The Forecast of Drought Condition During the Period 2020-2030 Based on Statistical Downscaling of Output of the Model LARS-WG5 (Case Study: Eqlid City Station)

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Abstract: Precipitation is one of the most important meteorology parameters that has considerable time and place changes particularly in the dry and semiarid regions. Because drought is one of consequences of these changes and it also influences on different sectors of the society such as water resources, drinking, industry, economy and etc., therefore, it is very necessary to monitor and to analyze it in future to offer proper planning. To this aim, in this study, the effects of climate change on drought conditions of Eqlid station during the period of 2020-2030 have been investigated. At first, daily data of output of atmosphere general circulation model of HadCM3 under two emission scenarios of A2 and B1 through statistical model of LARS-WG5 has been downscaled and the ability of the model in simulation of previous climate (1992-2008) for studied station has been simulated. The results showed that temperature degree of the region increases in most of the months and this increase rate differs in different months of the year. On average, yearly temperature degree increases. /62 °C and. /7 °C respectively in the period of 2020-2030 under emission scenario A2 and B1 than the period 1992-2008. Monthly rainfall changes do not represent up or down trend. However, the average of rainfall rate will increase 4 % under emission scenario A2 and it will decrease 4.8% under scenario B1. Afterwards, it has been investigated in yearly scale by using precipitation data of drought condition with the help of stated index, which based on the results, the most severe drought will happen in 2025 under scenario B1 and 2021 under scenario A2. In 11 years period, simulation of scenario B1 will experience 4 periods of consecutive drought and scenario A2 will experience 6 periods of consecutive drought.

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1. Introduction

Water is the main constituent of world complex evolutions and sustainable development of the countries. In the report "challenges of water security in 21st century", on the importance of the effect of water security on different parts of world countries such as environmental and social-economic issues has been accentuated (Grey and Garrick, 2012). The pressure on water resources is increasing day by day due to population growth; social-economic development and climate change (Vorosmarty et al., 2010). The distribution of water resources and the hydrologic cycle have been to a great extent influenced by the increasing of greenhouse gases in atmosphere and occurrence of global warming phenomenon (Hagemann et al., 2013). Climate change phenomenon will lead to temperature increase and rain possible decrease in a multitude of regions particularly hot and dry regions. Hydrologic cycle determines the existence of water in time and in place by circulating water in the nature. This amount of water is under effect of hydrologic cycle so that if it changes, drought will occur. Droughts are one of the most destructive weather events so that their occurrence seriously damages natural resources and human life (Belayneh & Adamowski, 2012). One of the parts that drought undoubtedly affects on is each country's water resources, subsequently, the regions that are susceptible to drought, they have more limitation and more sensitivity of water resources, therefore actions should be taken before, during and after drought. For this reason, proper management of surface water and groundwater resources decreases drought damages (Farajzadeh, 1374) and this result will not been achieved unless the managers come up with long-term plans to manage water resources. In a multitude of long-term plans, it is necessary to consider a prospect of future conditions of rainfall and wet and dry periods for the region, for this reason, in water resources management and in many economic and environmental plannings, prediction of drought is if much importance. Iran is, among other countries, one of the driest countries that is exposure to sever droughts. The shortage of water also influenced on all economic-social sectors and it threatens sustainability of natural resources too. Moreover, researchers believe that climate change increases the shortage of water resources in future periods. The annals the current studies represents that drought phenomenon has most of the years surrounded some regions or even the whole country (Pirie at al., 2004). Zarghami and his colleagues (2011) downscaled weather changes of six synoptic stations located in east Azerbaijan province by using HadCm3 model under three emission scenarios of A2, A1B and B1 with horizon 2020, 2055 and 2090 and by using random generator of weather LARS-WG, therefore they concluded that according to scenario A2, in the first half of the current century, daily temperature average will increase 3.2 °C and daily rainfall will decrease 3%.

Blenkinsop and Fowler (2007) investigated future droughts of England by making use of atmosphere general circulation models. The results of their investigation showed that severity of droughts will decrease, but they will continue (Blenkinsop & Fowler, 2007). Loukas and Fowler investigated the effects of climate change on drought severity in the region of Thessaly, a region in Greece. They used the output of GCM1 model and emission scenarios of A2 and B2 to forecast climate changes and to evaluate drought trend and used SPI index in the periods of 2020-2050 and 2070-2100. Their results represented that drought severity has increasing trend and this increase will be under scenario B2 (Loukas et al., 2008).

2. Material and Methods

Area of study

Eghlid city is located in the north of Fars province and in the geographical range of 52 degrees and 55 minutes east longitude and 31 degrees and 13 minutes north latitude. From the north, it borders Abadeh; from the south, it borders Marvdasht and Sepidan; from the east, it borders Khorrambid; from the west, it borders Esfahan and Kohgiluyeh and Boyer-Ahmad provinces. Eqlid synoptic station is located in coordinates 54′ 30° N, 38′ 52° and 2300 meters high above the sea level. The geographical location of Eqlid is demonstrated in figure 1.

The introduction of LARS-WG software

Artificial generator of weather data is used to simulate meteorology data in a single place under current and future climate conditions. Statistical features of generated data are similar to statistical period, but their standard deviation is scattered in past and future periods than data difference of GCM model.

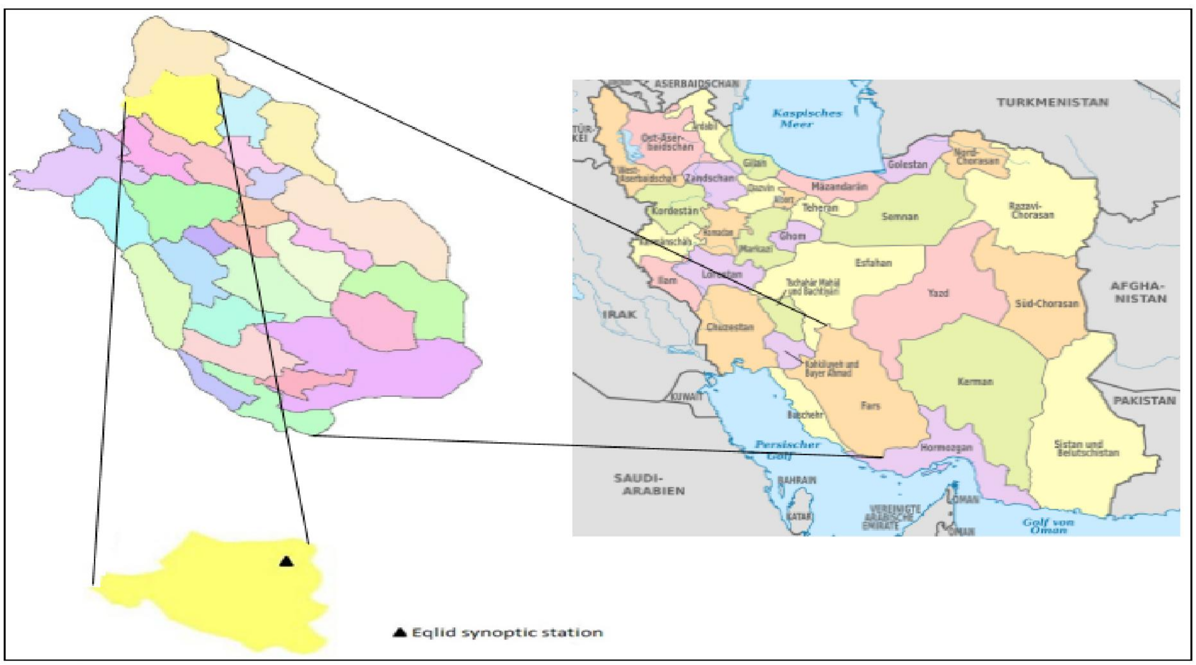

Figure 1. Geographic location of area of study

Data are produced in daily time series for a series of suitable climate variables such as rainfall, minimum and maximum temperature and radiation (MJ / m2). The notable point is that artificial generators of weather data are not tools to predict; therefore, it is not possible to use them to predict weather. However, they have the ability to generate time series of weather data similar to monitoring period. In this way, the studies of climate change will be carried out in a single station through simulation and production of artificial weather data in a local scale.

Calibration of model

At first, the specifications of the station (name, longitude and latitude and above mean sea level) and observation data collected during 17 years since 1992-2008 such as the minimum temperature, the maximum temperature and rainfall was imported into the model. During calibration operations, the model determines input files and the analysis of the station data and then it uses them in the stage of verification and the production of time series.

Verification of the model

In this stage, generated data, assuming that there is no climate change, is generated based on parameter file of selected station, then observed and generated statistical characteristics of meteorology data are compared. In this model, the comparison between observed and generated data is drawn through chi-squared test for probabilistic functions, student's t statistical test for the averages and Fisher`s F test for standard deviation.

The analysis of the model

In order to analyze the model, calculation and analysis of indicators of average of square root of error (RMSE) are coefficient of determination (R^2) and residual coefficient (CRM). Their mathematical formula is represented in the following section:

$$\text{RMSE}=\left(\sqrt{\frac{\sum_{i=1}^{n}(Pi-Oi)^{\wedge}2}{n}}\right)/\bar{O}$$

$$R^2=\frac{\left[\sum_{i=1}^{n}(O_i-\bar{O})(P_i-\bar{P})\right]^2}{\sum_{i=1}^{n}(O_i-\bar{O})^2\times\sum_{i=1}^{n}(P_i-\bar{P})^2}$$

$$CRM=\frac{\sum_{i=1}^{n}O_i-\sum_{i=1}^{n}P_i}{\sum_{i=1}^{n}O_i}$$

O_i indicates the observed value of intended parameter, $\bar{O}$ observed values average, P_i predicted value of intended parameter, $\bar{P}$ predicted values average and n indicates the number of data. The value of RMSE indicates that how much is the overestimation and underestimation of model than observations or measured. The value of R^2 indicates the proportion of dispersion between predicted and measured values. CRM indicates the model inclination towards overestimating or underestimating of measured values. If all of predicted and measured values are equal, then CRM and RMSE values are equal to zero and R^2 is equal to 1.

Production of climate scenarios

There will be different ways to simulate climate variables in future periods; however, the most reliable tool to produce climate scenarios is currently Atmosphere-Ocean General Circulation coupled three-dimensional Models (AOGCM). In this study, the output of HadCM3 model under two emission scenarios A2 and B1 was utilized. Then, in order to access to climate data of the region in the basic and the future period, temperature and rainfall time series in the basic period (1992-2008) and the future period (2020-2030) was achieved by importing geographic coordinates of the closest synoptic station to the region (Eqlid synoptic station) and the duration of required statistical period was achieved through the center of data distribution of DDC, temperature and precipitation time series in the basic period (1992-2008) and future period (2020-2030). Considering that the outputs of AOGCM model are not directly used in different studies to predict and to analyze the consequences of climate change in local scale, downscaling methods are used to solve this problem. In this study, statistical downscaling by using weather generator model (LARS-WG) was applied. This model is one of the most common models of climate random data generator that is used to produce temperature of maximum and minimum of air, radiation and daily rainfall in a single station under conditions of climate change.

Drought index of standard precipitation (SPI)

Edward and mckee (1993), from climatic center and national center of drought decrease of United States, used standard precipitation index to define and to monitor drought condition. SPI changeability of causes that groundwater resources, river streams, lakes level and surface resources to be used in short term scales for agricultural purposes and in long term scales for hydrologic purposes (Edward and Mckee, 1997).

$$SPI=\frac{Xij-Xim}{\sigma}$$

In the above formula Xij, i indicates seasonal rainfall in rain station, j indicates the number of observations, xim indicates long term average of rain, σ indicates standard deviation.

Table 1. Categorization of SPI Index

Value SPI	The kind of drought	Row
≥ -2	Very severe drought	1
-1.5 TO -1.99	Severe drought	2
-1 TO -1.49	Medium drought	3
0 TO -0.99	Mild drought	4

(Mckee at all, 1993)

3. Results

In order to analyze LARS-WG model, statistics was used that its results is put into the following table.

Table (2) represents calibration statistics values to analyze the model. The analysis of statistical parameters between simulated and observed data shows the high accuracy of the model in simulation of rain parameters, minimum and maximum temperature. As it is clear in this table, the model benefits from high ability in simulation of climatic parameters in future.

Simulation of climate change scenarios of the region by HadCM3 model

Climate change scenarios of temperature and precipitation by HadCM3 model under two emission scenarios for future periods was simulated. Table (3) represents the climate change scenarios of temperature and rain of the region under two emission scenarios B1 and A2 in the period 2020-2030 than the basic period.

Table 2. Value of Calibration Statistics to Analyze

Station	Statistical Parameters	Precipitation (mm)	The Minimum Temperature (°c)	The Maximum Temperature (°c)
Eqlid	RMSE	0.106	0.017	0.017
	R^2	0.95	1	1
	CRM	-0.027	-0.001	0.005

Table 3. climate change scenarios of temperature and precipitation of Eqlid County under two emission scenarios B1 and A2

Temperature (daily)		Precipitation (mm / day)		Month
HadCM3-B1	HadCM3-A2	HadCM3-B1	HadCM3-A2	
0.08	-0.04	-0.05	0.17	January
0.46	0.46	0.09	0.00	February
0.92	0.90	-0.35	-0.12	March
1.37	1.42	0.27	0.25	April
1.83	1.47	-0.24	-0.05	May
1.64	1.13	-0.31	-0.02	June
1.28	1.09	0.07	0.13	July
1.04	0.46	-0.20	0.00	August
0.12	0.21	0.09	-0.18	September
-0.06	-0.28	-0.11	0.24	October
-0.30	0.09	0.27	0.16	November
0.01	0.45	-0.10	-0.12	December

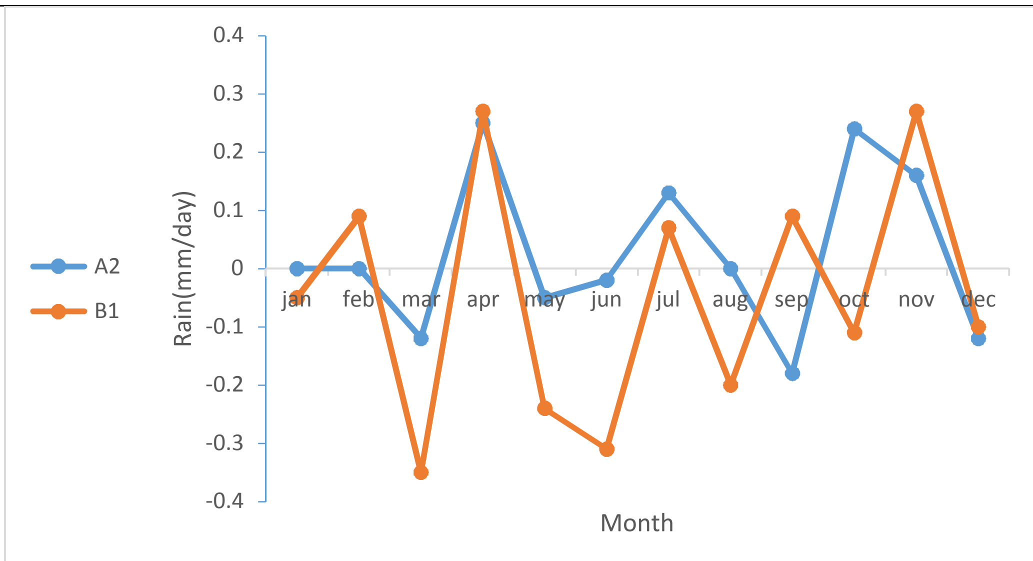

Figure 2. Rain changes in comparison to the basic period for scenarios A2 and B1

The positive values in the table for the temperature scenario represent that HadCM3 model simulates temperature increase in most of months for the county in the period 2020-2030, that the highest temperature increase of is in May under scenario of B1 that its amount is 1.83 °C. Generally, the context will encounter hot and drier conditions due to climate change. The results also show that the highest rate of precipitation increase is in November and the highest rate of precipitation decrease is in March under scenario of B1.

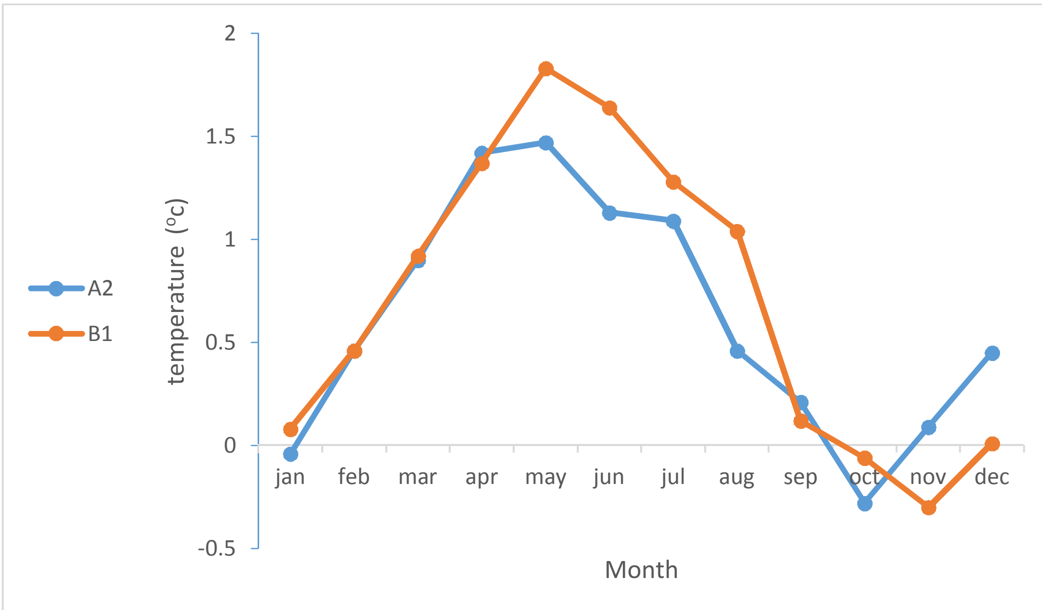

Figure 3. Temperature changes than basic period for scenarios of A2 and B1

The calculation of drought index of SPI for climate scenarios in the period 2020-2030

In order to forecast the drought, the results of scenarios A2 and B1 through using drought index of SPI were utilized. The related chart to this index has been yearly represented in figures 4 and 5. The results achieved from this index for climate scenario match in terms of recognition of drought periods. As it is observed in this chart, the most severe drought occurred in 2025, scenario B1 and 2021, scenario A2. In 11 period, simulation of scenario B1 shows successive 4 drought periods and scenario A2 shows successive 6 drought periods.

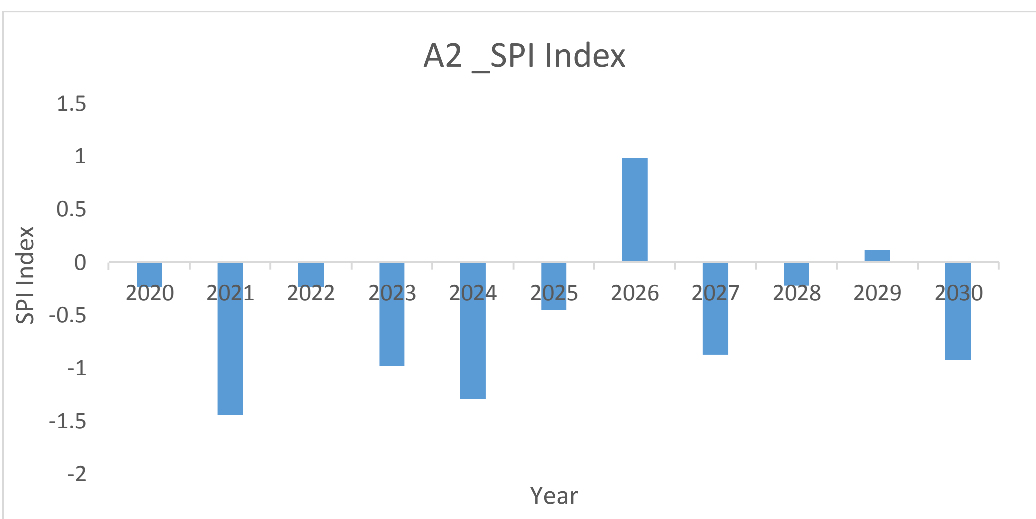

Figure 4. SPI index for scenario A2 in the period of 2020-2030

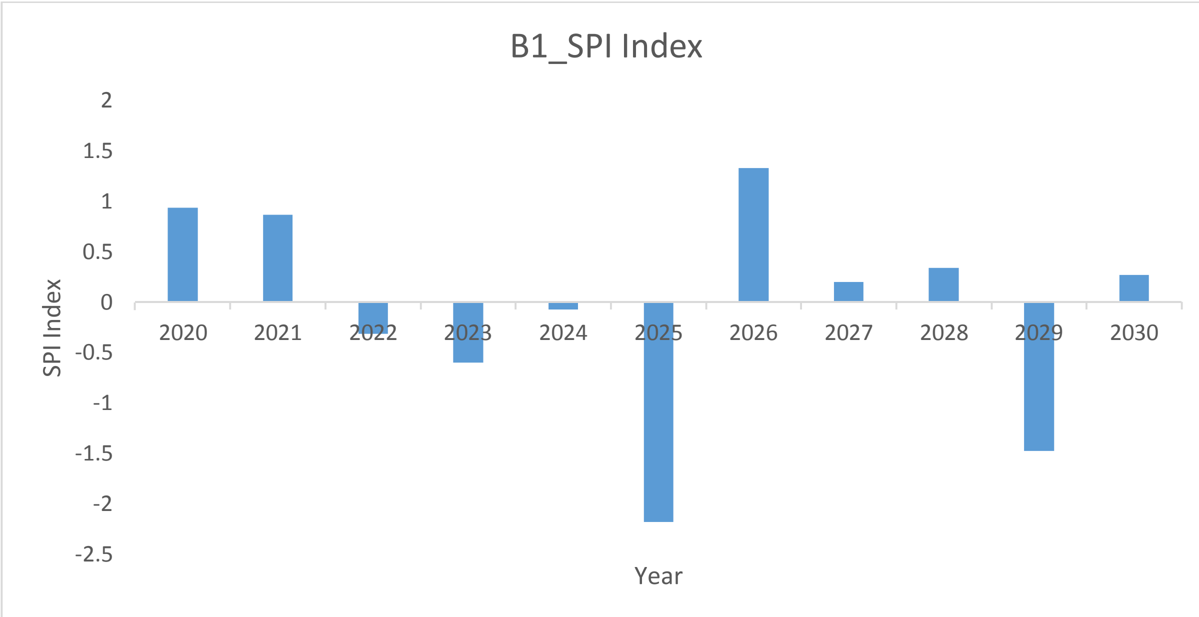

Figure 5. SPI index for scenario of B1 in the period of 2020-2030

4. Conclusion

Downscaling represented that the region temperature degree increases in most of the month of the year and this increase differs in different months of the year. On average, yearly temperature degree increases. /62 °C and. /7 °C respectively in the period of 2020-2030 under emission scenario A2 and B1 than the period 1992-2008. Monthly rainfall changes do not represent up or down trend. However, the average of rainfall rate will increase 4 % under emission scenario A2 and it will decrease 4.8 % under scenario B1.

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