Pol. J. Environ. Stud. Vol. 32, No. 1 (2023), 705-716
DOI: *10.15244/pjoes/151988* ONLINE PUBLICATION DATE: 2022-12-19

Original Research

Climate Change and Water Crisis (Case Study, Mashhad in Northeastern Iran)

Rostam Saberifar*

Associate Professor, Department of Geography, Payame Noor University, Tehran, 43183-14556, Iran

Received: 29 April 2022
Accepted: 8 July 2022

Abstract

This study evaluates the situation of climate change in the metropolis of Mashhad. The data required for this study were obtained from the available documents, especially the meteorological station of Mashhad, and the research method was descriptive and analytical. The findings of this study indicate that showed significant changes in the average of all three temperatures in Mashhad station. So we can assume the intensification of temperature rise is due to the formation of the heat island phenomenon in Mashhad. Heat penalties not only affect energy consumption and increase emissions but also have other abnormal consequences. The study of the relationship between temperature changes and rainfall in the city of Mashhad with economic, environmental, and other indicators shows that almost all the indicators have decreased sharply with decreasing rainfall and increasing temperature. Specifically, the amount of investment in the tourism sector has decreased by almost 30%. Meanwhile, about 50% of the income and employment of this city is provided by the tourism industry. In particular, a comparison of the two climatic elements of temperature and precipitation shows that the region has been ruled by drought since 1993, which is still ongoing. Given these changes, four key risks can be prioritized for this city: Severe evaporation in the area; Occurrence of severe floods; Increased energy demand in hot seasons; and Fundamental change in the efficiency of energy production and consumption equipment. Increased investment in protection infrastructure (especially in the case of floods, recently intensified due to flash floods); transportation (the extreme sub- urbanism of the people due to the increase of pollutants in the built-up areas); health and medical facilities and equipment and the provision of green space, etc., are among the other consequences attributed to the climate change that has occurred in this city.

Keywords: climate change, water crisis, drinking water, Mann-Kendall method, Mashhad

*e-mail: r_saberifar@pnu.ac.ir

Introduction

Temperature and precipitation changes are among the elements considered in the process of climate change and emphasized in the field of environmental sciences. Because climate change has led to many scientific and practical challenges (environmental, socio-economic effects), it has been of significant importance, and climate-dependent human systems such as agriculture, industry, etc., are considered based on climate stability [1]. The new field of climate change is a realm that deals with climate and how it changes and fluctuates in statistical periods or different geological periods. Climate change is a complex atmospheric-oceanic phenomenon whose causes are divided into cosmic and terrestrial categories [2-3]. According to one of the existing theories, part of climate change in statistical periods is related to excessive human activities, especially in industries, and increasing greenhouse gases.

During the twentieth century, the amount of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrogen dioxide (NO_2) significantly increased in the atmosphere, according to which up to 5 to 6.2 billion tons of carbon dioxide enters the atmosphere annually [4-5]. According to forecasts by the Intergovernmental Panel on Climate Change (IPCC), carbon dioxide will increase from 3.1 billion tonnes in 1985 to 4.7 billion tonnes in 2025 due to population growth and increasing human energy needs [6]. Severe climate change is the main consequence of such a trend. This process itself has substantial human and economic consequences, one of the most important of which is the emergence of fundamental bottlenecks related to livelihood and basic needs of life. Hence, climate change is regarded as one of the most complex problems that human beings will face in the present and future. As in recent years (2000-2017), we have seen that many industrial plants and polluting activities have started operating in and around major cities, paving the way for significant air pollution and climate change [7]. This phenomenon, which is itself the result of changes, taken place in atmospheric processes and leading to global warming, is one of the primary challenges of modern man because climate change has important effects and consequences on the life cycle, especially hydrology. As a small example of the effects of climate change, we can mention the reduction or decline in resources and consumption of drinking and agricultural water [8-9]. Of course, the increase in temperature at the Earth's surface will not be uniform, but the increase in temperature of the middle and upper latitudes of the Earth is predicted to double compared to the tropics [6]. In general, consequences such as drought, flash floods, and hot and cold airwaves are among the effects and evidence of climatic anomalies facing the planet with various crises [8-9].

Iran has an arid and semi-arid climate due to its location in the Old World drought belt and its proximity to subtropical hypertension. As a result, it has experienced severe droughts over the years. The scarcity of water and its periodic changes are not related to the recent period and have apparently, raised since the beginning of history. As a proof of this claim, we can refer to the rain-seeking rituals that have a history of seven thousand years in Iran [10-11]. This situation is especially important in some areas facing more severe droughts and pressured by the environmental and natural conditions due to demographic and industrial changes. Accordingly, knowledge of the current and future climatic conditions in Iran and particularly the industrial metropolis of Mashhad, which has recently faced major problems in drinking water supply and land subsidence, is necessary. Hence, there have been several studies in this field, among which we can mention the research of Khordadi et al. (2017) [6]. The meteorological variables were examined from 1951 to 2005 using three methods of statistical tests: condenser, cumulative deviation, and trend regression analysis by monthly examination of the trend of changing four meteorological parameters of temperature, relative humidity, wind speed, and rainfall. The results of this study showed that the temperature parameter and the relative humidity had an increasing and a decreasing trend, relatively, in Mashhad. This trend means a reduction in water resources and exacerbation of the current problems, indicating changes in the flow of meteorological parameters, significant changes in water resources, energy demand, agricultural production, etc. As a result, climate studies, especially climate change research, can enable managers and planners to implement various programs to combat and reduce the devastating effects of this phenomenon and improve the current situation. For this purpose, this study tried to examine the temporal changes of temperature, rain, and humidity in the city of Mashhad.

Material and Methods

Mashhad is the center of the city of the same name. The city is located at 59 degrees and 15 minutes to 60 degrees and 36 minutes of longitude and 35 degrees and 43 minutes to 37 degrees and 37 minutes of latitude. It has an area of 350 square kilometers and accommodates almost 60% of the population of Khorasan province. The city of Mashhad, with a population of 3.25 million in 2020, is the second metropolis of Iran, located in northeastern Iran, between the Hezarmasjed mountain range in the north and Binalood in the south (Fig. 1). The climate of Mashhad is semi-arid, according to the Domarten method [12].

Various methods have been used in connection with climate change and trends in this area. For example, trend analysis is one of the most important statistical methods widely used to evaluate the potential effects of climate change on time series such as temperature, precipitation, river flow, etc., in different parts of

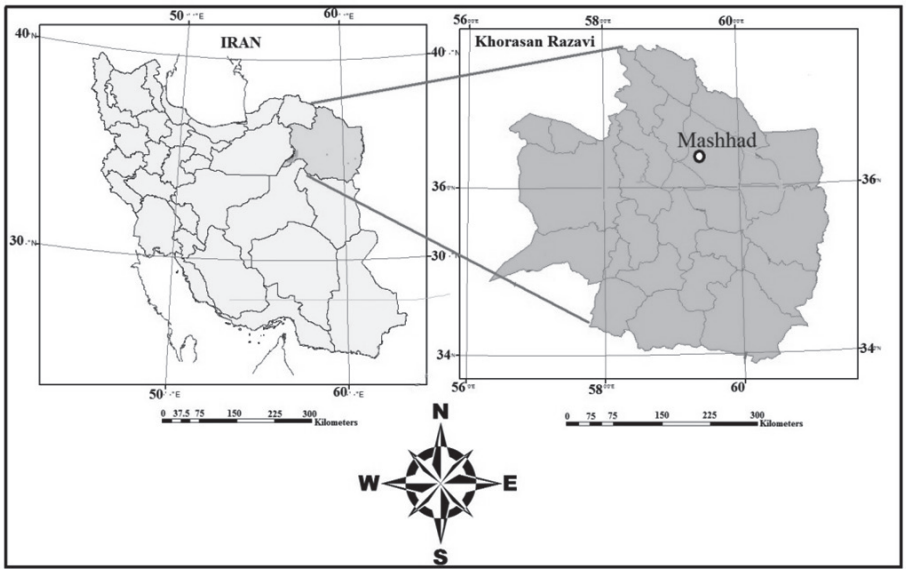

Fig. 1. Location of Mashhad city.

the world [13]. Proving the existence of a significant trend in a rainfall time series alone cannot be a conclusive reason for the occurrence of climate change in an area, but rather strengthens the assumption of its occurrence. This feature is associated with numerous factors controlling the climate system.

It is more appropriate to use non-parametric methods for series with no fitting of specific statistical distributions or significant skewness or elongation. Mann-Kendall test is one of the most common and widely used non-parametric methods of time series trend analysis. It is possible to identify data changed and determine their type and time using the Mann-Kendall method. This research, conducted in connection with this field, is descriptive-analytical in terms of implementation method and practical in terms of objectives.

The Mann-Kendall test examined and determined the trends to obtain accurate and scientific results. This test, first proposed by the World Meteorological Organization in 1988, has had extensive applications in several studies [1-2, 14]. The test first ranks the data according to their value, assigning a score of 1 to the smallest data and continuing in ascending order. The next step rearranges the data by the year of occurrence.

According to the t_i statistic, the number of smaller ranks before the rank of each row, was placed in the next column. mathematical expectation, variance, and Men-Kendall index were calculated based on the following relationships [11]:

$$E_i = \frac{n_i(n_i-1)}{4}$$

$$V_i = \frac{n_i(n_i-1)(2n_i+5)}{72}$$

$$U_i = \frac{(\sum t_i - E_i)}{\sqrt{V_i}}$$

In the presented relations, n_i is the chronological order of the data. It is necessary to specify 'U' index to check for changes.

The steps for calculating 'U were as follows:

The data were ranked and this time the t_i statistic was considered equal to the number of smaller ranks after each row, and then the cumulative frequency of the t_i was calculated from the bottom to the top. Mathematical expectation, variance, and 'U index were calculated as follows [1]:

$$E_i' = \frac{[N-(n_i-1)](N-n_i)}{4}$$

$$V_i' = \frac{[N-(n_i-1)](N-n_i)\left[2\left(N-(n_i-1)\right)+5\right]}{72}$$

$$U_i' = \frac{(\sum t_i' - E_i')}{\sqrt{V_i'}}$$

The data required for this study were obtained from documentary sources, especially the recent 30-year data of the Mashhad Meteorological Station. This station is at longitude 59 and 38, latitude 36 and 16, and height 999/2 Meters above sea level.

The mentioned data were analyzed by Mann-Kendall statistical test after classification, summarization, and entering into the machine. The results of previous research and field observations were used to determine the reasons for the change in climatic elements and the consequences of these effects on the lives and livelihoods of residents of the metropolis of Mashhad. Since proving the occurrence of climate change phenomenon in the world is not easily possible, it seems necessary to prepare long-term and accurate atmospheric parameters [13] and determine the changes occurring in the conditions of the region. Hence, this study collected and evaluated various statistics

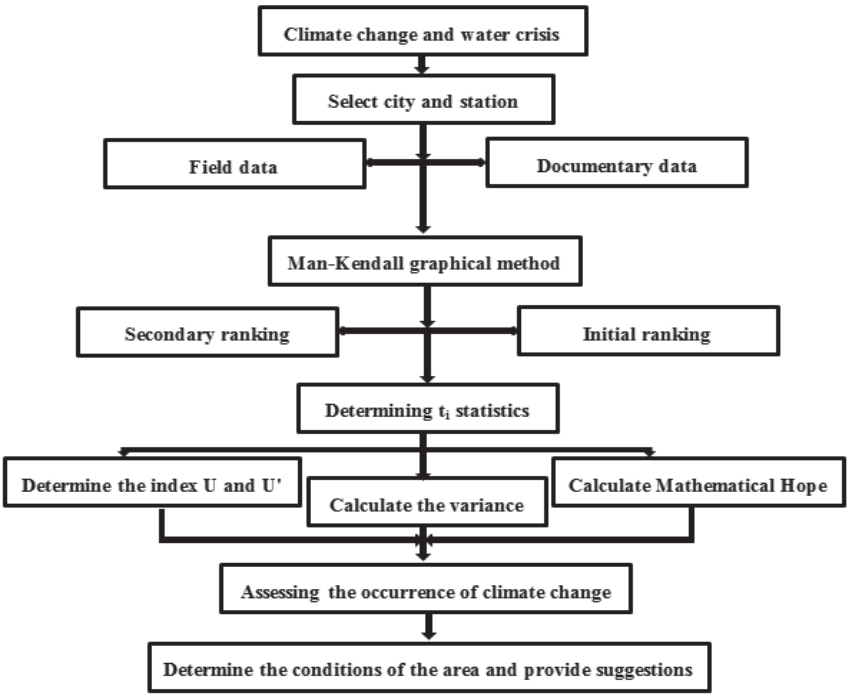

Fig. 2. Methodology flowchart.

and information to determine climate change in Mashhad. However, since these data did not determine research objectives, the study only focused on the annual statistics of rainfall, temperature, and relative humidity of Mashhad station in the statistical period of 1991-2020. Since the statistical period is long enough, there can certainly be no fundamental changes in the general climate unless the man manipulates the environment with his activities. Therefore, the main effort was to reveal the possible changes in the climate data using the Mann-Kendall graphical method and then provide the necessary suggestions for the future planning of the city.

Results and Discussion

Table 1 presents the calculations performed concerning the thermal situation of Mashhad for 30 years. Then, the relationships related to 'N, U' for the volume of a 30-year statistical sample were examined to obtain more tangible results. After calculating U and 'U and drawing the relevant graphs, it was possible to judge the presence or absence of trend in time series. The intersection of the U and 'U indices showed a sign of a sudden change in the time behavior of the statistical series. However, the non-intersection of the two curves or their placement within the 95% confidence interval indicated insignificant changes. If the lines intersected within the critical range of +1.96 and went out of the critical range, it would indicate a sudden change and a significant trend. For example, when the U-curve tends to be positive, the trend will be positive; otherwise, the trend will be negative. Intersections outside the critical range indicated a sudden change in the behavior of the series [14].

A review of Mashhad station data over 60 years shows that the average temperature in Mashhad has increased by 1.1 degrees Celsius. Due to the increase in temperature, the indices related to the maximum temperature faced a relative increase so that hot days, tropical nights, dry periods, heat waves, etc., have had an increasing trend. This study evaluated the meteorological data of Mashhad station in a shorter period of 30 years from 1991 to 2020 for scientific and statistical verification of these changes. Although the study examined all climatic elements, only some detailed results were provided due to space constraints.

The first part of this study assessed the temperature conditions in Mashhad. Hence, Mashhad temperature data were analyzed in three parts of minimum, maximum, and average temperature. An examination of u and u' values of the city's minimum annual temperature indicates that it experienced its first changes in 1992, indicating the intersection of these two curves. However, since the intersection is within the range of 1.97 (Fig. 3), this trend indicates that climate change has not occurred, and there is only an increasing trend in the minimum temperature. However, according to the extension of the two curves, climate change in this city seems quite probable, and since this intersection is outside the range of 1.97, such a change is inevitable.

Fig. 4 shows the changes for the U and U' curves. As it is evident from this figure, the intersection point was in 1992 for this important climatic element, and the

Table 1. Statistical calculations for one of the sample climatic elements (Mashhad average temperature).

Rank-ti	ti	Ei	Vi	Z ti	Ui-60	Rank-ti'	ti'	E'	V'	Z ti'	U'i-60	U	U'
3	0	0	0	0	0	0	0	0	0	0	0	-	-
1	0	0.5	0.25	0	-1	0	1	0.5	0.25	1	-1	1.96	-1.96
2	1	1.5	0.91667	1	-0.52223	0	2	1.5	0.91667	3	-1.5667	1.96	-1.96
8	3	3	2.16667	4	0.67937	0	3	3	2.16667	6	-2.0381	1.96	-1.96
5	3	5	4.16667	7	0.9798	0	4	5	4.16667	10	-2.44949	1.96	-1.96
6	4	7.5	7.08333	11	1.31507	0	5	7.5	7.08333	15	-2.81801	1.96	-1.96
7	5	10.5	11.0833	16	1.65207	0	6	10.5	11.0833	21	-3.15394	1.96	-1.96
22	7	14	16.3333	23	2.22692	0	7	14	16.3333	28	-3.4641	1.96	-1.96
11	7	18	23	30	2.50217	0	8	18	23	36	-3.75326	1.96	-1.96
19	8	22.5	31.25	38	2.77272	0	9	22.5	31.25	45	-4.02492	1.96	-1.96
28	10	27.5	41.25	48	3.19185	0	10	27.5	41.25	55	-4.28174	1.96	-1.96
15	8	33	53.1667	56	3.15434	0	11	33	53.1667	66	-4.52579	1.96	-1.96
16	9	39	67.1667	65	3.17246	0	12	39	67.1667	78	-4.75869	1.96	-1.96
13	8	45.5	83.4167	73	3.01097	0	13	45.5	83.4167	91	-4.98179	1.96	-1.96
17	11	52.5	102.083	84	3.11769	31	14	52.5	102.083	105	-5.19615	1.96	-1.96
25	14	60	123.333	98	3.42171	9	14	60	123.333	119	-5.31266	1.96	-1.96
4	3	68	147.333	101	2.71871	23	15	68	147.333	134	-5.43743	1.96	-1.96
27	16	76.5	174.25	117	3.06809	26	16	76.5	174.25	150	-5.56802	1.96	-1.96
14	10	85.5	204.25	127	2.9038	30	17	85.5	204.25	167	-5.70265	1.96	-1.96
21	15	95	237.5	142	3.04976	18	15	95	237.5	182	-5.64531	1.96	-1.96
10	8	105	274.167	150	2.71772	29	18	105	274.167	200	-5.73742	1.96	-1.96
24	18	115.5	314.417	168	2.96078	20	16	115.5	314.417	216	-5.66778	1.96	-1.96
12	10	126.5	358.417	178	2.72028	12	15	126.5	358.417	231	-5.51979	1.96	-1.96
20	17	138	406.333	195	2.8277	24	19	138	406.333	250	-5.55619	1.96	-1.96
29	24	150	458.333	219	3.22299	10	15	150	458.333	265	-5.37164	1.96	-1.96
18	16	162.5	514.583	235	3.19602	21	19	162.5	514.583	284	-5.3561	1.96	-1.96
30	26	175.5	575.25	261	3.56482	14	17	175.5	575.25	301	-5.23257	1.96	-1.96
26	23	189	640.5	284	3.75374	27	24	189	640.5	325	-5.37377	1.96	-1.96
23	21	203	710.5	305	3.82664	4	14	203	710.5	339	-5.10219	1.96	-1.96
9	8	217.5	785.417	313	3.40764	25	24	217.5	785.417	363	-5.19174	1.96	-1.96
31	30	232.5	865.417	343	3.75621	17	19	232.5	865.417	382	-5.08193	1.96	-1.96

intersection point is in the range of 1.97. Although it shows the increasing trend of the maximum temperature of Mashhad, climate change cannot be stated with certainty. However, the continuation of these trends and the intersection of two curves in 2020 will increase the likelihood of climate change in all dimensions in the long run. Most of the researchers indicate a dryer regime for the future in addition to lesser precipitation events, which is more evident in the warm season [15] indicating the changes inconsistent with global warming/climate change [16].

Fig. 5 shows that in general, the temperature in Mashhad has followed an increasing trend since 1992 similar to the maximum and minimum temperatures. However, since the intersection site is in the range of 1.97, this change does not seem significant. However, the continuation of the above trend indicates that this time the intersection will be in 2020 outside

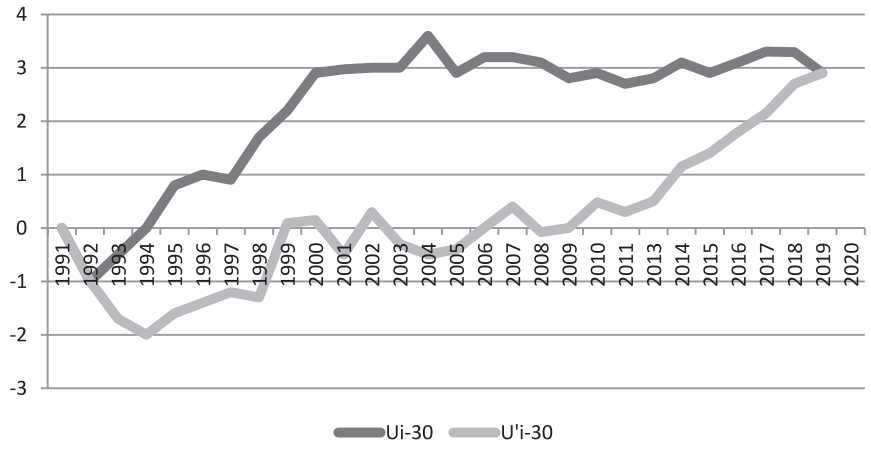

Fig. 3. Minimum temperature of Mashhad.

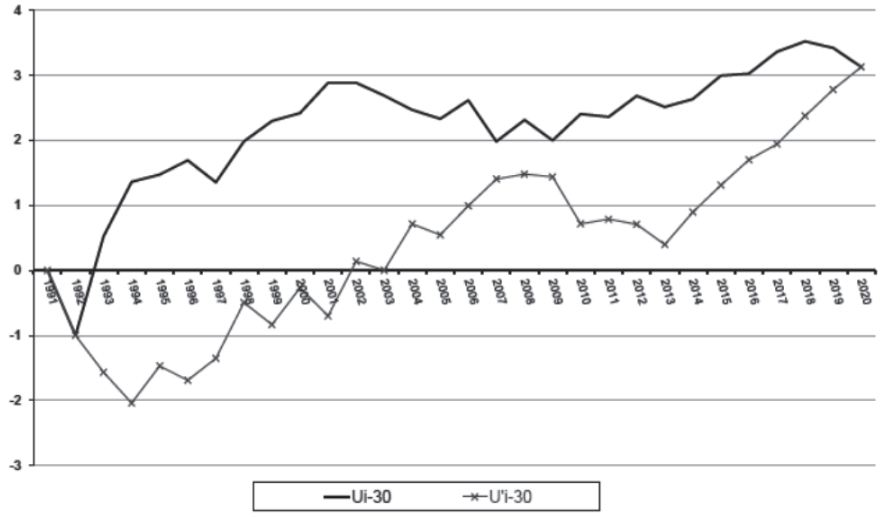

Fig. 4. Maximum temperature of Mashhad.

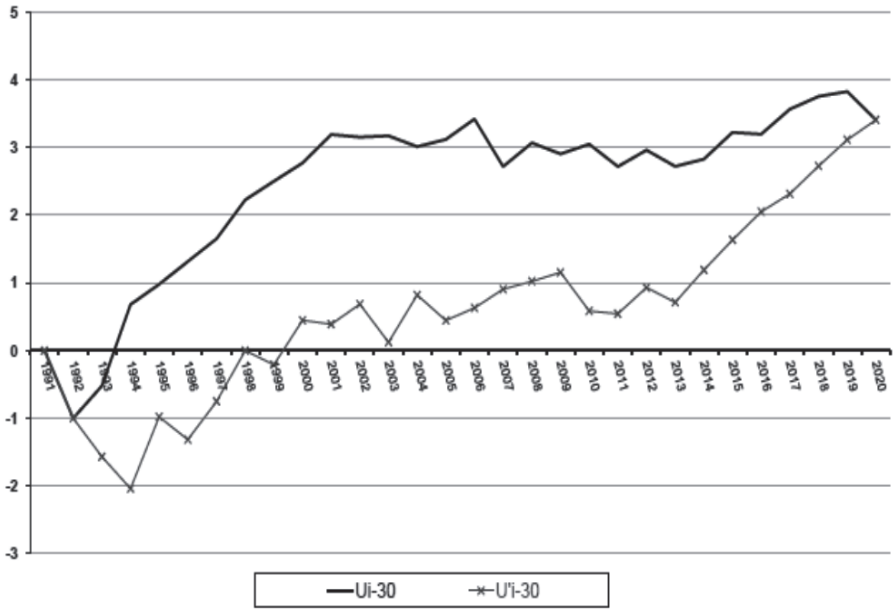

Fig. 5. Mashhad average temperature.

the mentioned area, and the changes will be significant. Precipitation was another factor examined in this study, showing significant fluctuations in the normal values of this factor.

According to Man Kendall's annual rainfall statistics, the first jump occurred in 1993. However, since the intersection site is in the range of 1.97, this change does not seem significant (Fig. 6). However, the trend of declining rainfall has continued during the period under review, and this time the intersection point is in 2020 when climate change cannot be taken in the short term for granted.

Relative humidity in Mashhad is 42% overall. A review of the presented statistics shows that the humidity was more than 50% during the statistical period under review for only four years, i.e., 1992, 1995, 1997, and 2003. According to the same statistics, the relative humidity in this city has experienced a decreasing trend since 2004 (Fig. 7). Given that the city of Mashhad is in a dry area and according to the values of u and 'u calculated for this city, Mashhad has faced a decreasing trend in time series concerning humidity in most years. Since the intersection of the two curves is outside the limit of 1.97 at the end of the period, climate change is possible.

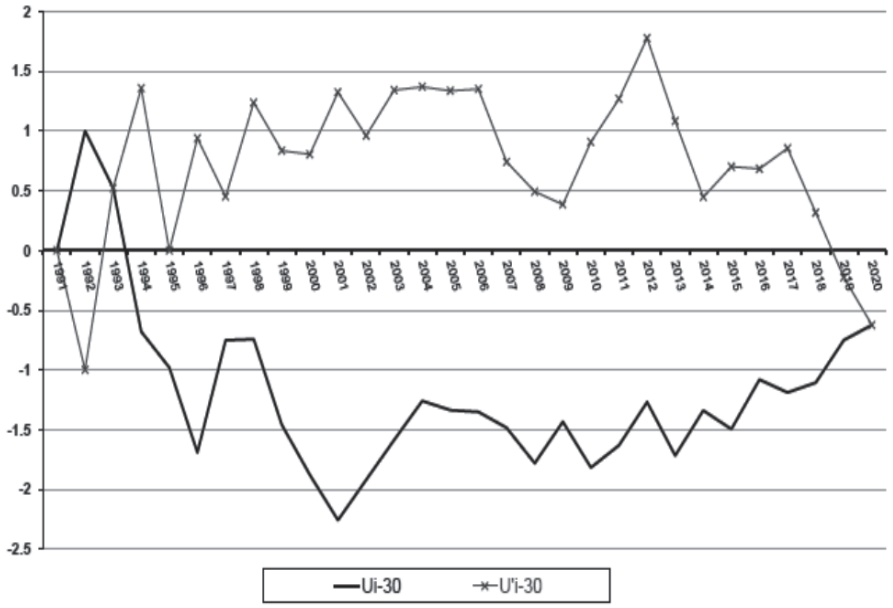

Fig. 6. Mashhad rainfall.

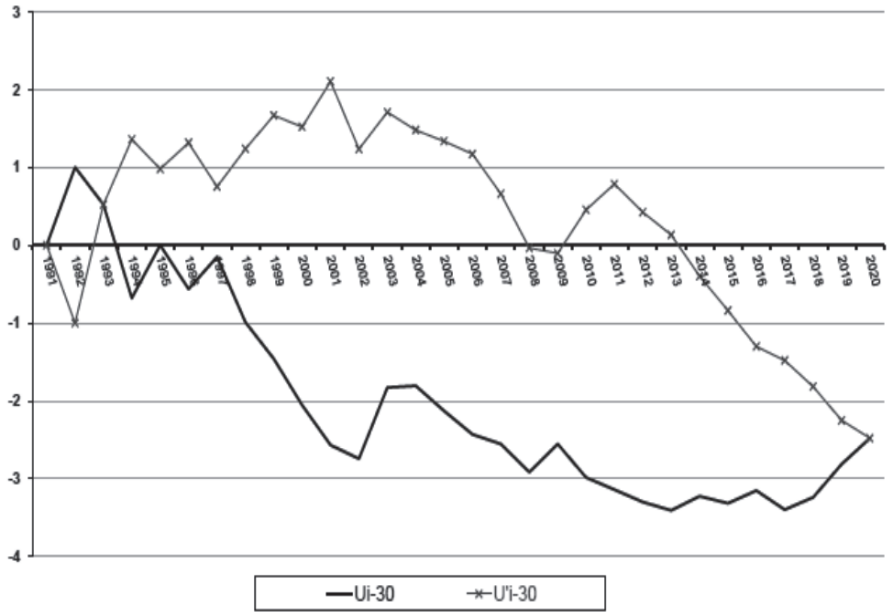

Fig. 7. Mashhad average humidity

Fig. 8 shows the linear trend of the time series of 30 years of relative humidity in Mashhad. As can be seen from this figure, although the trend of change is not significant, the overall relative humidity has declined. Fig. 8 shows the relative humidity changes. In this figure, the jump points of the average 30-year time series are determined by the Mann-Kendall method. In addition, the data are compared with the 5-year average of available series and periods. Hence, climate change facts are statistically observable in the past times and predictable in the future periods. For instance, Bazrkar et al. (2015) have estimated an increase in monthly temperature in prospective years for Tehran based on SRES scenarios of the IPCC [17].

These conditions and the situation of other climatic elements of this city show that Mashhad has not been excluded from the process of climate change. This finding has been confirmed in other studies, for example, the IPCC estimates an increase in temperature in the Middle East up to 2ºC in the next 15-20 years and over 4ºC by the end of the century. This fact is combined with a decline in precipitation by 20% [18, 19]. Hence, the Middle East countries are very vulnerable to facing climate change effects. Among the Middle East countries, Iran will experience an increase of 2.6ºC in mean temperatures and a 35% decline in precipitation in the next decades [20]. Hence, the climate change fact of Iran is more severe than the Middle East region.

Researchers showed significant positive trends for temperature variations at several urbanized regions in Iran [20]. This trend is particularly evident in snowfall, the formation of heat islands, the increase in unhealthy days, and so on. Specifically, the same statistics show that the height of the snow border has increased from 300 to 1000 meters, and the average temperature has increased by about 2 degrees during the last two decades. These conditions have more or less continued for precipitation, the amount of which has decreased by 10 to 12 mm during the same period. Rainfall trends analysis of Iran using the Mann–Kendall test indicated a decreasing trend in annual and seasonal precipitation at stations located mostly in the northwest of Iran [21]. Fanni et al. (2013) have indicated that the climatic change and its effect such as the increasing trend of temperature are accompanied by changes in urban population growth in Tehran [22]. These conditions have led to a 2-3 meter annual decrease in the water level of the city's drinking and agricultural water supply so that according to official announcements, only 30% of the volume of dams in Mashhad will have water by December 2021. Meanwhile, part of the water of Dosti Dam, located about 150 km from this city, has been used for drinking in Mashhad for several years. This transfer, not only incurs material costs but also leads to many destructive effects on the city and its surrounding area. However, new water resources, especially the Dosti Dam, are not very reliable for political and security reasons. Besides, the groundwater abstraction is so intense that the rate of land subsidence in the Mashhad plain is 57 cm per year. Yet, the transfer of water from distant places and even unprincipled access to groundwater resources has not met the shortcomings, and it seems that the city will face widespread water stress in the coming years.

Of course, the problems of climate change are not limited to water and have affected other elements as well. For example, with the increase of temperatures in Mashhad, the occurrence and formation of gram-shaped islands have become more frequent and intense (Table 2). As can be seen in Table 2, the average of

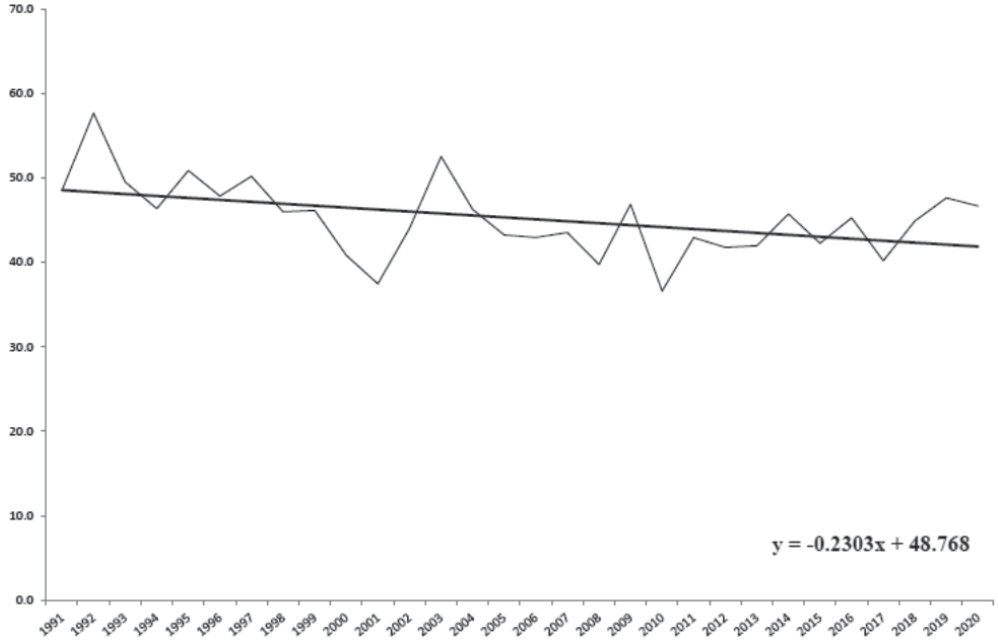

Fig. 8. Linear trend of time series of 30 years relative humidity of Mashhad.

Table 2. Kruskal-Wallis test results for comparison of average temperature in Mashhad station (1991-2021 period).

Temperature	Average course	Long-term average	Difference in averages	P-value	Condition
Minimum	8.5	6.2	2.3	<0.001	Significant
Maximum	21.55	20.87	0.68	0.009	Significant
Average	14.8	13.45	1.35	<0.001	Significant

Table 3. The NDVI and LSt mean value in various land cover and their difference in Mashhad in 1991 and 2020.

Land Use	Normalized vegetation index			Temperature changes		
	1991	2020	1991-2020	1991	2020	1991-2020
Natural cover	0.26	0.19	-0.08	25	35.7	11.7
Crop cover	0.67	0.34	-0.34	19.9	34.5	11.6
Blue areas	-0.40	0	0.40	35.5	15.4	

all three temperatures (minimum, maximum, and average) in Mashhad station has increased significantly during 1991-2020 compared to the long period, i.e., the period of 1951-1991. As a result, we can assume the intensification of temperature rise due to the formation of the heat island phenomenon in Mashhad.

Heat penalties not only affect energy consumption and increase emissions but also have other abnormal consequences. For example, the phenomenon of heat islands reduces rainfall in rainy seasons and increases rainfall in warm seasons, leading to increased flood damage. There is also research indicating that the trend of increasing temperature and dust has led to a growing trend of the rate and severity of some diseases (especially asthma, trachoma, etc.) [23].

The study of the relationship between temperature changes and rainfall in the city of Mashhad with economic, environmental, and other indicators shows that almost all the indicators have decreased sharply with decreasing rainfall and increasing temperature. Specifically, the amount of investment in the tourism sector has decreased by almost 30%. Meanwhile, about 50% of the income and employment of this city is provided by the tourism industry [12]. Also, the type of land use in and around the city has changed dramatically during this period (Table 3). Although climate and climate data have had a major contribution to the creation of the urban landscape, housing design, and urban planning process, there is not enough research on the contribution of these developments to meeting the basic needs of citizens. Hence, managers and policymakers have recently sought to discuss this area as well. Given the population growth in many countries, and especially in big cities, the way of life has changed, leading to climatic changes. These factors have affected resources base, especially drinking water.

Now the concern about over-extraction of groundwater resources, landslides, and related hazards is not limited to experts and has attracted the attention of ordinary people as well. Climate change has had the highest effect among these, which is itself the result of the unprincipled development of metropolises. The climate change fact is intensive among the Middle East countries and especially Iran. Among the Middle East countries, Iran will experience an increase of 2.6ºC in mean temperatures and a 35% decline in precipitation in the next decades. In vice versa, Iran by total greenhouse gas (GHG) emissions nearly to 616,741 million tons of CO_2 is the first responsible country to climate change in the Middle East, and seventh in the world. The high-level contribution of Iran to emissions of GHG depends on a significant production of oil, gas, and rapid urbanization [20]. Hence, study and research in this field are becoming more and more critical. One of the most important human goals in building a city is to achieve comfort and tranquility. It is necessary to study the factors involved in this matter to have cities compatible with the climate. Among climatic elements, temperature and humidity have the greatest effect on human health and comfort. Temperature changes depend on the amount of sunlight and changes in air humidity depending on the amount of water vapor in the air [24]. Climate change can be an obstacle to achieving the ideals of human beings today, and the sensitivity of the issue is doubled in Mashhad, which is a relatively dry city with water bottlenecks and constraints. According to the results of the research during the statistical period, the climatic characteristics of the city of Mashhad have shown significant changes. In particular, a comparison of the two climatic elements of temperature and precipitation in the region shows that drought has prevailed in the region since 1993 and follows a continuous trend. Since this situation has continued for years to come, the issue of climate change can rise [25].

The important point is that such an increasing drought trend in the region limits the work of urban planners to some extent because the urban and regional

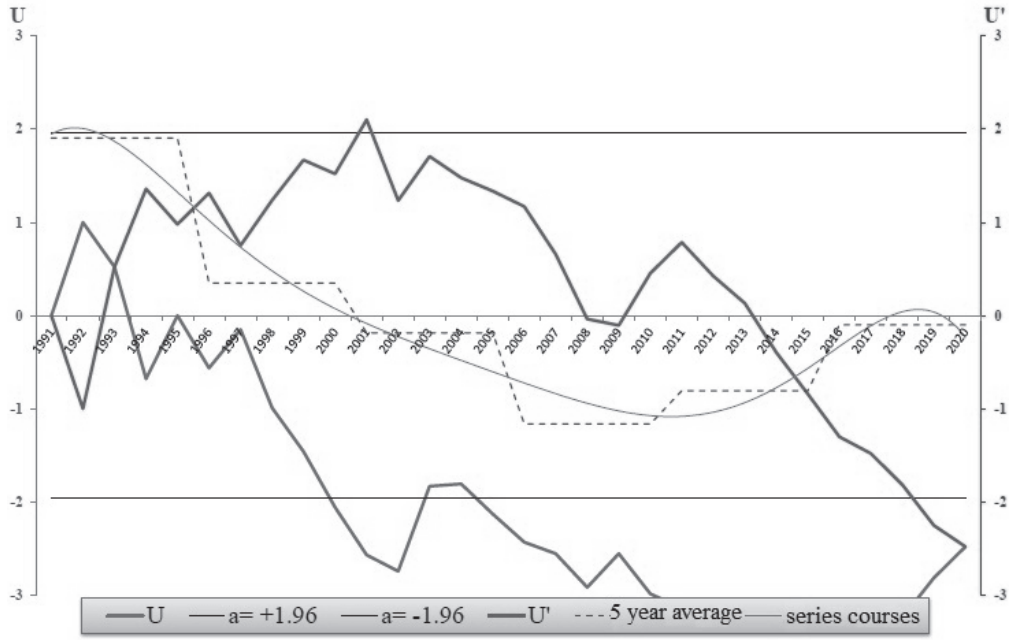

Fig. 9. Shows the jump points of the mean and its adaptation to the mean and series periods.

development plan of Mashhad needs adjustment to water reduction to avoid this drought. This means that development should take place in areas that require less water. However, climate change has not only led to bottlenecks such as various diseases, the development of heat islands, etc. but has also limited investment in tourism (Fig. 9).

Yet, water harvesting in the Mashhad plain has now reached a critical level [6], and the product obtained from this water is in no way comparable to the damage caused (Fig. 10). Hence, it is suggested to transform the exploitation of water resources completely. For example, aquifers in this area not only fail to provide sufficient employment and income but also increase the risk of subsidence due to groundwater depletion. Thus, using the available water in other areas such as tourism and forest and rangeland development instead of agriculture and animal husbandry will not only provide more employment and income [12] but will also moderate the destructive effects of industrial development on the climate and remove many of the current bottlenecks. The author's field studies show that if all production activities in the Mashhad plain are shut down, there will be even more benefits. In this way, the government purchases the water used in agriculture and animal husbandry and uses it for drinking and the development of green and forest areas. Accordingly, water supply costs will significantly decrease. In addition, with such a method of water exploitation, the soil condition and environmental conditions of the region will undergo the minimum damage.

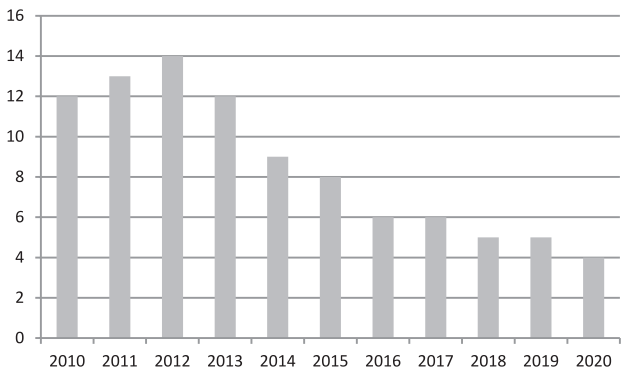

Fig. 10. Ratio of investment in tourism to other industries [12].

Yet, water harvesting in the Mashhad plain has now reached a critical level [6], and the product obtained from this water is in no way comparable to the damage caused (Fig. 10). Hence, it is suggested to transform the exploitation of water resources completely. For example, aquifers in this area not only fail to provide sufficient employment and income but also increase the risk of subsidence due to groundwater depletion. Thus, using the available water in other areas such as tourism and forest and rangeland development instead of agriculture and animal husbandry will not only provide more employment and income [12] but will also moderate the destructive effects of industrial development on the climate and remove many of the current bottlenecks. The author's field studies show that if all production activities in the Mashhad plain are shut down, there will be even more benefits. In this way, the government purchases the water used in agriculture and animal husbandry and uses it for drinking and the development of green and forest areas. Accordingly, water supply costs will significantly decrease. In addition, with such a method of water exploitation, the soil condition and environmental conditions of the region will undergo the minimum damage.

Conclusions

According to the general summary of the analysis of the studied parameters, the climate of the region is undergoing a process of increasing temperature and relative warming. This factor has reduced the trend of precipitation while increasing heat and evaporation rates. The trend of rising temperatures in the city of Mashhad has been recently continuous [26]. Due to the increase in temperature, the indicators related to the maximum temperature have increased relatively so that hot days, tropical nights, dry periods, heat waves, etc., have had an increasing trend. The city's cooling requirements have increased during summer due to the increase in hot days, increasing the use of fossil fuels, pollution, and so on. Based on the daily minimum temperature, cold days with frost and heatwaves have decreased [27]. The results show a decrease in rainfall and an increase in temperature, indicating the occurrence of climate change and drought in the region. All these cases indicate that the climate of Mashhad is changing and getting warmer than before [28]. Warming caused by climate change has led to several consequences such as water depletion and disease [29-30] and has consequently overshadowed food and water security [8-9]. In such circumstances, it is necessary to increase people's awareness and change their lifestyles to be less vulnerable to this climatic change; otherwise, it will lead to serious damage not only in the field of climate but also concerning public health and security of this metropolis and subsequently the country. Accordingly, the largest metropolis of eastern Iran will face a shortage of surface water resources in rivers and pressure on the remaining groundwater resources due to atmospheric heating conditions. The unavailability of new information, especially statistics on drinking water consumption and its changes in recent years, was one of the limitations of this study. Therefore, future research can focus on this dimension.

Acknowledgments

The author thanks Payam e Noor University for its cooperation.

Conflict of Interest

The author declare no conflict of interest.

References

1. ALIJANI B., KAVIANI M. Fundamentals of Hydrometeorology. **5rd ed**.; Samat Publications; Iran, **2017**.
2. ALAVIPANAH K., HASHEMI S., KAZWMZADEH A. Spatial - Temporal Analysis of Urban Heat- Island of Mashhad City due to Land Use/ Cover Change and Expansion. Geographical research of urban planning, **3**, 1, **2017**.
3. JAVARI M. Spatial-temporal Variability of Seasonal Precipitation in Iran. The Open Atmospheric Science Journal, **13**, 84, **2020**.
4. SANJUAN M.A., ANDRADE C., MORA P., ZARAGOZA A., Carbon Dioxide Uptake by Cement-Based Materials: A Spanish Case Study. Applied Science, **10**, 1, **2020**.
5. WAITE C. 2019 UK Greenhouse Gas Emissions, Final Figs. National Statistics, **9** (4), 1, **2021**.
6. KHORDADI M., ISLAMIAN S., ABEDI J. Investigation of meteorological parameters in Iran region. Khorasan regional water, **201**, 73-78, **2017**.
7. SAMETI M., FATABADI M., RANJBAR H. Geographical Aggregation of Industrial Activities and Productivity Growth: The Evidence from Iran's Provinces Manufacturing Industries. Journal of Economic Modeling, **10** (34), 51, **2017**.
8. EBRAHIMI H. The study of the effect of climate change on agricultural water consumption in Mashhad plain. **3rd ed**.; Islamic Azad University; Iran, **2005**.
9. SOLEYMANI NEJAD S., DOURANDISH A., SABOUHI M., BANAYAN M. The Effects of Climate Change on Cropping Pattern (Case Study: Mashhad Plain). J. Agr. Eco. Res., **2**, 249, **2019**.
10. BANIWAHB A. The analysis and forecasting of climatic fluctuation of khorasan. Territory, **29**, 93, **2016**.
11. BANIWAHB A., ALIJANI B. Study of Drought, New Year and Prediction of Climate Change in Birjand Region Using Statistical Models. Geographical Research, **32**, 46, **2003**.
12. SABERIFAR R. The role of creative tourism in the survival of tourists and its effect on economic development (Case study of Boshrouyeh, South Khorasan. Space planning, **4**, 207, **2020**.
13. BAKHSHI J., BEIROUDIAN N. A Study of Climate Change in Arak during the Past 46 Years. Journal of Forests and Rangelands, **75**, 78, **2018**.
14. WORLD METEOROLOGICA ORGANIZATION, World Climate Data 19873. WMO, **112**, Switzerland, **1988**.
15. SHAMAMI FG., SABZIPARVAR AA., SHINODA S. Long-term comparison of the climate extremes variability in different climate types located in coastal and inland regions of Iran. Theor Appl Climatol, **3**, 6, **2018**.
16. ABOLVERDI J., FERDOSIFAR G., KHALILI D., HAGHIGHI A.K., HAGHIGHI M.A. Recent trends in regional air temperature and precipitation and links to global climate change in the Maharlo watershed, Southwestern Iran. Meteorol Atmos Phys., **126**, 192, **2014**.
17. BAZRKAR M.H., ZAMANI N., ESLAMIAN S., ESLAMIAN A., DEHGHAN D. Urbanization and climate change. In: Filho WL (ed.), Handbook of climate change adaptation. **3rd**.; Springer; England, **2015**.
18. IPCC., Climate Change 2007 – The physical science basis. Intergovernmental panel on climate change. **4rd**.; Cambridge University Press; England, **2007**.
19. ELASHA B.O. Mapping of climate change threats and human development impacts in the Arab region. **4rd**.; United Nations Development; New York, **2010**.
20. MANSOURI DANESHVAR M.R., EBRAHIMI M., NEJADSOLEYMANI H. An overview of climate change in Iran: facts and statistics. Environ Syst Res., **8**, 7, **2019**.
21. MODARRES R., SARHADI A. Rainfall trends analysis of Iran in the last half of the twentieth century. J Geophys Res., **114**, 3, **2009**.

22. FANNI Z., HOSAYNI Z., AFSHARMANESH H., NAZEMMAHALLEH M.A., RASTEGAR A. The effects of urban environment on climate changes, case study: Tehran. J Tethys, **1** (2), 138, **2013**.
23. SABERIFAR R., VAFAYI E. Investigating the impact of Residential Environment in Increasing the Risk of AIDS (Case Study of Mashhad). Medical Journal of Mashhad University of Medical Sciences, **66** (3), 1025, **2018**.
24. ALIJANI B., MOAYEDFAR S., SABAEI MEHR M. A Study of Climate Change in Yazd in Relation to Urban and Regional Development. Urban Research and Planning, **3**, 58, **2006**.
25. HEIDARI H., GOLBABAEI F., SHAMSIPOUR A., RAHIMI A. Occupational Heat Stress in Outdoor Settings Considering the Regional Climate Change in the Future Decades in Iran. Ioh., **2**, 33, **2019.**
26. NASERIKIA M., ASADI E., RAFIEIN M., FILHO W. The Urban Heat Island in an Urban Context: A Case Study of Mashhad, Iran. Int. J. Environ. Res. Public Health, **16** (3), 1, **2019**.
27. FALL S., COUIBALY K.M., QUANSAH J. E., El AFANDI G., ANKUMAH R. Observed Daily Temperature Variability and Extremes over Southeastern USA (1978-2017). Climate, **9** (110), 1, **2021**.
28. FARZANDI M., REZAINEJAD H., SANAEI H. Restoration and expansion of 127 years of monthly temperature statistics in Mashhad. Climatological Research, **17**, 111, **2019**.
29. SANAGAR DARBANI E., RAFIEIAN R., HANAEE T., MONSEFI PARAPARI D. Climate Change Impact Assessment on Outdoor Thermal Comfort Changes Using Physiological Equivalent Temperature (PET) Index in Mashhad. Geographical Research, **33** (3), 38, **2018**.
30. EBRAHIMZADEH I., ESMAEIL NEGAD M. The future challenge of climatic refugees regional developments dase study: South Khorasan. Geography and Development, **15** (48), 16, **2017**.