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Modeling the Impacts of Climate Change on Chickpea Production in Adaa Woreda (East Showa Zone) In the Semi-Arid Central Rift Valley of Ethiopia

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Abstract

Since agriculture is highly dependent on Mother Nature such as soil, water and climatic conditions, the extreme weather events and climatic conditions have major impacts on agriculture. Likewise, climate change has become one of important up growing issues and the biggest concern of mankind as a consequence of scientific evidence about the increasing concentration of greenhouse gases (GHG) in the atmosphere. Therefore, simulating future climate on chickpea production is very essential for the study area. The Future climate was simulated based on one Global Climate Model (HadGEM2-ES) with three time period and two representative concentration pathways (RCP s). Moreover, DSSAT V4.6 model was calibrated, evaluated and used for simulating yield of chickpea under baseline and future climate. To do that the model was calibrated and evaluated using experimental phonological and yield data obtained from Debrezeit Agricultural Research Center (DARC). The result show that the projected rainfall showed a decreasing trend over the 2020s by -1.5% and 2050s by -4.5% under RCP 4.5 whereas it showed an increasing trend over the 2080s by 12.1% when simulated under RCP 8.5. While the maximum and minimum temperature in Adaa woreda projected to rise under RCP 4.5 and RCP 8.5 scenarios in different rate. The temperature trend generally showed greater warming in the coming 2010 to 2099 in both emission scenarios. The days to flowering, maturity and yield of Arerti variety simulated by the model was calibrated and evaluated by Root Mean Square Error (RMSE), Index of agreement (IA) and coefficient of determination (R^2). Therefore, RMSE, IA and R^2 were revealed a very nice agreement with observed data's set. These indicates good relationships of the observed with simulated values of the model. Similar to the model calibration, the performance of the model evaluation indicates a very good agreement with the observed data. Then, it was convincing enough to undertake climate change impact analysis using this model (DSSAT - CROPGRO). The result showed that planting time could be used as climate change adaptation strategy in the study area. Accordingly early planting (on July 20) was found to have significant increase of chickpea yield when compared to normal (August 20) and late (September 10) planting in the study area. To adapt to the changing climate, early planting, moisture conservation during less availability of water and drainage during water logging and climate adviser service would be better option.

Keywords: DSSAT model; Climate characterization; Climate change prediction; Adaptation

Introduction

Agriculture is highly dependent on Mother Nature such as soil, water and including climatic conditions. However, extreme weather events and climatic conditions have major impacts on agriculture. Whereas climate change has become one of important up growing issues and the biggest concern of mankind as a consequence of scientific evidence about the increasing concentration of greenhouse gases in the atmosphere. Now a day, temperature is increasing and the amount and distribution of rainfall is being altered from one region to another in the worldwide [1]. Of the total annual crop losses in the world agriculture, the major cause is direct weather and climatic effects such as drought, flood and inconvenient rain [2].

The impacts of climate change on the agricultural crop production as predicted a 10% decrease in maize production in 2055 in Africa and Latin America using climate scenarios generated using a GCM and the CERES Maize crop model predicted a 13% decrease in simulated maize yield at two locations in Italy using climate scenarios generated from two GCMs for an equivalent doubling of atmospheric CO_2 [3,4]. Whereas the impacts of climate change on agriculture crop production in Ethiopia, for instant climate change reduced yield of wheat staple by 33% [5]. Many works have been done on the side of releasing new improved chick pea varieties and supplying improved seed to the farmers. However, Climate impact assessment on chickpea production not yet in Ethiopia.

The concerns of climate impact on agriculture in developing countries have been increasing [6]. Among which chickpea productivity is of paramount importance. In Ethiopia, chickpea productivity is very low, despite its social (diet), economic and ecological benefits and co-benefits. The national average yield of chickpea in Ethiopia under farmers condition is less than 1.5 ton/ha [7]. While its potential productivity under improved management and suitable climate condition is more than 3 ton/ha in Ethiopia [8]. However, research on impact of climate change on chickpea production under rainfed in Ethiopia is very rare. Recently, the application of crop modeling technique for assessing impacts of climate change on crops has received major attention, which provided a solution in terms of reducing cost and improving knowledge. Therefore, this study was initiated to examine the impacts of future climate change on chickpea production in Adaa woreda, in the Central Rift Valley of Ethiopia. Therefore, the main objective of this study was to assess the impact of climate change

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on chickpea production in the Adaa Woreda, in the Central Rift Valley of Ethiopia.

Material and Methods

Description of the study area

The study was conducted in Adaa woreda around Debrezeit Agricultural Research Centre (DZARC). It is located 50 km south from Addis Ababa, capital city of Ethiopia, in Oromia National Regional State, East shewa zone. Its geographical location is from 8°20΄0˝ to 9°0΄0˝ N latitude and 38°45΄0˝ to 39°18΄0˝ E longitudes (Figure 1).

Rainfall and temperature: ADAA woreda has unimodal rainfall characteristics (small rains in March and April with main rain season between June and September). The mean annual total rainfall is about 830.4 mm while the length of growing period (LGP) ranges from 99 to 215 days. The annual mean daily minimum and maximum temperature of the district are approximately 13.02°C and 24.6°C respectively [9].

Topography and land use: The study site is agro-ecologically sub divided in to weinadega (36%) and dega (64%). The altitude ranges from 1580 to 3009 meters a.s.l, and the slope is classified in to six classes [4,10] (Figure 2). The soil type is dominated by black clay (Vertisols) and Nitosols with good water holding capacity [10]. As far as land use and land cover is concerned, from the total area of 89,544 hectare about 62219 hectares of land is used for growing annual crop (69.5%). Of

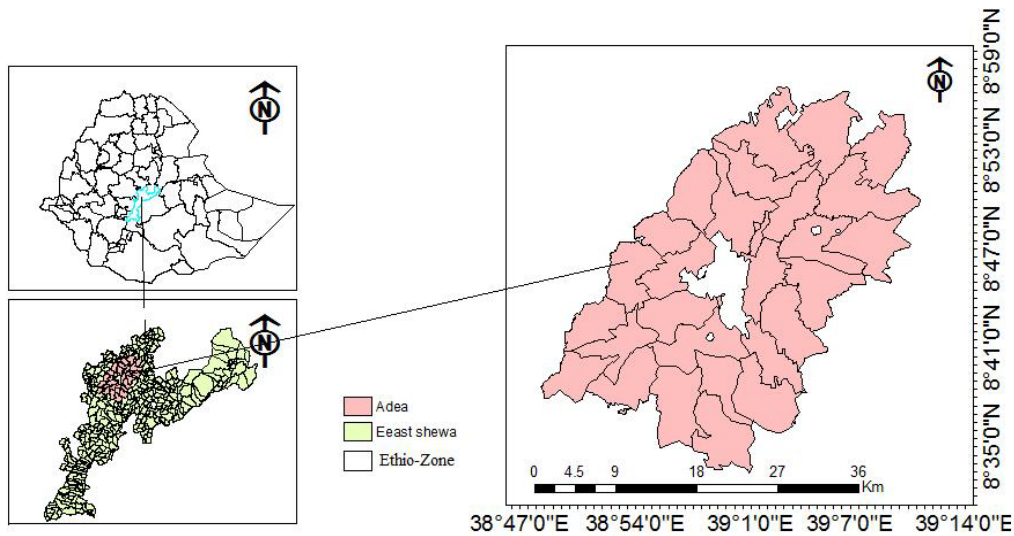


Figure 1: Map of the study area.

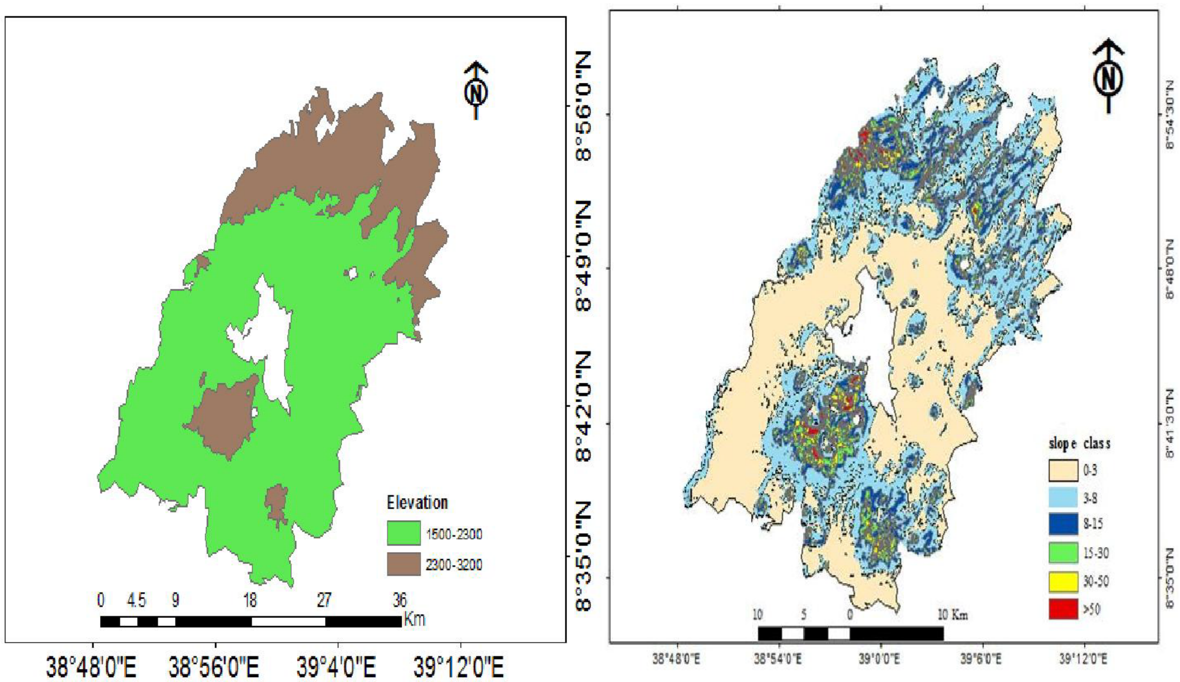


Figure 2: Elevation and slope map of the study area.

the total cultivable area 338 hectare (0.4%) is irrigated land, 2603 hectare (2.9%) is grazing land, 6011 hectare (6.7%) is forest land [11] (Figure 3).

Calibration of chickpea for DSSAT model: Calibration which is the critical process of improving the agreement of a code calculation with respect to a chosen set of benchmarks through the adjustment of parameters was implemented in this study. To do this, data of climate were collected from the National Meteorological Agency (NMA) of Ethiopia, whereas, soil variable such as texture (clay %, Silt %, sand %), organic carbon, soil PH, total N%, permanent wilting point (lower limit LL), field capacity (Drained upper limit DUL), bulk density (g/cm^3) were adopted from the study area which were already analyzed [12]. As the same time, the cultivar specific parameters; emergence, flowering, maturity dates and grain yield data were collected from Debrezeit Agricultural Research Center and used for DSSAT mode calibration and evaluation. The model was calibrated using eight years research data of 1993, 1997, 2001, 2004, 2005,2006, 2007 and 2010 collected from Debrezeit Agricultural Research Center. It is essential for getting genetic coefficients for new cultivars used in the model study, but the collected data were not sufficient for genetic coefficient manipulation. So to do the manipulation KAK-2 variety genetic coefficient that is found in DSSAT V4.6 model was found to be a good match with that of chickpea Arerti variety. DSSAT-CROPGRO model were used for calibrations and evaluation of DSSAT model.

Evaluation of DSSAT model for chickpea: The study was conducted using the crop growth simulation model available in the Decision Support Systems for Agro-Technology Transfer (DSSAT V4.6), DSSAT-CROPGRO. The DSSAT model evaluation carried out using by 5year data Therefore, evaluation of DSSAT V4.6 model was the determination of the degree to which a model is an accurate representation of the real world of the study area from the perspective of the intended uses of the model, was conducted [13]. Model data inputs such as past climate and cultivar specific parameters with soil variable were used. After calibration of the model, its performance was evaluated by the reproducing ability of the chickpea production that was not used in the calibration process. Then, the model was evaluated by comparing the observed days to flowering, maturity and yield (for the observation years in 1994, 1995, 1996, 2000 and 2002) against to the respective simulated yield.

The model performance evaluation was carried out using statistical techniques such as Root Mean Square Error (RMSE), coefficient of determination (R^2) and Index of agreement (IA) as presented in Eq. 1 and 2. The RMSE and IA approach is computed according to the following equations which increase model accuracy.

$$RMSE = \left[\frac{\sqrt{\sum (\text{simulation - observation})^2}}{\text{n}} \right] \text{ ----------------- (Eq 1)}$$

N is number of observation RMSE=Root Mean Square Error

Degree of fitness or indicates a perfect competition

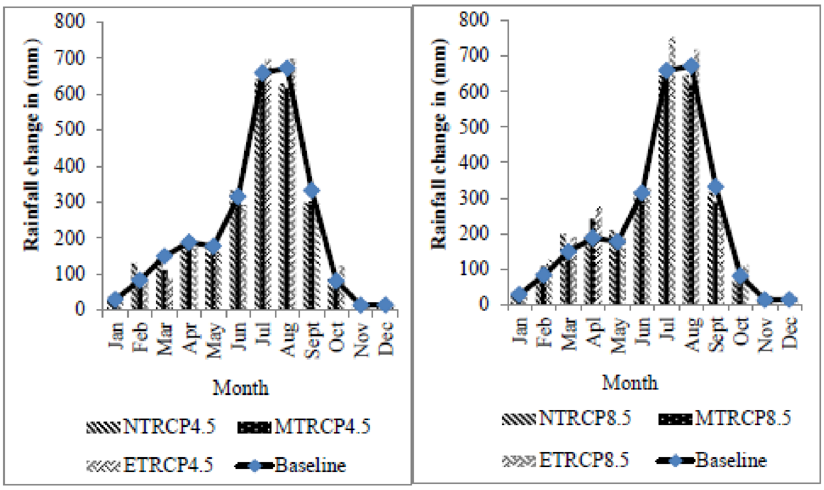
$$IA = 1 - \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} \left(|P_i - P_m| + |O_i - O_m| \right)^2} \text{ ---------------------------- (Eq 2)}$$

The index of agreement (IA) was calculated as (0≤ IA ≤1), When IA= 1 indicates excellent agreement between the predicted and observed data. Where, O_i and Pi are observed and are predicted values, P_m and O_m are the mean values of P_i and O_i, respectively [1].

Index of agreement was a common tool to test the goodness of fit of simulation models. Whereas the RMSE (Equation 1) between the simulated and observed values for a data set with "n" measured points. Therefore, computed values of RMSE and IA-value determine the degr,ee of agreement between the predicted and observed yield.

Analysis of impacts of climate change: AgMIP SSA (Sub- Saharen Africa) mid-term workshop on integrated regional assessment have used the same 5 GCMs for consistency among regions and therefore require to be used in all locations in Sub-Saharan Africa. GCMs such as (CCSM4 (E), GFDL-ESM2M (I), HadGEM2- ES (K), MIROC5 (O), MPI-ESM-MR(R) were selected to be used in all farms widely due to their recentness, consistency of processes and resolution-performance [14,15]. In addition AgMIP team of Mekelle University compared HAdGEM2-ES to other 20 GCM's and hence, was able to consistently predict rainfall at an average of the study area.

Therefore, HadGEM2-ES climate model was chosen for predicting future rainfall and temperature of Adaa woreda, while DSSAT V4.6 was used to analyze the possible impact of the future climate change on chickpea production. The climate input was obtained from CMIP5



(Note: - NT stands for near term, MT stand for midterm and ET stand for end term).

Figure 3: Mean monthly rainfall from HadGEM2-ES model (RCP 4.5 and RCP 8.5) concentration pathway.

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for the three time periods and two RCP s based on one GCM that is "HadGEM2-ES". Therefore, the climate change scenarios of rainfall and temperature were projected for the near-term (2010-2039), mid-term (2040-2069), end-term (2070-2099). Then the projected climate datasets were used in DSSATv.4.6 to simulate chickpea crop yield. Then the yield within each scenario probability of exceedance chart that displays set of data was compared against its cumulative probability. As a result, based on the output of the model, the plots for probability of exceedance to get exceeding a given quantity of yield in Kg/ha in 2010s-2099s under RCP 4.5 and RCP 8.5 scenarios was presented. Besides, the percentage change was calculated and descriptive statistics was used to show how the yield changes were different from each other.

Change in yield (Δyield) = Simulated/observed × 100 -------- (Eq.3)

Depending on the impact study's, analyzing for adaption option by keeping the climate scenario and making other factors constant, the model (DSSAT) was let to run only by varying the plantation date. Hence, selecting the planting date that provides reasonably better yield, which has positive impact on chickpea production as best adaptation options is necessary by keeping the negative impacts of climate change.

Results and Discussion

Projected rainfall and temperature for ADAA

Woreda: There are more than 24 GCMs in the world from different centers among those GCM HadGEM2-ES model features and their experimental out puts is important to study the future impact of climate change for the study area. As compared to the baseline situation, the percentage difference in projected rainfall for the study area in the three time horizons (2020s, 2050s, and 2080s) showed variability, i.e. increasing in some cases and decreasing in the other cases within both RCP 4.5 and RCP 8.5 scenarios (Table 1).

The future mean annual rainfall pattern projections at Adaa woreda show decreasing trend in the RCP 4.5 scenarios for the near term (-1.50%), midterm (-4.57%) and end term (-0.04%). However in RCP 8.5 the future rainfall projections showed increasing trend by 1.35%, 0.05% and 12.10% in the near term, mid-term and end term, respectively (Table 1). To the contrary, [16] which used four GCMs and two emission scenarios (A2 and B1) and predicted that the annual and seasonal rainfall projected to decline by 2080 relative to the current baseline in the central rift valley areas. This might be an indication to the uncertainty of model predictions in rainfall particularly in mountainous areas like Ethiopia, as indicated by different studies [17,18]. Not only this but also the difference could be from the emission senarious (A2 & B1) and. varies between models [3]. In general, the downscaled output for precipitation by using only one GCM i.e. HadGEM2-ES was more complex and difficult to obtain a good agreement between observed and simulated as compared to downscaling of temperature [9] and [4]. Some reports suggested that, relative to the minimum and maximum temperature, the precipitation could not able to replicate the historical (observed) data [9] and [4].

This is due to complicated nature of precipitation processes and its distribution in space and time. In addition to this, Thorpe confirms that, simulation for precipitation improved over time but is still a problematic [16]. In addition, rainfall predictions have a larger degree of uncertainty than those for temperature. This is because rainfall is highly variable in space and so the relatively coarse spatial resolution of the current generation of climate models is not adequate to fully capture that variability. Therefore, the present study provides only a clue about the future precipitation of the area and opens a window for researchers to conduct further research by using different GCM.

Projected minimum and maximum temperature: The projected scenarios of RCP 4.5 and RCP 8.5 predicted that future minimum and maximum temperatures will be higher than baseline (Table 2) (Figure 4). Change in mean annual minimum temperature in all period in both carbon dioxide (CO_2) concentration pathway (near, mid and end term) greater than the base line for minimum temperature. Future minimum temperature trends for RCP 4.5 in the periods increased 2.13°C, 3.68°C and 4.32°C in 2020, 2050 and 2080, respectively. In the same way RCP 8.5 scenarios for future minimum temperature change projections shows increasing trend during the periods for near, mid and end term 2.47°C, 4.31°C and 6.09°C, respectively (Table 1). On the other hand, projected mean minimum temperature in both scenarios shows that slight increment from the actual mean monthly minimum temperature in the study area (Figures 5 and 6).

The future maximum temperature projections indicate that increasing trend in both RCP s scenarios. Maximum temperature increases by 0.16°C and 1.68°C by 2020, 2.7°C and 0.6°C by 2050, 2.47°C and 5.17°C by 2080 for RCP 4.5 and RCP 8.5 scenarios respectively (Table 1). In addition to this RCP 4.5 scenarios show that the maximum

Variables	2010-2039		2040-2069		2070-2099	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Rainfall (%)	-1.5	1.35	-4.57	0.05	0.04	12.01
Tmin (°c)	2.13	2.47	3.68	4.31	4.32	6.09
Tmax(°c)	0.16	0.6	1.68	2.47	2.7	5.17

Table 1: Future changes of rainfall, minimum and maximum temperature at Adaa woreda.

Planting date and scenarios	Percentage (%) change of chickpea yield		
	2010 - 2039	2040 - 2069	2070 - 2099
Early planting date (RCP4.5)	2.33	-5.52	-0.06
Early planting date (RCP8.5)			
Normal planting date(RCP4.5)	-0.12	-4.35	-2.65
Normal Planting date (RCP8.5)			
Late planting date (RCP4.5)	-2.18	-2.8	-2.59
Late Planting date (RCP8.5)			

Table 2: Impact projected carbon dioxide consternation on chickpea yield at Adaa woreda (Change in chickpea yield as result of the tow RCPs carbon dioxide consternation in three times period).

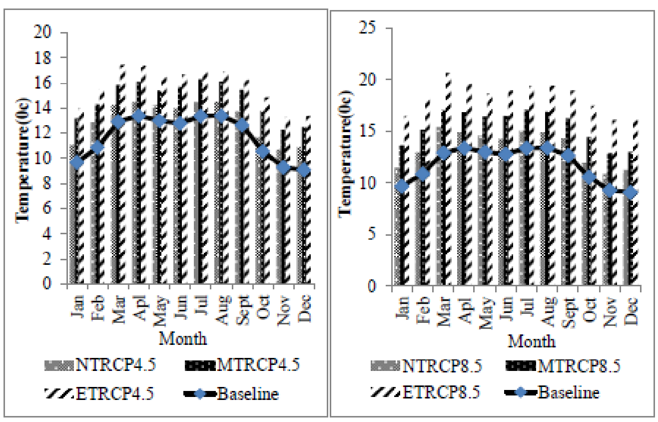

Figure 4: Mean monthly minimum temperature for RCP 4.5 and RCP 8.5 representative concentration pathway.

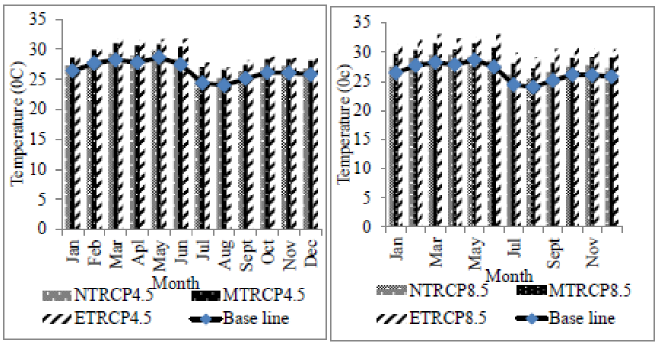

Figure 5: Mean monthly maximum temperature for RCP 4.5 and RCP 8.5 representative concentration pathway.

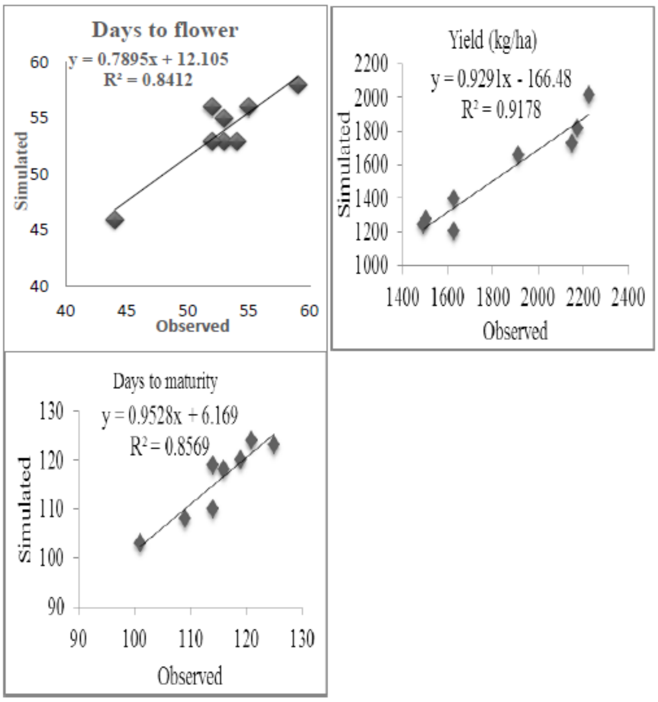

Figure 6: Calibration of chickpea model in observed verses simulated days to flower days, days to maturity and yield (Kg/ha) for Arerti variety at Adaa woreda.

temperature will be higher in mid and end-term than near-term. The mean monthly maximum temperature for both RCP s increasing from January to June at the same time will decline during July and August months, again the mean monthly maximum temperature increases from September to December (Figure 7). Generally increasing in temperature may increase moisture loss through evapotranspiration which leads to moisture shortage. This loss of moisture has its own impact on chickpea flowering, maturity and grain yield. Therefore it is better to use additional moisture conservation practice to overcome shortage of moisture and to reduce crop yield loss. The temperature results obtained from RCP s in this study is in agreement with the result of Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report result shows that the average global mean surface temperature has increased by 0.3°C to 0.6°C due to anthropogenic activities [12]. Moreover, according to the study by [19], temperature of Ethiopia is projected to increase for midterm from 1.1°C to 3.1°C and also for end term from 1.5°C to 5.1°C. Temperature, moisture and greenhouse gases are the major variables of climate change. The most obvious effect of climate change is on the global mean temperature which is expected to rise between 0.9°C and 3.5°C by the year 2100 [12].

Analysis of climate change impact on chickpea production at Adaa Woreda

DSSAT model calibration for chickpea: Calibration of CROPGRO for chickpea in DSSAT V4.6 was carried out based on yearly based data collected for 1993, 1997, 2001, 2004, 2005, 2006, 2007 and 2010 from Debrezeit Agricultural Research Center. CROPGRO is one of the most common models used for simulating chickpea yield.

Accordingly, the coefficient of determination (R^2) values for flowering (0.84), maturity (0.86), and yield (0.92) (Figure 8). While the Root Mean Square Error (RMSE) values from comparison of phenoalogical parameters of chickpea simulated verses observed were 1.5, 2.3 and 252 kg/ha, respectively. Likewise, the index of agreement (IA) values obtained were 0.99 for days to flower, 0.99 days to maturity and 0.99 for yield, these indicating good relationships of the observed with simulated values (Table 3).

DSSAT model evaluation for chickpea: The model performance was evaluated by comparing the observed data of days to flower, days to maturity and yield data of Arerti variety collected during 1994, 1995 1996, 2000 and 2001 against the corresponding simulated values (Table 4). The model underestimated the days to flower in year 1994 and overestimated in year 1996. Similarly, the model has underestimated the days to maturity by 3.97 and 1.69% in the year 1994 and 1995, respectively. There was good relationship between observed and simulated for days to flower, days to maturity and yield with a RMES of 4.94, 3.87 and 227.72 (kg/ha), respectively. In addition, the index of agreement (IA) value for days to flower (0.54), days to maturity (0.89) and grain yield (0.84) showed good simulation performance of the model. At the same time, the coefficient of determination analysis (R^2) between the simulated and observed value for days to flower (0.7), days to maturity (0.96) and yield (0.89). As Figure 9 showed strong

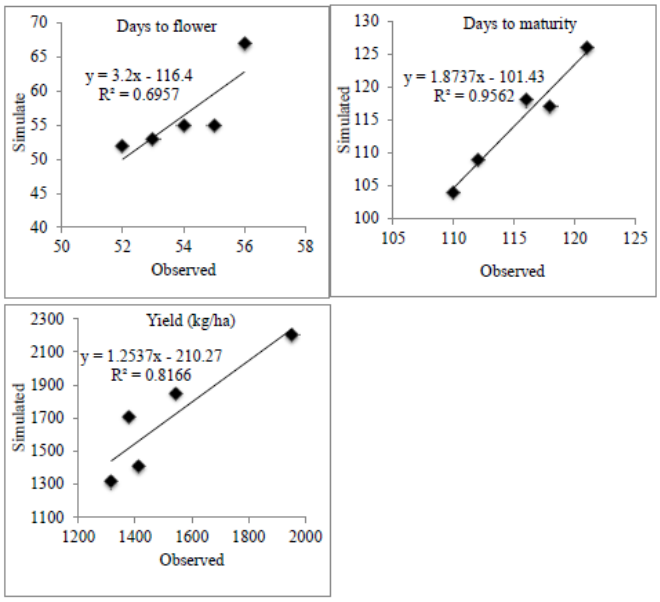

Figure 7: Evaluation of chickpea model through observed and simulated days to flower, days to maturity and yield (Kg/ha) for Arerti variety.

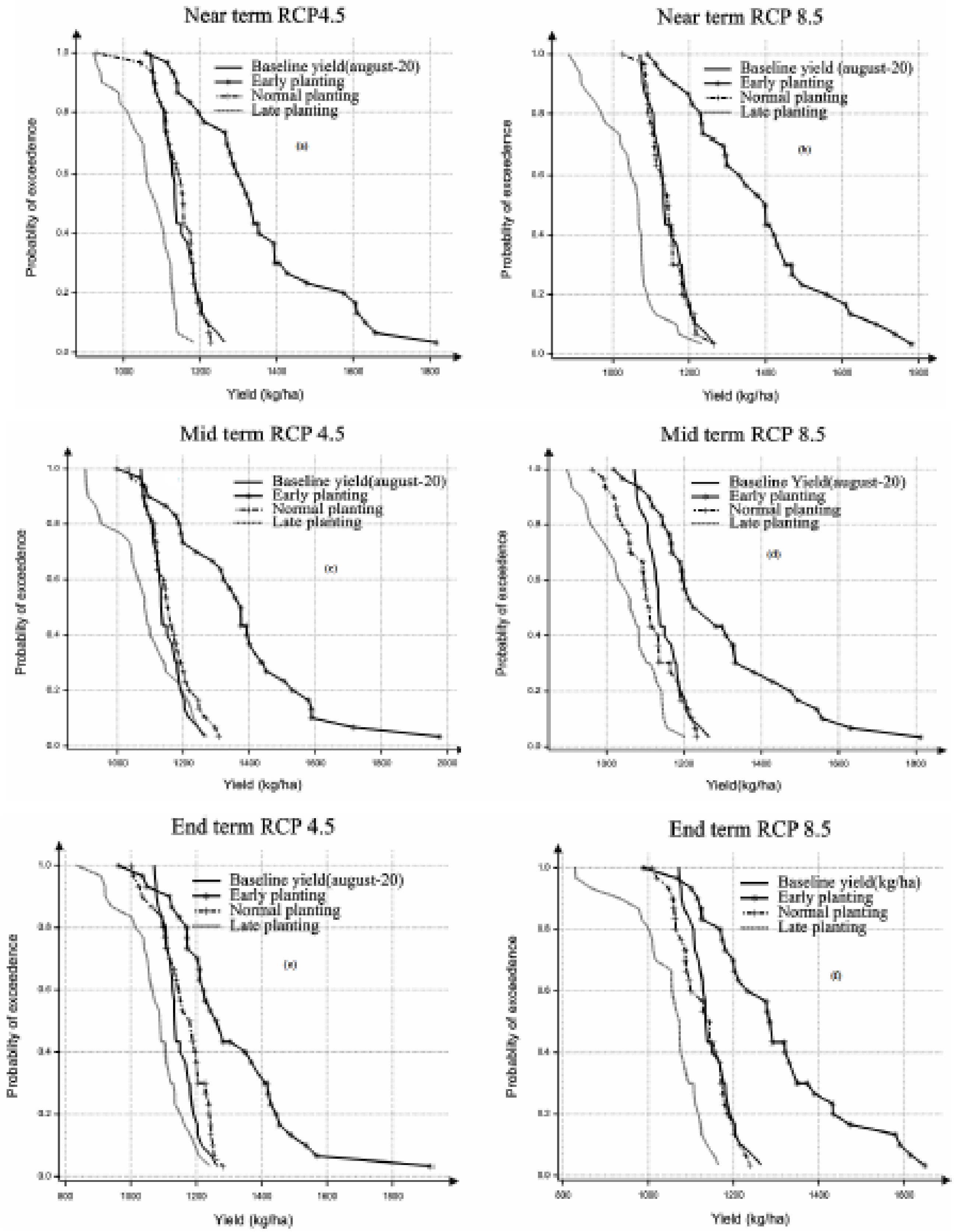

Figure 8: The probability of exceedance for chickpea yield over the base, near, mid and end term time period under early, normal and late planting time and two RCPs scenario at Adaa woreda.

Cropping season	Days to flower		Days to maturity		Yield (kg/ha)	
	SI	OB	SI	OB	SI	OB
1993/1994	46	44	108	109	1276	1504
1997/1998	53	53	103	101	1728	2150
2001/2002	53	54	110	114	1816	2174
2004/2005	56	55	124	121	1397	1629
2005/2006	55	53	120	119	1244	1493
2006/2007	56	52	119	114	1657	1913
2007/2008	58	59	123	125	2018	2225
2010/2011	53	52	118	116	1206	1629
R2	0.84		0.86		0.92	
RMSE	1.5		2.3		252	
IA	1.99		0.99		0.99	

Table 3: Comparison of phenoalogical parameters of observed verses simulated days to flower, days to maturity and yield (Kg/ha) for Arerti variety at Adaa woreda.

Cropping season	Days to flower		Days to maturity		Yield (kg/ha)	
	SI	OB	SI	OB	SI	OB
1994/1995	56	67	121	126	1316	1313
1995/1996	55	55	116	118	1411	1408
1996/1997	54	55	118	117	1543	1850
2000/2001	53	53	112	109	1955	2200
2002/2003	52	52	110	104	1377	1708
R2	0.7		0.96		0.89	
RMSE	4.94		3.87		229.72	
IA	0.54		0.89		0.84	

Table 4: Evaluation of chickpea model through observed and simulated days to flower, days to maturity and yield (Kg/ha) for Arerti variety.

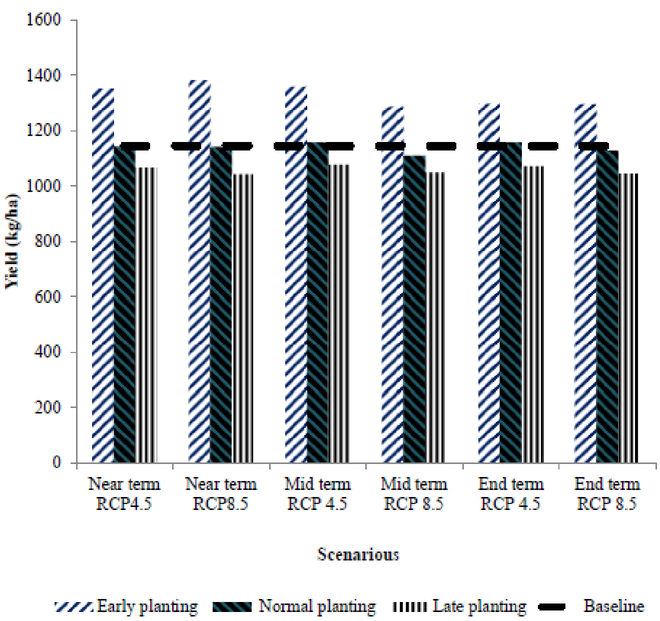

Figure 9: Chickpea production under projected carbon dioxide (CO2) concentration pathway.

agreement for days to flower, days to maturity and yield for the study area. Moreover, the model performed well in predicting the days to flower, days to maturity and the yield of Arerti variety. In general, the performance of the model appeared to be satisfactory and it could be used to predict the response of chickpea to climate change in the study area as an indicator for adjusting crop management practices. Where, R^2 is coefficient of determination, IA is index of agreement, RMSE) is Root Mean Square Error, whereas SI and OB is represented simulated or predicated and observed values respectively.

Chickpea production under different planting

Dates and climate change scenarios: Different planting date under the projected climate change has both positive and negative impact on grain yield of chickpea Arerti variety. Grain yield of chickpea for all periods of 2020, 2050 and 2080 increases by 18.08%, 4.77% and 13.26% with the CV 13.6%, 15.5% and 14.8%, respectively, in early planting (July-20) under RCP 4.5 as compared to the baseline (Table 5). For normal planting (August-20) the change in yield varied by -0.22%, 1.19% and 1.17% with CV 5.4%, 6% and 6.8% for the respective periods (near, mid and end term) respectively. Late planting of chickpea has negative impact on chickpea grain yield under near and end term, the yield declined by -5.83% and -6.31% with CV 10.2% and 8.9 respectively, while in RCP 4.5 and RCP 8.5 under midterm the yield declined by 5.83% and 8.92% with CV 10.2% and 8.1% respectively in the study area.

In similar way under RCP 8.5 early planting has increased the yield as compared to the baseline by 20.74%, 12.35% and 13.19% with CV 13.3%, 14.5%, and 13.1% for near, mid and end term respectively. Whereas normal planting and late planting has negative impact across the three time horizon due to changing in climate in the study site (Table 5). This could be due to the increase of maximum and minimum temperature in to a level at which the impacts of temperature couldn't be offsetted by the exhibited change in precipitation. This could also be strengthened by the decreasing trend of September rainfall that reduces the residual moisture in the soil.

Figure 10 shows the response of chickpea production to different planting date, under the projected future climate. Results showed that there was no probability of getting greater than 1200 kg/ha of yield in all RCP and periods except for early planting (July-20). The probability of getting 1200 kg/ha of yield was 80% for near term in both RCP s and in the same way the probability of getting 1200 kg/ha of yield increment was 75% (under RCP 4.5) and 65% (under RCP 8.5) in midterm and 70% for end term in both RCP scenarios respectively whereas for the rest of the planting dates the probability of getting 1200 kg/ha is none/ null. The probability of getting 1200 kg/ha in the base year is about less than 40% in all periods and RCP s while it is above 65% for all July sowing date. Similarly sowing on September is more risky (probability of around 90%) than the base year yield (with probability of only 20%). Generally, the probability of obtaining better chickpea yield could be most likely when farmers plant in July than in August or September. There was less or no probability of obtaining 1350 kg/ha of yield in both August and September sowing while the probability of getting the same yield was greater than 40% when sowing was carried out in July. Therefore, this analysis reveals that sowing in July was preferable to sowing in August or September. Sowing earlier has more advantage than late sowing, provided that water logging is well managed [19].

Planting date	CV (%)			Change (%)		
	2020	2050	2080	2020	2050	2080
Early planting(RCP4.5)	13.6	15.5	14.8	18.08	4.77	13.26
Normal planting(RCP4.5)	5.4	6	6.8	-0.22	1.19	1.17
Late planting (RCP4.5)	6.7	10.2	8.9	6.93	-5.83	-6.31
Early planting(RCP8.5)	13.3	14.5	13.1	20.74	12.35	13.19
Normal planting(RCP8.5)	4.5	6.8	5.6	-0.34	-3.16	-1.48
Late planting (RCP8.5)	7.8	8.1	8.4	-8.92	-8.4	-8.69

Table 5: Impacts of planting date on grain yield of chickpea.

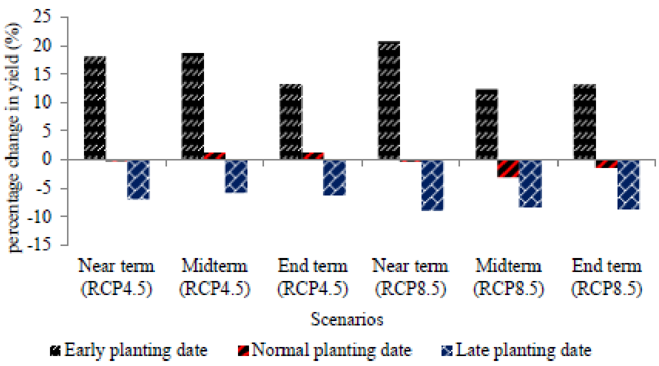

Figure 10: Adaption option for chickpea production under different planting date at Adaa woreda.

To evaluate the impact of climate change the deviation of yield from each baseline, yield was computed from planting dates and climate scenarios. Accordingly, the highest increment of yield was recorded in near term RCP 8.5 (5.57%) followed by the near (3.25%) and midterm (3.76%) RCP 4.5 in the early planting date. However, a reduction of yield was observed in the remaining periods under the same planting date. An increase in yield was projected only in the mid (1.19%) and end term (1.17%) during the normal planting date. Therefore, the impact of climate change is higher in the midterm RCP 8.5 (-3.16) followed by end term (-1.48%). In the late planting date yield was increased from 1.71% to 2.9% under RCP 4.5 climate scenario. Whereas in the RCP 8.5 a slight reduction of yield was observed in the near (-0.47%) and end term (-0.22%). Regardless of the positive impact of climate change, the coefficient of variation is high in early planting followed by late and normal planting dates respectively (Table 6). Generally, the impact of climate change using all planting dates was found negligible in all periods and in both RCP s. However, planting date was found to be important factor than climate change impact.

Response of chickpea production to carbon dioxide

CO_2 concentration: The response of chickpea to the different CO_2 concentrations was evaluated by the yield difference between RCP 4.5 and RCP 8.5 of the same periods (Figure 9). As the concentration of carbon dioxide increases from 499 ppm in the RCP 4.5 ppm to 571 ppm in the RCP 8.5, the yield of chickpea (Arerti variety) has reduced by 5.5% in the midterm and early planting. Similarly, in the midterm and normal planting date, the yield has reduced by 4.3% in the RCP 8.5. In the end term and late planting the yield was reduced by 2.6% as the concentration of carbon dioxide changes from 532 ppm in the RCP 4.5 to 801 ppm in the RCP 8.5 of the same period (Table 7).

Therefore, in this analysis chickpea has a negative response to the increase carbon dioxide concentrations, this could be an indication of the indirect effects of CO_2 (i.e. by increasing the temperature and rate of evapotranspiration) than its fertilization effect. Most likely, high temperature has an influence on chickpea growth, development and grain yield [20].

Adaptation strategies for chickpea

Production: Climate change adaptation analyses are crucial for several distinct purposes. Impact assessments assume adaptations to estimate damages to longer term climate scenarios with and without adjustments. Evaluations of specified adaptation options to identify preferred measures and take actions in response to changes in local and regional climatic conditions are very crucial. An adaptation response includes actions taken by individual actors such as single farmers or agricultural organizations, as well as planned adaptation measures [21-25].

Changing in planting dates is least-cost of adaptation strategy that should be emphasized for farmers who couldn't cope up with the challenges of climate change by introducing other technologies. Thus, from climate change impact analysis of chickpea production at Adaa woreda, the possibilities for gathering more benefit of chickpea yield were tested by changing planting date on DSSAT model by early, normal and late planting as a management adaptation under both RCP s scenarious and all periods (Figure 10).

The deviation in yield was done by subtracting the base yield from each simulated yield obtained in each planting date and dividing to the yield of common planting date (August-20). The yield benefits provided with earlier planting of (July-20) were between 12.34 to 20.74 percent under the two carbon dioxide concentration and over the three projections time periods as compared to the baseline (Table 7) [26-28].

Reduction in average yield of chickpea was observed in normal and late planting under RCP 4.5 (0.22 to 6.93%) and RCP 8.5, (0.34 to 3.16%) respectively as compared to the baseline (Table 7). Giving the highest future yields come from early planting (July 20) enables chickpea to complete the flowering and pod set stage before acute water stress which usually occurs in end of September and October. On the

Statistical Summary	Early Planning (July-20)						
	RCP4.5			RCP8.5			Baseline
	2020	2050	2080	2020	2050	2080	
Mean	1352.1	1358.8	1296.9	1382.6	1286.5	1296.1	1309.6
SD	184.5	210.33	192.12	184.39	186.47	169.56	211.52
CV(%)	13.6	15.5	14.8	13.3	14.5	13.1	16.2
Change(%)	3.25	3.76	-0.97	5.57	-1.76	-1.03	
Early Planning (July-20)							
Statistical Summary	RCP4.5			RCP8.5			Baseline
	2020	2050	2080	2020	2050	2080	
Mean	1142.6	1158.7	1158.5	1141.2	1108.9	1128.1	1145.1
SD	61.57	69.78	76.25	51.48	74.87	63.18	51.51
CV(%)	5.4	6	6.8	4.5	6.8	5.6	4.5
Change(%)	-0.22	1.19	1.17	-0.34	-3.16	-1.48	
Early Planning (July-20)							
Statistical Summary	RCP4.5			RCP8.5			Baseline
	2020	2050	2080	2020	2050	2080	
Mean	1065.8	1078.3	1072.7	1043	1048.9	1045.6	1047.9
SD	71.03	109.53	93.34	81.54	85.35	87.57	95.27
CV(%)	6.7	10.2	8.9	7.8	8.1	8.4	9.1
Change(%)	1.71	2.9	2.37	-0.47	0.1	-0.22	

Table 6: Impact of climate change on chickpea yield (kg/ha).

Scenarios and periods	Changing in planting date		
	Early planting date	Normal planting date	Late planting date
Near term (RCP4.5)	18.08	-0.22	-6.93
Midterm (RCP4.5)	18.66	1.19	-5.83
End term (RCP4.5)	13.26	1.17	-6.32
Near term (RCP8.5)	20.74	-0.34	-8.92
Midterm (RCP8.5)	12.34	-3.16	-8.4
End term (RCP8.5)	13.19	-1.48	-8.69

Table 7: Percentage change for selection of adaption option under different planting date.

contrary, Normal (August 20) and Late planting date (September 10) has the lowest consistent yields, as rain ends too early before the crop reaches maturity period and evapotranspiration is become high due to longer dry spell which leads to moisture stress on chickpea production. Therefore, to reduce negative impacts of climate change, early planting is one of the adaptation options for chickpea production. In addition to this, agronomic adaptations strategies such as improving drainage and row planting could be safe for chickpea production under changed future climatic scenarios. Moreover, other management responses such as re-adjustments of planting density, application of supplementary irrigation, getting timely weather information, soil water management practices and using new varieties, which have better resistance against adverse effects of climate change could also be considered as some of the adaptation strategies.

Conclusion and Recommendations

The RCP 4.5 and RCP 8.5 future climate of minimum and maximum temperature shows an increasing trend, whereas, the rainfall is variable in the study area for the coming 2010 to 2099 periods. The reduction in average yield of chickpea was observed in normal and late planting under RCP 4.5 (0.22 to 6.93%) and RCP 8.5, (0.34 to 3.16%) respectively as compared to the baseline.

DSSAT model calibration and evaluation was very successful studying impact of climate change at Adaa district. Mora over, the model performed well in predicting the days to flower, days to maturity and the yield of Arerti variety. In general, the performance of the model appeared to be satisfactory and it could be used to predict the response of chickpea to climate change in the study area as an indicator for adjusting crop management practices.

Therefore, planting in early planting (July-20) would have better chance of getting higher yields in both emission scenarios than in the base period under practicing proper drainage. The impact of climate change using all planting dates was found negligible in all periods and both RCP s. Similarly, changing CO_2 concentration would also make not much difference in crop yields for all projections. Planting date was found to be important than climate change impacts. Hence, to reduce the negative impacts of climate change, early planting is one of the adaptation options to consider for chickpea production in the study area. At the final point disseminate climate information's and appropriate adaptation options early planting in (July 20) to farm localities and improve researches related to climate change and agricultural production different stakeholders (crop breeders, agronomists, researchers, policy makers, GO's, NGO's and environmentalists) should work on integration. As the output of the present study is based on a single GCM (HadGEM2-ES) model, more GCM models should be considered for more policy building options and minimize uncertainties of the model. More research should be done in other additional parameters, such as disease and pest incidence to confirm the result obtained from DSSAT model. Finally, it is better if tested through other climate models such as APSIM and Aqua crop for different planting window and planting date for chickpea production in the study area.

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