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ResearchArticle

Investigation of interactive effects between temperature trend and urban climate during the last decades: a case study of Isfahan-Iran

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Abstract

Researchers are investigating a possible relation of climate change with anthropogenic behavior by studying trends in different climatic parameters. Nowadays, Isfahan city is experiencing growth of its urban areas due to a high rate of rural–urban migration and a population boom during the last decades. So in this study, various data base by emphasizing descriptive and interpretive approaches have been used for detecting the effects of anthropogenic behaviors such as urbanism and land cover change along with global warming conditions. The results of analyzing satellite images over study area shows that the percentage of agriculture and undeveloped areas had respectively decreased from 46.85% to 25.5% and 41.87% to 39.65% in favor of the extension of urban areas during the last three decades. In this field, population growth trends in Isfahan province within past years (1990 to 2013) shows increasing growth rate in cities rather than rural areas. Also, there is a positive trend at the 0.05 significance level in annual temperature by a rate of 0.06 °C per year at Isfahan station during the observation period (1980-2010). On the other hand, heart and respiratory moralities with warm temperatures trend at Isfahan city shows a positive correlation about 0.62 and 0.55 at the 0.05 significance level, respectively. Since these issues are directly related to global warming in coming decades, there should be more consideration towards all aspects of urban growth and its probable risk to public health in the mitigation and adaptation programs. Therefore, the results of this study can be useful for planners to make more informed strategic decisions.

Keywords: Global warming, urban climate, temperature trends, human health, Isfahan

1. Introduction

Global warming continues to affect the whole world causing numerous adverse social and economic consequences. Nowadays, climate change is considered as one of the most serious hazards to human's life (Confalonieri et al., 2007).It can be said that the first step to control or at least reduce the damages of global warming is to identify its features in any regions. Climate change and air pollution is an important factor affecting human health. So that, the accumulation of greenhouse gases such as carbon dioxide, primarily from burning fossil fuels results in warming, which has an impact on air pollution, particularly on levels of ozone and particulates. Rapid urbanization and unprecedented population growth were amongst significant world changes that took place by the end of the 20th century.

These transitions were along with human's manipulation in the world natural environment (Miller and Small, 2003). Furthermore, in 2007, for the first time in human history, the total population of the world's cities exceeded the rural population (Griffiths et al., 2009). Demographers and human geographers predict that this growth in urban population will be continued in a way that by 2025, large cities and urban agglomerations will accommodate a vast majority of the world's population (O'Meara, 1999). They also believe that most of this increase in urban population will occur in low and middle income countries (Griffiths et al., 2009). However, natural ecosystems and environments are highly affected by the presence of urban areas. The negative impacts of urbanization and increase in urban population disturb global biogeochemical cycles, accelerate climate change, and affect hydrologic regimes (e.g., Tayanc and Toros, 1997; Foley et al., 2005, Grimm et al., 2008; Habete and Ferreira, 2016). Furthermore, some of these studies are almost carried out in the field of urban heat island and its characteristics that is related to the intrinsic nature of the city (i.e. building density and materials as well as urban land use distribution) especially in the North America and Europe (Karaca et al., 1995). land use and land cover changes over time due to urbanization is an important urban issue which should be take into consideration in urban research projects.

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Over a hundred years ago, the actual number of cities in the world with at least a million people was only 16. The number of cities of this type is expected to reach up to 564, in 2015 (United Nations, 2007). In the mid-20th century, Iran, like other parts of the world experienced significant changes in terms of population growth, rapid urbanization, and rural to urban transition. In 1970, 45% of the population was living in urban areas, while in 2011 this population increased to 69%. More than 23% of Iran's rapidly growing urban population is concentrated in the three large cities of Tehran, Mashhad, and Isfahan (The World Bank, 2011). Tehran, after Istanbul, with a population of over 12 million in 2010, is a mega city and the second largest and most populous city in the Middle East. Isfahan is the third largest city in Iran which experienced significant urban expansion during the past 30 years. These transformations have both changed people's life style and created a series of environmental and socioeconomic issues associated with urban development. It is clear that rapidly rate of population growth and expansion of urbanism in Isfahan have resulted in a number of problems and issues in recent years such as; high density of population, more air pollution, land cover changes, rapid warming trend in the temperatures, more health issues and Etc. These issues make Isfahan a suitable case study for investigating land use changes over time by affected from urbanism growth and climate change, especially in the past three decades.

2. Study Area

Isfahan Province (Fig. 1) is located at the center of Iranian plateau (30°42′–34°27′ N, 49°38′–55°32′ E). It covers an enormous area (107.045 km2) of numerous mountainous and plain regions and occupies about 6.57 % of the total area of the country (Isfahan Provincial Government Portal, 2016). The capital of this province, Isfahan city (32°38′ N, 51°38′ E) which is located in the lush plain of the Zayanderood river, at the foothills of the Zagros mountain range. Zayanderood river divides Isfahan city into north and south parts (BihamtaToosi et al., 2012: 150). The minimum height is 1550 m around Zayanderood River and maximum is 2232 m in Sofeh Mountains. Mean annual precipitation and temperature is 121mm and 16.2°C, respectively. Isfahan is the third biggest city in population and one of metropolis which are situated in Iran country. In recent decades, it has been the center of attention and high density of population because of concentration of economic activities like industries, business, tourism and etc.

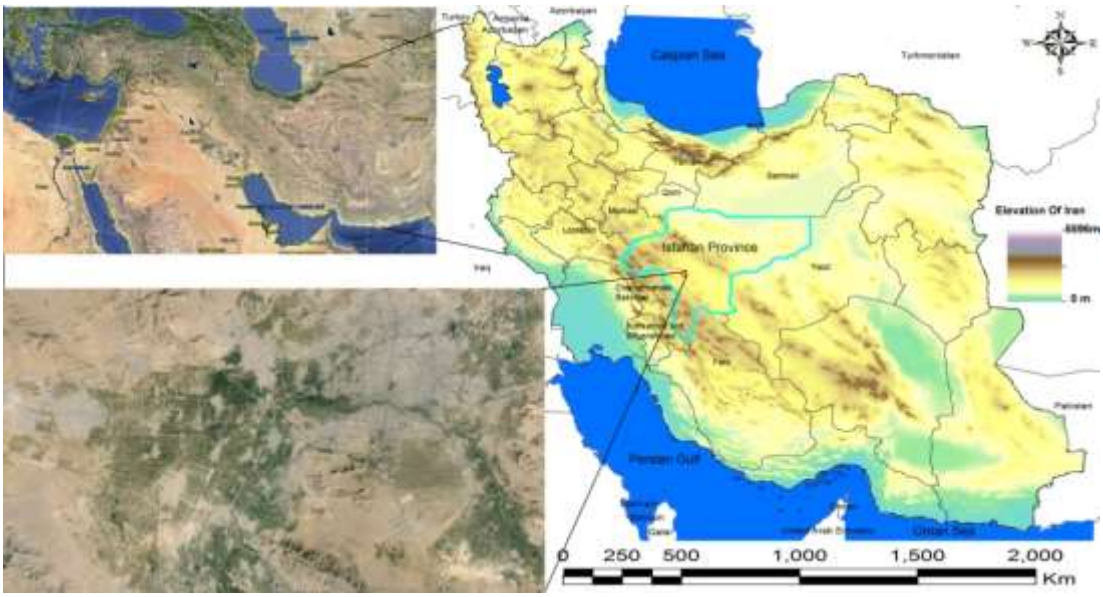

Fig.1. Location map of Isfahan province in Iran (right) and the extent of Isfahan city (left).

3. Materials and Methods:

To understanding and recognizing interactive effects between expansion rate of urbanity in Isfahan and global warming, three groups of technical data base are needed to conducting the current study as well as studying results of other researcher as library resources:

1) Daily temperature data of Isfahan in the observation period (1981-2010) that were obtained from the Iran Meteorological Organization (www.IRIMO.ir).

2) Remote Sensing images for monitoring the changes of land cover under urbanization conditions in study area during the last three decades that was prepared from satellite images of Landsat (TM and TM+).

3) Population data of Isfahan during the last three decades to examine the rate of urban and rural population growth that were extracted from the Statistical Centre of Iran (www.amar.org.ir).

After preparing the initial data, the various combination methods are employed by an emphasis on descriptive and interpretive approaches. So in the first step, many electronic resources are licensed that we used for better understanding and having of comprehensive view in the study area during the observation period. Afterward, land use and land-cover maps of the study area were prepared for monitoring spatial pattern changes by using of Landsat images (TM and TM+) that are taken during the last three decades (1980-2010). After preprocessing with acceptable accuracies, the classes of land use in study area were identified for monitoring and comparing the changes of land cover by using of the maximum likelihood classifier on all satellite images. At the next step, data of temperature parameters

were examined at the Isfahan station with regarding to limited availability of climatic data (Table 1).

Table 1. Descriptive statistics of temperature parameters at the Isfahan station during the period of 1981-2010

Parameter	Min	Mean	Max	Std	Skewness	Kurtosis
Tmax	21.8	23.7	25.6	0.88	-0.096	-0.14
Tmean	15.5	16.7	18.1	0.57	-0.08	0.04
Tmin	8.1	9.66	11	0.74	0.02	-0.49

To estimate the annual trends in temperature parameters and in population growth time series, the accuracy of these data at the 95% significance level were approved based on data adequacy test, homogeneity of Run test. While the results of normality test of Kolmogorov-Smirnov was not approved in the all data series especially Tmin. Also, to better understanding whether temperature time series are approximately normally distributed, histograms of temperature parameters are overlaid with a normal curve (Fig. 2).

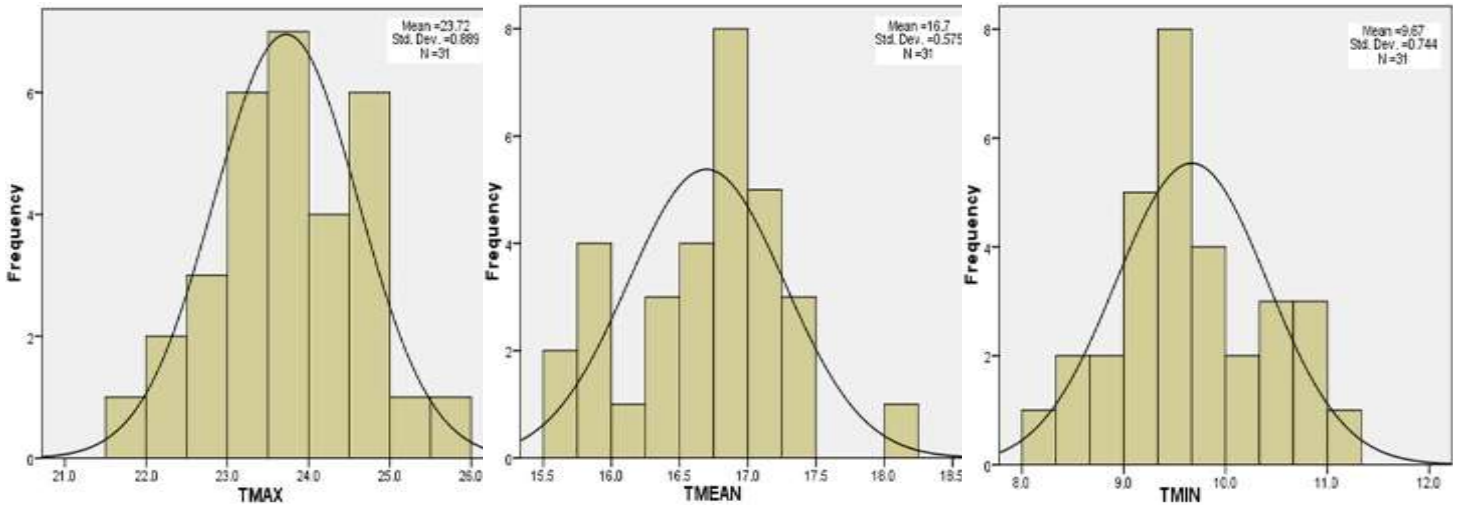

Fig. 2. The histogram of temperature parameters of Isfahan station during the period of 1981-2010

Overall, two parametric and non-parametric tests there are to trend detection in various probability distributions. While we don't have confidence to normality of data distribution, it should be considered applying the nonparametric tests (Vinnikov and Robock, 2002). In this paper, since the Mann-Kendall (MK) test which does not require normally distributed data and is well suited for analyzing datasets that have missing or tied data, is performed to detect the presence of monotonic trend (either increasing or decreasing). The null hypothesis states that no trend is present while the alternative states that there is a trend (Toros, 2012: 1318). So that, to detect the trend of any dependent variable such as temperature, it is assumes that the temperature is a function of time line as independent variable (equation 1) (for the more details refer to Neumann et al., 2003).

$$\text{Temperature} = \alpha + \beta \text{Time} \quad (1)$$

In the above model of linear regression, Temperature as dependent variable is a continuous monotonic increasing or decreasing function of time.

In this field, the MAKESENS software was used that is developed by researchers of the Finnish Meteorological Institute (Salmi et al., 2002). The procedure is based on the non-parametric Mann-Kendall test for the monotonic trend and Sen's non-parametric method for the magnitude or slope of the trend (Mann, 1945; Kendall, 1975). Finally, it has been tried to understanding and comparing the results of temperature changes along with of population grow and urbanism rate over the study area under global warming during the past decades.

4. Results and Discussion:

The Fifth assessment reports of the Intergovernmental Panel on Climate Change (IPCC, 2013) suggest that because of the increase in greenhouse gas emissions over the last century, average global temperature has increased about 0.4 to 0.8 °C. And even this trend has accelerated in recent decades. So far, different parts of the world had experienced dramatic changes in terms of population growth, rapid urbanization, and rural to urban transition that caused more warming in global scale. Global surface temperature in 2015 was +0.87°C (~1.6°F) warmer than the base period of 1951-1980 (Fig. 3). In this field, the occurrence of the maximum temperature over Iran country will increased between 1 and 2 °C in the middle and the end of 21st century (Abbasnia et al., 2016). Therefore, there is a general tendency of warming trends in the global scale in the current and future periods. Thus, temperatures have received special attention because of their direct relation with climate change. Since climate change in the future will be highly dependent on human activities and also human knowledge is not enough to prevent the occurrence of extreme phenomena, but through studying and understanding their characteristics consequences can be prevented in various places.

Global warming can be affected from local and regional air pollution, different urbanization characteristics and physical factors such as the local physical geographic, topography, exposure, etc. In this case, satellite images and landscape metrics can be extremely useful for planners in assessing and monitoring the ecological consequences of landscape patterns under anthropogenic behaviors of human. Therefore in study area, as it is clear on Landsat images, visual comparison between the 1985, the 2000 and the 2010 maps clearly display the expansion of the urban class during the last decades (Fig. 3).In the Isfahan city during the 1985 to 2010 period can be observed more expansion of this city in the north and north-west parts (Niloofar Alavi, 2012: 93), as well as the amalgamation of some small towns to

the main city core in the west side of the city. On the other hand, the proportion of agriculture reduced while the proportion of urban was significantly increased during the study period, mainly due to reduced agricultural area in Isfahan. Also, official statistics showed a huge increase in the total construction and built up area in Isfahan city. Therefore, two classes of agricultural land and urban area during the last decades have had a significant changes rather than the previous situation. So that, the percentage of agriculture and undeveloped areas had respectively decreased from 46.85% to 25.5% and 41.87% to 39.65% and also the percentage of urban area had increased from 8.3% to 28.73% in the Isfahan during the 1990-2010 (BihamtaToosi et al., 2012: 151). All of these changes in land cover are more affected from fast growing of urbanism in Isfahan city as anthropogenic behaviors.

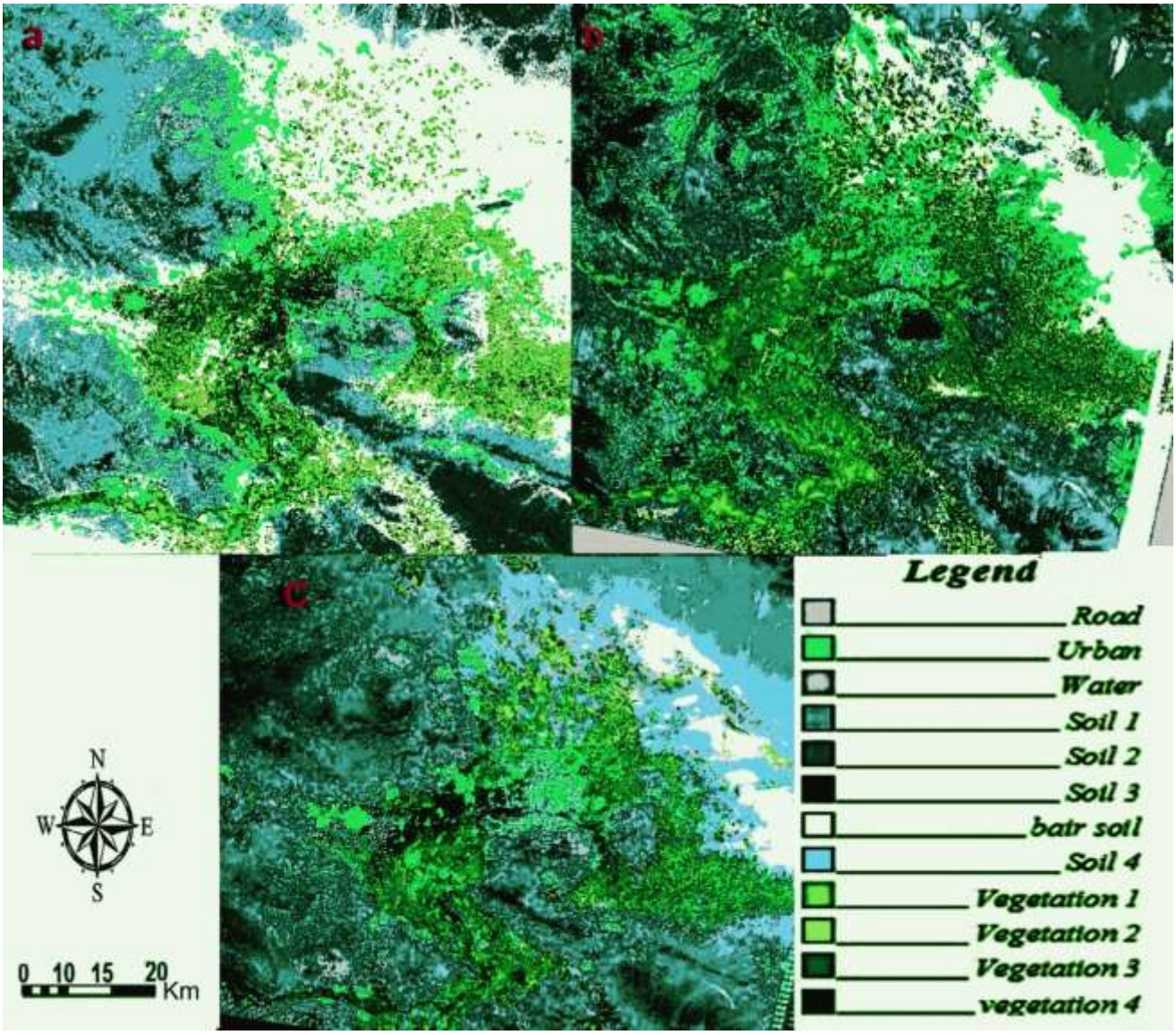

Fig. 3. The Landsat images over the study area in the last decades includes:1985 a- 2000 b- 2010 c, (Source: Niloofar Alavi, 2012: 93)

The urbanization trends during the last decades had been accelerated by high rate of rural–urban migration along with rapid socio-economic and political changes that formed unbalanced urban growth in Iran. In this field, population growth trend in Isfahan province within the past years (1990 to 2013) shows the increasing growth rate in cities rather than rural areas (Fig. 4). It is clear that population growth in Isfahan province has resulted in a big number of issues such as high density, land cover changes and more air pollution especially in Isfahan city as third mega city of Iran. So that, demographic statistics during last decades shows large amounts of increase in population as well as immigration from the suburbs and surrounding villages to Isfahan city. Therefore, population growth of Isfahan city during the last decades will be approximately cause to accumulation greater rate of carbon emissions and faster rate of increasing trend in the temperatures over study area.

As that is clear, urbanization effects under climate change conditions will be consistent with the general increase in the temperature parameters. In contrast, effects of agricultural development such as: increasing evaporation during the day and irrigation by increasing the heat capacity of the soil that caused to decrease the temperature trends. While, the results of trends in the annual temperature parameters at Isfahan station during the observation period (1980-2010) showed that a positive trends at the 0.05 significance level in the maximum temperatures series a rate of 0.06 °C per year but in the average and minimum temperatures series, there are not significant trends.

Supplementary Fig. 5 shows the temperature trends in the difference between maximum and minimum temperatures or diurnal temperature range (DTR). In this field, the result of the newest research about temperature changes over Iran in the whole of 21th century (2011-99) has shown that the average maximum temperatures will increased about 0.3 to 3.5 °C. On the annually basis, the positive slope trend in higher rate will happened at Esfahan station based on A2 scenarios of CGCM3 model (Abbasnia and Toros, 2016: 6). So in study area, health risks due to climate change especially occurrence of warm extremes will be more important with regarding to changes in natural and agriculture land uses in favor of the artificial land cover under rapid increase in urban population that are combined to increasing rate of global warming in coming decades.

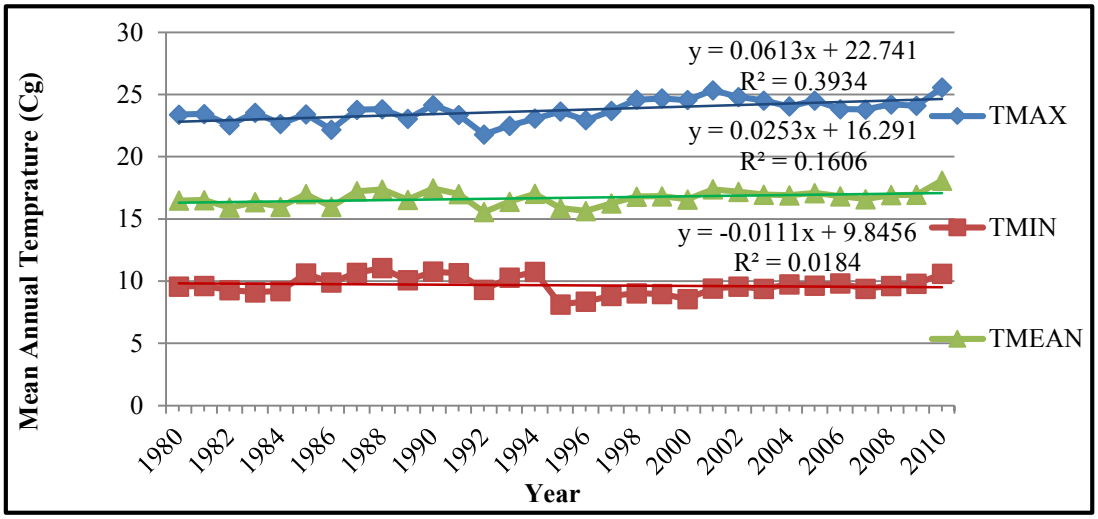

Fig .4. Demographic statistics in Isfahan province during the past few years

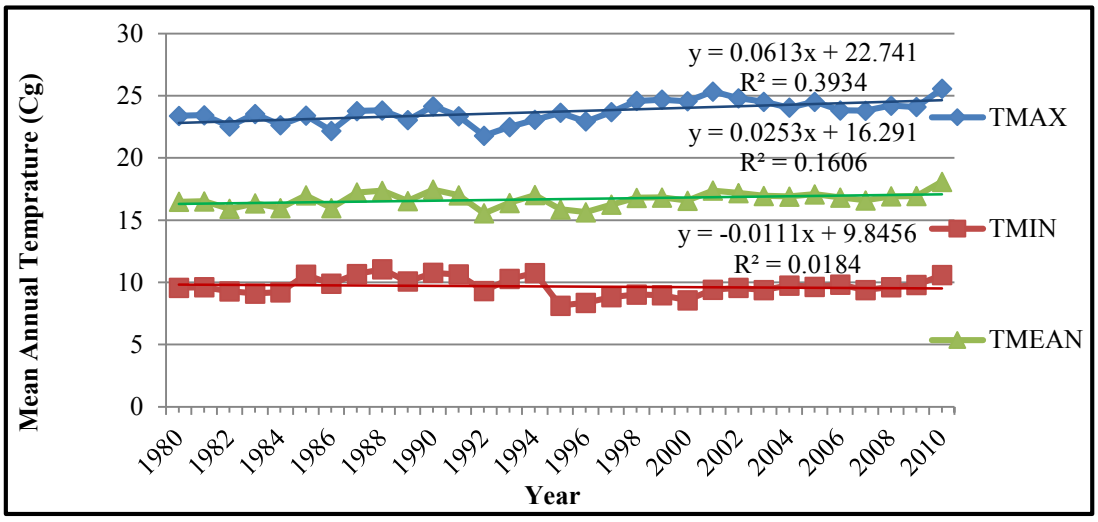

Fig .5. The annual trends of temperature parameters at Isfahan station during the last three decades

Structure and function of human body is influenced by climate and reacts to changes in climate parameters. Thermoregulation system of human body stabilized around 36.7 °C. Warm temperatures are thought to be associated with increased death rates (Zanobettia, 2012). Indeed during consecutives hot days such as; heat waves, the temperature of human body do not able to evacuate the exceeding heat so the resulted stress induced the various health outcomes and the stroke may occur when the body temperature rise up 40 °C (Kunst, et al., 1993). There are the well-known examples, which demonstrated the relation between extreme events and mortality such as; at least 35,000 people died as a result of the record heat wave that scorched Europe in August 2003 (Cheung et al., 2007). These temperature extremes are the known phenomenon in mega-cities which is responsible for part of further augments increase in regional temperature. Likewise, based on the result of the newest research over the study area (Abbasnia and Toros, 2016), it could be concluded that the occurrences of temperature extremes and heat waves will be more severe in the future decades. In other hand, between the heart and respiratory moralities with occurrences of warm temperatures in Isfahan city there is a significant positive correlation about 0.62 and 0.55 at the 0.05 significance level, respectively (Ghanbari et al., 2011). These numbers of death are associated with rapid rate of urbanization and land use changes in Isfahan city under climate change conditions. In fact, an increase in temperature parameter that is uncomfortable for human body, would lead to higher death rates caused by different diseases. So with regarding to the rising trend of temperature over Isfahan due to various factors, the governmental planners should be more considerate the all aspects of urbanism growth and its probable risk to public health in the mitigation and adaptation programs.

5. Conclusion

In arid and semi-arid regions, observed climatic instability is an unpredictable and complex phenomenon mainly attributed to human activity and in particular to gas emissions, which seem to influence the global warming of the planet. Also in recent decades, people are interested to live in metropolitan city because of lots of economic, social and political reasons. Up to now, impacts of climate change have not been studied much in details, so in the current study has been tries to understanding the association between climate change and urbanism with its impacts on human health. Isfahan as mega city is experiencing growth of its urban areas during the last decades by high rate of rural–urban migration. In the Isfahan city can be observed more city expansion since 1985 till 2010. In this field, population growth trend in Isfahan province within last years (1990 to 2013) shows the rapid increasing growth rate in cities rather than rural areas. In other hand, proportion of agriculture lands was reduced while proportion of urban lands was significantly increased during the current period.

It is worth to mentioning that the urbanization effects under climate change conditions will be consistent with the general increase in the temperature parameters. Then, there is a general tendency of warming trends in local scale during the observation and future period. The results of trends in annual temperature parameters at Isfahan station during the observation period (1980-2010) showed a positive trend at the 0.05 significance level in the maximum temperature by a rate of 0.06 °C per year. This trend will also be more severe in future decades. Therefore, an enormous number of issues associated with human health risks due to occurrence of warm extremes will impact Isfahan. These risks will be happening with regard to changes in natural and agricultural land uses in favor of artificial land cover along with a rapid increase in urban population that combine to increase the rate of global warming in coming decades.

Therefore, what seems important is that the characteristics of these events could be on the focus of planning in order to implement the best large scale programs and managerial patterns. However, Isfahan population would adjust to warm temperature but growing global warming and urbanization and aging may be faster than adaptation. Then the timely intervention for future probable such as heat waves or extreme temperatures would be considered. Accompanying the warm temperatures has additive risk on mortalities in Isfahan perhaps due to high concentration of air pollutants. Unbalance population is the most important problem in municipality district. As solution over study area, reverse migration could be considerate from rural area to urban area. Since the studies of urban climate changes in developing countries which are facing complex urbanization problems such as large human flux from rural areas to cities are not yet enough to make generalizations, studies of urban climate in the third world countries are still necessary by focusing on a comprehensive view.

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