Advances in Environmental Biology, 6(8): 2285-2295, 2012
ISSN 1995-0756

This is a refereed journal and all articles are professionally screened and reviewed **ORIGINAL ARTICLE**

# Spatial Distribution of Sandstorm Disaster in Iran Using Numerical Taxonomy Model

**[1]Dr Hossein Kalantari Khalil Abad, [2]Dr Mohammad Mireh**

*[1]Associate Professor of Art & Culture Institute, Iran*
*[2]Assistant Professor of Geography Payame Noor University, Iran*

Dr Hossein Kalantari Khalil Abad, Dr Mohammad Mireh: Spatial Distribution of Sandstorm Disaster in Iran Using Numerical Taxonomy Model

**ABSTRACT**

More than a half of Iran terrain is located in arid and waterless areas and is exposed to desertification and sandstorm phenomenon. Sandstorm occurrence cause yearly some treats like losing agricultural farms, outbreak of diseases, damaged road establishments and making accidents, destruction of facilities and equipments, environmental damages in urban and rural areas etc. Therefore, providing scientific plans for sandstorm disaster management is necessary. The step to provide a plan is knowledge. This article is going to identify sandstorm areas by first two methods; library-based method and survey (16 indices of a 15-year period were collected.) After collecting the data Numerical Taxonomy Model has been used to analyze them. The obtained results show that sandstorm is mostly happening in Yazd and Sistan & Baluchistan provinces. In other word, center and half of the southeast Iran is the most risky, risk-taking and disaster-prone foci of sandstorm disaster.

***Key words:*** Sandstorm, spatial distribution, Numeric Taxonomy Model, natural disaster, Iran

## Introduction

Changes in environmental factors across the globe have created different climates. Increase in temperature, intensive wind blowing, and increasing precipitation in a geographical area beyond the normal limit always cause some losses which may convert to a national disaster. In Iran, climatic and topographic variation on the one hand and human meddling in natural resources on the other hand has caused the country to be exposed to various threats. Climate treats cause a high percentage in natural disasters [2]. Sandstorm is a special natural disaster that frequently occurs in deserts and their surrounding areas [20]. All years have seen damages by sandstorm in desert areas. Most of actions are carried out against it after occurrence and usually the governmental and nongovernmental organizations try to reduce the damages rate. This trend has always been seen across the country but actions are considered as a position and a special work has not been done. If an introduction of spatial distribution across the country for prevention sandstorms, it will be important. So spatial distribution would be so important that sandstorm has its own special characteristics in every place and it differs from other places.

To prevent the problem, some actions have historically been done and in any case, authorities breed to solve and fight against it. However, unfortunately up to 1964 no action or plan was materialized. Then in 1965, the Organization for Forests and Pastures with repetitive revisions of plans and works carried out in foreign countries tried to design a plan named as "Fixation of Shifting Sands" from Havasabaad of Sabzevar and in 1964, the second station for sand fixation was established in Moomenabaad of Kerman. Now after 43 years, we see significant successes in sand fixation in 17 provinces and providing technical help to other same countries.

However, sandstorms and duststorms are the most basic and problematic issue in Iran and middle eastern countries. These storms are almost created in spring and summer with fast-blowing winds. So in spring, the country' western and central provinces are exposed to windstorms and gradually in warmer months their location distribution is rather across eastern and east-western provinces [8]. Most storms are associated with cold weather masses and they can displace dusts. The dusts are separated from the grounds by severe winds and would be displaced in three forms of hanging, jumping and rolling [19]. Very small particles of sediment or soil are moving over the ground in a hanging manner, larger one in a rolling manner and the particles with medium diameter are moving in a jumping manner. Jumping movement is the most important mode, because most amounts of sands would be displaced through it. Studies indicate that about 55 to 75 percent of the materials are displaced by jumping movement. In addition, 3 to 38 percents are carried in a hanging

**Corresponding Author**
Dr Hossein Kalantari Khalil Abad, Associate Professor of Art & Culture Institute, Iran

manner and 7 to 25 percents through rolling manner. Movement of 50 percent of materials in a 6-centimeter distance and its 90 percent in a 30-centimeter distance of soil's level is done [17]. In any case, vast amounts of financial and humane damages are caused. Disaster management is a consistent and group work, which without support might not be causing increase of abilities of residents in risk-taking communities and the most important task for disaster management is a comprehensive perception of all sources and capacities for optimal application [1].

Here in the paper, we have tried to study the spatial distribution of sandstorm in Iran in order to present the preventive methods against them.

*Research design:*

Natural disasters caused treats to the environment across all places and times and caused many financial and humane damages to the country. Unfortunately Iran is one of the most risky and risk-taking countries of the world. In reality, Iran is located in the earth's risk-taking belt and some disasters like flood, earthquake, landslide, typhoon, draught etc have always threaten Iranian inhabitants [21]. For example, since 1994 to 2003, Iran sustained an amount of 12.34 billion dollars arising from damages of national disasters. In this sense, Iran is located at 17th in world ranking. In addition, 32698 people have been killed through these years, which place Iran at 3rd in world ranking. This figure is prominent when we compare it with China and India -as the world's most populated countries (www.fema.gov/regions). Growing number of populations, limiting resources and irregularities in ecologic balance dominating on environment caused some problem because of ever-increased utilization of the human especially during recent decades. Among major problems, floods, ground erosion, and sandstorm in desert lands of arid, semi-arid and wet areas might be noted. Wind erosion and attacks by shifting sands on economics facilities and biological sources are among the most prominent factors of creating desert in the country.

Sandstorm, which is referred to the strong upheaval of sand and dust by strong winds occur in subtropical regions like Iran. This phenomenon often occur in no green, waterless, bare deserts or the place where very high exploitation of lands have forced them to lost their plant coverage. Lands without plant and fast-blowing winds dominating on environment cause the storms to form. Sandstorm that is one of the most risky and dangerous phenomena for the local residents on health, transportation and navigation [6] might cause damages particularly to urban environment and human communities, so managing it is very difficult and complicated. Sandstorm is considered as a natural event originating from the climate and atmosphere. This event comprises 29.7 percents of natural disasters (www.fema.gov/regions) and causes many damages as follows:

One of the most threatening effects of sandstorm and dust storm is vision reduction, which usually causes the vision to reduce to a quarter of a mile or sometime to lesser. An example has been seen in Arizona in April 1995. This was the place the vision reduced to half a car's length, and following it a number of 24 cars crashed together, and eventually 10 people died (http//www.disaster, an.blogfa.com). Severe winds make difficult conditions for driving and cause dangerous accidents or improper control on the vehicles by drivers [8]. In Iran, one of the indices of crashes in 2000 was seen on the Tehran-Bandarabas transit road in a limit named as "Wind Channel of Meybod" where more than 40 light and heavy vehicles crashed. These storms sometimes cause cancellation or stoppage of air flights [24]. Also every year (spatially in recent years), many villages have been buried under streams of sand and dust storms in desert areas. For example, during last 100 years more than three villages have completely buried in Yazd City around under vast masses of shifting sands. People safety might be risked by these sandstorms. Sand articles may cause breathing diseases spatially asthma in Iran. For example, in the region where the "120-day Wind of Sistan"1 is dominant, people suffer from breathing diseases. In addition, this wind is responsible for 28 percent of blindness in these areas and it is the most important factor for generating sandstorms and dusts in this area. The viruses and microbes in the dusts may lead to disease for inhabitants. Regarding the matter, that Iran is located at arid points of the world and it is also surrounded by desert areas, sandstorms cause problems, which some of their effects are temporary and local, but others are continuous and global. Sandstorms can destroy the agriculture, transportation, products, cattle, business, health and public welfare [22]. Agriculture processes might also be influenced by sandstorms. Damages to the production are a usual issue, but erosion is the other available one. With carrying available surface solid, an area is left valueless. Urban areas are not guarded against sandstorms. Therefore, sandstorms may cause harsh damages to communication equipments. Today, business is dependent on such technologies as computers and communication tools. This may influence negatively on business. The nature can be damaged, trees might be uprooted, and the earth might be turned into desert [18]. Sandstorm leads to a kind of strong wind erosion reduces to less than 11.6 km, this phenomenon is occurring. All storms are called sandstorm when the dominating vision reduces to less than one km. The universal assemblies verify this standard [7]. It can cause harsh damages through displacing a green volume of earth from a point to the other point. One of the consequences of is precipitation of eroded materials,

cut of roads, limitation of drivers' vision, and entangling in the situation. Overall, risks of sandstorms on transportation are less considered compare to risks of precipitation and fog. In most parts of Iran including Isfahan, Ilam, Bushehr, Tehran, Khorasan, Fars, Qazvin, Qom, Kerman, Markazi, Hormozgan and Yazd, the situation is prepared for making various wind erosions and sandstorms (Iran Technical Office for Sand Fixation and Desertification Prevention, 2008: 99). In these regions, desert lands and dunes (sand hills) cover about 80 millions hectares of the country's area. Wind erosions and dunes cause harsh damages to the residential places and communicative roads and many rural and urban areas especially in the country's central and southeastern vast deserts named "Dasht e Kavir'2 (salt desert plain) and "Kavir e Loot"1 (Loot desert) have forced to leave their homes and have migrated to the large cities. Thus, it is vital to identify the major foci of sandstorms and to plan for sustainable development. Development without comprehensive planning for managing disaster would not be a sustainable development [2].

*Methods:*

In studying sandstorms having access to the reliable meteorological data in a desired period is very important. Therefore, an appropriate statistic period's length depends solely on a given climatic element. The compression of station network is sensitive to the topography of the area and climatic element. The early studies show that the existing synoptic stations of Meteorological Organization for the Country have perfect data for dusts and sandstorms. Abovementioned provinces are shown on climatic maps with the identity codes of 30, 31. 32, 33, 34, 35 and 98 [17], and they have been reduced when consecutive data has been lost. To use more stations the statistics for 15 years (1992-2006) in 57 stations in 17 provinces have been applied. In addition, for completing the information and appropriately ranking, using the questionnaire, some data from the General Office for Natural Resources and the Institute for Unexpected Events and the Department of Transportation has been collected. After having been classified, the data has been analyzed by using the scientific research model of Numerical Taxonomy Model.

*Numerical Taxonomy Model:*

This model was proposed by Adunson in 1763 at first, and then was developed as a tool for ranking and classifying the development of nations by professor Helving in UNESCO Higher College of Economics [14]. In this model, for determining the units and kinds of integrated topics in a 3-dimentional vector space and without using regression, variance and dependency analysis, it may be able to divide any set into some rather integrated subsets [10]. This model can also be used as a criterion for defining social and economical dimensions growth of a region [4]. Numerical Taxonomy Model is a method for classifying the subjects. There is a strong parity among elements comprising the subjects and this group maintains a maximum difference with other groups. So the groups are a cluster of subjects and events which are defined by parities or proximities of their elements [5]. This model is implemented in 6 phases as summarized below:

After the results obtained by Numerical Taxonomy Model, the findings was put into GIS environment and ranking of provinces is formed into a map and finally classification was done through that technique.

*The Research Findings:*

The findings of the research have been practiced by using the Numerical Taxonomy Model in six above-mentioned stages (figure 1) as follows in detail:

*Stage 1: Forming data matrix:*

The matrix for initial data based on the indices used in tables 1 and 2 are provided in a column. In a column, the provinces and amounts for indices of sandstorms are provided and in the opposite columns, some indices for 17 provinces are provided. These indices include: number of storms, period of storm occurrence, number of critic focal points and their areas, amount of yearly damages to the environmental resources and road facilities influenced by sandstorms, damages to infrastructures and facilities of transportation, number of villages and cities damaged, number of people died, number of bridges damaged, the length of roads damaged, number of vehicles damaged, number of factories and industries damaged, number of cattle damaged and number of road blockages.

*Stage 2: Forming data standard matrix:*

Having prepared the data matrix, regarding the different indices of sandstorm in different scales, to separate indices from units, they would be standardized. Therefore, the mean and standard deviation each column are computed. To compute the standard matrix 2 formula has been used.

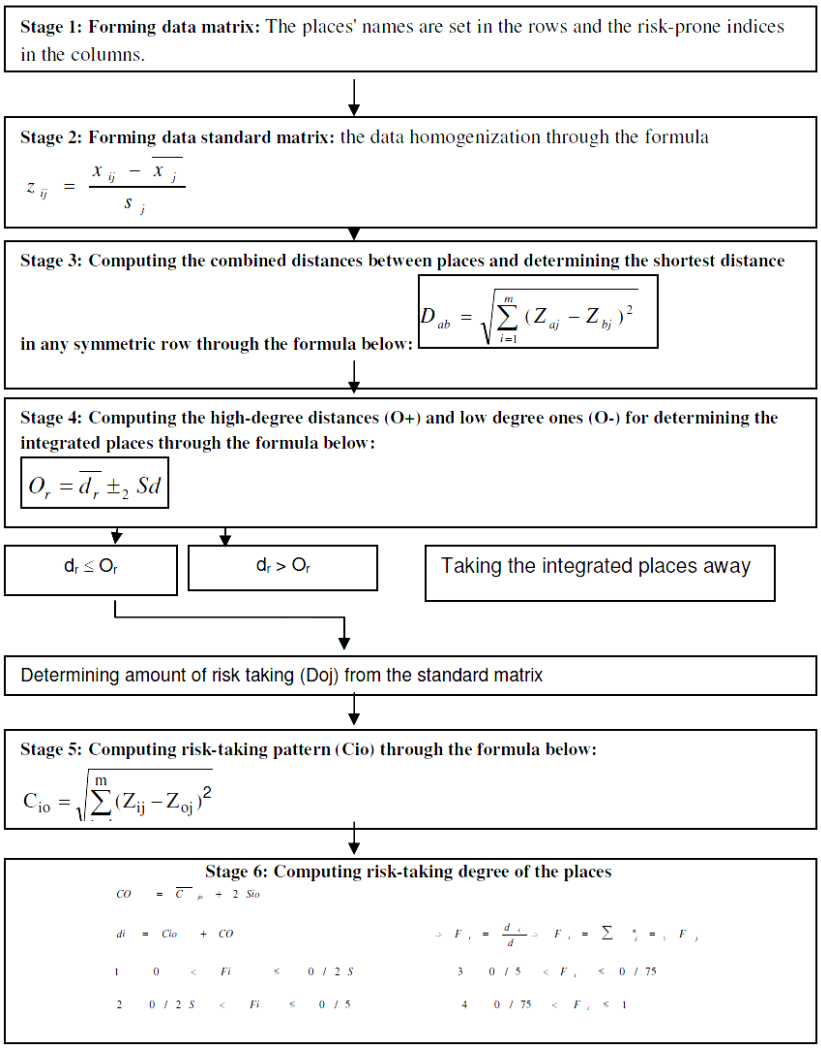



**Fig. 1:** Different stages of Numerical Taxonomy Analysis model
(Hekmatnia and Mousavi, 2006:220-227, Kalantari, 2001:149-160)

*Stage 3: Computing the combined distances between provinces and determining the shortest distance:*

Having access to the standard matrix, the different or distance of any area from the other may be found in every index. As the table below shows, the diameter for distance matrix is zero and symmetric. In the table the shortest distance between two provinces has been indicated, which is index for similarity of that province with another one. Generally, regarding the importance of the shortest distance, a column was put in the end of matrix and the lowest amount in each row has been provided. This column indicates the mode for province I and other provinces. The nearest area to I is called the model for I and I area itself is referred to as the symmetric province for the closest area. For example, in table 4, row 13, the shortest distance i.e. 3.11 is related to Kerman province. Therefore, Kerman is the symmetric province and Isfahan is called as the model province.

*Stage 4: Forming integrated regions:*

Any case similar to the respective model is the symmetric case linked by a vector and a graph is obtained, which indicates integrated provinces. The shortest distance for each province would be indicated and put in the other column and finally each symmetric would be linked to the respective model and second-class connections would be obtained. This action was repeated to all next connections would be obtained and all the graph areas could be connected. To obtain integrated provinces, the upper and lower distances have obtained. Finally, the combined distance of each province to the other one has provided as table 5.

**Table 1:** Indices of sandstorm disaster (data matrix) for 1991-2006

| Variances / Province | Number of storm* | Duration of storm* | Number of critic focus** | Area of critic foci (hectare)** | Yearly loss to environmental resources and road constrictions (million Rial)[4]** | Under-impact arenas of sandstorm (hectare)** |
|---|---|---|---|---|---|---|
| Bushehr | 15 | 1 | 10 | 251567 | 100200 | 320819 |
| Fars | 1 | 1 | 15 | 123500 | 4578.522 | 447755 |
| Hormozgan | 31 | 1 | 19 | 209333 | 12958 | 475136 |
| Ilam | 6 | 1 | 1 | 70307 | 19049.094 | 70307 |
| Isfahan | 40 | 4 | 16 | 736891 | 39506.331 | 1866026 |
| Kerman | 14 | 4 | 16 | 676234 | 107309 | 4771205 |
| Khorasan (Northern, Southern & Razavi) | 67 | 3 | 30 | 1958456 | 77621/874 | 3882150 |
| Khuzestan | 9 | 1 | 5 | 279505 | 9720 | 696721 |
| Markazi | 3 | 1 | 1 | 11865 | 2964.879 | 11865 |
| Qazvin | 21 | 1 | 2 | 687 | 575 | 9939 |
| Qom | 13 | 2.5 | 3 | 98125 | 5930.25 | 470156.25 |
| Semnan | 49 | 1 | 12 | 300047 | 13337/8 | 1028625 |
| Sistan & Baluchistan | 271 | 6 | 24 | 1107351.5 | 231083.285 | 2291713.95 |
| Tehran | 6 | 0.5 | 3 | 10172.5 | 50141.727 | 10172.5 |
| Yazd | 68 | 4.5 | 19 | 659113 | 13843.6968 | 3391131 |

*- Meteorology Organization of the Country, Automotive Data Center, 2008;
**- Office of Sand Fixation and Desertification Prevention with the aid of General Offices of the Provinces for Natural Resources, 2003, Critic Foci of Wind Erosion;
**- The writers: Obtained data through questionnaire from General Offices of Road and Transportation, Unexpected Disasters Institute of the Country, General Offices of the Provinces for Natural Resources and Police Command Center for Roads in 17 under-studying provinces

**Table 2:** Indices of sandstorm disaster (data matrix) for 1991-2006

| Variances / Province | Damages to constructions & equipments of roads & transportation (thousand Rial) | Number of damaged villages | Number of damaged cities | Number of died peoples | Number of damaged bridges (km) | Number of damaged roads (km) | Number of damaged vehicles | Number of damages to factories & industries | Number of died cattle | Hours of road blockage |
|---|---|---|---|---|---|---|---|---|---|---|
| Bushehr | - | 40 | 8 | 5 | - | - | - | 2 | 650 | - |
| Fars | - | - | - | - | - | - | - | - | - | - |
| Hormozgan | - | 88 | 4 | - | 3 | - | - | - | - | - |
| Ilam | - | - | - | - | - | - | - | 38 | 1100 | - |
| Isfahan | 2953 | 80 | 14 | - | - | 3 | 5 | 53 | 1622 | - |
| Kerman | - | 60 | 9 | - | - | 100 | 1 | 4 | 4460 | - |
| Khorasan | - | 94 | - | - | - | - | - | 5 | 2914 | - |
| Khuzestan | - | 481 | 5 | - | - | - | - | - | 250 | - |
| Markazi | - | 100 | 10 | 26 | - | - | 19 | 10 | 500 | - |
| Qazvin | - | 25 | 1 | - | - | - | 55 | 25 | - | - |
| Qom | - | - | - | - | - | - | 1 | 2 | - | - |
| Semnan | - | - | - | - | - | 4 | 3 | 8 | 3500 | - |
| Sistan & Baluchistan | 4500 | - | 4 | - | 110 | 547 | - | - | - | 1 |
| Tehran | - | - | - | - | - | - | - | - | - | - |
| Yazd | 3000 | 154 | 7 | 26 | 117 | 585 | 227 | 100 | 15500 | 2 |

**- The writers: Obtained data through questionnaire from General Offices of Road and Transportation, Unexpected Disasters Institute of the Country, General Offices of the Provinces for Natural Resources and Police Command Center for Roads in 17 under-studying provinces

**Table 3:** Indices of sandstorm disaster (data standard matrix)

| Variances / Province | Number of storm during period | Damages to constructions & equipments of roads & transportation | Number of damaged villages | Number of damaged cities | Number of died peoples | Number of yearly damaged bridges (km) | Number of yearly damaged roads (km) | Number of damaged vehicles | Number of yearly damages to factories & industries | Hours of road blockage | Number of damaged bridges | Duration of storm occurrence | Number of critic foci | Area of critic foci (hectare) | Number of yearly damages to environmental resources & road constructions (million Rial) | Under-impact arenas of sandstorm (hectare) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bushehr | -0.38478 | -0.37892 | -0.32745 | 0.848684 | 0.372059 | -0.38431 | -0.4416 | -0.35219 | -0.51568 | -0.34618 | -0.35714 | -0.68023 | -0.0019 | -0.33958 | 0.87030342 | -0.63521 |
| Fars | -0.59252 | -0.37892 | -0.6588 | -0.9057 | -0.36324 | -0.38431 | -0.4416 | -0.35219 | -0.58696 | -0.50888 | -0.35714 | -0.68023 | 0.003589 | -0.57944 | -0.66204221 | -0.55421 |
| Hormozgan | -0.14735 | -0.37892 | 0.070162 | -0.02851 | -0.36324 | -0.3091 | -0.4416 | -0.35219 | -0.58696 | -0.50888 | -0.35714 | -0.68023 | 0.00798 | -0.41868 | -0.52776007 | -0.53674 |
| Ilam | -0.51833 | -0.37892 | -0.6588 | -0.9057 | -0.36324 | -0.38431 | -0.4416 | -0.35219 | 0.767284 | -0.23355 | -0.35714 | -0.68023 | -0.01178 | -0.67906 | -0.43014956 | -0.79507 |
| Isfahan | -0.0138 | -0.37892 | -0.07066 | 2.164474 | -0.36324 | -0.38431 | -0.28897 | -0.26724 | 1.301853 | -0.10289 | -0.35714 | 1.063953 | 0.004687 | 0.569392 | -0.10231989 | 0.350828 |
| Kerman | -0.39961 | -0.37892 | -0.16178 | 1.067982 | -0.36324 | -0.38431 | 0.067155 | -0.3352 | -0.4444 | 0.60747 | -0.35714 | 1.063953 | 0.004687 | 0.455787 | 0.98422599 | 2.204702 |
| Khorasan | 0.386853 | -0.37892 | 0.119864 | -0.9057 | -0.36324 | -0.38431 | -0.4416 | -0.35219 | -0.40877 | 0.220502 | -0.35714 | 0.482558 | 0.020055 | 2.857279 | 0.50848625 | 1.637372 |
| Khouzestan | -0.47381 | -0.37892 | 3.32563 | 0.190789 | -0.36324 | -0.38431 | -0.4416 | -0.35219 | -0.58696 | -0.44631 | -0.35714 | -0.68023 | -0.00739 | -0.28725 | -0.58686072 | -0.39534 |
| Markazi | -0.56284 | -0.37892 | 0.169566 | 1.287281 | 0.519118 | -0.38431 | -0.4416 | -0.02939 | -0.23058 | -0.38373 | -0.35714 | -0.68023 | -0.01178 | -0.78852 | -0.68790103 | -0.83236 |
| Qazvin | -0.29574 | -0.37892 | -0.45171 | -0.6864 | -0.36324 | -0.38431 | -0.4416 | 0.582229 | 0.303991 | -0.50888 | -0.35714 | -0.68023 | -0.01068 | -0.80945 | -0.72619913 | -0.83359 |
| Qom | -0.41445 | -0.37892 | -0.6588 | -0.9057 | -0.36324 | -0.38431 | -0.4416 | -0.3352 | -0.51568 | -0.50888 | -0.35714 | 0.19186 | -0.00958 | -0.62696 | -0.64038061 | -0.53991 |
| Semnan | 0.119751 | -0.37892 | -0.6588 | -0.9057 | -0.36324 | -0.38431 | -0.2381 | -0.30122 | -0.30185 | 0.367179 | -0.35714 | -0.68023 | 0.000296 | -0.24878 | -0.52167373 | -0.18354 |
| Sistan & Baluchistan | 3.414008 | 2.440522 | 0.003893 | -0.02851 | -0.36324 | 2.373277 | 2.34127 | -0.35219 | -0.58696 | -0.50888 | 1.428571 | 2.226744 | 0.013469 | 1.263233 | 2.96772373 | 0.622471 |
| Tehran | -0.51833 | -0.37892 | -0.6588 | -0.9057 | -0.36324 | -0.38431 | -0.4416 | -0.35219 | -0.58696 | -0.50888 | -0.35714 | -0.97093 | -0.00958 | -0.79169 | 0.0681136 | -0.83344 |
| Yazd | 0.401692 | 2.485397 | 0.616882 | 0.629386 | 3.460294 | 2.548759 | 2.534595 | 3.504417 | 2.976835 | 3.370814 | 3.214286 | 1.354651 | 0.00798 | 0.423721 | -0.51356668 | 1.324039 |
| Optimum amount | **3.414008** | **2.485397** | **3.32563** | **2.164474** | **3.460294** | **2.548759** | **2.534595** | **3.504417** | **2.976835** | **3.370814** | **3.214286** | **2.226744** | **0.020055** | **2.857279** | **2.96772373** | **2.204702** |

The writers, 2008 (Computed through Numerical Taxonomy Model)

**Table 4:** Matrix of combined distances between desert provinces

| province | Bushehr | Fars | Hormozgan | Ilam | Isfahan | Kerman | Khorasan | Khouzestan | Markazi | Qazvin | Qom | Semnan | Sistan & Baluchestan | Tehran | Yazd | Shortest distance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bushehr | 3.413 | 2.69 | 0 | 2.179 | 4.649 | 4.065 | 2.594 | 7.7 | 2.493 | 2.625 | 2.625 | 3.68 | 1.83 | 1.879 | 10.049 | 1.83 |
| Fars | 4.4 | 1.427 | 2.493 | 0.864 | 4.633 | 4.149 | 1.291 | 8.376 | 0 | 0.895 | 0.895 | 4.488 | 2.577 | 1.245 | 10.456 | 0.864 |
| Hormozgan | 4.075 | 1.87 | 1.879 | 1.453 | 4.417 | 3.287 | 1.557 | 7.975 | 1.245 | 1.483 | 1.483 | 4.057 | 1.787 | 0 | 10.226 | 1.245 |
| Ilam | 4.047 | 0 | 2.69 | 105 | 4.865 | 4.393 | 1.588 | 8.417 | 1.427 | 1.614 | 1.614 | 4.682 | 3.735 | 1.87 | 10.024 | 1.187 |
| Isfahan | 0 | 4.047 | 3.413 | 4.606 | 4.504 | 4.891 | 4.094 | 7.569 | 4.4 | 4.087 | 4.087 | 3.11 | 3.323 | 4.075 | 9.245 | 3.413 |
| Kerman | 3.11 | 4.682 | 3.68 | 4.631 | 3.414 | 5.21 | 4.012 | 7.028 | 4.488 | 4.214 | 4.214 | 0 | 4.354 | 4.057 | 9.429 | 3.11 |
| Khorasan | 4.504 | 4.865 | 4.649 | 4.87 | 0 | 5.41 | 4.016 | 7.047 | 4.633 | 4.48 | 4.48 | 3.414 | 5.4 | 1.417 | 9.986 | 1.417 |
| Khouzestan | 4.891 | 4.393 | 4.065 | 2.248 | 5.41 | 0 | 4.274 | 7.787 | 4.149 | 4.241 | 4.241 | 5.21 | 3.555 | 3.287 | 10.54 | 2.248 |
| Markazi | 3.323 | 3.735 | 1.83 | 2.68 | 5.4 | 3.555 | 2.858 | 8.557 | 2.577 | 2.713 | 2.713 | 4.354 | 0 | 1.787 | 9.786 | 1.787 |
| Qazvin | 4.122 | 1.187 | 2.702 | 1.588 | 5.018 | 4.15 | 1.732 | 8.43 | 1.407 | 1.583 | 1.583 | 4.783 | 2.41 | 1.637 | 9.874 | 1.187 |
| Qom | 4.087 | 1.614 | 2.625 | 1.408 | 4.48 | 4.241 | 1.479 | 8.028 | 0.895 | 0 | 0 | 4.214 | 2.713 | 1.483 | 10.278 | 0.895 |
| Semnan | 4.094 | 1.588 | 2.594 | 1.565 | 4.016 | 4.274 | 0 | 7.866 | 1.291 | 1.479 | 1.479 | 4.012 | 2.858 | 1.557 | 9.852 | 1.291 |
| Sistan & Baluchestan | 7.569 | 8.417 | 7.7 | 8.254 | 7.047 | 7.787 | 7.866 | 0 | 8.376 | 8.028 | 8.028 | 7.028 | 8.557 | 7.975 | 9.19 | 7.028 |
| Tehran | 4.606 | 1.5 | 2.179 | 0 | 4.87 | 4.248 | 1.565 | 8.254 | 0.864 | 1.408 | 1.408 | 4.631 | 2.68 | 1.453 | 10.6 | 0.864 |
| Yazd | 9.245 | 10.024 | 10.049 | 10.6 | 9.986 | 10.54 | 9.852 | 9.19 | 10.456 | 10.278 | 10.278 | 9.429 | 9.786 | 10.226 | 0 | 9.19 |
| mean | 4.365733 | 3.469267 | 3.5032 | 10.12973 | 4.847267 | 4.68 | 3.251867 | 7.4816 | 3.246733 | 3.2752 | 3.2752 | 4.4728 | 3.704333 | 2.929867 | 9.302333 | 4.80232 |
| Deviation | 2.025738 | 2.771804 | 2.471461 | 26.40277 | 2.046982 | 2.260333 | 2.628345 | 2.145651 | 2.9421 | 2.780442 | 2.780442 | 1.997869 | 2.543997 | 2.757749 | 2.609402 36 | 4.076778 |

The writers, 2008 (Computed through Numerical Taxonomy Model)

**Table 5:** Standard and optimum amounts of Under-studying indices

| Variances / Province | Under-impact arenas of sandstorm (hectare) | Number of yearly damages to environmental resources & road constructions (million Rial) | Area of critic foci (hectare) | Number of critic foci | Duration of storm occurrence | Hours of road blockage | Number of died cattle | Number of yearly damages to factories & industries | Number of damaged vehicles | Number of yearly damaged roads (km) | Number of yearly damaged bridges (km) | Number of died peoples | Number of damaged cities | Number of damaged villages | Damages to constructions & equipments of roads & transportation | Number of storm during period |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bushehr | 14.432 | 8.202 | 13.334 | 1.729 | 12.752 | 8.602 | 14. 869 | 8.863 | 12.201 | 13.816 | 9.536 | 8.451 | 0.0004 | 10.221 | 4.402 | 8.066 |
| Fars | 16.56 | 8.202 | 15.88 | 9.425 | 12.752 | 8.602 | 14. 869 | 8.863 | 12.702 | 15.054 | 14.615 | 8.451 | 0.0003 | 11.813 | 13.177 | 7.162 |
| Hormozgan | 12.68 | 8.202 | 10.602 | 4.809 | 12.752 | 8.168 | 14. 869 | 8.863 | 12.702 | 15.054 | 14.615 | 8.451 | 0.0001 | 10.732 | 12.222 | 7.519 |
| Ilam | 15.461 | 8.202 | 15.88 | 9.425 | 12.752 | 8.602 | 14.689 | 8.863 | 4.884 | 13.01 | 14.615 | 8.451 | 0.0001 | 12.503 | 11.546 | 9 |
| Isfahan | 11.75 | 8.202 | 11.538 | 0 | 12.752 | 8.602 | 14.22 | 7.975 | 2.806 | 12.069 | 14.615 | 1.353 | 0.0002 | 5.235 | 9.425 | 4.437 |
| Kerman | 14.547 | 8.202 | 12.166 | 1.201 | 12.752 | 8.602 | 14. 738 | 6.091 | 11.703 | 7.64 | 14.615 | 1.353 | 0.0002 | 5.765 | 3.936 | 0 |
| Khorasan | 9.163 | 8.202 | 10.278 | 9.425 | 12.752 | 8.602 | 14. 869 | 8.863 | 11.465 | 9.923 | 14.615 | 3.042 | 0 | 0 | 6.052 | 0.323 |
| Khouzestan | 15.117 | 8.202 | 0 | 3.893 | 12.752 | 8.602 | 14. 869 | 8.863 | 12.702 | 14.569 | 14.615 | 8.451 | 0.001 | 9.885 | 12.638 | 6.76 |
| Markazi | 15.817 | 8.202 | 9.96 | 0.769 | 12.752 | 8.602 | 12.482 | 8.863 | 10.291 | 14.1 | 8.649 | 8.451 | 0.001 | 13.293 | 13.666 | 9.223 |
| Qazvin | 13.764 | 8.202 | 14.272 | 8.123 | 12.752 | 8.602 | 8.544 | 8.863 | 7.145 | 15.054 | 14.615 | 8.451 | 0.001 | 13.44 | 13.646 | 9.236 |
| Qom | 14.653 | 8.202 | 15.88 | 9.425 | 12.752 | 8.602 | 14. 738 | 8.863 | 12.201 | 15.054 | 14.615 | 4.141 | 0.001 | 12.138 | 13.018 | 7.535 |
| Semnan | 10.85 | 8.202 | 15.88 | 9.425 | 12.752 | 8.602 | 14.478 | 7.69 | 10.75 | 9.024 | 14.615 | 8.451 | 0.0004 | 9.645 | 12.18 | 5.707 |
| Sistan & Baluchistan | 0 | 0.002 | 11.036 | 4.809 | 3.186 | 0.031 | 8.863 | 0.038 | 12.702 | 15.054 | 14.615 | 0 | 0 | 2.541 | 0 | 2.506 |
| Tehran | 15.461 | 8.202 | 13.334 | 1.729 | 12.752 | 8.602 | 14. 869 | 8.863 | 12.702 | 15.054 | 9.536 | 10.227 | 0.0001 | 13.315 | 8.41 | 9.23 |
| Yazd | 9.72 | 0 | 7.339 | 2.356 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.76 | 0.0001 | 5.919 | 12.124 | 0.776 |
| Optimum amount | 3.414008 | 2.485397 | 3.32563 | 2.164474 | 3.214286 | 2.548759 | 3.504417 | 2.534595 | 2.976835 | 3.370814 | 3.460294 | 2.226744 | 0.020055 | 2.857279 | 2.96772373 | 2.204702 |

The writers, 2008 (Computed through Numerical Taxonomy Model)

*Stage 5: Classification of integrated regions and determining the amount of development pattern:*

Having computed the combined distances, a standard matrix and optimum amount should be computed. The distance between any province and the optimum province for every index presents a part of a form, which the combined index for these distances creates a general form and indicates a combined distance of a province to the optimum province. It is shown by *Cio* , which is the exemplar of risk-taking and $(Z_{ij} - Z_{oj})$ below the radical is the distance from province I to the province O and would be computed with the following formula

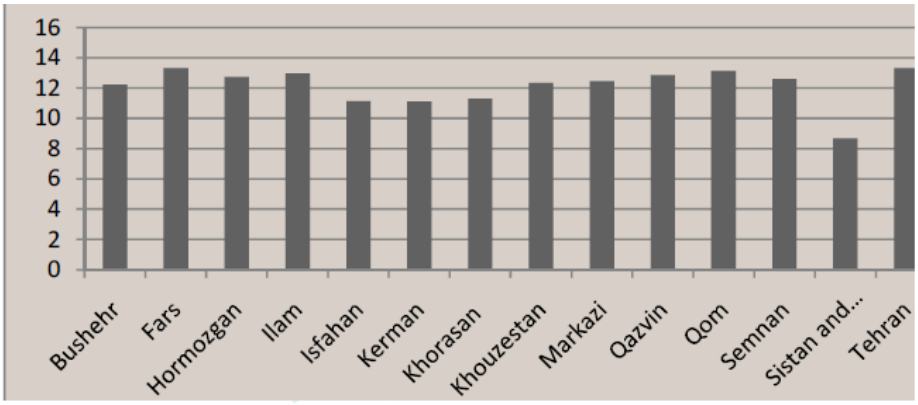
$$C_{io} = \sqrt{\sum (Z_{ij} - Z_{oj})^2}$$

In this relationship, *Cio* or the exemplar of risk-taking is a parameter based upon the more small it indicates the more risk-taking i.e. the distance of province I is less than the optimum province and the more the *Cio* the less disaster-prone. Table 6 followed by figure 2 show the exemplar of risk-taking in the Under-studying provinces.

**Table 6:** Risk-taking pattern of the under-studying provinces

| Province | Risk-taking pattern () $C_{io}$ |
|---|---|
| Bushehr | 12.226 |
| Fars | 13.334 |
| Hormozgan | 12.737 |
| Ilam | 12.964 |
| Isfahan | 11.135 |
| Kerman | 11.105 |
| Khorasan | 11.295 |
| Khouzestan | 12.326 |
| Markazi | 12.445 |
| Qazvin | 12.834 |
| Qom | 13.108 |
| Semnan | 12.58 |
| Sistan & Baluchistan | 8.682 |
| Tehran | 13.327 |
| Yazd | 6.192 |
| mean | 11.753 |
| Deviation | 2.983 |

The writers, 2008 (Computed through Numerical Taxonomy Model)
Source: The Writers, produced based on data of table 6




**Flg. 2:** Frequency of sandstorm occurrence in under-studying pro during 1992-2006
Source: The Writers, produced based on data of table 6

*Stage 6: Computing the risk-taking degree of the provinces:*

After computing the exemplar risk-taking of the provinces, the degree of risk-taking in each province is computed as follows:

$$F_i = \frac{C_{io}}{C_o}$$

$$C_o = \overline{C}_{io} + 2s_{io}$$

is the mean *Cio* is the exemplar of risk-taking; *C io* is the degree of risk-taking; Where *F I* is the standard deviation. and *S io*

$$\overline{C}_{io} = \frac{\sum_{i=1}^{n} C_{io}}{n}$$

$$S_{io} = \sqrt{\frac{\sum_{i=1}^{n} (C_{io} - \overline{C}_{io})^2}{N}}$$

The degree of risk-taking in the Under-studying provinces was computed using the Taxonomy Numerical Model. As table 7 shows Yazd ranks first and faces the most treats and risks. Fars ranks at the end and is encountered the least treats and risks. Table 7 shows the real ranking of provinces for sandstorm treat and figure 3 illustrate it in a good manner.

**Table 7:** risk-taking ranking and classifying of the under-studying Provinces based on Numerical Taxonomy Model

| Province | risk-taking degree | Rank | Level |
|---|---|---|---|
| Yazd | 0.349 | 1 | 1 |
| Sistan & Baluchistan | 0.490 | 2 | |
| Kerman | 0.627 | 3 | 2 |
| Isfahan | 0.628 | 4 | |
| Khorasan | 0.637 | 5 | |
| Bushehr | 0.690 | 6 | 3 |
| Khouzestan | 0.696 | 7 | |
| Markazi | 0.703 | 8 | |
| Semnen | 0.710 | 9 | |
| Hormozgan | 0.719 | 10 | |
| Qazvin | 0.724 | 11 | 4 |
| Ilam | 0.732 | 12 | |
| Qom | 0.740 | 13 | |
| Tehran | 0.752 | 14 | |
| Fars | 0.753 | 15 | |

The writers, 2008 (Computed through Numerical Taxonomy Model)

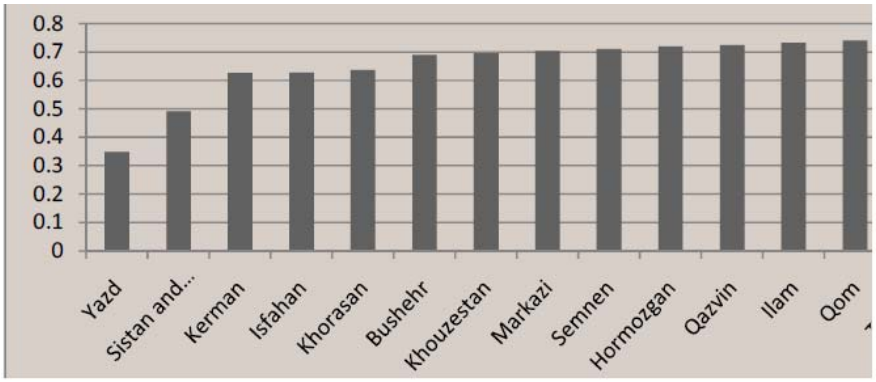



**Fig. 3:** Risk-taking degree of under-studying provinces based on NumericalTaxonomy Model
Source: The Writers (2008) produced based on data of table 7, row two

*Classifying the provinces for disaster-prone:*

Having determined the degree of treats by sandstorm in the given provinces and distinguishing the rank of each province, classifying the provinces was carried out using Geographic Information System (GIS). This classifying was determined based on risk-taking and their failure points were determined. Therefore, 4 levels were determined (table 8).

**Table 8:** Under-studying provinces classifying for sandstorm disaster

| Province | Level |
|---|---|
| Yazd- Sistan & Baluchistan | 1 |
| Kerman- Isfahan- Khorasan | 2 |
| Bushehr-Khouzestan-Markazi-Semnen-Hormozgan | 3 |
| Qazvin-Ilam-Qom-Tehran-Fars | 4 |

The writers, 2008 (Computed through Numerical Taxonomy Model)

Level 1 is the most risky and level 4 is the least risky on sandstorm. In addition, results show that Yazd and Sistan & Baluchistan which maintaining high degree of risk-taking are located at level 1. In level 2 Kerman, Isfahan and Khorasan are located. Bushehr, Khouzestan, Markazi, Semnen and Hormozgan are located in level 3, and at the level 4 Qazvin, Ilam, Qom, Tehran and Fars are located (figure 4).

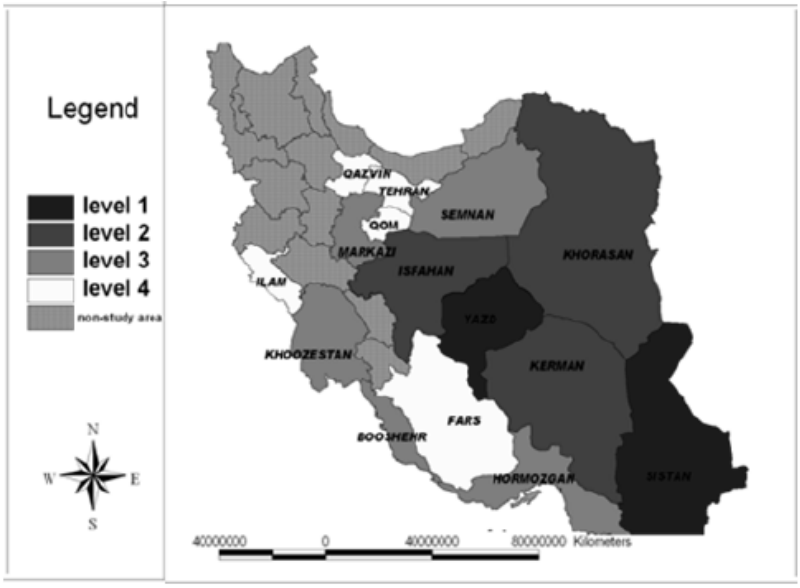



**Fig. 4:** Iran provinces ranking for sandstorm disaster

*Adv. Environ. Biol., 6(8): 2285-2295, 2012*

*Conclusion:*

Sandstorm is arisen from movements by sand near the surface of the earth. Usually, with movement of sand and its distribution in high altitudes, an intense turbulence is caused by disorder in heat and pressure balance in the atmosphere near the earth's surface. It causes increasing windstorm and its conversion to sandstorm. Sandstorm is not distributed integrate across the country and it indicates different patterns in the terrain. Although sandstorm was analyzed using a 15-year statistics (1992-2006) throughout the country, but certainly regarding he arid and semi-arid climate and the necessity for longer-period data a more exact results of sandstorm and its fluctuations would be obtained.

**Table 9:** Frequency of sandstorm in the period of 1992-2006

| Row | Province | Frequency | Rank at the period |
|---|---|---|---|
| 1 | Bushehr | 7 | 11 |
| 2 | Fars | 1 | 15 |
| 3 | Hormozgan | 31 | 6 |
| 4 | Ilam | 3 | 13 or 14 |
| 5 | Isfahan | 40 | 5 |
| 6 | Kerman | 14 | 9 |
| 7 | Khorasan | 67 | 3 |
| 8 | Khouzestan | 17 | 8 |
| 9 | Markazi | 3 | 13 or 14 |
| 10 | Qazvin | 21 | 7 |
| 11 | Qom | 13 | 10 |
| 12 | Semnan | 49 | 4 |
| 13 | Sistan & Baluchistan | 271 | 1 |
| 14 | Tehran | 6 | 12 |
| 15 | Yazd | 68 | 2 |
| **Total of the period** | | **611** | – |

The writers (2008) (Computed through Numerical Taxonomy Model)

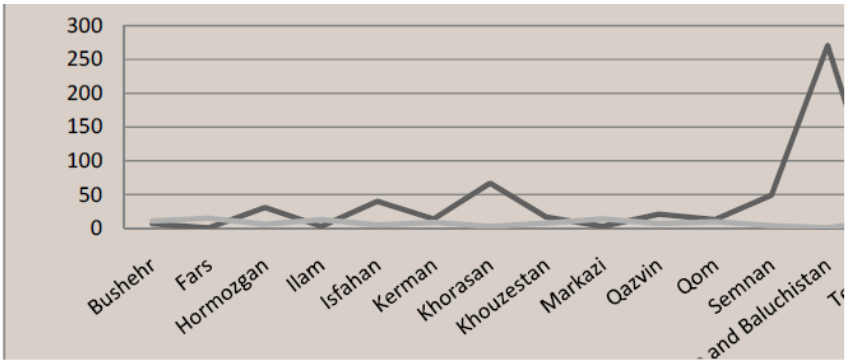



**Fig. 5:** Risk-taking pattern of under-studying provinces based on NumericalTaxonomy Model
Source: The Writers (2008) produced based on data of table 9

Based on the studies was carried out by the authors, 614 sandstorms have occurred in the countries desert provinces during 1992 to 2006. Meanwhile, the most sandstorms have occurred in the late May because of passing cold season and begging hot season. The months of September, March, April and February (from beginning of fall season to the end of winter). This period is associated with cyclones and an shifting air mass, which is caused by sun shining on arid and bare salty lands. In Sistan & Baluchistan province, the highest amount of sandstorm is seen in September and the least sandstorms occur in January. Sandstorm occurs in Zabol because of its unique situation- the 120-day Wind of Sistan. Climate and atmospheric conditions are considered as factors affecting wind erosion, which is identified in 17 desert provinces for the 138 regions under the influence of sandstorms. More than 83counties are exposed to sandstorm and a number of 165 regions are covered by sandstorm in Iran (Kalantari, 2008:202). All regions affected by wind erosion in the country is amounted up to 19813495.7 hectares from which 12836656.2 hectares is located in jumping off region, 1909539.25 hectares in transportation region and 5067300.25 hectares in

sedimentation area (Technical Office for Sand Fixation and Desertification Prevention, 2003:45).

Generally, south eastern, central and southern parts of Iran are the most risky and critic regions influenced by sandstorms. These parts are faced heavy sandstorms because of vast sand distribution, weak plant coverage and fast-blowing winds. This caused the increase of sandstorm disasters in the provinces around. After Yazd and Sistan & Baluchistan provinces, which rank first in sandstorm disaster, Kerman, Isfahan and Khorasan maintain lower amounts of sandstorm. Bushehr, Khouzestan, Markazi, Semnan and Hormozgan locate at third level, and Qazvin, Ilam, Qom, Tehran and Fars set in fourth level of sandstorm disaster. Other main findings of the research are summarized as follows: 1) Of all under-studying provinces, 17 desert ones are exposed to the sandstorm disaster; 2) The central and southeastern parts enjoy a high degree of instability; 3) There is no ratio regarding the number of storms, while Zabol in Sistan & Baluchistan has the highest number and Arak has the lowest number of storms; 4) Most storms have occurred during the hours of 10 to 18 in local time and just 10% has occurred at night; 5) Given stability and continuity of storms, the highest probable occurrence of storm is seen in the period of March to October and high degree of persistence with a medium level of 6 hours is for Zabol station in Sistan & Baluchistan; 6) A comparison between intense winds and the number of storms show that there is a close relationship between intense wind and storm creation at first and secondly a significant between different stations. In this sense, studies indicate that geomorphologic position and the kind of soil affect creation of storm; 7) Although Sistan & Baluchistan maintains the highest figures for the number of storms, duration of storm, occurrence number and regions of critic focal points and the amount of damages, but Yazd is considered at the high. This is because of damages to structures, transport facilities, number of villages and cities damaged, people died, roads and bridges destroyed, vehicles damaged, damages to the factories and industries, cattle died and high level other damages by sandstorm.

**References**

1. Ahmadinejad, Mahmoud et al., 2006. 'Inspection & Application of Disaster Command System in Disaster Management of Road Transportation Network'. The 2nd International Conference of Disaster Comprehensive Management on Natural Unexpected Hazards, 18-19 February, Tehran University, Tehran, pp: 246-263.
2. Alamdari, Shahram, 2007. ' Disaster Comprehensive Management: Doctrines, Policies and Strategies'. The 3rd International Conference of Disaster Comprehensive Management on Natural Unexpected Hazards, 18-19 February, Tehran University, Tehran, pp: 203-219.
3. Alijani, Bohlol, 2007. 'Role of Spatial Analysis on Hazards Management of Iran Precipitation' the 3rd International Conference of Disaster Comprehensive Management on Natural Unexpected Hazards, 18-19 February, Tehran University, Tehran., pp: 118-133.
4. Badri, Sayed Ali. and Saeed Reza Akbarian, 2006. 'Comparative Study of Application for Methods of Development Scaling in Regional Studies (Case Study: Esfarayen County)' Quarterly journal of Geography and Development., 7: 78-94.
5. Bidabadi, Bijan, 1985. Taxonomy Analysis. Programming and Budging Organization for Markaz Province, Arak. - Source: CRED-EMDAT, Universite Catholique de Louvain, Belgium, 2006
6. Dehghanpoor Farashah, Alireza, 2005. Statistical and Synoptic Situation Dust Storms in Iran Central Plateau during 1990-2000, Tarbiat Moalem University Press, Tehran.
7. Goudie, A.S., 1978. 'Duststorms and their Geomorphological Implications'. Journal of Arid Environment, 1: 132-149.
8. Habibi Nokhandan, Majid, 2004. Climate and Safety of Iran Mountainous Roads. Doctorate tessie, under supervision of Dr. Qasem Azizi. Faculty of Geography, Tehran University, Tehran. - Habibi Nokhandan, Majid (2007) 'Determining Critic Regions of typhoon Occurrence at Iran Road Transporation Network'. Road Quarterly, 58: 26-41.
9. Habibi Nokhandan, Majid et al., 2006. 'Location Analysis on Climate Conditions in Iran'. Road Quarterly, 54: 79-93.
10. Hekmatnia Hasan & Mousavi Mirnajaf, 2006. Model Application on Geography with Focusing on Urban and Regional Planning. Elm-e-Novin Publications, Tehran. - http://www.disaster,an.blogfa.com2006
11. http://www.disaster,an.blogfa.com2006
12. Iran Technical Office for Sand Fixation and Desertification Prevention, 2003. Plan of Determining Critic Foci of Wind Erosion and Operational Priorities of 14 Provinces. The Country's Organization for Forests, Pastures and Drainage Works, Tehran. - Iran Technical Office for Sand Fixation and Desertification Prevention (2008) Periodic Reports. the Country's Organization for Forests, Pastures and Drainage Works, Tehran.
13. Kalantari Khalilabad, Hossein, 2008. Patterns of Out-of-town Transportation Management against Sand Storm Disaster. PhD Thesis, With Supervision of Dr. Ahmad Pourahmad, Faculty of Geography, Tehran University, Tehran.

14. Kalantari, Khalil, 2001. Regional Planning and Development: Theories and Techniques. Khoshbin Publications, Tehran.
15. Meteorology Organization of the Country, 1998. Astaneh Wind in Removing Shifting Sands and Forecasting the Storm Start. Deputy for Training and Research, Tehran.
16. Meteorology Organization of the Country, 2001. A Project for Study of Managerial methods of Fighting against Atmospherics and Climatic Disasters and organizing Destructive Climatic Alarming Systems, Ministry of Road and Transportation, Tehran.
17. Meteorology Organization of the Country, 2008. Data for Sand and Duststorm, Automatic Data Management, Tehran.
18. Mozafari, Kamran, 1992. 'Storm Hazards and its Prevention Methods' the first Conference for Natural Disasters in Urban Regions. Tehran Urban Planning and Research Center, Tehran
19. NoAA, 2003. Duststorms, 'sandstorms and related NOAA Activities in the Middle East'. NOAA Magazine Online, No. 86
20. Qing-yang, Zhang, 2002. 'Preliminary Study on Sand-Dust Disaster and Countermeasures'. Chinese Geographic Science, 12(1): 9-13.
21. Smith, Kit, 2003. Environmental Hazards. Translated by Dr. Ebrahim Motiei & Shapour Goudarzinejad. Sam Press, Tehran.
22. United nations, UNCCO, UNEP, 2001. Global Alarm: dust and storms from the world's drylands.
23. www.fema-gov/regions.
24. Yazd Province General Office for Road and Transit, 2000. Periodic Reports, Reports No. 36-43, Deputy of Road Maintenance, Yazd.