more effects on the angle of view, the data of a station in the mentioned 10 years was examined. In the method when the number of units under investigation is less than 3 times than the sum of the input and output indicators, in order to achieve a better result, the unit under investigation can be removed from the data set when the model is executed, which in fact results It is called the super efficiency, and as a result, the Model 1 turns out as follows:

$$Min\ \sum_{i=1}^{m} v_i x_{io} - v_o$$

$$\text{S.T}\quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + v_o \leq 0$$

$$\forall j \neq o \qquad \text{(Model 2)}$$

$$\sum_{r=1}^{s} u_r y_{ro} = 1$$

The weights u_1 to u_2 are related to the indicators, as shown in Table 7, and, as can be seen, the average temperature indicator is more sensitive for evaluating climatic conditions. Then, the total weight for each index was calculated at each station during these 10 years. The results are shown in Table 8 and whatever the total weight be larger, it is more affected on the viewing angle.

Table 5. The considered time periods in the window analysis

Periods	Years
First period	2001-2005
Second period	2002-2006
Third Period	2003-2007
Fourth period	2004-2008
Fifth Period	2005-2009
Sixth period	2006-2010

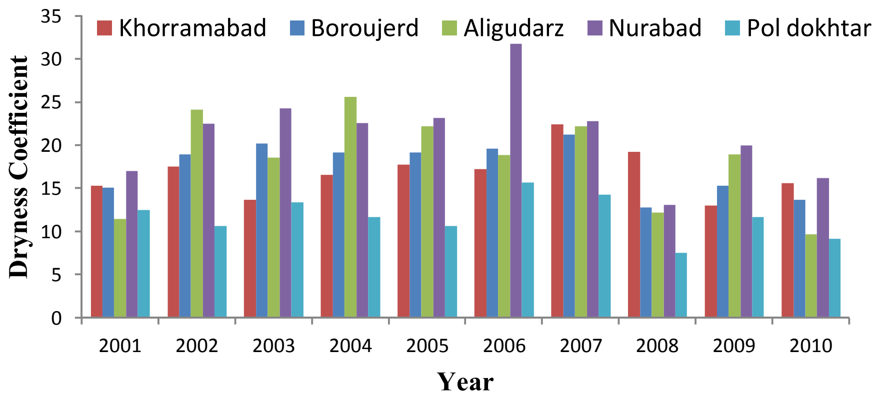

Fig 4. Dryness coefficient at different meteorological stations in the study area during 10-year period

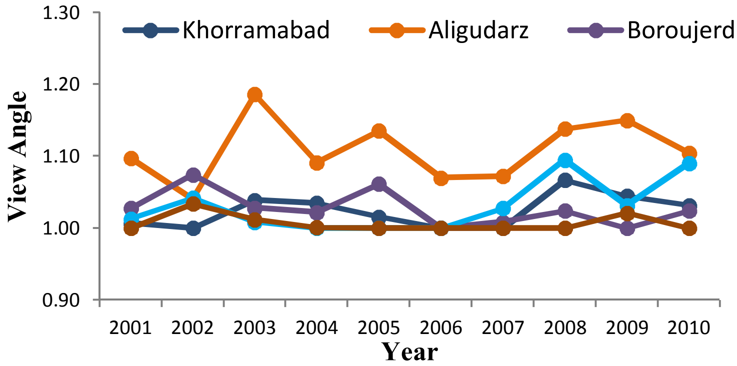

Fig 5. The viewing angle of the stations studied in the period of 10 years

Table 6. Results of the implementation of Model 1 at the stations under study in the 10-year period

City	**Period**	**Year**									
		2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
	First	1.0068	1	1.066	1	1	0	0	0	0	0
	Second Third	0	1	1.0685	1.0495	1.0223	1	0	0	0	0
	Fourth	0	0	1.04040	1.0445	1.0184	1	1	0	0	0
Khorramabad	Fifth	0	0	0	1.0445	1.0184	1	1	1.0667	0	0
	Sixth	0	0	0	0	1.0184	1	1	1.0667	1.0444	0
	Average	0	0	0	0	0	1	1	1.0667	1.0442	1.0314
	First	1.0068	1	1.0385	1.0346	1.0155	1	1	1.0667	1.0443	1.0314
	Second Third	1.0227	1.0445	1	1	1.0273	0	0	0	0	0
	Fourth	0	1.1033	1.0426	1.0387	1.0730	1	0	0	0	0
	Fifth	0	0	1.0410	1.0244	1.0721	1	1.0115	0	0	0
Borujerd	Sixth	0	0	0	1.0244	1.0721	1	1.0115	1.0321	0	0
	Average	0	0	0	0	1.0672	1	1.0104	1.0199	1	0
	First	0	0	0	0	0	1	1	1.0199	1	1.0238
	Second Third	1.0227	1.0744	1.0279	1.0219	1.0614	1	1.0084	1.0240	1	1.0238
	Fourth	1.0974	1	1.1467	1	1.0580	0	0	0	0	0
	Fifth	0	1.0818	1.2080	1.1193	1.1549	1.0737	0	0	0	0
	Sixth	0	0	1.2043	1.1232	1.1549	1.0737	1.0815	0	0	0
Aligudarz	Average	0	0	0	1.1232	1.1549	1.0737	1.0815	1.1311	0	0
	First	0	0	0	0	1.1549	1.0693	1.0778	1.1418	1.1561	0
	Second	0	0	0	0	0	1.0595	1.0477	1.1418	1.1441	1.1047
	Third	1.0974	1.0490	1.1863	1.0914	1.1355	1.0700	1.0721	1.1382	1.1503	1.1047
	Fourth	1.0127	1.0303	1	1	1	0	0	0	0	0
	Fifth	0	1.0537	1.0125	1	1	1	0	0	0	0
	Sixth	0	0	1.0125	1	1	1	1.0367	0	0	0
Nurabad	Average	0	0	0	1	1	1	1.0367	1.0911	0	0
	First	0	0	0	0	1	1	1.0367	1.0968	1.0538	0
	Second Third	0	0	0	0	0	1	1	1.0968	1.0049	1.0904
	Fourth	1.0127	1.0420	1.0083	1	1	1	1.0275	1.0949	1.0316	1.0904
	Fifth	1	1.0360	1	1.0025	1	0	0	0	0	0
	Sixth	0	1.0315	1.0176	1	1	1	0	0	0	0
	Average	0	0	1.0179	1	1	1	1	0	0	0
		0	0	0	1.0018	1	1	1	1	0	0
Pol dokhtar		0	0	0	0	1	1	1	1	1.0192	0
		0	0	0	0	0	1	1	1	1.0227	1
		1	1.0338	1.0118	1.0011	1	1	1	1	1.0210	1

Table 7. The weights and the indicators

Indicators	Weights
Aridity index	u_1
Average wind speed	u_2
Average wind direction	u_3
Average precipitation	u_4
Average temperature	u_5

Table 8. Results of Model 2 implementation at the stations under study at a 10-year period

City	Weight	Year										Summation
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Khorramabad	u_1	0	0	0	0.004	0.006	0	0.038	0.007	0	0	0.055
	u_2	0.016	0.019	0.01	0	0	0	0	0	0	0.001	0.046
	u_3	0	0.019	0.006	0	0.009	0	0	0	0.014	0.004	0.052
	u_4	0.002	0	0.001	0.001	0	0.02	0.003	0	0	0	0.027
	u_5	0.028	0	0.034	0.05	0.04	0	0	0.049	0.041	0.049	0.029
Borujerd	u_1	0	0.013	0	0	0.013	0.011	0.047	0	0	0	0.084
	u_2	0.001	0	0	0	0.002	0.018	0	0.012	0.008	0.004	0.0045
	u_3	0.022	0	0	0.041	0	0	0	0.015	0.033	0	0.111
	u_4	0	0	0.007	0.003	0	0.001	0	0	0	0	0.011
	u_5	0.034	0.051	0.048	0	0.0046	0	0	0.017	0	0.05	0.246
Aligudarz	u_1	0	0.023	0.005	0.024	0.008	0	0.007	0	0.004	0	0.071
	u_2	0	0	0.001	0	0.008	0	0.022	0.031	0.006	0	0.068
	u_3	0.049	0.025	0.007	0	0	0.018	0.008	0	0	0	0.107
	u_4	0.002	0	0.003	0.008	0	0.014	0	0	0.002	0	0.029
	u_5	0	0	0.053	0	0.047	0	0	0	0.051	0.068	0.219
Nurabad	u_1	0	0.006	0.014	0.001	0	0	0.007	0	0	0	0.028
	u_2	0.009	0.003	0.018	0.019	0	0	0	0.004	0	0	0.053
	u_3	0	0.012	0	0.01	0.048	0	0.015	0.021	0.03	0.017	0.153
	u_4	0	0	0	0	0	0.017	0	0	0	0	0.017
	u_5	0.051	0.046	0	0	0	0	0.046	0.038	0.035	0.051	0.267
Poldokhtar	u_1	0.009	0.01	0.01	0.01	0	0.04	0	0	0.005	0	0.09
	u_2	0	0	0	0	0	0	0	0.029	0	0	0.029
	u_3	0	0	0	0	0.047	0.021	0	0	0	0	0.068
	u_4	0	0	0	0	0	0	0.023	0	0	0.001	0.024
	u_5	0.038	0.04	0.039	0.039	0	0	0	0	0.039	0.041	0.0231

Conclusion

Dust storm as an important environmental threat impacts on residents in the western and southwestern parts of Iran by decreasing solar radiation and vegetative growth. Lorestan province in the western part of Iran has been influenced by suspended dust in the atmosphere. The objective of present study was to evaluate the effects of climatic parameters (including precipitation, temperature, the maximum wind speed and direction of predominant wind) on dust storm occurrence in Lorestan province. Results showed that the maximum and minimum numbers of dusty days during a 10-year period were recorded in 2008 and 2003, respectively. It is also concluded that the maximum and minimum dust storm occurrence were observed in Pol dokhtar (in the west) and Aligudarz (in the east) cities, respectively. Considering the fact that dust storm intensity decreases by moving from the west (location of indoor dust hotspot like dried lagoons of Khuzestan and outdoor dust sources like the northern deserts of Saudi Arabia, the south of Iraq and the east of Syria) toward the east, frequency of dust occurrence were varied in different cities of Lorestan province based on the geographic position of cities. The maximum and minimum numbers of dusty days per year were recorded in June and February, respectively. Taking importance of air dryness as an effective factor on dust borne into account, it is reasonable that dust storm frequency is more in warmer period of time. Therefore, it is assumed that the main dust borne sources in Lorestan province are indoor. Climatic determination showed that climate changes (including diminishing precipitation and increasing temperature) in recent years changed the predominant climate in the southern and western parts of the study area to semiarid. The maximum and minimum fluctuation in climatic parameters during a 10-year period were observed in precipitation and temperature, respectively. Average wind speed and wind direction during 10 years were recorded 42 m s^{-1} and 252 degree, respectively. Predominant wind from the southwest enters dust particles into Lorestan province. Vegetative coverage and position of industrial cities and companies have significant effect on decreasing dust particles in the atmosphere. The results of the model along with the window analysis indicate that the viewing angles of the stations change over time intervals, and the average temperature index is more sensitive than other indicators used in this paper to study the climatic conditions.

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