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RAIN AND TEMPERATURE TRENDS IN NAMAK LAKE BASIN (IRAN) DURING THE LAST HALF- CENTURY

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ABSTRACT
FAO in its last definition of desertification has cited climate as a main component of creation and development of desert. In this research monthly precipitation and temperature data during 1956 to 2005 have been gathered and rebuilt. Then average precipitation and minimum and maximum temperatures of six sub- basins of Namak Lake are calculated by using Thiessen method in Arcmap environment. To evaluate precipitation trends, Standard Precipitation Index was used. The trend of precipitation and temperature climatic components were examined based on parametric linear regression and non- parametric Mann–Kendall test. No significant trend was observed in standardized precipitation of Namak Lake basin and its sub basins , expect for Arak sub basin in which precipitation change trend was decreasing and significant. The examination of monthly precipitation showed that in Arak, Qharechai and Karaj sub basins we have encountered harsh drought during these 50 years. Minimum and maximum temperature changing trends were increasing and significant in most sub basins. Increase in Namak Lake temperature conform to world temperature increase, that its main reason can be related to green house gases, Especially in large cities include Tehran, Qom, Arak, Kashan, Hamedan and Qazvin.

KEYWORDS: Linear trend test, Mann-Kendall test, SPI

INTRODUCTION

Namak Lake basin, in an area about 10 million hectares, is located in northeast of central Iran zone and includes some important population centers like Tehran, Arak, Qom, Kashan, Qazvin, Hamedan and Golpayegan. Considering to the development of desert and its converse environment consequences and the role of climate in controlling or developing this phenomenon (considering to the last definition presented by FAO and UNEP for desertification). It is necessary to study climate and its changing trends. Several studies have analyzed rainfall and temperature trends in arid and semi-arid regions all over the world. By analyzing temporal trends, Silva (2004) observed climate variability in northeast Brazil. Jiangping *et al.* (2002) used climatic variables to discuss climate changes in China. They observed that the annual mean values of air temperature, evaporation, sunshine and wind speed have all declined, while annual rainfall and mean relative humidity have slightly increased. Masoodian in 2004 reviewed Iran temperature trends in the last half- century and calculated that Iran's night, day and round- the- clock temperatures have increased 3,1 and 2 degrees, respectively, in each 100 years. Temperature increasing trends have been observed in hot and low- level areas and temperature decreasing trends have been observed in mountainous zones. He also reviewed Iran's rain trends in last 50 years, and concluded that the precipitation rate, in most areas of Iran, has not shown increasing trend. But it has shown increasing trends in central, eastern and southern Iran for several months. Montazeri (2008) analyzed Iran's climatic droughts in the Zayandeh Rood sub basins within 50 years. Based on parametric linear regression, the precipitation of Zayandeh Rood sub basins has no increasing significant trends, and increasing trends have been observed only in February, March, May and June. Only in February, precipitation has had positive trends in all sub basins. Ensafi Moqaddam, in 2004, calculated ACI (Aridity Climatic Index) for stations in Namak Lake basins. Results of annual evaluation of this index showed that aridity is developing slowly and consistently. Khalili and Bazrafshan analyzed precipitation changing trends in 5 ancient stations in the last 116 years. Zahedi in 2007 reviewed temporal and spatial changes of temperature in northwest of Iran by using regression and Mann–Kendall test. Khoshhal Dastjerdi (2008) studied using Mann–Kendall test in measuring temperature changes of Synoptic station in Isfahan. Results showed that there are no significant changes in long- term trends of Isfahan extreme temperatures. Chung et al (2000) evaluated temperature and precipitation trends of the earth during 1974 to 1997 and concluded that this region's temperature has increased by 0.96 degree. This increase in urban areas is 1.5ºc and in rural areas is 0.58ºc. Hooth and Pookarta, in 2004, examined parametric and non parametric methods in evaluating climatic elements in Czech Republic. Taqavi, in 2008, studied the relationship between climate change and desertification, by using Extreme Climate Index Software (ECIS) in Kashan. He found a positive trend in weather warming during 1995 to 2004. Soboohi and Soltani (2008) analyzed climatic factors trend in Iran's main cities. They found that there is an increasing trend in climatic factors of average temperature, and this trend is positive in 62 percent of stations. Also he evaluated the relationship between climate change and air pollution in Isfahan in 2009 and concluded that there is a significant negative trend in number of rainy days in April and May and an increasing significant trend in raining rate and maximum 24 hours raining in March, and the temperature of most months of the year had a significant increasing trend. These trends were calculated by using non- parametric Mann–Kendall test. The impact of human activities on general climate at a global scale is widely accepted. The basic hypothesis of this study was that global climate change could be observed as climate variability in Iran. The purpose of this research is evaluating temperature and precipitation trends during 50 years in Namak lake basins.

MATERIALS AND METHODS

Central Iran basin including more than 50 percent of Iran's total area is divided into 7 sub basins, one of these is Namak lake basin in an area about 10 million hectares(Fig.1).

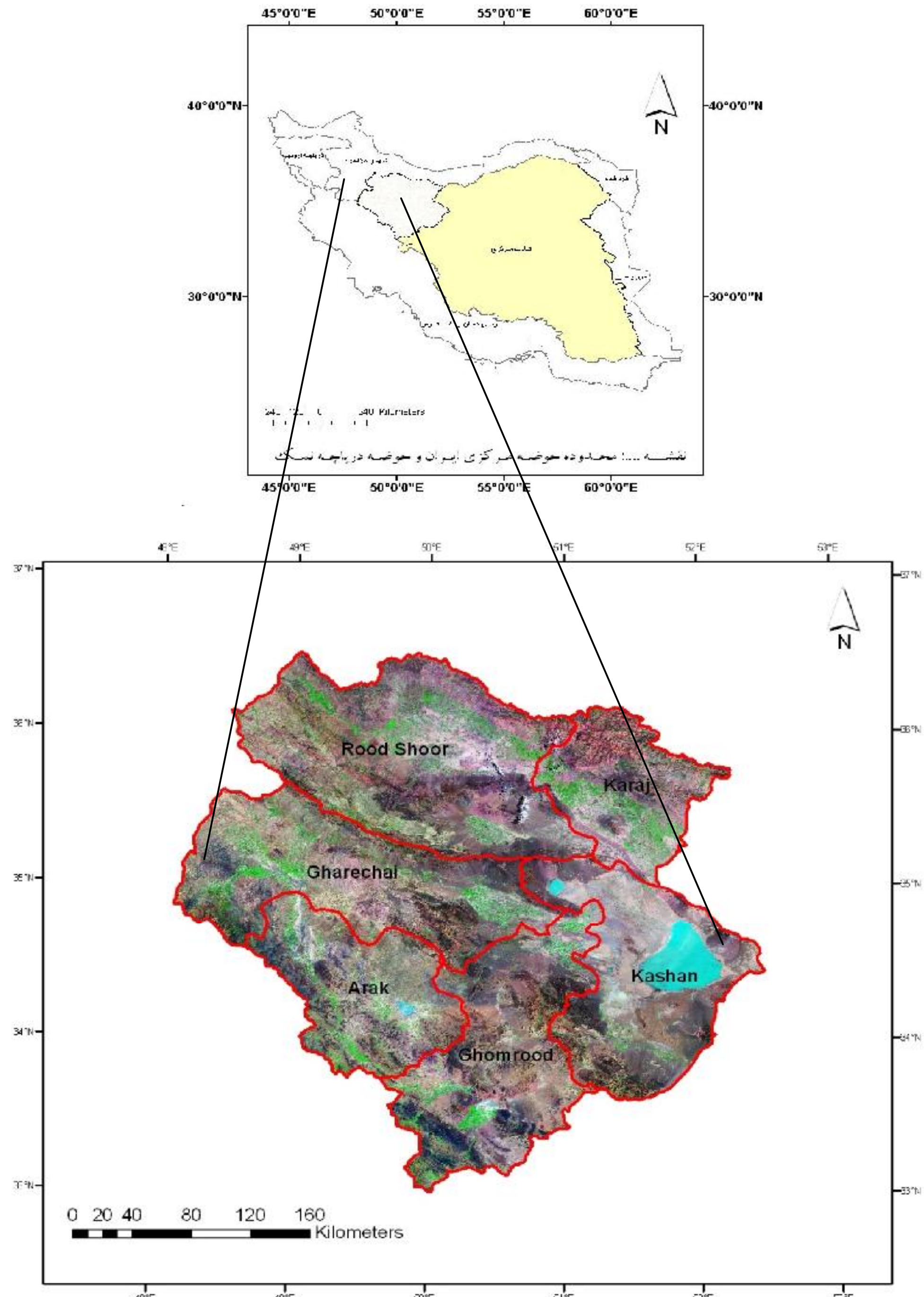

Figure1: Map of Namak Lake basin and its sub basins

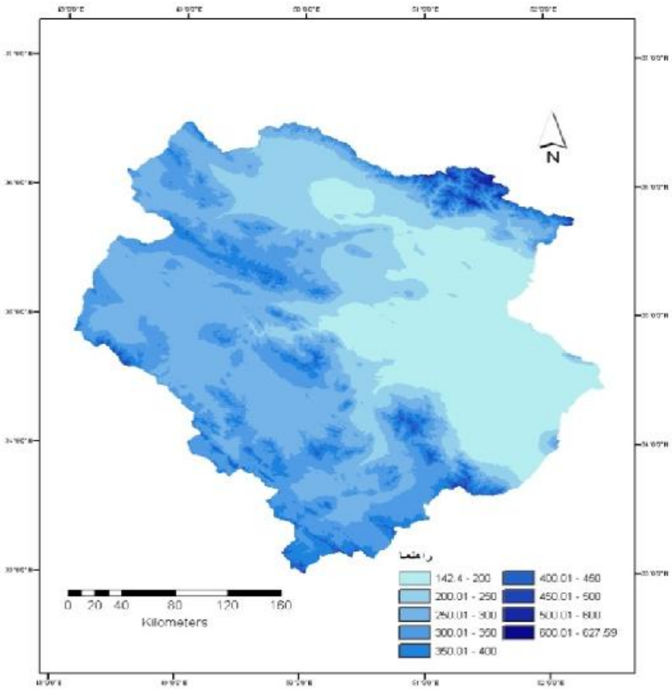

FIGURE2: Map of Rain Namak Lake basin

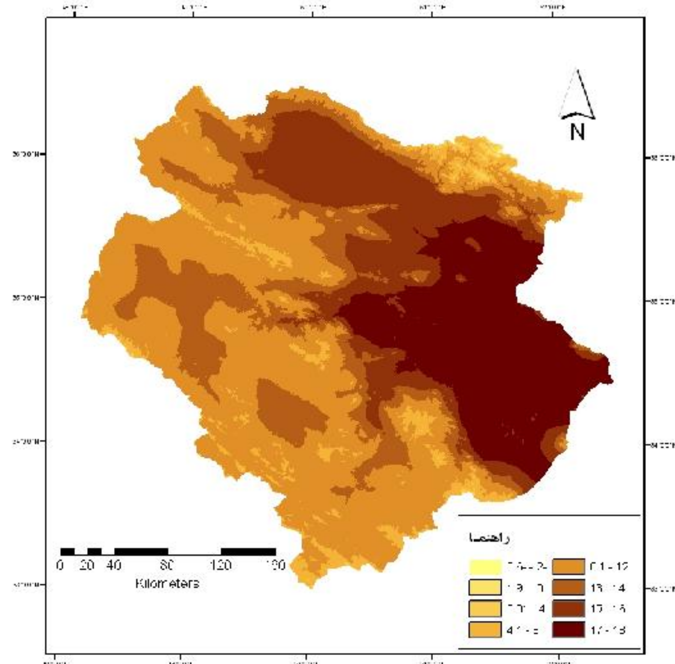

FIGURE3: Map of Temperature Namak Lake basin

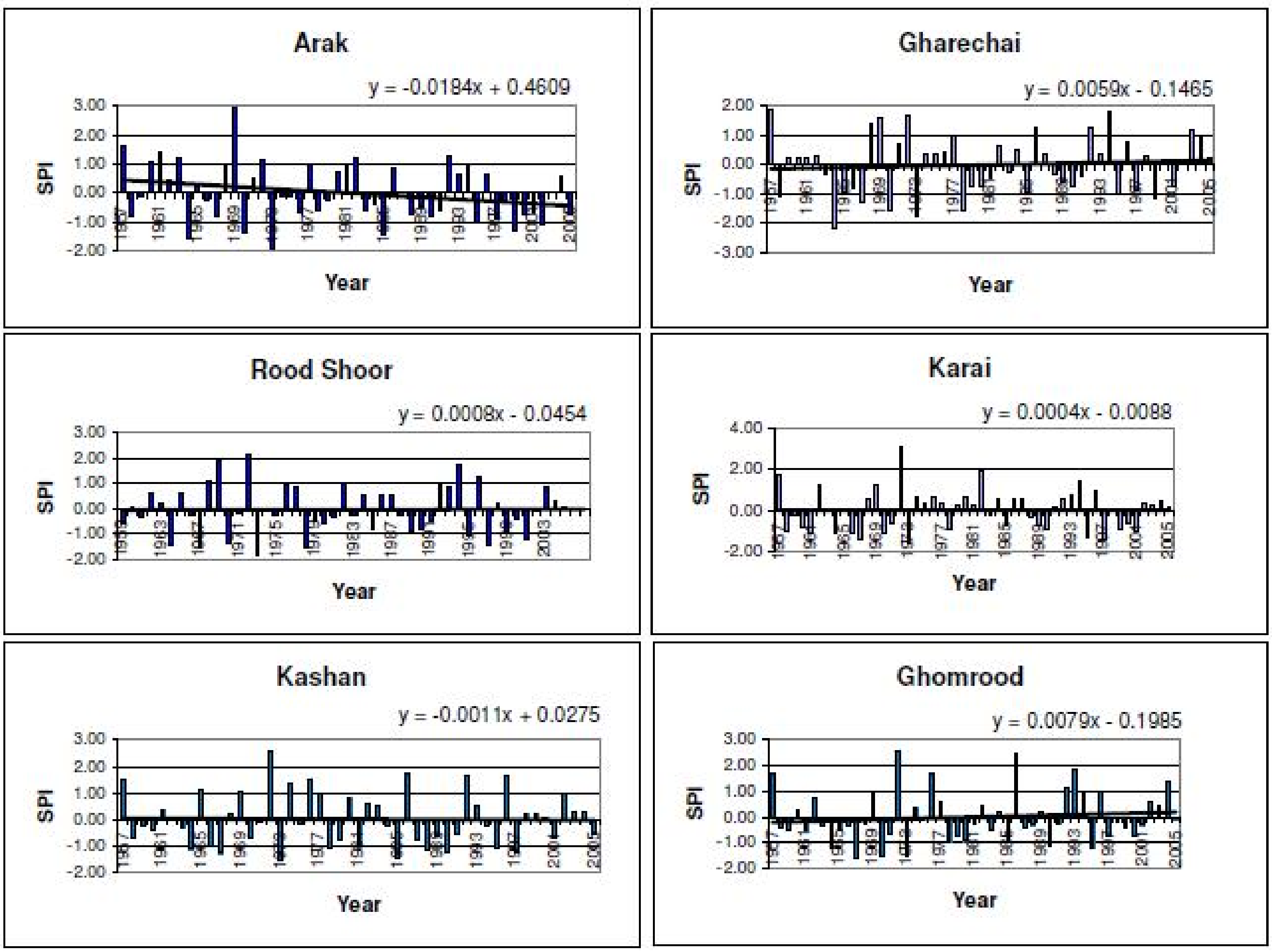

FIGURE 4: Trend of SPI in sub basins (1956 - 2005)

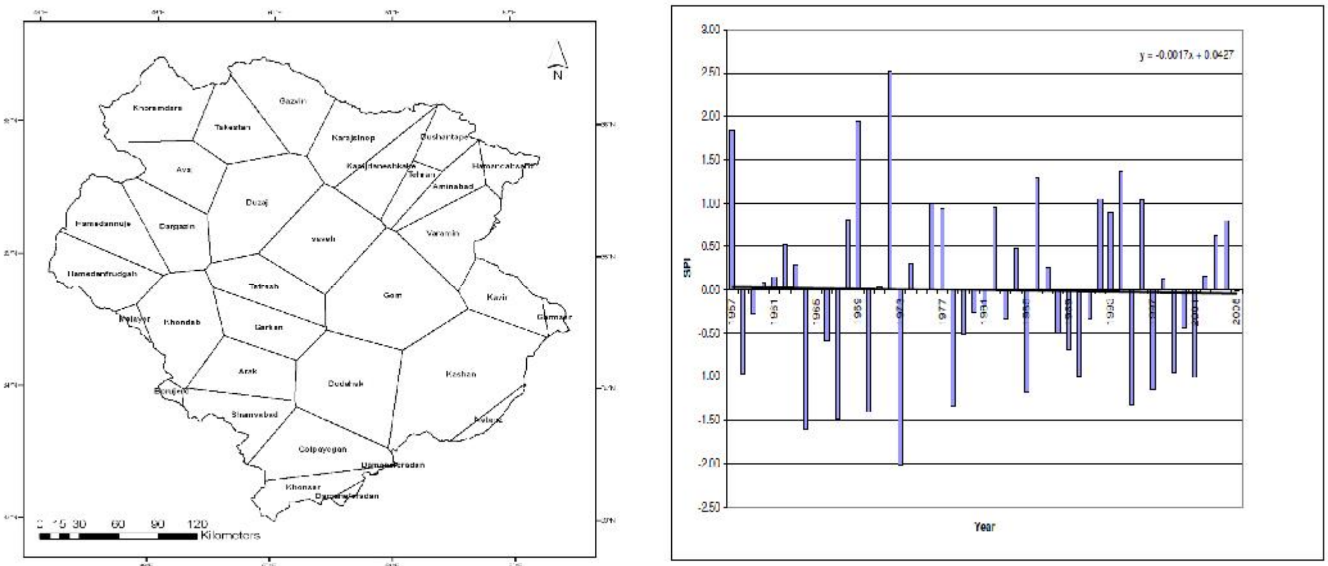

FIGURE 5: Map of Thiessen Namak Lake basin and diagram rain trend (1956 - 2005)

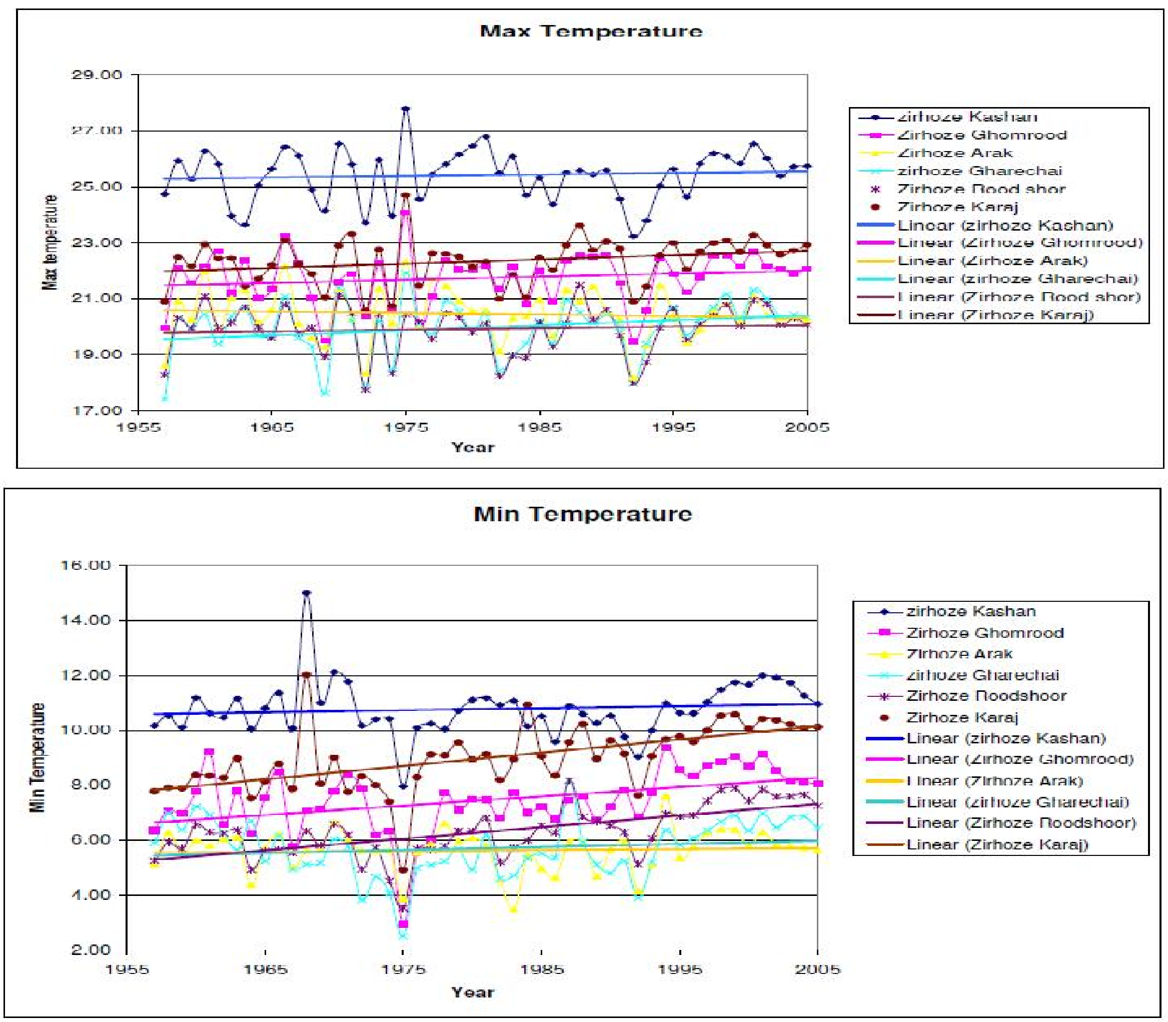

FIGURE 6: Diagram of Min and Max temperature trend in sub basins

Namak lake basin is located in northwest of central watershed basin and is the third vast sub basin of this basin. From northwest and northeast, it is limited to Caspian Sea basin, from west and southwest it is limited to Persian Gulf basin and Oman Sea, from south is limited to Gavkhooni sub basin, from southeast to Siahkooh Kavir sub basin, and from east it is limited to central Kavir sub basin. Annual average precipitation of the study basin is less than 200 mm in southeast to more than 800 mm in north heights (Fig.2). Precipitation regimen is Mediterranean, i.e. raining seasons conforms to the cold half of the year and arid season conforms to summer. Summer has a little share in the basin raining and this little rate is from sudden rains happening every several years in summer. In zone scale, minimum average precipitation is in September and its maximum varies between Januarys to May. Namak Lake basin watershed can be divided into followings, based on climate view: East areas including Garmsar, Varamin, Qom and Kashan has an arid climate. Annual average raining in these zones is about 130 mm happening in Januarys, February and March. Annual evaporation is more than annual raining. This zone has temperate winter and hot and long summer. Its average annual temperature is more than 18ºc. The northern and central areas of this basin, around Arak, Qazvin and Tehran have semi- arid weather, cold winter and long, hot summer. The duration of raining period of this zone is comparatively longer and besides winter months, has precipitation in November and December. The west and southwest of this basin, around Hamedan, Golpayegan and Khomein, has temperate weather, rather cold damp winter and hot summer .The precipitation rate is mostly centered on winter and early spring. Weather in Namak lake watershed basin is influenced by height and has all climates and thermal sub climates except for hot. In thermal view, 44 percent of this area is ultra cold, 49 percent cold and 7 percent temperate (Fig.3). Namak lake basin composes of 6 sub basins and its average precipitation is 251.7 mm. Arak, Qarachai, Karaj ,Roodshoor, Qomrood and Kashan with average precipitation of 327.5,289, 275.9, 233.7, 215.5, and 141.5 mm, respectively, are the most precipitated basins. To examine precipitation and temperature trends in Namak lake basin, 32 climatological stations, located in the basin and with long statistical history, were selected (table 1).

TABLE 1: Stations selected in Namak Lake basin

Row	Station	Lat	Lon	Heigh	Rain	Temperature
1	Arak	49.77	34.1	1708	345.27	13.65
2	Ardestan	52.38	33.38	1252	104.82	17.4
3	Avaj	49.22	35.57	2034	345.52	10.24
4	Brujerd	48.8	33.9	1632	474.4	13.64
5	Damane Feraidan	50.48	33.02	2300	323.06	10.01
6	Dargazin	49.07	35.35	1870	329.53	10.74
7	Dodahak	50.63	34.06	1400	142.96	15
8	Dushan Tape	51.33	35.7	1209	254.77	17.52
9	Duzaj	49.82	35.4	2100	226.48	10.37
10	Gakan Ashtian	49.97	34.55	1741	282.51	12.96
11	Garmsar	52.27	35.2	825	123.54	17.58
12	Ghazvin	50	36.25	1278	318.85	13.88
13	Golpayegan	50.28	33.47	1870	249.01	12.95
14	Gom	50.85	34.7	877	157.66	18.03
15	Hamedan	48.53	34.85	1749	305.48	10.77
16	Hamedan (Noje)	48.72	35.2	1679	331.62	10.8
17	Esfahan	51.66	32.62	1800	364.9	10.38
18	Karaj (synoptic)	50.9	35.92	1550	118.13	15.91
19	Karaj (Daneshkade)	51.03	35.8	1312	272.83	13.71
20	Kashan	51.45	33.98	1321	240.06	13.86
21	Khonsar	50.32	33.23	2300	318	11.7
22	Khandab	49.2	34.4	2300	352.88	11.66
23	Khoramdare	49.18	36.18	1742	331.23	13.78
24	Malayer	48.82	34.28	1575	309.63	11.29
25	Natanz	51.9	33.53	1725	309.28	13.31
26	Save	50.33	35.05	1684	143.79	14.3
27	Shams Abad	49.73	33.82	1108	202.24	18.32
28	Tafresh	50.03	34.68	2400	341.32	11.54
29	Takestan	49.65	36.05	1930	294.02	12.56
30	Tehran	51.32	35.68	1325	239.72	13.55
31	Veramin	51.65	35.31	1190	229.88	17.08
32	Zanjan	48.48	36.68	1000	162.73	16.58

After gathering statistics in period of 1956 to 2005, they were reproduced. The study climatic components include monthly precipitation average minimum and maximum temperature. After completing and reproducing precipitation statistics and monthly and annual temperature of 32 stations, SPI was calculated to evaluate drought. Many researchers in our country have used SPI in spite of the existence of various evaluating and controlling methods. This index has been realized as the most appropriate index to analyze aridity because of the simplicity of calculations, using of available precipitation data, and calculability for every favorite temporal scale and its competence for spatial comparison of results. In other words, it has been realized as a good and profitable index, because of using temporal scale to control arid periods. This index invented by Maky et al in 1993. SPI is dimensionless and results from a ratio of discrete data disorder to precipitation standard deviation.

$$SPI = (P_{ik} - P_i)/ \sigma_i$$

In which P_{ik} is precipitation rate of i th station in k th observation in mm, P_i average precipitation of i th station in mm and σ_i is precipitation standard deviation of i th station in considered period. The degree of dryness and dampness is determined by standardized precipitation index in table 2.

TABLE 2: adapted from McKee *et al.* (1993)

SPI Values	Category
= 2.00	Extremely Wet
1.50 to 1.99	Severely Wet
1.00 to 1.49	Moderately Wet
-0.99 to 0.99	Near Normal
-1.00 to -1.49	Moderately Dry
-1.50 to -1.99	Severely Dry
<=-2.00	Extremely Dry

TABLE 3: Thiessen effect surface of stations in Namak Lake basin

Row	Station	Lat	Lon	Area (Hectare) Thiessen	Area (%)
1	Shamsabad	382462.6	3742981.3	246894.1	2.7
2	Damaneferadan	451432.3	3653680.1	19214.8	0.2
3	Garmsar	615615.2	3896023.0	37916.3	0.4
4	Gom	486261.9	3839845.6	673017.4	7.3
5	Khondab	334539.9	3808036.8	421287.4	4.5
6	Khoramdare	336325.6	4005512.7	380224.0	4.1
7	Karajsinop	490977.7	3975143.7	334426.0	3.6
8	Hamandabsard	597772.3	3945729.5	106197.8	1.1
9	Borujerd	296569.1	3753305.4	25319.4	0.3
10	Khonsar	436639.2	3677047.7	180894.5	2.0
11	Kashan	541568.2	3760088.0	826538.4	8.9
12	Golpayegan	433095.9	3703682.0	383990.9	4.1
13	Natanz	583573.0	3710465.0	54488.6	0.6
14	Kavir	593800.3	3892442.9	246402.7	2.7
15	Varamin	559084.8	3908786.6	336363.0	3.6
16	saveh	438895.4	3878854.3	467174.7	5.0
17	Dodahak	465857.8	3770037.8	561146.0	6.0
18	Tafresh	411137.3	3838045.5	292558.4	3.2
19	Malayer	299318.0	3795412.6	30049.3	0.3
20	Hamedannuje	292426.1	3897665.8	338854.4	3.7
21	Hamedanfrudgah	274163.5	3859252.2	309926.4	3.3
22	Garkan	405493.2	3823683.3	263717.5	2.8
23	Arak	386537.2	3773985.4	292975.5	3.2
24	Takestan	378395.7	3990401.4	294401.1	3.2
25	Gazvin	410152.3	4012206.0	360008.6	3.9
26	Duzaj	392842.4	3918104.5	523060.6	5.6
27	Dargazin	324618.7	3913629.3	301292.8	3.2
28	Avaj	338690.9	3937777.4	292229.2	3.2
29	Tehran	528958.2	3948566.9	103568.6	1.1
30	Karajdaneshkake	502710.8	3961829.7	240729.9	2.6
31	Dushantape	529855.7	3950788.1	155715.5	1.7
32	Aminabad	542585.5	3937530.3	175150.8	1.9

TABLE 4: Effect surface of stations in sub basins

Row	Sub Basin	Station	Area Thiessen(Hectar)	Area (%)
1		Garmsar	37722.2	2.4
2		Gom	270552.8	17.3
3		Kashan	783710.4	50.1
4	Kashan	Natanz	54193.8	3.5
5		Kavir	244482.3	15.6
6		Varamin	116993.3	7.5
7		saveh	21438.6	1.4
8		Dodahak	36164.2	2.3
9		Shamsabad	112131.4	7.0
10		Damaneferadan	18989.1	1.2
11		Gom	297048.7	18.4
12		Khonsar	180374.5	11.2
13	Ghomrood	Kashan	42433.4	2.6
14		Golpayegan	383961.4	23.8
15		Dodahak	507086.7	31.4
16		Tafresh	8003.1	0.5
17		Garkan	60657.5	3.8
18		Arak	2243.6	0.1
19		Shamsabad	134369.0	11.8
20		Khondab	385507.2	34.0
21		Borujerd	25235.7	2.2
22		Dodahak	17895.1	1.6
23	Arak	Tafresh	8162.8	0.7
24		Malayer	29875.9	2.6
25		Hamedannuje	11975.8	1.1
26		Hamedanfrudgah	62843.2	5.5
27		Garkan	168898.9	14.9
28		Arak	290731.9	25.6
29		Gom	99409.3	5.6
30	Shoor	Khondab	35662.3	2.0
31		saveh	250294.3	14.1
Row	Sub Basin	Station	Area Thiessen	Area (%)
32		Tafresh	276392.5	15.5
33		Hamedannuje	326636.9	18.3
34		Hamedanfrudgah	246752.6	13.9
35	Shoor	Garkan	34161.0	1.9
36		Duzaj	159015.1	8.9
37		Dargazin	301218.4	16.9
38		Avaj	51627.3	2.9
39		Gom	6006.5	0.3
40		Khoramdare	379741.9	16.7
41		Karajsinop	285481.8	12.6
42	Gharechai	Varamin	10514.4	0.5
43		saveh	195441.9	8.6
44		Takestan	294370.2	12.9
45		Gazvin	359583.4	15.8
46		Duzaj	364045.4	16.0

47		Avaj	240415.3	10.6
48		Tehran	25558.3	1.1
49		Karajdaneshkake	97222.1	4.3
50		Aminabad	15299.7	0.7
51		Karajsinop	48528.7	5.4
52		Hamandabsard	105689.5	11.7
53		Kavir	1632.4	0.2
54	Karaj	Varamin	208604.0	23.1
55		Tehran	78010.3	8.7
56		Karajdaneshkake	143507.3	15.9
57		Dushantape	155548.2	17.3
58		Aminabad	159851.1	17.7

TABLE 5: Z Index of sub basins rain trend

Sub Basin	Ghomrood	Shoor	Arak	Karaj	Gharechai	Kashan	Total
Z	1.11	0.59	-1.97	0.16	-0.13	0	0.04

TABLE 6: Number of month with like SPI in the sub basins (1956 – 2005)

SPI		Basin Total	Kashan	Ghom rood	Arak	Rood shoor	Ghare chai	Karaj
Extremely Wet	= 2.00	29	28	30	26	26	27	23
Severely Wet	1.50 to 1.99	17	20	17	25	31	23	27
Moderately Wet	1.00 to 1.49	45	46	52	37	43	42	44
Near Normal	-0.99 to 0.99	479	506	501	432	413	508	462
Moderately Dry	-1.00 to -1.49	30	-	-	80	87	-	44
Severely Dry	-1.50 to -1.99	-	-	-	-	-	-	-
Extremely Dry	<=-2.00	-	-	-	-	-	-	-

In order to calculate precipitation and temperature of basin, effect level of each station was determined by using thiessen method in Arc map environment. In this method, it is supposed that the precipitation of one point in the space between two stations is equal to station precipitation closer to that point. So after specifying points of stations on the map , effect level of each station will be specified , by drawing bisecting vertical lines between stations and is considered as weigh coefficient of them. If the sum of effect level products in precipitation or temperature of stations is divided by total area, average rainfall or temperature is resulted. Figure 5 and table 3 show each station's effect level in Namak Lake by Thiessen method. To specify average temperature and precipitation in these six basins, a Thiessen map for each sub basin is provided in Arc map environment and each station's effect level has been determined (table 4). To calculate temperature and precipitation trends, two parametric linear regression and non- parametric Mann-Kendall test have been used. Non- parametric Mann–Kendall test, as a programming in mini tab software, was calculated. In this test each measure, in temporal continuous series, was compared to other series measures. S showing the sum of all counting's is as follow:

$$S=\sum_{i=1}^{n-1}\sum_{k=i+1}^{n} Sgn(Xk-Xi)$$

In which Xi and Xk are successive measures. N is temporal series length and sgn(ɵ) is equal to 1, 0,-1 , if ɵ is, respectively, greater, equal and less than 0, Ho hypothesis is rejected when $-z_{1-\alpha/2} \leq Z \leq z_{1-\alpha/2}$

$$Z=\begin{cases}\frac{s-1}{\sqrt{var(s)}} & S>0\\ 0 & S=0\\ \frac{s+1}{\sqrt{var(s)}} & S<0\end{cases}$$

In which Var(s) is evaluated based on the following relation:

$$Var(S)=\frac{n(n-1)(2n+5)-\sum_{i=1}^{n}(ti-1)(2ti+5)}{18}$$

In the above relation, ti is the number of similar measures for ith measure and n is the number of similar measures in series (Montazeri 2008).

RESULTS

Parametric linear regression and non-parametric Mann-Kendall test were conducted on standardized precipitation. The results of linear regression test, as diagram with slope

rate of fitting lines Thiessen map of each sub basin are shown in figure 4.
It is necessary to note that negative slope represents decreasing trend and positive slope represents increasing trend. The results of Mann-Kendall test on standardized precipitation of Namak lake sub basins are shown in table 5. Also, based on monthly standardized precipitation rate in each sub basin, number of months with dryness and dampness were calculated, which are shown in table 6. Parametric linear regression and non- parametric Mann-Kendall were calculated on average minimum and maximum temperature statistic. The results of this regression test are shown in figure 6 and table 7.The results of non-parametric Mann- Kendall are shown in table 8.

TABLE 7: Linear regression trend of Max and Min temperature (1956 – 2005)

Sub Basin	Temperature	Linear regression
Kashn	Min	Y= 0.0076x-4.28
	Max	Y= 0.0053x+14.83
Rood Shoor	Min	Y= 0.011x-16.15
	Max	Y= 0.0179x-15.42
Karaj	Min	Y= 0.0484x-86.82
	Max	Y= 0.0152x-7.82
Ghomrood	Min	Y= 0.0339x-59.62
	Max	Y= 0.0111x-0.18
Arak	Min	Y= 0.0034x-1.17
	Max	Y= -0.0053x+31.02
Gharechai	Min	Y= 0.0424x-77.73
	Max	Y= 0.0056x+8.89
Basin Total	Min	Y= 0.0244x-41.02
	Max	Y= 0.0084x+4.89

TABLE 8: Man- kendall test on the Min and Max temperature (1956 - 2005)

Sub Basin	Kashan	Gharechai	Karaj	Arak	Rood Shoor	Ghom Rood	Total
Z (Min)	1.6	4.85	5.3	0.23	1.23	3.3	3.2
Z (Max)	0.66	0.58	2.26	-0.59	1.87	1.3	1.16

DISCUSSION

Namak lake basin has climatic variations because of its large vastness and great height differences. Elborz and Zagros mounts surround this basin from north and east, and prevent raining clouds from going to this basin. Arid and desert climate dominate over this basin. So intense fluctuations are observed in temperature and raining annually. Namak lake basin is composed of 6 sub basins and its average rainfall is 251.7mm. Arak, Qarechai, Roodshoor, Karaj, Qomrood and Kashan with average precipitation rates of, respectively, 327.5, 289,275.9, 233.7, 215.5, 141.5 mm are the most precipitated sub basins. Linear regression and Mann-Kendall tests were conducted on SPI of the last half century of Namak Lake and its six sub basins, which show no significant trend. Only in Arak and based on Man- Kendall, this trend is decreasing and significant. The examination of SPI of the basin shows that in the last years there has been more intense dryness and dampness. The review of monthly precipitation of this basin and its sub basins indicate normal conditions of most months. Only in Arak, Qharechai and Karaj, harsh droughts have been observed and in all sub basins, dampness is observed. The minimum and maximum temperatures of this basin have increasing trends, approved by Mann- Kendall and linear regression tests. As you see in table 7, trend line's slope is positive and increasing in all sub basins except for maximum temperature of Arak. The results of Mann-Kendall show that trends of both minimum and maximum temperature is increasing in all sub basins except for maximum temperature of Arak(table 8).Temperature change trend in sub basins Roodshoor, Karaj, Qomrood and all basins is increasing and significant in 0.95 level and minimum temperature of Karaj is significant and positive.
Although precipitation shows no specific trend, human has caused aggravation of arid and desert conditions especially in lower regions of built dams. So in recent 50 years, building Karaj, Latyan, 15 Khordad dams, etc and exploiting their water to supply for agriculture and drinking in upper regions of the basin and its cities have adversely affected water balance of lower regions. The round-the – clock pumping of underground water and rush of salt water into sweet water have made water quality and quantity critical. The subsidence of water reservoirs and soil degradation because of using salty water and leaving farms and migrating to big cities are consequences of this irregular aggression and human's unwise interferences (Abtahi 2007).
Increasing trend of basin's temperature conforms to global temperature rise resulting from increase of green house gases and recently, dusts of wind erosion. This temperature rise has influenced water balance of the region by increasing evaporation and water needs. Generally, we shall say that both factors influencing in desertification i.e. climate and human activities in Namak lake basin have intensified the

current conditions and it shall be considered in huge decisions and policies of the country.

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