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Research Article

PERFORMANCE EVALUATION OF SOME METEOROLOGICAL DROUGHT INDICES IN SOUTH OF KHUZESTAN PROVINCE AND ZONING IT USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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ABSTRACT
Drought is one of the climate issues which affect living creatures. Khuzestan is a semi-arid province of Iran. Its average rainfall is around 246 mm. The main sources of water supply for agriculture in this region include rivers such as Karkheh, Dez, Karun and Jarahi. Due to drought, all of these resources have been faced with the problem of water shortage. This problem has been intensified in recent years. The drought phenomenon has negative impacts on natural resources and people who are mostly farmers. The aim of this study is to investigate the different aspects of drought phenomenon and its spatial variations in the south of Khuzestan. Geostatistical methods using Geographic Information System (GIS) were employed for this aim. For this purpose, the 25-year rainfall data of 11 stations in the south of Khuzestan was used. First drought review was done based on moving average of 3, 5 and 7 years. Its overall results indicate the decreasing trend of rainfall in the region in recent years. Then, using the indices of ZSI, PNPI, RAI and SPI, drought severity and duration were studied. In order to select the most appropriate descriptor index based on the research paradigm, performance evaluation of meteorological drought index of the area was done. In this method, the ZSI drought index was introduced as the best descriptor index, which reflects the development of the region drought with return period of 5 to 6 years. In order to investigate drought spatial variations in the south of Khuzestan, Inverse Distance Weighted (IDW) interpolation method and simple kriging method were used for zoning the drought distribution based on the best indicator in the area. To determine the most appropriate zoning method, two measures including the mean absolute error (MAE) and the root-mean-square deviation (RMSD) were used. Given that the zoning errors in inverse interpolation method are greater, so, for zoning in the area, kriging method was used. This indicates that the drought has engulfed the entire region intensively in recent years.

Keywords: *South of Khuzestan, Drought, ZSI, PNPI, RAI, SPI, Kriging.*

INTRODUCTION
Drought is one of the environmental events and is an integral part of climate fluctuations. It is a condition of lack of rain and rising of temperatures which can happen in any climate. Drought situation awareness through prediction and zoning the severity of drought can considerably reduce the risk of losses caused by this phenomenon. This phenomenon associated with limited availability of water sources, which limits plant growth, changes in time and space with reduced precipitation, increased evapotranspiration, temperature and other parameters that its occurrence leads to natural imbalance in regional scale and the effects of this issue can be associated with changes of agricultural and water resources (Ramezani Gourabi, 2005). Complete prevention of water shortage is not possible, but by analyzing historical records of the drought phenomenon and relying on available statics and information, return periods of drought can be estimated for different regions, and the problems caused by drought phenomenon can be reduced (Sha'bani, 2009). Metrological drought which is called climatology drought in most sources is caused by lack or reduction of annual raining in a period of time. In other words, metrological drought occurs whenever the amount of rain is less than the long term average amount. This lack of rain may be evaluated regarding the normal average of a region or the duration of a dry period. Agriculture is the biggest consumer of freshwater; currently around 70% of the world freshwater is used for agriculture. In

our country also more than 90% of the water demand is devoted to agriculture (Rahmanian, 2000). Little rainfall and drought have a lot of influence on environment and human of which the increase in the average temperature, and alteration in region climate, increase of pollution concentration, and increase in water EC, increase in energy consumption due to increase of temperature, water shortage crisis on the living and well-being, security and hygiene, forest fires, spread of pests and diseases, reduction in the amount of groundwater and surface water, reduced agricultural production and economic and social problems caused by drought can be mentioned. Due to recent droughts and increased knowledge and information about its properties for managing and coping with the effects of drought, in this study, it has been tried to evaluate and analyze the south of Khuzestan province droughts using the ZSI, PNPI, RAI, SPI indices, in a statistical period of 30 years (1981-2011) and zoned by using the Interpolation methods in GIS environment.

Research Background

In the area of drought, several studies have been done both inside and outside the country. Moghadam *et al.*, (2001) using the three Standardized Precipitation Index, analyzed and assessed Docile (DI) and normal percentage evaluated and estimated droughts of Sistan and Baluchistan province and using the SPI method, suggested the best index for the region. Banejad *et al.*, (2006) used the SPI index in evaluating the drought process of Hamadan province and zoned the results suing the ArcView software. Yazdani *et al.*, (2007) evaluated droughts in the basin and adjacent areas of Zayandehroud in a time period of 32 years, and precipitation statistic of 85 meteorological stations using the indices of average rainfall, rainfall distribution index and the standardized precipitation index, and then tended to interpolate and to creates mapping extends the drought every year. Results of their assessment shows that the Standardized Precipitation Index has better application in the basin of Zayandehroud. Ameri *et al.*, (2010) using the index of rainfall percentage, zoned drought in Kerman province in a 30-year period and for the entire rain-gauge stations. Their study results showed that the method of interpolation radial basis function (RBF) is better than other known methods for drought intensity zoning map of Fars province. Yazdani *et al.*, (2010) evaluated droughts in Iran using Standardized Precipitation Index (SPI) and precipitation data of 119 stations with the same statistical period of 32 years (1974-2003). Their results showed that the number of droughts at shorter intervals is more than the number at longer intervals, and then zoned the droughts resulted by SPI using the Kriging method. Haghighatjou *et al.*, (2011) using the percentage of normal rainfall (PNPI) and statistics of 80 rain-gauge stations in the period of 15 years (1994-2009) evaluated droughts in Fars province in different areas and suggested the IDW to zone droughts in Fars province. Zamani and Amiri (2011) estimated droughts of south of Fars province, using ZSI index and rainfall of 30 meteorological stations and synoptic survey in the statistical period of (1977-2005) and zoned drought in the area using the GIS and inverse distance interpolation IDW software. Kouzehgaran *et al.*, (2012) studied frequency and zoning of drought in Southern Khorasan province using rainfall anomaly index (RAI) in the statistical period of 24 years based on the precipitation data of 23 stations and after zoning drought, using the ArcGIS software, showed that drought with various severities has covered 1 to 34 percent of the province. Eivazi *et al.*, (2011) reviewed and determined the most suitable climatic drought index in Golestan province using the four indices of DI, PNPI, SPI and ZSI and data from 20 rain-gauge stations in a 30-year period. Their results show that apart from 2 stations, all the stations under study of occurrence of extreme drought were coincided with minimum rainfall. Al-Abed *et al.*, (2001) in Zarqa area, after a 36-month evaluation using the standardized precipitation index, normal rainfall, and docile, produces a practical map in which data is distributed into 4 drought classes using the GIS. Theses maps showed drought in different areas over time and allow control and monitoring with help of practical methods. Conciller *et al.*, (2007) forecasted monthly droughts with probability transfer functions, SPI, and assuming monthly precipitation data being normal; their results didn't have a vast difference with the estimated precipitation in the area. Shahid and Hazarika (2009) suggested that the SPI is only an index in which the possibility of drought zoning in different time scales is possible and therefore has a high flexibility in determination and zoning of drought periods and their influence on agriculture. Murad *et al.*,

(2011) evaluated drought in north-west of Bangladesh using the RS and GIS. For this, they used the SPI and NDVI indices. They found use of these data highly influential on reducing environmental and economic damages of drought. Shofiati *et al.,* (2011) evaluated the drought situation on Indonesian basin using the GIS and satellite data. For this purpose, they evaluated the drought risk using factors such as rainfall patterns, irrigation, ground water capacity, soil drainage, and vegetation of the land. With regard to the high correlation between these factors with the NDVI index, use of biophysical factors to create maps of drought-prone areas was suggested. Legesse (2012) used the GIS and remote sensing in evaluation of drought risk in southern Ethiopia and after evaluation of satellite data in an 8-year period and precipitation data, used the NDVI and VCI indices to zone drought and further forecasts. Lima *et al.,* (2012) assessed drought zoning and forecasting methods based of GIS. Their results were so useful in forecasting and reduction drought risks.

MATERIALS AND METHODS

1. The Region under Study

Khuzestan province is of the southern provinces of Iran and is the seventh biggest province of the country which is in the range of 47 degrees 42 minutes and 50 degrees 39 minutes east of the Greenwich meridian and 29 degrees 58 minutes and 32 degrees 58 minutes north of the equator (Ashtari *et al*., 2013). The region under study is south of the province including cities of Shadgan, Mahshahr, Khorramshahr, Ramshir, Omidieh, Hendijan, Behbahan, Ramhormoz, Ahvaz, and Baq-e-molk. In this study the statistics of 11 regional meteorology stations in the statistical period of 25 years (1987-2011) were used and its features are shown in table 1.

Table 1: Geographical characteristics of the studied metrological stations

Number	Station name	UTM	
		Y	X
1	Ahvaz	3467715	277019
2	Khoramshahr	3403479	228710
3	Baq-e-Molk	3488275	393084
4	Pagachi Ramhormoz	3463716	365175
5	Shohada Dam Behbahan	3392880	431345
6	Ramshir	3418692	347072
7	Mahshar Port	3383708	326748
8	Hendijan	3345337	376511
9	Youzi Shadgan	3393579	281849
10	Cham Nezam	3397893	397301
11	Ab-Shirin	3377482	442893

2. Research Method

To assess the drought situation in different countries different parameters are used, these indices are obtained based on definitions of drought and with the estimation methods in which one or two metrological variable is used. In this study, 25-year precipitation data (1987-2011) of 11 metrological stations in south of Khuzestan province, were used as region index station in drought analysis. First to assess the correctness and correlation of the data the run test was used and after estimating drought level using the ZSI, PNPI, RAI, SPI indices and after determination of the best index describing drought in the region, using the Kriging interpolation method (due to being the most accurate in comparison with other methods) the final drought zoning map in the region was created. Various indices have been invented and

provided to analyze drought. In this study the indices that have been used more in the research history at a national and international level, were used that are described as follows:

1. The Standardized Precipitation Index or Standardized Variables (ZSI)

This index is obtained from subtract of annual rainfall total with average precipitation of the whole period Divided by the standard deviation of annual rainfall. This index is estimated using the following equation:

$$ZSI = (X_i - X) / S \quad (1)$$

In which:

X_i = Average of annual rainfall

X = Average of rainfall in the whole period

S = Standard deviation in any time scale.

Which is used in an annual form in this study and finally the severity of drought in various years in different stations was determined using this index. Classification of drought severity based on ZSI index is mentioned in table 2.

Table 2: Drought classification based on ZSI index (Reference: Lashti Zand, 2004)

Drought Severity	Value of ZSI
Weak	(-0.25)_ +0.25
Average	(-0.25)_(-0.52)
Severe	(-0.52)_(-0.84)
Extremely severe	(-0.84)_(-1.28)

2. The Precipitation Normal Percentage Index (PNIP)

The precipitation normal percentage is one of the simplest indices of drought in a region. Analysis of precipitation normal percentage is very influential while being used for drought or the opposite in one specific region on season. This index is obtained by dividing real precipitation (P_i) by precipitation (P) and multiplication by 100 (Equation 2):

$$PNPI = P_i / P \times 100 \quad (2)$$

Table 3: Various classes of precipitation normal percentage index

Situation Description	Index classes
Normal	80-120%
Weak drought	70-80%
Average drought	55-70%
Severe drought	40-55%
Extremely severe drought	Less than 40%

3. Standardized Precipitation Index (SPI)

The standardized precipitation index was introduced by (McKee, 1995) in order to determine and monitor and quantify the lack of rain and to monitor drought situation for time scales of 3, 6, 12, 24, and 48 months. Application of Standardized Precipitation Index gives this possibility to monitor drought for both short term scales like soil humidity and long term scales such as surface water and groundwater. How the index is estimated is mentioned in equation 3 and described in table 4.

$$SPI = (P_{iK} - P_i) / S \quad (3)$$

In which:

P_{iK} = the precipitation amount in station i at observation k (mm)

P_i = the average of long term precipitation of station i (mm)

S = standard deviation of long term precipitation data of station i.

Table 4: Value of Standardized Precipitation Index (SPI) (Reference: Lashti Zand, 2004)

Drought Severity	Index value
Very, very humid	Greater than or equal to 2
Very humid	1.5-1.99
Average humid	1-1.5
Mild humid	0.5-0.99
Almost normal	-0.49 – 0.49
Mild dry	(-0.99) – (-0.5)
Average dry	(-1) – (-1.49)
Very dry	(-1.5) – (-1.99)
Beyond dry	Smaller than or equal to -2

4. Rainfall Abnormalities Index (RAI)

This index was introduced by Roy in 1965.This index is obtained by comparing the rainfall to random numbers between +3 to -3. In a way that 10 banks are allocated to rainfall abnormalities. The only effective factor in estimation of this index is rainfall and it is used in two time scales of monthly and annual.

a) If $P_i > P$, or the abnormality is positive, the rainfall abnormality index is estimated from the following equation:

$$RAI = 3[(P_i - P) / (m - P)]$$

b) If $P_i < P$, or the abnormality is negative, the rainfall abnormality index would be as follows:

$$RAI = -3[(P_i - P) / (x - P)]$$

c) Attribution of +3 to -3 thresholds respectively to the average of 10 cases of the most severe positive and negative abnormalities obtained from the rainfall abnormality index.

d) Finally by scaling the values amounted from the rainfall abnormality index, 9 abnormal classes are defined with the domain of extremely humid to extremely severe drought.

e) In this equation P_i is annual rainfall in the year i, P is the average rainfall of the period, m is the average of 10 years with the most rain, and x is the average of years with the least rain.

Table 5: Classification of Rainfall Abnormality Index (RAI) value

Drought Severity	Index Value
Normal	Greater than 0.3
Almost normal	0.3 – (-0.3)
Weak drought	(-0.3) – (-1.2)
Average drought	(-1.2) –(-2.1)
Severe drought	(-2.1) – (-3)
Extremely severe drought	Smaller than or equal to -3

Choosing the best Descriptive Index

After estimation of indices, based on the research model for assessing the performance of a meteorological drought indices for climate samples of Iran (Khalili and BazrAfshan, 2002), the hypothesis that the minimum precipitation during a long term climate period reflects the extremely severe metrological drought in the region is used. Based on this hypothesis, the indices that introduce the highest extent of drought based on the minimum amount of precipitation during the statistical period to, have the most accordance (Khalili and BazrAfshan, 2002). In this research it is tried to assess the indices under

evaluation based on this matter in order to select and introduce the best index that has the most accordance with the region under study.

Zoning Drought, and Measurement of the Accuracy of Interpolation Methods

In this study after selecting the best index describing drought in a region, it will be tried to zone drought in the region to demonstrate the drought situation better, using the two methods of weighted inverse distance interpolation and ordinary Kriging. Also in order to select the best interpolation, the mutual evaluation method was used. In this method, at every stage one point of the observations is omitted and that point is evaluated by other observed points. This is repeated for all the observed points in a way that at the end there will be the same number of evaluations as the observed points, finally by having the real and evaluated values, error and deviation of the method used can be measured. Various measures are available to do this, among which the Mean of Absolute Error (MAE) and the Root Mean Square Error (RMSE) can be pointed out (Yazdani, 2004). The equations to calculate RMSE and MAE are according to equations (4) and (5).

$$RMS_e = \sqrt{(\sum_{i=1}^{n}[Z^*(x_i) - Z(x_i)]^2)/2} \quad (4)$$

$$MAE = \frac{\sum_{i=1}^{n}|Z^*(x_i) - Z(x_i)|}{n} \quad (5)$$

In which n is the number of observed points, $Z^*(X_i)$ is the evaluation for the point i, $Z(X_i)$is the value of observation i, and $\overline{Z}(X_i)$ is the average of observed values.

RESULTS AND DISCUSSION

After assessing the ZSI, PNPI, RAI, and SPI indices we reached generic conclusions of regional precipitation and drought level in stations under study, in a way that we can discuss drought in this stations with full outright because droughts in the region had been assessed by various and valid indices. Now to achieve a more complete analysis of this issue, among the indices, one that has the most accordance with the region should be chosen as the most practical and scientific methods. To do this, the Khalili and Bazrafshan (2003) method was used. Namely, the data obtained from each index under study for each station in 4 years, respectively 1987, 1999, 2007, and 2008 which indicate the minimal amount of precipitation during the period, were chosen and added separately to EXCEL and the calculations regarding each station that indicates the severity of drought were done in order to choose the index that demonstrates the most drought severity in those years as the best descriptive index according to Khalili and Bazr afshan equation. Results of evaluation of various indices is provided in table (5) which show that among the four indices under study (SPI, RAI, PNPI, and ZSI) the ZSI index can be used more and provide more favorable results. Because it assesses the severity of drought in the region better and more completely and also has demonstrated more practicality in the region under study.

Table 6: Comparison of dryness percentage determined in the minimum precipitation occurred in stations under study

Index	Weak Dryness	Medium Dryness	Severe Dryness	Extremely Severe Dryness	Total
ZSI	0	2.2	9.1	88.7	100
PNPI	11.4	29.5	34.1	25	100
RAI	2.3	2.3	22.7	72.7	100
SPI	29.5	45.5	15.9	9.1	100

As it can be said according to table (6) the ZSI index has distributed the greatest minimum of precipitation in stations at severe, 88.7 and extremely severe, 9.1 levels while this amount of precipitation is classified in RAI, PNPI, and SPI indices respectively at levels of extremely severe to 72.7, 25, 9.1 and severe 22.7, 34.1, and 15.9.After identifying the ZSI index as the best index to assess drought in the region, the two weighted inverse distance and Kriging methods were used for interpolation the results obtained from these to method also showed that the Kriging provides more accuracy in regards to the region under study (table 6). The zoning maps of the years 1987, 1999, and 2008 are shown in figure (1) as the driest years in three decades which show the drought severity changes in various years and parts of south of Khuzestan province.

Table 7: Comparison between the value of interpolation error with two methods of IDW and Kriging

Choice measure	IDW		Kriging	
	MAE	RMSE	MAE	RMSE
ZSI-87	0.0294	0.1987	0.0204	0.1874
ZSI-99	0.0139	0.3460	0.0057	0.3381
ZSI-08	0.0079	0.2405	0.0011	0.2271

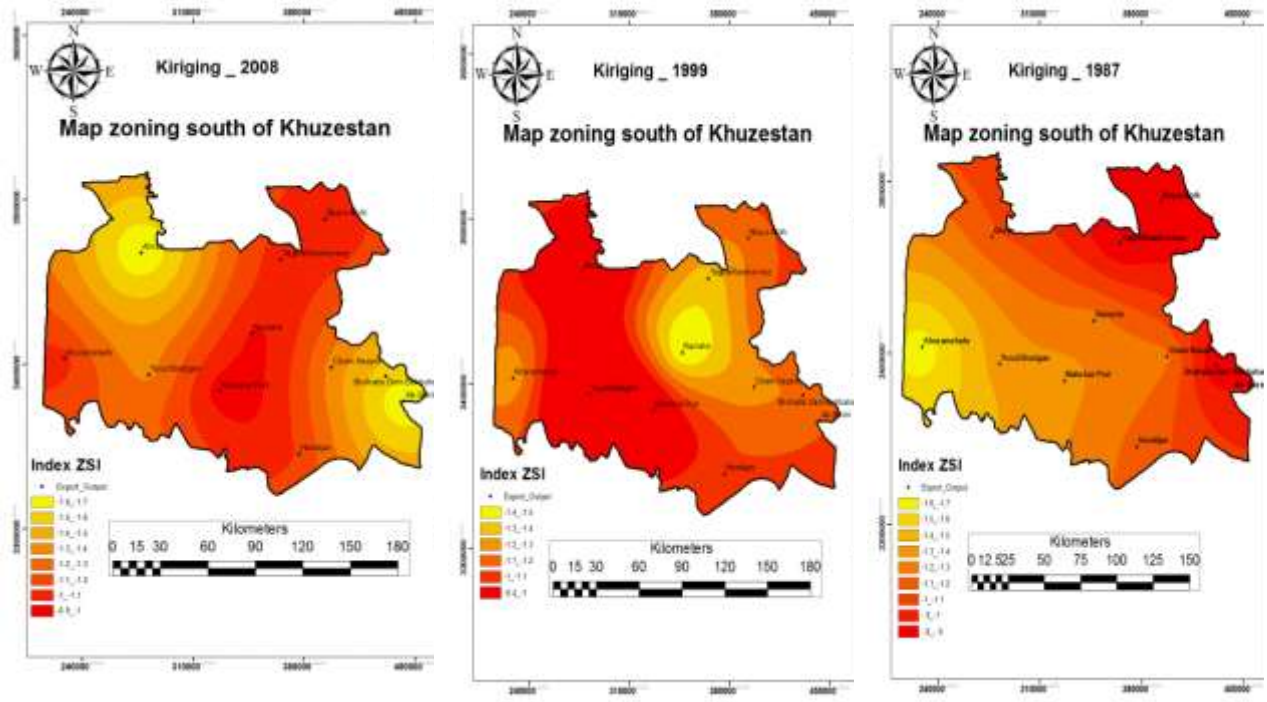

Figure 1: Drought zoning map using the ZSI index in the studied region

The results obtained from evaluating the drought zoning maps in the region demonstrate that in the year 1987, an extremely severe drought covered most parts of south of Khuzestan province which, its severity in Khoramshahr is more than other regions. Also evaluating the map in the year 1999 indicates that an extremely severe drought covered almost all the studied region which is most severe in Ramshir and Ramhormoz. After evaluating the map in the year 2008, it becomes clear that most of the studied region is covered with severe drought and just some parts of Mahshahr Port are under extremely severe drought. This means that drought in driest years of the 80's and 90's is more than the driest of the 2000's.

Conclusion

In the overall conclusion about the result of indices in a 25-year period in 11 stations, the ZSO indices has indicated37.82% of years humid, and 19.27% of years normal, and8.55% of years with severe drought and 34.36% of years with extremely severe droughts. The SPI index has indicated 64.72% of years as humid, 27.27% of years as normal, 6.55% of years with severe drought and 1.45% of years with extremely severe drought. The PNPI index has described 65.81% of years as humid, 18.55% as normal, 11.64% as severe drought and 4% as extremely severe drought. The RAI index has shown 54.73% of years as humid, 19.09% of years and normal, 13.27% of years and dry, and 12.91% of years as extremely dry.

At the end in regards to application evaluation of indices and analysis of the given percentages (table 5) it can be said the ZSI index due to showing 34.36% of the years with severe drought, is the best index the evaluate drought severity in stations south of Khuzestan province. According to evaluation in all the studied stations, a severe drought existed in the years 1987, 1999, and 2008 which all the indices have shown these three years as very dry and it can be said that the Z score index has a suitable accordance with the years of lack of rain and is confirmed as a practical index in this region. Drought zoning using the Arc-GIS 9.3x software with the Kriging method also showed that drought has been frequent in most places but it is increasing in northern and southern parts of the studied region and its continuity has prolonged to 2000's.

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