International Journal of Environment and Climate Change

Volume 12, Issue 12, Page 579-588, 2022; Article no.IJECC.94458
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Suitability of Representative Concentration Pathway Climate Change Scenarios to Project Weather Elements in the Agro-climatic Zones of Egypt

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Authors' contributions

This work was carried out in collaboration among all authors. All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by authors TN, DOO and SMAEH. The first draft of the manuscript was written by author TN and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i121495

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/94458

Original Research Article

Received: 06/10/2022
Accepted: 09/12/2022
Published: 13/12/2022

ABSTRACT

The objective of this study was to compare between measured weather data (2010-2019) and projected data for the same period obtained from three global climate models (HadGEM2-ES, CSIRO-Mk3-6-0, and MIROC5), with its four RCPs scenarios (RCP2.6, RCP4.5, RCP6.0 and

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RCP8.5) developed for the five agro climatic zones of Egypt and determine the most suitable scenario to be used in each agro-climatic zone for projection of the effect of climate change in the future on the agro-climatic zones of Egypt. Our results revealed that the four climate change scenarios developed from the three models show high level of suitability in the projection of the three studied weather elements. Climate change scenario RCP6.0 and RCP8.5 developed by HadGEM2-ES and CSIRO-Mk3-6-0 attained the highest agreement between measured and projected values of the studied weather elements. Whereas, climate change scenario RCP2.6, RCP6.0 and RCP8.5 developed by MIROC5 attained the highest agreement between measured and projected values of the studied weather elements. Thus, we recommend the use these models in the projection of the effect of climate change in the future in the agro-climatic zones of Egypt.

Keywords: HadGEM2-ES; CSIRO-Mk3-6-0; MIROC5; RCP2.6; RCP4.5; RCP6.0; RCP8.5; agro climatic zone.

1. INTRODUCTION

"Uncertainty in climate information form limitations in our ability to model climate system, as well as in our understanding of how future greenhouse gas emissions will change" [1]. "This situation due to the impacts of climate change on the environment and society will depend not only on the response of the Earth system but also on how humankind responds through changes in technology, economy, lifestyle and policy, which are uncertain" [2]. Climate projections are based on a variety of scenarios, models and simulations procedures, which contain a number of embedded assumptions [3]. Noted that "the level of certainty associated with climate change and impact projections is a key in determining the extent to which such information can be used to formulate appropriate adaptation responses". Nevertheless, [4] indicated that "global climate models are probably the only way to investigate the non-linear interactions between the four major components of the climate system: atmosphere, biosphere, oceans and sea-ice". "These models that describe global climate are mathematical representations of physical and dynamical processes to simulate the interaction within and in between the atmosphere, land surface, oceans and sea ice" [4].

"The new global climate change models for new projection, mitigation and adaptation scenarios involving policy decisions and options for targeted climate change stabilization at different levels" [5]. "These models were developed during the IPCC Fifth Assessment report (AR5) of the Intergovernmental Panel on Climate Change" [6]. "Its findings were based on a new set of scenarios that replace SRES scenarios" [7]. "A scenario is a description of potential future conditions produced to inform decision-making under uncertainty" [5]. "Scenarios are descriptions of different possible futures, a series of alternative visions of futures (storylines) which are possible, plausible, and internally consistent but none of which is necessarily probable" [8]. "The efforts included in the Fifth Assessment report (AR5) of the Intergovernmental Panel on Climate Change in 2013 are enormous, with a larger number of more complex models run at higher resolution, with more complete representations of external forcings, more types of scenario and more diagnostics stored" [9].

Starting from the early 2000s, most of climate change studies in Egypt to assess the effect of climate change on crops [10-13] and on its water requirements [14] have been done using the IPCC climate change scenarios published in 2001 and 2007. In 2011, IPCC scenarios published in Fourth Assessment report (AR4) were used to project productivity of cotton in salt affected soil [15], to project productivity of cultivated crops under rain fed area in Egypt [16], to project water requirements for four economically important crops in Egypt [17]. An ensemble AR4 model for North Nile Delta was published by [18] to lower uncertainty in evapotranspiration projection under climate change.

The climate change scenarios released by four models from the Fifth Assessment report (AR5) were used by [19] in a simulation model to project wheat and maize productivity in 2030 in nine governorates in Egypt and to develop the most suitable adaptation strategies under climate change conditions in these governorates. Similarly, [20] compared "between measured weather data and projected data (2006-2014) from four global climate models, with its four Representative Concentration Pathways scenarios (RCPs) to determine the suitable climate change scenario in 2030. They recommended the use the RCP6.0 scenario developed by CCSM4 model as it was found to be suitable scenario for Egypt".

Furthermore, [21] used "RCP6.0 climate change scenario resulted from MIROC5 climate change model to quantify how climate change will affect the value of Kc and water consumptive use of 14 field crops, 7 fruit crops and 13 vegetable crops in the five agro-climatic zones of Egypt in 2030 in Egypt".

In the light of warming phenomena that was prevailing lately in Egypt, a need was arisen to define the agro-climatic zones in Egypt to facilitate water management. Therefore, [22] studied trends of mean evapotranspiration (ETo) values calculated from 30-year interval (1986-2015), and compared it with the mean value of 20-year time interval (1996-2015) and the 10-year interval (2006-2015) in an attempt to define agro-climatic zones responded to the warming. They found that the highest mean values of ETo was the calculated mean in the 10-year interval (2006-2015) and they use it to define the five agro-climatic zones of Egypt.

Thus, the objective of this work was to compare between measured weather data (2010-2019) and projected data for the same period obtained from three global climate models (HadGEM2-ES, CSIRO-Mk3-6-0, and MIROC5), with its four RCPs scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) developed for the five agro-climatic zones of Egypt and determine the most suitable scenario to be used in each agro-climatic zone for the projection of the effect of climate change in the future on the agro-climatic zones of Egypt.

2. MATERIALS AND METHODS

Three climate change models were used in this study, namely HadGEM2-ES, CSIRO-Mk3-6-0, and MIROC5. The selection of models in this study was designed to include models with differing levels of sensitivity to Green House Gases (GHG) forcing.

2.1 HadGEM2-ES Model

"HadGEM2-ES ESM is a coupled AOGCM with atmospheric resolution of N96 (1.875° X1.25°) with 38 vertical levels and an ocean resolution of 1° (increasing to 1/3° at the equator) and 40 vertical levels. HadGEM2-ES ESM also represents interactive land and ocean carbon cycles and dynamic vegetation with an option to prescribe either atmospheric CO2 concentrations or to prescribe anthropogenic CO2 emissions and simulate CO2 concentrations.An interactive tropospheric chemistry scheme is also included, which simulates the evolution of atmospheric composition and interactions with atmospheric aerosols. The model time step is 30 min (atmosphere and land) and 1 h (ocean). Extensive diagnostic output is being made available to the CMIP5 multi-model archive. Output is available either at certain prescribed frequencies or as time- average values over certain periods as detailed in the CMIP5 output guidelines" [23].

2.2 CSIRO-MK3.6.0 Model

"The CSIRO-Mk3.6.0 model, hereafter called Mk3.6, is an upgrade from the CSIRO-Mk3.5 GCM" [24]. "The atmospheric component has a horizontal resolution of approximately 1.9° x 1.9° and every atmospheric grid-point is coupled to two ocean grid-points. This enhanced north-south resolution in the ocean component is expected to increase the capacity for the ocean to simulate important tropical and extra-tropical seasonal interactions. The atmosphere has 18 vertical levels whereas the ocean has 30 levels with most found in the upper 1500m. By far the most important improvement of the Mk3.6 model from its predecessor is the inclusion of an interactive aerosol scheme that also required an update to the radiation scheme used in the model. This allows for the investigation of the impact of a number of aerosol agents on climate" [25].

2.3 MIROC5 Model

MIROC5 model has updated and newly-developed parameterizations in both of the atmospheric and oceanic components, including a cumulus convection scheme, a prognostic large-scale condensation scheme [26], a radiative transfer scheme [27], a land surface model a multi-category sea-ice model and a highly accurate tracer transport algorithm. The resolution of the atmospheric component is a T85 spectral truncation with 40 levels in the vertical, and that of the oceanic component is 1.4 in the zonal, 0.5-1.4 in the meridional directions, respectively, and 50 vertical layers. The ocean model is formulated on generalized curvilinear horizontal coordinates, and the two coordinate singularities are placed at 80 N, 40 W on Green-l and 80 S, 40 W on Antarctica [28].

2.4 Climate Change Scenarios

The CMIP5 GCMs outputs provide four RCPs; these scenarios are RCP2.6, RCP4.5, RCP6.0 and RCP8.5, where the numbers refer to forcings for each RCP. The radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system, measured in watts per square meter. Each RCP defines a specific emissions trajectory and subsequent radiative forcing. The scenarios are described as following:

2.4.1 RCP2.6

"The emission pathway is representative of scenarios in the literature that lead to very low greenhouse gas concentration levels. It is a "peak-and-decline" scenario; its radiative forcing level first reaches a value of around 3.1 W/m^2 by mid-century, and returns to 2.6 W/m^2 by 2100. In order to reach such radiative forcing levels, greenhouse gas emissions (and indirectly emissions of air pollutants) are reduced substantially over time" [29].

2.4.2 RCP4.5

"It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level" [30].

2.4.3 RCP6.0

"It is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshoot, by the application of a range of technologies and strategies for reducing greenhouse gas emissions" [31].

2.4.4 RCP8.5

"It is characterized by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high greenhouse gas concentration levels" [32].

2.5 The Agro-climatic Zones of Egypt

Ouda and Noreldin [22] used values of reference evapotranspiration (ETo) for 10-year time period from 2005 to 2014 to develop agro-climatic zones for Egypt. In that methodology, monthly means of weather data for 10-year were calculated for each governorate. Analysis of variance was used and the means was separated and ranked using least significant difference test (LSD 0.05). Zoning using 10-year values of ETo resulted in five agro-climatic zones (Table 1). The first agro-climatic zone is composed of two governorates. They are located between latitudes 31.70º and 31.07º and between longitudes 29.00º and 30.57º, where the ETo values ranged between 4.28-4.85 mm/day. The second ago-climatic zone is composed of four governorates located between latitudes 30.47º and 31.25º. The longitude values of this agro-climatic zone is between 32.14º and 31.49º. The ETo values in this zone ranged between 5.12-5.34 mm/day. The third agro-climatic zone contains five governorates located between latitudes 29.18º and 30.36º and between latitudes 30.36º and 31.13º, where ETo values ranged between 5.59-5.96 mm/day. Four governorates are located in the fourth agro-climatic zone. The range of latitude is between 26.36º and 29.04º and the range of longitude is between 31.38º and 31.06º, with ETo values ranged between 6.12 and 6.14 mm/day. The fifth agro-climatic zone is composed of two governorates with latitude values ranges between 24.02º and 26.10º and longitude values ranged between 32.53º and 32.43º. The ETo value in the agro-climatic zone ranged between 6.48-6.60 mm/day.

2.6 Comparison Procedure

The observed daily measured weather data in the five agro-climatic zones during the period from 2010 to 2019 were compared with the daily projected climate data from the studied three models. The goodness of fit between the measured and projected data was examined by calculating the following measurements:

2.6.1 Willmott index of agreement (d)

"It is the standardized measure of the degree of model prediction error which varies between 0 and 1. A value of 1 indicates a perfect match, and value of 0 indicates no agreement at all" [33].

$$d = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}[(|(S_i - \bar{O})| + |(O_i - \bar{O})|)^2]} \quad (1)$$

Where Oi, $\bar{O}$ and Si represent the observed, observed average and simulated values.

Table 1. Agro-climatic zones of Egypt as determined using 10-year values of ETo

Zone number	Governorate	ETo (mm/day)
Zone 1	Alexandria	4.28
	Kafr El-Sheik	4.85
Zone 2	Demiatte	5.12
	El-Dakahlia	5.34
	El-Behira	5.19
	El-Gharbia	5.12
Zone 3	El-Monofia	5.80
	El-Sharkia	5.87
	El-Kalubia	5.96
	Giza	5.70
	Fayom	5.59
Zone 4	Beni Sweif	6.14
	El-Minia	6.14
	Assuit	6.12
	Sohag	6.13
Zone 5	Qena	6.48
	Aswan	6.60
Average		5.67
Rang		2.32
LSD0.05		0.217

2.6.2 Root mean square error per observation (RMSE/obs)

It gives the general standard deviation of the model prediction error per observation [34].

$$\mathrm{RMSE/obs} = \sqrt{\left(\frac{\sum_{i=1}^{n}(S_i - O_i)^2}{n}\right)} \quad (2)$$

Where, n represents the number of observed and simulated values used in comparison.

Depending on the above analysis, the suitable RCP scenario for each model can be determined.

3. RESULTS AND DISCUSSION

3.1 The First Agro-climatic Zone

The results in Table (2) indicated that the highest value of d-stat and the lowest value of RMSE/obs for solar radiation, maximum temperature and minimum temperature were obtained under RCP6.0 predicted by CSIRO-MK3.6.0 and HadGEM2-ES models. Whereas, RCP8.5 predicted by MIROC5 model attained the highest value of d-stat and the lowest value of RMSE/obs for these weather elements in the first agro-climatic zone [20]. Indicated that the RCP6.0 developed by CCSM4 model and RCP8.5 and MIROC5 models were acceptable for to predict weather elements in governorates located in the first agro-climatic zone.

3.2 The Second Agro-climatic Zone

The results in Table (3) indicated that, in the second ago-climatic zone, the highest value of d-stat and the lowest value of RMSE/obs for solar radiation, maximum temperature and minimum temperature were obtained under RCP6.0 predicted by CSIRO-MK3.6.0 model. Furthermore, the projection of HadGEM2-ES and MIROC5 models showed that the highest value of d-stat and the lowest value of RMSE/obs for the three weather elements were obtained under RCP8.5. [20] reported that the suitable scenarios some of the governorates located in the second agro-climatic zone was RCP6.0 developed by CCSM4 model and RCP8.5 developed by MIROC5 model.

Table 2. Goodness of fit between measured and predicted weather data by three climate change models averaged from 2010-2019 in the first agro climatic zone

	CSIRO-MK3.6.0											
	RCP2.6			RCP4.5			RCP6.0			RCP8.5		
	SR	Mx	Mn	SR	Mx	Mn	SR	Mx	Mn	SR	Mx	Mn
d-stat	0.91	0.90	0.97	0.91	0.94	0.96	0.97	0.95	0.96	0.91	0.95	0.96
RMSE/obs	0.20	0.12	0.11	0.18	0.10	0.14	0.11	0.10	0.14	0.19	0.12	0.13
HadGEM2-ES												
d-stat	0.91	0.95	0.97	0.90	0.95	0.97	0.97	0.96	0.97	0.91	0.90	0.97
RMSE/obs	0.19	0.14	0.12	0.19	0.10	0.11	0.18	0.09	0.10	0.18	0.13	0.13
MIROC5												
d-stat	0.88	0.95	0.95	0.88	0.94	0.97	0.90	0.93	0.97	0.91	0.95	0.97
RMSE/obs	0.21	0.10	0.10	0.21	0.11	0.11	0.21	0.12	0.10	0.18	0.10	0.10

SR = solar radiation (MJ/m^2/day),MX: maximum temperature (°C); Mn: Minimum temperature (°C).

Table 3. Goodness of fit between measured and predicted weather data by three climate change models averaged from 2010-2019 in the second agro-climatic zone

	CSIRO-MK3.6.0											
	RCP2.6			RCP4.5			RCP6.0			RCP8.5		
	SR	Mx	Mn	SR	Mx	Mn	SR	Mx	Mn	SR	Mx	Mn
d-stat	0.96	0.97	0.84	0.96	0.97	0.83	0.97	0.98	0.95	0.96	0.99	0.84
RMSE/obs	0.13	0.03	0.26	0.13	0.05	0.26	0.11	0.04	0.10	0.23	0.04	0.26
HadGEM2-ES												
d-stat	0.96	0.99	0.85	0.96	0.99	0.84	0.86	0.98	0.86	0.96	0.99	0.87
RMSE/obs	0.13	0.03	0.25	0.13	0.03	0.25	0.17	0.06	0.23	0.13	0.03	0.23
MIROC5												
d-stat	0.95	0.99	0.85	0.96	0.99	0.86	0.96	0.99	0.85	0.97	0.99	0.86
RMSE/obs	0.14	0.05	0.24	0.13	0.05	0.24	0.13	0.05	0.25	0.12	0.03	0.24

*SR = solar radiation (MJ/m^2/day),*MX: maximum temperature *(°C)*; Mn: Minimum temperature *(°C)*

3.3 The Third Agro-climatic Zone

Average measured and predicted weather data by CSIRO-MK3.6.0 model in the third agro-climatic zone, Table (4) showed that the highest value of d-stat and the lowest value of RMSE/obs for solar radiation, maximum temperature and minimum temperature were obtained under RCP8.5 predicted by CSIRO-MK3.6.0 and HadGEM2-ES models. Whereas, the projection of RCP2.6 climate change scenario resulted from MIROC5 model attained the highest value of d-stat and the lowest value of RMSE/obs for these weather elements.

Table 4. Goodness of fit between measured and predicted weather data by three climate change models averaged from 2010-2019 in the third agro-climatic zones

	CSIRO-MK3.6.0											
	RCP2.6			RCP4.5			RCP6.0			RCP8.5		
	SR	Mx	Mn	SR	Mx	Mn	SR	Mx	Mn	SR	Mx	Mn
d-stat	0.76	0.97	0.92	0.82	0.98	0.93	0.71	0.95	0.88	0.83	0.98	0.93
RMSE/obs	0.32	0.08	0.19	0.27	0.06	0.18	0.32	0.10	0.23	0.27	0.05	0.19
HadGEM2-ES												
d-stat	0.84	0.98	0.92	0.84	0.99	0.92	0.78	0.96	0.92	0.85	0.98	0.93
RMSE/obs	0.26	0.06	0.19	0.26	0.06	0.19	0.27	0.08	0.19	0.25	0.05	0.18
MIROC5												
d-stat	0.84	0.98	0.93	0.83	0.97	0.92	0.74	0.94	0.91	0.79	0.98	0.92
RMSE/obs	0.29	0.06	0.18	0.27	0.06	0.19	0.30	0.10	0.20	0.30	0.07	0.19

*SR = solar radiation (MJ/m^2/day),*MX: maximum temperature *(°C)*; Mn: Minimum temperature *(°C)*

3.4 The Fourth Agro-climatic Zone

The highest value of d-stat and the lowest value of RMSE/obs for solar radiation, maximum temperature and minimum temperature in the fourth agro-climatic zone were obtained for RCP8.5 predicted by CSIRO-MK3.6.0 model. Furthermore, the projection of HadGEM2-ES model showed that the highest value of d-stat and the lowest value of RMSE/obs for the three weather elements were obtained under RCP6.0. Whereas, the projection of climate change scenario RCP2.6 resulted from MIROC5 model attained the highest value of d-stat and the lowest value of RMSE/obs for these weather elements (Table 5) [20]. Reported RCP8.5 and RCP6.0 scenarios developed by CCSM4 model were found suitable for some governorates located in the fourth agro-climatic zone.

3.5 The Fifth Agro-climatic Zone

The results in Table (6) indicated that highest value of d-stat and the lowest value of RMSE/obs for solar radiation, maximum temperature and minimum temperature were obtained under RCP6.0 predicted by CSIRO-MK3.6.0 and MIROC5 models. Furthermore, the projection of HadGEM2-ES model showed that the highest value of d-stat and the lowest value of RMSE/obs for the three weather elements were obtained under RCP8.5 for the three studied weather elements in the fifth agro-climatic zone.

3.6 Determination of the Suitable RCP of the Studied Climate Models in the Five Agro-climatic Zones in Egypt

The above analysis defined one scenario obtained from the studied climate change models for each agro-climatic zone that could be recommended to be used. Table (7) indicated that the suitable scenarios for most zones were RCP6.0 and RCP8.5 resulted from CSIRO-MK3.6.0 and HadGEM2-ES models. Whereas, the RCP8.5, RCP2.6 and RCP6.0 resulted from MIROC5 model were the suitable scenarios for most agro-climatic zones.

Table 5. Goodness of fit between measured and predicted weather data by three climate change models averaged from 2010-2019 in the fourth agro climatic zones

	CSIRO-MK3.6.0											
	RCP2.6			**RCP4.5**			**RCP6.0**			**RCP8.5**		
	SR	**Mx**	**Mn**	**SR**	**Mx**	**Mn**	**SR**	**Mx**	**Mn**	**SR**	**Mx**	**Mn**
d-stat	0.57	0.97	0.87	0.62	0.98	0.90	0.51	0.97	0.92	0.64	0.98	0.93
RMSE/obs	0.63	0.09	0.25	0.56	0.07	0.23	0.60	0.05	0.21	0.55	0.05	0.20
HadGEM2-ES												
d-stat	0.61	0.98	0.89	0.57	0.98	0.98	0.62	0.98	0.99	0.57	0.86	0.98
RMSE/obs	0.39	0.07	0.23	0.39	0.06	0.13	0.38	0.06	0.12	0.41	0.26	0.13
MIROC5												
d-stat	0.62	0.98	0.89	0.51	0.98	0.88	0.55	0.96	0.92	0.59	0.98	0.86
RMSE/obs	0.38	0.06	0.24	0.39	0.07	0.24	0.42	0.09	0.21	0.40	0.06	0.26

SR = solar radiation (MJ/m^2/day), MX: maximum temperature *(°C)*; Mn: Minimum temperature *(°C)*.

Table 6. Goodness of fit between measured and predicted weather data by three climate change models averaged from 2010-2019 in the fifth agro climatic zones

	CSIRO-MK3.6.0											
	RCP2.6			**RCP4.5**			**RCP6.0**			**RCP8.5**		
	SR	**Mx**	**Mn**	**SR**	**Mx**	**Mn**	**SR**	**Mx**	**Mn**	**SR**	**Mx**	**Mn**
d-stat	0.69	0.97	0.94	0.63	0.97	0.93	0.70	0.98	0.92	0.66	0.96	0.94
RMSE/obs	0.32	0.07	0.17	0.34	0.07	0.12	0.30	0.06	0.11	0.30	0.09	0.12
HadGEM2-ES												
d-stat	0.69	0.97	0.94	0.70	0.98	0.93	0.68	0.98	0.93	0.72	0.98	0.94
RMSE/obs	0.31	0.07	0.17	0.31	0.07	0.18	0.32	0.07	0.17	0.30	0.07	0.16
MIROC5												
d-stat	0.70	0.97	0.92	0.69	0.97	0.92	0.69	0.98	0.93	0.69	0.97	0.92
RMSE/obs	0.33	0.09	0.20	0.32	0.08	0.18	0.32	0.07	0.17	0.32	0.08	0.18

SR = solar radiation (MJ/m^2/day), MX: maximum temperature *(°C)*; Mn: Minimum temperature *(°C)*.

Table 7. The suitable RCP scenarios resulted from the studied climate models in the five agro-climatic zones in Egypt

Zones	CSIRO-MK3.6.0	HadGEM2-ES	MIROC5
Zone 1	RCP6.0	RCP6.0	RCP8.5
Zone 2	RCP6.0	RCP8.5	RCP8.5
Zone 3	RCP8.5	RCP8.5	RCP2.6
Zone 4	RCP8.5	RCP6.0	RCP2.6
Zone 5	RCP6.0	RCP8.5	RCP6.0

4. CONCLUSION

In this study, we compared between measured solar radiation, maximum temperature and minimum temperature in the period from 2010-2019 and projected data for the same period obtained from three global climate models, namely HadGEM2-ES, CSIRO-Mk3-6-0, and MIROC5. These three climate change models are differing in the levels of its sensitivity to Green House Gases forcing with its four RCPs scenarios, namely RCP2.6, RCP4.5, RCP6.0 and RCP8.5. We used these models to develop the RCPs scenarios for the five agro-climatic zones of Egypt to determine the most suitable scenario to be used in each agro-climatic zone for irrigation determination purposes. Our results revealed that the following:

1. In general, the four climate change scenarios developed from the three models show high level of suitability in the projection of the three studied weather elements.
2. Climate change scenario RCP6.0 and RCP8.5 developed by HadGEM2-ES and CSIRO-Mk3-6-0 attained the highest agreement between measured and projected values of the studied weather elements.
3. Whereas, climate change scenario RCP2.6, RCP6.0 and RCP8.5 developed by MIROC5 attained the highest agreement between measured and projected values of the studied weather elements.
4. Thus, we recommend the use either one of these models in the projection of the effect of climate change in the future on the agro-climatic zones of Egypt.

ACKNOWLEDGEMENT

The authors extend their thanks to Water Requirements and Field Irrigation Research Department, Soils, Water and Environment Research Institute Agriculture Research Center (ARC), Giza, Egypt; Central Laboratory of Agricultural Climate, Agricultural Research Center, Egypt and Horticulture Research Institute, Agricultural Research Center, Egypt.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Moss RH, Edmonds JA, Hibbard KA, Manning MR, Rose SK, van Vuuren DP, Carter TR, Emori S, Kainuma M, Kram T, Meehl GA, Mitchell JFB, Nakićenović N, Riahi K, Smith SJ, Stouffer RJ, Thomson AM, Weyant JP, Wilbanks TJ. The next generation of scenarios for climate change research and assessment. Nature. 2010;463:747–756.
2. Rogelj J, Meinshausen M and Knutti R. Global warming under old and new scenarios using IPCC climate sensitivity range estimates. Nature Clim. Change. 2012;2:248–253. DOI:10.1038/nclimate1385
3. Gagnon-Lebrun F and Agrawala S. Progress on Adaptation to Climate Change in Developed Countries: An Analysis of Broad Trends, ENV/EPOC/GSP1/FINAL, OECD, Paris. 2006.
4. IPCC. Climate change 2007: AR4 summary for policymakers. The physical science basis. Con-tribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge; 2007.
5. Quante M and Bjørnæs C. Emission Scenarios for Climate Projections. In: M. Quante and F. Colijn (eds.), North Sea Region Climate Change Assessment, Regional Climate Studies; 2016. DOI :10.1007/978-3-319-39745-0

6. IPCC. Summary for Policymakers in Climate Change. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM, Eds. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; 2013.
7. Wayne GP. The Beginner's Guide to Representative Concentration Pathways. Skeptical Science, Version 1.0; 2013. Available:http://www.skepticalscience.com/docs/RCP_Guide.pdf.
8. Von Storch H. Climate change scenarios – purpose and construction. In: von Storch H, Tol R.S.J, Flöser G. (eds) Environmental Crises – Science and Policy, Springer. 2008:5–15.
9. Knutti R, Sedlacek J. Robustness and uncertainties in the new CMIP5 climate model projections. Nature Climate Change, Advance Online Publication; 2012. DOI: 10.1038/NCLIMATE1716
10. Abou-Shleel SMK and Saleh SM. Sensitivity of tomato crop to air temperature under climate change conditions. J. Biol. Chem. Environ Research Sci. 2011;6(4):421-435.
11. Ouda S, Abdrabbo M and Noreldin T. Effect of changing sowing dates and irrigation scheduling on maize yield grown under climate change conditions. 10th International Conference of Egyptian Soil Science Society (ESSS) and 4th International Conference of Water Requirements & Metrology Dept. 5 -7 November. Ameria, Egypt (Cl 07); 2012a.
12. Ouda S, Noreldin T, AbouElenin R and Abd El-Baky H. Improved agricultural management practices reduced wheat vulnerably to climate change in salt affected soils. Egypt. J. Agric. Res. 2012b; 904:499-513.
13. Ouda S, Noreldin T, Abou Elenein R and Abd El-Baky H. Adaptation of cotton crop to climate change in salt affected soil. Proceeding of the 11th International Conference on Development of Dry lands. Beijing, China; 2013.
14. Noreldin T, Abdrabbo M and Ouda S. Increasing water productivity for wheat grown under climate change conditions. 10th International Conference of Egyptian Soil Science Society (ESSS) and 4th International Conference of Water Requirements & Metrology Dept. 5 -7 November. Ameria, Egypt (Cl 06);2012.
15. Ouda S, Noreldin T, Abou Elenein R, Abd El-Baky H. Adaptation of cotton crop to climate change in salt affected soil. Proceeding of the 11th International Conference on Development of Dry lands. Beijing, China; 2013.
16. Ouda S, Ewise M, Noreldin T. Projection of productivity of cultivated crops in rain-fed areas in Egypt under climate change. Cogent Food and Agriculture. 2016a;2(1):1136256.
17. Ouda S, Noreldin T, Hosny M. Evapotranspiration under Changing Climate. In: Major Crops and Water Scarcity in Egypt. Springer Publishing House. 2016b;1-22. ISBN: 978-3-319-21770-3.
18. Ouda S, Morsy M and Noreldin T. Ensemble AR4 model for North Nile Delta to lower uncertainty in evapotranspiration calculation under climate change. 4th African Regional ICID Conference. 24-28th April; 2016c.
19. Morsy M. Use of regional climate and crop simulation models to predict wheat and maize productivity and their adaptation under climate change. PhD thesis. Faculty of Science Al-Azhar University; 2015.
20. Sayad T, Ouda S, Morsy M, El-Hoseiny F. Robust statistical procedure to determine suitable scenario of some CMIP5 models for four locations in Egypt. Global Journal of Advanced Research. 2015; 2:1009-1019.
21. Ouda S. Projected Crop Coefficients under Climate Change in Egypt. In: Climate Change Impacts on Agriculture and Food Security in Egypt. Springer Publishing House. ISBN: 978-3-030-41628-7; 2020.
22. Ouda S and Noreldin T. Evapotranspiration data to determine agro- climatic zones in Egypt. Journal of Water and Land Development. 2017; 32(I-III)79-86.
23. Collins WJ, Bellouin N, Doutriaux-Boucher M, Gedney N, Halloran P, Hinton T, Hughes J, Jones CD, Joshi M, Liddicoat S, Martin G, O'Connor F, Rae J, Senior C, Sitch S, Totterdell I, Wiltshire A and Woodward S. Development and evaluation of an Earth-system model HadGEM2, Geosci. Model Dev. Discuss. 2011;4:997–1062. DOI:10.5194/gmdd-4-997

24. Gordon HB and (co-authors) The CSIRO Mk3.5 Climate Model. CAWCR Technical Report No. 2010; 21:74.
25. Rotstayn LD, Jeffrey SJ, Syktus JI, Collier MA, Dravitzki SM, Hirst AC and Wong KK-H. Have anthropogenic aerosols delayed greenhouse gas-induced changes in Indo-Pacific regional circulation and rainfall? Atmospheric Science Letters, Submitted; 2011.
26. Watanabe M, Emori S, Satoh M and Miura H. A PDF-based hybrid prognostic cloud scheme for general circulation models. Clim. Dyn. 2009;33. DOI:10.1007/s00382-008-0489-0.
27. Sekiguchi M and Nakajima T. A k-distribution based radiation code and its computational optimization for an atmospheric general circulation model. J. Quant. Spectrosc. Radiat. Transfer. 2008;109:2779–2793.
28. Yamazaki D, Oki T and Kanae S. Deriving a global river network map and its sub-grid topographic characteristics from a fine-resolution flow direction map. Hydrol. Earth Syst. Sci. 2009;13:2241– 2251.
29. van Vuuren, D P et al. Stabilizing greenhouse gas concentrations at low levels: An assessment of reduction strategies and costs. Climatic Change. 2007;81:119–159. Available:http://dx.doi.org/10.1007/s10584-006-9172-9.
30. Wise M A, Calvin KV, Thomson AM, Clarke LE, Bond-Lamberty B, Sands RD, Smith SJ, Janetos AC and Edmonds J A. Implications of limiting CO2 concentrations for land use and energy. Science. 2009;324:1183-1186.
31. Hijioka Y, Matsuoka Y, Nishimoto H, Masui M and Kainuma M. Global GHG emissions scenarios under GHG concentration stabilization targets. Journal of Global Environmental Engineering. 2008;13: 97–108.
32. Riahi K, Grübler A, Nakicenovic N. Scenarios of long-term socioeconomic and environmental development under climate stabilization. Greenhouse Gases-Integrated Assessment. Special Issue of Technological Forecasting and Social Change. 2007;74(7):887–935, DOI:10.1016/j.techfore.2006.05.026
33. Willmott C J. On the validation of models. Physical Geography. 1981;2:184–194.
34. Jamieson PD, Porter JR, Goudriaan J, Ritchie JT, Keulen H and Stol W. A comparison of the models AFRCWHEAT2, CERES-Wheat, Sirius, SUCROS2 and SWHEAT with measurements from wheat grown under drought. Field Crops Res. 1998;55:23–44.

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