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GIS Assessment of Climate Change Impacts on Tomato Crop in Egypt

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Abstract: This study was carried out to assess the impact of climate change on tomato fruit setting (*Solanum lycopersicum* L) in Egypt and find out the best suitable sites and sawing dates for cultivation the tomato crop in the future and also to adapt with futuristic climate change conditions by using Geographic Information Systems (GIS) techniques. Monthly data for air temperature (T_{air}) were used from 35 ground meteorological stations inside and around Egypt. MAGICC/SCENGEN software was used to generate temperatures at the years of 2050 and 2100 and it was suite that allows investigating future climate change and its uncertainties at both the global-mean and regional levels. T_{air} will increase at the years of 2050 and 2100 and it will be 1.58 and 2.96°C, respectively. Kriging is a group of geo-statistical techniques to interpolate the value of a random field at an unobserved location from observations of its value at nearby locations. The results indicated that the availability of tomato growing in 2009 was very good in place and time where air temperature was suitable but in the year of 2050 the sowing date and time will be changing; July will be not suitable for tomato fruit setting. On the other hand, tomato fruit setting will not be suitable for three months which are June, July and August at the year of 2100.

Key words: Climate Models · Sowing Dates · Optimum Temperature · Fruit Setting

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops grown under outdoor and indoor conditions. It has become an important commercial crop in Egypt so far as the cultivation area, production, industrial values and its contribution to human nutrition. The total cultivated area of tomato is 507.6 thousands fed. and the productivity is about 16.0 Tons/fed. which produced about 8.1 million Tons and the total tomato export was 5700 ton/year [1].

Tomato can grow under a wide range of temperature however; fruit set is limited in a narrow range. Relatively low or high temperature lead to poor fruit set. The critical factor in tomato fruit setting is the night temperature, the optimal range being 15-20°C [2]. Fruit set is also low when the average maximal temperature is above 32°C and the average minimal temperature is above 21°C [3].

More empirical evidence has revealed that global climate is changing as a result of the combined anthropogenic forces due to greenhouse gases, aerosols and changes of the land surface [4]. Recent climatologically studies have also found that the global surface air temperature has increased by 0.76°C from 1850 to 2005. Moreover, the trend for linear warming over the last 50 years has been recorded at 0.13°C per decade [4]. Currently, it has been observed that the trend of global warming, which has been at +0.6°C since 1900 will continue and that the average global temperature will increase in the range of 1.4 to 5.8°C over the period 1990 to 2100 [5]. The impact of this type of climate change will probably lead to a decrease in crop productivity, but with important differences between regions [6]. Also, the sensitivity of tomato to air temperature under climate change conditions, by using the future climate data and the results indicated that a yield will be reduced from -12 to -33% without adaptation for the years of 2025 to 2100. Farther more, this negative impact of yield reduction was decreased from -5 to -28% when planting date was changed for 30 days after planting dates under the study [7].

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Geographic information systems (GIS) and crop simulation models are two powerful and highly complementary tools that are increasingly used to predict the responses of crops to environment and management. Also, it can be integrated, to predicting impacts of climate change on crops and examining options for adaptation [8]. The present investigation was imposed to assess the impact of climate change on tomato fruit setting in Egypt using GIS technique, to find out the best suitable sites and sawing dates for cultivation tomato crop in the future and also to adapt with futuristic climate change conditions.

MATERIALS AND METHODS

Study Area: Egypt located at northern east part of Africa continental. Egypt bordered by the Mediterranean Sea to the north, Sudan to the south, the Red Sea to the east and Libya to the west. The area of Egypt is approximately 1,000,000 sq km (Fig, 1). The climate in Egypt is dry arid according to Koppen Climate Classification System, where precipitation is less than 50% of potential Evapotranspiration (ET), Annual average temperature is over 18°C.

The Zero Growth and Optimum Temperature Range of Tomato Growth Stages: The average of the daily maximum and minimum temperatures for tomato changes from growth stage to another and the zero growth temperatures are 10, 7, 13, 15 and 13 in germination stage [9], vegetative stage [10], flowering and fruit set stages [11] and fruiting stage [12], respectively, (Table 1). Also, the monthly average minimum and maximum air temperature for all weather stations inside and around Egypt through the years of 2009 are shown in (Table 2); finally the MAGICC/SCENGEN software was used to generate temperatures at the years of 2050 and 2100.

Geographical Information Systems (GIS): Interpolation methods based directly on the surrounding measured values or on specified mathematical formulas that determine the smoothness of the resulting surface. Kriging is a group of geo-statistical techniques to interpolate the value of a random field at an unobserved location from observations of its value at nearby locations. Kriging belongs to the family of linear least squares estimation algorithms. The aim of Kriging is to estimate the value of an unknown

Table 1: Minimum, optimum and maximum temperature of tomato growth stages

Growth stage	Mini. Temp. (°C)	Optimum Temp. (°C)	Maxi. Temp. (°C)	References
Germination	10.0	21-30 (25.0)	35.0	[9]
Vegetation	7.0	18-25 (23.0)	35.0	[10]
Flowering	13.0	15-25 (21.0)	30.0	[11]
Fruit setting	15.0	18-20	27.0	[11]
Fruiting	13.0	15-25	35.0	[12]
Zero growth	10.0	[13]		

Table 2: Monthly average air temperature during 2009, 2050 and 2100 on all over Egypt

	2009(*)		2050(**)		2100(**)	
Month	Minimum (°C)	Maximum (°C)	Minimum (°C)	Maximum (°C)	Minimum (°C)	Maximum (°C)
January	9.7	24.7	11.3	26.3	12.7	27.7
February	11.6	25.4	13.2	27.0	14.6	28.4
March	12.3	25.3	13.9	26.9	15.3	28.3
April	17.7	32.9	19.3	34.5	20.7	35.9
May	19.6	32.2	21.2	33.8	22.6	35.2
June	24.3	35.3	25.9	36.9	27.3	38.3
July	26.0	36.9	27.6	38.5	29.0	39.9
August	25.1	36.2	26.7	37.8	28.1	39.2
September	22.5	35.5	24.1	37.1	25.5	38.5
October	21.8	31.7	23.4	33.3	24.8	34.7
November	14.7	27.6	16.3	29.2	17.7	30.6
December	11.8	25.0	13.4	26.6	14.8	28.0

(*) NASA ground meteorological stations inside and around Egypt.

(**) MAGICC 4.1/ SCENGEN climate model

Fig. 1: Study area location

real-valued function, at a point, given the values of the function at some other points. A Kriging estimator is said to bilinear because the predicted value is a linear combination.

Although Kriging was developed originally for applications in geo-statistics, it is a general method of statistical interpolation that can be applied within any discipline to sampled data from random fields that satisfy the appropriate mathematical assumptions. Kriging has been used in a variety of disciplines, including the following: Environmental science [14], Hydrogeology [15], Mining [16], Natural resources [17], Remote sensing [18], Real estate appraisal [19] and many others.

RESULTS AND DISCUSSION

First Quarter of the Year (Winter Season): Maps presented in Fig (2-4) showed that predicted availability of tomato fruit setting in Jan. Feb. and March months though the years of 2050 and 2100 under climate change conditions compared to the years of 2009 in Egypt. It's indicated also there are no problems for tomato fruit setting during this period and climate change do not has major impacts of 2050. On the other hand, there are impacts on very small area at southern east of Egypt at year of 2100 only. These results could be attributed to decreasing of average maximum and minimum temperature degrees especially night temperature in winter season, also these conditions will reduce the negative impacts of cold weather on tomato fruit setting as a result of temperature increase during the years of 2050 and 2100. These results are in agreement with those obtained by Went [2] who reported that tomato can grow under a wide range of temperature however; fruit set is limited in a narrow range. Relatively low or high temperature leads to poor fruit set and the optimal range being 15-20°C.

Second Quarter of the Year (Spring Season): Maps detected in Fig (5-7) indicated that predicted availability of tomato fruit setting in April, May and June months though the years of 2050 and 2100 under climate change conditions compared to the years of 2009 in Egypt.

Maps of April and May showed that there are no problems for tomato fruit setting during this period and climate change do not has major impacts of 2050 and 2100 for northern part of Egypt. On the other hand, there are gradually increasing impacts on southern part of Egypt form 2009 to 2100. June maps showed that there is a

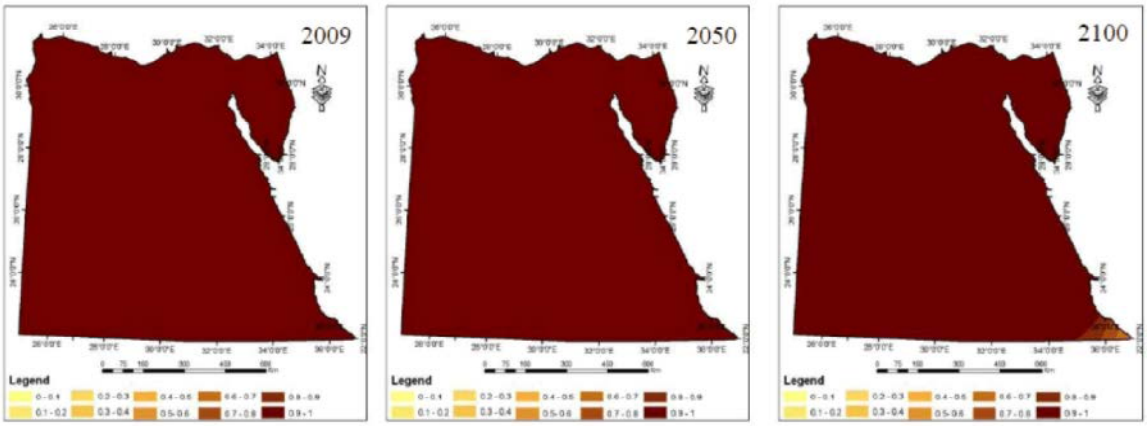

Fig. 2: Monitoring of fruit setting availability distribution for tomato crop in Egypt during January (2009, 2050 and 2100)

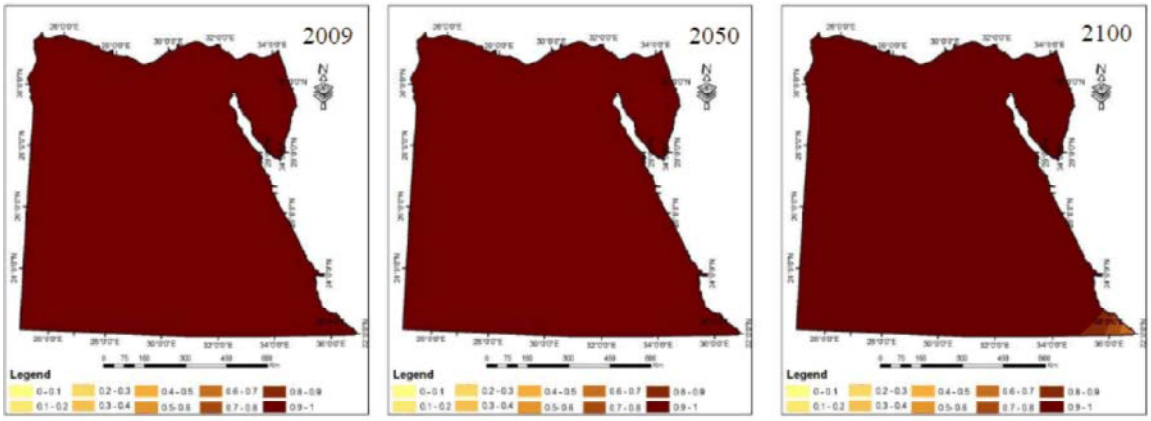

Fig. 3: Monitoring of fruit setting availability distribution for tomato crop in Egypt during February (2009, 2050 and 2100)

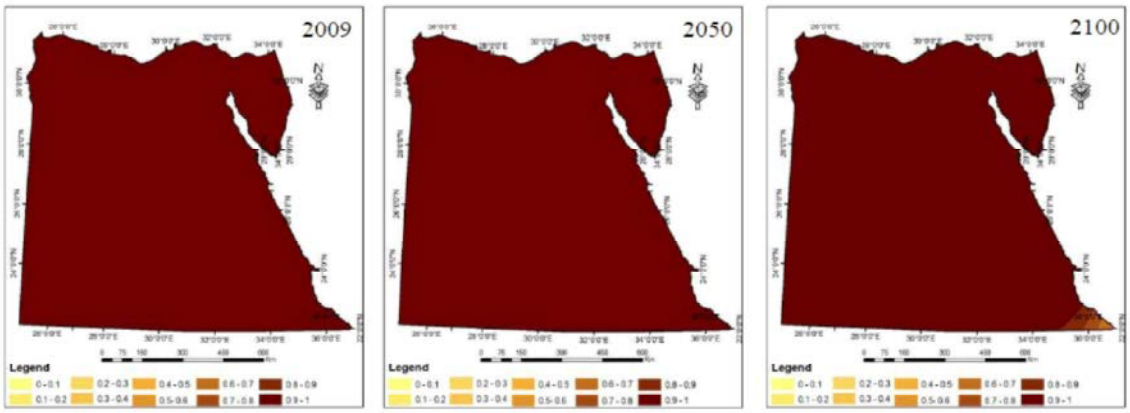

Fig. 4: Monitoring of fruit setting availability distribution for tomato crop in Egypt during March (2009, 2050 and 2100)

narrow area close to Mediterranean Sea available for fruit setting but there is a big problem for fruit setting at other area of Egypt at years of 2009 and 2050. At, 2100, there are no suitable places for fruit setting. These results could be attributed to gradually increasing of temperature in spring season especially day temperature. These results are in a harmony with those obtained by Moore and Thomas [3] who showed that fruit set is also low when the average maximal temperature is above 32°C and the average minimal temperature is above 21°C. Also, climate change will effect on tomato crop where maximum temperature for fruit setting is 27°C [11].

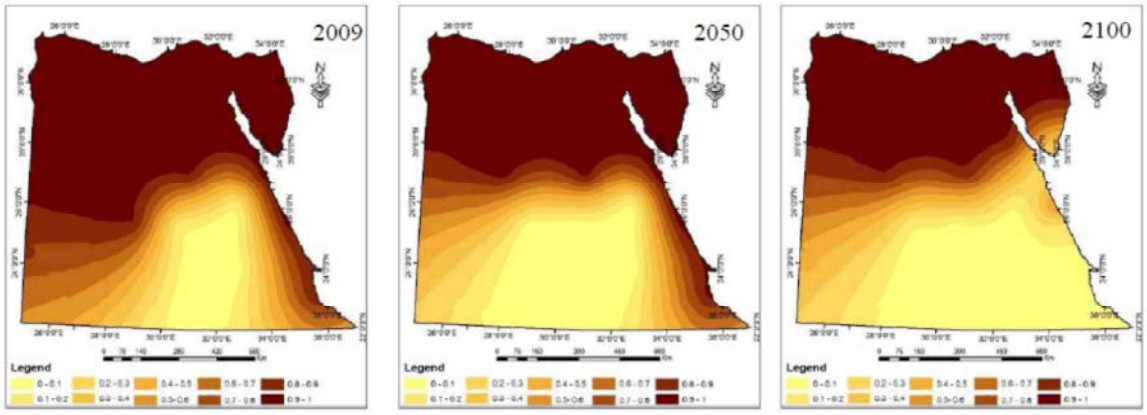

Fig. 5: Monitoring of fruit setting availability distribution for tomato crop in Egypt during April (2009, 2050 and 2100)

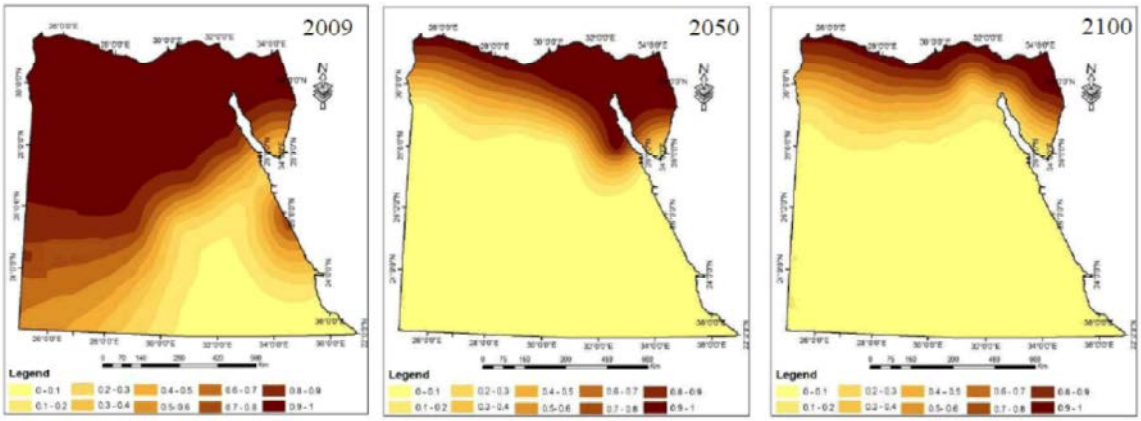

Fig. 6: Monitoring of fruit setting availability distribution for tomato crop in Egypt during May (2009, 2050 and 2100)

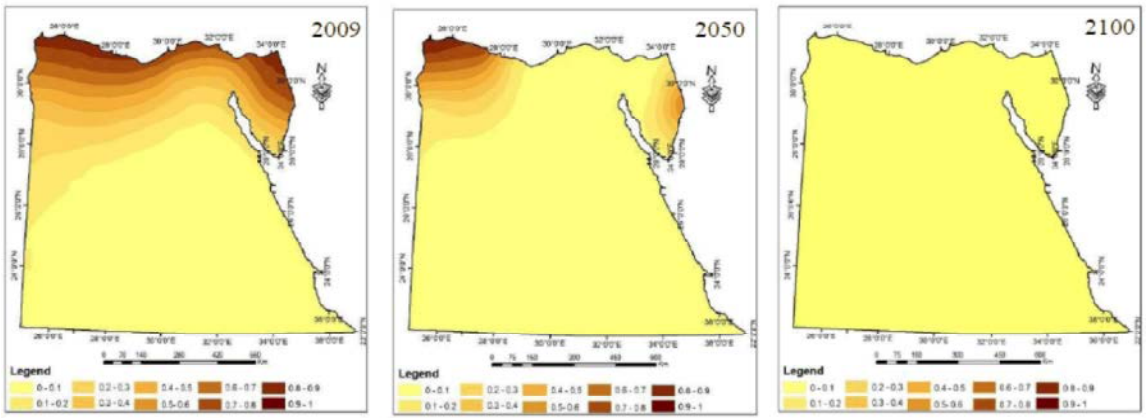

Fig. 7: Monitoring of fruit setting availability distribution for tomato crop in Egypt during June (2009, 2050 and 2100)

Third Quarter of the Year (Summer Season): Maps detected in Fig (8-10) showed that predicted availability of tomato fruit setting in the July, August and September months though the years of 2050 and 2100 under climate change conditions compared to the years of 2009 in Egypt. For July indicated that there are problems for tomato fruit setting during this period and climate change will increase these problems, whereas there is no suitable area to fruit setting in Egypt. Concerning with August the maps showed that also a great problem in tomato fruit setting and there is a small area at northern west has availability to fruit setting through 2009 and

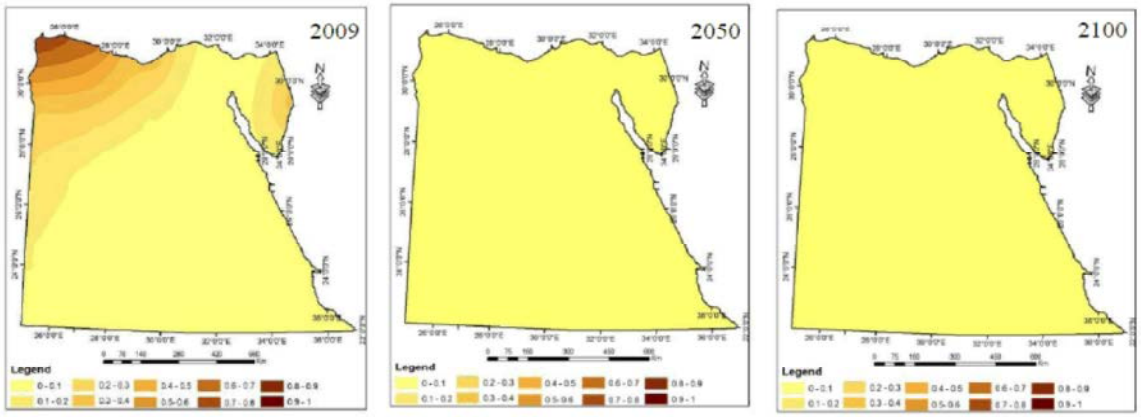

Fig. 8: Monitoring of fruit setting availability distribution for tomato crop in Egypt during July (2009, 2050 and 2100)

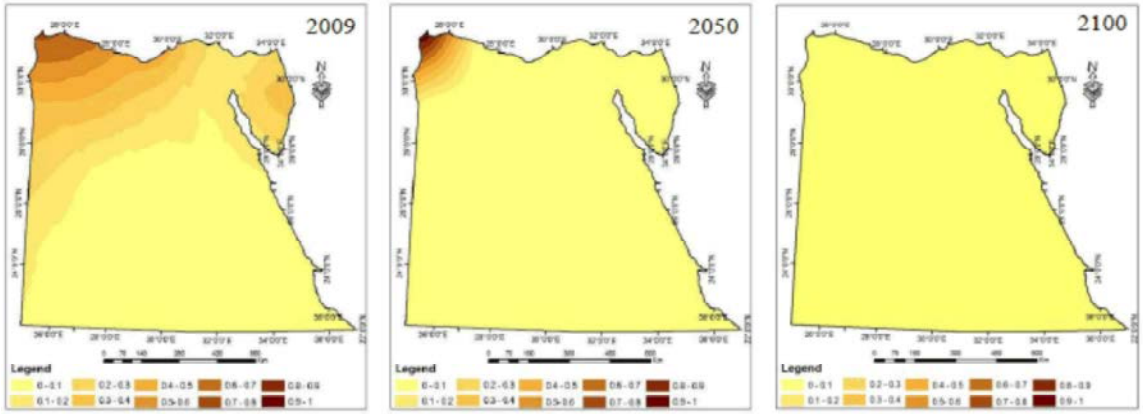

Fig. 9: Monitoring of fruit setting availability distribution for tomato crop in Egypt during August (2009, 2050 and 2100)

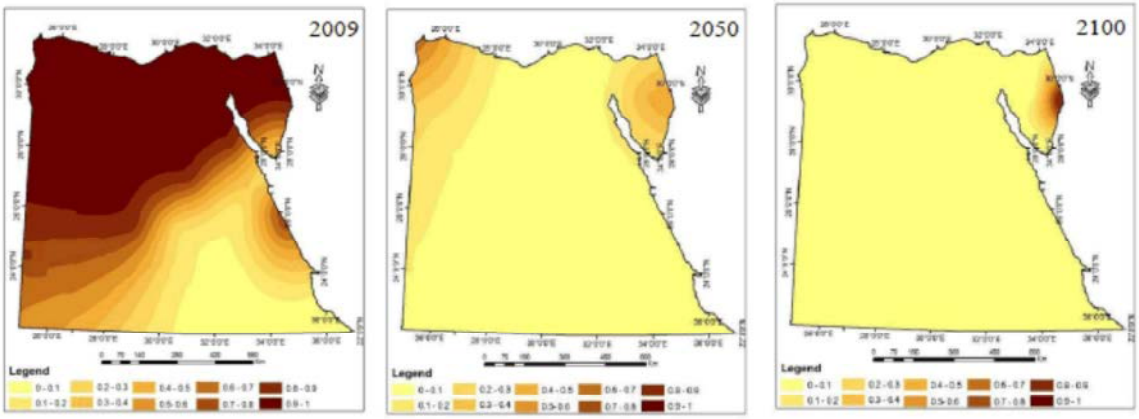

Fig. 10: Monitoring of fruit setting availability distribution for tomato crop in Egypt during September (2009, 2050 and 2100)

2050, but there is not suitable climate in the same month of 2100. Farther more, maps of September indicated that there are no problems for tomato fruit setting during the year of 2009 at the northern part of Egypt, but the southern east part has great impacts on fruit setting. Climate change also has major impacts all over Egypt through the years of 2050 and 2100; and the maps showed there are small areas have availability to fruit setting at northern west and east in 2050 and 2100, respectively. These obtained results could be attributed to the increase

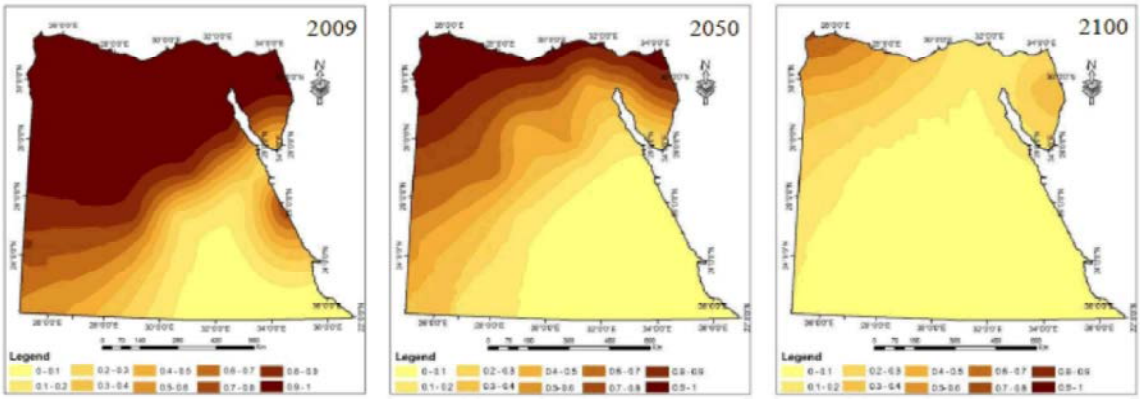

Fig. 11: Monitoring of fruit setting availability distribution for tomato crop in Egypt during October (2009, 2050 and 2100)

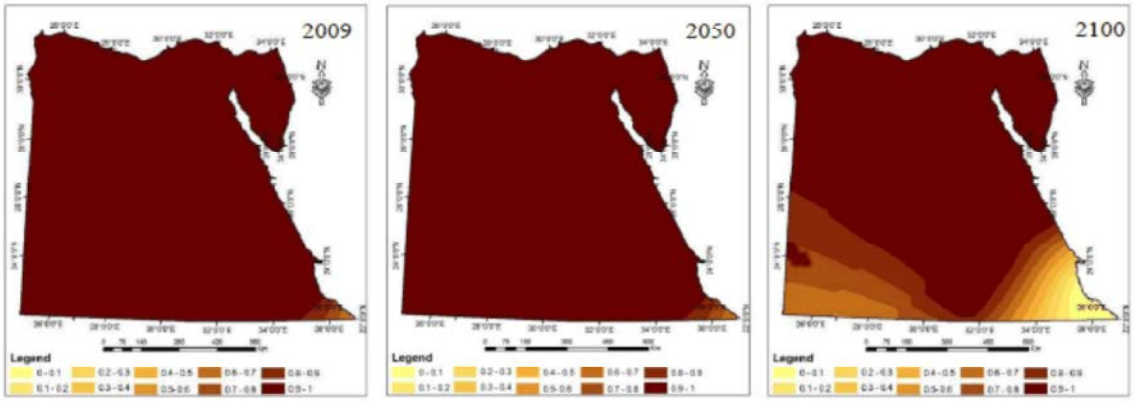

Fig. 12: Monitoring of fruit setting availability distribution for tomato crop in Egypt during November (2009, 2050 and 2100)

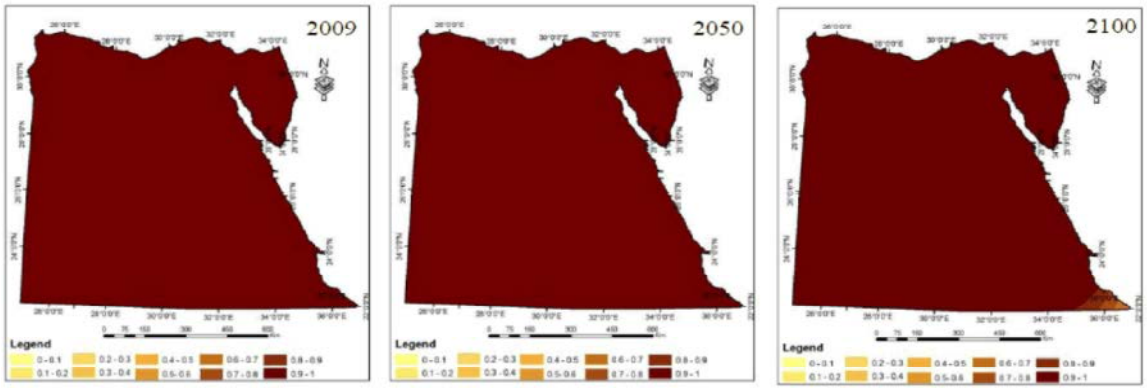

Fig. 13: Monitoring of fruit setting availability distribution for tomato crop in Egypt during December (2009, 2050 and 2100)

in global average temperature, which affect on growth and fruit set of tomato. These results are in agreement with those recorded by Moore and Thomas [3] who reported that fruit set is also low when the average maximal temperature is above 32°C and the average minimal temperature is above 21°C. Also, the increase of air temperature will led to decrease of tomato yield from -12 to -33% without adaptation for the years of 2025 to 2100 [7].

Fourth Quarter of the Year (Autumn Season): Maps illustrated in Fig (11-13) showed that predicted availability

of tomato fruit setting in Oct. Nov. and Dec. months though the years of 2050 and 2100 under climate change conditions compared to the years of 2009 in Egypt. It's indicated also Oct. maps do not have problems for tomato fruit setting during the year of 2009 at the northern part of Egypt and these problems will gradually increasing under climate change conditions up to 2100. On the vice versa, the south east part of Egypt has gradual increasing impacts on fruit setting.

Maps of Nov. indicated that the years of 2009 and 2050 have the same features; whereas all areas in Egypt have availability to fruit setting except that the small area at southern east, but in 2100 this month has availability at the northern part only and the southern part has major impacts on fruit setting.

Finally, Dec. maps showed there are no problem for tomato fruit setting during the year of 2009 and climate change do not has major impacts except that very small area in southern east part of Egypt in the year of 2100. These results could be attributed to decreasing of average maximum and minimum temperature degrees especially night temperature in autumn season. These results are in agreement with those obtained by Went [2] who reported that tomato can grow under a wide range of temperature however; fruit set is limited in a narrow range. Relatively low or high temperature leads to poor fruit set and the optimal range being 15-20°C. Also, climate change will effect on tomato crop where maximum temperature for fruit setting is 27°C [11].

CONCLUSION

It could be concluded that the increase of air temperature will have a great effect on fruit setting and led to decrease of tomato yield. Also the availability of tomato fruit setting in 2009 was very good in place and time where air temperature was suitable but in the year of 2050 the sowing date and time will change; July will not be suitable for tomato fruit setting. On the other hand, tomato fruit setting will not be suitable for three months which are June, July and August at the year of 2100.

REFERENCES

1. FAOSTAT, 2011. www.fao.org.agro- statistics database.
2. Went, F.W., 1945. Plant growth under controlled condition. II. Thermo periodicity in growth and fruit of tomato. American J. Botany. 31: 135-150.
3. Moore, E.L. and W. Thomas, 1952. Some effects of shading and parachloro-phenoxy acetic acid on fruitfulness of tomatoes. Proc. Am. Soc. Hortscience, 60: 289-294.
4. IPCC, 2010. Climate Change 2010: The Scientific Basis, Summary of Policymakers-Contribution of Working Group I to the IPCC Fourth Assessment Report 2010.
5. Houghton, J., Y. Ding, D. Griggs, M. Noguer, P. Van Der Linden, X. Dai, K. Maskell and C. Johnson, 2001. Climate Change. The Scientific Basis. Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.
6. McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, 2001. Climate change Report 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report (TAR). Cambridge Univ. Press, Cambridge, UK, pp: 1005.
7. Abou-Shleel, S.M.K. and S.M. Saleh, 2011. Sensitivity of tomato crop to air temperature under climatic changes conditions. J. Biol. Chem. Environ. Sci., 6(4): 421-435.
8. Hodson, D. and J. White, 2010. GIS and crop simulation modeling applications in climate change research. Climate Change and Crop Production (ed. M.P. Reynolds).
9. Kemble, J. and M.B. Musgrove, 2006. Soil temperature conditions for vegetable seed germination. Horticulture Notes, Alabama Corporative Extension System (ACES). www. aces. edu.
10. Witter, S.H. and L.H. Aung, 1969. *Lycopersicon esculentum* Mill. In: L.T. Evans (Editor), the Induction of Flowering. Macmillan of Australia.
11. DeKoning, A.N.M., 1994. Development and dry matter distribution in glasshouse tomato: a quantitative approach. Ph.D. Thesis, Wagenin-gen Agricultural University, The Netherlands.
12. Adams, S., K. Cockshull and C. Cave, 2001. Effect of temperature on the growth and development of tomato fruits. Annals of Botany, 88: 1-9.
13. Slake, D.C., F.A. Fox, E.C. Martin and L.J. Clark, 1994. Growing degree days based crop coefficients for irrigation management. Proceeding of the IV National Congress of the American Association of Agricultural Engineers; pp: 7-13, sep. 28-30, 1994.
14. Bayraktar, H. and F.S. Turalioglu, 2005. A Kriging based approach for locating a sampling site in the assessment of air quality, SERRA, 19(4): 301-305 doi:10.1007/s00477-005-0234-8.

15. Larson, T.M.J., 2002. Kriging Water Levels with a Regional-Linear and Point Logarithmic Drift, Ground Water, 33(1): 338-353.
16. Richmond, A., 2003. Financially Efficient or Selection Incorporating Grade Uncertainty, Mathematical Geology, 35(2): 195-215.
17. Emery, X., 2005. Simple and Ordinary Kriging, Multigaussian Kriging for estimating recoverarble Reserves, Mathematical Geology, 37(3): 25-31.
18. Stein, A., F. Van der Meer and B. Gorte, 2002. Spatial statistics for remote sensing. Springer. ISBN 0-7923-5978-X
19. Barris, J., 2008. An expert system for appraisal by the method of comparison. PhD Thesis, UPC, Barcelona.