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# Evaluation of changes in different climates of Iran, using De Martonne index and Mann–Kendall trend test

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## Abstract

In this paper, according to the data of 40 stations in Iran during 1967–2005, changes in different climates of Iran evaluated. The De Martonne index and Mann–Kendall trend test are indexes that by uses the precipitation and temperature provide the evaluate possibility of the climate condition and pattern of climate changes. The objective of this study is to evaluation of changes in different climates in Iran. The results of this research showed that, The surface percent of Iran in the hyper arid, semi arid, humid and hyper humid type 1 climate categories have had a ascending trend, but only the ascending trend of the hyper arid category has been significant and the surface percent of the humid, hyper humid type 1 and semi arid categories have had a insignificant trend. The surface percent of Iran in the arid, Mediterranean, semi humid and hyper humid type 2 climate categories have had a descending trend, but the descending trend of the hyper humid type 2, Mediterranean and semi humid categories have been significant and the surface percent of the arid categories have had an insignificant trend. So the total results showed that, Iran is going to be more arid.

## 1 Introduction

The Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report defines "vulnerability" as "the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with adverse impacts of climate change" (IPCC, 2007). In the Sect. 2 of the IPCC paper provides a review of the ample scientific literature on vulnerability, adaptations, and impact assessments based on climate change scenarios. It is crucial to consider adaptations to climate change. Even if GHG emissions were abruptly reduced now, the inertia in the climate system would mean a long period until stabilization (IPCC and WGI, 2007).

Vulnerability can also be described as a function of sensitivity to climatic changes, adaptive capacity and exposure to climate hazards (De Sherbinin et al., 2007; Smit



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et al., 2002; Mearns, 1997). De Sherbinin et al. (2007) continue to argue that vulnerability to the risks of climate change consists of macro forces that come together in different combinations to create unique "bundles of stresses" upon environmental and human systems. Developing countries are vulnerable to extreme weather events in present day climatic variability and this cause's substantial economic damage. On an annual basis over the past decade, developing countries have absorbed US$ 35 billion a year in damages from natural disasters. On a per capita gross domestic product (GDP) basis, this is 20 times the cost in the developed world (Freeman, 2001a). Many global and regional assessments of vulnerability to climate change rely primarily on the global climate change scenarios. They focus on the physical aspects of vulnerability, such as land degradation and changes in agricultural or silvicultural productivity (Mizina et al., 1999; Pilifosova et al., 1997; Smit and Skinner, 2002), and on impacts of the availability of water resources to meet future needs (Alcamo and Henrich, 2002; Arnell, 2004; Shiklomanov and Rodda, 2001). Huq and Ayers (2007) have compiled a critical list of the 100 nations most vulnerable to climate change. Under climate changes, the potential for such projected changes to increase the risk of soil erosion and related environmental consequences is clear, but the actual damage is not known and needs to be assessed (SWCS, 2003). The objective of this study is to identify the pattern of climate changes in Iran during a forty years period 1967–2005 using De Martonne index.

## 2 Materials and methods

### 2.1 Study area

Iran was selected as a study area (Fig. 1) for a test assessment of climate change. Iran is situated in South-West Asia, at the crossroads of the Middle East. Iran borders on the Caspian Sea in the north and the Persian Gulf and the Gulf of Oman in the south. Iran shares borders with seven countries: Armenia, Azerbaijan, Afghanistan,





Iraq, Pakistan, Turkey and Turkmenistan. It covers an area of 1 648 195 $km^2$, which lies between the latitudes of 25°14′ and 39°42′ N and the longitudes of 44°10′ and 63°11′ E. The population of the country has increased from 34 million in 1978 before of the revolution to 68 million in 2006, showing double increase during less than thirty years. The elevation varies between the see level to around 5604 m in Damavand mountain. Most of Iran's territory is covered by mountains. It has the Alborz Range in the north and the Zagros mountain system in the south-west. Iran is divided to eight major basins on the basis of hydrology and topography. In Iran, there are no large rivers and there is only one navigable river, the Karun. The Karun starts in the Zagros and runs mainly through the territory of Khuzestan in the south-west of the country. The total length of the river is 950 km. Other rivers flowing through Iran include the Sefidrud, the Karkheh, the Zayanderud, the Dez, the Atrak, the Aras and the Mond that flow to the Persian Gulf, Caspian Sea and internal plains. The climate differs but in most part of the country is arid and semi arid with a mean annual rainfall range of 50–2000 mm. Precipitation in some central parts of Iran is about 50 mm, while it can reach up 2000 mm $year^{-1}$ on the northern slopes of the Alborz Range and the South Caspian lowlands. Average precipitation of this country is 245 mm $year^{-1}$. The average temperature stands at +2 °C in January and +29 °C in July. The main period of precipitation is during winter (60 % of total rainfall).

## 3 Data and methodology

The meteorological data used in this study, consisting of annual precipitation and temperature measurements from 40 synoptic stations distributed fairly evenly in the country (Fig. 1), were collected from the Iran Meteorological Organization (IMO). From homogeneous precipitation records, we created a regional precipitation series by means of the weighted average of monthly records. The weight was the surface represented by each observatory by means of Thiessen polygons method, following Jones and Hulme (1996). Distribution of stations in the area is rather sparsely in the central and southeastern areas and densely in the northwestern part, because in the northwestern parts, the topographic conditional is very severe but in the central and southeastern areas, the topographic conditional is not severe.

## 4 Mann–Kendall trend test

A nonparametric trend test has first been proposed by Mann (1945) then further studied by Kendall (1975) and improved by Hirsch et al. (1982, 1984) who allowed taking into account seasonality. The null hypothesis H0 for these tests is that there is no trend in the series. The three alternative hypotheses that there is a negative, non-null, or positive trend can be chosen. The Mann–Kendall tests are based on the calculation of Kendall's tau measure of association between two samples, which is itself based on the ranks with the samples. In the particular case of the trend test, the first series is an increasing time indicator generated automatically for which ranks are obvious, which simplifies the calculations.

In the present work, the adequate number of station was determined with suitable scatter Eq. (1) (Mahdavi, 2002). An exhaustive list of the selected stations is given in Table 1.

$$N = \left(\frac{\mathrm{CV}\%}{E\%}\right)^2 \quad (1)$$

In this paper: $N = 40$.

To determine the common duration of the suitable statistic period for all the stations, Eq. (2) was used (Mahdavi, 2002).

$$N = (4.3t \times \log R)^2 + 6 \quad (2)$$

In this paper: $N = 37.5$ years.

In the next stage, for each of the stations in every year, annual precipitation, annual temperature and De Martonne Index have been calculated (Table 2). Measurement De





Martonne index using Table 3. While we have determined the climate category of each station using the De Martonne index (Table 3). For each year, spatial maps of climate of the all of the country are prepared (Fig. 2).

Now, for each year, we have determined the percentage of the country surface that is located in each dry or wet category (Table 4). Using the Table 4, the changes trend of the country surface percent in each category has been determined (Fig. 3).

## 5 Results and discussion

In this paper, according to the data of 40 stations in Iran during 1967–2005, the pattern of climate changes are evaluated. The methods used include the Mann–Kendall trend test and De Martonne method. Figure 3 and Table 5 showed that:

1. The surface percent of Iran in the hyper arid, semi arid, humid and hyper humid type 1 climate categories have had a ascending trend, but only the ascending trend of the hyper arid category has been significant and the surface percent of the humid, hyper humid type 1 and semi arid categories have had a insignificant trend.

2. The surface percent of Iran in the arid, Mediterranean, semi humid and hyper humid type 2 climate categories have had a descending trend, but the descending trend of the hyper humid type 2, Mediterranean and semi humid categories have been significant and the surface percent of the arid categories have had an insignificant trend.

3. So, according to the De Martonne index, the surface percent of the humid areas of Iran is going to be decreased and the surface percent of the arid areas of Iran is going to be increased.



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## 6 Conclusion

This paper has analyzed the De Martonne Index to assessment the trend of changes the areal coverage in different climate categories of Iran. The results of this paper showed that the surface percent of Iran in the hyper arid, semi arid, humid and hyper humid type 1 climate categories have had a ascending trend, but only the ascending trend of the hyper arid category has been significant and the surface percent of the humid, hyper humid type 1 and semi arid categories have had a insignificant trend. The surface percent of Iran in the arid, Mediterranean, semi humid and hyper humid type 2 climate categories have had a descending trend, but the descending trend of the hyper humid type 2, Mediterranean and semi humid categories have been significant and the surface percent of the arid categories have had an insignificant trend.So, according to the De Martonne index, the surface percent of the humid areas of Iran is going to be decreased and the surface percent of the arid areas of Iran is going to be increased.

Result of research by Asrari et al. (2011) in analyzing spatial and temporal pattern of drought by PNPI showed that the surface percent trends of areas under moderate, severe and extreme dry classes have been increased during the period which for severe and extreme classes is significant. Only areas under light drought class had a significant descending trend. Result of research by zareiee and mahmodi in analyzing Standardized Precipitation Index (SPI) showed that the surface percent of the wet areas has been decreased during the evaluation period. The surface percent of the extremely wet areas, very wet areas and moderately wet areas have had a descending trend. However, only the descending trend of moderately wet areas has been significant. The surface percent of the dry areas have had an ascending trend. The surface percent of moderately dry areas and very dry areas have had an ascending trend. However, only the ascending trend of moderately dry areas has been significant. The surface percent of near normal areas has had an ascending trend no significantly, and the trend of surface percent of the extremely dry areas has been descending insignificantly during a period evaluation.



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

| code | Station | Latitude | Longitude | Elevation | code | Station | Latitude | Longitude | Elevation |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Abadan | 30°22′ N | 48°15′ E | 6 | 21 | Khoram Abad | 33°26′ N | 48°17′ E | 1147 |
| 2 | Ahvaz | 31°20′ N | 48°40′ E | 22 | 22 | Khoy | 38°33′ N | 44°58′ E | 1103 |
| 3 | Arak | 34°6′ N | 49°46′ E | 1708 | 23 | Mashhad | 36°16′ N | 59°38′ E | 999 |
| 4 | Babolsar | 36°43′ N | 52°39′ E | −21 | 24 | Oroomieh | 37°32′ N | 45°5′ E | 1315 |
| 5 | Bandar Abbas | 27°13′ N | 56°22′ E | 10 | 25 | Ramsar | 36°54′ N | 50°40′ E | −20 |
| 6 | Bandar Anzali | 37°28′ N | 49°28′ E | −26 | 26 | Rasht | 37°15′ N | 49°36′ E | −6 |
| 7 | Bandar Lenge | 26°32′ N | 54°50′ E | 23 | 27 | Sabzevar | 36°12′ N | 57°43′ E | 977 |
| 8 | Birjand | 32°52′ N | 59°12′ E | 1491 | 28 | Saghez | 36°15′ N | 46°16′ E | 1522 |
| 9 | Bushehr | 28°59′ N | 50°50′ E | 20 | 29 | Sanandaj | 35°20′ N | 47°0′ E | 1373 |
| 10 | Chabahar | 25°17′ N | 60°37′ E | 8 | 30 | Semnan | 35°35′ N | 53°33′ E | 1130 |
| 11 | Dezful | 32°24′ N | 48°23′ E | 143 | 31 | Shahre Kord | 32°17′ N | 50°51′ E | 2048 |
| 12 | Esfahan | 32°37′ N | 51°40′ E | 1550 | 32 | Shiraz | 29°32′ N | 52°36′ E | 1484 |
| 13 | Fassa | 28°58′ N | 53°41′ E | 1288 | 33 | Tabass | 33°36′ N | 56°55′ E | 711 |
| 14 | Ghazvin | 36°15′ N | 50°3′ E | 1279 | 34 | Tabriz | 38°5′ N | 46°17′ E | 1361 |
| 15 | Gorgan | 36°51′ N | 54°16′ E | 13 | 35 | Tehran | 35°41′ N | 51°19′ E | 1190 |
| 16 | Hamedan | 35°12′ N | 48°43′ E | 1697 | 36 | Torbat Hydarieh | 35°16′ N | 59°13′ E | 1450 |
| 17 | Iran Shahr | 27°12′ N | 60°42′ E | 591 | 37 | Yazd | 31°54′ N | 54°17′ E | 1237 |
| 18 | Kashan | 33°59′ N | 51°27′ E | 982 | 38 | Zabol | 31°2′ N | 61°29′ E | 489 |
| 19 | Kerman | 30°15′ N | 56°58′ E | 1753 | 39 | Zahedan | 29°28′ N | 60°53′ E | 1370 |
| 20 | Kermanshah | 34°21′ N | 47°9′ E | 1318 | 40 | Zanjan | 36°41′ N | 48°29′ E | 1663 |

**Table 2.** Annually De Martonne[a] index.

| Station name | Abadan | Ahvaz | ... | Zabol | Zahedan | Zanjan |
|---|---|---|---|---|---|---|
| Year | De Martonne index for each station in every year | | | | | |
| 1967 | 5.48 | 7.87 | ... | 1.74 | 2.78 | 15.34 |
| 1968 | 2.85 | 8.31 | ... | 1.89 | 4.60 | 18.61 |
| ... | ... | ... | ... | ... | ... | ... |
| 2004 | 5.71 | 7.49 | ... | 2.58 | 2.15 | 15.06 |
| 2005 | 5.31 | 5.18 | ... | 2.97 | 3.54 | 11.77 |

[a] De Martonne index = $(\frac{\overline{P}}{T+10})$, $\overline{P}$: annual precipitation average and $T$: average of annual temperature during the period.





**Table 3.** De Martonne index classification (Iran meteorological organization, 2010).

| De Martonne index value | climate category | symbol |
|---|---|---|
| 4.99 ≥ | Hyper arid | A1.1 |
| 5 to 9.99 | Arid | A1.2 |
| 10 to 19.99 | Semi arid | A2 |
| 20 to 23.99 | Mediterranean | A3 |
| 24 to 27.99 | Semi humid | A4 |
| 28 to 34.99 | Humid | A5 |
| 35 to 54.99 | Hyper humid type 1 | A5.1 |
| ≥ 55 | Hyper humid type 2 | A5.2 |

**Table 4.** Areal coverage (%) of Iran in each climate categories for each year.

| | De Martonne climate categories | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | A1.1 | A1.2 | A2 | A3 | A4 | A5 | A5.1 | A5.2 |
| | Areal coverage (%) of Iran in each climate categories for each year | | | | | | | |
| 1967 | 27.24 | 20.67 | 29.65 | 1.80 | 7.56 | 0.00 | 0.82 | 12.27 |
| 1968 | 13.08 | 27.13 | 9.14 | 17.30 | 8.95 | 7.31 | 1.39 | 15.70 |
| 1969 | 19.70 | 14.98 | 19.67 | 3.30 | 2.64 | 30.94 | 5.21 | 3.55 |
| 1970 | 32.11 | 29.63 | 25.20 | 4.30 | 5.21 | 0.00 | 3.55 | 0.00 |
| 1971 | 31.04 | 21.31 | 23.67 | 10.93 | 4.30 | 5.21 | 3.55 | 0.00 |
| 1972 | 9.25 | 23.13 | 28.04 | 13.46 | 2.82 | 1.89 | 0.99 | 20.42 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 2000 | 44.75 | 15.66 | 33.86 | 0.99 | 0.00 | 2.94 | 0.77 | 1.03 |
| 2001 | 52.68 | 14.41 | 29.17 | 0.00 | 1.05 | 0.00 | 1.89 | 0.80 |
| 2002 | 53.47 | 11.53 | 25.14 | 0.00 | 0.99 | 0.00 | 8.87 | 0.00 |
| 2003 | 49.30 | 24.16 | 23.11 | 1.55 | 0.00 | 0.00 | 0.23 | 1.64 |
| 2004 | 36.09 | 34.24 | 22.37 | 5.42 | 0.00 | 0.00 | 0.23 | 1.64 |
| 2005 | 52.44 | 20.35 | 17.35 | 0.99 | 0.00 | 1.47 | 6.91 | 0.49 |





**Table 5.** Trend of changes the areal coverage in different climate categories of Iran by percent, using Mann–Kendall trend test (*p* value: significance level of that trend).

| climate category | symbol | annual trend | *p* value |
|---|---|---|---|
| Hyper arid | A1.1 | 1.027 | 0.0001* |
| Arid | A1.2 | −0.195 | 0.193 |
| Semi arid | A2 | 0.055 | 0.697 |
| Mediterranean | A3 | −0.252 | 0.001* |
| Semi humid | A4 | −0.085 | 0.001* |
| Humid | A5 | 0.145 | 0.00 |
| Hyper humid type 1 | A5.1 | 0.014 | 0.606 |
| Hyper humid type 2 | A5.2 | −0.181 | 0.035* |

* Significant at $p < 0.05$.

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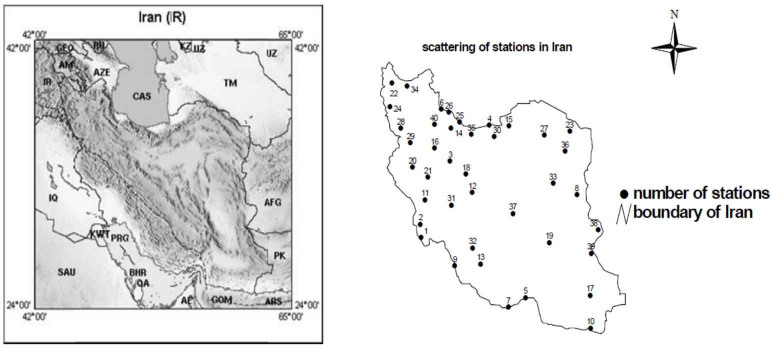


**Fig. 1.** Iran map and scattering of stations.



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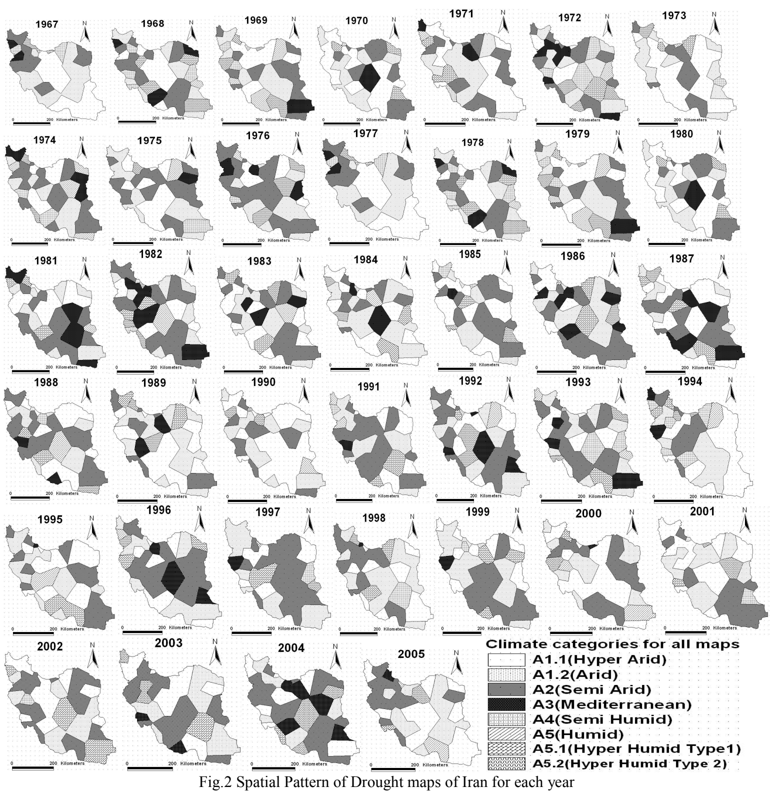


**Fig. 2.** Spatial pattern of drought maps of Iran for each year.

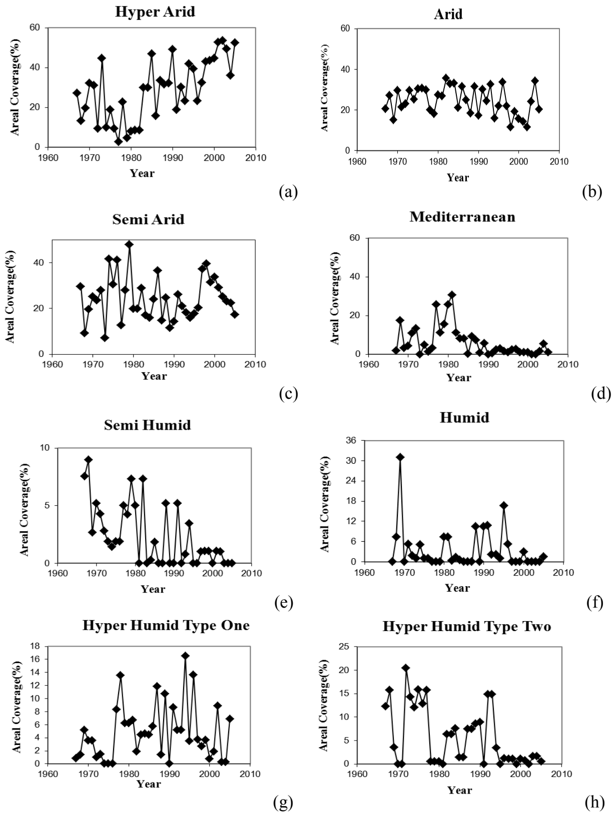


**Fig. 3.** Changes the areal coverage in different climate categories of Iran by percent.