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Evaluation of the Effects of Climate Change on Temperature, Precipitation and Evapotranspiration in Iran

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Abstract
The purpose of this research is a comprehensive evaluation of climate change effects on temperature, precipitation and evapotranspiration over the country of Iran in next time periods of 2010-2039, 2040-2069 and 2070-2099, and under scenarios of A2 and B2. After preparation of measured temperature and precipitation data and calculation of evapotranspiration for the base time period of 1960- 1990 in 46 meteorological stations (with a nationwide distribution), it was tried to have initial zoning of these three parameters over the country. Then after receiving of maximum and minimum temperature and the values of precipitation from HadCM3 model under scenarios A2 and B2 for the mentioned next three time periods, these data were downscaled. By evaluation of uncertainties, most critical parts of the country that would be affected by climate change were specified. Results show that the highest increase in temperature occurs in west parts of the country, but the highest increase of evapotranspiration belongs to central regions of Iran. However, variation of precipitation is different in different parts of the country depending on the used scenarios and the selected time periods.
Keywords: Climate Change, Iran, Precipitation, Temperature, Evapotranspiration.

1. Introduction
The climate change phenomenon is caused by greenhouse gasses, which affect the greenhouse properties of the earth's atmosphere. Emissions of greenhouse gasses have been increased since industrialization in the 1900s, due to increasing in fossil fuel burning. These gasses allow solar radiation to travel from the sun to the ground but prevent the reflected heat from the surface into the space. This causes to rise the earth's temperature, gradually (Takara et al., 2009)
It is expected that climate change would strongly affect the hydrologic cycle of water in future decades (Gedney et al, 2006, Milly et al, 2005). It will also have significant impacts on the availability, as well as the quality and quantity of water. Among the climatic variables, precipitation (P) and evapotranspiration (ET) have the great importance in long term changes of water resources (Piao et al, 2006). In this regard, many researchers predicted that climate change accelerates water cycles with more ET and increased precipitation (Betts et al, 2007, Oki and Kanae, 2006). But increased precipitation does not necessarily lead to sustainable water resources because less frequent but heavier precipitation may lead to extremely flood or drought occurrence (Andreadis and Lettenmaier, 2006). Therefore, it should be emphasized that to monitor and assess the impact of climate change on drought occurrence, ET and P should be considered together as two major climatic variables. Kirono et al. (2011) study is an example of RDI application for characterization of Australian droughts under enhanced greenhouse conditions. In their study, RDI was applied to simulate climate variables from 14 GCMs performed for the IPCC 4th assessment report. The results showed a general increase in drought areal extent and frequency for most regions of the country. Karamouz et al.(2009) simulated the flood flow under climate change phenomenon using GCM models in Kajoo river basin located in arid and semi-arid region of south-east Iran.
The purpose of present research is the evaluation and mapping of the impacts of climate change on the parameters of precipitation, temperature and evapotranspiration in Iran under the scenaries of A2 and B2 for the periods of 2010-2039, 2040-2069 and 2070-2099. Awareness about the type and the amount of the

impacts would help the authorities and planners to take more optimized and effective management strategies on water resources to cope with the expected condition.

2. Materials and methods

2.1. Study area

The study area of the research is the country of Iran. Climate condition varies considerably over the country especially from north to the south. In a narrow strip in north of Iran annual precipitation is over 1000 mm and in some parts of it reachs over 1700 mm covered by dense forests. However the most parts of Iran especially central and south east regions are very warm hypper arid areas with less than 100 mm annual precipitation and over 3500 mm potential evapotranspiration. This considerable variations in climate condition causes wide range of biodiversity in animal and plant communities. In this study it was tried to use data from different parts of Iran to cover these variations.

Table 1 presents general information of 46 meteorological stations used in this research. As it is seen from the table, the highest mean annual precipitation belongs to Anzali station with 1780 mm, while Zabol station recievs only 54 mm per year as the lowest value through the selected sites. The warmest site is Bandarabbas with annual average temperature of 27.4 ºC while the value of this parameter is Saghez as the coldest site in northwest is 11.5 ºC.

Table 1-Main properties of stations used in this research

Station	Lat.	Long.	P (mm)	T (ºC)	Station	Lat.	Long.	P(mm)	T
Abadan	30.37	48.25	128	25.15	Saghez	36.25	46.27	422	11.55
Ahvaz	31.33	48.67	196	24.8	Sanandaj	35.33	47.00	470	13.55
Anzali	37.47	49.47	1780	16	Semnan	35.55	53.38	105	17.65
Arak	34.10	49.40	354	13.95	Shahrekord	32.32	50.85	285	11.95
Babulsar	36.72	52.65	813	16.7	Shahroud	36.42	55.03	135	14.3
Bakhtaran	34.27	47.12	443	14.05	Shiraz	29.53	52.58	323	17.15
Bam	29.10	58.40	67	22.3	Tabas	33.60	56.90	74	21.05
Bandarabbas	27.22	56.37	139	27.4	Tabriz	38.08	46.28	222	11.85
Bandarlengeh	26.58	54.83	81	26.1	Tehran	35.68	51.32	226	16.65
Birjand	32.87	59.20	161	16.95	Torbat- Hey.	35.27	59.22	237	14.45
Bushehr	28.98	50.83	256	24.25	Varamin	35.35	51.68	156	16.5
Chabahar	25.42	60.75	87	26.1	Yazd	31.90	54.40	57	18.85
Dezful	32.40	48.38	366	24.35	Zabol	31.33	61.48	54	21.75
Esfahan	32.62	51.07	110	15.8	Zahedan	29.47	60.88	108	18.25
Fasa	28.97	53.68	219	19.25	Zanjan	36.23	48.48	320	11.45
Garmsar	35.25	52.17	100	17.55	Khoramabad	33.50	48.30	516	17.95
Ghazvin	36.25	50.00	285	14.5	Khoy	38.55	44.97	269	12.5
Gorgan	36.82	54.47	655	17.8	Mashhad	36.27	59.63	239	13.6
Iranshahr	27.20	60.70	81	26.6	Nowjeh	35.20	48.72	343	11.5
Jask	25.63	57.77	152	26.7	Orumiyeh	37.53	45.08	367	12.3
Kashafrud	35.98	60.83	284	17.15	Ramsar	36.90	50.67	1234	15.9
Kashan	33.98	51.45	134	19.5	Rasht	37.25	49.60	1278	15.6
Kerman	30.25	56.97	164	15.9	Sabzevar	36.22	57.67	155	16.5

2.2. Methodology

In this study three main sources of data were used which are as follows:

1-Historical daily temperature and precipitation data of the selected meteorological stations from 1961 to 1990 (T_{min}, T_{max} and P).

2-Projected monthly data of HadCM3 for projected period of 2010 to 2039 (T_{min}, T_{max} and P), 2040-2069 (T_{min}, T_{max} and P), 2070-2099 (T_{min}, T_{max} and P) that were resulted from GCM-runs for the Third Assessment Report (TAR) based on the IPCC-SRES scenario of A2.

3-Projected monthly data of HadCM3 from 2010 to 2039 (T_{min}, T_{max} and P), 2040 to 2069 (T_{min}, T_{max} and P), 2070 to 2099 (T_{min}, T_{max} and P), based on scenario of B2**.**

4- Calculated evapotranspiration for each time period using T_{min} and T_{max}.

Figure 1 illustrates the procedure for study the impact of climate change on temperature, Precipitation and Evapotranspiration in this research. After downscaling of the temperature and precipitation data for three time periods of 2010-2039, 2040-2069 and 2070-2099 in all selected sites, the values of reference evaporanspiration were calculated for the base time period as well as the mentioned future time periods. Then the nationwide maps of mean temperature, precipitation and the evapotranspiration of the mentioned

future time periods were prepared. Based on these maps the effects of climate change phenomenon on the studied parameters (T,P and ETO) has been analysed.

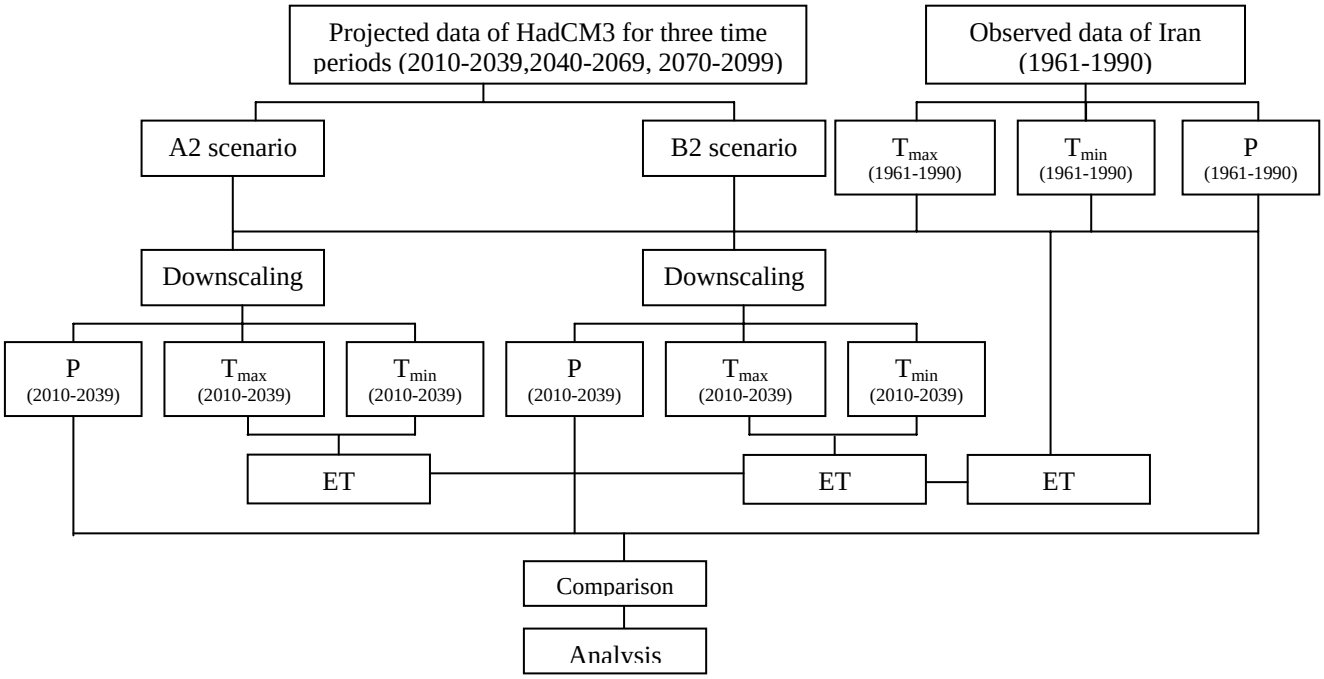
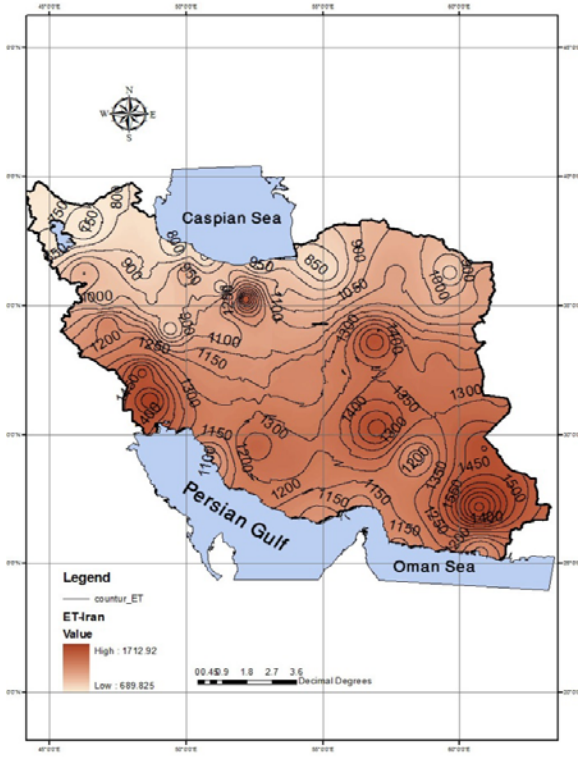


Figure 1. Proposed methodology for study of climate change impacts on temperature, precipitation and evapotranspiration in this research.

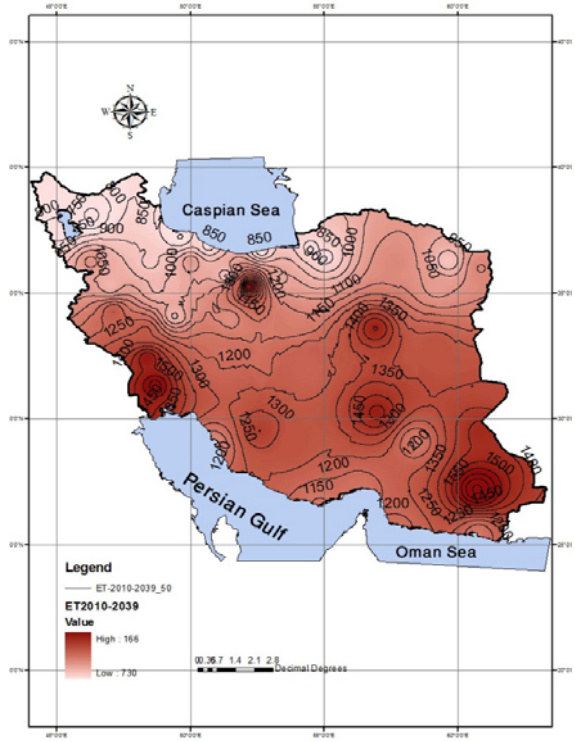
3. Results and discussion

Scenario A2: As a sample, figure 2 shows the maps of evapotranspiration rate of Iran in the base time period of 1961-1990 and the next periods of 2010-2039, 2040-2069 and 2070-2099 under the scenario A2. It must be mentioned that several maps for studied parameters including temperature, precipitation and evapotranspiration unber both scenarios were prepared and interpreted, which is not possible to show here due to page limitationjh.Comparing the map 11-B and 11-A, it is understood that evaporanspiration increased in all time periods of 2010-2039 2040-2069 and 2070-2099 and almost in all stations.

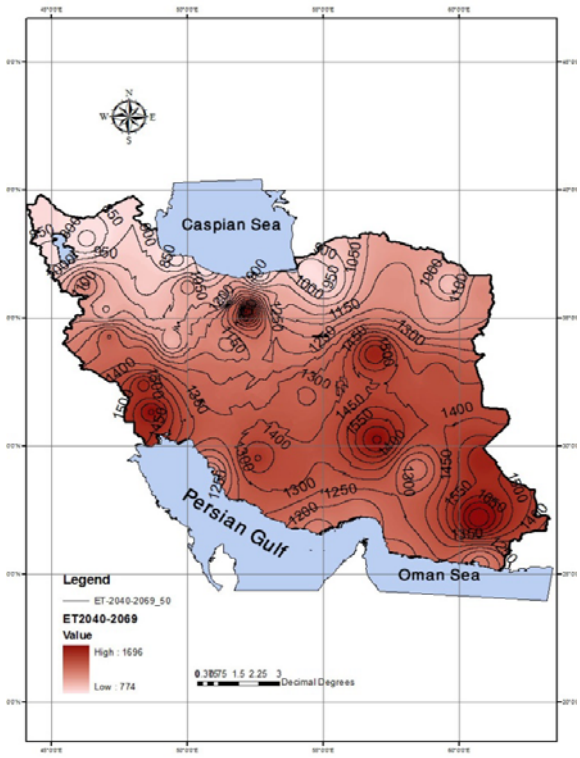
Results show that under scenario A2, stations located in north parts of Iran would experience the highest increase of precipitation. However, under scenario B2 Bushehr and other stations located in south coast show the highest increase in precipitation during next decades. Therefore, north and south coasts are the regions experiencing highest increase in precipitation under both scenarios and therefore, management of water resulted from extra precipitation in agriculture, natural resources, storage and hydropower plants are important. In the other hand, increase in precipitation in these regions would increase the risk of flooding, soil erosion as well as land slides that needs affective management and planning strategies. In this regard investigation on seasonal variation of precipitation is of importance, as seasonal variation of precipitation affects the type of compatible species and growing period for crops especially in rainfed farming. Results also show that under both scenarios highest decrease in precipitation amount occurs in west and northwest parts of the country. Therefore, according to the results of this research, west and northwest parts of Iran will be affected by precipitation decrease and water scarcity in time period of 2010-2039. This necessitates specific planning and management of water resources for these regions to overcome the problem of water shortage especially in drought periods when water availability would be more limited due to climate change effects. West and northwest regions of Iran are the main parts of the country for rainfed agriculture (especially for rainfed wheat production) which will be considerably affected by precipitation decrease caused by climate change. Estimation and analysis of seasonal variation of precipitation under climate change scenarios is of importance for sustainable agricultural planning in these parts of the country. Results also show that under both scenarios, in 2010-2039 the highest increase of temperature would be occur in west half of the country, where is mostly mountainous and cold. Temperature increase in these regions will considerably affect agricultural and natural resources, and due to population density that are mostly dependent on agricultural activities in this regions, the effects of climate change on precipitation decrease and temperature increase (in 2010-2039) on people life cannot be ignored.



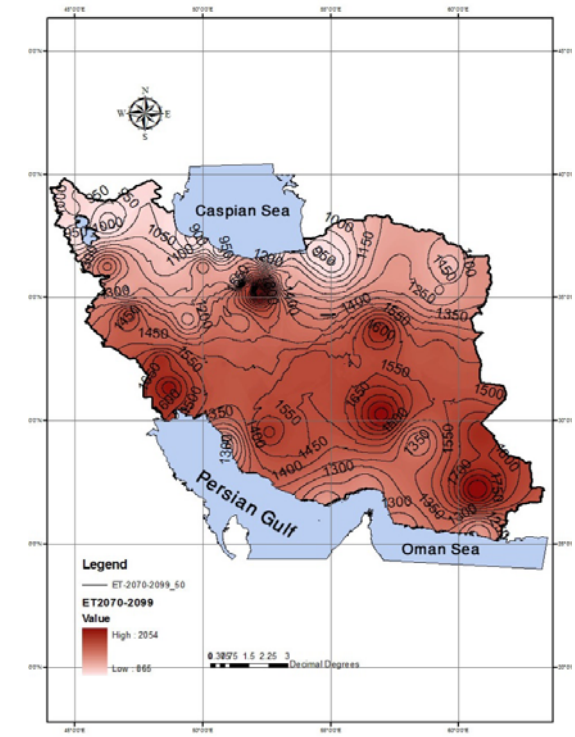
A) Base time evapotranspiration



B) A2 Scenario (2010-2039)



C) A2 Scenario (2040-2069)



D) A2 Scenario (2070-2099)

Figure 2- Maps of evapotranspiration values in base and the future time periods under scenario A2.

4. Conclusions

Climate change modeling is usually with many uncertainties. As was seen in this research, the results of model for three parameters of temperature, precipitation and evapotranspiration under two scenarios of A2

and B2 were different in different areas over the Iran. The extreme values produced by scenarios A2 were higher than those of B2. Although in all stations, and for all three time periods of 2010-2039, 2040-2069 and 2070-2099 under both scenarios, temperature is increasing but the rate of increase under scenario A2 is higher than B2. Evapotranspiration is another parameter that is increasing in all three studied time periods under both scenaeios and in all stations (except few stations in time period 2010-2039), but the rate of increase under scenario A2 is again higher than scenario B2. Therefore, it can be said that duing next decades and under both scenarios, temperature and evapotranspiration are increased, and this increase is internsified from 2010-2039 toward 2070-2099. This condition will limit water availability and increase the demand for water in different sectors. However, about precipitation, the results do not follow a clear asending or desending trend like what was seen about temperature and evapotranspiration. For example, under both scenarios in time period of 2010-2039, some stations show increase but in some other decrease in precipitation occurs. From 2010-2039 toward 2070-2099 more stations show decrease in precipitation, and in 2070-2099 except few of them, in all other stations decrease of precipitation will occur comparing to the base time period. Variation of precipitation under scenario A2 is hgher than B2. Athough results produced under scenarios A2 and B2 are different but the general trends for all three parameters of temperature, precipitation and evapotranspiration for both scenarios are almost the same. This indicates that Iran will be strongly affected by global warming and climate change during next decades. As the main parts of Iran are hyper arid, arid and semi-arid regions, water shortage is even now a big problem against social and economical development. Mean annual precipitation over the country is about 250 mm where mean annual potential evapotranspiration is over 2100mm, showing high sensitivity of the state to water related problems. Climate change will definitly intensify this condition over next decades. Therefore, to be able able to cope with the next expected hard condition, more research as well as efficient management and planning strategies are required especially for risky zones where the higher effects are expected to take place.

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