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ORIGINAL ARTICLE

Investigation Standard Distribution and Deciles in north of Iran

Jalal Behzadi
Department of Agriculture, Lahijan Branch ,Islamic Azad University,Lahijan, Iran
Email:drbehzadijalal@yahoo.com

ABSTRACT
Drought is a repetitive phenomenon in different continents and its effects are not limited only to dry and semidry areas, but they could also be seen in areas with high rates of precipitation and in any season of year. One of the most important stages in monitoring the drought is to determine indices in order to analyze its intensity, continuity and frequency. The information related to the overall monthly precipitation collected from synoptic stations in the region during the statistical period of 1976-2005 have been used for monitoring drought in Guilan and analyzing its features. In the present study, continuity, intensity and frequency of drought have been pulled up using two indices, the standard distribution and deciles and with the aid of time series of standardized precipitation index. The results of this study indicated that the two analyzed methods give the same results and drought is not an infrequent phenomenon in the rainy part of northern Iran, but it is a repetitive and reversible phenomenon. The surveys indicated that in 1991 and 1995, an intense drought has happened in the province.
Keywords: *drought, standard distribution drought index, deciles index, Guilan*

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INTRODUCTION

Precipitation is an important continental factor which has an important role in agricultural and industrial economy. Its uncontrolled surplus may cause floods and damages made by them. Drought is an insensible natural disaster which is caused by deficiency of precipitation during a specific period of time, usually a season or more. Hydrological drought is a phenomenon which usually comes with an effect of deficiency of precipitation on underground or surface water supplies and this kind of drought always happens with more delay compared to aerological or agricultural droughts, but it takes more time for the effects of precipitation deficiency to appear. Drought is a repetitive continental disaster which is dependent on intensity and frequency of precipitations and the delay in start of the rain season. Factors like wind speed, high temperature and relatively low moisture are effective on its intensity. Since the start, intensity, continuity and end of drought are all dependent on time, evaluating drought and its effects requires determining these factors. Aerology scientists have suggested various indices in different parts of world for evaluation and monitoring of drought [1]. Hong Wu et al. [2] utilized a factor named China-Z Index (CZI) which had been introduced by The National Aerology Center of China in 1995. This index is so close to the Standardized Precipitation Index (SPI) and meanwhile has very simpler calculations. V. U. Smakhtin et al. [3] utilized a new software which is able to analyze 5 factors including Deciles index (DI), SPI, The Efficient Drought Index (EDI), average and the Standard Deviation along with each one's map and is generally used in south of Asia. In another survey in south of Portugal, Elsa Moriera et al. [4] used the linear logarithm model resulted from SPI to predict the intensity of drought. Except for a few number of predictions, the rest showed good results in giving warning for short periods of drought. S. Khan et al. [5] in a study in Australia after analyzing SPI in 2000-2006 suggested that improvement of water sources management has an important role in preventing drought and they also related the difference between dry years and minus SPI with high levels of underground water to the above mentioned factor. Also some researchers have been conducted in Iran about this matter. Saeid Morid et al. [6] compared 7 drought factors in Tehran province during a 32 years statistical period. The results showed that Z-Score, CZI and SPI are the same considering drought indices and slow reaction to drought attacks. Deciles Index (DI) is highly affected by precipitation rate. DI and SPI are able to find drought attacks in various temperature conditions. That's why these two have been suggested for monitoring drought performance. Taeb Rezaei et al. [7] studied drought in west of Iran. The data from 12 months SPI in statistical period of 1948-2007, showed two various aerological zones in this region. In another study in center of Iran, Isfahan, Mohammad Karaamooz et al. [8] conducted a thorough study about aerological data such as precipitation rate, temperature and water stream. Parameter analysis has been used for evaluating drought and its intensity and duration and the data have been compared using various methods. The results showed that preplanned methods are of high importance in dry and semidry regions for organizing consumption and maintaining water. Kiumars Zarafshani et al. [9] offered methods for managing the agricultural crisis and the existing stress to farmers during dry periods in southwest of Iran, Fars province while studying evaporation rates and SPI index. Iran is capable of drought because of having special geographical and continental conditions. This is while Iran has about 25 percent of average global precipitation with about 250 millimeters of annual rainfall and has an evaporation rate of 4 times higher than global average because of being located in a dry and semidry region. Today, drought is more apparent in Iran because of population raise and change of consumption pattern compared to past, as well as the global warming. This study has been conducted in order to evaluate various precipitation based models for identifying and classifying drought in northern parts of Iran and defining statistical characteristics of them and monitoring continental changes and precipitation trends in the region.

RESEARCH METHOD

Guilan is located in north of Iran between eastern 32' and 48° to 33' and 50° and northern 33' and 36° and 39' and 38°. The area of province equals 13810.5 square kilometers and has the highest annual precipitation amongst Iranian provinces according to the statistics of Iranian Aerology Center. Considering the analyzed 30 years statistics (1967-2005), the average annual precipitation has been 1070 millimeters. The average annual precipitation of the region during the 30 years period equals 1393 mm for Astara, 1745 mm for Anzali, 1491 mm for Lahijan, 1369 mm for Rasht and 1220 mm for Saravan. Percentage of precipitation in various seasons is as following: 15% for spring, 22% for summer, 39% for fall and 24% for winter. The southern part of Guilan consisting of Rudbar and Manjil has a different climate compared to the other parts and there is a huge difference in extracted patterns such as the average precipitation between this region and others. The precipitation analysis is based on utilizing daily, monthly and annual precipitation statistics. This is why first of all the data related to precipitation in different stations have been gathered from Aerology Center during the 30 years statistical period from 1976 to 2005. Then these raw numbers have been reviewed and analyzed and 13 stations with more correct numbers and longer statistical periods have been chosen. Next drought of the province has been evaluated and monitored using the Standard Distribution and Deciles indices. Table 1 shows statistical measures of 13 aerological stations in the studied region. With respect to the table, Anzali has the most rate of precipitation in the 30 years and the fewest rate goes to Manjil. Standard Deviation and Variance increase with raise of precipitation rate. On the other hand, coefficient of changes is more in stations with less precipitation. This coefficient is mostly used for precipitation changes and is calculated by dividing Standard Deviation in average precipitation. Also the skewness is smaller in stations with higher average precipitation. This parameter shows the precipitation regime distribution and the less it is, the more monotone the distribution would be. It can be seen from analysis of area which shows the intensity and weakness of receiving precipitation in regions stations that, a specific trend cannot be found in the studied period. The important point is the regional differences which are important due to the regional drought. The reason could be found in the wideness of studied area and topographical variety of different parts of the province which have created various capabilities for precipitation in different stations.

Table 1: Statistical factors of 13 Aerological stations of the region (1976-2005)

Station	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
GhaleRodkhan	1683.9	1223	2534.5	272.9	74517	1.33	44.25
Kasma	1070.8	774.5	1564	181.1	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	34152

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	1.06	40.14
Manjil	264.1	87.20	402.5	78.6	6178	-0.38	23.4

Drought Indices

Drought has aerological differences with other aerological phenomena. Usually the start and end of drought is important and its duration could be relatively long. Since defining, appearing and measuring drought is so complicated, researchers are looking for indices for determining these factors. The purpose of creating and applying each drought index, is to determine its intensity, duration and distribution. Various indices are used in different countries for monitoring drought status. These indices are obtained based on definitions of drought and using a calculation method in which one or more aerological variables are used.

Deciles Index

Deciles method has been utilized by Gibbs and Maher [10] in Australia as an aerological index for monitoring drought. In this method, the amounts of precipitation distribution put in order from minimum to maximum in a long period are divided into 10 parts. Each of these parts is called a "Decile". The first decile represents the amount of precipitation lower than 10 percent of total precipitation. The fifth or "middle" decile is the amount of precipitation not more than 50 percent of total precipitation. Table 2 shows classification of drought intensity based on these indices.

Table 2: classification of drought based on deciles index

Classification of deciles	Description of status
Deciles 1-2	Intense drought
Deciles 3-4	Mild drought
Deciles 5-6	Normal drought
Deciles 7-8	Mild wet year
Deciles 9-10	Intense wet year

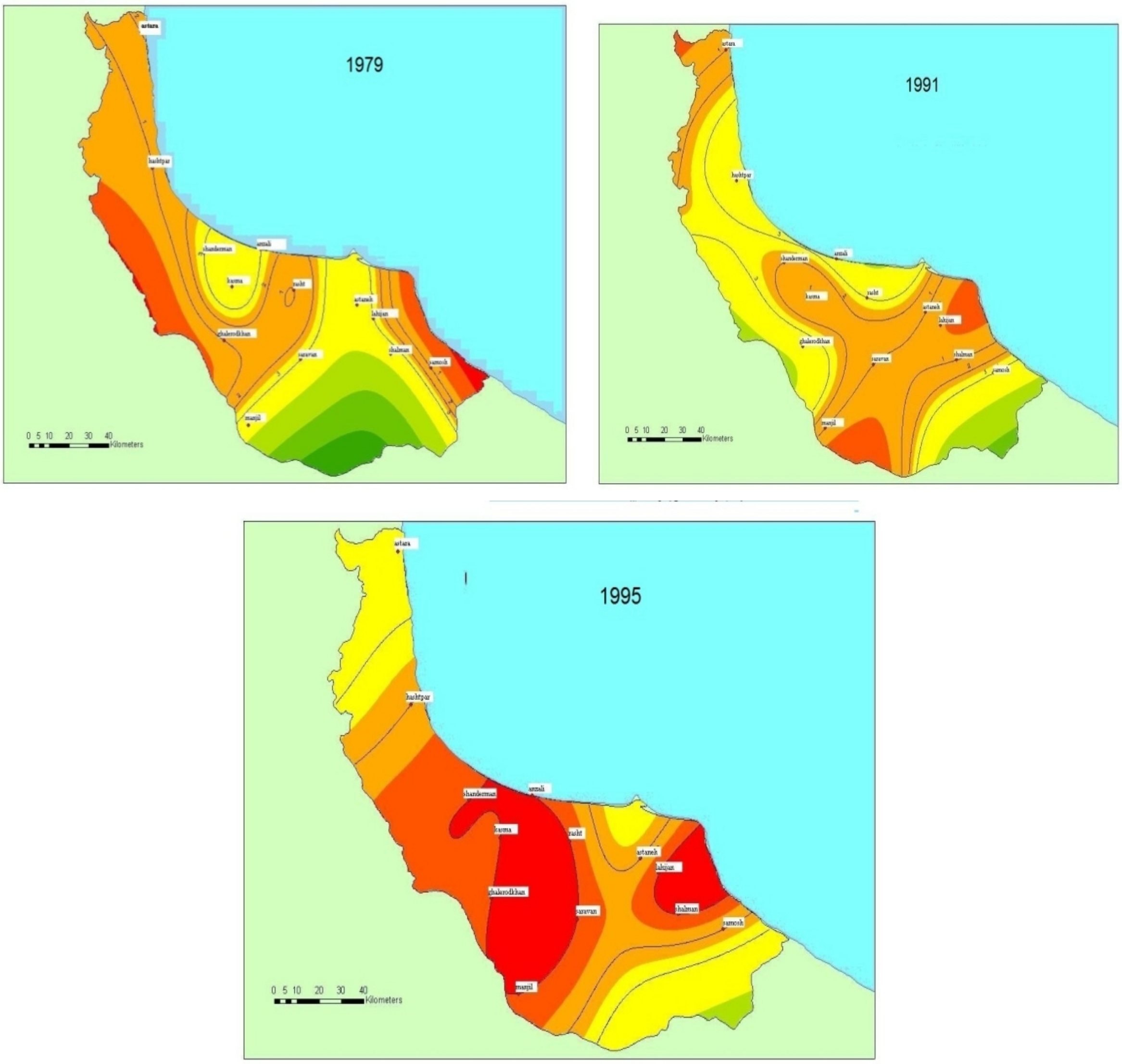
Using the above method and based on the results obtained from analysis of deciles 1 to 3, the province has experienced intense drought in 1979, 1981, 1983, 1991 and 1995. Table 3 shows deciles 1 to 3 of the annual precipitation in Guilan and Figure 1 represents scales of intense droughts during the above years.

Table 3: Deciles 1-3 of annual precipitation in Guilan

Station / year	Rasht	Samoosh	Shalman	Saravan	Lahijan	Manjil	Shanderman	Kasma	GHalerodkhan	Hashtpar	Astara	Anzali	Astaneh
1976							1			2	3		
1977			1				1						
1978					1				3	2			2
1979	1	1		3	3		3		1	1	2	3	
1980		1		2	3								
1981	2	2	2	3	2			2	3	1	2	2	
1982													
1983	1		3		1	2	3	3	2			3	1
1984			3					3					
1985						3			1				1
1986													2
1987					2		2						
1988											2		
1989		2					2	3		3	3		
1990													3
1991	3	3	1	1		1	2	1			1		1
1992													
1993													
1994										3	1	1	
1995	1	2	1	1	1	1	1		1	2		1	2
1996	2			2				1			3	2	

1997				2						3			
1998	3				3	2	3						
1999	2	1	2	1		1			3				3
2000		3	3										
2001				2		3			2				
2002	3			2				2	2			1	3
2003													
2004													
2005		3	2			3		2		3	1		

Figure 1: Maps of distribution of drought based on Deciles Index during 1979, 1991 and 1995



As can be seen, number of drought years is almost the same in all stations. However, it covers some parts of the province each year. In other words, drought is equally distributed in the whole province. It must be noted that in most of years, middle and then western parts of the province were dealing with this natural disaster, which can be related to the way systems penetrate the region and create less precipitation in these areas. In 1995, almost all parts of the province were facing drought. The map of drought distribution related to this year shows exactly the same thing.

Standard Distribution Index

Standard Distribution Index is an important global index which determines the possibility of drought. In fact, this method has been presented considering analysis of various effects of lack of precipitation on underground and surface water supplies, soil moisture, water streams, etc. This index is calculated using the following equation:

Equation 1: $Z = \frac{P_1 - P}{SD}$

In the above equation, Z is the Standardized Index of Precipitation in a specific period of time (year), P is the long period average of precipitation and SD is the Standard Deviation of data. Average and SD of this factor equal zero and one and therefore it can have a lot of applications in comparisons between various stations. A drought phenomenon occurs when the standard index is continuously negative and the value riches -1 or less. The phenomenon ends when the standard index returns to positive values. Considering the values resulting from this index, the intensity of drought is classified into the following table:

Table 4: Classification of Standard Distribution drought index

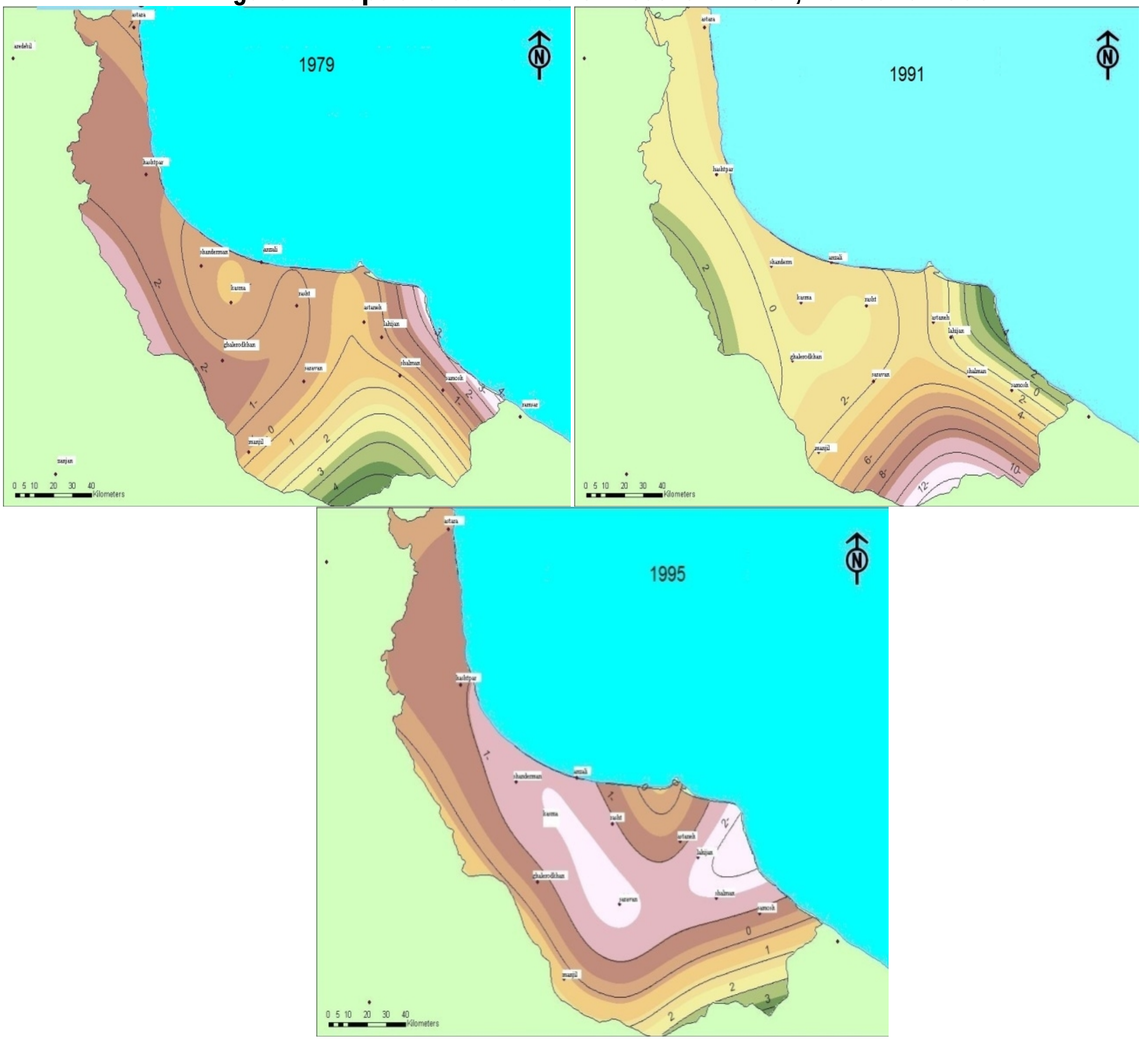
Values of Z	Intensity of drought
0 to -1	Weak drought
-1 to -1.5	Mild drought
-1.5 to 2	Intense drought
<-2	Very intense drought

Analyzing this index has given interesting results in Guilan province. Table 5 shows values of Z obtained from 13 stations and Figure 2 shows the map of distribution of Z score in 1979, 1991, 1995 during 30 years.

Table 5: Values of Z in 13 stations and during the 30 years statistical period

Year	Percentage of surface drought	0>Z>-1		-1>Z>-1.5		-1.5>Z>-2		Z<-2		Z>0	
		km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
1976	66	4618	33	1335	10	1093	8	2048	15	4724	34
1977	34	1436	10	1434	10	1292	9	483	4	9142	66
1978	78	6972	50	1490	11	1646	12	646	5	3073	22
1979	74	3503	25	3109	22	2236	16	1438	10	3533	26
1980	26	2339	17	334	2	203	1	659	5	10281	74
1981	75	6539	47	2423	18	1335	10	0	0	3520	25
1982	11	1075	8	213	2	137	1	126	1	12264	89
1983	77	6698	48	2555	18	1143	8	211	2	3214	23
1984	57	7396	54	411	3	54	0	0	0	5961	43
1985	47	2688	19	1116	8	900	7	1798	13	7298	53
1986	54	5372	39	1007	7	691	5	448	3	6298	46
1987	39	4311	31	506	4	157	1	443	3	8402	61
1988	69	9561	69	0	0	0	0	0	0	4249	31
1989	73	4410	32	2515	18	916	7	2284	17	3691	27
1990	42	3523	25	540	4	462	3	1342	10	7951	58
1991	90	3436	32	1435	13	1292	12	3483	33	1043	10
1992	0	0	0	0	0	0	0	0	0	13818	100
1993	20	773	6	234	2	221	2	1532	11	11063	80
1994	56	5835	42	1269	9	626	5	0	0	6090	44
1995	87	4012	29	4023	29	3267	24	664	5	1738	13
1996	69	3436	25	1144	8	1292	10	3484	26	4171	31
1997	52	4715	34	1129	8	684	5	631	5	6656	48
1998	41	3061	22	749	5	988	7	979	7	8437	59
1999	82	5844	42	1748	13	1640	12	2095	15	2494	18
2000	50	5721	41	734	5	463	3	0	0	6893	50
2001	73	8400	59	1474	10	407	3	0	0	3896	27
2002	64	8359	60	426	3	0	0	0	0	5032	36
2003	49	6002	44	289	2	152	1	191	1	6864	51
2004	9	1230	9	0	0	0	0	0	0	12584	91
2005	61	3984	30	1074	8	1003	8	1971	15	5156	39

Figure 2: Maps of distribution of Z score in 1991, 1979 and 1995



Results obtained from Standard Index show that during the studied 30 years, the region has been facing drought in 29 years (97 percent of the total time). By studying table 5, the statistical period can be divided into two groups considering the occurrence of drought:

1. Territorial drought (zonular)
2. Absence of drought

Group one, which is made up of 29 years out of the 30 studied years, can be further divided into three groups:

a. Years in which more than 70 percent of the province was facing drought
b. Years in which less than 20 percent of the province was facing drought
c. Years in which between 20 to 70 percent of the province was facing drought

Group "a" consists of 9 years or 30 percent, group "b" consists of 2 years or 7 percent and group "c" is made of 18 years or 60 percent of the whole period. It was only in 1992, right after 1991 which was the most intense drought in the region, that the province experienced a wet year. Most of surfaces dealing with drought in the weak drought area, were in the zone of 0>Z>-1 and the middle parts of the province has experienced more drought compared to the other parts. In 19 percent of the total studied period, more than 50 percent of the province has experienced drought. This amount makes up 63 percent of the whole period. 1992 was the only year in which there was no drought. However, in 1991 this natural disaster was at its highest level and the least wet year exists. Distribution maps which are related to 1991, 1995 and 1979 (Figure 2) show the years with an area of more than 70 percent dealing with drought. Colors become darker according to the intensity of drought and therefore they are representative of drought intensity.

RESULTS AND DISCUSSION

Considering table 1, the highest average of annual precipitation goes to Anzali with 1745 millimeters and the least goes to Manjil with 264 millimeters. Standard Deviation, Variance and coefficient of changes increase with rise of precipitation. Also skewness is smaller in stations with more precipitation average. This parameter represents the distribution of precipitation regime and the smaller it is, the more monotonous precipitation regime would be. The two study methods showed the most intense droughts in 1991, 1995 and 1979. Figures 1 and 2 confirm this. Analyzing drought maps also give interesting results. Figures 1 and 2 show that the middle parts of the province including Rasht, Saravan, Kasma, Anzali and Shanderman have experienced the most intense droughts, after them are the western parts including Hashtpar and Astara, and eventually Samoosh, Shalman and Lahijan have gone through the least droughts. In other words, apparently during these three years, the middle part of the province has had the most droughts. After the middle part, stands the west and then east of Guilan. It seems that decrease in input water of Sefidrood dam which supplies the drinking water of 80 percent of people in Guilan and the water required for 180000 hectares of farm lands because of raise of sediments, and building 10 new dams on branches of Sefidrood are the main causes of water crisis in the middle parts. Results from the Standard Index show that occurrence of drought is not a rare and random phenomenon, but it is even common and reversible. In 29 years out of the studied 30 years (97 percent of the whole period), the region has faced drought. Considering the importance of agriculture in Guilan which is effective on employment and economy of people, analyzing precipitation rate and determining droughts are of high importance. The obtained results can be utilized by the authorities and managers for making decisions and programming in different areas. Studying areas facing more intense droughts and having more focus on them, appropriate management of water resources, optimal irrigation, using wasted waters and optimizing use of water for agricultural and urban purposes can all reduce losses made by drought.

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