J. Appl. Environ. Biol. Sci., 4(1s)109-117, 2014
ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Simulation of the Effect of Global Warming on Temperature Thresholds of Palm Plant in The Middle Of the Present Century Using HadGEM Model: Case Study on Abadan, Iran

[1]Mohammad Amin Heidari, [2]Faramarz Khoshakhlagh, [3]Mehdi Sahnalizadeh

[1]PhD student, Climatology, University of Tehran,
[2]Assistant professor, Climatology, University of Tehran,
[3]MSc, Agricultural Climatology, Isfahan University,

ABSTRACT

Climate is one of the most important factors affecting the growth and productivity of agricultural crops. In general, the best performance of plants in growth period occurs in specific temperature ranges, and out of such intervals, plant performance declines. Global warming is a major environmental threat for the future of world's agriculture. It can make great changes in the growth and productivity of agricultural crops by altering the values of climatic thresholds. In this study, using atmospheric general circulation model, HadGEM, and Scenario A2, and based on the output of LARS-WG model, the average changes of temperature threshold values of palm tree in the middle of the present century (2046-2065) as well as the effect of temperature changes of this period on date products of Abadan region was investigated. The findings revealed that considering the future trend of temperature changes in the region due to global warming, average increase in the number of days with maximum temperature of over 45°C in the period under study will result in the decline in the performance of date crop, and probably, increase in occurrence of disorders like date bunch fading. According to the findings, predicted temperature changes make greatest harm to date crop in July and August as the peak time of plant's activity for producing crops. Evaluation of the model's performance through statistical tests revealed its relative capability for studying the effect of climatic changes in the region under study.
KEYWORDS: climate change, global warming, date crop, HadGEM model, Abadan region

1. INTRODUCTION

Environmental changes have close and effective connection with all human activities, especially, agriculture. Climate, as one of the main factors affecting environmental changes, plays a determining role in the control of growth and productivity of agricultural crops. Changes in the values of climatic factors definitely alter environmental condition and performance of plants. Nowadays, the increasing trend of temperature in different parts of world had become one of the main challenges of human activities, especially in agricultural sector. Studies conducted on global warming point to increase in extreme values and undesirable climatic condition, daily temperature variations, and frequency and number of extreme climatic events in different areas of the world (Shen, 2003). Climatic changes in future will impose negative impacts on crop production and food security throughout the world (Giglioli et al., 2003) which can even manifest itself as an economic crisis. Also, the probability of appropriate agricultural production will decrease due to increase in undesirable atmospheric and climatic events (Torriani et al., 2007). Although climate change in some areas, particularly those located in latitudes over 55°, will have a positive impact on agricultural production, its negative effect will be very intense in hot and dry regions (Gregory et al., 2005; Hadley et al., 2006; Perry et al., 2004; Sivakumar et al. ,2005; Stern et al., 2006). Considering the increase in greenhouse gasses emission and continuous trend of global warming, today climatologists seek to identify the outcomes of this great challenge and its effects on the environment and human activities, like agriculture. In this respect, use of climate change models is the main focus of many research centers. Different aspects of climate change exert varying influences on the growth process as well as physiological and phonological properties of plants, especially agricultural crops. Many studies have been conducted in this area, each of which assessing the relationship between climatic change and crop growth in one way or another. Tingem at al. (2008) investigate the effect of climatic changes on the production of corn, peanut, sorghum and bean in Cameron. Their study investigated the changes of carbon dioxide and other greenhouse gasses. It was found that the impact of temperature change on growth and performance of plants is more important that changes of rainfall in this region.

*** Corresponding Author:** Mohammad Amin Heidari, PhD student, Climatology, University of Tehran,
Email: heydaryamin@yahoo.com

Wolfram and Roberts (2006) studied the effect of climate change on three major products of the U.S. Their findings revealed that temperature of about +29°C is associated with increase in the performance of cane and bean and +33°C is related to increase in the performance of cotton. However, raising the temperature over these thresholds is harmful for all three products. Regarding the impact of climate change in tropical areas on date crop, Paterson et al. (2012) indicated that the threshold of date changes by increasing temperature and changes of the moisture. In this way, the condition becomes undesirable and the plant faces stress caused by mycosis. Studying the impact of climatic change on the growth of palm and the amount of oil obtained from it revealed that change of climate reduces plant's performance. Increasing temperature lengthens drought period and leads to underdevelopment, date bunch fading, instability, reduction in crops, and change in the length of blooming period of palm tree (Sutarta et al., 2012).

Siqueira and Peterson (2003) investigated the effect of global climate change on the distribution of tree species in Krado region of Brazil. Their study utilized different scenarios of climate change like HHGSDX50 and HadCM2. Their findings revealed a servers decline in the variety and distribution of tree species. Since only 2.25% of this region was protected, other findings of this study showed negative changes and decrease in the distribution of trees in the east and south and increasing concern about loss of tree variety in this area.

Considering the complexities of climate system, the first models were developed on the atmosphere from among climate's many components, as atmosphere, compared to other parts of this combinational system, has less density and more mobility (Asakereh, 2007). Currently, the most valid tool for developing climatic scenarios is general circulation model of atmosphere-ocean (Lane et al., 1999; Mitchell, 2003; Wilby & Harris, 2003). HadGEM model with its different versions is one of the mostly-used models. Collins et al. (2008), in a study entitled evaluation of HadGEM model, introduced and investigated the application and different versions of this model. General circulation models of atmosphere-ocean, due to their thermodynamic mechanism, are mostly capable of simulating and predicting atmospheric condition. However, the main problem with these models is spatial scale, and in some instances, temporal steps of running them. Most general circulation models of atmosphere-ocean, such as HadGEM, involve large fields of plant scales and do not offer appropriate spatial resolution for local and regional predictions. Hence, they require downscaling. In general, none of the general circulation models can estimate or predict the real climate in local or even smaller scales. Artificial weather generator models are the models which downscale the output of numerical general circulation models using statistical methods so that they resemble real values in the station scale (Babaian & Najafinik, 2007). One of those models is LARS-WG which has been used in this study for downscaling the output of HadGEM model for Abadan region. LARS _WG is also utilized for assessing climate changes and reconstructing climatology data. By evaluating the performance of LARS-WG model in 12 coastal climatology stations in Iran, the model was found appropriate for simulating daily distribution and monthly and seasonal averages of most series (Ababaee et al., 2011).

Considering temperature changes of recent decades in Abadan and precedent increase in summer temperature of this area and their possible effects on performance of date crop, the present study embarked on investigation of such changes in future decades based on the models relevant to climate change.

2. MATERIALS AND METHODS

The geographical area under study was Abadan region in Khoozestan province (Fig. 1) and the data were obtained from the statistics of Abadan synoptic station in 30-year period of 1976-2005. Abadan is considered as one of the important areas of date production in Iran. The date crop of this region is exported to different countries. It also has a major role in providing the date of the country. Palm tree as the plant studied in this research is the major tree in Khoozestan province, especially Abadan. It is resistant against heat and drought. However, like any other plants, it has specified temperature thresholds and above those thresholds, it is vulnerable to performance disorders and in some cases, diseases. These thresholds which are considered as the basis of this study are presented in Table 1.

Table 1. Important Thresholds of Date Plant (Pejman, 2002)

Temperature (°C)	***Stage***
Over 45	Stoppage of growth
Over 40	Starting growth decline
32-38	Desirable growth temperature
Less than 18	Basic generative temperature
Less than 10	Basic growth temperature

In this study, in order to measure average changes of daily minimum and maximum temperature, autocorrelation tests was utilized whose results are presented in figures 2 and 3. To predict temperature changes, HadGEM model, based on scenario A2 was used. Also, using LARS-WG downscaling model, the climatic period of 2046-2065 was predicted based on the data of statistical period 1976-2005 of Abadan climatology station.

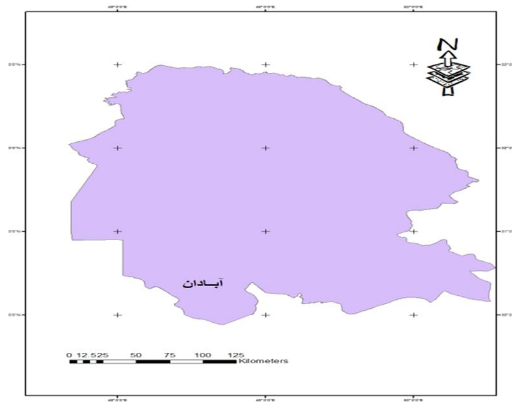

Fig 1. Location of Abadan

Autocorrelation test is one of the common statistical methods for identifying linear and non-linear behavior of climatic elements. It is one of the best methods for long-term assessment of climate in lag times. Autocorrelation function, r(k), measures the linear relationship among time-series observations which are separated by k lag time. The value of r is always between +1 and -1. The value of correlation in different lags is indicated by a diagram called autocorrelation graph. Those values of r(k) which are close to 1 (or which are positive and statistically significant) indicate that observations are separated by k lag times and are greatly inclines to move together in linear path with positive gradients, while those close to -1 (or which are negative and statistically significant) show declining trend of the parameter under study (Heidari, 2013).

The HadGEM model is of the type of paired atmosphere-ocean paired general circulation models (AOGCM). It is the improved form of HadCM3 and was developed in Hadley Centre of England climatology organization. This model does not need surface flux settings (excess artificial flux for ocean surface) for the improvement of simulation. Simulations are done based on 365-day calendar and in 30-day months. High resolution power of oceanic component is the main advantage of this model. Other advantages of it include good coordination between its atmospheric and oceanic components. Investigating simulations of HadGEM1 model with reanalyzed values indicated its improved ability compared to HadCM3 (Martin et al., 2006). The main variables such as temperature, wind, moisture, and pressure in high latitudes of free atmosphere have been improved. The resolution power and dynamic and physical schemas of the model have also been promoted.

A group of the major improvement in the model relate to tropopause structure and pressure pattern of the earth surface in North Pole. Water vapor and rare gasses transmission schemas have been improved, as well. However, some variability aspects like water surface temperature in Pacific region, ENSO phenomenon, and Monsoon rainfall are less improved. These problems provided the major incentive for developing the new versionof general circulation model, HadGEM2, in which the latter problems are corrected (Babaian, 2012). In this study, considering appropriate outputs of HadGEM series, the new and powerful general circulation model of HadGEM1 is utilized which has provided better results in the fourth report of IPCC (2007). As mentioned earlier, this study has been conducted on the basis of A2 scenario. Some features of this scenario are: a world in which countries act independently and are self-relied, the population of the world is continually increasing, and the economic development of the region. The reason for the selection of this scenario is that it simulates the most pessimistic condition which seems more possible due to temperature change trend of recent years in the region. LARS-WG model was used for downscaling data. LARS-WG model is a time-series simulator of daily weather in point scale. This model is specifically used for evaluating agricultural and hydrological risks in climatic changes, and for estimating temperature, amount of rainfall, radiation, evapotranspiration (Semenov et al., 1999). This model employs semi-experimental distribution for modeling the duration of dry and wet period, daily rainfall, and radiation series. Fourier series also estimates temperature. The amount of radiation is calculated through semi-experimental distribution as equal division of intervals between monthly minimum and maximum (Babaian & Najafinik, 2007). Based on the purpose of the study, only minimum, maximum and average daily and monthly temperatures were investigated. In general, using the technique describes, in this study, while identifying the trend of temperature changes in monthly scale in 1976-2005 period based on the temperature thresholds of date crop, the number of days of each threshold per month in 1976-2005 and 2046-2065 periods was compared based on the output of HadGEM model and A2 scenario. And then, the performance of the model was validated using t-student test.

3. RESULTS

Figures 2 and 3 present the results of autocorrelation analysis of daily minimum and maximum temperatures in observation period (1976-2005). Considering the period length and critical significance values in 0.05 level of significance threshold values more or less that 0.35 are considered significant. Positive values refer to increasing trend and negative values point to decreasing trend. The results indicate that the values of both components in all months are increasing, and the average maximum value in May, August, and October are significantly increasing, and January and February are close to significance level. Therefore, the trend of changes of all components is increasing in all months and significant in most months. The significance is observed more in hot months and less in cold months. Thus, it can be concluded that the weather in the region under study shows more increasing trend in hot season. This is important since in hot and dry regions, increasing temperature in summer has more negative impacts on the environment than cold or temperate seasons due to high temperature and lack of rainfall.

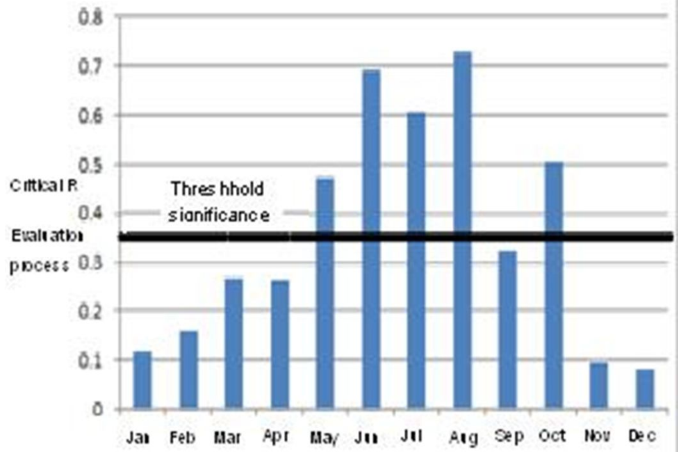

Fig 2. Autocorrelation Test of Trending Average Maximum Daily Temperature (0.05 level of significance)

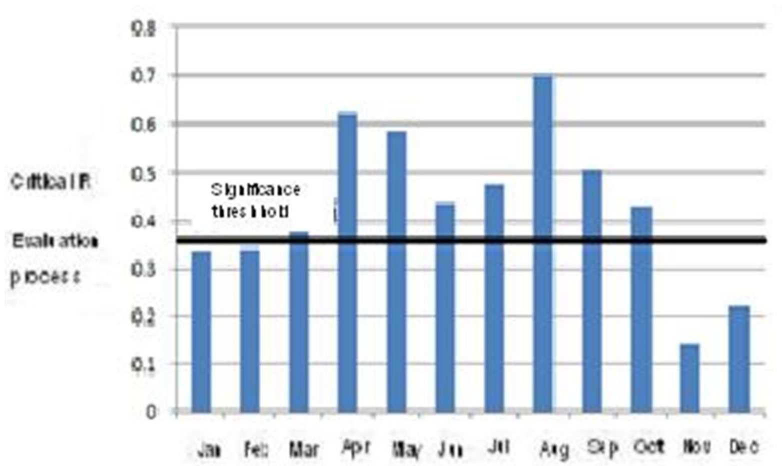

Fig 3. Autocorrelation Test of Trending Average Minimum Daily Temperature (0.05 level of significance)

Figure 4 compares the number of days with maximum temperature of 40°C (the starting temperature of palm tree growth decline)in the observation period and prediction period at the middle of 21st century. Indeed, the threshold mentioned is the condition over plant's tolerance in which plan's growth declines. Accordingly, figure 4 indicates that from July to September, considering the hot weather of the region in both periods, the average temperature of all days are above maximum temperature of 40°C. Hence, there is no significant difference between the two periods. However, in April, May, June, October, and November, the changes point to increase in the number of days with temperature higher than threshold throughout the year. These changes in spring (April to June) are more than cold months like October and November.

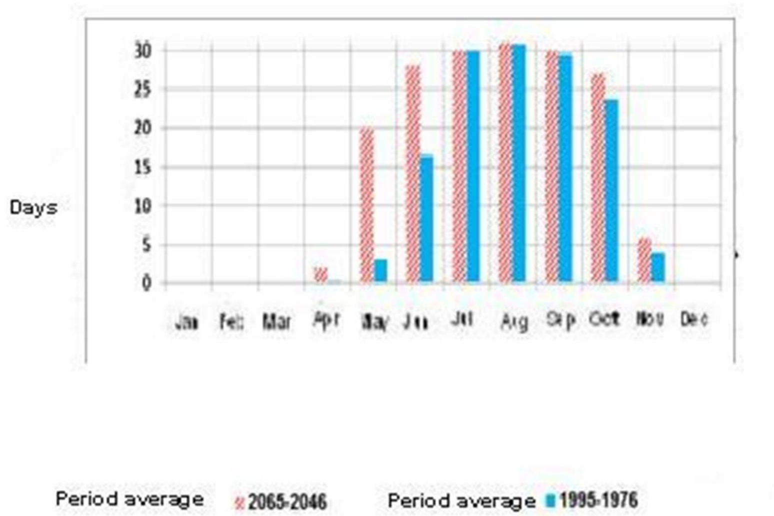

Fig 4. Average Number of days with Maximum Temperature of over 40°C in the Two Observation Periods

Figure 5 shows the average number of days of each month with maximum temperature based on plant growth stoppage threshold (45°C and more) in two observation periods. In this figure, June, July, and August show an increasing trend in the number of days with maximum temperature over the threshold in predicted period. For example, in June and July the number of such days raise from 3 to 17 and from 15 to 27, respectively. This shows an accurate growth condition for palm tree in the future in these months.

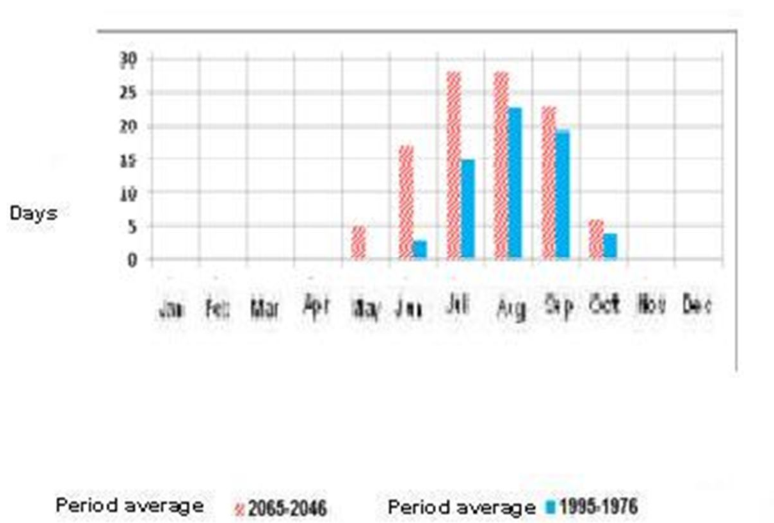

Fig 5. Number of Days with Maximum Temperature over 45°C in Each Month of the Two Observation Periods

In figure 6, the number of days with minimum temperature less than 18°C as the zero point of date generative temperature is presented. As the graph shows, in the predicted period, the number of days with minimum temperature less than 18°C will decrease. This decline will be 3-5 days in cold months and 12-20 days in temperate months like April and May. Hence, it can be argued that in the predicted period, a change will occur in the generative season of the plant.

Fig 6. Number of Days with Minimum Temperature Less than 18°C in the Two Periods under Study

The zero growth point of palm tree is 10°C. In figure 7, the changes in the number of days of this threshold in cold moths of the observation period are presented. According to graph, a significant decline will happen in the average number of days with threshold temperature of 10°C (Zero growth temperature) in the predicted period affecting plant growth during November to March.

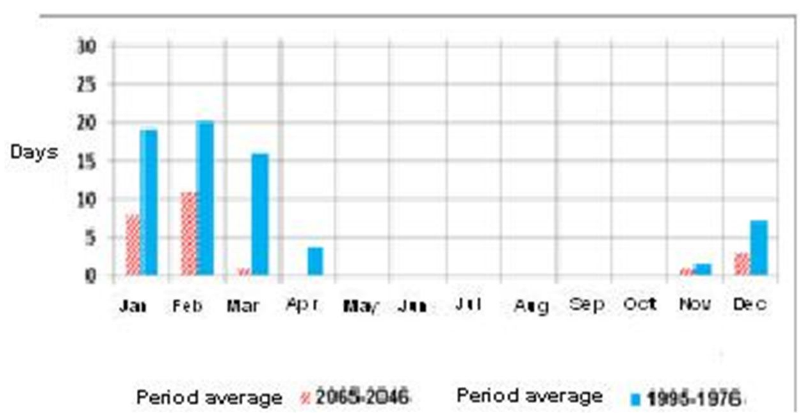

Fig 7. Number of Days with Minimum Temperature Less than 10°C in the Two Periods under Study

Figure 8 shows the best temperature range for this crop, i.e. 32-38 in average daily temperature of two periods. Changes point to a complex and considerable pattern. In fact, this graph indicates the number of days with average appropriate growth temperature in both periods. According to graph, the number of appropriate days increases in April, May, and November, while it decreases in June to October. It seems that the reason for this situation is average temperature changes in predicted period when increase in the temperature increases the number of days with 32-38 degrees. However, in the observation period, in these months (April, May and November) the number of days with this temperature range is less, and the temperature is mostly below 32°C. considering the warming trend in predicted period, the number of days with average threshold temperature increases which is considerable in May reaching from 3 to 15 days in month. On the other hand, by continuing global warming, the number of days with average temperature of 38°C increases leading to decrease in the number of days with appropriate temperature in hot months. In sum, the incident of predicted changes in the middle period of 21st is a warning about days with temperature thresholds over the tolerance of palm tree and increasing the number of such days in hot months.

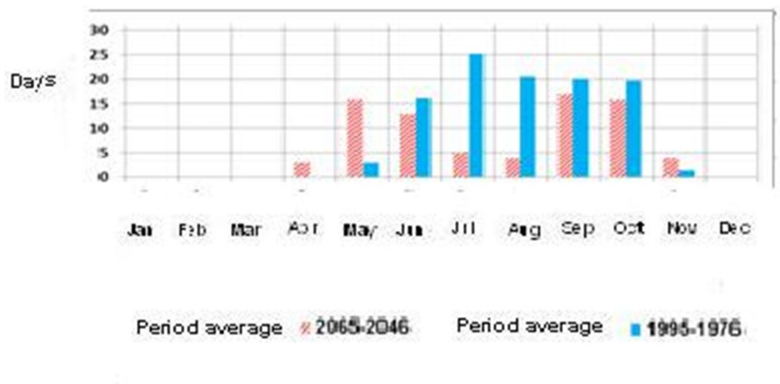

Fig 8. Number of Days with Average Temperature of 32-38°C in two Periods under Study

4. Model Performance Evaluation

In Lars-WG model some statistical tests are used for evaluating model's correctness. In this study, t-student test was utilized to this aim. In this test, after calculating t value, and based on the table of critical values, the SD of two groups was compared. In t-test, if the calculated t value is more than critical values in the table, the null hypothesis (homogeneity of two groups) is not rejected, and the two groups under study (observation period and prediction period) are considered as having similar SD. This confirms model's performance.

Figure 9 shows t value for two modeled components of the study (minimum and maximum temperature) in two periods. According to this test and degree of freedom of data, the critical value was obtained to be 1.7. Hence, model performance is confirmed in all months. In this respect, the maximum temperature with less variability than minimum temperature is accepted with more confidence.

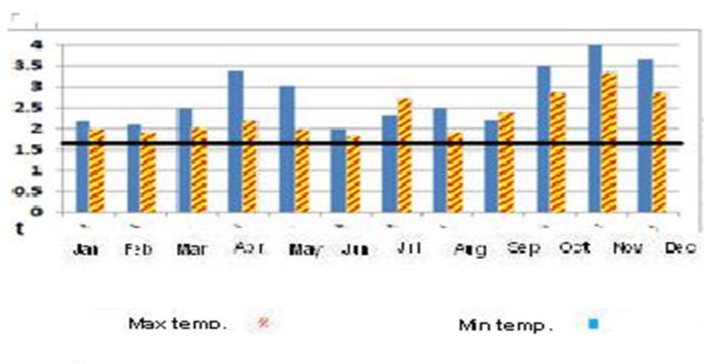

Fig 9. T Value of Student's t-Test in Each month in Two Periods Studied (Critical Value = 1.7)

5. Conclusion

Change of climate leading to global warming at local and regional scalesrepresents a great challenge to the future of agriculture in hot and dry areas. Regardless of the positive impacts of climate change on agriculture in North Pole, the climatic threshold of plants will not be compatible with climatic conditions in tropical latitudes and hot and dry regions of Iran in near future (future decades). In this study, which is conducted on the resistant palm tree using climate change models, it was found that continuation of temperature increase in the region under study in hot months will lead to increase in the number of days with temperature over tolerance threshold of the plant. The worst thing is that the fruiting period of this tree is the interval of hot months, especially July and August. But by changing temperature thresholds of growth in February and March, the probability of change in fruiting period increases, and it is possible that in prediction period (2046-2065) the starting and ending point of date production interval might change. In sum, increasing temperature lead to better condition for growth and biological activity of palm tree, but in hot months, its thermobiological condition, due to increasing temperature over plant's tolerance threshold, is harmful and reduces plant's performance.

REFERENCES

Ababaee, B., Mirzaee, F. & Sohrabi, T. (2011). Investigating performance of LARS-WG model in 12 coastal climatology stations of Iran. *Iranian Water Studies*, 5, 9, 217-222.

Asakereh, H. (2007). Statistical investigation of yearly temperature of Tabriz. *Journal of Geographical Thought*, 1, 9-21.

Babaian. I. 2012. www.climate.mihanblog.com

Babaian, I., Najafinik, Z., Habibi Nokhandan, M, Zabol Abbasi, F., Adab, H. & Malbousi, Sh. (2007). *Modeling climate in 2010-2039 period using downscaling of ECHO-G model output*. Technical workshop of climate change in water resource management, National Iranian Committee of Irrigation and Drainage.

Collins, W.J.,Bellouin, N.,Doutriaux-Boucher, M.,Gedney, N.,Hinton, T.,Jones, C.D.,Liddicoat, S.,Martin, G., O'Connor, F., Rae, J.,Senior, C.,Totterdell, I.,Woodward,S. Reichler and Kim, J. (2008). Evaluation of the Had GEM 2 model. *Met Office Hadley Centre*, Exter.

Edy, Sigit, Sutarta. Heri, Santoso, and Yusuf,M.A.(2012). Climate change on oil palm: Its impacts and adaptation strategies *International seminar on agriculture adaptation in the tropics Bogor.*

Ferreira de Siqueira, M., Peterson, A. (2003). Consequences of global climate change for Geographic distribution of Cerrado tree species. *Biota Neotropica*, 3. 1-14.

Giglioli, N. Saltelli, A. SimLab, 2.2. (2003).*Software for sensitivity and uncertainty Analysis, Simlab Manual*. Joint Research Centre European Commission.

Gregory, P.J., Ingram,J.S.I., & Brklacich, M. (2005).Climate change and food security. *Phil. Trans. Roy. Soc*. 360, 2139–2148.

Hadley Centre. (2006).*Effects of Climate Change in the Developing Countries*. UK Met. Office.

Heidari, M. A. (2013). *The effect of global warming on atmospheric reaction centers affecting Iran's climate*. Master's Thesis, University of Tehran.

Lane, M. E., Kirshen, P. H., & Vogel, R. M. (1999). Indicators of impact of global climate change on U.S. (1999). *Water Resources, ASCE, Journal of Water Resource Planning and Management*, 125, 4, 194-204.

Martin, G. M., Ringer, M. A., Pope, V. D., Jones, A., Dearden, C. & Hinton, T. J. (2006). The Physical properties of the atmosphere in the new Hadley Centre Global Environmental Model, HadGEM1. Part I. Model description and global climatology. J. *Clim.* 19, 1274–1301.

Mitchell, T. D. (2003). Pattern scaling: an examination of accuracy of the technique for describing future climates. *Climatic Change*, 60, 217-242.

Parry, M., C., Rosenzweig, A., Inglesias, M., Livermore & Gischer, G. (2004). *Effects of climate change on global.*

Paterson,R.R.M., Sariah, M.&Lima,N. (2013). How will climate change affect oil palm fungal diseases? *Elsevier. Crop Protection*, 46, 113-120.

Pejman, H. (2001). *Date manual*, Agriculture Education Publication.

Semenov M.A. & Brooks R.J. (1999). Spatial interpolation of the LARS-WG stochastic weathergenerator in Great Britain. *Climate Research* 11, 137-148.

Shen, S. (2003). Global warming science and policy: Progress 2002-2003. *Proceeding of 14th Global Warming International conference &.xpo* (27-30 May Boston. USA).

Sivakumar, M.V.K., Das,H.P., & Brunini, O. Impacts of present and future climate variability and change

Stern, (2006). *Review on the Economics of Climate Change*. HM Treasury, London.

Tingem, M., Rivington, M., Bellocchi, G., Azam-Ali, S. & Jeremy Colls, J. (2008). Effects of climate change on crop production in Cameroon. *Climate Research*, 36, 65-77.

Torriani, D.S., Calanca, P., Schmid, S., Beniston, M., and Fuhrer, J. (2007).Potential effects of changes in mean climate and climate variability on the yield of winter and spring crops in Switzerland. *Climate Research*, 34, 59-69.

Wilby, R. L., and Harris, I. a frame work for assessing uncertainties in climate change impacts: low flow scenarios for the River Thames, UK.2006. Water Resources Research.

Wolfram, S.& Roberts, M. J. (2006). *Estimating the impact of climate change on crop yields: the importance of non-linear temperature effects*. U.S. Department of Agriculture.