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EVALUATE IMPACT OF CLIMATE CHANGE ON YIELD AND WATER CONSUMPTIVE USE FOR PEANUT UNDER NORTH EGYPT ENVIRONMENTAL CONDITION

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ABSTRACT

The impact of climate change on yield and water consumptive use for peanut was evaluated under north Egypt environmental condition (Noubaria region) by using crop simulation model (DSSAT 3.5) . The model first was calibrated and validated to evaluate it's ability to simulate and predict water consumptive use and yields using data collected form field experiments establish at private farm at El –Hossian village, Noubarai region. The experiments conducted involving three water regimes (irrigating at 100, 80 % of the daily potential evapotranspiration "ETp"" and farmer application) Giaz 5 cultivar was planted during two successive summer seasons of,2010 and 2011 years . The data were used together with the region environmental data under climate change scenarios. These climate change scenarios were HadCM3 'A2' (temperature increase by 3.1°C and CO_2 concentration is 834 ppm) and HadCM3 'B2' (temperature increase by 2.2°C and CO_2 concentration is 601 ppm) developed by Hadley Center for Climate Prediction and Research(United Kingdom). Calibration/ Validation results reveal that model was acceptable and accurate under study condition. Results reveal that climate HadCM3 B2 scenario recorded the maximum increase in peanut consumptive use compared with A2 scenario. Furthermore, A2 scenario predicted greater reduction in peanut grain and biomass yields, compared with B2 scenario. The adaptation irrigation treatment gave a slight percent increase in water requirement and minimal percent reduction in yield.

Keyword: Climate change, , DSSAT, Peanut, Water consumptive use, Yield

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INTRODUCTION

Climate change refers to the change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and in addition to natural climate variability observed over comparable time periods. (UN Framework Convention) IPCC (2001). Most recent assessments of the effect of climate change on arid and semi-arid regions concluded that these areas are highly vulnerable to climate change. The projected climatic changes will be among the most important challenges for agriculture in the twenty-first century, especially for developing countries. The most likely rate of future global change over the period 1990-2100 due to anthropogenic emissions is estimated to be an increase in global average surface temperature by 1.5-4.5 ºC IPCC (2007a). The risks associated with agriculture and climate change arise out strong complicated relationships between agriculture and the climate system, plus the high reliance of agriculture on finite natural resources (Abou-Hadid 2006).The inter annual, monthly and daily distribution of climate variables, such as temperature, radiation, precipitation, water vapor pressure and wind speed affects a number of physical, chemical and biological processes that drive the productivity of agricultural (IPCC 2007a).Previous studies on the effects of climate change on agriculture in Egypt (El-Shaer *et al.* 1997, Eid *et al..* 2001 Abou-Hadid 2006, Mokhktar 2009 and El Marsafowy *et al.,* 2012) concluded that climate change pose as a risk to sustainable development in agriculture sector.

Groundnut (Arachis hypogea L.) is an important legume cash crop and oil seed crop as its seed contains 43–55% oil and 25–28% protein on a dry seed basis (Reddy *et al.,* 2003). It is grown on 19.3 million ha of land area in about 82 countries and more than half of the production area is in arid and semi-arid regions. Although ,the increasing in the import of oil, which will increase in the future due to the rapidly increasing in population and the lack of productivity due to affected by climate change condition , Egypt's production of peanut stable since 2004 till now with value of 190.000 metric ton.

Computer simulation models, which are able to capture the long-term effects of weather fluctuations and the effects of various soil properties and management practices on the soil water balance, nutrient dynamics, and crop growth could contribute to further our understanding of cropping systems performance . Using such models should improve the efficacy of decision making for soil, water and crop management and farmers will be able to reduce production risks and increase crop yield by tailoring management decisions to current and expected weather.

The Decision Support System for Agrotechnology Transfer “DSSAT” (IBSNAT, 1989) has been in use for the last 15 years by researchers worldwide. It is a mathematical representation of the integration of the disciplines of biology, physics, and chemistry (Jones et al. 2003). Based on the agronomic knowledge of the crop growing process, this model incorporates weather information including temperature, precipitation, solar radiation, and humidity with other factors including fertilizer applications and soil properties to simulate their impact on that process through a set of mathematical equations. The expected crop yields and their variance are generated by the crop growth simulation model

The CROPGRO-peanut model (Boote et al., 1998) is the most recent version of the PNUTGRO model (Boote et al., 1986, 1989b) which has been steadily improved since 1986. This model was tested in India (Singh et al., 1994) and with on-farm trials in Florida (Boote et al., 1989a; Gilbert, 1992; Gilbert et al., 2002). Between 1990 and 1994, more mechanistic features of plot leaf-level photosynthesis, hedge-row canopy photosynthesis, explicit N2–fixation, explicit soil N uptake, soil N balance were added, and the CROPGRO-legume model was released (Hoogenboomet al., 1992, 1993, 1994). This version simulates three grain legumes {soybean, peanut, and bean } follows the standard input/output protocols of DSSAT .

The objective of this study is to(i) evaluate the ability of CROPGRO-peanut model to simulate peanut growth, yield, and water use and to (ii) assess the potential impact of climate change on peanut yield production and water conceptive use under North Egypt environmental condition (Nobaria region).

MATERIALS AND METHODS

1. The field experiments

The field data used for model calibration/ validation were obtained from field experiments carried out at a private farm in Al-Hussein village of Noubaria region , Egypt, during 2010 and 2011 growing season under condition of North Egypt. The experiment was laid out in a randomize complete plot design with three replicates. The plot area was 450 m^2 (45 x 10 m). Sowing dates were 5th and 12st May for the first and second seasons, respectively in row with spacing 0.30 X 0.50 meter inter and within row. Plants were harvested on 2^{nd} and 6^{th} of September for the two respective seasons. The preceding crop was wheat and dry beans in the two seasons. Irrigation was practiced according to calculation of crop water requirements (CWR) from the accumulative values of the daily potential evapotranspiration (ETp) estimated by Penman Monteith formula under “CROPWAT 4.3” model (Smith 1991), and applied using sprinkler irrigation system every 5 days . Application of irrigation regime treatments, started from the third irrigation as follows: (I_1) 100 ETp (I_2) 80 % ETp and (I_3) farmer application . Water consumptive use (CU) was determined via soil samples from the sub plots just before each irrigation and 4 hrs after irrigation as well as at harvest. Sampling depths were 15-cm successive layers down 60-cm depth of the soil profile. The CU was calculated according to Israelsen and Hansen (1962) as follows:

$$CU = D \times Bd \times Q_2 - Q_1 / 100$$

Where:

CU = actual evapotranspiration (in mm).
D = effective root depth (in mm).
Bd = bulk density of soil in (g/cm3).
Q2 = soil moisture percentage four hrs after irrigation (w/w).
Q1 = soil moisture percentage before next irrigation (w/w).

Sufficient NPK was applied to insure optimum plants growth. Application was done in two equal splits; the first was applied before the life irrigation (El- Mohayah irrigation) and the second one after 21 days from the first one. All other practices were applied as adopted in the area. During two growing season duration, all growth parameter are needed for calibration model were measured . At harvest, the plants of each entire two row were harvested from each replicate in order to determine straw and grain yield. Weather data from a Agro- climatological Station located at the Delengate, Al- Bahria Governorate (Lat: 31.02, Long: 30.28 and sea level 6.7 m) 26 km from the experimental site were recorded . Precipitation, maximum and minimum temperatures, sunshine and solar radiation were measured on a daily basis in each growing season for the model and then summarized as monthly weather data in Table1.

Table (1) Some meteorological data at Noubarai Agric. Res. Station, 2010 and 2011 seasons

Season	2010							
Month	**T max**	**T min**	**WS**	**RH**	**RF**	**SS**	**SR**	**Etp**
May	28.5	18.4	4.8	54.2	0.0	13.6	30.0	4.9
June	33.9	22.5	4.5	52.9	0.0	14.0	30.9	5.7
July	34.3	24.5	4.8	58.0	0.0	13.8	30.4	5.9
August	32.9	24.4	4.1	57.1	0.0	13.2	28.4	5.3
September	31.6	23.7	4.4	57.5	0.0	12.2	24.7	4.5
Mean	32.2	22.7	4.5	55.9	0.0	13.4	28.9	5.2
	2011							
May	30.9	19.5	4.6	49.3	0.0	13.6	30.0	4.9
June	32.8	21.7	4.4	54.0	0.0	14.0	30.9	5.6
July	33.4	24.2	4.7	59.6	0.0	13.8	30.4	5.7
August	36.0	25.7	4.2	60.4	0.0	13.2	28.4	5.6
September	33.4	23.2	4.5	56.2	0.0	12.2	24.7	4.6
Mean	33.3	22.9	4.5	55.9	0.0	13.4	28.9	5.3

Where: T.max., T.min.=maximum and minimum temperatures °C; W.S= wind speed (km/ day); R.H.= relative humidity (%); R.F = rain full (mm/ month) , SS = sunshine Hr, SR =solar radiation (Mj/m^2/day) Etp= potential evapotranspiration

Table (2) Soil moisture constants (% by weight) and bulk density (g/cm^3) of soil of experimental site .

Soil Depth, cm	Field capacity (ϴ 0.33bar%)	Wilting point (15 bar %)	Available water(mm)	Bulk density (g/ cm^3)
0-15	9.82	4.68	5.14	1.44
15-30	9.7	4.62	5.08	1.63
30-45	9.453	4.5	4.95	1.7
45-60	9.32	4.44	4.88	1.8
Average	9.57	4.56	5.01	1.64

2. Crop Simulation studied:

1. Climate change scenarios

According to scenarios of Intergovernmental Panel on Climate Change IPCC (1995, 2001 and 2007a). Egypt will experience a significant rise in mean temperature in the middle of the twenty first century. Baseline to above -mentioned two climate change scenarios were used for the site, based on output from 'HadCM3' which is a coupled Atmosphere-Ocean General Circulation Model (AOGCM) developed at the Hadley Center for Climate Prediction and Research (United Kingdom). The 'HadCM3' scenario issued monthly projections for the 100 years for the entire globe. Two climate change scenarios were considered in this study: A2 and B2. These selected two scenarios consider a rise in global annual mean temperature by 3.09 and 2.16°C, respectively, CO_2 concentration 834 and 601 cm3/cm3, respectively and global mean sea level rise of 62 and 52 cm, respectively. As the resolution of the model is too big, a simple interpolation technique has been applied to fit the station site. This monthly output weather data for the grid box where the site is located was generate for the (2010-2040) periods to the daily weather data including solar radiation , perspiration ,Maximum and

Minimum temperatures and 2037 and 2038 years were used for running model.

2. Crop Simulation Model description:

The CROPGRO-peanut model (Boote *et al.,*1998) included in DSSAT 3.5 improved since 1986, and considered to serve as an analytical tool to assist researchers, decision makers and planners in identifying strategies that are desirable environmentally and economically in studying the effect of cropping systems management on productivity and the environment. The model simulates the soil water budget, soil-plant nitrogen budget, crop canopy and root growth, dry matter production, grain yield, residue production and decomposition.

The experimental data and site database were used in a simulation study using such above model as follows:

1-Simulation Models parameter requirements

Simulation model require files contain information allowing the user to build simulation conditions from a database of existing location, soil, crop, and management files. Simulation files also contain information regarding the period of simulation and initial values for variables, which require initialization.

2-Climatic Data file

Location file includes latitude, longitude and sea levels, daily maximum and minimum temperatures, precipitation and solar radiation in real daily weather database format 'DAT files generated by Weather Man module can be used directly by model for climate change scenarios

3- Soils Data

Soil file includes physical and chemical properties of the experimental site were estimated according to (Page et al.,1982)and presented in Table 3 .moreover water balance file includes soil moisture constants Table 2 and hydrology properties used in combination with soil file to management water uptake.

Table (3): Some physical and chemical properties of the soil at experimental site

Particle-size distribution			
Soil fraction	**%**	**Soil chemical analyses**	**Content**
Coarse sand	66.8	Organic matter	0. 80%
Fine sand	25.5	Available N (KCl-extract)	22 mg kg^{-1}
Silt	1.55	Available P (Na-bicarbonate extract)	3 mg kg^{-1}
Clay	6.15	Available K (NH4- acetate extract)	13 mg kg^{-1}
$CaCo_3$ %	4.80	EC (dS/m) Soil paste extract	0.29
Textural class	Sandy	pH (1:2.5, soil: water suspension)	8.2

4- Crop Variables:

Monthly crop growth, expressed of biomass increase per unit area, is calculated on the basis of the minimum of four limiting factors; light, temperature, water and nitrogen. Details on the technical aspects and use of the models are reported elsewhere in DSSAT user***.***

5 Management Variables:

Management variable include: cultivar selection , crop rotation (including fallow years), irrigation , nitrogen fertilization, tillage operations and residue management as follows:

1. Planting and harvesting date
2. Maximum leaf area index at the flowering period.
3. Pod, seed and biomes yield/ ha.
4. Water management: date, amount and irrigation system.
5. Fertilizer management: date, amount, forms and method of application.
6. Pre-planting practices (type, date, and times of application).
7. Previous crop residue: quantity and depth.

6-Crop model calibration/ validation:

All the data of climate, soil, crop growth, and yields collected for the two seasons were entered in the standard file formats needed for execution of the CROPGRO-peanut model to calibration. Then, the models were validate by comparing observed data of seed and biological yield, cumulative Etc and growing season duration to simulated values, to test the goodness of fit between the measured and predicted data, percent difference between measured and predicted values in each growing season were calculated. Furthermore, regression analysis was done to test the strength of the relationship between measured and predicted yield and water consumptive use values.

RESULTS OF SIMULATION STUDIED

Crop model calibration:

The field data used for calibration/validation of this model are those obtained from the current field experiment, the following are experimental data, which were used as input data for crop management file in simulation model: but the irrigation were scheduled as study treatments.

Soil type : sandy.
Cultivar : Giza 5.
Planting date : 5th and 12th May of 2010 and 2011growing seasons
Row spacing : 0.5 m ,
Plant population : 11 plants/m^2 as average
Initial soil water (depth cm, water content %): (5 & 14) (15 & 14) (15 &11) (15& 9) (15&7) (30&7) (30&6) (30& 6).
Irrigation dates (Julian calendar) and amounts: (schedule (I_1=100 % ETp) (I_2=80% ETp and I_3=farmer application) for every 5 days intervals from sowing until 16 day before harvesting .
Genetic coefficients of the Egyptian cultivars were created through the model in the calibration/validation tests (Boote *et al.,* 1998). .

Crop model validation:

Crop model was validated comparing the observed experimental field results for normal treatment (irrigation at 1.00 ETp) with simulated values obtained from the same treatment input with the baseline scenario in both growing seasons.

Simulated cumulative ET crop, grain yield, biomass yield and growing season duration at harvest are presented in Table (4).The simulated variable followed closely the 1:1 line when plotted against the experimental data (Figures 1,2, 3 and 4).

The statistical analysis confirmed that the CROPGRO -PEANUT Crop Model (under DSSAT v3.5) predicted tested variable reasonably well.). Regarding cumulative crop (ETc) prediction, the model was highly accurate with percent difference between measured and predicted peanut cumulative ET crop of less than 4.0 %. Statistical analysis (Fig 1) showed that all predicted peanut ETc values lies within 95% confidence interval. A statistically significant relationship was found with equation of: y = 0.979 x + 9.8137 (R^2 = 0.969) *** in 2010 season and y = 0.752 x + 120.2 (R^2 = 0.912) ** in 2011 season. With respect to predicted peanut grain yield, results in Table 4 implied that the model for peanut yield was with acceptable degree of accuracy. Percent difference between measured and predicted peanut yield ranged between 1.18 – 6.87 %, while regression analysis of the measured and predicted peanut yield values indicate a significant relationship with R^2 value of 0.97*** over the two growing seasons (Fig. 2). Similar results were obtained for the prediction of peanut biological yield (Table 4), where percent difference between measured and predicted values less than 6 %. The results also showed that all predicted values lies within 95% confidence interval (Fig.4). Regression analysis between measured and predicted peanut biological yield had a significant linear relationship with (R^2= 0.937)**.

Table (4) Statistical summary comparing simulated vs. observed data

Variable	**Data from**	**Obs.**	**Sim.**	**R2**	**Slope**	**Const**	**d c %**
	2010						
Grain Yield kg /ha	Fig. 2a	5124	5403	0.98	0,651	1620	0.95
Biomass Yield kg /ha	Fig. 3a	9267	12213	0.95	1.26	5997	0.76
Actual Evap(mm/season	Fig. 1a	535	547	0.97	0.979	9.18	0.98
Growing Seas. Dura.(day)	Fig. 4a	125	131	0.99	0.954	6.003	0.95
	2011						
Grain Yield kg /ha	Fig. 2b	5326	5758	0,96	0,564	2059	0.93
Biomass Yield kg /ha	Fig. 3b	9430	12660	0.93	0.992	2837	0.75
Actual Evap(mm/season	Fig. 1b	541	567	0.91	0,752	120.2	0.95
Growing Seas. Dura.(day)	Fig. 4b	133	141	0.97	1.02	8.83	0.94

d c= percent differences between measured and simulated values.
Obs. = observed , Sim.= simulated and Seas.=season , Dura. =duration

Crop phenology was predicted closely to the observed values for anthesis, grain filling and physiological maturity for peanut cultivar, some differences happened at maturity-harvest duration. Simulated maturity date was about one week later than observed in 2010 season. However, although over estimation occurred with this stage , other growing periods showed high response in matching with the model .Percent difference between measured and predicted growing season duration ranged between 0.00 and 6.01 % (Table 4) .The statistical analysis indicates that growing season duration was predicted closely to the actual values with R^2 value of 0.999 *** for (2010 season) (Fig. 4a) In general, validation results were acceptable for the purpose of the study, which is peanut yield predicted with high degree of accuracy and indicates that CROPGRO PEANUT Crop models under (DSSAT v3.0) are useful for testing and generating peanut crop production and water requirement using environmental condition. In this respect, Naab *et al.,* (2004) evaluate CROPGRO-peanut model in Guinean Savanna Zone of Ghana and conclude that the CROPGRO-peanut model can be successfully used to quantify the yield potential and yield gaps associated with yield-reducing stresses and crop management for region. Moreover, Singh *et al.,* (2012) reported that the CROPGRO model can be used to assess the potential of individual or combination of plant traits for guiding breeding of improved groundnut varieties for current and future climates in India.

Results of climate change scenarios:

Results of running simulation model DASSAT3.5 using climate change scenarios HadCM3 A2 and B2 data, showed expected reduction in grain and biological peanut and this reduction was higher under A2 scenario, compared with B2 scenario, while peanut water consumptive use recorded expected increased for two scenarios but the increase percentage was higher under B2 scenario, compared with A2 scenario, (Table 5). With respect to adopted irrigation schedule treatments, results show similar values with those of the three-irrigation treatments for both grain and biological yield and also for wheat consumptive use under each climate change scenario. This trend was found for two evaluated years.

Predicted results for the two growing season indicate that overall average of the expected reduction in yield was -33.4 % for A2 versus -16.1 % for B2 scenario (Table 5).the expected reduction reach to -32.4 and -16.4 % for A2 and B2 scenarios, respectively in 2038 year. In evaluated 2039 summer growing season expected reduction in yield reach to -34.5 for A2 and -16.6 for B2 scenarios. Expected predicted reduction in biomass yield took a similar trend to grain yield which reduction percentage was higher under A2 scenario compared with B2 scenario by overall average percentage of -29.1 % for A2 versus -18.6 % for B2 scenario. Expected predicted reduction in biomass yield in 2038 year were - 28.1 and -18.3% for A2 and B2 scenarios. Corresponding values for 2039 year reach to -30.0 for A2 and -18.9 for A2 scenario. The situation was different with predicted cumulative evapotranspiration (seasonal water consumptive use (ETa), where Eta values were higher under B2 scenario more than those under A2 scenario with an overall average values for two evaluated years being +9.6 for B2 and +3.5 for A2 scenarios. An increase percentage reach to 11.2 %for B2 versus 3.6 %

for A2 scenario in 2038 year. Corresponding values for 2039 year were +8.1 for B2 versus +3.3 % for A2 scenario. These results may be attributed to global warming happen under A2 scenario would shortage length of the growth cycle and reduce increase percentage in Eta values. Results of the two evaluated years clearly show that the response of peanut yield to the two climate scenarios was different. The A2 scenario (temperature increase by 3.1°C) predicted greater reduction in peanut yield, compared with B2 (temperature increase by 2.2°C). In this respect**,** (Rosenzweig et al.,1998) stated that, higher temperature was the major cause of yield reductions because shorter crop life cycles occurred with corresponding decreases in seed grain filling.

Table (5):Predicted percent reduction in pod and biological peanut yield and percent increase in peanut consumptive use as a result of the two scenarios under DSSAT model for 2038 and 2039 season.

Evaluate year	Climate scenario	Grain yield (kg/ha)	PR %	Biological yield (kg/ha)	PR %	Water consumptive use (mm)	PI %
2038	Current	5124		9267		535	
	A2	3464	-32.4	6662	-28.11	554	+3.6
	B2	4284	-16.4	7571	-18.30	595	+11.2
	Average		22.4		23.20		7.4
2039	Current	5326		9430		541	
	A2	3494	-34.5	6581	-30.01	559	+3.3
	B2	4273	-16.6	7648	-18.90	585	+8.1
	Average		25.5		24.4		5.7
Average	A2		33.4		29.1		9.6
	B2		16.5		18.5		3.5

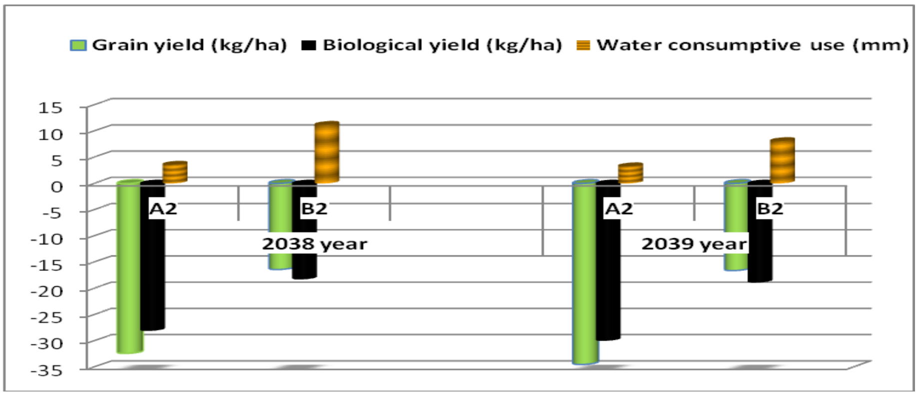

Fig. (1):Predicted percent reduction in pod and biological peanut yield and percent increase in consumptive use as a result of the two scenarios under DSSAT model for 2038 and 2039 season.

CONCLUSIONS

Although the above situation provides only a limited evaluation of the model, the model should be further tested, as more data from more treatments in different locations and years become available. However, for the purposes of this study the model worked sufficiently to warrant the exploration of the effect of climate change on crop yield and water requirements

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تقييم تأثير تغير المناخ على المحصول والاستهلاك المائى لمحصول الفول السوداني تحت الظروف البيئية لشمال مصر

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تم تقييم أثر تغير المناخ على المحصول والاستهلاك المائي لمحصول الفول السوداني تحت الظروف البيئية لمنطقة النوبارية- شمال مصر باستخدام برنامج محاكاة المحاصيل (DSSAT ٣.٥). تمت معايرة البرنامج أولا باستخدام البيانات التي تم جمعها من تجربة حقلية اقيمت بمزرعة خاصة فى قرية الحسين بمنطقة النوبارية خلال موسمي الصيف ٢٠١٠ و ٢٠١١ . حيث زرع الصنف جيزة ٥ تحت ثلاث مستويات من الرى (الري عند ١٠٠، ٨٠% من البخرنح اليومي "ETp" بالاضافة الى تطبيق رى المزارع). بعد تعديل بيانات البرنامج بالبيانات الحقلية و البيئية و إجراء اختبار التأكد والصلاحية تم تشغيل البرامج تحت سيناريوهات تغير المناخ وكانت هذه السيناريوهات هى النسخة "A2" HadCM3 (زيادة في درجة الحرارة المتوقعة بقيمة ٣.١ درجة مئوية وتركيز CO_2 هو ٨٣٤ جزء في المليون) والنسخة HadCM3 "B2" (زيادة في درجة الحرارة المتوقعة بمقدار ٢.٢ درجة مئوية وتركيز CO_2 هو ٦٠١ جزء في المليون) وذلك خلال النصف الاول من القرن الحادى والعشرين) . اظهرت نتائج اختبار التأكد والصلاحية للبرنامج كفاءة عالية للتنبؤ عند مقارنة القيم الفعلية والمتنبأ بها. كما أن التحليل الإحصائي أظهر قيما عالية لمعامل الارتباط .كما أشارت نتائج دراسات المحاكاة أن سيناريو التغير في المناخ "A2" HadCM٣ سجل قيم أعلى للنقص المتوقع في إنتاجية محصول القرون والمحصول البيولوجى مقارنة مع B2 ،بينما سجل سيناريو التغير في المناخ HadCM B2 أعلى قيم الزيادة المتوقعة في الاستهلاك المائي مقارنة مع A2 خلال الموسمين المختبرين. لم يظهر فروق فى قيم النقص المتوقع فى الانتاجية وكذا الزيادة المتوقعة فى الاستهلاك المائى نتيجة جدولة الرى حيث كانت الاختلافات طفيفة لا تذكر تحت معاملات الري خلال الموسمين المختبرين .