HAZARD ASSESSMENT OF CLIMATE CHANGES IN SOUTH KHORASAN PROVINCE, IRAN

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Abstract

In the present research to assess past climate change trend and its severity in South Khorasan province located in the east of Iran, the climatic parameters included annual precipitation and annual average of temperature data for 10 meteorological stations over the study area during a study period of 23 years from 1989 to 2012 were analyzed using linear regression analysis and Pearson correlation coefficient. Similarly in order to analyze the temporal fluctuations of dry and humid periods over the study area, three and five years moving average graphs were also prepared. Based on the results of temperature analysis 93% of the extent of the region has become warmer than before, while 7% has no significant changes in the temperature trends. The precipitation in 51% of the extent of the region has been decreased and 49 % of the land doesn't show any significant changes. Also about climate change in the region using trends of De Martonne index, 76% of the extent of the region has become drier than before, while 24% of the region doesn't show any significant changes. Similarly regarding the applied hazard classification for climate change based on the trends of temperature and aridity index of De Martonne , a great proportion (69%) of land is under very severe hazard in region, and the rest (31% of the land area) was classified under severe hazard. This contribution provides evidence demonstrating intensity of drought during the last two decades in the study area.

Key words: *climate change, De Martonne index, hazard class, moving average*

Introduction

Climate change due to global warming and its effects on natural resources, plants, animals and human life are the worldwide issues that received attention of scientists, and politicians significantly in recent years. Carbon dioxide and other produced Green House Gases (GHGs) have involved in warming up the earth. Scientists found this warming up resulted from increase evaporation and density of water steam in atmosphere. As a result, precipitation pattern including rain and snow will change. Other facts and projections show, warm and dry regions will

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become warmer and drier (Jafari, 2010) The Intergovernmental Panel on Climate Change (IPCC) has projected that by 2100 atmospheric concentrations of carbon dioxide could have reached between 540 ppm to 970 ppm and as a result, global surface temperature could rise between 1.4^{o}C to 5.8^{o}C. However the effects will be not uniform. Global warming will for example be greater at higher latitudes than in tropics, and there could also be different weather consequences; while some regions will have more intense rainfall, others will have more prolonged dry periods and a number of regions will experience both. These predicted changes in climate have raised concerns about potential impacts on terrestrial ecosystem productivity, biogeochemical cycling, and the availability of water resources (Melillo et al., 1990; Kirschbaum and Fischlin, 1996).

In recent years a change in climate has been documented in many locations throughout the world. Increasing rainfall trends were reported in Argentina (Viglizzo et al., 1995), Australia and New Zealand (Suppiah and Hennessy, 1998; Plummer et al., 1999). Decreasing rainfall trends were found in the Russian Federation (Gruza et al., 1999), Turkey (Türke, 1996, 1998), Africa (Hess et al., 1995; Mason, 1996) and in China (Zhai et al., 1999). In 19 northern and central European weather stations, Heino et al. (1999) found no changes in precipitation extremes. The minimum temperature increased almost everywhere and the maximum and mean temperature increased in northern and central Europe, over the Russian Federation, Canada (Bootsma, 1994) and in Australia and New Zealand (Plummer et al., 1999).

Arid and semi arid zones are very sensitive and vulnerable to the climate change impacts. Vulnerability to climate change and other hazards constitutes a critical set of interactions between society and environment. The central Asia is particularly vulnerable due to physical geography, which dominated by temperate deserts and semi deserts. Aridity is expected to increase across the entire Central Asian region. Temperature increases are projected to be particularly high in summer and fall, accompanied by decreases in precipitation (Jafari, 2010). Four reports published by Intergovernmental Panel on Climate Change (IPCC) show lack of adequate research result on climate change and it means there are no significant published research from the Near East and Central Asia, which could be used for compellation of the reports.

I.R of Iran is located in the North Temperate Zone which lies between the latitudes of 25° 14' and 39°42' N and the longitudes of 44° 10' and 63° 11' E with a total area of approximately 1650000 square kilometers. Elevations range from 26 meters below sea level on the shores of the Caspian Sea to 5671 meters above sea level at the pick of the Mt. Damavand. Drought is one of the most critical factors in Iran. About 50 % of Iran can be classified as arid or semi-arid zones (Jafari, 2010, Asrari et al., 2012). The average precipitation of the country is 245 mm per year. Climate parameters, particularly precipitation varies significantly in different parts of the country. There is not a good annual rainfall distribution in most regions of Iran. Not only high temperature in southern, central and lowlands of Iran is a limiting factor, but also low temperature in northern, western and highlands is another limiting factor too. As a fact which Iran is located on dry belt of earth and importance of its vegetation cover and forest ecosystems (Jafari, 2010) and also limited of adequate research on climate change, consideration of past climate changes and investigation on future climate projection play an important role in development programs. In the present paper, the temporal and special climatic changes trends of South Khorasan Province located in the east of Iran were investigated over the two last decades.

Materials and methods

Study Area

South Khorasan Province located in the east of Iran with a total area of 15,030120 ha and mean annual temperature of 17.5°C and precipitation of 134 mm, which lies between the latitudes of 30° 31$'$ and 35°05$'$ N and the longitudes of 55° 22$'$ and 60° 55$'$ E was selected to be a study area for a test assessment of climate change in the present research.

Data and Methodology

In the present study, to analyze the special and temporal trends of climate change over South Khorasan province during a study period of 23 years from 1989 to 2012, the meteorological data consisting of monthly precipitation and temperature measurements for 10 synoptic and rainfall stations distributed fairly evenly in the region (Fig. 1), were collected from the Meteorological Organization and Regional Water Organization of South Khorasan Province.

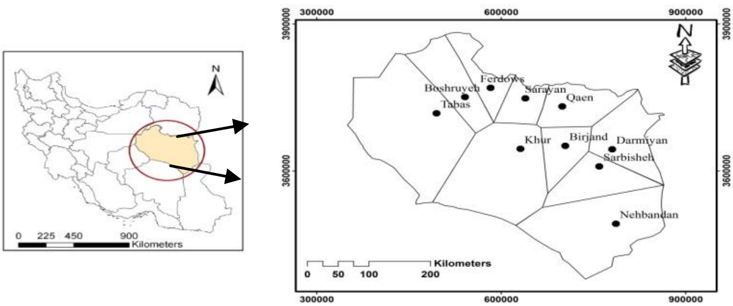

Figure 1 *Scattering of selected stations on South Khorasan Province map*

The missing values were estimated using ratios & differences methods with the optimum reference station for precipitation and temperature missing data respectively (Alizadeh et al., 2000). Characteristics of the selected stations over the study area consisted of the geographical location and climatic parameters during the study period were reported in Table 1.

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Table 1. *Characteristics of selected stations over the study area.*

Symbol	Station name	Longitude	Latitude	Elevation (m asl)	Average of annual precipitation (mm)	Average temperature (ºC)	Mean of De Martonne index * in the period
1	Birjand	59º 12' E	32º 59' N	1491	154.1	16.45	5.82
2	Qaen	59º 10' E	33º 43' N	1432	165.2	14.5	6.74
3	Nehbandan	60º 02' E	31º 32' N	1211	122.2	20.0	4.07
4	Khour	58º 26' E	32º 56' N	1117	88.9	19.8	2.98
5	Ferdows	58º 10' E	34º 01' N	1400	133.1	17.5	4.84
6	Boshroyeh	57º 27' E	33º 54' N	885	88.1	19.1	4.38
7	Sarayan	58º 31' E	33º 52' N	1482	146.7	18.1	5.22
8	Darmian	60º 01' E	32º 55' N	1500	149.7	15.2	5.94
9	Sarbisheh	59º 47' E	32º 36' N	1482	157.4	13.6	6.66
10	Tabas	56º 57' E	33º 36' N	700	81.9	22.6	2.51

* De Martonne index = $\frac{P}{T + 10}$ where P=annual precipitation average, T=average of annual temperature during the period.

The annual precipitation, average of annual temperature and De Martonne index as a climatic index have been also calculated for each station in every year (Table 2).

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Table 2
Annually statistically characteristics of Birjand station.

Year	Annual precipitation (mm)	Average of annual temperature (°C)	De Martonne index
1989	192.1	16.2	7.33
1990	188.1	15.7	7.32
1991	197.8	14.6	8.04
1992	218.8	15.8	8.48
1993	112.5	16.1	4.31
1994	214.4	16.3	8.15
1995	239.5	15.5	9.39
1996	130.0	16.0	5.00
1997	228.4	16.4	8.65
1998	143.3	17.3	5.25
1999	68.3	16.8	2.55
2000	62.5	17.2	2.30
2001	175.9	17.5	6.40
2002	144.5	16.8	5.39
2003	76.9	16.9	2.86
2004	233.5	16.0	8.98
2005	84.5	17.3	3.10
2006	180.9	16.7	6.78
2007	63.5	16.5	2.40
2008	232.0	17.2	8.53
2009	166.3	17.3	6.09
2010	70.7	16.9	2.63
2011	113.7	15.5	4.45
2012	161.3	16.1	6.18

Following this stage, three graphs were prepared for each station showing trends of average of annual temperature, annual precipitation and De Martonne index (Fig. 2). Linear regression analysis was used for assessment of climate change trend using the applied climatic parameters and De Martonne index. Similarly Pearson correlation coefficient was calculated to measure the trend analysis and to show those trends which are significant (Table 3). All analysis was conducted using SPSS software.

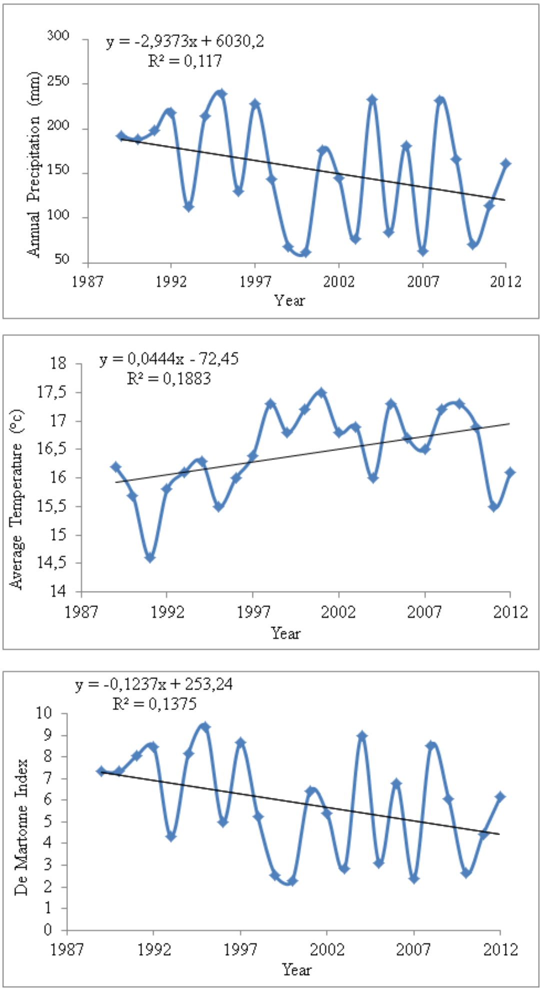

Figure 2
Trend of climate indices used in Birjand station.

<u>Results and discussion</u>

Trend maps of changes for precipitation, temperature and climatic index of De Martonne were prepared during the study period using the results of Table 3 and thiessen method (Fig. 3). Also a hazard classification for trend of climate change (Asrari & Masoudi, 2010) over the study area was prepared using temperature and De Martonne index changes trends to show and classify climate changes in the form of hazardous classes for the thiessen zone of each station (Tables 4 and 5). In the next step hazard map of climate changes trend showing different hazard classes

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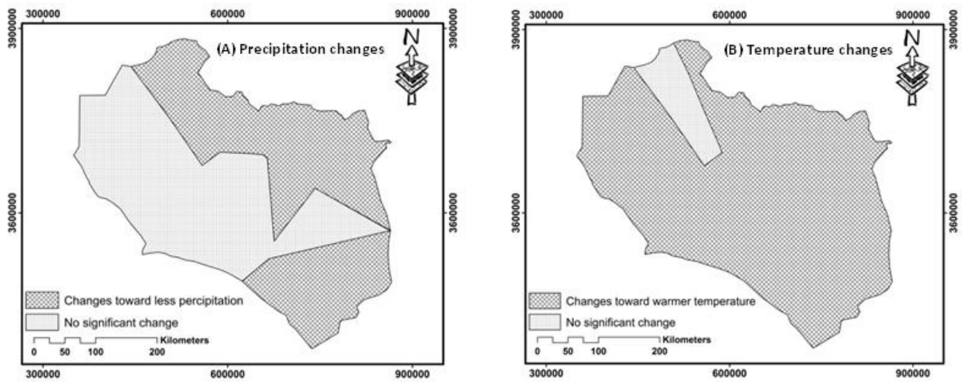
was also prepared based on the results of Table 6. (Fig. 4) Furthermore 4 graphs were prepared to determine percent of land under different climate indices changes

Table 3. *Trend of climate parameters changes at the selected stations over the study area*

Symbol	Station Name	Trend of precipitation changes	Trend of temperature changes	Trend of De Martonne Index changes
1	Birjand	Decrease at the significant level of 0.05	Warmer at the significant level of 0.05	Drier at the significant level of 0. 1
2	Qaen	Decrease at the significant level of 0.01	Warmer at the significant level of 0.01	Drier at the significant level of .0.01
3	Nehbandan	Decrease at the significant level of 0.05	Warmer at the significant level of 0.01	Drier at the significant level of 0.05
4	Khour	Without significant change	Warmer at the significant level of 0.01	Drier at the significant level of .0.01
5	Ferdows	Decrease at the significant level of 0.05	Warmer at the significant level of 0.01	Drier at the significant level of 0.05
6	Boshroyeh	Decrease at the significant level of 0.01	Without significant change	Drier at the significant level of 0.05
7	Tabas	Without significant change	Warmer at the significant level of 0.01	Without significant change
8	Sarbisheh	Without significant change	Warmer at the significant level of 0.05	Drier at the significant level of 0. 1
9	Darmian	Decrease at the significant level of 0.05	Warmer at the significant level of 0.05	Drier at the significant level of 0. 1
10	Sarayan	Decrease at the significant level of 0.05	Warmer at the significant level of 0.01	Drier at the significant level of 0.05



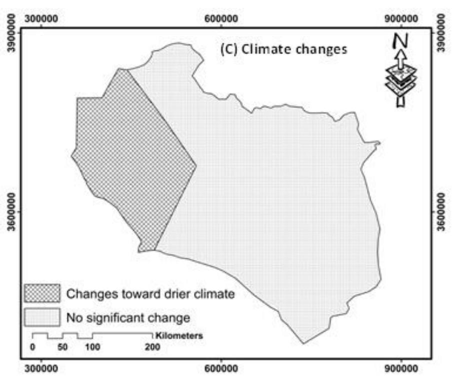


Figure 3
Trend maps of changes for precipitation, temperature and climate index of De Martonne during the study period

Table 4. *Hazard classification for trend of climate changes (Asrari and Masoudi, 2010).*

Symbol	Hazard classes	Description of hazard classes
1	Without	Without changes in temperature and climate.
2	Slight	Significant changes in temperature (<1°C increase in temperature during 100 years), without significant changes in climate index trend.
3	Moderate	Significant changes in temperature (between 1-4°C increase in temperature during 100 years), without significant changes in climate index trend.
4	Severe	Significant changes in temperature (>4°C increase in temperature during 100 years) or significant changes in decreasing of climate index trend toward drier condition.
5	Very severe	Significant changes in temperature (>4°C increase in temperature during 100 years) and significant changes in decreasing of climate index trend toward drier condition.

Table 5
Hazard classification for trend of climate changes at the selected stations over the study area

Station Name	Hazard Class	Symbol
Birjand	Very severe	5
Qaen	Very severe	5
Nehbandan	Very severe	5
Khour	Very severe	5
Ferdows	Very severe	5
Boshroyeh	Severe	4
Tabas	Severe	4
Sarbisheh	Very severe	5
Darmian	Very severe	5
Sarayan	Very severe	5

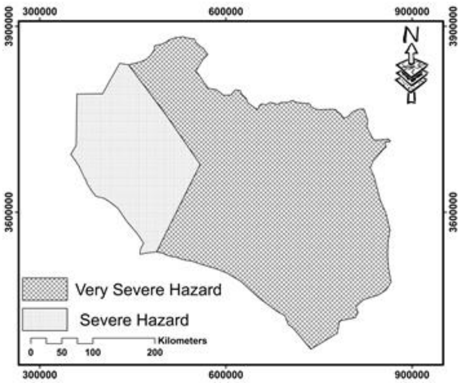


Figure 4
Hazard map of climate changes trend showing different hazard classless.

(Fig. 5). Similarly in order to analyze the temporal fluctuations of dry and humid periods over the study area, three and five years moving average graphs were also prepared (Fig. 6).Regarding the results of linear regression analysis for the used climate indices during the period of study increasing trend in temperature and decreasing trends with time in precipitation and De Martonne index were observed in most selected stations over the study area (Table 3). Furthermore based on result of this research in case of temperature changes during the period of study, 93% of

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the extent of the region has become warmer than before at 95% and 99% confidence level, while 7% has no significant changes in the temperature trends. In urban areas, the urban heat island (UHI) effect caused by land-use change from urbanization and industrialization exacerbate the warming in climate, signifying the impact of climate change (Arnfield, 2003; Hinkel et al., 2003). It was reported in a recent study that several mega-cities in Asia experienced intense surface UHIs which raised the urban air temperature by 4–12°C during dry seasons (Hung et al., 2006).

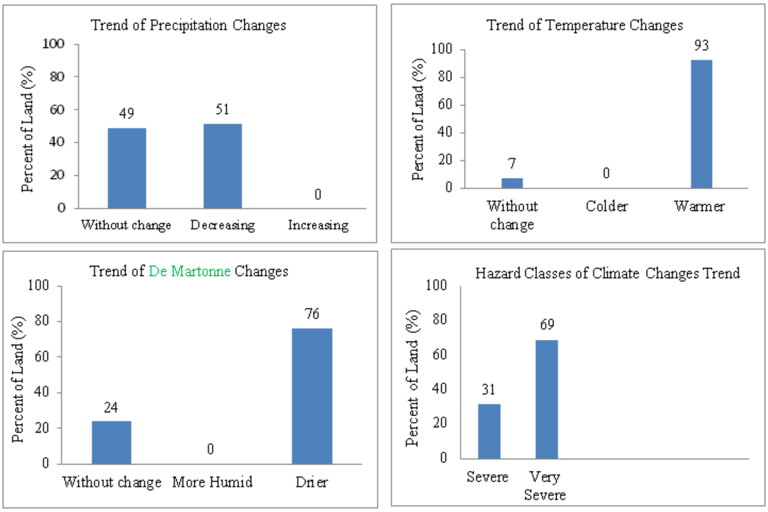

Figure 5 *Percent land under different climate indices changes.*

On the other hand, precipitation trends during the period of study show 71% of the extent of the region has been decreased at 95% and 99% confidence level and 29 % of the land doesn't show any significant changes. Most of the reduction was observed in the northern and eastern half parts and without change in precipitation were observed in the western and central parts. This amount of precipitation reduction is high when it is compared with many other studies related to other parts in the country (Asrari and Masoudi, 2010; Zareiee et al., 2011; Asrari and Masoudi, 2011; Asrari et al., 2012; Masoudi and Hakimi, 2014; Masoudi and Elhaeesahar, 2016).

Also about climate change in the region using trends of De Martonne index, 76% of the extent of the region has become drier than before at 95% and 99% confidence level, while 24% of the region doesn't show any significant changes. Most of the lands which show drier condition than before are observed more in all parts except of western parts of the region (Fig. 3). Similarly, from Fig. 4, it is concluded that in the region, areas under very severe hazard of climate changes (69%) are more widespread compared to severe hazard class. Unfortunately, only two classes of severe and very severe are observed in the region. These results obviously imply that the climate changes in the region with more arid climate become worse when it is compared with many other studies related to other places in the country (Asrari and Masoudi, 2010; Asrari et al., 2012; Masoudi and Hakimi, 2014; Masoudi and Elhaeesahar, 2016).

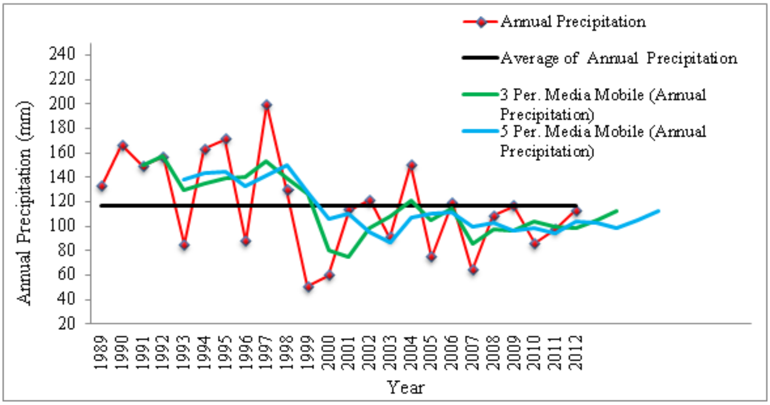

Figure 6
Moving average graphs.

During 23 last years in the region, 1 humid (from 1989 - 1999) and 2 dry periods from 1999 to 2003 and from 2004 to 2012 and 1 humid (1993- 1999) and 1 dry period (1999-2012) were observed based on three and five years moving average graphs respectively (Fig. 6). The most humid and driest years during the study period in the region were 1997 and 1999 with a total precipitation of 199.3 and 50.7mm respectively.

Conclusion

Annual precipitation and annual average of temperature data for 10 meteorological stations from 1989–2012 in the region have been analyzed in the present research for temporal and spatial trends. The methods used include the simple regression analysis. Results showed that in the province, a greater portion of land during the period of the study became warmer than before. This confirmed the overall global warming in the world. Furthermore, those areas showing decreasing in precipitation during the time were more widespread compared with those areas without any changes. The results derived from the trends of climate index confirmed this fact that the overall climate of the province became worse because more than 76% of the lands showed that the region goes to the drier condition. The hazard classification for climate change was used in the research can be used in the other Places. Unfortunately, the results based on this classification indicated that the areas under very severe and severe hazards cover all parts of province showing need more attention to this part of country and doing related remedial measures like current project of carbon sequestration.

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