Original Research Article

Evaluation of meteorological drought index for drought assessment and mapping in Lorestan province in Iran

Abstract

Drought is a quiet and creeping phenomenon that associates with rainfall and relative humidityreducing, increasing temperature and wind speed. In recent decades among natural disasters witch have affected human societies, this phenomenon quantity and frequency was more than other events. Therefore, understanding of the drought conditions through the prediction and zoning of drought extents can considerably decrease the damaging risks of this phenomenon.This research has been studied with statistical correlations of 5 meteorological drought indicators and use of monthly rainfall dataof36 synoptic and climatology stations in Khuzestan province and its surrounding. Statistical years weren't similar and the statistic period is between 1951 to 2010 years. Drought events determined with the use of indicators such as: Standardized Precipitation Indicator (SPI), percentage of normal indicator (PNI), decilesindicator (DI), Chinese Z indicator (CZI), Z standardizedindicator (ZSI) and sequences.Dual correlations coefficients in all stations of this province showed relatively high values, so 54 maps for 54 years plotted with SPI indicator and sequences and the driest years were: 2008,1973.1966,1964,1990 and 2010.

Key words: drought , drought indicators,Lorestan,monthly rainfall, zoning.

Instruction

Nowadays drought has become to one of the most expensive natural disasters (Klaineet al, 2013). Drought is a rainfall shortcoming and temperature increasing situation that may occur in each climatic conditions and it has different types such as: agricultural drought, hydrological and meteorological. We attention to rivers discharge in hydrological drought (Alizadeh, 1387). Meteorological drought happens more than other types of droughts,agricultural and hydrological droughts occur after that (Mahmoodi, 1380). Drought reduces agricultural products (Azizi, 1378). Unlike the arid, drought occurs in humid areas too (Soltaniet al, 1386). There are many methods for study on drought. It's difficult to define and monitor the drought. Drought has a major impact on soil and vegetation cover. HedayatiDezfuli, Akram has studied on drought with the use of standard precipitation

methods, percent difference, deciles and Z standard precipitation method and she has concluded thatrainfall has increasedtoward the northeast because of heights increasing. Rainfall didn't have a clear trend in total area and there were so difference between area droughts because of extent.ZarehAbyane, Hamid has studied on Hamadan drought with 60 percent threshold methods, percent of normal, rainfall classified and deviation of the mean. Precipitation time heterogeneity was a result of this research and generally the most rainfall occurs in winter and the lowest in summer. Farajzadeh, Hasan in his research has used Nietzsche method, SPI and DRI for evaluation and monitoring Northwest drought and wet that he has announced for selection dry and wet years the SPI method is the best, because this method obeys from normal distribution. LashtiZand, Mehranin his research has studied on Northwest droughts. Azizi has studied on relation between Iran droughts and El Niño southern oscillation. Montazeri studied on Zayanderoud basin with standardized precipitation. Celine White et al. reconstructed past climate with tree rings and understood that one unprecedented drought has occurred in medieval that these droughts have relation with Enso. Celine White et al. studied on USA droughts. They found there is a global pattern that explains the whole earth droughts except Europe; and when drought is common in non-tropical areas, tropical areas have no drought and this is relation between Enso and drought. Cook et al. studied on West USA drought with Palmer indicator, principal component analyses and network point. They found there is a relation between 1930's drought and dust; and year 1700 was the driest year of USA. Khideretal.simulated the El Nino and medieval glacier courses, it was collected from the Sulawesi sea sediment cores, and there was heat in the western edge of the tropical Pacific. Results showed that Enso was the strongest and La Nina was more than El Ninoduring the Lia little ice. Chi Hu Chiin a research between 1470-1997 years showed that when south China has drought conditions, there is a humidity conditions in northeast and this is a meridional variety. In this research firstly anomaly happened in the northeast and then came to the down latitudes.These events have happened in USA too and it happens at 30 degree of northern latitude every 10 years.AimalJulien et al. have attempted to examine human effects on climate. Their model was wavelet that showed strong relation between solar energy and El Nino at 200 but human effects were short-term and it was just on radiation. Kaplan etal.evaluated three tests at sea level following the unprecedented drought and heat in 1988. They did it at 21st, 22nd and 23rd may. Their purpose was estimate the relation between sea surface temperature and rotational pattern of the northern hemisphere. All experimentswere performed very detailed but it wasn't like originally conditions because it was performed on the ocean surface sojustsea surface wave

wasn't drought factor. Justin realized the relation between western America humidity and dry and the relation of El Nino and southern, Arcticand high-latitudes oscillations by tree rings. Siger et al.studied on southeast of United States drought and relation between hydro climatology and human climate change. They predicted drought with use of rainfall, water oscillations and tree rings during the last millennium and they found that winter droughts areagree with El Nino in Southeast but summer droughts totally obey from internal factors. He found that tree rings of 20th century are wetter than last millennium and a 21 years droughthasoccurredin the 16th century.in short-term rainfall increases but evaporation increases too. Summary when drought happens by human changes, rainfall and evaporation reduce. Vedhouse et al. studied on 1930 and 1950 droughts. Some of the medieval droughts were longer and wider. From Paleoclimatology literature can be deduced that past droughts were more varied. In other research Vedhouseet al. studied United States droughts and reconstructed drought with use of tree rings and they found that last millennium droughts of America arise from two patterns and these two patterns are pressure pattern of the northern hemisphere and ENSO teleconnection.

Materials and methods:

Geographical structure and nature situation

is a province of western Iran in the Zagros Mountains. The population of Lorestan was estimated at 1,716,527 people in 2006. Lorestan covers an area of 28,392 km².it is Location of Lorestan within Iran33.4871°N 48.3538°E.

The climate is generally sub-humid continental with winter precipitation, a lot of which falls as snow (Köppen *Csa*). Because it lies on the westernmost slopes of the Zagros Mountains, annual precipitation in Lorestan is among the highest anywhere in Iran south of the Alborz Mountains. At Khorramabad, the average annual precipitation totals 530 millimetres (21 inches) of rainfall equivalent, whilst up to 1270 millimetres (50 inches) may fall on the highest mountains. The months June to September are usually absolutely dry, but Khorramabad can expect 4 inches of rainfall equivalent in December and January.

Temperatures vary widely with the seasons and between day and night. At Khorramabad, summer temperatures typically range from a minimum of 12 °C (54 °F) to a hot maximum of 32 °C (90 °F). In winter, they range from a minimum of -2 °C (28 °F) to a chilly maximum of 8 °C (46 °F).

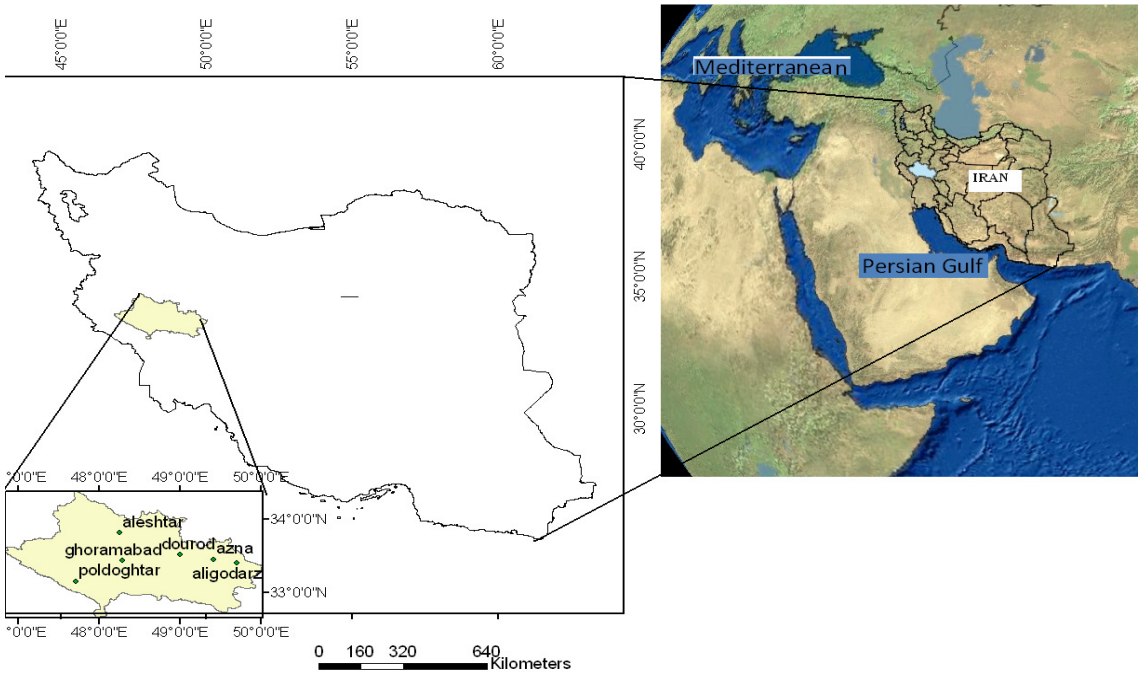

Figure 1 Location of Lorestan within Iran

Percent of normal indicator

Advantage: calculations are so simple and appropriate for public awareness of drought condition in locally and seasonally scale. Disadvantages: it can simply have the wrong interpretation.

Table 1: percent of normal indicator classification

class	PNI quantities	PNI Rating
slight drought	70-80 percent	1
moderate drought	55-70 percent	2
intense drought	40-55 percent	3
very intense drought	less than 40	4

Standard precipitation indicator method

This indicator has been edited byMackeeet al. from Colorado University. SPI indicator is for lack of rainfall measurements from various sources. SPI is calculated in each area based on long-term statistics and for specific period. For this work the following formula is used: SPI= (rainfall in specific period -same period rainfall mean)/standard deviation. SPI positive amount indicates that rainfall is more than average rainfall and negative amount means the opposite of that. As SPI has been standardized, it's usable for wet and dry climates and the results are comparable for specific period. According to this method, drought period

occurswhen SPI is continuously negative and its amount reduces to -1 or less and ends when SPI becomes positive. SPI cumulative amounts show the drought intensity and magnitude. SPI amounts classification has been came in table 1 (Alizadeh, 1387).

SPI: Standardized precipitation indicator

$\bar{P}i$: Station rainfall mean in millimeters

σ!: Standard deviation of station rainfall data

Table 2: drought classification and occurrence probability of standardized precipitation drought indicator 1995 (Mackee et al)

Less than -2	-1.99 to -1.5	-1.49 to -1	-0.99 to 0	0 to 0.99	1 to 1.49	1.5 to 1.99	More than 2	SPI amount
Infra dry	Very dry	Slightly dry	Almost normal dry	Almost normal wet	Slightly wet	very wet	Ultra wet	Event description
0.028	0.04	0.0919	0.3413	0.3413	0.0919	0.04	0.0228	Occurrence probability

3-3 deciles:

This method is a meteorological indicator for drought monitoring that has been edited by Gibbs and Maher. In this method, rainfall distribution amounts were organized from the smallest to the largest and divided into 10 sections. The first decile represents 10 percent of rainfall and 10^{th}decile shows 100 percent of rainfall. Table 3 has been edited based on this indicator.

Table 3: drought classification based on deciles

9-10	7-8	5-6	3-4	1-2	Deciles classification
Severe wet	Moderate wet	Normal situation	Moderate drought	Severe drought	Situation description

3-4 Chinese Z indicator (CZI), Zstandardizedindicator (ZSI):

CZI indicator has been formed based on turning third rootofWilson-Hilbert. With the assumption that the rainfall data follows Pearson distributiontype three, indicator is calculated as follows:

J: month CS: coefficient of skewnessΦj: standard variable X_j: monthly rainfall σ: standard deviation of the rainfall data $\boldsymbol{\sigma^2}$: variance of the monthly rainfall data $\bar{\boldsymbol{X}}$: monthly rainfall average

3-5: normal threshold climatic indicator or sequences:

In this indicator mean of annual or seasonal rainfalls and one threshold are considered (Abiyane, 1383). Rainfall threshold for drought (X_0) is usually 75 to 80 percent of the annual rainfall average, so =.80P(X0) and we get difference of annual rainfall from (X0).Negative amounts of (X-X0) represents a drought and positive amounts of that represents wet (Alizadeh, 1387). However, in a limited system of coordination that the horizontal axis is statistical number of the years and the vertical axis is statistic obtained from the sequences, wet and dry years can be shown graphically. So that the downward histograms indicate drought and the upward histograms indicate wet. Drought statistic periods begin when sequences answer is negative and continues as long as sequences answer becomes positive.

Discussion and conclusion

Table 4 shows the correlation coefficient ofdrought indices in **Khoramabad** station. The maximumcorrelation is between percentage of normal and number Z that it is 100 percent. The minimumcorrelation is between deciles and precipitation indicator.The results of the 36 stations and around them show that CZI-SPI, DI-PN-ZSI indicators have very high correlation with each other in all studied stations

Table 4correlation coefficient results for meteorological drought indicators inKhoramabadstation

		di	pn	spi	zsi	czi	Test sequences
di	Pearson Correlation	1	.980**	.977**	.980**	.981**	.980**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	55	55	55	55	55	55
pn	Pearson Correlation	.980**	1	.994**	1.000**	.999**	1.000**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	55	55	55	55	55	55
spi	Pearson Correlation	.977**	.994**	1	.994**	.998**	.994**

	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	55	55	55	55	55	55
zsi	Pearson Correlation	.980**	1.000**	.994**	1	.999**	1.000**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	55	55	55	55	55	55
czi	Pearson Correlation	.981**	.999**	.998**	.999**	1	.999**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	55	55	55	55	55	55
Test sequences	Pearson Correlation	.980**	1.000**	.994**	1.000**	.999**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	55	55	55	55	55	55
**. Correlation is significant at the 0.01 level (2-tailed).							

2-4 Drought study with standardized precipitation indicator:

Maps were drawn for all years with standardized precipitation indicator that the driest have been shown in figure 2.2008 and 2010 years are drier than all years.

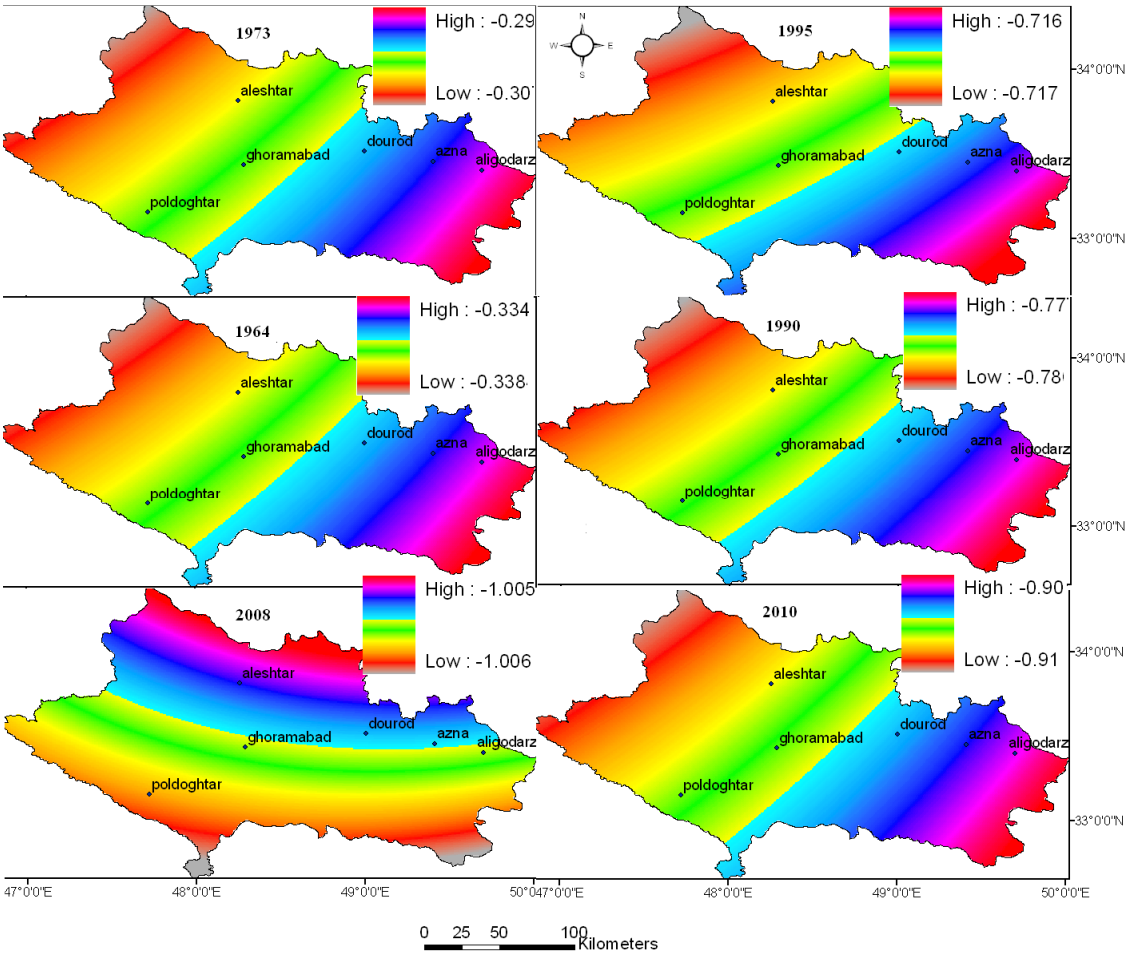

Figure 2: dry years were studied with standardized precipitation indicator in Lorestan Province

3-4 Drought study with deciles indicator:

Although all indicators have high numerical correlation coefficient with each other without any classification but in Cluster analyses these aren't inasamecategory.This show the levels of these indicators were not well defined or are notcoordinate with each other. There are 8 classifications in standardized precipitation indicator and 5 classifications in deciles and due to this problem dry years are not identical in figures 2and 3. In terms of drought amount, two indicators haven't equal amount, in 2008 the most parts of province has experience drought with standardized precipitation indicator while with deciles indicator 1990 is most drought amount.

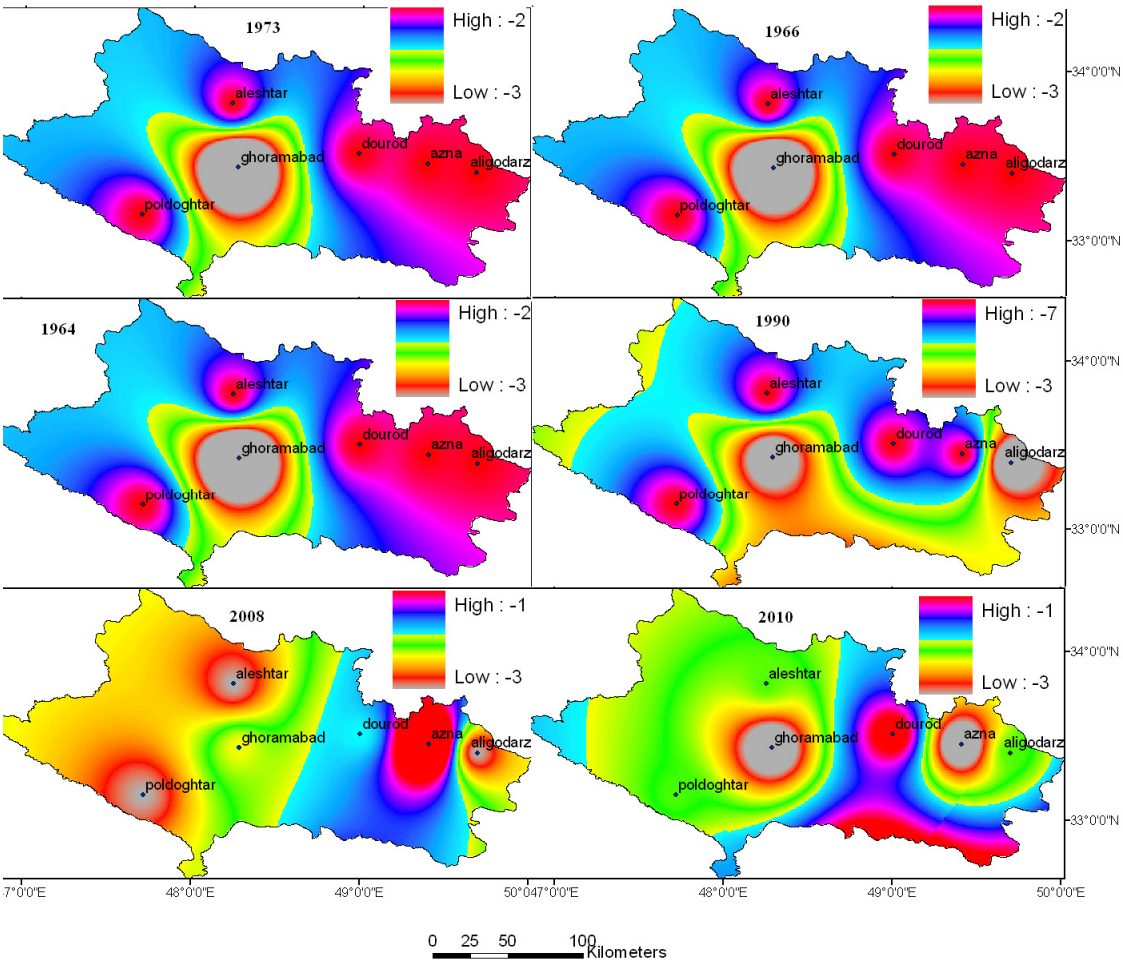

Figure 3: study of dry years in Lorestan province with deciles

4-4 study of drought with sequences indicator:

Chart 3 has been drawn with sequences test. This test is drawn on a histogram that negative amounts show drought and positive amounts show wet. In this histogram dry years are: in the fifties: 1954 and 1958; in the sixties: 60, 66 and 68; in the seventies: 76 and 78; in the eighties: 80, 84 and 86; in the nineties: 92, 94 and 96, and at 2000 century the most years show negative amount. Upward histograms are seen in 50, 70 and 90 decades and wet years have been reduced and dry years have been increased. Figure 5 showsdry years with sequences indicator. There isn't special classification for this indicator but in this figure purple color shows drought and red color shows wet. The driest year is 2010 and the wettest year is 2006. Figure 6 shows amount and intensityofdrought. As previously mentioned both of these almost show the same concept and this figure's maps also confirm that matter. Ahvaz, Ize, MasjedSoleiman and Haft Tappe have had the most amounts and intensitiesdroughtandRamhormoz, Hendijan, Shoushtar, Keshtkar and Bestan have had the lowest.

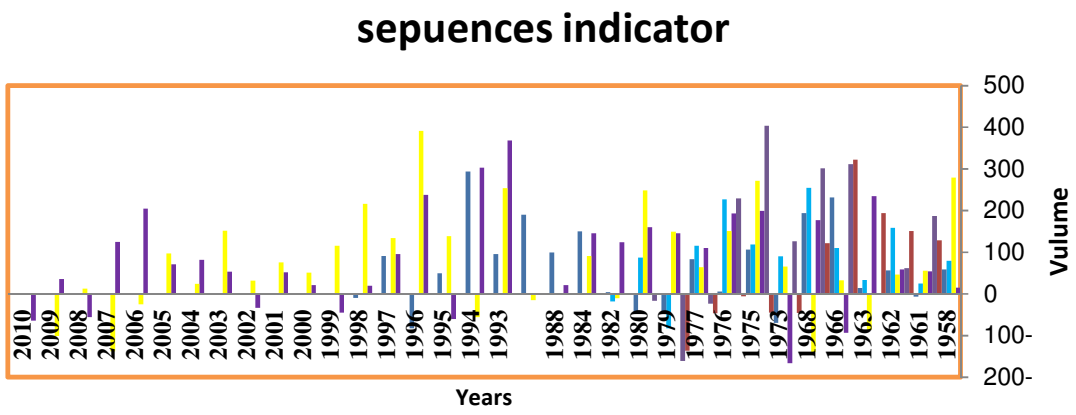

Chart 3: evaluation of drought with sequences indicator in some selected stations,

Table 5 studiesdrought with **sequences indicator**				
	During periods of drought	Amount drought	Drought Severity	The most severe drought
Azna	5	-277	-282	-146
Iezh	2	-428.3	-430.3	201.4
Baghmalk	2	-192.4	-194.4	156.7
Daran	2	-93.1	-95.1	47.7
Dezful	6	-368.3	-374.3	-138
Keshtkar	4	-115.492	-119.492	-53.12
Mazo	7	587.6	580.6	-238

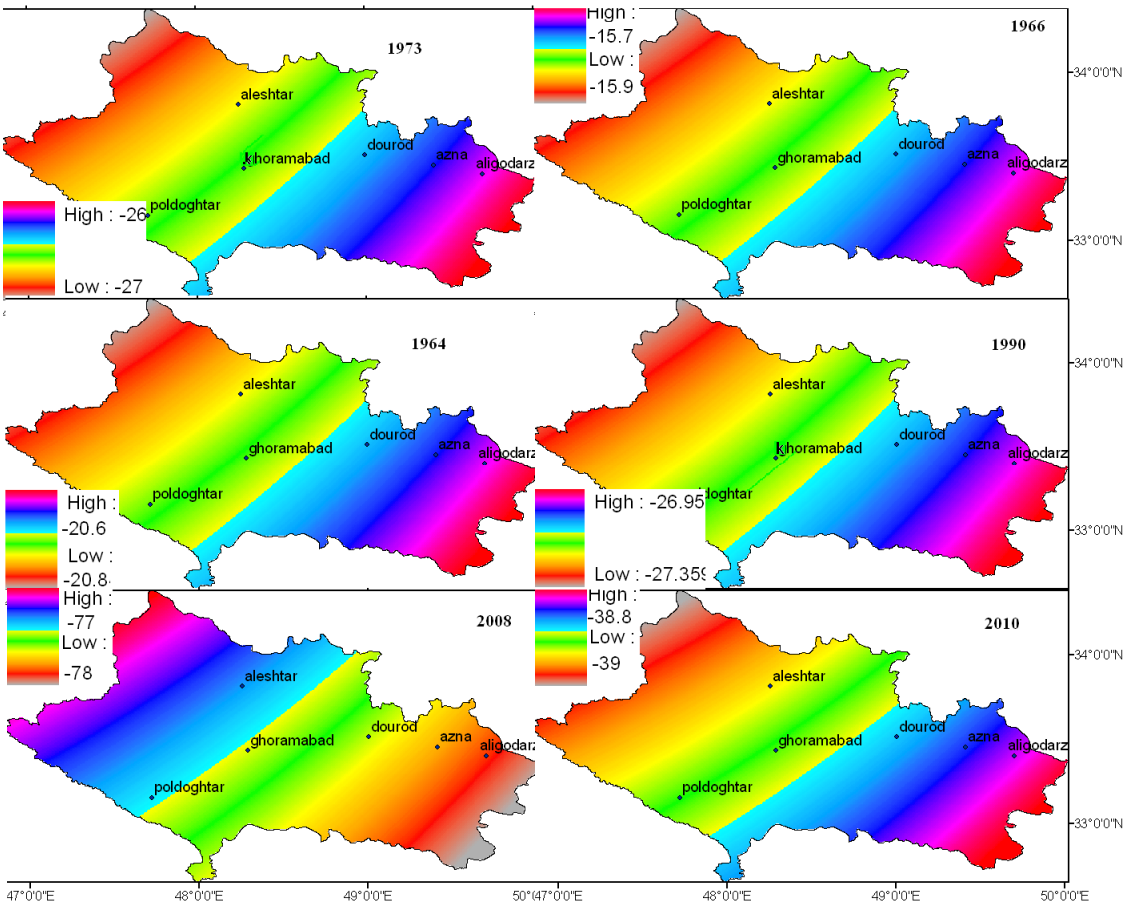

Figure 4: study of drought intensity and amount with sequences indicator, reference: the authors.

Table 5 studiesdrought with sequences indicator. In this table duration, amount, intensity and the most severecharacteristics of drought are shown Shared dry years are: 1990 and 2001 to 2010, it means that in the most years of 2000 century drought haspredominated. Drought value obtained from sum of negative values in a dry period can represent dry amountof a station in that period.Mazo station with a period of 5 years and amount of -784.4 has spent the longest period. But the most severe drought of a period can show the best result because this amount shows that which period and station have experienced the most severe drought. The most severe drought related to Mazu station with amount of -238 that drought period was 5 years and amount of the most severe (-151.8), Mazu

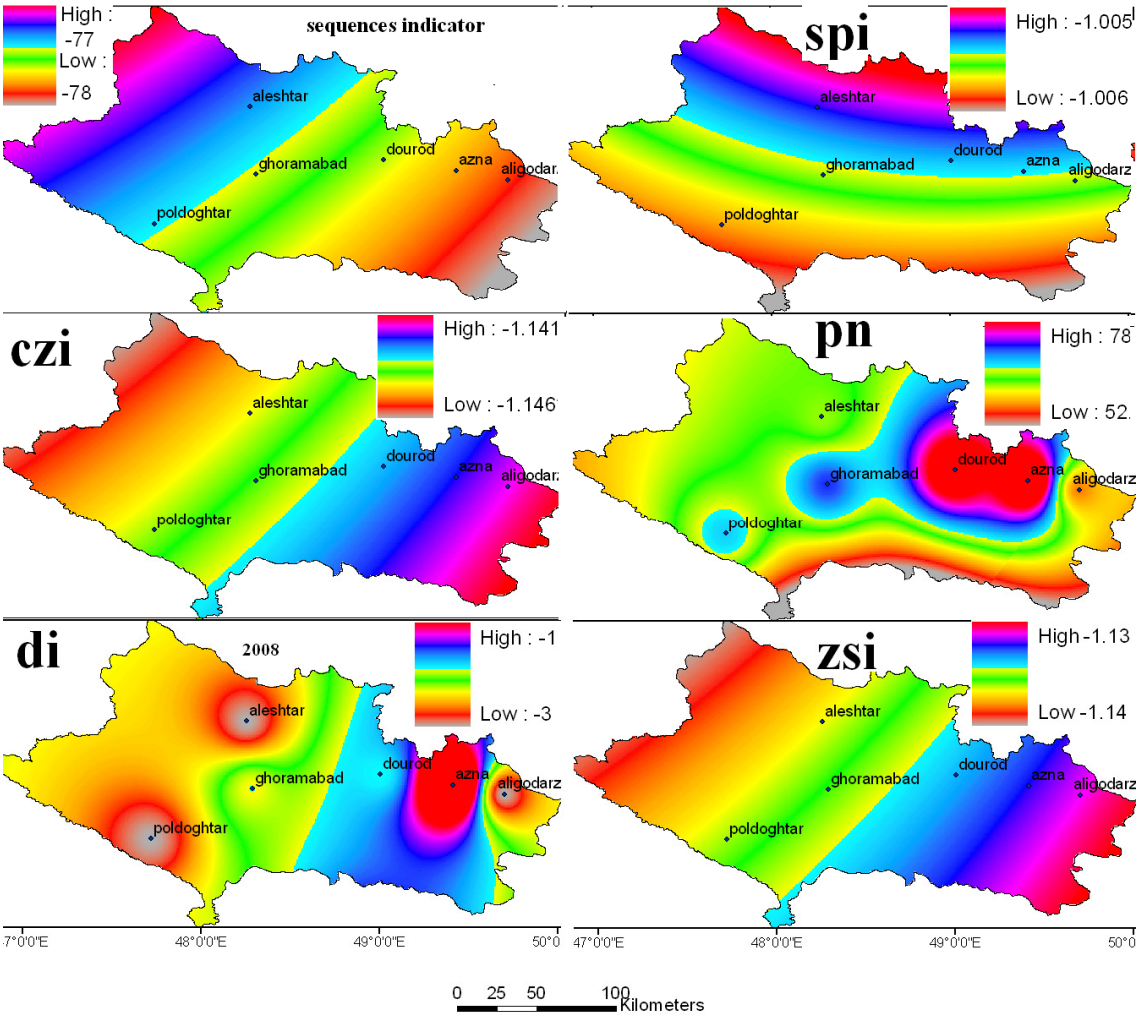

Figure 5: comparative study of drought of 2008 year in Lorestan province

5-4 comparative study of drought:

Year 2008 was studied with all of the indicators that all of them show this year is dry and due to different classification of indicators a little differences is observed between maps.

5- conclusion:

Climate change is one of the most important topics in the world nowadays. The first effect of climate change is the drought prolongation and intensification in some parts of the world. Our country Iran is on the dry zones of the world and scarcity of water resources isaserious threat that requires our special attention to water resources. In this article was obtained the following results:

Correlation coefficient is very high between drought indicators. Correlation coefficient in Behbahan station is less than Dezful and in Agajariisless than Shahrekord but it is more than 90 percent in all stations. Drought intensity and amount in Khuzestan province is more than Shahrekord,Khormabad and surround stations. Drought amount and duration has increased in

last years and the most severe and widespread drought has happened in Khuzestan at 2010. Extensive droughts have occurred in 60 and 90 decades and 1960, 1995 and 1996 years are dry years. The correct and efficient use of water can save us from water scarcity somewhat to escape the drought crisis. Watershed management can help us in this field. If dam construction is performed correctly and with study can solve many problems of water scarcity and here that it is necessary to say that GetvandOliya dam has been built on salt domes that not only any problem isn't solvedbut also a new environmental crisis is taking shape. Droughts intensifying require more attention to water resources in the recent years, especially rivers discharge reducing will effect waters quality and if climate changes are associated with our self-seeking changes, we will have to waituntil Karun and Arvand become to a stinking wetland in the not too distant future. Because Arvand is only navigable river in Iran and it has key role in the creation of natural and human outlooks to tourist attraction. Management and planning for this water resource is one of the moves that should be placed on top of the all programs.

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Enclosure

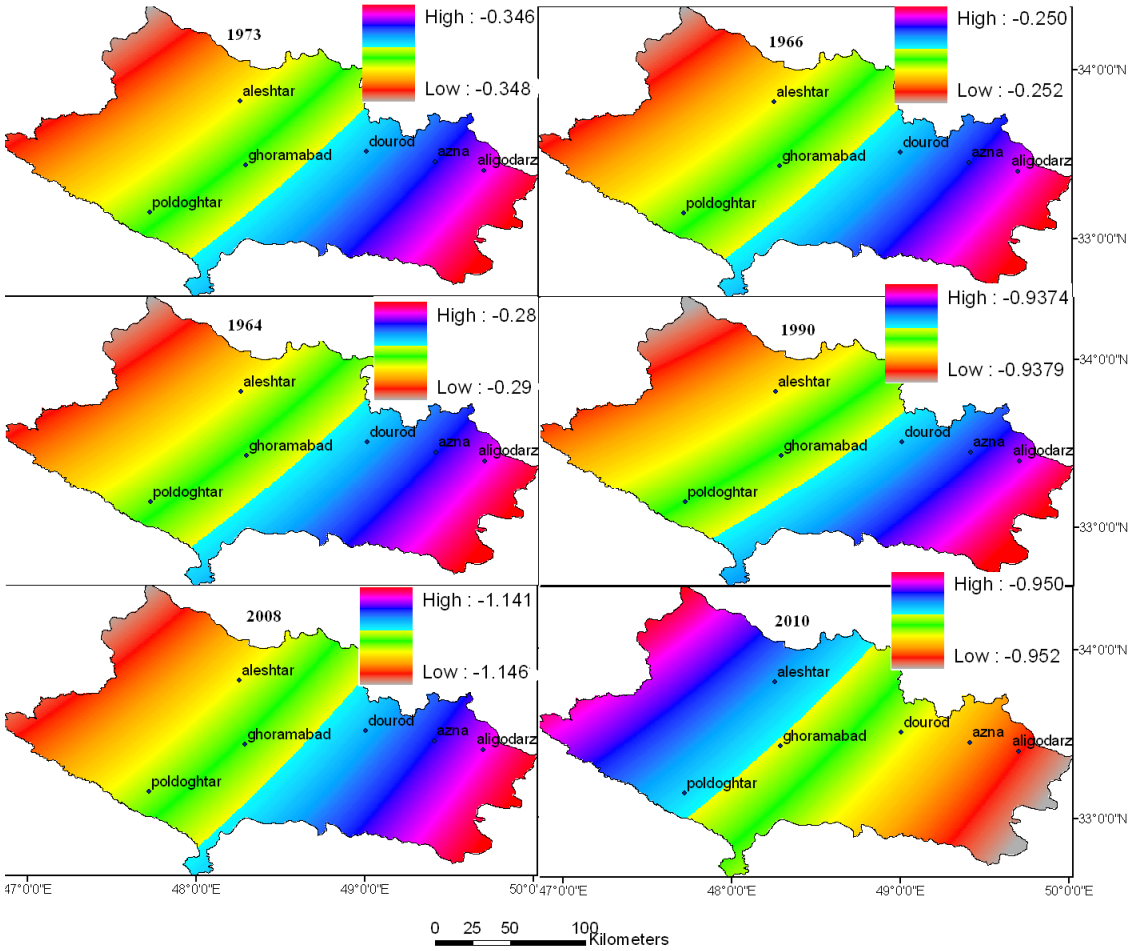

Figure 6: study of dry years in Lorestan province with Czi

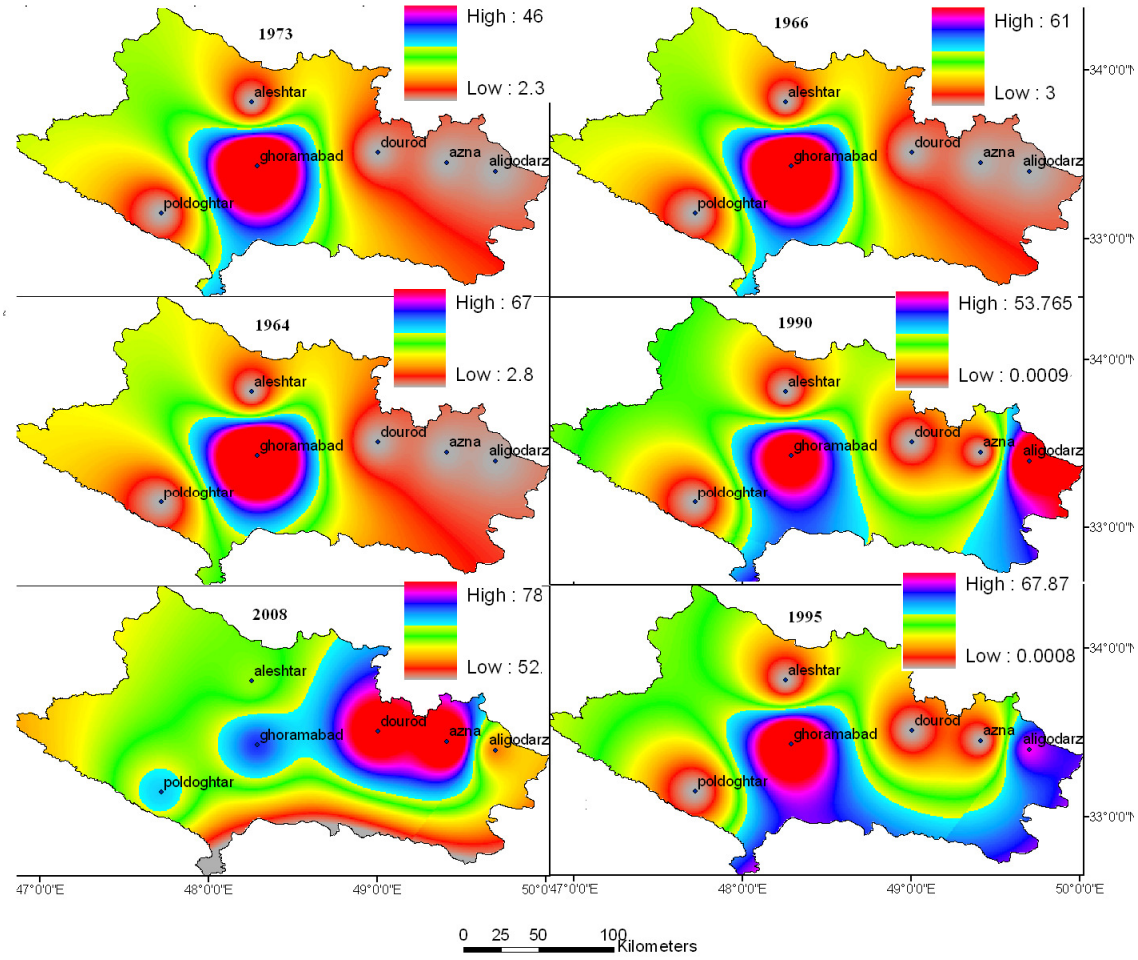

Figure 7: study of dry years in Lorestan province with pni

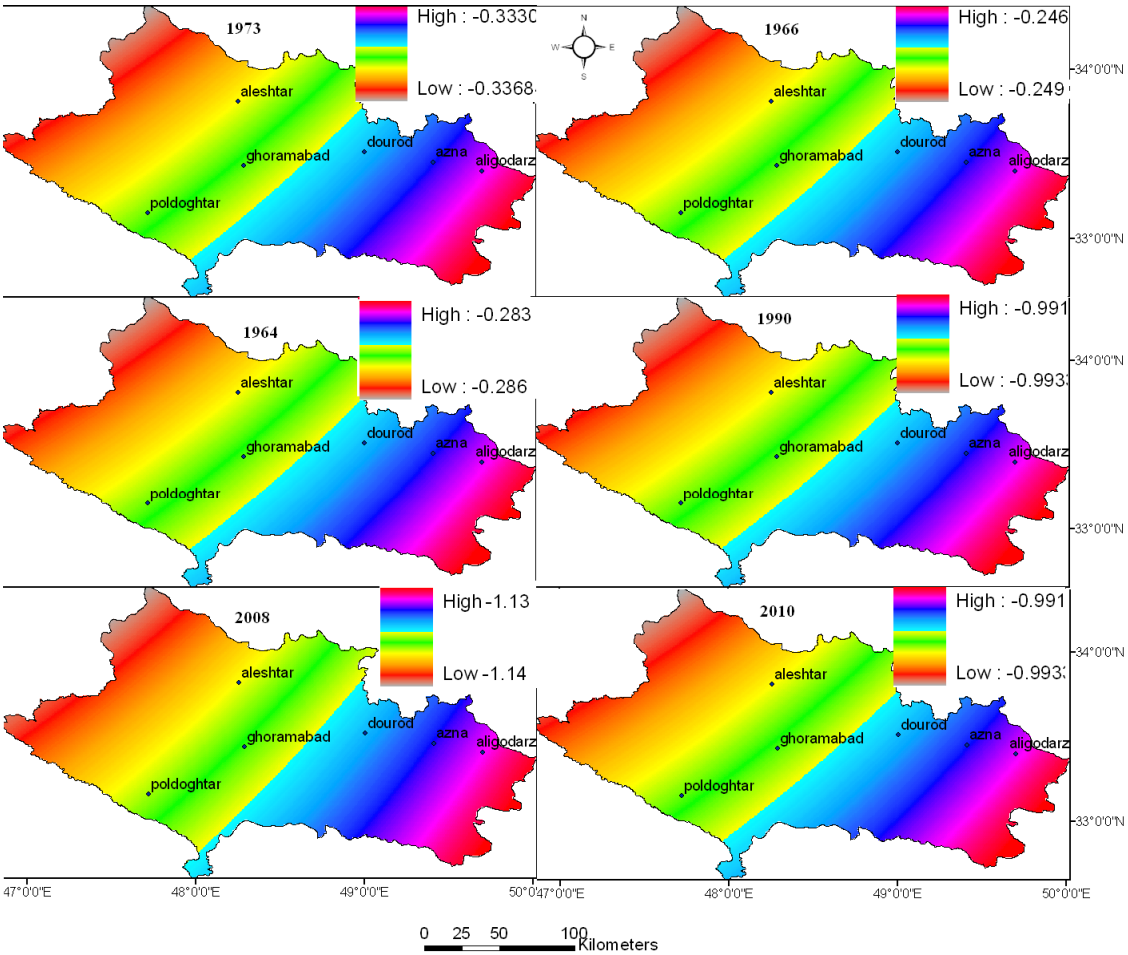

Figure 8: study of dry years in Lorestan province with zsi

The most humidmonths.								
JAN.	FEB.	MAR.	APR.	MAY	OCT.	NOV.	DEC.	mean
1958	1965	1979	1964	1992	1953	1988	1958	1993
1978	2004	1983	1988	1970	1973	1989	1975	1969
2009	1980	1973	1997	1955	1977	1990	1996	1957
2003	2010	1955	1983	1952	1962	2002	1966	1994
1959	1971	2001	1993	2002	1982	1985	1977	1954
The driest months								
JAN.	FEB.	MAR.	APR.	MAY	OCT.	NOV.	DEC.	mean
1956	1972	1961	1951	1979	1979	1969	1981	1973
1986	1999	1998	1961	1987	1986	1955	1987	1990
1993	1982	1999	1996	1971	1964	1986	2006	1966
1984	1995	1984	2002	2005	1983	1995	1988	2010
1969	1958	1992	1966	1962	1981	2007	1960	1995