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Mapping Drought Hazard Using SPI index And GIS (A Case study: Fars province, Iran)

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Abstract

Drought is defined as the continuous and abnormal moisture deficit. The term of continues means continuation of deficit and the term abnormal means deviation of favorite index of natural condition from the mean. In every drought study four main characteristics are considered: Severity, Duration, Frequency or Return period and Areal Extent. The objective of this study was to analyze these characteristics of droughts and to use them in plotting drought maps over Fars province. To study drought and mapping, different indexes have been invented, one of these index is the Standardized Precipitation Index (SPI) .It is practical and simple method. The base of this index is precipitation. To study the drought, Records from10 stations within the same period of 13 years (1994-2006) and 17 stations within the same period of (2007-2011) in scale of annual. For better results kriging, natural neighbor interpolation and IDW are compared and Inverse Distance Weighted (IDW) interpolation is more practical for this study area. The result of analysis, is showed that the least SPI and drought magnitude has happened in Sadedorodzan station, in the north of Fars province for 17 stations between 1994-2011 and 10 stations between 2007-2011. For 10 stations during 1994-2006, the least SPI is related to the Lamerd station in the south of the province. Figures that produced by interpolation method between 1994-2011 illustrated that drought was generated in the south and it was rapidly extended to north and northeast and northwest. This prediction is used in Fars province to manage the drought.

Keywords: Drought mapping, SPI, GIS, Fars province

Introduction

Drought is considered by many to be the most complex but least understood of all natural hazards affecting more people than any other hazard. However, there remains much confusion within the scientific and policy making community about its characteristics (Mishra and Desai, 2005a). Drought is a complex phenomenon which involves different human and natural factors that determine the risk and vulnerability to drought. Although the definition of drought is very complex (Wilhite and Glantz 1985), it is usually related to a long and sustained period in which water availability becomes scarce (Dracup et al. 1980, Redmond 2002). Important efforts for developing methodologies to quantify different aspects related to droughts have been made, such as the spatial differences in the drought hazard (Vicente-Serrano and Beguer´ıa 2003, Beersma and Buishand 2004), the prediction of droughts by means of the use of atmospheric circulation indices (Cordery and McCall 2000), and the mitigation of drought effects (WMO 2000). Drought indices are very important for monitoring droughts continuously in time and space, and drought early warning systems are based primarily on the information that drought indices provide (Svoboda et al., 2002). The majority of drought indices have a fixed time scale. For example, the Palmer Drought Severity Index (PDSI, Palmer, 1965) has a time scale of about 9 months (Guttman, 1998), which does not allow identification of droughts at shorter time scales. Moreover, this index has many other problems related to calibration and spatial comparability (Karl, 1983). To solve these problems, McKee et al. (1993) developed the Standardized Precipitation Index (SPI), which can be calculated at different time scales to monitor droughts in the different usable water resources. Moreover, the SPI is comparable in time and space (Hayes et al., 1999; Lana et al., 2001; Wu et al., 2005). The SPI was developed in 1993 following a careful procedure (Redmond 2002), but due to its robustness it has already been widely used to study droughts in different regions, among others in the USA (Hayes et al. 1999), Italy (Bonaccorso et al. 2003), Hungary (Domonkos 2003), Turkey (Sönmez, F et al., 2005), Greece (Tsakiris and Vangelis 2004), Spain (Lana et al. 2001 , VicenteSerrano et al. 2004) and Iran (Noruzi 2007). The purpose of this study is to establish spatial pattern of different drought hazard classes and also humid and normal classes in a GIS in Fars Province located in the southern Iran. This attempt may prove to be useful for regional planners, and policy makers for agricultural and environmental strategies, not only in Southern Iran but also in other countries facing similar problem.

Materials and Methods

Study Area

Fars Province located in the southern Iran was selected to be a study area for a test assessment of climate change taking into consideration trend of different drought hazard classes and also humid and normal classes using SPI. It covers an area of 12 million ha, which lies between the latitudes of 27° 02' and 31° 43' N and the longitudes of 50° 42' and 55° 36' E. Precipitation changes between 100 to 600 mm showing an average of 330 m in the region.

Data and methodology

The meteorological data used in this study, consisting of annual precipitation measurements for 10 station between 1994-2011 and 7 station between 2007-2011 meteorological stations distributed fairly evenly in the region as shown in Fig. 1, were collected from the Regional Water Organization of Fars Province. An exhaustive list of the selected stations is given in Table 1.

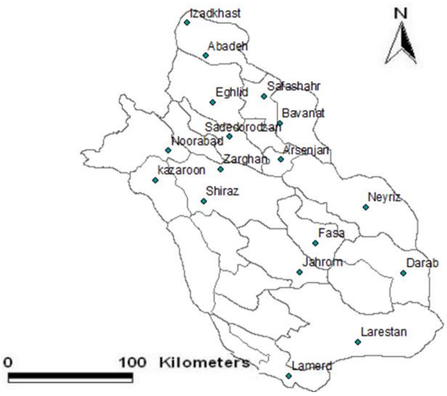

Fig 1. Scattering of stations in Fars Province map

Table 1. Name of the selected stations over the study area.

Station Name	Longitude(L)	Latitude(N)	Average precipitation (mm)	Elevation
Arsenjan	29.91	53.30	162	1660
Izadkhast	31.32	52.70	94.88	2188
Bavanat	30.28	53.40	130.22	2231
Safashahr	30.16	53.19	139.04	2324
kazaroon	29.62	51.65	234.76	860
Neyriz	2912	54.20	12.25	1632
Noorabad	29.97	51.83	311.25	920
Abade	31.11	52.37	125.36	2030
Fasa	28.55	53.38	276.46	1288
Larestan	27.42	54.17	177.41	792
Jahrom	28.29	53.33	170.21	1082
Eghlid	30.55	52.47	311.42	2300
Shiraz	29.36	52.32	301.45	1488
Darab	28.47	54.17	241.69	1098
Lamerd	27.18	53.07	205.61	411
Sadedorodzan	30.13	52.16	450.56	1620
Zarghan	29.47	52.43	305.75	1590

For each station in every year, with DIC (Drought Indicis Calculator 1.0) software, annual precipitation and annual SPI have been calculated, as illustrated in Table 2 and Table 3. After that, for each station in every year, Annual SPI based on wetness, normal and dryness was classified using Table 4 to analyze spatial pattern of wetness, normal and dryness trends during the period of study based on SPI.

Table 2**.** Annual Standardized Precipitation Index (SPI) for 10 station from 1994-2011

Station Name	**Abadeh**	**Fasa**	**...........**	**Sadedorodzan**	**Zarghan**
1994	0.33	0.32	…………..	0.44	0.45
1995	0.42	0.84	....	0.19	0.63
1996	-1.06	-0.79	....	-0.11	-0.91
....	.....	.....	....	......	......
2007	-0.85	-0.96	....	-0.74	-0.04
2008	-1.16	-2.03	....	-1.37	-1.58
2009	-0.21	-0.12	....	-0.34	-0.56
2010	-0.28	-0.41	....	-0.58	-0.91
2011	-3.46	-2.81	....	-3.61	-3.15

Table 3. Annual Standardized Precipitation Index (SPI) for 7 stations from 2007-2011.

Station Name	**Arsenjan**	**Izadkhast**	**……**	**Neyriz**	**Noorabad**
2007	0.12	0.0089		0.27	0
2008	-0.57	-0.08		-0.84	-0.39
…….	……….	………	…….	……	…….
2011	-2.22	-2.33	…….	-2.14	-2.02

Table 4. Annual Standardized Precipitation Index (SPI) $SPI = p_i - \overline{p} / sd$ Classification

SPI value	Drought Category
≥ 2	Extremely Humid
1.5 to 1.99	Very Humid
1.0 to 1.49	Moderately Humid
0.5 to 0.99	Lightly Humid
-0.49 to 0.49	Normal
-0.99 to -0.5	Lightly drought
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
$\leq$ -2	Extreme drought

*: pi : Annual precipitation in each station $\overline{p}$: Average precipitation in each station

sd : Standard deviation of precipitation in each station

To check normality of the data for each station; the software of "IBM SPSS statistics 22" was used. Data from option of "Normality Test" have been analyzed. Amounts more than 0.05 indicate distribution of data in the period of record is normal while amounts less than this indicate distribution data is not normal. In the assessment 90% of stations have normal data that is acceptable for the assessment. In order to generalize calculated SPI values for 17station to the whole study area, inverse distance weighting (IDW) interpolation, kriging interpolation and natural neighbor interpolation are used. But because of the better results about the study area, inverse distance weighting (IDW) interpolation was selected.

Results

SPI values and drought

Some studies so far done in Iran and in the world have based on their estimation on the 'present state' of hazard of drought during a specific year using some indices like SPI. From fig. 2 ,SPI for 17 stations in Fars province with the period of 1994-2011 can be analysed which indicate that in 2011 SPI dropped as low as -3.46 is related to Sadedorodzan station in the north of the province and most of the stations in 2011 below -2.20 that they faced extreme drought. Also, 2011 was extreme drought year than 2008 where SPI only up to -2 at two stations of Fasa and Shiraz. This indicates that 1999 was less severe drought affected than 2011. This situation and SPI values are true for a time between 2007- 2011. Another fig. 3 is illustrated for a period of 1994-2006, in 1999, Lamerd station in the south of the province with having -1.71 SPI value is faced severe drought . However if we look towards the normal years only few stations experienced SPI below (-1), which is considered to be a normal situation. Investigation showed that dry periods using SPI, continuing drought have increased in recent years. The analysis of very severe dry periods shows that this type of dry periods with calculation of SPI in an annual scale has a repetition and continuity different.

SPI and drought severity

After the interpolation with kriging method, inverse distance weighted method and natural neighbor method, the figures illustared that inverse distance weighted interpolation is the best method for this study. For stations between 1994-2011, kriging interpolatopn and natural neighbor interpolatio can not cover all of the surface of this area and it is not practical for this study.

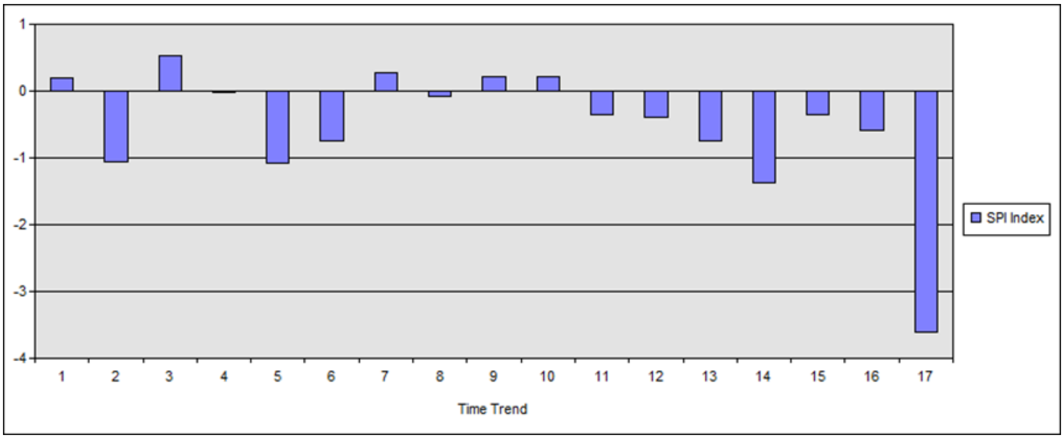

Fig 2. 17 years SPI for Sadedorodzan station.

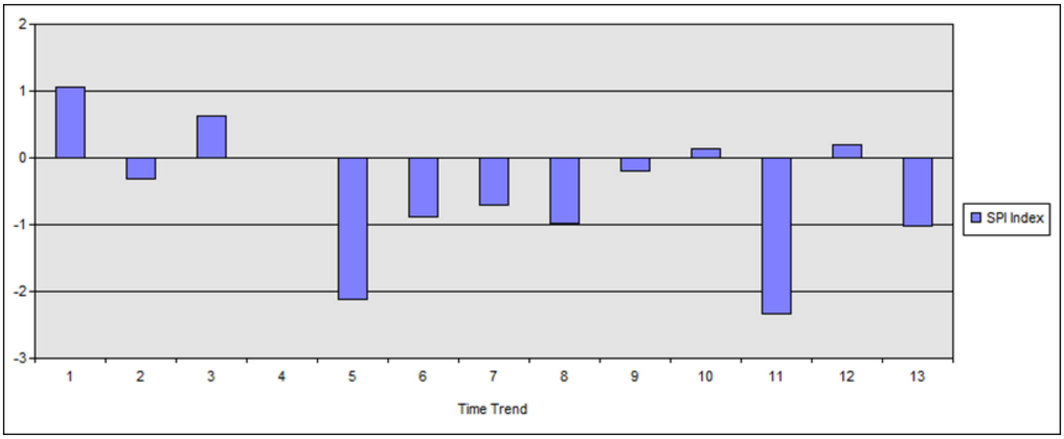

Fig 3. 13 years SPI for Lamerd station.

With inverse distance weighted interpolation and SPI values, selected drought years were reclassified into severity classes. During the period of 17 years in the Fars province, each year has a special feature of drought that this thesis considered the most important events. For 17 station between 1994-2011, From 1994-1998 and 2000-2004 the hazard maps show almost a normal and lightly humid, but in 1999 and 2005 compared with previous years province faced severe drought. Several factors such as amount of precipitation, wind Velocity, evapo-transpiration, atmospheric Circulation, hemispheric nature and temperature have effective in drought. As mentioned in previous part (SPI values and drought) and Fig. 4, the most severity drought during 19994-2011 is related to Sadedorodzan station with the number of SPI -3.46 and located in the north of the Fars province in 2011. Fig 5 is illustrated that between 1994-2006, in 1999, Lamerd station in the south of the province is faced drought.

Other figures are generated according to inverse distance weighted method are in app. During this year, others stations live in drought conditions. İt is well recognised the usefulness of SPI to quantify different drought types. Since SPI can be calculated at different time scales, it often severes as indicator of different drought types. Many studies have demonstrated that short term and long term drought are considered as agricultural and hydrological drought indicators. Hence annual SPI during these years was used in the present work to quantify severity of drought for selected drought and wet years.

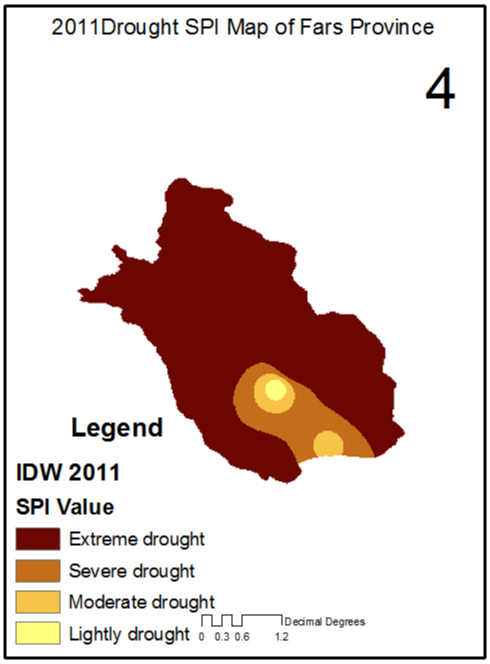

Fig 4: Hazard map of drought vulnerability in 2011

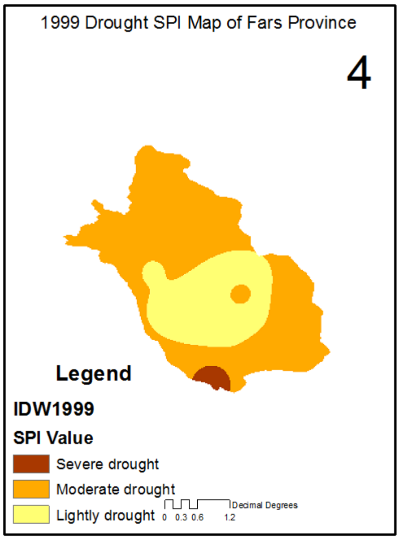

Fig 5. Hazard map of drought vulnerability in 1999.

Discussion and Conclusion

Lorem ipsum dolor sit amet, consectetur In this thesis, for the monitoring and assessment of the drought effective area variations during 17 years in the Fars province, the annual rainfall data from a total of 17 rainfall measuring sites was used. The SPI values in time scales (12 months) were calculated as the surrogate of drought severity for a total of 17 years of data from 1994-2011. Through kriging interpolation and natural neighbor interpolation, inverse distance weighting (IDW) algorithm was applied to spatially expand the SPI data to the whole study area. The results suggest that the nature of utilized data for the drought area assessment has no conflict with the basic assumption of IDW algorithm. Most stations in 2010 to 2011 faced very severity drought. Droughts occurred in the considered stations did not follow a specific order. Obtained results from zoning showed that the most droughts specially severe and very severe occurred in North and Northwest of the study area. In these regions, moderate drought has more frequency in comparison with other values of SPI. This study showed that even wet regions are not safe from natural disaster of drought and also drought and wetness could not be predicted in wet regions, likely damages is more than dry and semi-dry regions.

ArcGIS couple with drought index (SPI) is vital tool for drought monitoring and mitigation. ArcGIS supports visualization of scientific based results important for decision making process. The results showed due to the advancement of computer technology and use it in collection, storage and analysis of data for optimal use of resources, GIS can be used for processing information about the degree, intensity, and spatial distribution of the continuing dry periods and identify better and wider (in terms of location and descriptive information), quick access to the target with cost and less time. Results may prove to be useful for regional planners, and policy makers for agricultural and environmental strategies, not only in Southern Iran but also in other countries facing similar problem.

Totally, province' situation is faced moderate drought and severe drought. Therefore in order to plan and manage the drought or water resources of Fars province, special attention Should be paid to this area since the lack of proper planning in these areas may cause irrecoverable disasters. So, by recognizing sensitive areas, Tension Management Committee of the province should plan how to deal with drought. As a result, some measures are recommended. Proposed proceedings to deal with the consequences of drought:

- Preparation and implementation of land use plans
- Public participation in the management of localized drought conditions
- Cooperation policy makers and experts from differents part of the country
- International cooperation
- General and effective training for how to deal with the consequences of the drought and its management
- Comprehensive risk management rather than crisis management plan to deal with the consequences of the drought
- Control and proper distribution of population and setteling on water potential

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