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ORIGINAL ARTICLE

An Evaluation of Drought in Gilan Province Using the Standard Z-Score

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ABSTRACT
Drought is a repetitive phenomenon in different climates and its effects are not limited only to dry and semi-dry areas, but they could also be observed in areas with high rates of precipitation and in any season of year. One of the most important phases in drought monitoring is determining indices essential for analyzing its intensity, duration and frequency. The data related to the overall monthly precipitation collected from synoptic stations of the area during the statistical period of 1976-2005 have been used for monitoring drought in Gilan and analyzing its characteristics. In the present study, intensity, dispersal and frequency of drought are obtained using the standard distribution index. The results of this study revealed that drought is not an infrequent phenomenon in the rainy part of northern Iran, but it is a repetitive and reversible phenomenon.

Key words: *drought, standard distribution index, Gilan, precipitation, Z-Score*.

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INTRODUCTION

Precipitation is an important climate factor which plays an important role in agricultural, industrial and tourism economy. However, the water obtained from precipitation depends on the capabilities of societies and conditions of different seasons and different applications. But most of the times the uncontrolled surplus amount which makes up a larger percentage compared to the optimal usage causes floods and damages resulting from them. This is while the drought problem and damages resulting from it has always harmed plant, animal and human societies. Drought is among intangible a natural disaster which is caused by lack of precipitation in a time period, usually a season or more. In the present study, intense drought has been identified using two drought indices by presenting thirty years precipitation and its undulations, and result have been compared with other years (years of moderate precipitation or wet years). Having such a drought pattern provides a better insight and understanding and will make a good base for future discussions. Hydrologic drought is a phenomenon which accompanies effects of periods of precipitation reduction on underground or surface water supplies and this type of drought often occurs with more delay compared to climate drought. Climate drought effects hydrologic drought with a delay, but it takes more for precipitation reduction to be apparent in hydrologic features. Drought is repetitive phenomenon in climatic disasters which is dependent on intensity, quantity of precipitations and delay in the initiation of precipitation season. Factors like wind speed; high temperature and relatively low humidity intensify it. Since the initiation, intensity, duration and end of drought are all dependent on the time scale, evaluating drought and its effects requires determining these factors [1].
Meteorology scientists have suggested various indices for evaluating and monitoring drought in different places of the world. In a study in Australia, improvement of water supplies has been suggested as an important factor for preventing intense droughts after evaluating standard distribution drought index in 2000-2006 period and the difference between dry years and negative Z along with high levels of underground waters has been related to the above mentioned factor [4]. In another study, 7 drought

factors in Tehran in 32 years statistical years have been compared. The results indicate that Z-Score, CZI, and SPI are the same in respect to drought indices and slow reaction to drought offences [2].
Iran has a high drought potential due to its special geographical and climatic conditions. This is while Iran has 25% of global precipitation by an average of 250 millimeters of annual precipitation and has an evaporation potential as high as 4 times of global rate due to being located in a dry and semi-dry zone. Gilan is specifically located in a plain area almost at the same level as Golestan and Mazandaran provinces and has managed to slip away out of dry or semi-dry areas. However, drought which is a repetitive phenomenon in all climates is also seen in Gilan. Today, drought is more explicit in the region due to raise of population and changes in consumption patterns compared to the past along with global temperature raise [3].
The present study is aimed to evaluate various precipitation based models in order to identify and classify drought in north of Iran and determine its statistical characteristics and evaluating climatic changes and precipitation procedures in the region.

MATERIALS AND METHODS

Study area characteristics

Gilan province is located in north of Iran coordinates 37°16′39″N and 49°35′20″E. The area of the province equals 1381.5 km^2 and holds the first rank of annual precipitation rate in the country according to the statistics of meteorology organization. Based on thirty years statistics (1976-2005), average precipitation is calculated to be 1070 millimeters according to Thiessen method. Average region precipitation during the 30 years period equaled 1393 mm in Astara, 1745 mm in Anzali, 1491 in Lahijan, 1369 in Rasht, and 1220 mm for Saravan. Precipitation percentage distribution for different seasons is as following: 15% for spring, 22% for summer, 39 for fall, and 24% for winter. South of Gilan including Rudbar and Manjil has a different climate compared to other parts and obtained patterns e.g. average precipitation have a considerable difference with other regions. Statistics related to daily, monthly and annual precipitation are the base for precipitation analysis. To do so, first precipitation data related to the 30 years period from 1976 to 2005 were collected from the meteorology organization. Then these raw numbers were analyzed, and 13 meteorology stations with longer statistical periods were selected. Precipitation statistics have been processed using the Minitab software. Then province drought has been analyzed using the standard index. Table 1 shows geographical location of the stations and in table 2 statistical features of the 13 stations can be observed. According to this table, the highest average 30 years precipitation has been in Anzali and the lowest is seen in Manjil. Standard deviation and variance increase with precipitation amount. Conversely, coefficient of changes is higher in stations with lower precipitation. This coefficient is usually used for precipitation changes and is obtained from dividing standard deviation in average precipitation. Also, skewers are lower in stations with higher average precipitation. This parameter shows distribution of precipitation regime and the smaller it is, precipitation regime would have a more balanced distribution. It can be observed from region monitoring that high or low precipitation levels cannot have a fixed procedure in the studied period. A notable point here is the existence of intense precipitation undulations due to various plain micro climates in different parts of the province which makes drought conditions different in all regions. The reason for this cannot be found in extent of the studied area and topographical variety of different regions.

Drought Indices

Drought differs with other meteorological phenomena. Often the initiation and end of drought is important and its duration can be pretty long. Since definition and measurement of drought is very sophisticated, scholars have been trying to develop and determine indices for them. The aim of developing any drought index is to determine intensity, duration and geographical distribution of the drought. Various indices are used in different countries in order to monitor drought condition. These indices are obtained based on drought definitions and a calculative approach in which one or more meteorological variables are used.

Table 1. Geographical location of the stations

Name	Longitude	Latitude	Altitude	Average precipitation
Anzali	49026	38.27	-26.8	**1745.4**
Rasht	49.36	37.19	-8.6	**1369.45**
Astaneh	49.55	37.15	-5	**1241.8**
Lahijan	50	37.12	34.2	**1049.1**
Shalman	50.6	37.3	150	**1163**
Samoosh	50.17	37	80	**1330**
Saravan	49.38	37.1	185	**1246**

QaleRudkhan	49.16	37.06	170	**1683.9**
Kasma	49.18	37.19	-2	**1070**
Shanderman	49.09	37.27	42	**974**
Hashtpar	48.54	37.48	99	**3100**
Astara	**48.5**	**38.21**	**-21.2**	**1396.9**

Table 2. Statistical criterions of 13 meteorological stations of the region (1976-2005)

Name	Average	Minimum	Maximum	Standard Deviation	Variance	Skewness	Coefficient of Changes
Astara	1393	1040	1930	217.8	47436	0.82	34.03
Anzali	1745.5	1237.8	2662.1	281.7	79382	1.02	45.48
Hashtpar	1100.3	813.9	1573.8	193.3	37373	0.8	33.97
Shanderman	974.6	751.5	1375.7	157.2	24698	1.2	25.34
Qale Rudkhan	1983.9	1223	2534.5	272.9	74517	1.33	44.25
Kasma	1070.8	774.5	1564	1818.1	32785	1.05	30.62
Saravan	1220.7	820	1699.1	199.5	38041	0.13	31.16
Rasht	1369.5	988.4	1937.2	245.8	60407	0.59	44.11
Astaneh	1241.8	857.5	1687.2	200.5	42867	0.19	34.15
Lahijan	1491.2	1041.5	2236	270.3	73063	1.13	48.99
Shalman	1163.5	724	1603	208.5	43487	--0.02	37.38
Samoosh	1330.9	1027.5	2010	231.14	53430	١1.06	40.14
Manjil	264.1	87.2	402.5	78.6	6178	-0.38	23.4

Standard Distribution Index

Standard distribution is an important international index which determines probability of drought. In fact, this method has been presented based on monitoring various effects of precipitation shortage on underground waters, surface water supplies, soil moisture, water currents, etc. This index is calculated from the following relation. In this relation, z is the standardized average precipitation index in a time period (year), average long term precipitation, and SD is the standard deviation of data. Average and standard deviation of this factor equals zero and one. A drought would occur if the standard index is negative continuously and its intensity reaches -1 or less. This ends when the standard index returns to positive values [5]. Considering the value obtained from this index, the intensity of drought is classified as the following table.

Table 3.Classification of the drought index: Standard Distribution

Z-Scores	Level of Drought
0 to -1	Weak drought
-1 to -1.5	Moderate drought
-1.5 to -2	Intense drought
<-2	Very intense drought

Studying this index in Gilan provided interesting results. Table 4 shows the obtained Z-scores from the 13 stations, and figure 1 shows the distribution of precipitation Z-score in 1991, 1979 and 1995 and during the 30 years. According the table and figure, although Gilan province has a high level of precipitation, drought is not unexpected in it.

Table 4. Z-scores in 13 stations and during the 30 years period

Z>0		-2>Z		-2>Z>-1.5		-1.5>Z>-1		-1>Z>0		Percent of surface drought	year
%	km²	%	km²	%	km²	%	km²	%	km²		
34	4724	15	2048	8	1093	10	1335	33	4618	66	1976
66	9142	4	483	9	1292	10	1434	10	1436	34	1977
22	3073	5	646	12	1646	11	1490	50	6972	78	1978
26	3533	10	1438	16	2236	22	3109	25	3503	74	1979
74	10281	5	659	1	203	2	334	17	2339	26	1980
25	3520	0	0	10	1335	18	2423	47	6539	75	1981
89	12264	1	126	1	137	2	213	8	1075	11	198
23	3214	2	211	8	1143	18	2555	48	6698	77	1983
43	5961	0	0	0	54	3	411	54	7396	57	1984
53	7298	13	1798	7	900	8	1116	19	2688	47	1985
46	6298	3	448	5	691	7	1007	39	5372	54	1986

61	8402	3	443	1	157	4	506	31	4311	39	1987
31	4249	0	0	0	0	0	0	69	9561	69	1988
27	3691	17	2284	7	916	18	2515	32	4410	73	1989
58	7951	10	1342	3	462	4	540	25	3523	42	1990
10	1043	33	3483	12	1292	13	1435	32	3436	90	1991
100	13818	0	0	0	0	0	0	0	0	0	1992
80	11063	11	1532	2	221	2	234	6	773	20	1993
44	6090	0	0	5	626	9	1269	42	5835	56	1994
13	1738	5	664	24	3267	29	4023	29	4012	87	1995
31	4171	26	3484	10	1292	8	1144	25	3436	69	1996
48	6656	5	631	5	684	8	1129	34	4715	52	1997
59	8437	7	979	7	988	5	749	22	3061	41	1998
18	2494	15	2095	12	1640	13	1748	42	5844	82	1999
50	6893	0	0	3	463	5	734	41	5721	50	2000
27	3896	0	0	3	407	10	1474	59	8400	73	2001
36	5032	0	0	0	0	3	426	60	8359	64	2002
51	6864	1	191	1	152	2	289	44	6002	49	2003
91	12584	0	0	0	0	0	0	9	1230	9	2004
39	5156	15	1971	8	1003	8	1074	30	3984	61	2005

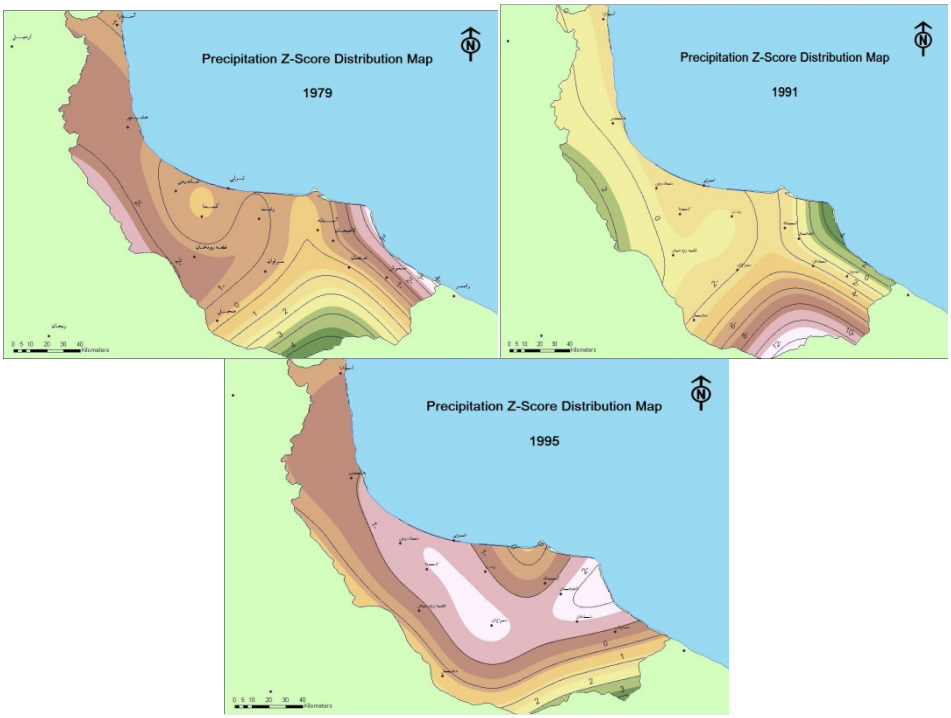

Figure .1.precipitation Z-score distribution map in 1991, 1979 and 1995

RESULTS

The results from the standard index indicate that during the studied thirty years, drought has occurred in twenty nine years, or in other words, 97% of the whole period. By studying table 6, the statistical period can be divided into 2 groups:

1. Region drought
2. Lack of drought.

Group 1 which includes 29 out of 30 studied years can further be divided in 3 classes:

a) Years in which more than 70 percent of the province faced drought
b) Years in which less than 20 percent of the province faced drought
c) Years in which 20 to 70 percent of the province faced drought.

group a includes 9 years or in other words 30% of the whole period, group b 2 years or 7%, and group c, 18 years or 60% of the whole period. Only in 1992 right after 1991 in which the most intense drought in the region was observed, we faced a wet year. The most drought facing surfaces were among weak

drought area, between 0 > Z > -1 and central parts of the province have experienced more drought compared to other parts. During 19 years of the studied statistical period, over 50% of the province has faced drought. This amount makes up 63% of the whole period. The year 1992 is the only year in which no drought has occurred. On the other hand, in 1991 this natural disaster had reached its maximum intensity. Division maps related to 1991, 1995 and 1979 (figure 1), show years in which drought had taken over more than 70% of the whole area. Colors turn darker along with intensity of drought.

DISCUSSION AND CONCLUSION

According to table 1, the highest annual precipitation is in Anzali with 1745 mm and the lowest amount is observed in Manjil with 264 mm. Standard Deviation, variance and coefficient of changes increase with precipitation raise. Also, skewness is lower in stations with a higher precipitation rate. This parameter indicates distribution of precipitation regime and the smaller it is, the more balanced precipitation distribution regime would be. The two studied methods indicated that the most intense droughts occurred in 1991, 1995 and 1979. Figures 4 and 5 prove this information. Studying drought maps also provides interesting results. Figures 4 and 5 indicate that central parts of the province including Rasht, Saravan, Kasma, Anzali and Shanderman have experienced the most, and western parts including Hashtpar and Astara, and then Samoosh and Lahijan have experienced the least drought. In other words, it seems that central parts of the province have experienced the most droughts during these 30 years. West and then East of Gilan hold the next ranks in occurrence of droughts. It seems that decrease in the input water of Sefidrood (Manjil) dam which supplies drinking water for 80% of the province and the water necessary for 180 thousand hectares of farming lands due to increase of sediments and building 10 new dams on Sefidrood currents is the main cause of water supply crisis in central parts. Thus, the results from standard index indicate that occurrence of drought in this region is not accidental and rare, but it is a common and repetitive phenomenon. Based on the results of the Z-score, the region has faced weak to intense drought in 29 out of the 30 or in other words, 97% of the studied years. Considering the importance of agriculture in the province which affects creation of employment opportunities and income of people, evaluating the amount of precipitation and studying droughts is crucially important. In turn, the results can be used by decision makers and managers in various areas. Studying areas which face more intense and frequent droughts and focusing more on them, proper management of water supply engineering, and deficit irrigation can all reduce the damages resulting from drought.

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