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An Analysis of Changes in Aridity Index and its Relationship with Water Crisis in Iran

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Abstract

In spite of total 400 billion m3 of yearly received water from precipitation, only 130 billion m3 is useable, while recent studies showed that it has decreased to 120 billion m3 in a year. Except for this natural factors, wrong water consumption pattern, heterogeneous spatial and temporal distribution of rainfall, population growth, uneven transitory development in different parts ignoring the land use planning and consecutive draught which can be the result of the earth climate change are other reasons leading to water crises and challenges.

In order to evaluate the feature and trend of aridity changes climatic data of 51 synoptic weather s tations with a statistical period of 30 years, from 1980 to 2010, was obtained from meteorology Organization of Iran. In this study Iq aridity index, having the ability to show aridity features of the similar region, was used. Moreover to find the trend of aridity index changes Mann-Kendal nonparametric test was applied. Spatial zoning of the country was done by ArcGis software. Results revealed that based on Iq index from total area of the country 20% has hyper arid climate, 34% arid climate, around 31% semi-arid climate, 13% semi-humid climate, while only 2% of Iran area has humid climate. Besides, aridity trend test showed that around 80% of the studied stations or majority of the country area is in danger of aridity increase, while 20% of the stations do not show decreasing or significant changes. Therefore it can be concluded that Iran's climate is getting arid which means double burden on the regional water source. It is necessary for the managers not only manage water resources, but also modify the consumption model in all parts and extents.

Keywords: aridity, aridity indexes, I_q index, water crisis, Iran.

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1. Introduction

Coincided with Islamic Revolution of Iran in 1978, per capita of fresh water was about 7000 m3 which has decreased to 1800 m3 after 35 years. The experts predicted that Iran population will have grown to 90 million by 2025, when per capita of water will have been 1500 m3. In such a situation 13 provinces out of the 30 will have been in danger of water crisis [6]. Population increase, water consumption increase, precipitation decrease and temperature increase followed by evaporation increase are the effective factors leading to this shortage. Nonetheless the experts consider the role of climatic changes and its impacts on water resources of Iran less than consumption increase and not optimized water distribution systems.

Although the experts consider population increase, health promotion, water need and wrong water consumption pattern as natural and climatic factors, they cannot deny the role of precipitation decrease and temperature and evaporation increase which are the result of greenhouse gas and global warming. The annual average of precipitation has decreased to 242 mm from 250 mm. Iran average temperature is considered as 2 oc during the recent century [11]. According to the various scenarios of climate change, Iran will have faced precipitation decrease by future decades; it will be intensified. Likewise based on the independent and complex models, by 2025 the temperature will have increased, as the temperature of southern and central regions of Iran will be more than southern regions [12]. Precipitation decrease and temperature increase followed by evaporation increase are the significant natural factors which cause the water shortages and crises. In fact studying climatic aridity of geographical regions like Iran can determine the present and future situation of this climatic phenomenon. Several indexes are used to study the condition of climatic aridity and its changes.

Nastost et al (2011) [7] studied spatial and temporal variations in Greece in which spatial and temporal traits of Ai aridity index were studied. These traits were among 28 terminology stations during a 50 year statistical period from 1951 to 2000. The results revealed that there was a gradual change from a humid region, as a wide region of Greece, to a semiarid one; the most important change was from 1991 to 2001.

Liu et al (2012) [5] investigated temporal and spatial changes of Ai arid index in Northwest of China from 1960 to 2011. The results, got from 80 meteorology stations, showed that annual aridity index decreased and it became more humid from 1960 to 2010.

Sahin (2012) presented a new aridity index, I_q, found from the ration of precipitation to moisture. In this study, done in Turkey, three indexes, Ai, I_q, and Im, were studied throughout 7 climatic regions of Turkey in 211 meteorology stations from 1974 to 2008. Considering similarities and differences of these 3 indexes throughout the 7 regions, it was proved that I_q index is the best index to indicate the degree of aridity and moisture in Turkey.

Ahani et al (2012) [1] have investigated the trend of aridity index throughout 3 large areas of arid and semiarid regions of Iran. In this study monthly trend of precipitation (P), potential evapotranspiration (PET), and Ai aridity index for synoptic weather stations among 3 large areas of Iran during recent 50 years. They used Mann-Kendal nonparametric test. Results revealed that in the northern part of the region, aridity condition was decreasing, while it was increasing across southern parts.

Shifteh et al (2012) [9] studied the process of temporal-spatial aridity index of arid and semiarid regions of Iran among 22 synoptic weather stations from 1966 to 2005, applying Mann-Kendal test and THEIL-SENS rater.

Tabari et al (2014) [10] studied aridity phenomenon in Iran, applying de Martonne and Pinna indexes. They believed that 88%, based on de Martonne, and 96%, based on Pinna index, of Iran area are in arid and semiarid regions respectively. In addition there is a significant decreasing trend in aridity index across the western and northwest of Iran.

Among previous studies there was no available study finding the traits of climatic aridity of Iran based on I_q index. In this research, however, I_q index is used to study the aridity and its changes in Iran, for it has shown acceptable findings throughout some regions of world like Turkey [8].

2. Methodology

In order to evaluate aridity in Iran, 51 stations, out of all main synoptic stations, were chosen. They had more complete data of a 30 year period from 1981 to 2010. The features and conditions are presented in figure 1. The data, including monthly precipitation, air vapor pressure, local pressure, daily temperature mean, maximum temperature, and monthly relative humidity, were received from meteorology organization website of the country.

The data are equalized by run-test method in the permissible level of changes ($|Z| \leq 1.64$) in the certain level of 95%. In some cases the lost or incomplete statistics were reconstructed in the environment of SPSS software, using correlation method among the stations. The data were proved to have normal distribution, using Kolmogorov-Smirnov test.

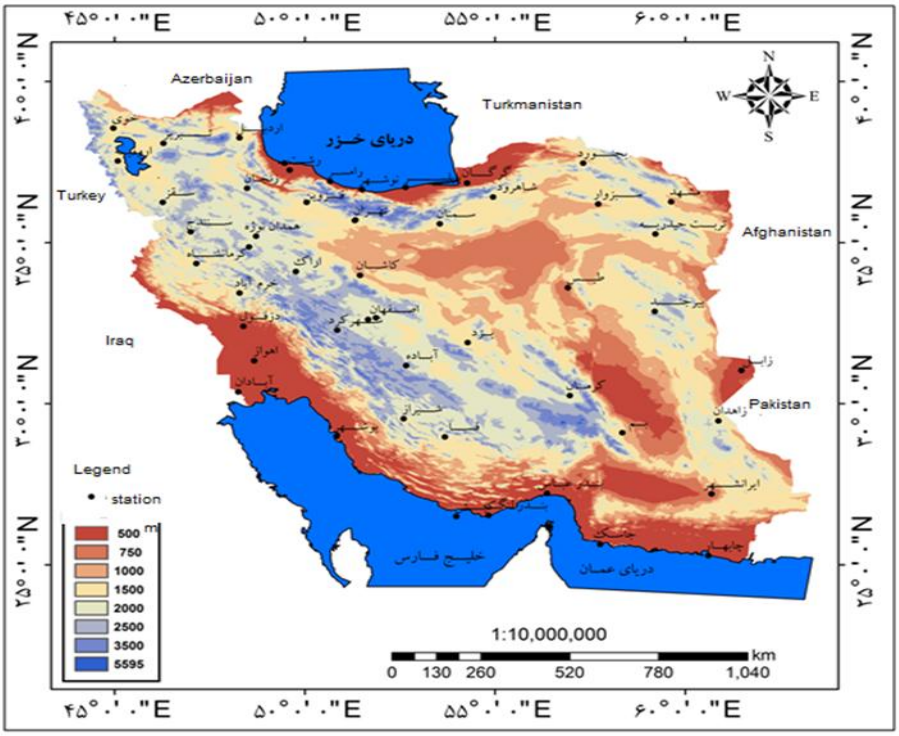

Figure 1. Topographic map of Iran and the position of the studied stations **I_q Index**

It is not easy to choose an appropriate index for different world regions correctly, for applying each climatic formula is more practical for the places which have similar climatic traits as the original climate where the formula was found. Moreover, restriction of climatic factors is a factor, restricted the efficacy of some indexes [4]. In this study I_q index was used to investigate the aridity in Iran. Based on the analyses this index is more able to both determine aridity condition and separate the regions more appropriately because it is more relevant to the required components in the model. In fact, other indexes use few components, namely precipitation, evaporation, and temperature, while in this index more components are applied; it can show the arid conditions of an environment more appropriately [8]. The value of this index, used to study the aridity or humidity of different regions, is calculated by precipitation divided into specific humidity. Specific humidity, $(\bar{S}_h)$ is calculated from the (q_e) formula [3]. Climatic regions which are the result of P/S_h are based on Sahin classification [8].

Relationship 1: $I_q = \frac{P}{\bar{S}_h}$

Relationship 2: $\bar{S}_h = q_e$ $\quad q_e = \frac{0.622 e_a}{p_a - 0.378 e_a}$

Relationship 3: $ea = r_h 10^{[(0.7859+0.03477 Ta)/(1.0+0.004212 Ta)+2]}$

Where:

S_h long-term average of the annual mean specific humidity (g/kg)

q_e Specific humidity (kg/kg)

e_a Vapor pressure of the air (Pa)

P_a Local pressure (Pa)

R_h Monthly mean relative humidity)%)

T_a Monthly mean temperature (0C)

Table 1. Various climatic classes based on I_q index

I_q	Climate
< 20	hyper arid
20 - 35	arid
35 - 60	Semi-arid
60 - 90	Semi moist
90 - 120	moist
>120	hyper moist

The value of specific humidity is effective to calculate the I_q index, for it is an indicator which has more stable quality than absolute humidity. As a result specific humidity with more stable quality is used in meteorology especially I_q aridity index. It is the weight of water vapor in unit weight of moist air which is usually defined as water vapor gram/humid air gram or gram/humid kilogram [2].

2. Mann-Kendall test

Mann-Kendall test was applied to study the trend of aridity index changes throughout Iran. The test statistics were calculated by MATLAB software.

3. Discussion and conclusion

Figure 2 presents the value of I_q index throughout Iran. This figure and table 1 revealed that all 6 humid conditions defined by Sahin (2012) [8] are seen in Iran. The confine of hyper arid regions with the area 342455 km2 (20.08%) covers parts of southeast, namely southern coast like Bandarabas, Jask, Chabahar to Kish island, and the center like Bam, Yazd, and Tabas. The most apparent climatic traits of this area are low precipitation and extremely high temperature. In spite of high specific humidity in southern coastal stations, these regions are considered as hyper arid regions, since they have less precipitation. As a matter of fact the stations with more specific humidity (Sh) and less precipitation are considered more arid which get I_q index decreased. Arid regions, covering 580390 km2 (34.04%) of Iran area, are located in vast area of central Iran and parts of south. In addition to low specific humidity in these regions, there is less precipitation. Simultaneous decrease of these factors leads to aridity throughout these regions. Vast area of Iran, 523176 km2 (30.68%), from northeast, northwest and center to southwest are located in semi-arid regions. Semi humid climate, 222631 km2 (13.06%), covers a vast area of west. The stations like Sanandaj, Kermanshah, Hamedan and Khoramabad which have closer precipitation condition to humid climate have higher I_q value, making more humid climate for these regions. Humid climate, covering 30607 km2 (1.80%), is the same as hyper humid class, although there is a slight difference in precipitation and specific humidity. Hyper humid regions with the area 5778 km2 (0.34%), covers the least area of the country. In fact the stations of this region show the highest value of I_q index. Unlike southern coast, specific humidity of northern coast decreases. This reduction and extremely high precipitation lead to I_q increase. Generally the regions with higher humidity and less precipitation experience more aridity, since the value of I_q decreases. Likewise, the regions with less humidity and more precipitation have better humidity conditions which show higher I_q.

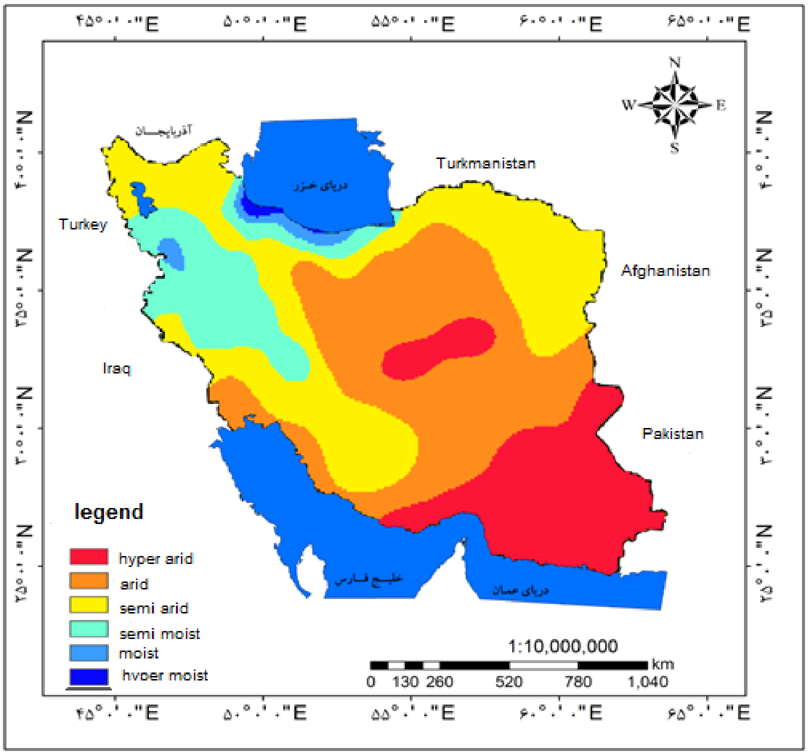

Figure 2. Climatic zoning of Iran using I_q index

4. Changes of aridity trend based on I_q index

In order to study the aridity trend of I_q index, Mann-Kendall non-parametric test was used. The Z statistics of the test was obtained by MATLAB software for certain level of 95%. Table 2 shows the results of the test Z statistics of I_q index in a 30 year period.

As can be seen in table 2, the trend of this index shows an insignificant decrease among all stations except for Abadan, Doushantape, Esfehan, East of Esfehan, Hamedan (airport), Iranshahr, Kashan, Sahrekord, Zanjan and Khoramabad where it has insignificant increase. This negative trend marks the decrease of the aforesaid index, gradual decrease of precipitation with temperature and specific humidity increase. In other words, lower numerical value of the index leads to more arid stations. The findings reveal that 80.4% and 19.6% of the stations have decreasing and increasing trends respectively. In fact analysing the trend of I_q arid index explains that aridity degree of Iran climate has increased during the statistical period (1981-2010). Besides the area of Iran arid region is increasing.

Table 2. The value of Mann-Kendall statistic Z

No	Station Name	Z Value	No	Station Name	Z Value
1	ABADAN	-0.267	27	KERMAN	-1.116
2	ABADEH	0.965	28	KERMANSHAH	-0.3054
3	AHVAZ	-0.120	29	KHORRAMABAD	0.230
4	ANZALI	-0.483	30	KHOY	-1.024
5	ARAK	-0.597	31	KISH	-0.388
6	ARDABIL	-0.388	32	MASHHAD	-0.777
7	URMIEH	-0.543	33	NOSHAHR	-0.306
8	BABOLSAR	-1.079	34	RAMSAR	-0.370
9	BAM	-0.213	35	RASHT	-0.682
10	BANDARABAS	-0.175	36	SABZVAR	-0.305
11	BANDARLENGEH	-0.179	37	SAGHEZ	-0.278
12	BIRJAND	-0.726	38	SANANDAJ	-0.856
13	BOJNORD	-0.201	39	SEMNAN	-0.996
14	BOOSHEHR	-0.125	40	SHAHREKORD	0.496
15	CHABAHAR	-0.231	41	SHAHROOD	-0.267
16	DEZFUL	-0.032	42	ESFAHAN(EAST)	0.566
17	DOSHANTAPE	0.020	43	SHIRAZ	-0.292
18	ESFAHAN	1.029	44	TABAS	-0.032
19	FASA	-0.440	45	TABRIZ	-0.711
20	GHAZVIN	-0.6005	46	TEHRAN	-0.292
21	GORGAN	-0.935	47	TORBATHEYDARIEH	-0.340
22	HAMADAN(AIRPORT)	0.297	48	YAZD	-0.050
23	HAMEDAN(NOZHE)	-0.942	49	ZABOL	-0.089
24	IRANSHAHR	0.001	50	ZAHEDAN	0.225
25	JASK	-0.121	51	ZANJAN	-0.526
26	KASHAN	0.524			

5. Conclusion

The information and statistic of the related organization show that 1200000000 of surface River currents have decreased. Moreover the amount of precipitation, with annual 250mm, has decreases to 242 mm. The Caspian Sea basin with 1.4 decreases, Persian Gulf and Oman Sea with 2.1 mm decrease, Orumiye Lake basin with 3.4 mm decrease and central plateau of Iran with 2.3 mm decrease are dangerous results of aridity intensifying throughout Iran. Studies show that precipitation was decreasing 1 mm yearly from 1968 to 1990, although this decreasing trend has been intensified since 1990, reaching 3.6 mm yearly.

Generally it can be said that not only the results of aridity indexes and the test determining the trend of changes based on the applied indexes, but also the information and statistics of the related organizations of field research evaluation of water resources prove that Iran climate is becoming warm and dry. Precipitation decrease, temperature increase, and evaporation are considered the most significant natural reasons of decreasing water resources. In addition to these reasons, weak insufficient management of water resources and wrong consumption pattern indicate threatening horizons for the country water resources. It is necessary to reduce water crises and protect water resources with appropriate management and correct water consumption pattern.

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