Modeling the Potential Impact of Climate Change on Cotton (*Gossypium hirsutum*) Production in Northeastern Semi-Arid Afar and Western Tigray Regions of Ethiopia

Asaminew TG¹, Araya A², Atkilt G² and Solomon H²

¹National Meteorological Agency of Ethiopia, Forecast, Addis Ababa, Ethiopia  
²Mekelle University, Ethiopia

Abstract

Cotton (*Gossypium hirsutum*) is a globally important fiber plant. Impact of climate change and variability is already being felt in Ethiopia in the form of higher temperature, erratic nature of rains (spatially and temporally), floods and drought. The aim of this study was to characterize the climate of the study areas, analyze the impact of climate change on cotton production and to recommend suitable adaptation strategies for cotton production under changing climate at Amibara, Dansha and Kebabo areas of Ethiopia. Historical climate data during 1980-2010, were collected from National Meteorological Agency and National aeronautical space administration while soil and cotton experimental data of the study areas were collected from respective agricultural research center. DSSATV4.6 model was calibrated and evaluated to assess the possible impact of climate change on cotton yield under the baseline and future climate. Model performance was assessed statistically by using quantitative statistical indicators: coefficient of de-term ination (R²), root mean square error (RMSE) and index of agreement (IA). In order to estimate the level of climate change impact (rainfall and temperature) on cotton production for the study areas, two Representative path ways as a three-time segment: Near-term i.e., 2010-2039, Mid-term i.e., 2040-2069 and End-term i.e., 2070-2099 using the coupled atmosphere-ocean HadGEM2-ES GCMs model. Time series anomaly plots for temperature showed that the mean temperature over Amibara, Dansha and Kebabo has increased by about 0.5 to-2°C, 0.5 to 1.65°C and 0.5 to 1.5°C and rainfall showed slight variability in start and end of season during the period of 1980-2010. The projected temperature and rainfall pattern shows that an overall increasing trend in annual temperature and significant variation of monthly and seasonal rainfall from the historical period of time. The rainfall varies between -1.6 to 3.3%, -0.7 to 3.8% and -0.8 to 3.3% at Amibara, Dansha and Kebabo respectively. Climate change analysis indicated a strong influence of temperature on cotton production in Amibara and Dansha sites and yield will be substantially decreased on average by 12% to 13% with projected increasing temperature and erratic nature of rainfall. Projected model simulations predict that climate change will shift planting dates towards late planting (May 15 and July 15) for the period of 2010-2099 at Amibara and Dansha while for Kebabo site early planting June 15 is preferable. In general cotton yield, will decrease but, late planting date and further research on different agronomic management practices will result in increased yield for Amibara and Dansha.

Keywords: Adaptation strategies; Cotton; Climate characterization; DSSATV4.6; GCM; Instat+3.37

Introduction

General background

Cotton is an agro-industrial crop produced in both developing and developed countries. It accounts for more than half of all fibers used in clothing and household furnishings [1]. The largest volume of cotton production in the world is concentrated in countries like China, United States, India, Pakistan and Brazil. And yet low income countries in Sub-Saharan Africa (Benin, Burkina Faso, Chad) and other similarly poor countries elsewhere in the world depend heavily on cotton for earning foreign exchange [2].

Agriculture is the main source of Ethiopian economy and provides direct livelihood for about 83% of the population contributing 45% of the country’s gross domestic product (GDP), 87% of export earnings and around 73% of the raw material for agro-processing industries [3]. However, the amount of cotton exported and the amount of revenue generated from the export is very low [4]. Despite its potential capacity to produce abundant cotton, Ethiopia performed weakly in its exports of textile and garment products. This situation shows that the country is receiving insignificant benefits from its cotton and textile products export [5]. It is important, therefore, to study factors that are responsible for such low production and benefits.

Climate change will impact disproportionately on poorer African countries. The impacts of climate change on Africa’s agricultural systems will most likely result from increased intra-annual (seasonal) and inter-annual climate variability and from an increased frequency of extreme events than from changes in mean climatic conditions and agricultural yields will continue to decline with rising temperature [6].

Statement of the problem

According to WMO approximately 70 percent of Africans or close to 700 million people rely on farming for their livelihood and over 95 percent of it is rainfed [7]. Changing weather patterns due to climate

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*Corresponding author: Asaminew Teshome Game, Meteorologist, National Meteorological Agency of Ethiopia, Forecast, Addis Ababa, Ethiopia 1000, Ethiopia, Tel: 251913582017, Fax: 251116625292; E-mail: asmin2met@gmail.com

Received December 09, 2016; Accepted March 03, 2017; Published March 10, 2017

Citation: Asaminew TG, Araya A, Atkilt G, Solomon H (2017) Modeling the Potential Impact of Climate Change on Cotton (*Gossypium hirsutum*) Production in Northeastern Semi-Arid Afar and Western Tigray Regions of Ethiopia. J Earth Sci Clim Change 8: 390. doi: 10.4172/2157-7617.1000390

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change are therefore expected to reduce agricultural yields in some areas by as much as 50 percent as early as 2020. Agricultural production is the most sensitive to climate because it depends for its production process on natural heat for energy and on water, both climate-related variables. This reinforces the need for the region to consider long-term constraints that any future climate changes may place on agriculture [8].

Though little is known so far, climate change impacts on cotton growth and development that influence yield and fiber quality is the result of increasing in temperature, reduced water availability and increased in atmospheric evaportranspiration and the changing rainfall levels are affecting cotton yields. Amibara, Dansha and Kebabo is the main cotton production areas in Ethiopia but there is no significant research conducted yet on the impact of climate change on cotton growth, development and on cotton yield in the three study areas (Amibara, Dansha and Kebabo).

Research objectives

General objective of the study: The main objective of this study is to investigate and analyze the impact of climate variability and change on cotton production using historical climate data and future climate projections. In addition to show climate adaptation strategies due to changing planting dates in two semi-arid regions of Ethiopia particularly in the Afar and Western Tigray regions, of Ethiopia.

Specific objectives:
1. To characterize and assess the seasonal climate variability of the past 30 years and to project future climate trends of the study areas.
2. To analyze climate change impact on future cotton production for the study areas.
3. To recommend appropriate adaptation strategies under changing climate for the study areas.

Material and Methods

Location

The study was carried out in Middle Awash of Afar regional state Amibara Woreda, Dansha and Kebabo of Western Tigray region for the reason that both study sites grow cotton in large quantities. Amibara is located 250 km northeast part from Addis Ababa the capital city of Ethiopia. Its geographical location is 9.26°N to 9.45°N latitude and 40.15°E to 40.25°E longitude and 740 m.a.s.l (Figure 1).

Based on the 2007 census conducted by the central statistical Agency of Ethiopia, Amibara Woreda has a total population of 63,378, of whom 35,374 are men and 28,004 women Among the total population 68.86% are Muslim, 21.2% are Orthodox Christians, and 9.18% are Protestants. Tsegede Woreda has a total population of 103,852 of whom 52,763 are men and 51,089 women [9].

Techniques of baseline climate characterization for Amibara, Dansha and Kebabo

The historical daily climate data such as maximum, minimum temperature, rainfall, and sunshine hours both observed and gridded data were collected from National Meteorological Agency of Ethiopia starting from 1980 to 2010, AgMERRA data from NASA and also from the records of Woreda Agricultural Research Center (WARC). The daily climate data was captured into Microsoft Excel 2010. In order to make the series acquisitive to further analyses, the missing data were checked using Excel sheet.

Analysis of the impact of climate change on cotton production

AgMIP SSA (Sub-Saharan Africa) integrated regional assessments have used the same 5 GCMs for consistency among regions and therefore require to be used in all locations in Sub-Saharan Africa. The 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 in monsoon regions [10]. In addition, AgMIP team of Mekelle University compared HadGEM2-ES to other 20 GCMs 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 Amibara, Dansha and Kebabo and DSSAT v4.6 was used to analyze the possible impact of the future climate change on cultivar of cotton yield production over Amibara, Dansha and Kebabo. The input required for impact analyses of CMIP5 procedure for three-time period and two RCPs based on GCM “HadGEM2-ES” were generated from historical data by using AgMIP project script. Therefore, the climate change scenarios of rainfall and temperature were projected for representative concentration pathways of both RCP4.5 and RCP8.5 for Near-term 4.5 (2010-2039), Near-term 8.5 (2010-2039), Mid-term 4.5 (2040-2069), Mid-term 8.5 (2040-2069), End-term 4.5 (2070-2099) and End-term 8.5 (2070-2099) times respectively.

Results and Discussion

Baseline and projected climate characterization for Amibara, Dansha and Kebabo

Baseline rainfall pattern for Amibara, Dansha and Kebabo (1980-2010): The mean annual and seasonal baseline rainfall for the last 30 years (1980-2010) in Amibara, Dansha and Kebabo is shown in Figure 2. The annual mean rainfall was 909 mm, 741 mm, and 566 mm for Kebabo, Dansha and Amibara respectively while the rainfall pattern was highly variable from season to season and from year to year. Though Dansha and Kebabo are located in vicinity, variable rainfall was observed as supported by Hadgu [11]. who conducted research in different parts of Tigray region and found that high inter-annual variability of coefficient of variation of rainfall in Alamata, Adigudum, Mekelle, Edagahamus and Adigrat towns.

Baseline rainfall anomalies for Amibara, Dansha and Kebabo: The rainfall anomaly over Amibara, Dansha and Kebabo shows that highly variable from year to year for the last periods. The annual Kiremt (IJAS) seasonal rainfall trend shows that both positive and negative anomalies for the last 30 years (1980-2010). The upward bar shows positive anomalies indicating that the rainfall was above the mean value and these years were wetter years while the downward bar shows negative anomalies indicating the rainfall was below normal from mean rainfall over Amibara, Dansha and Kebabo.

Projected rainfall pattern for Amibara, Dansha and Kebabo (2010-2099): The projected rainfall pattern for Amibara, Dansha and Kebabo is presented in Table 1. It is observed that the projected rainfall at Amibara decreases by -1.648% and -4.349% during Near-term 4.5 and Mid-term 4.5 respectively. While the rainfall increases during Nearterm 8.5, Mid-term 8.5, End-term 4.5 and End-term 8.5 by 4.175%, 3.097%, 0.214% and 2.27% respectively. The projected rainfall over Dansha shows that erratic nature from baseline rainfall. The rainfall decreases by -1.27%, -0.65% and -0.58% for Near-term 4.5, Near-term 8.5 and Mid-term 4.5 periods respectively. The rainfall increases relatively
Figure 1: Map of the study areas of Amibara, Dansha and Kebabo.

Figure 2: Kiremt seasonal rainfall amount for Amibara, Dansha and Kebabo.

During Mid-term 8.5, End-term 4.5 and End-term 8.5 scenarios by 3.84%, 0.30% and 1.33% respectively. The projected rainfall for Kebabo shows slight decreasing in amount from baseline rainfall during the periods of 2010-2099. The rainfall decreases by -0.8%, -1.1%, -4.8%, -0.1%, and -3.2% during the periods of Near-term 4.5, Near-term 8.5, Mid-term 4.5, Mid-term 8.5 and End-term 4.5 scenarios respectively. While the rainfall increase by 3.3% during End-term 8.5 scenario at Kebabo.

Generally, the projected rainfall pattern for the three places shows that the rainfall slightly increases for the period of RCP8.5 as compared to RCP4.5 and the current rainfall amount. This is similar with Collins report of CMIP5 model shows a gradual increase in global precipitation over the 21st century [12]. The rainfall percentage change exceeds 0.05 mm/day (~2% of global precipitation) and 0.15 mm/day (~5% of global precipitation) by 2100 in RCP2.6 and RCP8.5 respectively.

According to Bates and Kundzewicz, Fowler and Blenkinsop reported that unlike to the minimum and maximum temperature, precipitation could not able to replicate the historical (observed) data. [13,14]. This is due to complicated nature of precipitation processes and its distribution in space and time. In addition to this, Thorpe confirmed that climate model simulation for precipitation have been improved over time but is still a problematic and also added that rainfall predictions have a larger degree of uncertainty than those for temperature [15]. 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 provided only a clue about the future precipitation of the area and opens a window for researchers and policy makers to conduct further research by using different GCMs.

Projected maximum temperature for Amibara, Dansha and Kebabo (2010-2099): Temperature is one of the major environmental factors affecting the growth, development and yields of cotton crops, especially the rate of development. [16]. The projected maximum temperature for the period of 2010 to 2099 increases for Amibara, Dansha and Kebabo relative to baseline maximum temperature (Table 2).

Cotton production with different planting dates under future climate change scenarios at Amibara

The simulated cotton yield at Amibara decreased during early and normal planting dates in the future periods while delayed planting date relatively increases the future cotton yield (Table 3).

At Amibara the projected future cotton yield decreased more with early planting compared to the corresponding historical yield as presented in (Table 3). Yield change due to early planting date under RCP4.5 is -16.51%, -16.97% and -8.61% for the period of near-
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Table 1: Projected mean annual rainfall for Amibara, Dansha and Kebabo under RCP 4.5 and 8.5 RCPs.

| Sites     | Scenario    | Projected mean Rainfall (mm) | Change of Rf (%) | Baseline Rf (mm) |
|-----------|-------------|------------------------------|------------------|------------------|
| Amibara   | Near term 4.5RCP | 567.8                        | -1.6             | 577.34           |
|           | Near term 8.5RCP | 601.4                        | 4.2              |                  |
|           | Mid term 4.5RCP  | 552.2                        | -4.3             |                  |
|           | Mid term 8.5RCP  | 595.2                        | 3.1              |                  |
|           | End term 4.5RCP  | 578.6                        | 0.2              |                  |
|           | End term 8.5RCP  | 590.5                        | 2.2              |                  |
| Dansha    | Near term 4.5RCP | 756.3                        | -1.3             | 766              |
|           | Near term 8.5RCP | 761.1                        | -0.7             |                  |
|           | Mid term 4.5RCP  | 761.6                        | -0.6             |                  |
|           | Mid term 8.5RCP  | 795.4                        | 3.8              |                  |
|           | End term 4.5RCP  | 768.3                        | 0.3              |                  |
|           | End term 8.5RCP  | 776.2                        | 1.3              |                  |
| Kebabo    | Near term 4.5RCP | 902.2                        | -0.8             | 909.92           |
|           | Near term 8.5RCP | 900.2                        | -1.1             |                  |
|           | Mid term 4.5RCP  | 866                          | -4.8             |                  |
|           | Mid term 8.5RCP  | 909.1                        | -0.1             |                  |
|           | End term 4.5RCP  | 880.7                        | -3.2             |                  |
|           | End term 8.5RCP  | 940.1                        | 3.3              |                  |

Table 2: Projected maximum temperature change under different scenarios for Amibara, Dansha and Kebabo. $T_{max}$: Maximum temperature.

| Sites     | Scenario    | Projected maximum temperature (°C) | $T_{max}$ change (°C) | Baseline $T_{max}$ (°C) |
|-----------|-------------|-----------------------------------|-----------------------|--------------------------|
| Amibara   | Near term 4.5RCP | 35.7                            | 1.3                   | 34.39                    |
|           | Near term 8.5RCP | 35.7                            | 1.3                   | 35.34                    |
|           | Mid term 4.5RCP  | 36.6                            | 2.3                   | 36.6                     |
|           | Mid term 8.5RCP  | 37.5                            | 3.1                   | 37.5                     |
|           | End term 4.5RCP  | 37.5                            | 3.1                   | 37.5                     |
|           | End term 8.5RCP  | 39.3                            | 4.9                   | 39.3                     |
| Dansha    | Near term 4.5RCP | 36.6                            | 1.3                   | 35.34                    |
|           | Near term 8.5RCP | 36.9                            | 1.5                   | 36.9                     |
|           | Mid term 4.5RCP  | 37.6                            | 2.3                   | 37.6                     |
|           | Mid term 8.5RCP  | 38.5                            | 3.1                   | 38.5                     |
|           | End term 4.5RCP  | 38.4                            | 3.1                   | 38.4                     |
|           | End term 8.5RCP  | 40.7                            | 5.4                   | 40.7                     |
| Kebabo    | Near term 4.5RCP | 32                              | 1.3                   | 30.67                    |
|           | Near term 8.5RCP | 32.1                            | 1.4                   | 32.1                     |
|           | Mid term 4.5RCP  | 33.3                            | 2.6                   | 33.3                     |
|           | Mid term 8.5RCP  | 33.9                            | 3.2                   | 33.9                     |
|           | End term 4.5RCP  | 34.1                            | 3.5                   | 34.1                     |
|           | End term 8.5RCP  | 36                              | 5.3                   | 36                        |

term, mid-term and end-term respectively. Similarly cotton yield decreased under RCP8.5 for the respective time periods by-18.06%, -19.53% and -20.32% yields will decrease. The percentage yield change for normal planting under RCP4.5 for near, mid and end-term time period is-9.4%, -10.2 and -10.1% yield will decrease from the baseline. Whereas for RCP8.5 cotton yield will decrease more at the time of normal planting by-10.7%, -14.3% and -16.1%. The projected future yield relatively increased with delayed planting compared to historical yield. The cotton yield relatively increased when late planting date was used under RCP4.5 by 1.71%, 1.20%, and 0.5% for the near, mid and end-term period. Similarly cotton yield increased when late planting date was used for the respective time periods by 0.4% and 0.2% for Near-term 8.5 and Mid-term 8.5 while yield relatively decreases by-2.20% under End-term 8.5 scenario. In contrast with early and normal planting dates for the period of 2010-2099 at Amibara the yield slightly increased by using late planting date under both RCP scenarios. It should however be noted that yields change was simulated by assuming that the necessary inputs such as fertilizers and different seeds variety and the soil conditions do not change. According to Ali report cotton yield affected by different sowing dates under the climatic conditions of Vehari, Pakistan and concluded that the highest seed cotton yield of 2039 kg/ ha was obtained on 15th May [17].

Generally, the result shows that future cotton yield at Amibara decreased due to the negative impact of climate change. This finding is similar with the findings of Reddy reported that a decreased in cotton yield of 3–37% resulting from expected climate change in cotton belt countries of Southern United States [18]. Moreover, inconsistencies in the prediction of cotton yield changes due to climate change (including CO$_2$ enrichment) were reported by Doherty [19].

Buttar conducted research on irrigated cotton of India's Punjab region by using CropSyst model and reported that the future warming could reduce seed cotton yield through accelerated development and hence shorter growth duration [20].
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Table 3: Statistical summary of simulated cotton yield for early, normal and late planting date for Amibara, EP: Early planting, NP: Normal planting and LP: Late planting SD: Standard deviation and CV: Coefficient of variation.

| Amibara Descriptive statistics | Scenarios | Mean yield (kg/ha) | SD  | CV | % of yield change |
|-------------------------------|-----------|-------------------|-----|----|------------------|
| **Planting dates**            |           |                   |     |    |                  |
|                               | Baseline  |                   |     |    |                  |
| EP March 15                   | Baseline  | 4826              | 509 | 0.11 | -16.51           |
|                               | Near term 4.5RCP | 4029       | 449 | 0.11 | -16.97           |
|                               | Mid term 4.5RCP  | 4007       | 424 | 0.11 | -16.97           |
|                               | End term 4.5RCP  | 4410       | 366 | 0.08 | -8.61            |
|                               | Near term 8.5RCP | 3954       | 409 | 0.1  | -18.06           |
|                               | Mid term 8.5RCP  | 3883       | 359 | 0.09 | -19.53           |
|                               | End term 8.5RCP  | 3845       | 297 | 0.07 | -20.32           |
|                               | Baseline  | 5544              | 415 | 0.07 |                  |
|                               | Near term 4.5RCP | 5025       | 479 | 0.09 | -9.4             |
|                               | Mid term 4.5RCP  | 4980       | 519 | 0.1  | -10.2            |
|                               | End term 4.5RCP  | 4985       | 541 | 0.11 | -10.1            |
|                               | Near term 8.5RCP | 4948       | 397 | 0.08 | -10.7            |
|                               | Mid term 8.5RCP  | 4750       | 523 | 0.11 | -14.3            |
|                               | End term 8.5RCP  | 4650       | 385 | 0.08 | -16.1            |
| **NP April 15**               | Baseline  | 5879              | 325 | 0.05 |                  |
|                               | Near term 4.5RCP | 5980       | 402 | 0.07 | 1.71             |
|                               | Mid term 4.5RCP  | 5950       | 523 | 0.08 | 1.2              |
|                               | End term 4.5RCP  | 5910       | 404 | 0.07 | 0.53             |
|                               | Near term 8.5RCP | 5905       | 373 | 0.06 | 0.44             |
|                               | Mid term 8.5RCP  | 5892       | 528 | 0.09 | 0.22             |
|                               | End term 8.5RCP  | 5750       | 579 | 0.1  | -2.2             |
| **LP May 15**                 | Baseline  | 6053              | 460 | 0.08 |                  |
|                               | Near term 4.5RCP | 6029       | 398 | 0.07 | -0.4             |
|                               | Mid term 4.5RCP  | 5814       | 616 | 0.11 | -3.9             |
|                               | End term 4.5RCP  | 4841       | 634 | 0.13 | -20              |
|                               | Near term 8.5RCP | 6053       | 460 | 0.08 | 0               |
|                               | Mid term 8.5RCP  | 4914       | 616 | 0.13 | -18.8            |
|                               | End term 8.5RCP  | 4677       | 367 | 0.07 | -22.7            |

Table 4: Statistical summary of simulated cotton yield for early, normal and late planting date for Dansha, EP: Early planting, NP: Normal planting and LP: Late planting SD: Standard deviation and CV: Coefficient of variation.

| Dansha Descriptive statistics | Scenarios | Mean yield (kg/ha) | SD  | CV | % of yield change |
|-------------------------------|-----------|-------------------|-----|----|------------------|
| **Planting dates**            |           |                   |     |    |                  |
|                               | Baseline  |                   |     |    |                  |
| EP June 15                    | Baseline  | 6053              | 460 | 0.08 |                  |
|                               | Near term 4.5RCP | 6029       | 398 | 0.07 | -0.4             |
|                               | Mid term 4.5RCP  | 5814       | 616 | 0.11 | -3.9             |
|                               | End term 4.5RCP  | 4841       | 634 | 0.13 | -20              |
|                               | Near term 8.5RCP | 6053       | 460 | 0.08 | 0               |
|                               | Mid term 8.5RCP  | 4914       | 616 | 0.13 | -18.8            |
|                               | End term 8.5RCP  | 4677       | 367 | 0.07 | -22.7            |
|                               | Baseline  | 5550              | 396 | 0.07 |                  |
|                               | Near term 4.5RCP | 5496       | 339 | 0.06 | -0.08            |
|                               | Mid term 4.5RCP  | 4337       | 499 | 0.12 | -21.1            |
|                               | End term 4.5RCP  | 4471       | 461 | 0.1  | -16.7            |
|                               | Near term 8.5RCP | 5550       | 396 | 0.07 | 1.09             |
|                               | Mid term 8.5RCP  | 4337       | 499 | 0.12 | -21.1            |
|                               | End term 8.5RCP  | 4450       | 410 | 0.09 | -19.08           |
|                               | Baseline  | 4967              | 293 | 0.06 |                  |
|                               | Near term 4.5RCP | 4987       | 314 | 0.06 | 0.72             |
|                               | Mid term 4.5RCP  | 4252       | 538 | 0.13 | 0.86             |
|                               | End term 4.5RCP  | 4276       | 447 | 0.1  | -0.06            |
|                               | Near term 8.5RCP | 4967       | 293 | 0.06 | 1.25             |
|                               | Mid term 8.5RCP  | 4252       | 538 | 0.13 | 0.52             |
|                               | End term 8.5RCP  | 4152       | 316 | 0.07 | -0.27            |

Cotton production with different planting dates under future climate change scenarios at Dansha: The simulated cotton yield at Dansha shows that the yield decreases up to 22% in the coming periods during early and normal planting dates. The future yield comparatively increases by using late planting date of July 15 (Table 4).

Cotton production with different planting dates under future climate change scenarios at Kebabo: At Kebabo site the simulated cotton yield shows that in the coming periods the yield increases in all planting dates except during late planting date of Near-term 4.5 scenarios. The cotton yield increased up to 42% and only decreases...
by-3.4% during the periods of Near term 4.5 from the current yield at Kebabo (Table 5).

Conclusion and Recommendations

The analyzed historical long-term climate data shows that there was variability in rainfall on the start and end of season for the three study areas (Amibara, Dansha and Kebabo). The projected rainfall for Amibara demonstrates slight variability over all scenarios. The rainfall at this site decreased by-1.27% to -0.65% and-1.64% to -4.34% over the near-term and mid-term respectively. The projected rainfall at Dansha decreases by-0.24 to 2.27% over the end-term. While the projected rainfall at this site decreased by-3.4% during the periods of Near term 4.5 from the current yield at Kebabo (Table 5).

Table 5: Statistical summary of simulated cotton yield for early, normal and late planting date for Kebabo. EP: Early planting, NP: Normal planting and LP: Late planting SD: Standard deviation and CV: Coefficient of variation.

| Planting dates | Scenario          | Mean yield (kg/ha) | SD  | CV  | % of yield change |
|----------------|-------------------|--------------------|-----|-----|-------------------|
| EP June15      | Baseline          | 4417               | 430 | 0.09|                   |
|                | Near term 4.5RCP  | 4704               | 560 | 0.12| 6.5               |
|                | Mid term 4.5RCP   | 5733               | 339 | 0.06| 29.8              |
|                | End term 4.5RCP   | 6217               | 363 | 0.07| 48.5              |
|                | Near term 8.5RCP  | 4880               | 488 | 0.1 | 9.5               |
|                | Mid term 8.5RCP   | 6013               | 273 | 0.05| 36.1              |
|                | End term 8.5RCP   | 6285               | 527 | 0.08| 42.3              |
| NP June25      | Baseline          | 4220               | 403 | 0.09|                   |
|                | Near term 4.5RCP  | 4538               | 461 | 0.1 | 7.5               |
|                | Mid term 4.5RCP   | 5342               | 397 | 0.07| 26.6              |
|                | End term 4.5RCP   | 5987               | 345 | 0.05| 41.9              |
|                | Near term 8.5RCP  | 4592               | 407 | 0.08| 8.8               |
|                | Mid term 8.5RCP   | 5748               | 279 | 0.04| 36.2              |
|                | End term 8.5RCP   | 6026               | 462 | 0.07| 42.8              |
| LP July15      | Baseline          | 4106               | 486 | 0.12|                   |
|                | Near term 4.5RCP  | 3967               | 423 | 0.11| -3.4              |
|                | Mid term 4.5RCP   | 4799               | 320 | 0.07| 16.9              |
|                | End term 4.5RCP   | 5417               | 289 | 0.05| 31.9              |
|                | Near term 8.5RCP  | 4172               | 311 | 0.07| 1.6               |
|                | Mid term 8.5RCP   | 5227               | 301 | 0.06| 27.3              |
|                | End term 8.5RCP   | 5577               | 324 | 0.06| 35.8              |

Acknowledgments

At this point, above all God is to be praised for keeping me well and for his endless love in helping me succeed. I would like to thank Rockefeller Foundation project of Mekelle University for supporting my MSC study at Institute of climate and society in Mekelle University. The project covered my all stipend fund, tuition, and research costs. I would like to express my sincere thanks and appreciations to my major advisor Dr. Araya Nenime for his inspiration, whole hearted support, close guidance, and valuable suggestions that lead me to the start and completion of this work including all financial assistance of stipend fund and research costs. I am also so much thankful to my co-advisors Drs. Atkilit Girma and Dr. Solomon Habtu for their guidance, suggestions, and comments throughout my work. I would like also to thank Department head of climate and society Dr. Amanuel Zenabe within the staff members of ICS, Mekelle University, Dr. Grimay Gebersamueael, Grimay Gebru, Eskinder Giday, Amadon Gabremenid, Senait Baraki, Henok Shiferaw and all of my lecturers for their love and care during my stay in Mekelle University. I would like to express my deepest gratitude to my father, Mr. Teshome Game Ayane and my mother W/o Baye Ababu Bamle who had educated me being illiterate and who have been encouraging me from early school age to this level and led me to the line of success. I would like to thank my wife W/o Beshatu Zerihun; my little baby Hawi Amsinew for their love, patience and assistance to my success. I would like to thank Dr. Alex C. Ruane, Research Physical Scientist, Climate Impacts Group, Space Coordinator and Climate Team Leader in NASA GISS for providing me AgMERRA data. I am also deeply grateful to Werer Agricultural research center and staff members for assisting and providing all the necessary research materials for my work. Especially those who provided materials and information and who helped me a lot during the data collection period Mr. Solomon Seyifu, Mr. Samuel Damtew and Mr. Bethel Nekir for their unlimited dedication in assisting me in every aspect. I would like to thank Mr. Daniel Forsythe (NASA) for his support and assistance during the data collection period. I also deeply thankful to Dr. Henok Chifor and Mr. Mneta Shanks and Mr. Melesse Lemma for their constructive comment and suggestion. I would like to acknowledge NMA for providing all necessary climate data's and allowing me to stay in Mekelle University. I would like to express my gratitude to all members of my family, father, Mr. Teshome Game Ayane and my mother W/o Baye Ababu Bamle who had educated me being illiterate and who have been encouraging me from early school age to this level and led me to the line of success. I would like to thank my wife W/o Beshatu Zerihun; my little baby Hawi Amsinew for their love, patience and assistance to my success. I would like to thank Dr. Alex C. Ruane, Research Physical Scientist, Climate Impacts Group, Space Coordinator and Climate Team Leader in NASA GISS for providing me AgMERRA data. I am also deeply grateful to Werer Agricultural research center and staff members for assisting and providing all the necessary research materials for my work. Especially those who provided materials and information and who helped me a lot during the data collection period Mr. Solomon Seyifu, Mr. Samuel Damtew and Mr. Bethel Nekir for their unlimited dedication in assisting me in every aspect.

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