Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 1, p. 14-22, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

The study of climate change in Mazandaran Province using the limit indices of temperature and precipitation

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Article published on July 08, 2014

Key words: Mazandaran, climate change, drought, SPI.

Abstract

In recent years, we could rarely find a day in which the mass media do not release news and reports about natural disasters such as intensive storms, flood, drought and their heavy damages to catchments and human's environment. Most of the mentioned events are the result of climate changes that researchers believed it is the result of global warming. With regard to the fact that with today's technology, human could not prevent these disasters. Therefore, recognizing these phenomena and its consequences can help the human to learn what the best way is to overcome these events and suitable behavior to decrease the consequences. To do so, in this study, climate changes problem in Mazandaran province catchments was selected and considered. To achieve this aim, temperature and precipitation parameters were extracted and classified from synoptic and climatologic meteorological stations with long duration statistics. To achieve a total idea of precipitation and temperature behavior in the studied region, moving average was used with a quantitative analysis. In addition, Standard Precipitation Index (SPI) was used to study the intensity, duration and frequency of drought years in that region in order to specify the role of precipitation, temperature, and moisture in climate change. The results of the study indicated that temperature change causes precipitation reduction and could directly affect the water requirement of agricultural plants. Finally, by reviewing the above mentioned parameters it was concluded that in recent years, climate change has been obvious in the area and tends to become more arid.

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Introduction

Climate change is a long run complex climatic phenomenon in the world because of which abnormalities or frequencies in the process of climatic parameters, such as temperature and precipitation. These abnormalities are severe in many parts of the world, and can cause the disturbances in natural ecosystems. Drought is among the climate changes, which embraces many of arid and semi-arid areas of the world with a high intensity every other year (Razi'i *et al*, 2003). Various climatic parameters such as temperature, humidity and precipitation are the elements that affect the climate of an area that recognizing them determines the climate of the area. The occurrence of the phenomena such as sudden increase or decrease of temperature, precipitation, and some other climatic factors are the cause of the climate change of an area (Bakhtiyari, 2003). In fact, the most important effect of climate change is related to the change in temperature and precipitation. In this case, precipitation is of particular importance, since the change in the pattern of precipitation leads to the occurrence of floods, and drought in different areas (Reza'i and SarAfrozeh, 2006). The incidence of drought or wet year, in fact, means the transient deviation of precipitation from normal limit in a climate (Azizi, 2005). These events have different frequency, duration and intensity and accompany undesirable effects, such as the reduction of water resources and soil moisture and causing serious damages to agriculture sector and natural ecosystem. In addition, severe wet years cause the phenomena such as floods, increase of erosion and decrease of soil fertility, desertification, etc. Secondary consequences of this phenomenon are food shortage, creating social panic, famine, poverty and other social and economic issues that can affect the human society intensively. Hence, the study of climatic changes and fluctuations, such as drought and wet years with regard to their start and end, severity and persistence is of high importance (Mahmoud Zadeh and Owhadi, 2006). According to many studies conducted regionally and globally, almost all of the results refer to a common concept i.e. change in climate regime and increase of global warming in the past 100 years. According to the calculations made by the Intergovernmental Panel on Climate Change (IPCC) the mean temperature of lands and oceans has increased between 0.3° to 0.6°C from1900 to 1995, and approximately 0.2° to 0.3°Cduring last 40 years.In addition, on the regional scales maximum 6.18°C of temperature increase is reported in some regions during the past century. In its published reports in 1995 and 2001, this board has pointed out the climatic changes, including increase of global temperature for about 0.7 °C, since the second half of the nineteenth century. It seems that this global warming may cause the increased limit value of precipitation and temperature and bad climatic conditions in the short run (Soleymani, 2006).

The indices of drought are useful when they can offer quantitative, clear and simple evaluation of their main characteristics such as intensity, continuity and effectiveness. SPI (Standardized Precipitation Index) can be calculated based on precipitations probability for each time interval and in order for early warning and monitoring the drought severity, it is of great importance. Furthermore, this index is designed to quantitate the lack of precipitation in multiple time intervals. These time scales express the particular effects of drought on the availability of different water resources. The use of SPI requires fewer statistics and information and it is a simpler way of calculation. In comparison with other indicators, it is of relatively more appropriate conditions because of the capability of evaluation and monitoring, close to real time (monthly). Another feature of this index is that based on it may be drought threshold, determine for each period of time. Therefore, on the basis of this index, the drought threshold could be determined for each time interval (Razi'i *et al,* 2003).

In recent years drought studies have attracted many researchers due to the importance the topic of climate change and its direct effects on human life.

In order to study the climatic changes, the study of

temperature and precipitation parameters are of a higher priority compared to other parameters; since temperature and precipitation are the most fundamental and significant factors in determining the role and effects of other climatic elements, and the main indices in climatic classification and regionalization. Hence, the volatility of these two factors is of scientific and applied importance. In the study of the role of temperature in the climate change studies, determining the monthly temperature trends and comparison of monthly mean temperature change are more important (Carl and Diaz, 1998).

Since it is located in the dry geographical and desert belt (between 25° and 40° north latitudes), our country, Iran, is considered a region of low rainfall. Among the distinguishing characteristics of rainfall regime of Iran, is severe seasonal and annual and monthly precipitation that increases from North to South and from West to East. Studies show that the incidence of drought is the main characteristic of the climate in Iran, which is observed both in the realm of wet and dry climates. This case is the result of the presence of severe climatic fluctuations in different time scales (Lashni Zand, 2004). In recent years, studies related to climate change have attracted many authors, due to the direct effects of it on human life.
Rossi and Bandini (1992), evaluated the drought characteristics of Sicily area on the basis of time series precipitation data for two-time intervals (six wet months and watery the entire year) and applied similar drought index of other scientists, but with different hypotheses. Chbouk *et.al* (1995), tried to identify the spatial and temporal pattern of droughts in Morocco, trough the Kriging interpolation method. They tried to explain this pattern with the synoptic system after discovering the structure of the spatial and temporal drought. Thompson (1999) considers drought as a hydrologic phenomenon, and has employed the three approaches of the Runs theory, the drought indices and frequency analysis to study, assess and analyze the drought situation. Faraj Zadeh Asl (1995), evaluated the spatial and temporal characteristics of drought occurrences in Iran, while expressing various methods of drought review, and he concluded that the central, east and south of the country are more susceptible to drought because of the fluctuations in values of precipitation. To identify the annual dry and wet periods, KhoshAkhlagh (1997) used statistical coefficient, especially SPI, related to 37 synoptic stations and finally with the study of map synoptic, the monthly patterns of drought and wet periods were analyzed in Iran. Mas'oudian (1998) in his studies, reviewedthe spatial and temporal patterns of drought, and presented relationships to determine the scope and severity of drought, and concluded that the frequency distribution of drought intensity is of three-parametric log-normal type. By reviewing the drought index, Sultani (2009) assessed the drought, temperature, and precipitation and using geo-statistics methods in the GIS environment, he studied the drought in 2008 and lack of cultivation of about 25% of the paddy lands in Mazandaran province. His studies showed that temperature of different regions in the three-month period from March 2007 to April 2008 is warmer 1.6-8.2°c, compared to the same period. In his studies, he calculated the severity of drought in this three month period, based on the SPI, PNPI[2] and RAI[3] indices, and the results say that there is a very severe drought in most areas of the province
Due to specific climatic conditions, Mazandaran province plays a very important role in the agricultural products, and for this reason, any changes in environmental conditions could follow irreparable damage. Therefore, in order to study the process of climate change in this region the limit values of rainfall and temperature were used and for drought situation analysis SPI index was employed.

Materials and methods

Materials

Mazandaran province with the area of 23756 km2 is located in the south of the Caspian Sea and the north of the Alborz Mountains. According to the De marten classification, the western, central and eastern regions of Mazandaran have a very humid, humid and Mediterranean climate, respectively. Mazandaran annual precipitation is estimated 420mm in

SiyahBisheh, and up to about 1380mm, in Ramsar and Nooshahr. The annual mean temperature in different areas of the province is changing from approximately 10° in SiyahBisheh and Alborz heights up to 17.5° in coastal areas (Meteorological Organization of Iran, 2006). In order to study the climatic fluctuations in Mazandaran province, the necessary information was obtained from the meteorological station of the province and the country's Meteorological Organization and analyzed.

Methods

Mazandaran province now possesses15 synoptic stations, 16 stationof climatology and more than 100rain gauge stations. In this research, the rainfall statistics, mean temperature, monthly and annual humidity from synoptic stations of Nooshahr, Babolsar, Ramsarand Ghrakheil of Ghaemshahr, was respectively with 58, 53, 32 and 29 statistic year and climatology stations of Zardgol and Rineh Larijan with respectively 25 and 29 statistic year, were used due to the longer statistical period. With respect to the fact that in some of the months, the mentioned statistics were deficit, to find the lost data, with the help of Excel2010 software, different reconstruction methods and the estimation of data were investigated and finally were selected and used the method of fluxion and the method of ratios were used for continuous parameters, (such as temperature) and non-continuous parameters (such as precipitation), respectively. After this stage, SPSS 14 software was used to check the homogeneity of statistics, and succession test method. The method of moving average of 5 and 7 year was used for the analysis of long-term behavior of non-randomized components of the climatic series.

To calculate SPI, the density function of gamma distribution and sometimes the Pearson function were used for the fitting of long term data of precipitation. After conducting the required calculations and determining the relevant parameters, SPI is expressed as positive or negative values. SPI provides the values of Z normal distribution (a number of high or low standard numbers relative to the occurrence probability of 50%) and since has the precipitation values have skewness; the best way is to estimate the gamma parameter. In this study, the precipitation amounts of stations are fitted with different distributions and the best distribution is selected and, after selecting the suitable distribution, the required parameters, such as gamma distribution, were applied. Statistical distribution of gamma is a good fitting for climatic time series of precipitation (Tom, 1966). The gamma distribution functions defined as the probability density function or the frequency as follows:

$$H(x)=\frac{1}{B^{a}\sqrt{a}}x^{a-1}e^{-x/B} \quad (1)$$

Where $a>o$ is the form parameter, $B>o$is the scale parameter, $x>o$is the amount of precipitation, $\sqrt{a}$is the gamma function and $H(x)$ is the cumulative probability value. Calculating SPI using the fitting of gamma probability density function is different for each station and $a$and B parameters, which are a function of gamma density function are estimated for each time scale and every month of the year in each station. Tom (1966) estimated the optimum values of a and B based on the following equations using correct maximum method:

$$a=\frac{1}{A}\left[1+\frac{4A}{3}\right] \quad (2)$$

$$B=\frac{\bar{x}}{a} \quad (3)$$

In which it they $\bar{x}$are the mean precipitation and A is obtained from the following relation:

$$A=1n(\overline{x})-\frac{\sum 1n(x)}{n} \quad (4)$$

In this relation, n is the number of precipitation observations. At last, SPI values are obtained by the transfer of cumulative distribution probability to normal distribution. The simplest method to calculate SPI values, is using approximation of "Abramotizo Astogan". Using the following relationships, this approximation converts, the value of cumulative

probability *H(x)*, according to the desired range, into standard normal SPIvalue, as follows:

$$SPI = -\left[t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right] \quad ,0 < H(x) < 0.5 \, , c_0 = 2.515517 \, , c_1 = 0.802853 \quad , c_2 = 0.010328 \quad (5)$$

$$SPI = +\left[t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right] \quad ,0 < H(x) < 1, d_1 = 2.432788 \, , \quad d_2 = 0.189269 \quad , d_3 = 0.001308 \quad (6)$$

$$t = \sqrt{1n\left[\frac{1}{-(H(X))^2}\right]} \qquad , \; 0 < H(x) < 0.5 \quad (7)$$

$$t = \sqrt{1n\left[\frac{1}{1-(H(X))^2}\right]} \qquad , \; 0 < H(x) < 1 \quad (8)$$

Negative SPI expresses drought and since SPI equals -1 or less, drought becomes severe. When this value is positive, drought period finishes (Table 1).

Results

In this research, it was determined that despite the public perception, increasing trend (approximately 50mm) in the total mean rate of precipitation was observed in all stations.Of course this increasing trend does not represent the increase in snowing. Investigatingprecipitation graphs, it was determinedthat the range of precipitation fluctuations in relatively high in Mazandaran province(Fig 1).

Table 1. Determining the Drought state using SPI.

Drought state	Cumulative probability	SPI
Very extereme severe	0.0014	-3
Very severe	0.0062	-2.5
Severe	0.0228	-2
Average	0.0668	-1.5
Weak	0.1587	-1
Near to normal	0.3085	-0.5
Normal	0.50	0.00
Near to normal	0.6915	0.5
Weak wet years	0.8413	1
Mean wet years	0.9332	1.5
Severe wet years	0.9772	2
Very severe wet years	0.9938	2.5
Very extreme severe wet years	0.9986	3

Table 2. Drought state of studied stations using SPI.

Station	Statistical period	Drought years	Number of drought year
Babolsar	1951- 2010	1952,1954,1955,1961-1967 1970,1974,1979,1980,1983-1986 1990,1991,1999,2001,2006,2008,2010	26
Ramsar	1956 - 2010	1961,1962,1964,1965,1971 1972,1974,1975,1979,1980,1982-1985, 1989,1991,1995,1999,2005,2006,2008,2010	23
Nooshahr	1977 - 2010	1982-1985,1989,1995,1999,2005,2006,2008-2010	13
Ghaemshahr	1980 - 2010	1983-1986,1991,1994,1995,1999-001,2006,2008-2010	14

In addition, it became clear that precipitation days have had an increasing trend from the mean value in such a way that in the late decade, precipitation has been mostly in the form of shower, which has been temporary and transitory, and basically precipitation has decreased continuously. The sum of maximum and minimum annual precipitation belongs to the station of Ramsar (1825mm) and Ghaemshahr

(527m) respectively. Investigatingannual precipitation in the long run (31 year) expressed the increasing rate of total mean annual precipitationfor about 50mm. between the stations under study, Nooshahr (90mm) and Ghaemshahr(15mm) stations confronted precipitation increase and Babolsar (30mm) and Ramsar (20mm) stationsconfronted precipitation decrease (Fig 2).

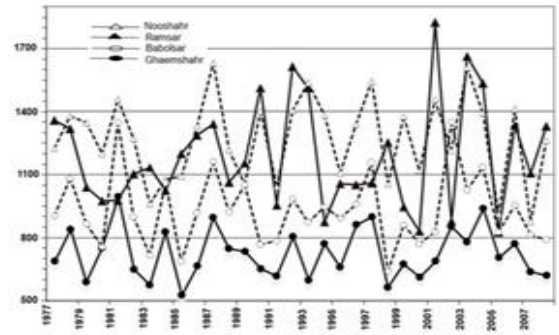

Fig . 1. Annual Precipitation Sum Change of Stations (1977-2007).

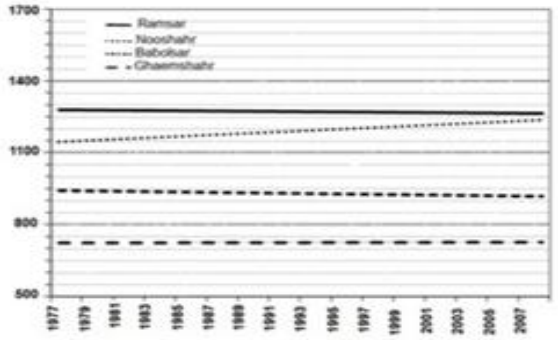

Fig. 2. Annual Rainfall Sum Change of Stations (1977-2007).

By studying the smoothed curves of the mean temperature graphs for four synoptic stations of Nooshahr, Babolsar, Ramsar and Ghaemshahr, it was determinedthat this parameter was of increasing trend (Fig3). In addition, studying the moving average of 5 and 7 years verified the above mentioned cases.

Investigation of mean annual temperature changes in the long run (statistical period of 29 year) expressed theincrease in temperature for an average of about 1.2°Cthat between the studied stations, the Ramsar (1.7°C) and Nooshahr (0.7°C) had the highest and lowest temperature increase, respectively (Fig 4).

Generally, it could be expressed thatclimate changes have been evident in the region based on temperature increasing trend, especiallyin recent years.On the other hand, thesechange caused the change in precipitationfeatures of the region, which can directly influence the water need of crops (Lashni Zand, 2005).

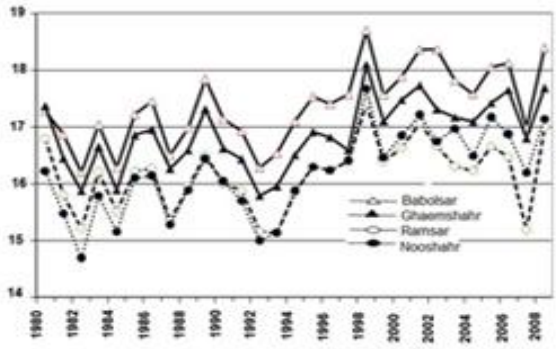

Fig . 3. Annual TemperatureMean of Stations (1980-2008).

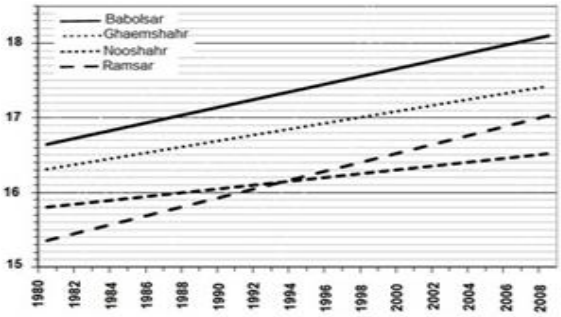

Fig. 4. Increase of AnnualTemperatureMean of Stations (1980-2008).

Investigating the SPI graph represents thateach of the stations have observed the occurrence of drought during the statistical period. In this research, the diagram of the SPI ineach station wereanalyzed in order tostudy the region's drought status(Figures5-8). In Table 2,asummary of the results from studying SPI diagrams and drought status is shown. Reviewing the data from Table 2 and SPI graphsin the common statistical period (1977-2010) determines that in 9 statistical years, from1983 to 1985 (three consecutive years), 1991, 1999, 2006 to 2010, most regions of the province have confronted the drought (Table 2).

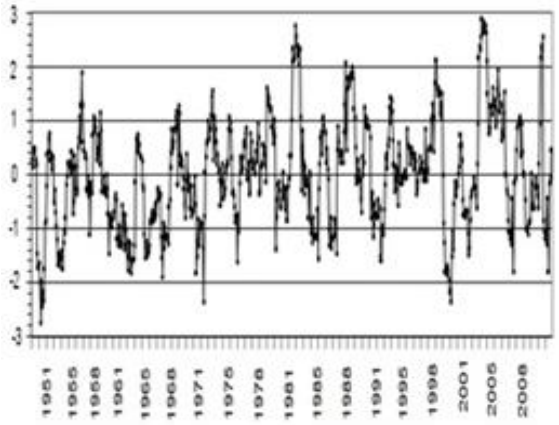

Fig. 5. SPI of Babolsar in Statistical Period (1951-2008).

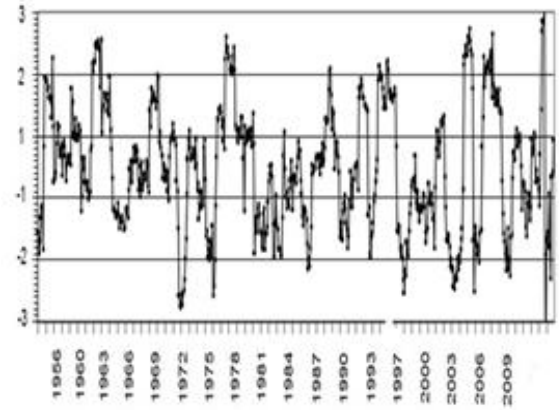

Fig. 6. SPI of Ramsar in Statistical Period (1951-2008).

Furthermore,reviewing the graphs, it became clear that the most severe droughts in the province belong to2005, 2006and 2009.Other results from analyzing the graphs was identifying the process of drought in the area during the common statistical period, which indicated that SPI average has decreased for approximately0.5%. This research confirms the fact that the climate of Mazandaran province has moved toward drought during the past 30 years. With regard to the fact that Mazandaran province is one of the country's agriculture poles, these changes can alter theslew patterns and date of planting in an area. In this respect, one of the applications of regional studies could be assisting the agricultural strategic decisions (long-term decisions) such as determining the type of planting.With regard to the fact that agriculture is the main factor of fresh water consumption, increasing the efficiency of water use in addition to cropping more valuable products are the fundamental principles of natural resources management to deal drought. Growing drought and salinity resistant plants and considering the comprehensive researches on soil and water as important, should be a priority. Among the ways to increase the water efficiency are the following: Reduction of the lands under cultivation and modified field operations; improvement ofirrigation methods; the observance of environmental principles; use of domestic wastewater in agriculture;channel cover; preventing theincrease of low-yield lands;addingrequired organic matterto plants; fertilizing the clouds and sweetening saline waters.

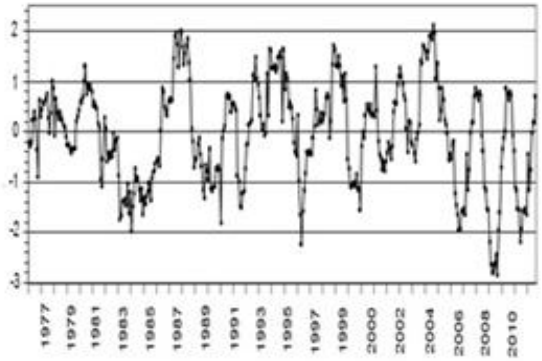

Fig. 7. SPI of Nooshahrin Statistical Period (1977-2010).

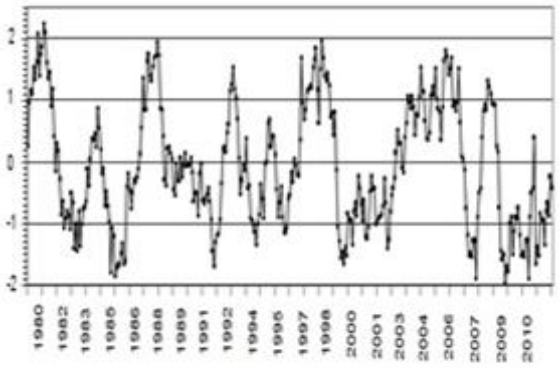

Fig. 8. SPI of Gha′emshahrin Statistical Period (1980-2010).

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