International Journal of Agricultural Management and Development (IJAMAD)
Available online on: www.ijamad.iaurasht.ac.ir
ISSN: 2159-5852 (Print)
ISSN:2159-5860 (Online)

Modeling the Impact of Climate Change on Peanut Production on the Basis of Increasing 2°C Temperature in Future Environmental Conditions of Guilan Province, Iran

Seyyed Ali Noorhosseini [1], Afshin Soltani [2] and Hossein Ajamnoroozi [3]*

Received: 14 August 2017,
Accepted: 18 September 2017

Abstract

To evaluate the effect of climate change on peanut production in Northern Iran on the basis of 2°C rise in temperature, a study was conducted using the SSM-Peanut. The simulation was done based on the long-term data obtained from synoptic stations in Guilan including Anzali, Astara, Kiashahr (Astaneh Ashrafieh), Lahijan, Rasht (Agriculture station), Rasht (Airport station), Roudsar and Talesh. When model was run for each year and each scenario, the following parameters were recorded in the outputs: days to beginning bloom, days to beginning pod, days to beginning seed, days to harvest maturity, maximum leaf area index, accumulated crop dry matter, seed yield, and pod yield. Data analysis: data analysis was done using SPSS 18. Furthermore, from ArcGIS was used for zoning of Guilan in terms of peanut production in the current condition and after the climate change. To compare the difference between peanut growth and yield in the current condition and when the climate change happens, t-test and discriminant analysis were used. The results showed that there is a statistically significant difference in terms of all parameters between the current condition and after climate change 2°C rise in temperature) in Guilan Province. With the rise temperature, average peanut growth period in Guilan decreased from 142 days to 123 days. Generally, the average peanut yield changes in Guilan with 2-degree rise in temperature is 8.73 percent more than that in the current condition.

Keywords:
ArcGIS zoning, climate change, peanut production, temperature rise

[1] Department of Agronomy, Gorgan Branch, Islamic Azad University, Gorgan, Iran
[2] Agronomy Group, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran
[3] Department of Agronomy, Gorgan Branch, Islamic Azad University, Gorgan, Iran
* Corresponding author's email: Noorhosseini.SA@gmail.com,

INTRODUCTION

Today, population growth and human activities have led to an increase in greenhouse gas emissions (especially CO_2, CH_4 and N_2O) which is the main cause of global warming and climate change (Intergovernmental Panel on Climate Change, 2013). An increase in the concentration of CO_2 with a rate of 2.4 percent a year (Goudriann, 1995) has resulted in a rise in temperature and a change in rain pattern in different parts of the world and the changes are still taking place. It has been predicted that the average temperature of the world in year 2100 will be two degrees higher than that of year 1990 (Saunders, 1999). According to the latest report of Intergovernmental Panel on Climate Change (IPCC), the average temperature of the world will increase by 0.6-2.5 degrees in 50 years, and by the end of this century, it will have increased by 1.1-6.4 degrees, and the scope of these changes will so vast in the regional scale (IPCC, 2007). Climate change processes will directly affect the production of crops (Bannayan, 2009). Climate changes in some part of the world has positive effects on the production of crops; however, the negative effects of these changes will be severe in hot and dry areas in developing countries (Gregory et al., 2005), a rise in temperature and a decrease in rainfall intensify natural disasters (drought, heatwave, flood, frost) (IPCC, 2007). Temperature rise also affects the crops production by increasing their development rate (Rawlins, 1991). So evaluating the effect of climate changes on crop production requires consideration of a rise in temperature that per se results from the increasing greenhouse gas emissions especially in the sensitive stages of growth.

Barzegar and Soltani (2007) have reported that the 26.17% increase in average yield of rain-fed pea in the Northwest of Iran is due to the decrease in plant growth period and premature ripening of it, and consequently, better adaptation of plant growth in rain-fed condition with water reservoir and a decrease in stress period at the end of growth season. Mirsaneh et al. (2010) concluded that with the temperature rise resulting from climate change in the future, the growth period of sugar beet will decrease and the irrigation requirement will increase considerably as a result of temperature rise. The result of study by Hajarpour et al. (2013) showed that the climate change will increase pea yield by 89% in rain-fed cultivation and 33% decrease in water cultivation. Meghdadi et al. (2015) simulated climate change effect on pea yield in Zanjan and reported that the future climate change on average increases the pea production by 33% comparing to the present condition. This is while yield sustainability in different years will decrease. Fengmei et al. (2007) evaluated the effects of climate change on rice from 2070 to 2090 and showed that by considering the direct effect of CO_2, rice yield will increase in all synoptic. At the same time, Roy et al. (2009) showed that rice and potato yield will have decreased in 2075 by 4 and 7.8 percent respectively compared to 1990. Ababaei et al. (2010) also showed that the average wheat yield decreased by 4.19 and 17.9 in Isfahan as a result of climate change. Lashkari et al. (2011) reported that in all their case study regions in the next following years corn yield will decrease by 1 to 39 percent comparing to the base period.

Peanut is one of the most important and economic oil seed in tropical and semi-tropical regions which is cultivated to produce oil and protein (Maiti & Ebeling, 2002). The area under peanut cultivation in the world is 24.07 million hectares, of which 11.45 million hectares are in Asia. The global production of peanut pod is 37.64 million tons annually (FAO, 2010). The area under cultivation of this plant in Iran is about 3500 hectares of which the highest amount is produced in Guilan (North of Iran) with about 2,800 ha. The average pod harvest in Northern Iran is about 3500 to 4000 Kg/ha (Safarzadeh, 2008; Noorhosseini et al., 2016). In addition, in regard to peanut, despite the fact that it has been a century since peanut was cultivated and produced in Iran and in spite of the fluctuation in the area under cultivation in different regions due to climate condition no effective prediction has been made for the future.

Although in recent years experiments performed in controlled environments have provided a lot of information about the effect of CO_2 or temperature rise on growth processes, they depend on the presence of exact tools. Development of modelling methods is a good alternative and cheap for these studies which has been considered by many researchers (Mattews et al., 1994). To evaluate the effect of climate change on production of crops, plant models can be used. The SSM model is one of these models that can simulate many crops in a vast range of climates (Soltani & Sinclair, 2012). On this account, the current studies attempts to evaluate the effect of climate change on peanut production in northern Iran on the basis of 2oC rise in temperature using the SSM-Peanut.

MATERIALS AND METHOD

Study site and observed climate data

The case study site is in Guilan province, and the meteorological data of this region are from Anzali, Astara, Kiashahr (Astaneh Ashrafieh), Lahijan, Rasht (Agriculture station, AG), Rasht (Airport station, AP), Roudsar and Talesh synoptic stations that are presented in Table 1.

Used model structure

The SSM model was used to simulate growth, development and yield of peanut. The SSM model predicts phenological stages as a function of temperature and day length. Leaf area development and senescence is a function of temperature, nitrogen for leaf growth, plant density and nitrogen remobilization. The SSM-model simulates the process of plant growth and development in response to environmental solar radiation, temperature, nitrogen, and water availability. The daily amount of dry matter produced can be readily calculated based on the amount of received global radiation (SRAD), the fraction of the incident radiation intercepted by the leaves (FINT) and radiation use efficiency of the crop (RUE). In this study, simulation of seed growth rate and formation of yield calculated based on linear increase harvest index. The SSM-model performs simulation on a daily basis and uses soil and the weather data (Soltani & Sinclair, 2012). It should be noted that this model does not consider the effects of pests, diseases and weeds on the plant, therefore, in this study, the effect of these factors on physiological characteristics and plant traits are not discussed. Long-term daily weather data, including minimum and maximum temperature, rainfall, and daily sunshine hours for all the available years, were collected from synoptic stations. Sunshine hours were converted to global radiation using the Angstrom equation. For this purpose, the Srad cale (Soltani & Maddah, 2010) program was used. In this study, data from different field experiments conducted in Astaneh Ashrafieh, northern Iran were used for coefficient estimation and model evaluation. Then, the model was used to simulate the effect of climate change on peanut growth and yield. In order to parameterize the SSM-peanut model for peanut (variety North Carolina 2, NC_2), first approximate values of parameters were extracted from previous references and inserted in the model. With regard to parameters that are approximately fixed in dif-

Table 1
List of Synoptic Stations of Investigated Locations with Latitude, Longitude and Altitude

Station	Latitude (°N)	Longitude (°E)	Altitude (m)	Baseline period	Mean temperature (°C)		Rainfall in year (mm)	Sunny hours
					Minimum	Maximum		
Anzali	37°29'	49°27'	-23.6	1992-2015	14.29	19.15	1718.20	5.25
Astara	38°21'	48°51'	-21.1	1992-2015	12.00	19.19	1359.27	5.09
Kiashahr	37°23'	49°53'	-22	2007-2015	13.23	20.47	1302.56	4.77
Lahijan	37°12'	50°01'	34.2	2005-2015	12.02	21.06	1383.06	5.04
Rasht (AP)	37°19'	49°37'	-8.6	1992-2015	12.42	20.86	1305.68	4.76
Rasht (AG)	37°12'	49°38'	24.9	2000-2015	12.16	21.15	1317.21	4.91
Roudsar	37°07'	50°19'	-22.0	2007-2015	12.96	20.40	1287.49	5.26
Talesh	37°50'	48°52'	7	2006-2015	12.77	19.81	1054.51	4.39

Table 2
Important Parameters in Soil Water Balance for the Study Area

Parameters	Value	References
Volumetric water content when the soil is fully saturated with water (SAT, m^3 m^{-3})	0.458	Batjes, 2000
Volumetric water content at drained upper limit (DUL, m^3 m^{-3})	0.405	Batjes, 2000
Volumetric water content extractable by the crops (EXTR, m^3 m^{-3})	0.172	Batjes, 2000
Volumetric water content at lower limit (LL, m^3 m^{-3})	0.233	Batjes, 2000
Soil inputs of depth (SOLDEP, mm)	1200	Batjes, 2000
Soil albedo (SALB)	0.050	Batjes, 2000
Drainage factor (DRAINF)	0.200	Batjes, 2000
Curve number (CN)	85.00	Batjes, 2000

ferent varieties, there was no report of any changes to the parameters and thus were regarded fixed for NC_2. However, with regard to other parameters, where differences were possible considering the variety of the region, results of the conducted studies in the region were used and Soltani and Sinclair's parameterization method was adopted (Soltani & Sinclair, 2012). Evaluation of the model was done separately using data of experiments in the parameterization stage and data of independent experiments. First, observed phenological stages (including days to beginning bloom (dtR1), beginning pod (dtR3), beginning seed (dtR5) and harvest maturity (dtR8)), maximum leaf area index (MXLAI, m^2 m^{-2}), accumulated crop dry matter at harvest maturity (WTOP, g m^{-2}), seed yield (WGRN, g m^{-2}) and pod yield (WPOD, g m^{-2}) were compared with model simulation values using data of experiments in the parameterization stage. Then, an independent model evaluation was performed using extracted data from other experiments, including days to harvest maturity (dtR1), accumulated crop dry matter in harvest at harvest maturity (WTOP, g m^{-2}), seed yield (WGRN, g m^{-2}) and pod yield (WPOD, g m^{-2}). So, Noorhosseini et al., (2018) reported that there was no significant difference between the values simulated by SSM-Peanut model and the observed values in the field.

Climate change scenarios

Evaluating reaction to temperature rise: to evaluate the reaction of peanut growth and yield to temperature rise in Guilan, the current condition is compared to 2°C increase in temperature. CO_2 concentration for both conditions is 350 ppm (According to current climate conditions). First the temperature changes in long-term meteorological data from synoptic stations were implemented based on two degrees increase in temperature. Then peanut growth and yield were simulated based on these changes.

Simulations

As was mentioned, SSM-Peanut model was used to simulate the growth and yield of peanut under existing climatic conditions of Guilan Province and different scenarios. To this end, the plant density of peanut was set at 6.25 plants m^{-2}. The planting date was May 14 for all scenarios and the parameters of locally prevailing cultivar 'North Carolina 2' (NC_2) were used. Soil net N content which was absorbable at the beginning of the season was estimated at 2.76 g m^{-2}. Since peanut is locally grown without irrigation because of high phreatic zone in the region, after a look at the phreatic zone, 0.5 was considered for fraction of soil available water (FTSW). Table 2 summarizes soil data with respect to geographical point and soil texture in the studied region derived from global database of Batjes (2000).

After the model was run for each year and each scenario, the following parameters were recorded in the outputs: days to beginning bloom (R1), days to beginning pod (R3), days to beginning seed (R5), days to harvest maturity (R8), maximum leaf area index (m^2 m^{-2}), accumulated crop dry matter (g m^{-2}), seed yield (g m^{-2}), and pod yield (g m^{-2}).

Data analysis

Data analysis was done by SPSS. In the section of descriptive statistics, standard error of the mean (S.E. Mean) and coefficient of variation (CV) were used. To compare the difference between peanut growth and yield in the current condition and when the climate change happens, t-test and discriminant analysis were used. Furthermore, zoning of Guilan in terms of peanut production in the current condition and after the climate change, ArcGIS was used.

RESULTS

Days to beginning bloom

Table 3 shows the days to beginning bloom of peanut in current condition and 2°C rise in temperature with standard error and coefficient of variation for the synoptic stations in Guilan. Predicting the days to beginning bloom of peanut with the SSM model showed that the minimum days to beginning bloom of peanut was in Kiashahr synoptic station in current condition and 2°C rise in temperature was 43 and 38 days respectively. The results showed that in all synoptic stations with 2°C rise in temperature, days to beginning bloom of peanut will decrease too (Table 3). The result of t-test showed that there is a significant difference ($p< 0.01$) between the average days to beginning bloom predicted for the current condition (46 days) and the 2°C rise in temperature (40 days) in Guilan province (Table 3). Generally, the average changes of peanut days to beginning bloom in Guilan with 2°C rise in temperature are 6 days less than the current condition (Table 3).

Days to beginning pod

Table 4 shows the days to beginning pod of peanut in current condition and 2°C rise in temperature with standard error and coefficient of variation for the synoptic stations in Guilan. Predicting the days to beginning pod of peanut with the SSM model showed that the minimum days to beginning pod of peanut was in Kiashahr synoptic station in current condition and 2°C rise in temperature was 59 and 53 days respectively. The results showed that in all synoptic stations with 2°C rise in temperature, days to beginning pod of peanut will decrease too (Table 4). The result of t-test showed that there is a significant difference ($p<0.01$) between the average days to beginning pod predicted for the current condition (62 days) and the 2°C rise in temperature (55 days) in Guilan province (Table 4). Generally, the average changes of peanut days to beginning pod in Guilan with 2°C rise in temperature are 7 days less than the current condition (Table 4).

Table 3
Comparison of Peanut Days to Beginning Bloom (R1) in Current Conditions and 2°C Rise in Temperature in Guilan, Iran

Parameter / Station	Replications (years)	Current conditions			After climate change (2°C rise in temperature)			Change Days to R1 (days)	t-test	Sig.
		Days to R1	S.E. Mean	CV (%)	Days to R1	S.E. Mean	CV (%)			
Anzali	24	46	0.86	9.21	40	0.66	8.10	-6	5.097	0.000
Astara	24	48	0.86	8.65	42	0.66	7.68	-6	5.656	0.000
Kiashahr	9	43	1.08	7.54	38	0.92	7.28	-5	3.603	0.002
Lahijan	12	47	1.00	7.48	41	0.74	6.36	-6	4.803	0.000
Rasht (AG)	16	45	0.94	8.27	40	0.72	7.20	-6	4.814	0.000
Rasht (AP)	24	45	0.67	7.35	39	0.51	6.39	-6	6.691	0.000
Roudsar	9	44	0.97	6.63	39	0.67	5.21	-5	4.615	0.000
Talesh	10	46	0.98	6.79	40	0.77	6.08	-6	4.582	0.000
Guilan	128	46	0.35	8.53	40	0.27	7.60	-6	13.033**	0.000

** $p<0.01$

Table 4

Comparison of Peanut Days to Beginning Pod (R3) in Current Conditions and 2°C Rise in Temperature in Guilan, Iran

Parameter / Station	Replications (years)	Current conditions			After climate change (2°C rise in temperature)			Change Days to R3 (days)	t-test	Sig.
		Days to R3	S.E. Mean	CV (%)	Days to R3	S.E. Mean	CV (%)			
Anzali	24	62	0.99	7.84	55	0.73	6.45	-7	5.448	0.000
Astara	24	65	0.97	7.31	58	0.78	6.61	-8	6.060	0.000
Kiashahr	9	59	1.36	6.94	53	0.96	5.45	-6	3.800	0.002
Lahijan	12	63	1.25	6.84	56	0.99	6.12	-8	4.702	0.000
Rasht (AG)	16	62	1.00	6.45	55	0.78	5.67	-7	5.383	0.000
Rasht (AP)	24	61	0.81	6.49	55	0.59	5.27	-7	6.892	0.000
Roudsar	9	60	1.05	5.27	54	0.77	4.29	-6	4.946	0.000
Talesh	10	62	1.14	5.77	55	0.83	4.75	-7	4.975	0.000
Guilan	128	62	0.40	7.25	55	0.30	6.22	-7	13.896**	0.000

** p<0.01

Days to beginning seed

Table 5 shows the days to beginning seed of peanut in current condition and 2°C rise in temperature with standard error and coefficient of variation for the synoptic stations in Guilan. Predicting the days to beginning seed of peanut with the SSM model showed that the minimum days to beginning seed of peanut was in Kiashahr synoptic station in current condition and 2°C rise in temperature was 76 and 69 days respectively. The results showed that in all synoptic stations with 2°C rise in temperature, days to

Table 5

Comparison of Peanut Days to Beginning Seed (R5) in Current Conditions and 2°C Rise in Temperature in Guilan, Iran

Parameter / Station	Replications (years)	Current conditions			After climate change (2°C rise in temperature)			Change Days to R5 (days)	t-test	Sig.
		Days to R5	S.E. Mean	CV (%)	Days to R5	S.E. Mean	CV (%)			
Anzali	24	80	1.11	6.82	72	0.76	5.21	-8	5.700	0.000
Astara	24	83	1.10	6.49	74	0.81	5.36	-9	6.624	0.000
Kiashahr	9	76	1.56	6.10	69	1.08	4.67	-7	3.755	0.002
Lahijan	12	82	1.37	5.81	73	0.96	4.55	-9	5.192	0.000
Rasht (AG)	16	80	1.08	5.44	72	0.80	4.48	-8	6.032	0.000
Rasht (AP)	24	79	0.86	5.30	71	0.63	4.31	-8	7.562	0.000
Roudsar	9	78	1.20	4.65	70	0.81	3.45	-7	5.139	0.000
Talesh	10	81	1.25	4.90	72	0.86	3.79	-9	5.732	0.000
Guilan	128	80	0.44	6.25	72	0.32	4.96	-8	15.044**	0.000

** p<0.01

Table 6

Comparison of Peanut Days to Harvest Maturity (R8) in Current Conditions and 2°C Rise in Temperature in Guilan, Iran

Parameter / Station	Replications (years)	Current conditions			After climate change (2°C rise in temperature)			Change Days to R8 (days)	t-test	Sig.
		Days to R8	S.E. Mean	CV (%)	Days to R8	S.E. Mean	CV (%)			
Anzali	24	141	2.66	9.25	123	1.23	4.88	-18	6.035	0.000
Astara	24	151	2.42	7.86	128	1.53	5.89	-23	8.038	0.000
Kiashahr	9	135	3.32	7.41	119	1.53	3.84	-16	4.160	0.002
Lahijan	12	145	3.38	8.05	124	1.57	4.39	-21	5.683	0.000
Rasht (AG)	16	140	2.32	6.61	122	1.12	3.65	-18	6.924	0.000
Rasht (AP)	24	141	2.21	7.68	122	0.95	3.79	-19	7.653	0.000
Roudsar	9	136	2.44	5.41	120	1.30	3.25	-16	5.455	0.000
Talesh	10	143	3.12	6.89	123	1.51	3.88	-20	5.859	0.000
Guilan	128	142	1.04	8.29	123	0.52	4.80	-19	16.323**	0.000

** $p<0.01$

beginning seed of peanut will decrease too (Table 5). The result of t-test showed that there is a significant difference ($p<0.01$) between the average days to beginning seed predicted for the current condition (80 days) and the 2°C rise in temperature (72 days) in Guilan province (Table 5). Generally, the average changes of peanut days to beginning seed in Guilan with 2oC rise in temperature are 8 days less than the current condition (Table 5).

Days to harvest maturity

Table 6 shows the days to harvest maturity of peanut in current condition and 2°C rise in temperature with standard error and coefficient of variation for the synoptic stations in Guilan. Predicting the days to harvest maturity of peanut with the SSM model showed that the minimum days to harvest maturity of peanut was in Kiashahr synoptic station in current condition and 2°C rise in temperature was 135 and 119 days respectively. The results showed that in all synoptic stations with 2°C rise in temperature, days to harvest maturity of peanut will decrease too (Table 6). The result of t-test showed that there is a significant difference ($p<0.01$) between the average days to harvest maturity predicted for the current condition (142 days) and the 2°C rise in temperature (123 days) in Guilan Province (Table 6). The maximum changes of days to harvest maturity are related to Astara Synoptic station with 23 days and the minimum changes of days to harvest maturity is related to Kiashahr and Roudsar with 16 days. Generally, the average changes of peanut days to harvest maturity in Guilan with 2°C rise in temperature are 19 days less than the current condition (Table 6).

Maximum leaf area index

Table 7 shows the maximum leaf area index (MXLAI) of peanut in current condition and 2°C rise in temperature with standard error and coefficient of variation for the synoptic stations in Guilan. Predicting the maximum leaf area index of peanut with the SSM model showed that the highest MXLAI of peanut was in Kiashahr synoptic station in current condition and 2°C rise in temperature was 4.22 and 4.46 $m^2.m^{-2}$ respectively. However, after increasing by 2oC temperature, the MXLAI in Talesh was 4.48 $m^2.m^{-2}$. The results showed that in all synoptic stations with 2°C rise in temperature, MXLAI of peanut will increase too (Table 7). The result of t-test showed that there is a significant difference ($p<0.01$) between the average

Table 7

Comparison of Peanut Maximum Leaf Area Index (MXLAI, m^2 m^{-2}) in Current Conditions and 2°C Rise in Temperature in Guilan, Iran

Parameter / Station	Replications (years)	Current conditions			After climate change (2°C rise in temperature)			Change MXLAI (%)	t-test	Sig.
		MXLAI (m^2 m^{-2})	S.E. Mean	CV (%)	MXLAI (m^2 m^{-2})	S.E. Mean	CV (%)			
Anzali	24	4.14	0.11	12.61	4.27	0.07	7.73	3.11	1.021	0.312
Astara	24	3.90	0.10	12.68	4.24	0.07	8.19	8.72	2.757	0.008
Kiashahr	9	4.22	0.19	13.40	4.46	0.18	12.32	5.85	0939	0.362
Lahijan	12	3.99	0.13	11.69	4.27	0.12	10.10	7.17	1.560	0.133
Rasht (AG)	16	4.01	0.13	13.04	4.25	0.11	10.00	6.05	1.441	0.160
Rasht (AP)	24	4.11	0.10	12.01	4.27	0.08	8.73	3.80	1.238	0.222
Roudsar	9	4.20	0.20	14.15	4.23	0.18	12.64	0.92	0.146	0.886
Talesh	10	4.08	0.12	8.94	4.48	0.13	9.12	10.01	2.355	0.030
Guilan	128	4.06	0.04	12.34	4.29	0.04	9.31	5.57	3.995**	0.000

** $p<0.01$

MXLAI predicted for the current condition (4.06 $m^2.m^{-2}$) and the 2oC rise in temperature (4.29 $m^2.m^{-2}$) in Guilan province (Table 7). The maximum MXLAI changes are related to Talesh Synoptic station with 10.01 percent and the minimum MXLAI changes is related to Roudsar with 0.92. Generally, the average peanut MXLAI changes in Guilan with 2oC rise in temperature are 5.57 percent more than the current condition (Table 7).

Accumulated crop dry matter

Table 8 shows the value of peanut accumulated

Table 8

Comparison of Peanut Accumulated Crop Dry Matter (WTOP, g m^{-2}) in Current Conditions and 2°C Rise in Temperature in Guilan, Iran

Parameter / Station	Replications (years)	Current conditions			After climate change (2°C rise in temperature)			Change WTOP (%)	t-test	Sig.
		WTOP ($g.m^{-2}$)	S.E. Mean	CV (%)	WTOP ($g.m^{-2}$)	S.E. Mean	CV (%)			
Anzali	24	846	20.98	12.16	865	18.55	10.51	2.27	0.686	0.496
Astara	24	810	18.74	11.33	855	14.76	8.45	5.53	1.880	0.066
Kiashahr	9	831	36.14	13.05	856	28.68	10.06	2.98	0.537	0.599
Lahijan	12	795	31.61	13.78	833	27.57	11.46	4.80	0.910	0.373
Rasht (AG)	16	801	22.40	11.19	825	20.54	9.96	3.00	0.790	0.436
Rasht (AP)	24	801	18.21	11.14	814	15.99	9.62	1.65	0.545	0.588
Roudsar	9	827	40.66	14.75	843	29.85	10.63	1.91	0.313	0.758
Talesh	10	793	31.66	12.63	835	28.44	10.77	5.30	0.987	0.337
Guilan	128	814	8.66	12.04	841	7.41	9.97	3.34	2.386**	0.018

** $p<0.01$

Table 9
Comparison of Peanut Seed Yield (g.m^{-2}) in Current Conditions and 2^{o}C Rise in Temperature in Guilan, Iran

Parameter / Station	Replications (years)	Current conditions			After climate change (2^{o}C rise in temperature)			Change yield (%)	t-test	Sig.
		Seed yield (g.m^{-2})	S.E. Mean	CV (%)	Seed yield (g.m^{-2})	S.E. Mean	CV (%)			
Anzali	24	310	11.36	17.93	326	9.16	14.04	5.18	1.084	0.284
Astara	24	282	10.99	19.06	320	7.82	12.21	13.32	2.749	0.009
Kiashahr	9	320	19.45	18.24	348	9.16	8.33	8.73	1.269	0.223
Lahijan	12	290	18.30	21.84	324	12.33	13.71	11.71	1.499	0.148
Rasht (AG)	16	288	12.31	17.12	314	10.63	13.95	9.22	1.588	0.123
Rasht (AP)	24	295	10.50	17.46	310	8.67	13.96	5.38	1.146	0.258
Roudsar	9	305	21.26	20.92	327	11.71	11.33	7.15	0.872	0.396
Talesh	10	296	16.68	17.83	332	13.18	13.16	12.26	1.639	0.119
Guilan	128	297	4.84	18.46	322	3.82	13.41	8.73	4.197**	0.000

** $p<0.01$

crop dry matter in current condition and 2^{o}C rise in temperature with standard error and coefficient of variation for the synoptic stations in Guilan. Predicting the value of peanut accumulated crop dry matter with the SSM model showed that the maximum accumulated crop dry matter of peanut was in Anzali and Kiashahr synoptic station for current condition with 846 and 931g.m^{-2} respectively and for 2^{o}C rise in temperature with 865 and 856g.m^{-2} respectively. The results showed that in all synoptic stations with 2^{o}C rise in temperature value of accumulated crop dry matter will increase too (Table 8). The result of t-test showed that there is a significant difference ($p<0.01$) between the average accumulated crop dry matter predicted for the current condition (814 g.m^{-2}) and the 2^{o}C rise in temperature (841 g.m^{-2}) in Guilan province (Table 8). The maximum accumulated crop dry matter changes are related to Astara Synoptic station with 5.53 percent and the minimum accumulated crop dry matter changes is related to Rasht (Airport) with 1.65. Generally, the average peanut accumulated crop dry matter changes in Guilan with 2^{o}C rise in temperature are 3.34 percent more than the current condition (Table 8).

Seed yield

Table 9 shows the value of peanut seed yield in current condition and 2^{o}C rise in temperature with standard error and coefficient of variation for the synoptic stations in Guilan. Predicting the value of peanut seed yield with the SSM model (with the use of long-term water, air, and soil data) showed that the highest yield of peanut was in Kiashahr synoptic station in current condition and 2^{o}C rise in temperature was 320 and 348 g.m^{-2} respectively. The results showed that in all synoptic stations with 2^{o}C rise in temperature value of peanut seed yield will increase too (Table 9 and Figure 1). The result of t-test showed that there is a significant difference ($p<0.01$) between the average peanut seed yield predicted for the current condition (279 g.m^{-2}) and the 2^{o}C rise in temperature (322 g.m^{-2}) in Guilan province (Table 9). Figure 2-A and 2-B show respectively zoning of peanut seed yield in current condition and the 2^{o}C rise in temperature with the use of GIS. As can be seen, changes of yield increase with 2^{o}C rise in temperature in all parts of Guilan are noticeable. The maximum seed yield changes are related to Astara Synoptic station with 13.32 percent and the minimum seed yield changes is related to

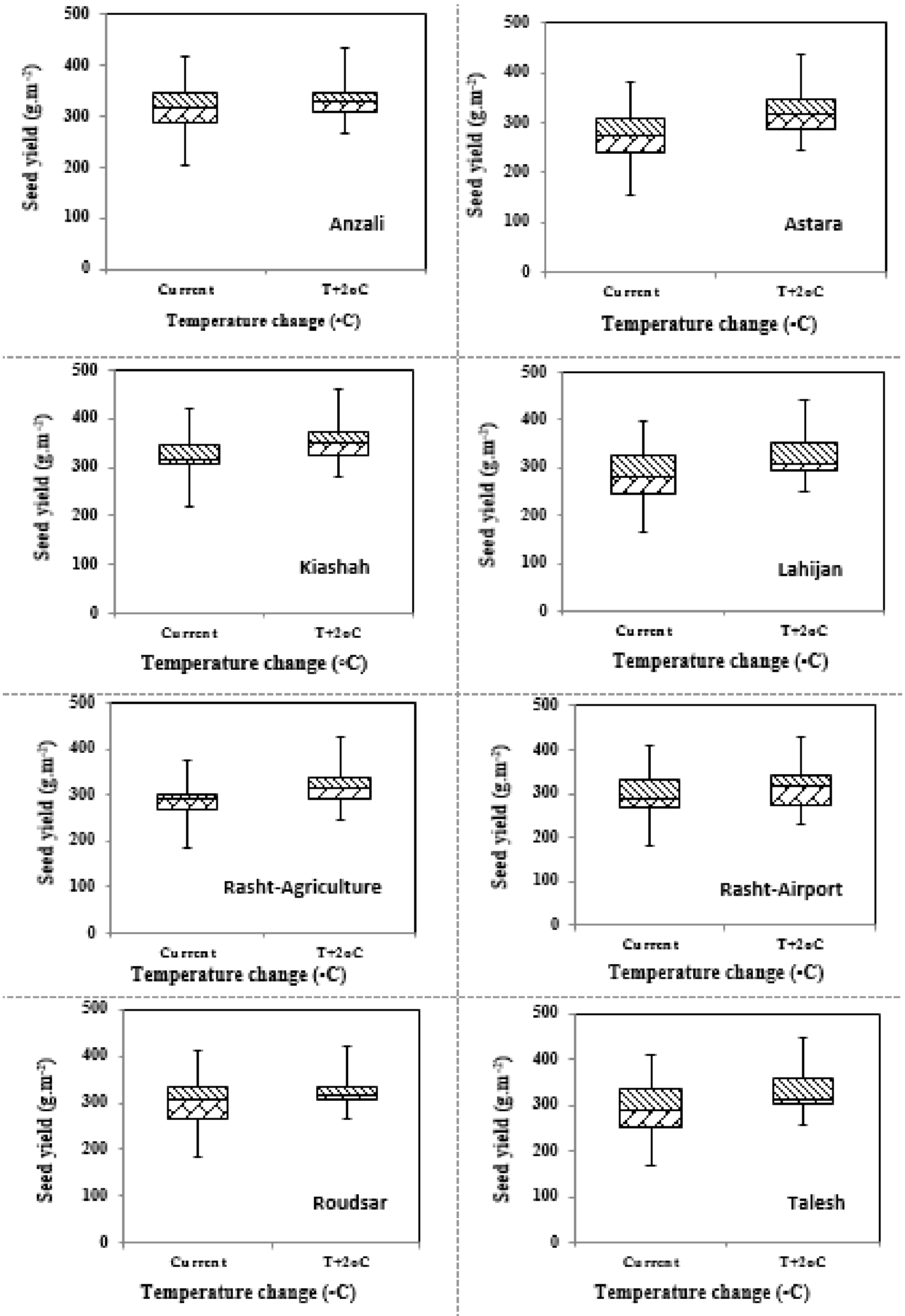

Figure 1. Comparison of peanut seed yield (g.m-2) in current conditions and after climate change (2oC rise in temperature) in Guilan, Iran

Anzali with 5.18. Generally, the average peanut seed yield changes in Guilan with 2°C rise in temperature are 8.73 percent more than the current condition (Table 9).

Pod yield

Table 10 shows the value of peanut pod yield in current condition and 2°C rise in temperature with standard error and coefficient of variation for the synoptic stations in Guilan. Predicting the value of peanut pod yield with the SSM model showed that the highest pod yield of peanut was in Kiashahr synoptic station in current condition and 2°C rise in temperature was 415 and 451g.m^{-2} respectively. The results showed that in all synoptic stations with 2°C rise in temperature value of peanut pod yield will increase too (Table 10 and Figure 3). The result of t-test showed that there is a significant difference ($p<0.01$) between the average peanut

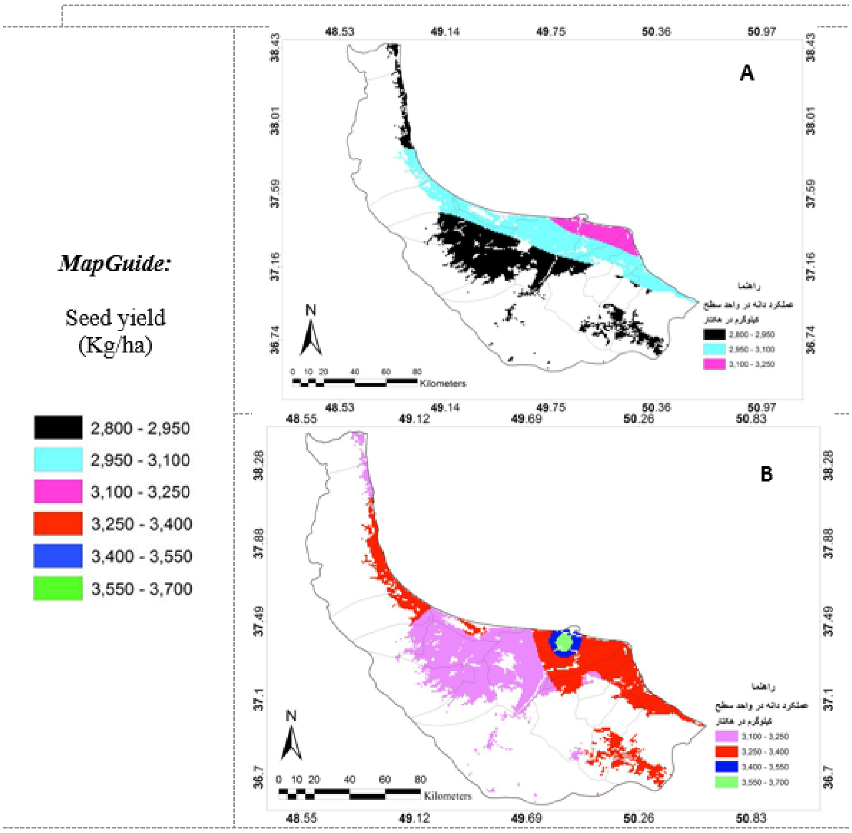

Figure 2. Zoning of seed yield of peanut in the current conditions (A) and after climate change (B) in Guilan (North of Iran)

pod yield predicted for the current condition (385 g.m^{-2}) and the 2^{o}C rise in temperature (419 g.m^{-2}) in Guilan province (Table 10). Figure 4-A and 4-B show respectively zoning of peanut pod yield in current condition and the 2^{o}C rise in temperature with the use of GIS. As can be seen, changes of pod yield increase with 2^{o}C rise in temperature in all parts of Guilan are noticeable. The maximum pod yield changes are related to Astara Synoptic station with 13.36 percent and the minimum pod yield changes is related to Anzali with 5.17. Generally, the average peanut pod yield changes in Guilan with 2^{o}C rise in temperature are 8.73 percent more than the current condition (Table 10).

Discriminant analysis

We used discriminant analysis on the basis of the observed characteristics to make predictions for future and distinguish the effects of climate change vs. the current conditions. The significance and fit of the function were examined by Wilks' Lambda. The canonical coefficient was used to verify the function fit and its repeatability. In the present study, the discriminant analysis could identify a canonical discriminant function in which the eigenvalue was 1.792. Also, the square of canonical correlation was 0.8. The function could account for 64.2 percent of the total variance between the two groups (current climate and climate change) (Wilks' Lambda = 0.358). Results showed that the means of the two groups (current climate conditions versus post-climate change conditions) were different in the presence of all growth and yield variables (χ^2 = 258.23, P < 0.01). Results revealed that all studied variables were present in discriminating the current conditions and post-climate change conditions, so that significant differences were observed between current climate conditions and post-climate change conditions in terms of various phenological phases (days to flowering, days to pod formation, days to seed formation, and days to maturity), leaf area index, dry matter accumulation, and grain and yield. Since there are variables with different units and scales in discriminant

Table 10

Comparison of Peanut Pod Yield (g.m^{-2}) in Current Conditions and 2^{o}C Rise in Temperature in Guilan, Iran

Station	Replications (years)	Current conditions: Pod yield (g.m^{-2})	Current conditions: S.E. Mean	Current conditions: CV (%)	After climate change (2^{o}C rise in temperature): Pod yield (g.m^{-2})	After climate change: S.E. Mean	After climate change: CV (%)	Change yield (%)	t-test	Sig.
Anzali	24	403	14.75	17.93	424	12.41	14.34	5.17	1.081	0.285
Astara	24	367	14.30	19.10	416	10.59	12.47	13.36	2.754	0.008
Kiashahr	9	415	25.31	18.28	451	13.26	8.82	8.64	1.256	0.227
Lahijan	12	377	23.75	21.84	421	17.43	14.33	11.81	1.511	0.145
Rasht (AG)	16	374	16.01	17.14	408	14.69	14.40	9.25	1.591	0.122
Rasht (AP)	24	383	13.63	17.45	403	11.74	14.27	5.37	1.142	0.260
Roudsar	9	396	27.65	20.94	424	16.96	11.99	7.09	0.867	0.399
Talesh	10	384	21.59	17.77	431	18.94	13.89	12.26	1.640	0.118
Guilan	128	385	6.29	18.47	419	4.96	13.41	8.73	4.197**	0.000

** p<0.01

Table 11

Tests of Equality of Group Means and Canonical Discriminant Functions

Parameters	Wilks' Lambda	F	Sig.	Standardized Coefficients	Structure Matrix [1]
dtR1	0.599	169.867	0.000	-0.135	0.611
dtR3	0.568	193.088	0.000	-0.881	0.651
dtR5	0.529	226.307	0.000	0.881	0.705
dtR8	0.488	266.442	0.000	1.362	0.765
MXLAI	0.941	15.959	0.000	0.187	-0.187
WTOP	0.978	5.692	0.018	1.558	-0.112
WGRN	0.935	17.615	0.000	-1.029	-0.197
WPOD	0.935	17.611	0.000		-0.196 [a]

[a] This variable not used in the analysis.

analysis, they should be converted to standardized coefficients to lend themselves to the determination of their relative contribution. It was found that the variables included in the model have a very high capability to discriminate the two groups of current conditions and post-climate change conditions. The correlation coefficient between each independent variable with the discriminant function was shown by structure matrix. These values are equivalent to factor loads in factor analysis. The closer these number are to 1, the more effective they are in the discriminant function. In this study, the variable dtR8 were found to be effective in discriminating the groups with structure matrix of and 0.765, respectively (Table 11).

Finally, Table 12 shows how successful the discriminant function was in the sound classification of the observations. The classification process of this function indicated its high prediction potential so that it could

[1] Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions Variables ordered by absolute size of correlation within function.

Table 12
Classification Results

Groups		Predicted Group Membership		Total
		Current Climate	Climate Change	
Count	Current Climate	115	13	128
	Climate Change	4	124	128
Percent	Current Climate	89.8	10.2	100.0
	Climate Change	3.1	96.9	100.0

93.4% of original grouped cases correctly classified.

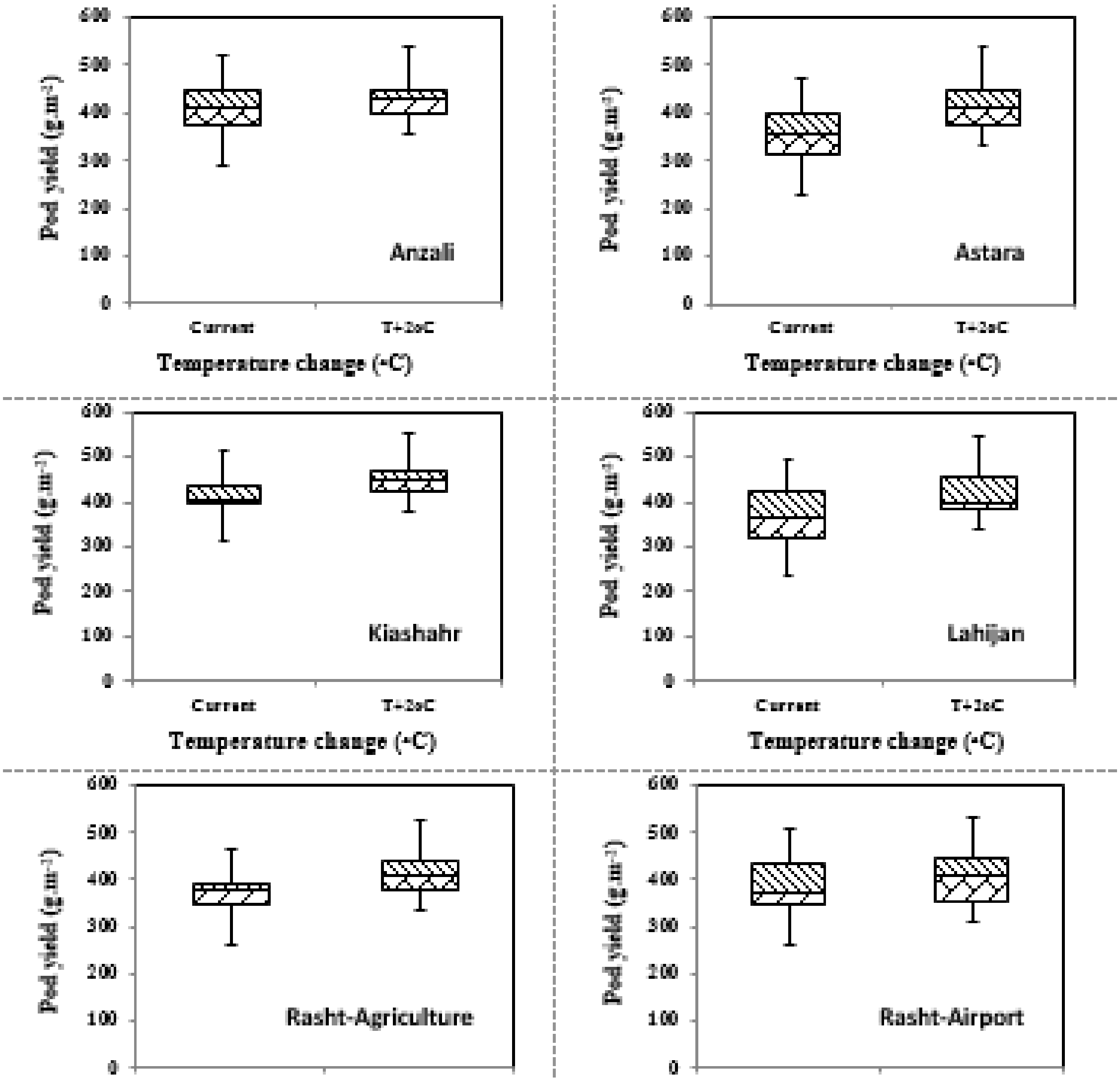

Figure 3. Comparison of peanut pod yield (g.m^{-2}) in current conditions and after climate change (2^{o}C rise in temperature) in Guilan, Iran

classify 93.4 percent of the cases correctly. The results of the classification revealed that only 10.2 percent of replications predicted by this function in current conditions were erroneously placed in post-climate change group and that 3.1 percent that were related to the climate change conditions were placed in a wrong current conditions group. The results indicate that this function had high discrimination potential for classifying the groups. The coefficients of all studied variables for predictions by this function are presented in Table 11 in which structure matrix is included too.

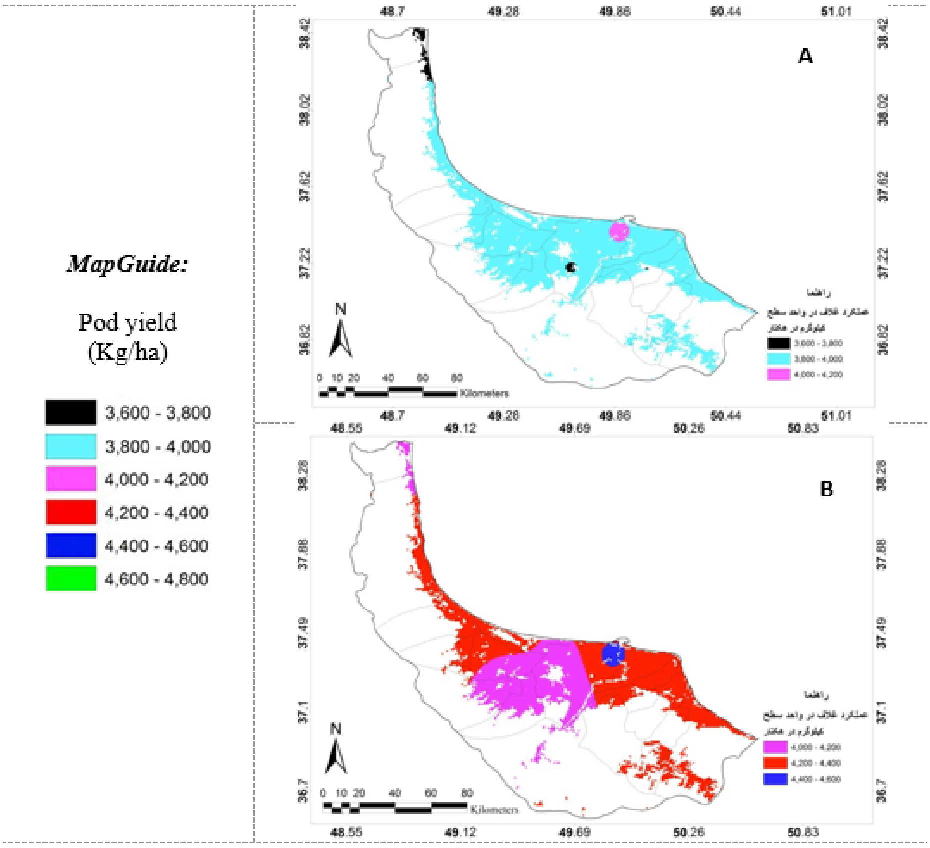

Figure 4. Zoning of pod yield of peanut in the current conditions (A) and after climate change (B) in Guilan (North of Iran)

DISCUSSION

Phenology responses to climate change may alter the ability of plants to acquire soil resources (water and nutrients) by altering the timing and duration of the deployment of roots and leaves, which drive resource acquisition (Nord & Lynch, 2009). This reduced period happens in a significantly wetter part of the year, sufficient to outweigh the lower radiation levels before and during grain filling (Ittersum et al., 2003).

increase in temperature resulted in a temperature shift from sub-optimal temperatures to the optimal range which may favour crop mass accumulation, but in spring-sown crops, the result was a shift in temperatures from optimal range to super-optimal range which had negative effect on yield (Hajarpoor et al., 2014).

In a study carried out by Gholipoor and Soltani (2009), positive differential grain yield of rainfed chickpea was discerned between the sites they examined. They represented that the increase in grain yield was not proportional to increase in biomass as the differential harvest index tended to be mainly negative. Due to lack of rainfall during flowering, podding and seed filling, terminal drought stress is a major abiotic stress that reduces chickpea productivity in drylands (Sabaghpour et al., 2006). It seems that the main reason for the increased grain yield as a result of increased temperatures might be attributed to reduced risk of late season drought stress due to earliness. Leport et al. (2006) in a study of the effect of terminal drought on chickpea expressed that in water-limited Mediterranean and subtropical environments, the plants are usually subjected to terminal drought unless irrigated. Soltani and Sinclair (2012) indicated that higher yields of chickpea were obtained with a 4°C increase in temperature and they concluded that this was mainly due to accelerated development rate and earlier maturity under higher temperature and resultant drought escape. Simulation results by Koocheki and Nassiri (2008) showed that wheat yield reduction at the target year could be prevented considerably with increasing temperature threshold of wheat cultivars at flowering by 2-4 °C.

CONCLUSIONS

In general, the results showed that there is a statistically significant difference in terms of all parameters between the current condition and after climate change (2°C rise in temperature) in Guilan province. With the rising temperature, the average peanut growth period in Guilan decreased from 142 days to 123 days. Generally, the average peanut yield changes in Guilan with a 2-degree rise in temperature is 8.73 percent more than the current condition.

All in all, climate changes influence the concentration of greenhouse gases and other atmospheric pollutants. The rising concentration of these gases varies with the emissions from natural and man-made resources. The data on the emission of greenhouse gases and other atmospheric pollutants as well as the data on the land use and vegetation cover are of importance as the inputs to the climate model. The climate change scenarios whose development is based on assumptions pertaining to the effective factors, such as economic patterns, population growth, and technology development, can provide more effective predictions of future crop production. Accordingly, the scenarios pertaining to economic and environmental factors can effectively analyze the consequences of climate change by climatic modeling and assessment of impacts, adaptation, and adjustment on crops. Each of these scenarios can be based on various assumptions about population growth, economic development, technology change, living standards, and energy production alternatives, which are referred to as emission scenarios. Although future greenhouse gases emission rate is a key variable for predicting peanut growth and yield, other factors should also be considered including technology development, variations of energy production and land use, global and local economic conditions, and population growth. Therefore, numerous factors should be taken into account when predicting how future global warming contributes to climate change. In order for the studies in the field of climate change to be complementary and comparable among different groups, a standard set of scenarios should be used to ensure that initiation conditions, past data, and future manifestation are uniformly used among different disciplines of the climate change. Thus, in addition to direct impacts of temperature rise on peanut production and yield, it is recommended to explore the effect of climate change on peanut growth and yield in future research by considering greenhouse gasses emission scenarios on the basis of the economic and environmental aspects.

ACKNOWLEDGEMENTS

This paper is extracted from the PhD thesis of S.A. Noorhosseini by Supervisor A. Soltani and Advisor H. Ajamnourozi. The authors acknowledge all those who improved the quality of this research.

REFERENCES

Ababaei B., Sohrabi, T., Mirzaei, F., Rezaverdinejad, V., & Karimi, B. (2010). Climate change impact on wheat yield and analysis of the related risks: (Case study: Esfahan Ruddasht Region). *Water and Soil Science (Agricultural Science), 20*(3), 135-148.

Bannayan, M. (2009). Crop models efficiency and performance under elevated atmospheric CO_2. *Journal Water and Soil, 23*(4), 115-126 (In Persian).

Barzegar, A.B., & Soltani, A. (2007). The effects of future climate change on chickpea yeild in Northwest Rainfed Conditions. Paper presented at the second ecological conference of Iran in 18 October. Gorgan University of Agricultural Sciences and Natural Resources Gorgan, Iran.

FAO (2010). Production statistics of crops. Food and Agriculture Organization. Retrieved from (http://faostat.fao.org).

Fengmei, Y., Yinglong, X., Erda, L., Masayuki, Y., & Jiahua, Z. (2007). Assessing the impacts of climate change on rice yields in the main rice areas of China. *Climatic Change, 80*, 395-409.

Gholipoor, M., & Soltani, A. (2009). Future climate impacts on chickpea in Iran and ICARDA. *Research Journal of Environmental Sciences, 3*(1), 16-28.

Goudriann, J. (1995). *Global carbon cycle and carbon sequestration.* In Beran, M, A. (ed). Paper presented at Carbon Sequestration in the Biosphere

(Processes and Prospects). *Springer, p*. 3-18.

Gregory, P.J., Ingram, J.S.I., & Brklacich, M. (2005). Climate change and food security. Philosophical Transactions of the Royal Society, 360, 2139-2148.

Hajarpoor, A., Soltani, A., Zeinali, E., & Sayyedi, F. (2014). Simulating climate change impacts on production of chickpea under water-limited conditions. *Agriculture Science Developments, 3*(6), 209-217.

Hajarpour, A., Soltani, A., Zeinali, E., & Sayyedi, F. (2013). Simulating the impact of climate change on production of Chickpea in rainfed and irrigated condition of Kermanshah. *Journal of Plant production research, 20*(2), 235-252.

IPCC (2007). *Summary for Policy Makers. Climate Change 2007: The Physical Science Basis*. Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York.

IPCC (2013). *Summary for policymakers. In: Climate Change 2013*. Fifth assessment report of the Intergovernmental Panel on Climate Change. Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.), Cambridge University Press, Cambridge, United Kingdom and New York.

Ittersum, M.k., Howden, S.M., & Asseng, S. (2003). Sensitivity of productivity and deep drainage of wheat cropping systems in a Mediterranean environment to changes in CO_2, temperature and precipitation. *Agriculture Ecosystems & Environment, 97*, 255-73.

Koocheki, A., & Nassiri, M. (2008). Impacts of climate change and CO_2 concentration on wheat yield in Iran and adaptation strategies. Iranian *Journal of Field Crops Research, 6*(1), 139-153

Lashkari, A., Alizadeh, A., & Bannayan, M. (2011). Investigation of Mitigation of Climate Change Impacts on Maize Production in Northeast of Iran. *Journal of Water and Soil, 25*(4), 926-939.

Leport, L., Turner, N.C., Davies S.L., & Siddique, K.H.M. (2006). Variation in pod production and abortion among chickpea cultivars under terminal drought. *European Journal of Agronomy, 24*(3), 236-246.

Maiti, R., & Ebeling, P.W. (2002). The Peanut (*Arachis hypogaea*) Crop. *Science Publishers, Inc.*, 376p.

Mattews, R.B., Kropff, M.J., & Bachelet, D. (1994). General introduction. In: Matthews, R.B., Kropff, M.J., Bachelet, and Vanlaar, H.H. (ed.) Modeling the impact of change on rice production in Asia. *CAB International,* pp, 3-7.

Meghdadi, N., Soltani, A., Kamkar, B., & Hajarpoor, A. (2015). Simulating climate change impacts on production of chickpea in Zanjan province. *Journal of Crop Production, 7*(1), 1-22.

Mirsaneh, M.S., Mesah-Bavani, A.R., Bolook-Azari, S., & Sohrabi-Molayousef, S. (2010). Assessment of the effect of climate change on the irrigation need for sugar beet and its growth period. Paper presented at the Second National Conference on Integrated Water Resources Management.

Noorhosseini, S.A., Safarzadeh, M.N., & Sadeghi, S.M. (2016). Effect of production region and seed weight on some characteristics related with germinability and seedling vigour of peanut (*Arachis hypogaea* L.). *Iranian Journal of Seed Science and Technology, 5*(1), 75-91. (In Persian)

Noorhosseini, S.A., Soltani, A., & Ajamnoroozi, H. (2018). Simulating peanut (*Arachis hypogaea* L.) growth and yield with the use of the Simple Simulation Model (SSM). *Computers and Electronics in Agriculture, 145*, 63-75.

Nord, E.A., & Lynch, J.P. (2009). Plant phenology: a critical controller of soil resource acquisition. *Journal of Experimental Botany, 60*(7), 1927-1937.

Rawlins. S.L. (1991). Global environmental change and agriculture. *Journal of production Agriculture, 4,* 291-293.

Roy, K., Masudur, R., & Uthpal, K. (2009). Future Climate Change and Moisture Stress: Impact on Crop Agriculture in South-Western Bangladesh. *Climate Change and Development, 1*(1), 1-8.

Sabaghpour, S.H., Mahmodi, A.A., Saeed, A., Kamel, M., & Malhotra, R. (2006). Study on chickpea drought tolerance lines under dryland condition of Iran. *Indian Journal of Crop Science, 1*, 70-73.

Safarzadeh, M.N. (2008). Peanut (*Arachis hypogaea* L.). Rasht: Islamic Azad University Publications,

Rasht Branch, Iran.
Saunders, M.A. (1999). Earth's future climate. *Philosophical Transactions of the Royal Society, 357*, 3459- 3480.
Soltani, A., & Sinclair, T.R., (2012). Optimizing chickpea phenology to available water under current and future climates. *European Journal of Agronomy, 38*(0), 22-31.

How to cite this article:
Noorhosseini, A., Soltani, A., & Ajamnoroozi , H. (2018). Modeling the impact of climate change on Peanut production on the basis of increasing 2°C temperature in future environmental conditions of Guilan Province, Iran. *International Journal of Agricultural Management and Development, 8(2), 257-273.*
URL: http://ijamad.iaurasht.ac.ir/article_541234_3eef716e187e51c09f7a99e567d4e501.pdf