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Impact of Land use Change on Precipitation and Temperature Trends in an Arid Environments

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ABSTRACT: Precipitation and temperature are the major variables in climatological and hydrological systems, especially in arid regions. The main aim of this study was to investigate the trend of precipitation and temperature of an arid area in the monthly and annual time scales. The possible relation of these climate change with anthropogenic behavior was also investigated. Observational data for temperature (12 stations) and precipitation (22 stations) have been obtained from Iran Water Resource Management Company during 1986-2012. The non-parametric method and remote sensing (RS) technology was used to analyze the possibility effects of land use and climate change on precipitation and temperature trends. The trends in precipitation and temperature were detected using Man-Kendall and Spearman's Rho tests. The LULC maps for the study area were produced using remote sensing and satellite images for the years of 1987 and 2013. The results of this study indicate that monthly precipitation had an increasing and decreasing significant trend, however monthly temperature was increased significantly in the study period. Annual T_{max} exhibited a significant increasing trend for six stations in the study area. The main increasing in LULC were irrigation farming and residential area. According to the land use maps, some parts of rangeland area changed to bear soil area. We conclude that increase in urban area can be linked to higher temperature, also increasing and decreasing in irrigation farming and rangeland may influence groundwater and surface water, respectively. So, the impacts of both land use and climate change must be included in hydrological modeling and watershed management.

Keywords: Precipitation, Temperature, Nonparametric trend tests, Land use change, Climate change

INTRODUCTION

Climate change is known as the major environmental issue in the world (IPCC. 2007; Qian Cao *et al*, 2016). In order to evaluate the global warming and develop climate impact researches, trend detection has been found as an interesting subject for both climatological and hydrological studies. Therefore, trend detection researches in hydrological and climatological characteristics such as precipitation, temperature, runoff, evaporation and ground water are used to investigate climate change and global warming. Nowadays, better understanding of trend analysis of long-term temperature and precipitation has been the main topic of climate and water resources researchers (Safari 2012).

Temperature and precipitation are fundamental elements of climate and changes in their pattern can affect climatology and hydrology regimes (Gunawardhana and So, 2011). Both of them are highly variable temporarily and spatially at local, regional and global scales, so the evaluation of their trends is important for understanding climate variability and predicting future climate conditions (Karabulut *et al* 2008. Changes in rain duration and intensity affected the availability of water and can cause a shift in plant and animal species (Karmeshu, 2012). Urbanization and land use change would affect hydrological response of urban watersheds via change in energy budget (Chung *et al,* 2011).

Several studies related to long-term trends of temperature and precipitation series have been carried out in the world. These studies come from different regions and they are: Italy (Brunetti *et al* 2000; Longobardi and Villani. 2009) ; Iran (Raziei *et al* 2005; Ghahraman. 2006); Spain (Esteban-Parra & Rodrigo. 1995; del Rio *et al* 2007); China (Su *et al* 2006; Miao *et al* 2012); India (Gadgil and Dhorde. 2005; Dhorde *et al* 2009; Mishra *et al* 2014); Greece (Karpouzos *et al*, 2010); Tanzania (Kassile. 2013); United States (Michaels *et al* 1998; Chattopadhyay and Edwards. 2016).

In the Middle East, trends in precipitation and temperature at annual, seasonal and monthly time scales in Samsun, Turkey was investigated by Karabulut *et al* (2008). No statistically significant clear trends in precipitation was reported in the study area. Trends in maximum and minimum temperatures in monthly, seasonal and annual time-scales during 1966-2005 was analyzed for arid and semi-arid regions of Iran (Tabari and Hosseinzadeh Talaee 2011). Tendency increasing in the annual, seasonal and monthly time scales during the last decades was reported.

Precipitation variability in the Swat River basin of Pakistan was investigated using Spearman's Rho and Mann-Kendall tests (Ahmad *et al* 2015). Both positive increase and negative decrease trends was observed for monthly, seasonal and annual precipitation. Non-parametric statistical tests were applied to determine the long-term trends in annual precipitation and mean annual temperature (1950-2010) for Kentucky State in the United States (Chattopadhyay and Edwards 2016). Positive significant trends was observed for only two stations out of 60 precipitation study stations. Trend detection in precipitation and temperature in arid and semi-arid regions is crucial for planning regional water resources management. Two-thirds of Iran is located in the arid and semi-arid regions. Such area have a fragile nature and were subjected to drought and desertification (Akbari *et al* 2009, in Persian). The main objective of this study was to detect the trends in temperature and precipitation using Mann-Kendall and Spearman's Rhotests in Mashhad basin located in an arid and semi-arid regions of Iran. Impact of land use and Climate change in temperature was investigated using non-parametric tests supported by remote sensing (RS technology-based images of LULC).

MATERIAL AND METHODS

A. Study area and Data Set

Mashhad basin is a semi-arid region located in the northeast of Iran (58°29' to 59°56' east longitude and 35°58' to 37°3' north latitude) is a sub basin of Kashafrud and Qaraqumbasin (Fig. 1). It has an area of 9909 km^2 where 3351 km^2 is plain and 6558 km^2 is highlands. The study area have a mean annual precipitation of 247.5 mm, whereas mean annual pan-evaporation of the study area is 2300 mm.

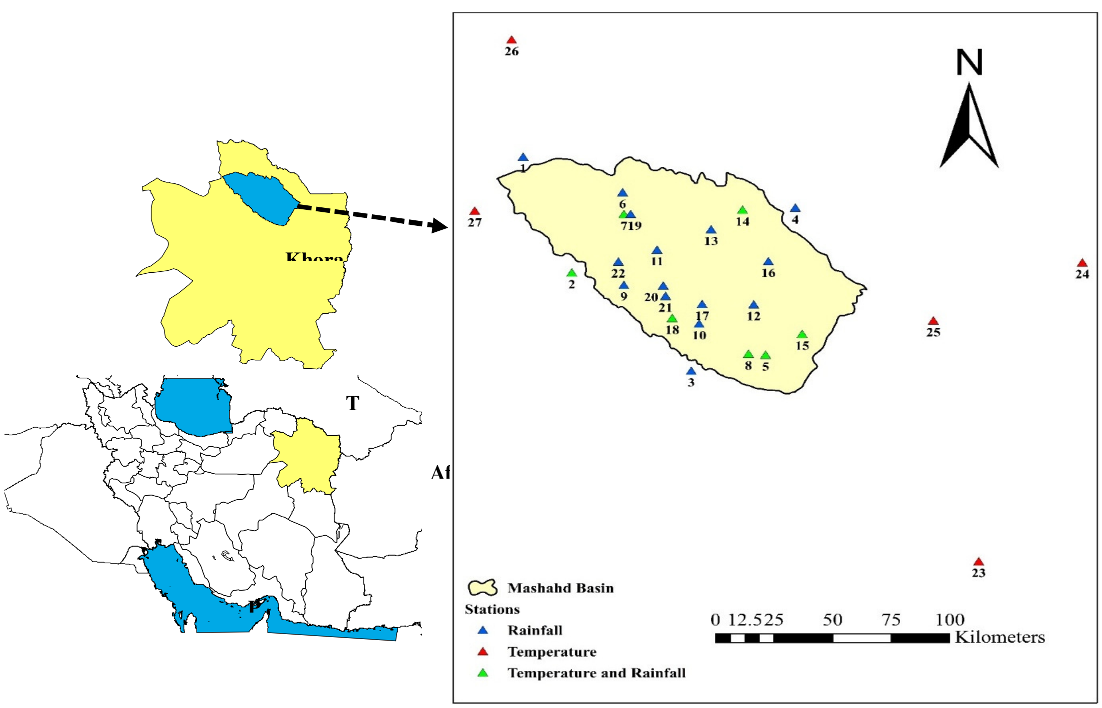

Fig. 1. Location of Mashhad basin including stations, Khorasan Razavi Province, Iran.

Since 1968, due to the extreme decline in water level, Mashhad plain was known as a prohibited plain (Akbari *et al* 2009, in Persian).

Monthly temperature and precipitation were analyzed for the period of 1986-2012. Geographic characteristics and data availability of the study stations was shown in Table 1. In order to evaluate the land-use changes impacts on temperature variability, two land use maps (1987 and 2013) created via Landsat TM images were analyzed.

Table 1: Geographic characteristics and data availability of the stations used in the study (stations inside the watershed with bold font).

Stations	Number of Stations	Longitude (E)	Latitude (N)	Data Availability
Ghochan	1	58° 30´	37° 04´	Rainfall
Bar	2	58° 42´	36° 27´	Temperature and Rainfall
DizBad	3	59° 16´	36° 6´	Rainfall
GhareTikan	4	60° 11´	36° 48	Rainfall
Mashhad	5	59° 8´	36° 16´	Temperature and Rainfall
BahmanJan	6	58° 58´	36° 54´	Rainfall
Ghadir Abad	7	58° 58´	36° 48´	Temperature and Rainfall
Torogh Dam	8	59° 33´	36° 10´	Temperature and Rainfall
Abghand	9	59° 27´	36° 45´	Rainfall
Jaghrogh	10	59° 19´	36° 18´	Rainfall
Chenaran	11	59° 07´	36° 38´	Rainfall
Balghor	12	58° 36´	36° 50´	Rainfall
Ardak	13	59° 23´	36° 43´	Rainfall
Marshak	14	52° 32´	36° 48´	Temperature and Rainfall
Olang	15	59° 48´	36° 15´	Temperature and Rainfall
Androkh	16	59° 39´	36° 34´	Rainfall
Sar Asiab	17	59° 20´	36° 23´	Rainfall
Zoshk	18	59° 11´	36° 20´	Temperature and Rainfall
Radkan	19	59° 00´	36° 48´	Rainfall
Golmakan	20	59° 9´	36° 29´	Rainfall
Dovlat Abad	21	59° 10´	36° 26´	Rainfall
Akhlamad	22	58° 56´	36° 35´	Rainfall
Baghsangan	23	60° 36´	35° 15´	Temperature

B. Methodology

Spearman method was used to detect the trend in monthly precipitation and temperature. Both Mann-Kendall and Spearman methods were applied to investigate the trend of annual T_{max}, T_{min}, annual maximum and annual total rainfall. For attribution analysis of trends to land use changes, Landsat TM images from 1987 and 2013 were used.

C. The Spearman's Rho (SR) Test

SR test is used to investigate the absence of trends in time series (Dahmen and Hall. 1990; Tonkaz *et al* 2007). In this method, for data sets of $\{X_i, i = 1, 2, \ldots n\}$, the null hypothesis (H0) is assumed that all data have the same distribution and are independent (Yue *et al* 2002). Standardized statistics (Z_{SR}) is defined as equation (1)

$$Z_{SR} = D\sqrt{\frac{n-2}{1-D^2}} \quad \ldots(1)$$

Where R_i is the rank of ith observation, i is the chronological order number and n is the length of the time series data. D in The Spearman's Rho (SR) Test is defined as equation (2)

$$D = 1 - \frac{6\sum_{i=1}^{n}(R_i - i)^2}{n(n^2-1)} \quad \ldots(2)$$

Positive Values of Z_{SR} show an increasing trend, whereas negative values represent descending trends in the time series. The critical value of t for 5 % significant level is defined as $t_{((n-2,1-\alpha/2)}$, from the t-student table (Dahmen and Hall. 1990). When $|Z_{SR}| > t_{((n-2,1-\alpha/2)}$, the null hypothesis ($H_0$) is rejected and a significant trend exists in the time series.

D. Mann-Kendall Test

This test was developed by Mann (1945) and Kendal (1975) as a rank non-parametric test for detecting linear and non-linear trends. In this test the alternative (Ha) and null hypotheses (Ho) are equal to the existence and non-existence of a trend in the time series, respectively. Equations (3), (4), (5) and (6) are the equations related to Mann-Kendall test statistic S and the standardized test statistic ZMK.

$$S = \sum_{i-1}^{n-1}\sum_{j=i+1}^{n} sgn(X_j - X_i) \ldots(3)$$

$$sgn(X_j - X_i) = \begin{cases} +1 & if \ (X_j - X_i) > 0 \\ 0 & if \ (X_j - X_i) = 0 \\ -1 & if \ (X_j - X_i) < 0 \end{cases} \ldots(4)$$

$$Var\,(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad ...(5)$$

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if \quad S>0 \\ 0 & if \quad S=0 \\ \frac{S+1}{\sqrt{Var(S)}} & if \quad S<0 \end{cases} \quad ...(6)$$

Where X_i and X_j are the sequential data values of the time series in the years I and j, n is the length of time series, tp is the number of ties for the pth value, and q is the number of tied values. Negative ZMK values present decreasing trends, while positive values of ZMK indicate increasing trends in the time series. When |Z_MK |>$Z_{(1-\alpha/2)}$, the null hypothesis is rejected and a significant trend exists in the time series. The value of $Z_{(1-\alpha/2)}$ which is the critical value of Z from the standard normal table, is 1.96 for 5% significant level (Shadmani *et al* 2012).

RESULTS AND DISCUSSION

A. Monthly Analysis

According to the results, monthly precipitation had a mixture of increasing and decreasing significant trend, however trend detection in monthly temperature showed only increasing statistically significant trend. The trend tests in monthly precipitation indicated no statistically significant trends in the months of April, March, September and December. At Androkh station an increasing trend were observed only in July and a decreasing trend during the months of January, February and March. A statistically significant decreasing trend was observed in Radkan and Ghadirabad stations during the months of October and August. Increasing in precipitation trends in arid and semi-arid area such as Mashhad basin may increase floods frequency. Decreasing trend in precipitation may lead to water scarcity and drought. Fig. 2 shows the spatial distribution of monthly rainfall trends in Mashhad basin during the period of 1986-2012. The trend analysis in monthly temperature showed no statistically significant trends in the months of January, November and December for the study stations. All the study stations had statistically significant increasing trend in the month of April. Fig. 3 shows the spatial distribution of monthly temperature trends.

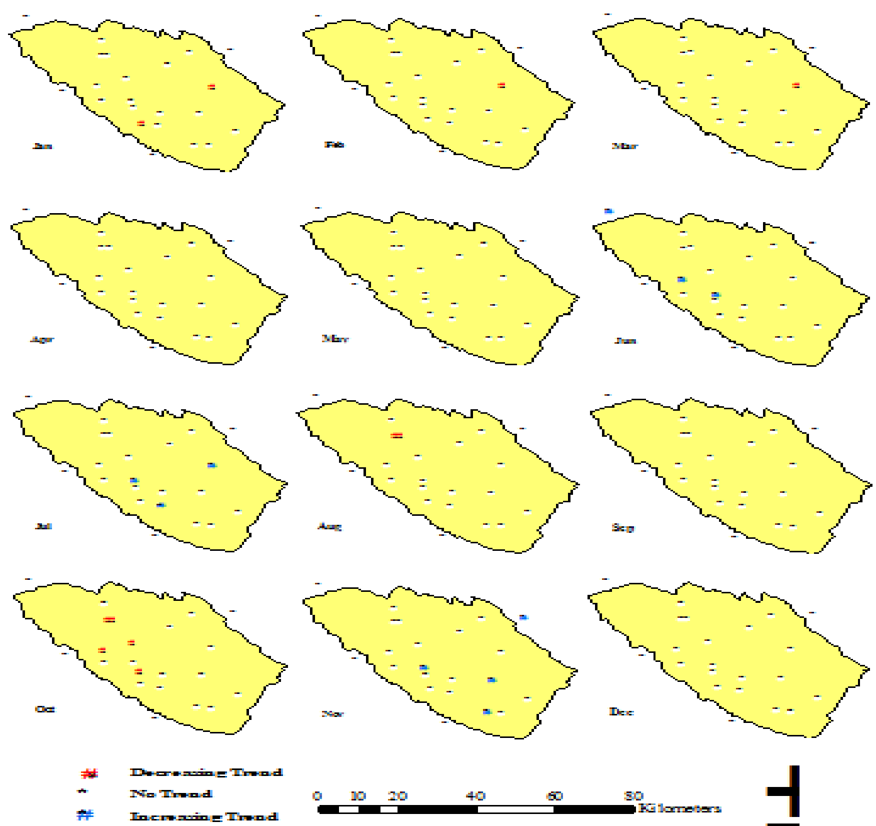

Fig. 2. Location of sites with decreasing, increasing, and no statistically significant trends at 5% level for the monthly precipitation time series for the period 1986 to 2012.

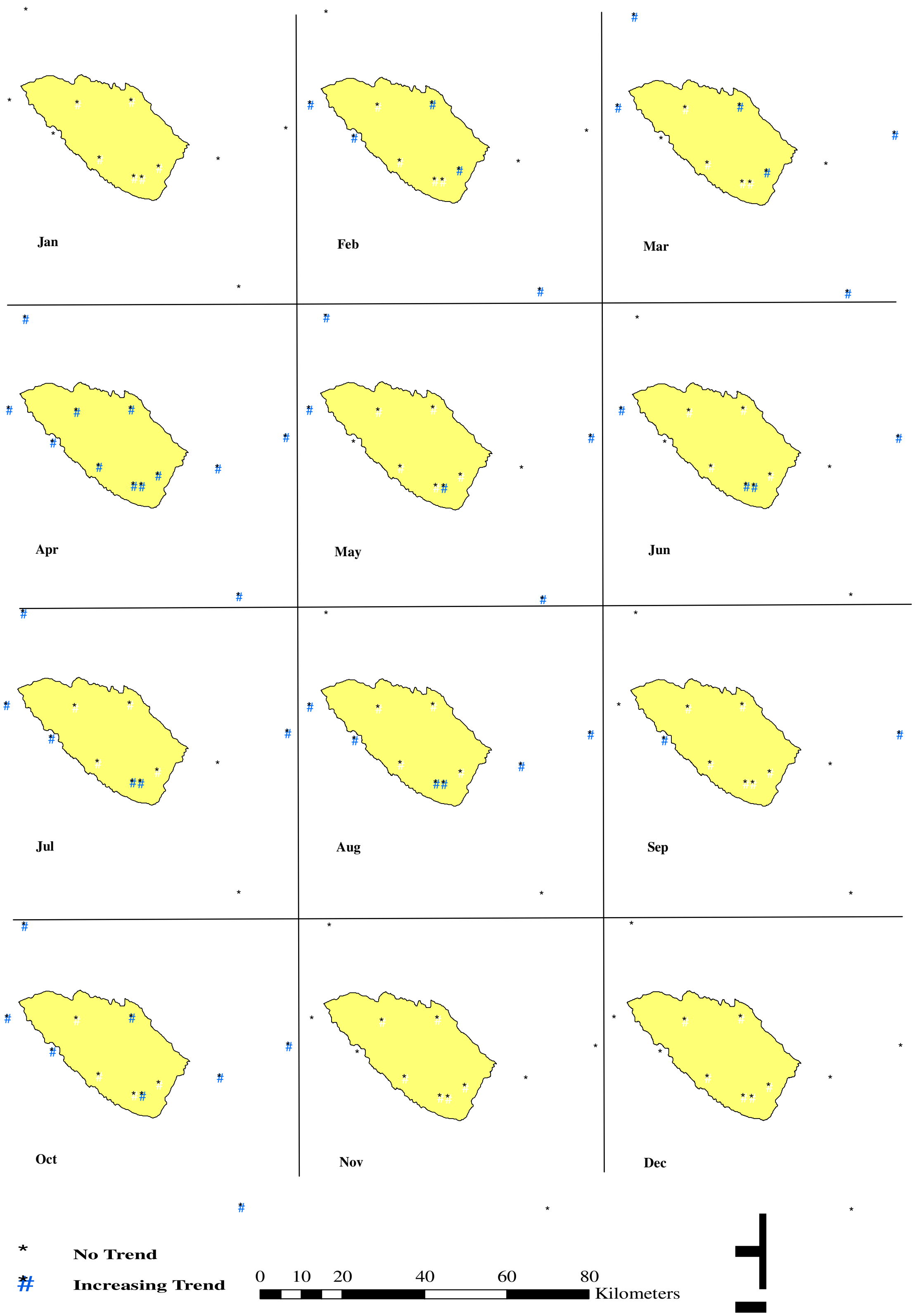

Fig. 3. Location of sites with increasing and no statistically significant trends at 5% level for the monthly temperature time series.

B. Annual Analysis

The existing of trends in the annual rainfall and annual maximum rainfall, annual T_{max} and T_{min} over the study period were examined via SR test. A statistically significant decreasing trend in annual rainfall was observed in Olang and Androkh stations and no significant trend exhibited for other station (Fig. 4). Except Androkh station, no statistically significant trend was observed in annual maximum rainfall (Fig. 5).

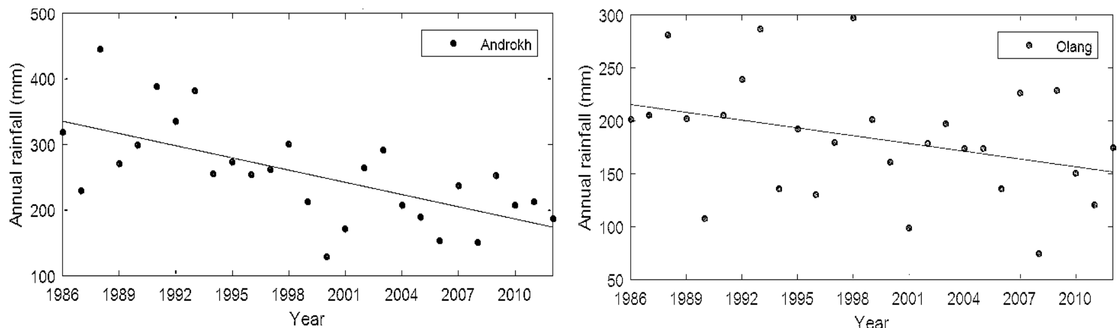

Fig. 4. Stations with statistically significant decreasing trends in annual precipitation for the period of 1986-2012.

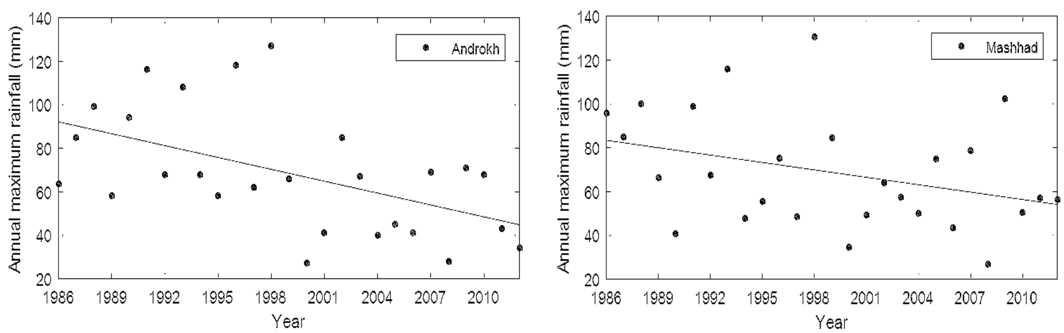

Fig. 5. Trends in annual maximum precipitation with statistically significant decreasing (Androkh) and non-significant decreasing (Mashhad).

The results of both Mann-Kendall and Spearman´s tests for annual maximum rainfall and annual total rainfall were similar and provided in Tables 2 and 3, respectively. According to SR test, all study stations (12 stations) were dominated by positive increasing trend in annual maximum temperature. However, among the study stations, Mashhad, Torogh Dam, Bar, Sarakhs, Yengeje and Shamkhal stations exhibited a significant increasing trend in annual T_{max} during the study period (Fig. 6). The positive significant trends of annual T_{max} was also showed by Tabari and Hosseinzadeh Talaee (2001)in arid and semi-arid area of Iran Turkes and Sumer(2004) in Turkey, and Smadi (2006) in Jordan. A trend detection in annual T_{max} was also reported by other researches in Iran (Tabari and Hosseinzadeh Talaee. 2011; Soltani and Soltani. 2008). Except Yengeje station, no significant trend was observed in annual T_{min}. The comparison between detected trends in T_{max} and T_{min} series exhibited very stronger warming trends in T_{max} compared with T_{min} time series. This variation in temperature trends may lead to more evapotranspiration and water related disaster like droughts.

The results of Mann-Kendall and Spearman´s tests for annual maximum temperature and annual minimum temperature are similar. Tables 4 and 5 provide the results of both tests for annual maximum and minimum temperature respectively.

C. Land-Use/Cover analysis

Land-use maps (1986 and 2013) were created using remote sensing method and satellite images of Landsat TM (Fig. 7). Land cover/ use classification was performed using supervised classification method with the maximum likelihood algorithm in ERDAS 9.3 imagine software. The delineated classes on the basis of supervised classification were bare soil, irrigation farming, rain-fed farming, orchard, outcrop, rangeland, residential and water body classes.

Table 2: Comparison of Mann-Kendall and Spearman´s test results for annual maximum rainfall.

	Spearman´s test results			Mann-Kendall test results	
Station	**Spearman's ρ**	**P-value**	**Hypothesis**	**P-value**	**Hypothesis**
Ghochan	0.1618	0.4184	H_o	0.4530	H_o
Bar	0.0360	0.8586	H_o	0.9005	H_o
DizBad	0.0644	0.7496	H_o	0.7230	H_o
GhareTikan	0.0440	0.8276	H_o	0.8840	H_o
Mashhad	-0.3126	0.1126	H_o	0.1563	H_o
BahmanJan	0.1404	0.4848	H_o	0.6316	H_o
GhadirAbad	-0.0339	0.8667	H_o	0.8186	H_o
Torogh Dam	-0.2863	0.1474	H_o	0.1334	H_o
Abghand	-0.0095	0.9626	H_o	0.9834	H_o
Jaghrogh	-0.0950	0.6375	H_o	0.6465	H_o
Chenaran	0.1169	0.5613	H_o	0.6465	H_o
Balghor	0.0232	0.9085	H_o	0.8675	H_o
Ardak	-0.0956	0.6352	H_o	0.6316	H_o
Marshak	-0.0095	0.9626	H_o	0.9667	H_o
Olang	-0.3381	0.0846	H_o	0.0635	H_o
Androkh	-0.4657	0.0144	H_a	0.0302	H_a
SarAsiab	-0.1274	0.5267	H_o	0.5878	H_o
Zoshk	-0.0406	0.8406	H_o	0.8675	H_o
Radkan	0.0846	0.6749	H_o	0.6767	H_o
Golmakan	-0.0098	0.9614	H_o	1.0000	H_o
Dovlat Abad	-0.1319	0.5120	H_o	0.4656	H_o
Akhlamad	-0.0171	0.9325	H_o	1.0000	H_o

Table 3: Comparison of Mann-Kendall and Spearman´s results for annual total rainfall.

	Spearman´s test results			Mann-Kendall test results	
Station	**Spearman's ρ**	**P-value**	**Hypothesis**	**P-value**	**Hypothesis**
Ghochan	0.2106	0.2903	H_o	0.3376	H_o
Bar	-0.0928	0.6441	H_o	0.5878	H_o
DizBad	0.0836	0.6773	H_o	0.7704	H_o
GhareTikan	0.0488	0.8087	H_o	0.6767	H_o
Mashhad	-0.2082	0.2960	H_o	0.4785	H_o
BahmanJan	0.1774	0.3761	H_o	0.3700	H_o
GhadirAbad	-0.1740	0.3837	H_o	0.4283	H_o
Torogh Dam	-0.0824	0.6818	H_o	0.6767	H_o
Abghand	0.0446	0.8253	H_o	0.8675	H_o
Jaghrogh	-0.1056	0.5987	H_o	0.6767	H_o
Chenaran	-0.2625	0.1853	H_o	0.1821	H_o
Balghor	-0.0864	0.6683	H_o	0.5181	H_o
Ardak	-0.1597	0.4263	H_o	0.4162	H_o
Marshak	-0.2155	0.2790	H_o	0.2603	H_o
Olang	-0.3848	0.0475	H_a	0.0635	H_a
Androkh	-0.6880	0.0001	H_a	0.0004	H_a
SarAsiab	-0.1441	0.4717	H_o	0.5047	H_o
Zoshk	-0.2924	0.1387	H_o	0.1039	H_o
Radkan	-0.1298	0.5189	H_o	0.5735	H_o
Golmakan	0.1008	0.6170	H_o	0.6767	H_o
Dovlat Abad	-0.3384	0.0843	H_o	0.0836	H_o
Akhlamad	-0.0549	0.7851	H_o	0.8675	H_o

Table 4: Comparison of Mann-Kendall and Spearman´s results for annual maximum temperature.

	Spearman´s test results			Mann-Kendall test results	
Station	**Spearman's ρ**	**P-value**	**Hypothesis**	**P-value**	**Hypothesis**
Mashhad	0.5170	0.0058	H_a	0.0139	H_a
Ghadir Abad	0.1799	0.3692	H_o	0.2973	H_o
Marshak	0.2230	0.2636	H_o	0.3272	H_o
Olang	0.1496	0.4548	H_o	0.5047	H_o
Torogh Dam	0.5488	0.0030	H_a	0.0043	H_a
Baghsangan	0.1759	0.3801	H_o	0.3482	H_o
Zoshk	0.1484	0.4601	H_o	0.5317	H_o
Sarakhs	0.8565	0.0000	H_a	0.0000	H_a
Bar	0.6209	0.0007	H_a	0.0005	H_a
Yengeje	0.5159	0.0065	H_a	0.0040	H_a
Bazangan	0.1453	0.4694	H_o	0.5735	H_o
Shamkhal	0.5501	0.0030	H_a	0.0049	H_a

Table 5: Comparison of Mann-Kendall and Spearman´s results for annual minimum temperature.

	Spearman´s Results			Mann-Kendall Results	
Station	**Spearman's ρ**	**P-value**	**Hypothesis**	**P-value**	**Hypothesis**
Mashhad	0.1835	0.3595	H_o	0.3813	H_o
Ghadir Abad	0.1181	0.5572	H_o	0.6022	H_o
Marshak	0.3596	0.0661	H_o	0.0799	H_o
Olang	0.1746	0.3821	H_o	0.4283	H_o
Torogh Dam	0.0244	0.9037	H_o	0.9005	H_o
Baghsangan	0.2177	0.2754	H_o	0.2516	H_o
Zoshk	0.1496	0.4564	H_o	0.3927	H_o
Sarakhs	0.0269	0.8946	H_o	0.7387	H_o
Bar	0.2665	0.1790	H_o	0.1503	H_o
Yengeje	0.4548	0.0181	H_a	0.0271	H_a
Bazangan	0.0754	0.7084	H_o	0.5317	H_o
Shamkhal	0.0804	0.6903	H_o	0.8512	H_o

Table 6: Area and amount of change in different land use/cover classes of study area during 1987 to 2013.

Land use/cover type	1987		2013		Change (1987-2013)	
	Area (Km^2)	**Percent of total area (%)**	**Area (Km^2)**	**Percent of total area (%)**	**Area (Km^2)**	**Percent of total area (%)**
Rangeland	5331.52	53.803	4504.67	45.46	-826.85	-8.34
Bare soil	69.67	0.703	185.58	1.87	115.92	1.17
Residential	509.85	5.145	831.26	8.39	321.41	3.24
Outcrop	69.73	0.704	69.73	0.704	0.00	0.00
Irrigation Farming	867.46	8.754	1260.49	12.72	393.03	3.97
Rain-Fed Farming	2983.06	30.104	2824.52	28.50	-158.54	-1.60
Orchard	77.65	0.784	229.87	2.32	152.21	1.54
Water body	0.39	0.004	3.21	0.032	2.83	0.028
Total	9909.34	100	9909.34	100	0.00	0.00

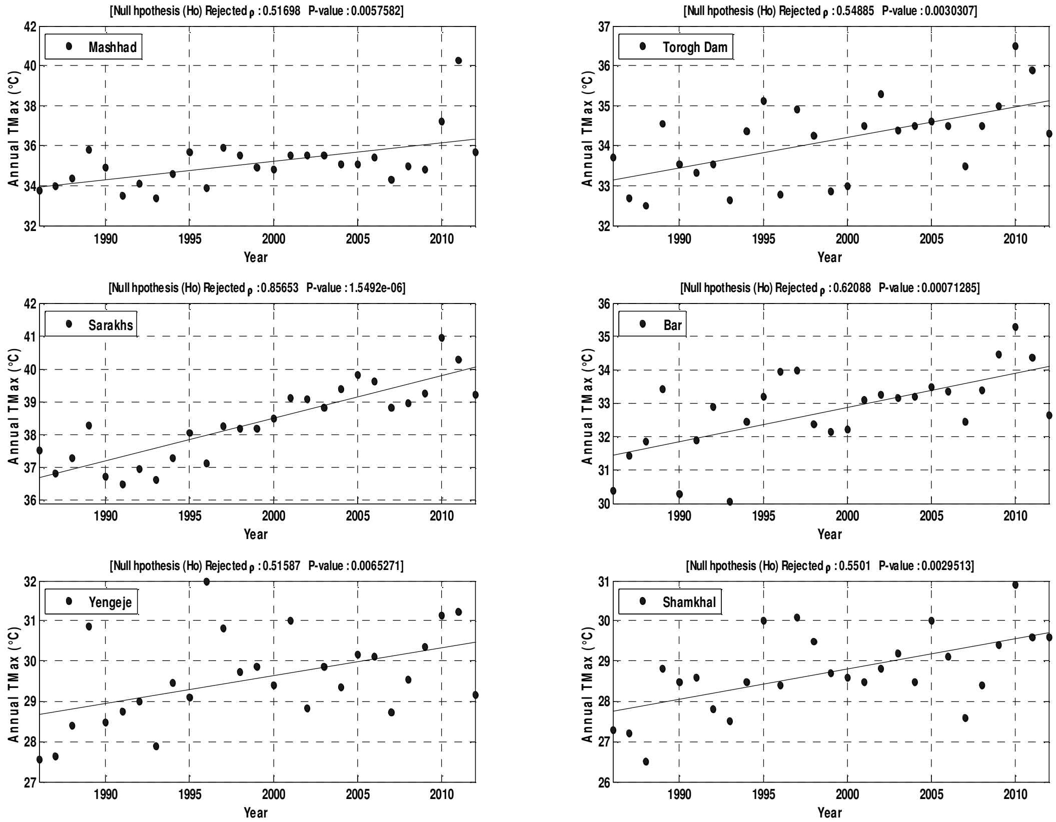

Fig. 6. Stations with the statistically significant increasing trends in annual maximum temperature during the study period.

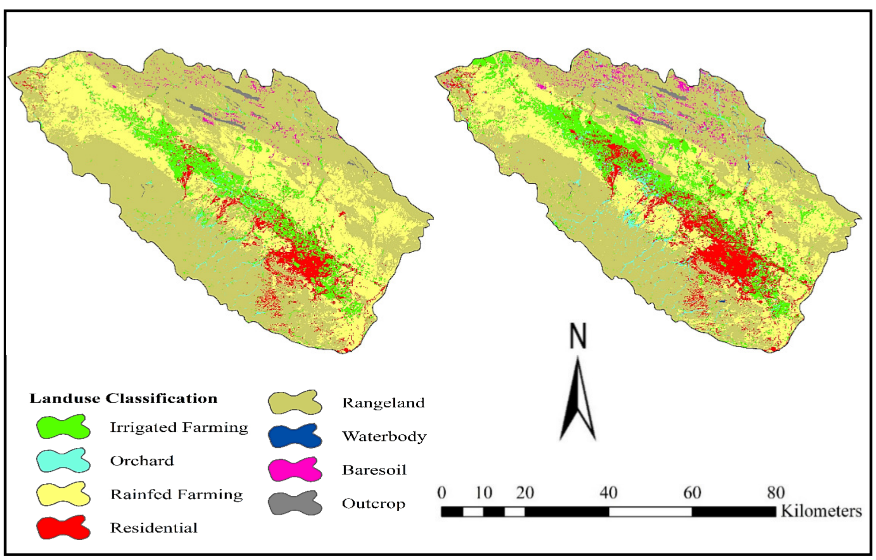

Fig. 7. Land-Use maps of the study area for period: 1987 (left), 2013 (right).

To assess the accuracy of classification, Kappa coefficient and Overall accuracy were used. According to results, residential area was increased by 321.41 km^2 from 1987 to 2013. The area that have experienced urbanization (such as Mashhad and Sarakhs stations) are associated with significant increasing trend in annual maximum temperature (Fig. 6).

We can conclude that this change should lead to higher temperature in the study area. Fang *et al* (2014) found that increasing temperature due to urbanization depends on economic level, population and geographical region of the city. Mashhad is the secondary mega city of Iran, which is different in many ways from other cities of study area. Urbanization and manufacturing developed around Mashhad station. These changes in residential area would affect the climate of Mashhad city. Other researches such as Hale *et al* (2008), Artfield (2003); Fall *et al* (2009); Zhou *et al* 2004; and Hua *et al* (2008) indicate that urbanization should increase temperature. According to results, irrigation farm land increased by 393 km^2, whereas rangeland area decreased by 826.85 km^2. Such land use change could influence groundwater recharge and surface runoff. Land use/cover in the study area during 1987 to 2013 was shown in Table 6. According to results, some parts of rangeland area convert to bare soil which is showed losing in vegetated area and creating desert area in this basin. Changing from vegetated area to bare soils generally leads to surface warming in area which were vegetated. Climate variability in terms of temperature and precipitation variation is known to be related to albedo modifications (Sarma *et al* 2001). Fall *et al* (2009) showed that shifting from vegetated area to bare land should increase air temperature. Sarma *et al* (2001) in east coast of India found that increase in vegetation cover tend to absorb heat, consequently temperature will decrease.

CONCLUSIONS

Trends in temperature and precipitation, also variations in land-use change were analyzed in an arid and semi-arid region of Iran. The results revealed increasing and decreasing trends in precipitation at different temporal scales, whereas only increasing trend in temperature were found at a monthly time scale. A positive significant trends in annual T_{max} at Mashhad, Torogh, Bar, Sarakhs, Yengeje and Shamkhal stations were observed ($P< 0.05$). According to results, increasing in T_{max} were more notable than those in T_{min} time series. Results of land use change detection analysis showed an increase in agricultural irrigated land and residential (especially due to urbanization), whereas rangeland area was decreased significantly. As a result of urbanization in the study area, increasing trends in annual T_{max} were noted in the stations located in the area that experienced more urbanization development. Results indicated that some parts of vegetated area that were converted to bare land have led to increase in temperature in the area.

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