Proceedings of the 3rd International Conference on Civil Engineering for Sustainable Development (ICCESD 2016), 12~14 February 2016, KUET, Khulna, Bangladesh (ISBN: 978-984-34-0265-3)

ASSESSING THE IMPACT OF CLIMATE CHANGE ON SUNFLOWER YIELD USING THE AQUACROP MODEL

Debanjali Saha*[1] and M. Shahjahan Mondal[2]

[1] *Lecturer, Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), Bangladesh, e-mail: debanjalisaha@iwfm.buet.ac.bd*
[2] *Professor, Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), Bangladesh, e-mail: mshahjahanmondal@iwfm.buet.ac.bd*

ABSTRACT

The coastal region of Bangladesh is highly vulnerable to frequent natural hazards where high soil and water salinity hampers the agricultural activity especially during the dry season. Due to lack of suitable freshwater, local people have started cultivation of less water requiring cash crop like sunflower. However, changes in future climate are likely to affect the yield of this crop. The objective of this study was to assess the impact of climate change on sunflower yield using the FAO AquaCrop model. For calibration and validation of the model, an experimental study was conducted with Hysun 33, a local variety of sunflower, during the dry season of 2014 in the coastal region of Bangladesh. From sowing to harvesting phases, necessary data on crop, soil, irrigation, management, etc., were collected from two different plots through field measurement and monitoring. Observed climate data for the year 2014 were collected from the local climatic station of Bangladesh Meteorological Department and future climatic data were available from the PRECIS model outputs for different ensemble members of IPCC-SRES scenario A1B from the Met Office, Hadley Centre, UK. Comparison of observed and model simulated yields indicated good performance of the model in simulating sunflower yield in saline coastal areas. The application of this parameterized model for future prediction of sunflower yield indicated a slightly increasing trend. Thus, it can be said that, the sunflower cultivation may be profitable for the local farmers to increase income and improve their standard of living.

Keywords: *Salinity, sunflower, climate change, AquaCrop model*

1. INTRODUCTION

Bangladesh is a delta shaped lower riparian country in the Ganges-Brahmaputra-Meghna basin. The coastal region of Bangladesh has a 700 km long coastal belt and an area of 47, 203 km^2 including 19 districts (Khan & Awal, 2009). The coastal area, mostly the south-western portion, is highly vulnerable to frequent natural hazards such as cyclone and associated storm surge, salinity intrusion, river erosion, flood, etc., due to several climatological and geographical characteristics. Frequent cyclone and storm surge events have caused sufferings to the coastal people damaging their houses, agricultural land and property. Intrusion of saline water from cyclonic storm surges has increased salinity of soil and water in the area since the last several years. Moreover, long term cultivation of saline water shrimp and some hostile practices of powerful shrimp farmers like cutting of polder for saline water entry have increased the salinity and degraded the environmental quality. The situation has been aggravated by the event of cyclone Aila in 2009, where both long and short term inundation and salinity ingression affected the lives and livelihoods of the people up to a damaging extent. The agricultural lands were severely affected and the food cycle throughout the coastal region was paralyzed. Though the cultivation of shrimp has been stopped for the last 6-7 years, but due to this practice and the cyclone Aila as well, the impact of salinity has been so detrimental that the agricultural activities had been restricted to almost single season crop cultivation, thus rendering threat to sustainability of agriculture in the local area. Due to lack of suitable irrigation water and high salinity condition, people could not grow any crops during the dry season for several years. But recently, the soil and water salinity has been reduced and agricultural activities are possible during the dry season. Under these circumstances, local people are interested in practicing crop cultivation during the dry season to improve their living standard and socio-economic condition. But due to lack of suitable irrigation water, people are not being able to cultivate boro rice which is the staple food crop. So, they have started cultivating less water requiring cash crop like sunflower.

Sunflower is an emerging crop, which was first introduced by an international non-governmental organization (NGO), Bangladesh Rural Advancement Committee (BRAC), in the coastal areas on an experimental basis. Now this crop is being cultivated by many farmers though in a small scale, but its lower water requirement, less investment cost with good profit and health benefits of its oil consumption have drawn farmers' attention. Many farmers are now willing to cultivate sunflower during the dry season instead of keeping their land fallow. In this way, an aman-rabi-fallow cropping pattern is being practiced in the coastal areas instead of an aman-fallow-fallow one. The price of sunflower seeds in the local market is 1300 tk/kg where 2.5 kg seed can cover 1 hectare (ha) of land area. The usual yield from 1 ha of land is almost 1.25 ton (1250 kg). The market price of 1 kg harvested sunflower seed is 40-50 tk which means the price of the harvested crop from 1 ha of land is 50000-60000 tk. This indicates that sunflower cultivation can bring good profit and assist in improving the local people's economic condition and achieving solvency. However, the agriculture sector of Bangladesh is highly vulnerable to global warming induced climate change impacts and these impacts are likely to affect the yield of sunflower. So, the impact of changed future climate on sunflower cultivation needs to be evaluated and the FAO AquaCrop model can assist in this process.

The AquaCrop is a crop growth and yield simulation model, developed by the Land and Water Division of Food and Agriculture Organization (FAO) to simulate yield response to water of several herbaceous crops (Steduto, Hsiao, Raes & Fereres, 2009; Steduto et al., 2011). This model is widely used for simulating crop yield under different field conditions in different seasons and locations. In a restructuring process of FAO irrigation and Drainage Paper 33: Yield Response to Water and to achieve an optimal balance between accuracy, simplicity and robustness, AquaCrop model was first developed in January, 2009 (Steduto et al., 2009; Steduto et al., 2011). This model has been parameterized and tested on a number of crops and the performance and user-friendliness of AquaCrop have been reported from many users around the world. The salinity module of the model has been released in 2012 and not much study has been performed for testing its performance. Also, other crop models like DSSAT do not have the salinity component. There are many coastal areas in the world where high salinity is a major restriction for coastal agriculture. The coastal population is increasing worldwide and agricultural activities are being intensified for maintaining food security and livelihood. Therefore, decision support via a suitable crop model is necessary for survival of coastal agriculture and betterment of the coastal people. For this purpose, the AquaCrop model can be helpful. Many studies have been conducted worldwide to simulate yield of different crops including sunflower using the AquaCrop model (Heng, Hsiao, Evett, Howell & Steduto, 2009; Hsiao et al., 2009; Araya, Habtu, Hadgu, Kebede, & Dejene, 2010; Geerts et al., 2010; Andarzian et al., 2011; Hussein, Janat, & Yakoub, 2011; Salemi et al., 2011; Stricevic, Cosic, Djurovic, Pejic, & Maksimovic, 2011; Abedinpour et al., 2012; Masanganise, Chipindu, Mhizha, & Mashonjowa, 2012; Mkhabela & Bullock, 2012; Bhattacharya and Panda, 2013; Sam-Amoah, Darko & Owusu-Sekyere, 2013; Mondal et al., 2015; Saha & Mondal, 2015; Zaman et al., 2015) under different climatic scenarios and in a number of different agro-ecological settings. But no study has yet been carried out for simulation of sunflower yield, to test the performance of this model based on the adverse conditions of high soil and water salinity of the south-west coastal Bangladesh during the dry season. Also, the impact of climate change on sunflower cultivation needs to be evaluated as this knowledge is required for bringing the cultivation of this crop in a large scale basis for economic improvement of the coastal people. This study was conducted to assess the performance of AquaCrop in simulating sunflower yield under present climatic condition and to evaluate the impact of changed climate on the yield to assist in the decision making process of bringing sunflower cultivation practice into a larger scale.

2. METHODOLOGY

2.1 Study Area

For the assessment of the impact of climate change on sunflower yield using the AquaCrop model, a field experiment was conducted with Hysun 33, a local variety of sunflower during the dry season of 2014 in the polder 31 of Dacope upazila, Khulna district, in the south-western coastal region of Bangladesh. Dacope upazila is in the southern side of Khulna and faces the common natural disasters of coastal Bangladesh. It consists of three different polders namely polders 31, 32 and 33. Among the three polders, polder 31 has more potential of agricultural activities than the other two, as the salinity is less than the other two polders and the people of this area are now willing to practice dry season crop cultivation instead of keeping bare land. Sunflower cultivation has been started for the last two years since BRAC introduced it to the local farmers and provided seeds and fertilizers for cultivation. Due to less water and labor requirement, this practice is now very popular among the farmers who do not have the facilities to cultivate rice during the dry season and still want to have agricultural crop production. The area has also been suitable for other cash crop cultivation as well like sesame, watermelon, mustard, etc. The map of the study area is provided below (Figure 1):

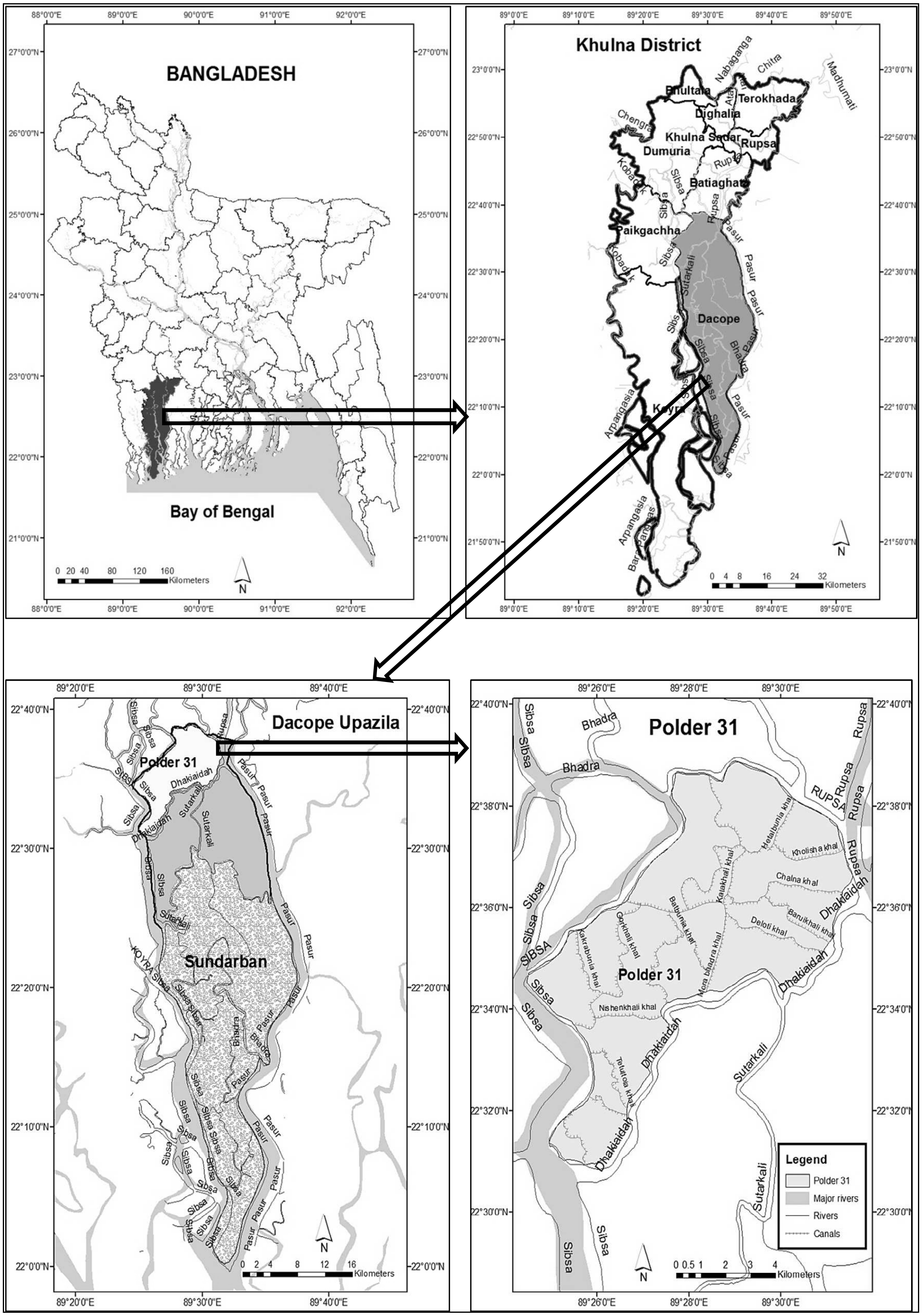

Figure 1: Map of the study area

2.2 Data Collection

The required climate data for both present and future climatic conditions included daily maximum and minimum air temperature, relative humidity, sunshine hour, wind speed, and rainfall. These data were used to calculate reference crop evapotranspiration (ET_0) for using in the AquaCrop model. Present climate data were collected from the Khulna station of Bangladesh Meteorological Department (BMD). For future climate data, outputs of PRECIS (Providing Regional Climates for Impact Studies) model from the Met Office, Hadley Centre, UK have been used. There are 17 different ensemble members of the IPCC-SRES scenario A1B, which is mostly suitable for the sub-tropical monsoon climate and socio-economic condition of Bangladesh, and they range from QUMP (Quantifying Uncertainty in Model Predictions)-00 to QUMP-16. Among all of them, the data for 2015-2050 (36 years) of three future climatic scenarios, QUMP-00 (wet condition), QUMP-08 (average condition) and QUMP-16 (dry condition) have been used in this study for future prediction of sunflower yield under local conditions. Also, for bias correction of future climatic data, observed climate data of previous 36 years from the Khulna station of BMD have been used.

For calibration and validation of the model, necessary primary data have been collected from two different plots by field measurements and monitoring during the different growth stages of sunflower from sowing to harvesting stage. The seeds were sown on 3 January, 2014 and harvested on 11 May, 2014 after 129 days. Collected field data included canopy cover at initial and maximum stages, maximum rooting depth, days to maximum canopy, senescence, maturity and harvesting, days to building up harvest index, duration of flowering, etc. All the data were collected from two different plots nearby each other, having the same sowing and harvesting date and soil type for calibration and validation of the model. Harvested yield and above ground biomass were also calculated from field information. Relevant conservative data for the model were obtained from the crop library of AquaCrop and it's Reference Manual (Raes, Steduto, Hsiao, & Fereres, 2012).

For determination of soil texture and salinity, soil samples were collected at different growth stages of sunflower and were tested in the laboratory of Soil Resource Development Institute (SRDI). The texture of the soil of both the plots was found to be silty clay loam. The initial soil salinity in the main test field was 7.70 dS/m. Irrigation water was applied from the nearly river to the crop field. The water sample was collected at a certain time interval and was tested in the field for determination of its salinity. At the initial stage, the salinity value was 2.40 dS/m and it varied up to 2.95 dS/m at the end of the growing period of sunflower. There were three irrigation events using surface irrigation method, in each of which 38 mm water was applied, just to wet the soil enough and not having any standing water on it. There was soil bund in the field to restrict surface runoff.

2.3 AquaCrop Model

AquaCrop is a canopy level and engineering type of model which simulates attainable yields of major herbaceous crops as a function of water consumption under rainfed, supplemental, deficit, and full irrigation conditions and is particularly suited to address conditions where water is a key limiting factor in crop production (Steduto et al., 2009; Steduto et al., 2011). It is a simple and robust model which has progressed from the Doorenbos and Kassam (1979) approach by separating the evapotranspiration (ET) into crop transpiration (T) and soil evaporation (E). It treats the final yield (Y) as a function of the final biomass and Harvest Index (HI) and segregates effects of water stress into four different components (Steduto et al., 2009). In addition to its core functions, AquaCrop has an extensive set of additional components namely, the climate, crop, soil and management.

In the climate component, the atmospheric environment of the crop is specified in AquaCrop with five weather input variables: maximum and minimum air temperatures, rainfall, evaporative demands of the atmosphere expressed as reference crop evapotranspiration (ET_0) and the mean annual carbon dioxide concentration (CO_2) in the atmosphere (Steduto et al., 2009). Except the CO_2 concentration, the first four parameters are manually incorporated in daily time step. Temperature data calculates growing degree day (GDD), ET_0 and rainfall determine water balance of the soil root zone and atmospheric CO_2 concentration is incorporated for its influence in canopy expansion and crop productivity. Also, it was found that, in future climatic condition, increase in atmospheric CO_2 concentration may have a positive impact on crop productivity and water use which is known as 'CO_2 fertilization effect' (Vanuytrecht and Raes, 2011)**.** Water productivity (WP) of the crop is proportional to the ambient CO_2 concentration (Steduto et al., 2011) and in AquaCrop, crop transpiration coefficient and crop water productivity responses to elevated CO_2 concentration, are simulated through a downward adjustment of crop transpiration coefficient and an upward adjustment of the water productivity to normalize CO_2 fertilization effect (Vanuytrecht and Raes, 2011). The procedure to adjust the effect of CO_2 was recently updated and this procedure treats C3 and C4 crops differently.

In the crop component of the model, the crop system has five major components and associated dynamic responses: phenology, foliage canopy, rooting depth, biomass production, and harvestable yield (Steduto et al., 2009). Green canopy cover and duration represent the source for transpiration, and the amount of water transpired translates into a proportional amount of biomass produced through WP. Canopy expansion is calculated from initial and maximum canopy covers (CC_0 and CC_x respectively) where two conservative parameters, canopy growth coefficient (CGC) and canopy decline coefficient (CDC) are used. For this study, initial and maximum canopy covers were calculated from photographs taken in the field at a vertical height of 1 meter at initial and maximum canopy stages of the crop. Then, each photograph was divided into a number of grids and from each grid in the whole photograph; the canopy coverage was translated into percentage of canopy cover. Soil water stresses on canopy expansion, stomatal closure and early canopy senescence are described by water stress coefficient K_s and convex shaped water-stress response curves (K_s curves) (Raes et al., 2012). In the model, Harvest Index (HI) is adjusted for water stress for different crop growth stage. Also, the crop response to salinity stress is obtained by calibrating the model for stressed condition incorporating the stressed maximum canopy and relative biomass production with the upper and lower limits (EC_{eLower} and EC_{eUpper}) of salinity stress tolerance.

The soil component of AquaCrop includes all the classical soil texture classes by default, but the user can also input own specific value (Raes et al., 2012). The level of groundwater in the location, date of observation and salinity of the water are incorporated in the groundwater file under soil component which determines the capillary rise of the crop. The management component of AquaCrop has two main categories: field management and water management. The field management component covers the information of soil mulching, presence and height of soil bunds and surface runoff occurrence. Water management options cover irrigation method, irrigation scheduling and the depth and salinity of irrigation water (Steduto et al., 2009). Initial soil and water quality data are also required in the model in the simulation portion, which determine the initial field condition. The user can define the simulation timing according to the crop growth season, and simulation run of the model generates the crop yield and biomass production along with other time wise representation of parameters.

2.4 Model Calibration and Validation

After incorporation of the necessary information in all the components, the model has been calibrated for one experimental crop field. Then the calibrated model was validated with the data of another experimental field. Keeping all other information of the components same as the calibration field, only the data of irrigation file (irrigation schedules, amount of water for each irrigation event and irrigation water quality) and initial soil salinity have been changed for model validation. The validation of the model was performed to determine if the model has been correctly calibrated and also to test the performance and accuracy of the model in simulating sunflower yield of different experimental fields properly.

2.5 Assessment of the Impact of Climate Change

Once the model is calibrated and validated, the parameterized model was used to predict sunflower yield under changed future climate. Keeping the data of all the other components same as the calibration, the simulation is performed for changed climate data. For each future year, ET_0 has been calculated for the cropping season from the climate parameters. In the climate component, future maximum and minimum temperature with future ET_0 have been incorporated while CO_2 concentration was automatically adjusted for each future year. From each simulation, yield of sunflower has been calculated and this process has been repeated for 36 future years and also for climate data of three different ensemble members (QUMP-00, 08 and 16). For model prediction of future yield, bias-corrected climate data have been incorporated.

2.5.1 Bias correction of future climate data

For bias correction of the future climate data, there are several methods, among which the 'Delta' approach has been used. This is a very common method, often referred to as 'Delta Change' method (Arnell, 1998; Lettenmaier, Wood, Palmer, Wood and Stakhiv, 1999; Graham, 2004, Paul, 2014). In this method, Regional Climate Model (RCM) simulated future climate data are super imposed upon observational time series (Teutschbein and Seibert, 2013). This approach is based upon transferring of mean monthly change signal using monthly change factors between control and scenario period to an observed baseline time series (Eisner, Voss, and Kynast, 2012). The meteorological variables are typically averaged over a historic period from a control simulation and a future period from a scenario simulation to estimate the changes. The advantage of the delta method is that observed patterns of temporal and spatial variability are preserved, and comparison between future scenarios and observations is straightforward and easily interpreted. Using this method, a historical 30 year time series, from 1976-2005, of meteorological parameters (maximum and minimum temperature, relative humidity, wind speed, sunshine hour and rainfall) are perturbed to estimate the data of 30 years future period

(2015-2044). For precipitation, relative change variables have been applied, whereas for other parameters, absolute change has been applied (Rasmussen et al., 2012).

The formulae as Eisner et al. (2012) used for bias correction of climate parameters are provided here:

$$\overset{scen}{\underset{d,m}{T}} = \overset{obs}{\underset{d,m}{T}} + \left(\overline{\overset{GCMscen}{\underset{m}{T}}} - \overline{\overset{GCMcon}{\underset{m}{T}}} \right) \tag{1}$$

The formula stated above (1) is the formula for correction of temperature data. The scenario daily temperature ($\overset{scen}{\underset{d,m}{T}}$) was derived from adding the absolute monthly change signals to the observed time series. The notations *d* and *m* means daily data. Here,

$\overline{\overset{GCMscen}{\underset{m}{T}}}$ = Mean monthly temperature obtained from PRECIS model simulation for each ensemble member for a 30 year future time period (2015-2044)

$\overline{\overset{GCMcon}{\underset{m}{T}}}$ = Mean monthly temperature obtained from PRECIS model simulation for each ensemble member for a 30 year observed time period (1976-2005)

$\overset{obs}{\underset{d,m}{T}}$ = Observed daily temperature obtained from BMD data of the local station for a 30 year observed time period (1976-2005)

$\overset{scen}{\underset{d,m}{T}}$ = Bias corrected daily temperature for a 30 year future time period (2015-2044)

The difference between model results of an observed and future time series data represents the change in future climate in relation to the present climate, generated from model. Then, by adding the changes with the observed climate data, bias corrected future climate data is obtained. The same formula has been used for bias correction of the maximum and minimum temperature parameters, relative humidity, wind speed and sunshine hour. The formula used for bias correction of rainfall data is provided below:

$$\overset{scen}{\underset{d,m}{P}} = \overset{obs}{\underset{d,m}{P}} * \left(\overline{\overset{GCMscen}{\underset{m}{P}}} / \overline{\overset{GCMcon}{\underset{m}{P}}} \right) \tag{2}$$

In the formula stated above (2), the scenario daily precipitation ($\overset{scen}{\underset{d,m}{P}}$) was derived from multiplying the absolute monthly change signals to the observed time series. Here,

$\overline{\overset{GCMscen}{\underset{m}{P}}}$ = Mean monthly precipitation obtained from PRECIS model simulation for each ensemble member for a 30 year future time period (2015-2044)

$\overline{\overset{GCMcon}{\underset{m}{P}}}$ = Mean monthly precipitation obtained from PRECIS model simulation for each ensemble member for a 30 year observed time period (1976-2005)

$\overset{obs}{\underset{d,m}{P}}$ = Observed daily precipitation obtained from BMD data of the local station for a 30 year observed time period (1976-2005)

$\overset{scen}{\underset{d,m}{P}}$ = Bias corrected daily precipitation for a 30 year future time period (2015-2044)

The difference between model results of an observed and future time series data is calculated by dividing future model data with observed model data. Then, by multiplying the changes with the observed precipitation, bias corrected future temperature is obtained. As the model prediction duration is up to 2050, so the correction of 2045-2050 has been performed using the monthly change signals of the above stated 30 years period on observed data of 2006-2011.

3. RESULTS AND DISCUSSIONS

For the growing period of Hysun 33, reference crop evapotranspiration (ET_0) values were calculated by Penman-Monteith equation using the ET_0 calculator (Allen, Pereira, Raes, and Smith, 1998). The values of ET_0 varied between 1.1 mm/day to 6.7 mm/day. Also there were rainfall events in five different days during the crop growth period. The ET_0 and rainfall are shown in Figure 2 along with the dates from sowing to harvesting.

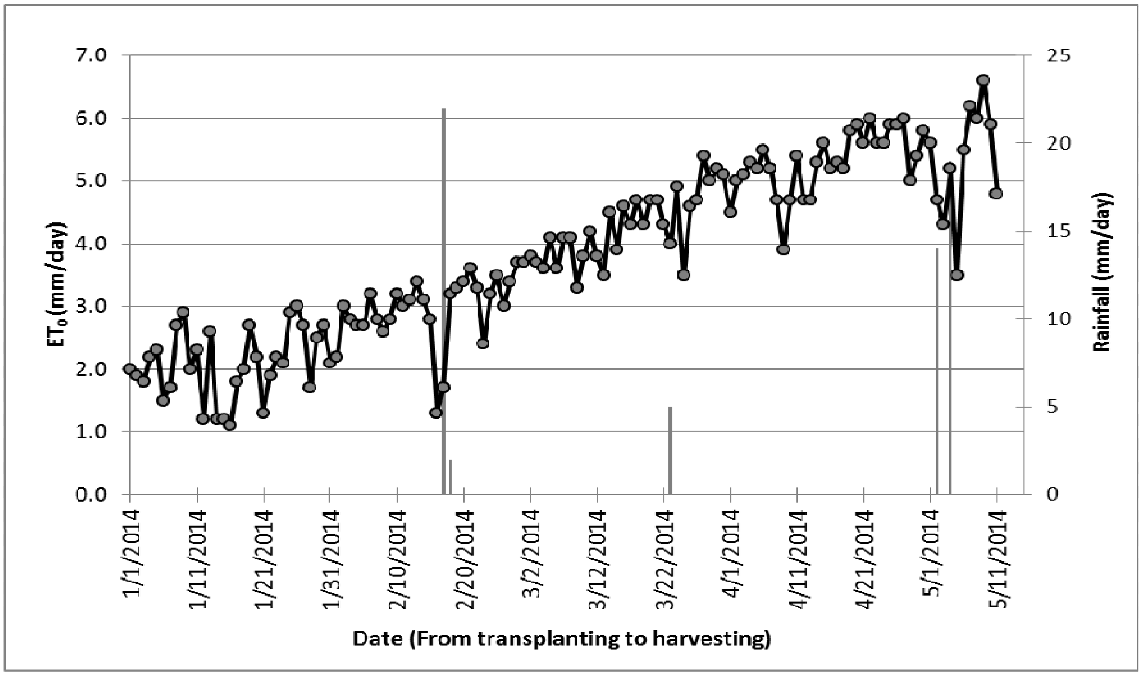

Figure 2: Daily ET_0 and rainfall values of the crop season from sowing to harvesting phase

The present yield of sunflower was simulated using the model with all the collected values from the field observations and relevant testing procedures. Other values of some conservative parameters were obtained from the crop library of AquaCrop and the Reference Manual (Raes et al., 2012). The values of input parameters along with the phenological characteristics are provided in Table 1:

Table 1: Input values of parameters used in the AquaCrop model

Parameters	Unit	Value
Initial canopy cover, CC_0	%	0.39
Maximum canopy cover, CC_x (optimum condition)	%	99
Canopy growth coefficient (CGC)	%	24.4
Canopy decline days	days	21
Canopy decline coefficient (CDC)	%	14.4
Days to emerge (DAS)	days	8
Days to maximum canopy (DAS)	days	40
Days to senescence (DAS)	days	115
Days to maturity (DAS)	days	129
Days to flowering (DAS)	days	60

Table 1: Input values of parameters used in the AquaCrop model (Continued)

Parameters	**Unit**	**Value**
Duration of flowering	days	9
Length building up HI	days	18
Determinacy linked with flowering		yes
Maximum effective rooting depth	m	0.33
Time to reach maximum rooting depth (DAS)	days	50
Minimum effective rooting depth	m	0.3
Shape factor describing root zone expansion		1.3
Base temperature	°C	4
Upper temperature	°C	30
Crop coefficient for transpiration		1.1
Decline of crop coefficient with age	%/day	0.3
Effect of canopy cover on reducing evaporation in late season stage	%	60
Water productivity, WP	gm/m^2	18
Reference harvest index, HI_0	%	35
Threshold for canopy expansion ($p_{exp,\ upper}$)		0.15
Threshold for canopy expansion ($p_{exp,\ lower}$)		0.65
Shape factor for water stress coefficient for canopy expansion		2.5
Threshold for stomatal control (p_{sto})		0.6
Shape factor for water stress coefficient for stomatal control		2.5
Threshold for canopy senescence (p_{sen})		0.7
Shape factor for water stress coefficient for canopy senescence		2.5
Soil water depletion threshold for failure of pollination (p_{pol})		0.85
Possible increase in HI due to water stress before flowering	%	4
Excess of potential fruits (%)		200
Maximum possible increase of HI	%	10
Cold stress temperature for pollination	°C	10
Heat stress temperature for pollination	°C	40

For calibration of the present yield in 2014, initial and maximum canopy covers were calculated as 0.39% and 65% from grid analysis of the photographs mentioned earlier.The canopy growth coefficient (CGC) value was 1.5% in GDD and canopy decline coefficient (CDC) value was 0.6% in GDD, both of which are in the range of the suggested values in the crop library. In a crop growth season of 129 days, 18 days were required for sunflower to build up the harvest index and the reference harvest index value found from the crop library was 35%. The values of minimum and maximum thresholds of salinity were 2 dS/m and 12 dS/m respectively. The shape of salinity stress coefficient curve was found to be convex in shape with a shape factor of 3. After calibration of the model, it was validated with the data of another test field. The observed yield and biomass of the clibration and validation field are provided in the following table (Table 2):

Table 2: Crop yield and biomass of calibration and validation fields

	Calibration field		**Validation field**	
	Crop yield (ton/ha)	Crop biomass (ton/ha)	Crop yield (ton/ha)	Crop biomass (ton/ha)
Observed	1.20	5.00	1.10	4.50
Simulated	1.25	3.58	1.14	3.25

The above results of calibration and validation of the model indicate that AquaCrop model has the ability to simulate sunflower yield with acceptable accuracy in saline condition of the coastal areas of Bangladesh. Also, the calibrated model performs well during validation in a different experimental field. So, if calibrated and validated properly, this model can simulate sunflower yield in variable soil, climatic and hydrologic conditions and also, in response to the changed atmospheric CO_2 concentration through adjustment of crop transpiration coefficient and water productivity.

Next, the parameterized model has been used for prediction of sunflower yield under future climate using the bias-corrected data of three ensemble members of IPCC-SRES scenario A1B. For each of the 36 future years, starting from 2015 to 2050, the yield of sunflower has been simulated for the crop growth period. In this process, the future sunflower yield for each of the three ensemble members, QUMP-00, 08 and 16 have been calculated and presented in three graphical representations and trend lines have also been fitted. They are provided below in Figure 3, Figure 4 and Figure 5:

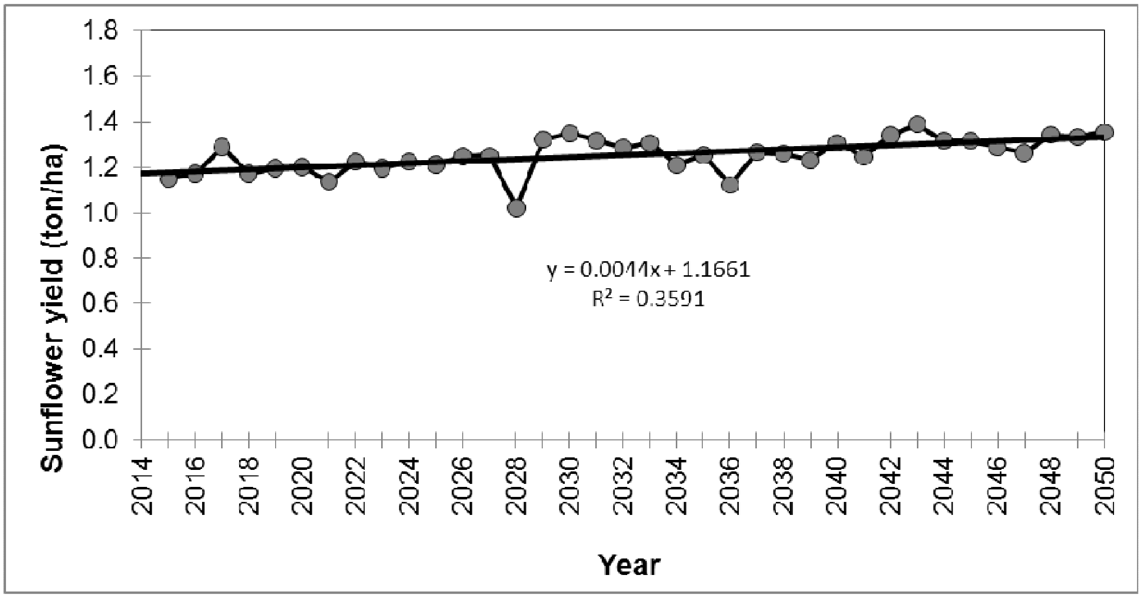

Figure 3: Future sunflower yield from 2015-2050 for QUMP-00

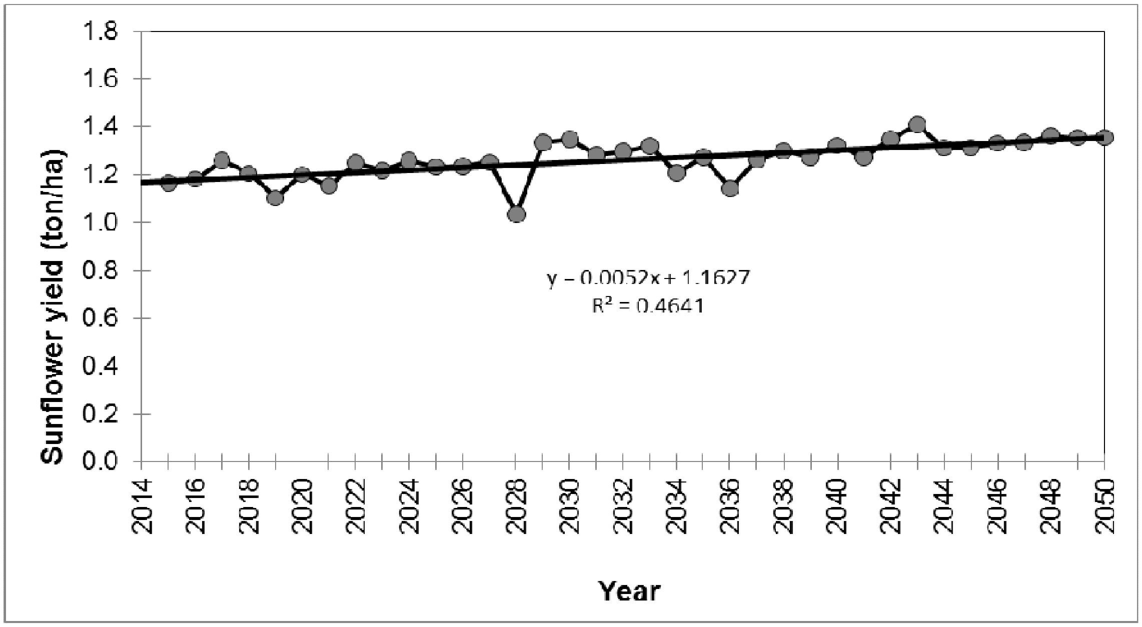

Figure 4: Future sunflower yield from 2015-2050 for QUMP-08

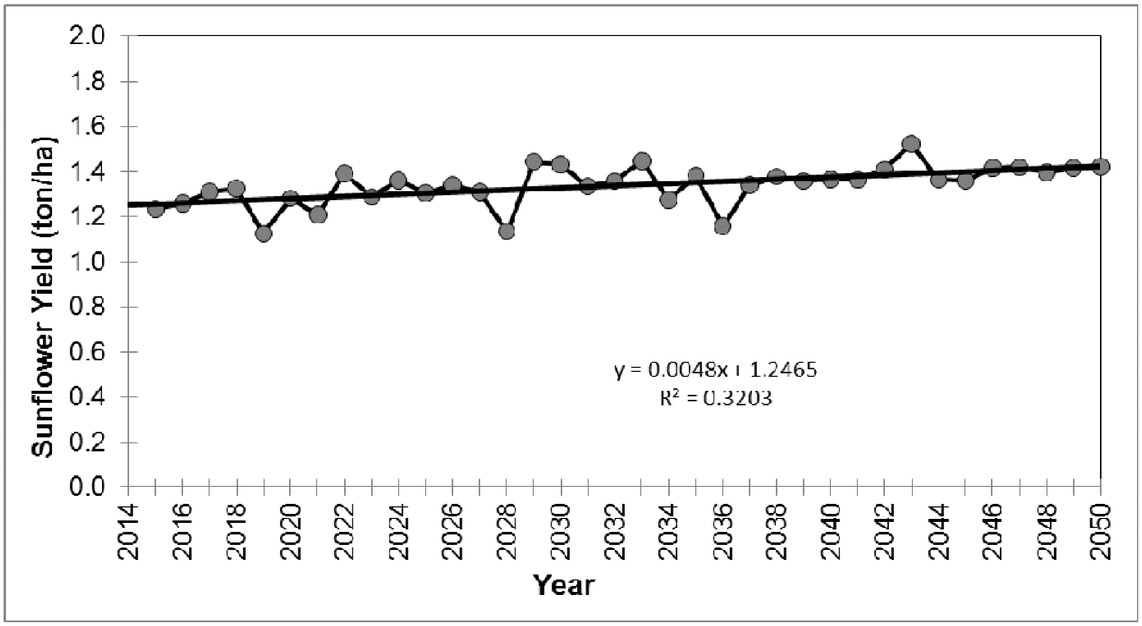

Figure 5: Future sunflower yield from 2015-2050 for QUMP-16

Future sunflower yield from 2015 to 2050 indicated increasing trend for each of the three future climate scenarios. It was observed that, in future, sunflower yield may increase up to 1.5 ton/ha if the present soil and water condition is maintained. If the maximum temperature during the flowering duration of sunflower, which is the most sensitive stage, remains within the acceptable limit of crop production in future, which is up to 40°C for this crop, then the crop yield can be well maintained and may increase. This increased yield may occur due to increased CO_2 concentration with time. Also, the still remaining salinity of soil and water in the study area is decreasing day by day and in future this will also provide suitable condition for sunflower cultivation. This knowledge of increased yield may encourage the local farmers to invest on this cash crop which is expected to increase income and provide better standard of living in future.

4. CONCLUSION

The increasing salinity of the coastal areas of Bangladesh has restricted the availability of fresh water for irrigation and people are now shifting to cultivation of cash crops like sunflower having suitability on both consumption and business basis. Though the impact of climate change on agriculture has mostly been found to be negative from many studies, its impact on sunflower appears to be positive indicating good future potential of this emerging crop in the study area. So, more crop specific studies are needed to be performed rather than having generalized opinion on the impact of climate change on different crops. Also, the knowledge of increased yield may encourage the local farmers to invest on sunflower cultivation which is expected to improve their economic condition in future. This study evaluated the performance of calibrated and validated AquaCrop model to assess the impact of climate change on sunflower yield in saline coastal areas of Bangladesh and it was found that, the model performs reasonably well in prediction of future crop yield and it can be utilized for prediction of different crop yields under variable soil and hydrologic conditions in coastal Bangladesh.

ACKNOWLEDGEMENTS

This research paper was prepared based on the Master's thesis of the first author under the 'IDRC-SAWA Fellowship Project' funded by IDRC, Canada.

REFERENCES

Abedinpour, M., Sarangi, A., Rajput, T. B. S., Singh, M., Pathak, H. and Ahmad, T. (2012). Performance evaluation of AquaCrop model for maize crop in a semi-arid environment. *Agricultural Water Management*, 110, 55-66.

Allen, R. G., Pereira, L. S., Raes, D. and Smith, M. (1998). Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper 56, Rome, Italy.

Andarzian, B., Bannayan, M., Steduto, P., Mazraeh, H., Barati, M. E. and Rahman, A. (2011). Validation and testing of the AquaCrop model under full and deficit irrigated wheat production in Iran. *Agricultural Water Management*, 100, 1-8.

Araya, A., Habtu, S., Hadgu, K. M., Kebede, A. and Dejene, T. (2010). Test of AquaCrop model in simulating biomass and yield of water deficient and irrigated Barley (Hordeum vulgare). *Agricultural Water Management*, 97, 1838–1846.

Arnell, N. W. (1998). Climate change and water resources in Britain. *Climatic Change,* 39**,** 83-110.

Bhattacharya, T. and Panda, R. K. (2013). Effect of climate change on rice yield at Kharagpur, West Bengal. *IOSR Journal of Agricultural and Veterinary Science,* 4(2), 6-12.

Doorenbos, J. and Kassam, A. H. (1979). Yield response to water. FAO Irrigation and Drainage Paper 33, Rome, Italy.

Eisner, S. Voss, F. and Kynast, E. (2012). Statistical Bias Correction of Global Climate Projections - Consequences for Large Scale Modelling of Flood Flows. *Advances in Geosciences,* 31, 75-82.

Geerts, S., Raes, D., Garcia, M., Miranda, R., Cusicanqui, J. A., Taboada, C., Mendoza, J., Huanca, R., Mamani, A., Condori, O., Mamani, J., Morales, B., Osco, V. and Steduto, P. (2009). Simulating Yield Response of Quinoa to Water Availability with AquaCrop. *Agronomy Journal*, 101, 499-508.

Graham, L. P. (2004). Climate change effects on river flow to the Baltic Sea. *AMBIO: A Journal of the Human Environment*, 33(4), 235-241.

Heng, L. K., Hsiao, T., Evett, S., Howell, T. and Steduto, P. (2009). Validating the FAO AquaCrop model for irrigated and water deficient maize. *Agronomy Journal,* 101(3), 488-498.

Hsiao, T. C., Heng, L. K., Steduto, P., Rojas-Lara, B., Raes, D. and Fereres, E. (2009). AquaCrop - The FAO crop model to simulate yield response to water: III. Parameterization and testing for maize. *Agronomy Journal,* 101, 448-459.

Hussein, F., Janat, M. and Yakoub. A. (2011). Simulating cotton yield response to deficit irrigation with the FAO AquaCrop model. *Spanish Journal of Agricultural Research, 9*(4), 1319-1330.

Khan, M. H. and Awal, M. A. (2009). Global Warming and Sea Level Rising: Impact on Bangladesh Agriculture and Food Security. *Available at Web site http://www. nfpcsp. org/agridrupal/sites/default/files/Final_Technical_Report_CF_10_Approved. pdf* (accessed February 10, 2014).

Lettenmaier, D. P., Wood, A.W., Palmer, R. N., Wood, E. F. and Stakhiv, E. Z. (1999). Water resources implications of global warming: A U.S. regional perspective. *Climatic Change,* 43**,** 537-579.

Masanganise, J., Chipindu, B., Mhizha, T. and Mashonjowa, E. (2012). Model prediction of maize yield response to climate change in north-eastern Zimbabwe. *African Crop Science Journal,* 20(2), 505-515.

Mkhabela, M. S. and Bullock, P. R. (2012). Performance of the FAO AquaCrop model for wheat grain yield and soil moisture simulation in western Canada. *Agricultural Water Management*, 110, 16-24.

Mondal, M. S., Saleh, A. F. M., Akanda, M. A. R., Biswas, S. K., Moslehuddin, A. Z. M., Zaman, S., Lazar, A. N. and Clarke, D. (2015). Simulating yield response of rice to salinity stress using the AquaCrop Model. *Environmental Science: Processes & Impacts,* 17(6), 1118-1126.

Paul, S. (2014). Assessment of change in future flow of Brahmaputra basin applying SWAT model using multi-member ensemble climate data. M.Sc. (WRD) Thesis, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology.

Raes, D., Steduto, P., Hsiao, T. C. and Fereres, E. (2012). Reference Manual, AquaCrop Version 4.0. FAO, Land and Water Division, Rome.

Rasmussen, J., Sonnenborg, T. O., Stisen, S., Seaby, L. P., Christensen, B. S. B. and Hinsby, K. (2012). Climate change effects on irrigation demands and minimum stream discharge: impact of bias-correction method. *Hydrology and Earth System Sciences,* 16, 4675-4691.

Saha, D. and Mondal, M. S., (2015). Simulation of rice yield in south-west coastal Bangladesh using the AquaCrop model. Proceedings of 5th International Conference on Water and Flood Management, Bangladesh, 81-88.

Salemi, H., Soom, M. A. M., Lee, T. S., Mousavi, S. F., Ganji, A. and Yusoff, M. K. (2011). Application of AquaCrop model in deficit irrigation management of winter wheat in arid region. *African Journal of Agricultural Research*, 610, 2204-2215.

Sam-Amoah, L. K., Darko, R. O. and Owusu-Sekyere, J. D. (2013). Calibration and Validation of AquaCrop for Full and Deficit Irrigation of Hot Pepper. *ARPN Journal of Agricultural and Biological Science,* 8(2), 175-178.

Steduto, P., Hsiao, T. C., Raes, D. and Fereres, E. (2009). AquaCrop - the FAO crop model to simulate yield response to water: I. Concepts and underlying principles. *Agronomy Journal,* 101(3), 426-437.

Steduto, P., Hsiao, T. C., Raes, D., Fereres, E., Izzi, G., Heng, L. and Hoogeveen, J. (2011). Performance review of AquaCrop - the FAO crop-water productivity model. ICID 21st International Congress on Irrigation and Drainage, Iran, 231-248.

Stricevic, R., Cosic, M., Djurovic, N., Pejic, B. and Maksimovic, L. (2011). Assessment of the FAO AquaCrop model in the simulation of rainfed and supplementally irrigated maize, sugar beet and sunflower. *Agricultural Water Management*, 98, 1615-1621.

Teutschbein, C and Seibert, J. (2013). Is bias correction of regional climate model (RCM) simulations possible for non-stationary conditions? *Hydrology and Earth System Sciences,* 17, 5061-5077.

Vanuytrecht, E. and Raes, D. (2011). Assessment of the 'CO_2 Fertilization Effect' on Crops with the AquaCrop Model. Geophysical Research Abstracts, 13, EGU General Assembly.

Zaman, S., Mondal, M. S., Saleh, A. F. M., Akanda, A. R., Biswas, S. K., Habib, M. A., Moslehuddin, A. Z. M. and Abedin, M. A. (2015). Assessing the Potential Impacts of Climate Changeon Musterd Yield Using FAO AquaCrop Model. Proceedings of the International Conference on Climate Change Impact and Adaptation, DUET, Gazipur, Bangladesh, 111-118.