

# Impacts of Climate Change on Bread Wheat (*Triticum aestivum* L) Yield in Adet, North Western Ethiopia

Endalew Assefa Abera<sup>1\*</sup>, Mezgebu Getnet<sup>2</sup>, Lisanework Nigatu<sup>3</sup>

<sup>1</sup>Ethiopian Institute of Agriculture Research, Addis Ababa, Ethiopia; <sup>2</sup>International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, Telangana, India; <sup>3</sup>Haramaya University, Haramaya, Oromia, Ethiopia

## ABSTRACT

Quantifying the extent and direction of climate change and its impacts is important on crop production as earth's climate is undergoing changes. Thus the aim of this study was to assess the historical and future climate and its change impact on the yield of Tay and Senkegna bread wheat varieties in Adet, North Western Ethiopia. The observed daily climate data were obtained from National Meteorological Agency of Ethiopia, Bahir Dar branch for 33 years (1983 - 2015). Future climate data were from Climate Research Programme's Fifth Coupled Model Intercomparison Project (CMIP5) database across 20 GCMs for RCP 8.5 emission scenarios in the time horizon of early-term (2010-2039), mid-century (2040-2069) and end-century (2070-2100). Soil data were obtained from Adet Agricultural Research Center. The onset, end dates, Length of Growing Period (LGP) and dry spell risk for the main rainy season were analyzed using first-order Markov model built in INSTAT tools version 3.36. Decision Support System for Agro-technology Transfer (DSSAT) crop model was employed during yield simulation. Onset of rainy seasons occurred before 1st decade of June was only 25% of the study years while it occurred before 2nd decade of June was 75% of the study years with coefficient of variation (CV) 5.3%. The end date of the rainy seasons occurred before 1st decade of November was 25% of the study years and occurred before 2nd decade of November was 75% of the study years with CV of 3.7%. Length of Growing Period (LGP) was ranged between 125-185 days with CV of 9%. The observed rainfall was decreased while both maximum and minimum temperatures were increased significantly ( $P < 0.05$ ). The projected maximum temperature is expected to increase by 1 to 4.69°C in 2030 to 2080. Furthermore, minimum temperature will increase by 0.93 to 4.73°C in 2030 to 2080. For Tay bread wheat variety, the grain yield is expected to increase by 0.5-1.3% in 2030 to 2050 but decreasing of 3% in 2080s. For Senkegna bread wheat variety, the yield is also increase by 1-2.3% in 2030 to 2080 relative to the baseline. However, days to anthesis and days to maturity of both wheat varieties will decline by 5-21% from the baseline.

**Keywords:** Climate change; Yield simulation; Wheat; Ethiopia; East Africa

## INTRODUCTION

Most climate models predict global temperature is increased compared to the mean historical due to higher levels of atmospheric carbon dioxide ( $\text{CO}_2$ ) concentration [1]. Some studies argued that the elevated of  $\text{CO}_2$  concentration increases photosynthesis, and thereby increasing the carbohydrate pools of leaves and stems, and finally to grain yield [2]. On the contrary, Wolf et al. [3] reported that temperature increase would result in yield reduction whereas increased the level of precipitation and  $\text{CO}_2$  fertilization would have positive impact on the production of wheat in Europe. Gbetibou and Hassan [4] also found that temperature increase would be havoc wheat productivity. In case of Ethiopia, climate change affects the wheat crop production, and wheat species will be shift

to higher altitude [5]. Raising temperature and rainfall variability are observed in Ethiopia [6]. The spatial and temporal variability of rainfall during the rainy season alter national crop production by 90-95% in Ethiopia [7]. According to Agnew and Chappel [8] report in Amhara region, extreme, severe and moderate droughts were occurred in 1987, 1990, and 1992 respectively. In addition to this report, Woldeamlak [9] found that the year 1984 was come up with the lowest rainfall record and caused the worst drought. Dereje et al. [6] point out the start of the rainy season over Amhara region experienced with little shift for most of the study stations. From the report, June 15 was the date when long rainy seasons were started in the region. Further, the end date of rainy season also about third of November, in which the normal rainy season ceases in most parts of the Amhara region.

**Correspondence to:** Endalew Assefa Abera, Ethiopian Institute of Agriculture Research, Addis Ababa, Ethiopia, E-mail: endalewassefa@yahoo.com

**Received:** July 25, 2019, **Accepted:** August 28, 2019, **Published:** September 03, 2019

**Citation:** Abera EA, Getnet M, Nigatu L (2019) Impacts of Climate Change on Bread Wheat (*Triticum aestivum* L) Yield in Adet, North Western Ethiopia. J Pet Environ Biotechnol 10:396. doi: 10.35248/2157-7463.19.10.396

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Tay and Senkegna bread wheat varieties are commonly grown in the Amhara region [10] and have the common planting date about mid-June [11]. The future production of Tay and Senkegna bread wheat varieties predicted to 44 and 45 qt ha<sup>-1</sup> in the time period of 2030 to 2080 respectively [12]. On the other hand, the simulation days from planting to flowering and to maturity of Tay and Senkegna wheat varieties will be declined.

Climate impact study using crop model is the recent approach in agricultural research, which is used to identify the critical effect of rainfall and temperature at different stages of the crop with related the physical and chemical properties soil and CO<sub>2</sub> concentration [13] and this approach is urgent instrument in Ethiopia [14]. Climate models are used to simulate global climate and downscale the reliable representation to local level [15], while crop models are also used to evaluate the impact of climate change on crop production as a result of increased greenhouse gases emissions [16]. CERES-Wheat is one of process-oriented management level tool, which is embedded in DSSAT model that has capacity to simulate the growth, development and yield of wheat under diverse environments in DSSAT model [17]. Therefore, this study focused on assessing the climate variables and simulating the climate change impact on phenological stage and yield of Tay and Senkegna bread wheat varieties in the study area.

## MATERIALS AND METHODS

### Description of study area

The study was conducted in Adet Agricultural Research Centre (AARC) including the similar agro ecological areas in North Western Ethiopia. The Adet is found in Amhara Region with the geographical reference of 11°16'N latitude and 37°29'E longitude at an altitude of 2216 m above mean sea level (Figure 1). The mean annual rainfall is 1250 mm, and the average annual maximum temperature is 25.5°C and minimum temperature is 9.2°C. The area is dominated with soil types of Nitosol, Vertisols and Luvisols [18].

### Materials

The basic data used for DESSAT model were climate and soil data, in which the climate data including rainfall, minimum and maximum temperatures, wind speed, relative humidity, and solar

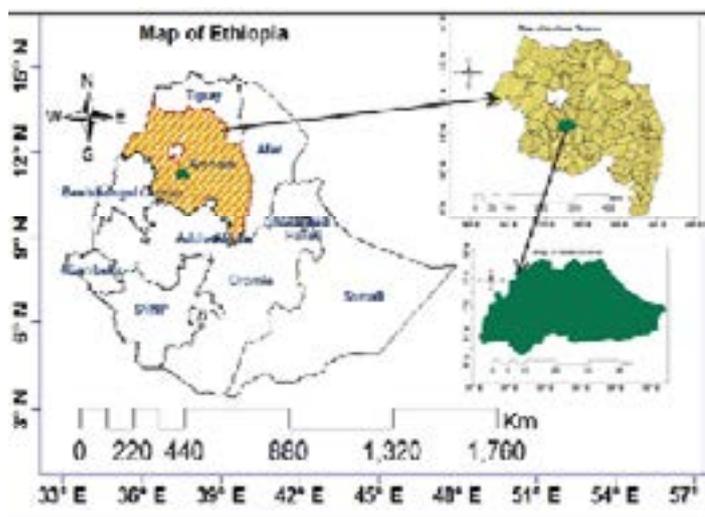


Figure 1: Location map of the study area, Adet, North Western Ethiopia.

radiation for 33 years (1983-2015) were obtained from National Meteorological Agency of Ethiopian, Bahir Dar Branch, and the projection climate data were obtained from Climate Research Programme's Fifth Coupled Model Inter-comparison Project (CMIP5) multi-model database systems for early-term (2010-2039), mid-century (2040-2069) and end-century (2070-2100) under RCP 8.5. Similarly, soil data obtained from Adet Research Site soil profile in sample of four layers (Table 1). Abera [12] was used the climate data and soil sample during model calibration and validation for both Tay and Senkegna bread wheat varieties.

**Trend analyses:** From the long term record of rainfall data during the rainy season (June to September), the rainfall characteristic, such as the onset dates, end dates, Length of growing season (LGP), and the dry spell risk have been analyzed using first-order Markov model built in INSTAT tools version 3.36 [19]. The temporal variability of rainfall and temperature for seasonal and annual totals across 1983 to 2015 years has been analyzed using equation (1 and 2).

$$CV = \left( \frac{\delta}{\bar{X}} \right) \times 100 \tag{1}$$

$$\bar{X} = \frac{\sum Xi}{N} \text{ and } \delta = \sqrt{\frac{\sum (Xi - \bar{X})^2}{N - 1}} \tag{2}$$

Where CV was the coefficient of variation,  $\delta$  was standard deviation  $\bar{X}$  was long year mean and N was total number of year during observations, Xi was rainfall of each month or season. If CV < 20% as less variable, 20-30% as moderately variable and > 30% as highly variable (Hare, 1983). Standardized anomaly index was calculated as the difference between the annual (seasonal) total of a particular year and the long term average rainfall records divided by the standard deviation of the long term data using the formula (3):

$$Z = \frac{(X - \bar{X})}{\delta} \tag{3}$$

Where Z was the standardized rainfall anomaly of the season for each year.

**Downscaling future climate data:** Agricultural Model Intercomparison and Improved Project (AgMIP) scenario generation scripts with R analytical tool [20-22] was used to generate the daily data of rainfall, minimum and maximum temperatures, and solar radiation by perturbing the daily baseline data (1980-2010) using Delta factors method. Many authors, such as Abera et al. [23] and Abera [12] used this method to assess the impact of climate change on maize production and to calibrate the bread wheat varieties in Ethiopia, respectively. The adjustment formula for modifying precipitation, maximum and minimum temperatures are stated to be given in equation (4) and (5) respectively.

$$P_{adj, fur, d} = P_{obs, d} \times \sum_{i=1}^k pi (\bar{P}_{GCM, fur, m} / \bar{P}_{GCM, ref, m}) \tag{4}$$

Where  $P_{adj, fur, d}$  was the adjusted daily rainfall for the future years,  $P_{obs, d}$  was the observed daily rainfall for the base years,  $\bar{P}_{GCM, fur, m}$  was the monthly mean rainfall of GCMs outputs for the future years,  $\bar{P}_{GCM, ref, m}$  was the monthly mean rainfall of GCMs outputs for the base years,  $pi$  was the weight of each grid cell, and k was the number of grid cells.

**For temperature:**

$$T_{adj, fur, d} = T_{obs, d} \times \sum_{i=1}^k Pi (\bar{T}_{GCM, fur, m} - \bar{T}_{GCM, ref, m}) \tag{5}$$

Where  $T_{adj, fur, d}$  was the adjusted daily maximum or minimum

temperature for the future years,  $T_{obs,d}$  was the observed daily maximum or minimum temperature for the baseline years,  $\bar{T}_{GCM}$  was the monthly mean maximum or minimum temperature of GCMs data outputs for the future years,  $\bar{T}_{GCM.ref,m}$  was the monthly mean temperature of GCMs outputs for the base years,  $\pi_i$  was the weight of each grid cell, and  $k$  was the number of grid cells.

The genetic coefficients used for yield simulation were obtained from well calibrated and validating by Abera [12] in DSSAT for Tay and Senkegna bread wheat varieties particularly in the study environment condition. These genetic coefficients are presented in Table 2. The performance of the model or goodness of fits ( $R^2$ ) were 86%, 70% and 96% for anthesis day, grain yield and for physiological maturity days respectively for Tay bread wheat varieties. Similarly for Senkegna bread wheat variety  $R^2$  were 89%, 82% and 75% for anthesis day, grain yield, and physiological maturity days respectively [12].

The yield simulation was depending on productivity of Tay and Senkegna bread wheat varieties in response to a range of temperature, rainfall, and solar radiation using the crop model of DSSAT v.4.7. The seasonal variability of wheat yield and phenology under future climate was determined using Excel Spreadsheet and R analytical tools. Yield gap analysis method was employed to quantify the differences between simulated potential yield and baseline levels and to identify those factors responsible for the yield differences [24-26]. For comparison purpose, the baseline yield was simulated depending on the historical climate data from 1983-

**Table 1:** Physical and chemical soil properties in Adet experimental site, North Western Ethiopia (CEC: Cation Exchange) methodology.

| Parameters                        | Soil depth (cm) |        |          |           |
|-----------------------------------|-----------------|--------|----------|-----------|
|                                   | 0 - 30          | 30 -90 | 90 - 140 | 140 - 200 |
| Clay                              | 66              | 69     | 68       | 64        |
| Silt                              | 24              | 15     | 18       | 24        |
| Sand                              | 12              | 16     | 14       | 12        |
| Bulk density (g/cm <sup>3</sup> ) | 1.13            | 1.19   | 1.21     | 1.29      |
| Organic carbon (%)                | 1.31            | 0.98   | 0.77     | 0.51      |
| Total Nitrogen (%)                | 0.11            | 0.09   | 0.06     | 0.04      |
| pH                                | 5.2             | 6.3    | 6.8      | 7.1       |
| CEC (meq/100 g soil)              | 50.1            | 52     | 55.2     | 55.8      |

**Table 2:** Genetic coefficients used for yield simulation for both bread wheat varieties in Adet, North Western Ethiopia.

| Symbols | Definitions   | Tay     | Senkegna |
|---------|---|---------|----------|
|         |   | variety | variety  |
| P1V     | Days, optimum temperature required for vernalization (°C)   | 9       | 10       |
| P1D     | Photoperiod response (% reduction in rate/10 h drop in pp)  | 25      | 31       |
| P5      | Grain filling (excluding lag) phase duration (°C.d)         | 727     | 745      |
| G1      | Kernel number per unit canopy weight at anthesis (#/g)      | 42      | 41       |
| G2      | Standard kernel size under optimum conditions (mg)          | 45      | 52       |
| G3      | Standard non-stressed mature tiller wt (incl grain) (g dwt) | 2.8     | 2.3      |
| PHINT   | Interval between successive leaf tip appearances (°C.d)     | 139     | 135      |

2015, and the future yield in time slices of 2030s, 2050s, and 2080s also simulated depending on the ensemble of 20 Global Climate Models climate data for RCP 8.5 scenario. Finally, the performance of both crops with the prescribed changes was compared with the baseline as follows:

$$\text{Change yield(\%)} = \frac{(Y_{\text{predicted}} - Y_{\text{base}})}{Y_{\text{base}}} \times 100 \quad (6)$$

## RESULT AND DISCUSSION

### Characteristics of rainfall features

Characteristics of rainfall (i.e., onset date, end date, Length of Growing Period and Dry spell) are depicted in Table 3. Onset of rainy seasons occurred before 1<sup>st</sup> decade of June (5-June) was in only 25% of the study years while it occurred before 2<sup>nd</sup> decade of June (15-June) in 75% of the study years with coefficient of variation (CV) was 5.3%. On the other hand, the end date of rainy season occurred before 1<sup>st</sup> decade of November (2-Nov) was only 25% of the study years and occurred before 2<sup>nd</sup> decade of November (18-Nov) was 75% of the study years with CV of 3.7%. Further, it could be noted from the Table 3, the Length of Growing Period (LGP) of the main rainy season was ranged between 145 days (25% of the study years) and 161 days (75% of the study years) and had minimum and maximum value of 125 and 185 days respectively with CV of 9% (Table 3). The variability of end date was less compared to the onset date and the length of growing period. The results of length of growing period about 145 to 161 are enough to support both bread wheat varieties. In line with this, [6] pointed out the start of the rainy season has been occurring with little shift for most of the study stations over western Ethiopia. Reliable prediction of rainfall characteristics, especially the onset is needed to determine a less risky planting date, planting method and sowing with less risky varieties of crops in responsive farming [27]. Shortening or lengthening of the LGP impacts the range of crops that can be cultivated in an area [28]. The subsistence farmers and farming systems strongly depend on the crop choice, the year-to-year LGP variability, and longer-term trends in LGP [29]. The spatial assessment of LGP can help to characterize farming systems and important input to the Agro-Ecological Zoning (AEZ) approach [30,31].

### Probability of dry spell length

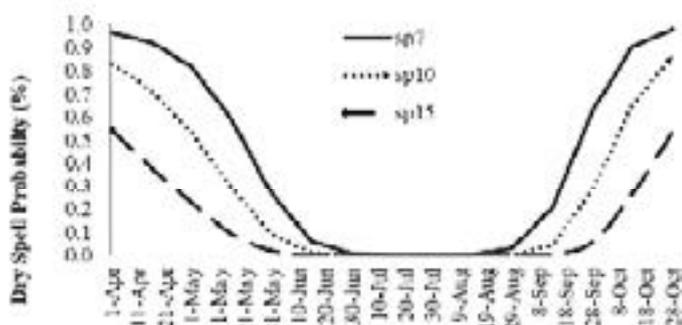
All dry spell days probability have less risk probability at the beginning of June and less than 10% during the rainy season (Figure 2). The lower dry spell probability during the rainy season was more appropriate for Tay and Senkegna bread wheat varieties which have recommended common planting dates in the mid of June and the maturity dates about in the 1st week of October. The dry spell length occurred at flowering and grain filling stages of any of crop is most sensitive and potentially damaging [6]. Identifying dry spell lengths is useful information for different groups of farmers to decide whether to plant long growing crops or short maturity crops.

### Seasonal (JJASO) rainfall trend

Using equation (1 and 2), the seasonal observed rainfall trend for the period of 1983 to 2015 is shown in Figures 3 and 4. From this analysis, the seasonal rainfall showed decreasing significantly ( $p < 0.05$ ) with 6 mm per year over the study area

**Table 3:** Descriptive statistics for climate characteristics (1983 to 2015) in Adet, North Western Ethiopia.

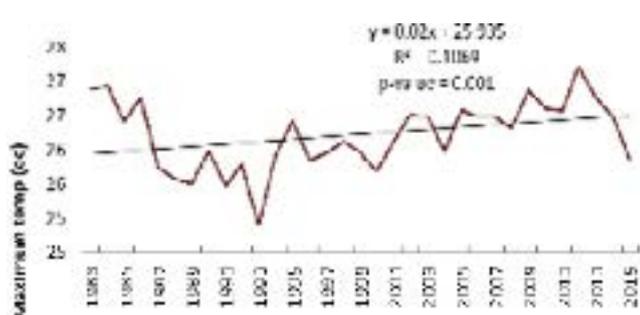
| Statistical parameters   | Onset  | End date (season) | LGP (No of days) |
|--------------------------|--------|-------------------|------------------|
| Minimum                  | 01-Jun | 18-Oct            | 125              |
| Quartile 1 (25%)         | 05-Jun | 02-Nov            | 145              |
| Median _Quartile 2 (50%) | 09-Jun | 08-Nov            | 151              |
| Quartile 3 (75%)         | 15-Jun | 18-Nov            | 161              |
| Maximum                  | 29-Jun | 05-Dec            | 185              |
| Mean                     | 09-Jun | 10-Nov            | 152              |
| CV (%)                   | 5.3    | 3.7               | 9                |



**Figure 2:** Probability of dry spell length (1983-2015) in Adet, North Western Ethiopia (Sp7=Seven dry spell days, Sp10=Ten dry spell days, Sp15=Fifteen dry spell days).



**Figure 3:** Seasonal (JJASO) rainfall trend (1983-2015) in Adet, North Western Ethiopia.



**Figure 4:** Annual maximum temperature trend (1983-2015) in Adet, North Western Ethiopia.

(Appendix-Table 1).

**Annual temperature trends**

Figures 5 and 6 depicted the trends of annual historical maximum and minimum temperature respectively for the study period (1983-2015). It has showed an increasing trend significantly ( $P < 0.05$ ) with 0.02 and 0.09°C per years for maximum and minimum temperature respectively (Appendix-Table 1). The increasing temperature might

enhance the evapotranspiration process which results soil moisture stress and shorten the growth period of wheat crop. In Ethiopia, the average annual minimum and maximum temperatures have increased by about 0.25°C and 0.1°C every ten years respectively [32-35].

**Seasonal rainfall anomaly**

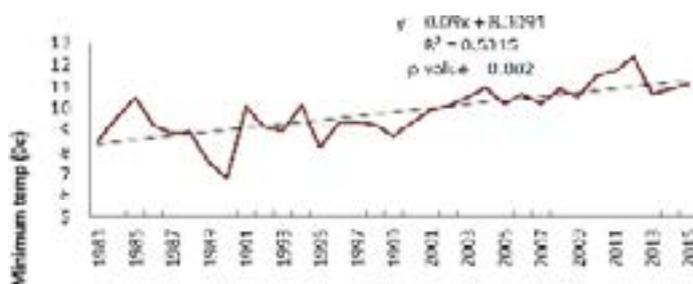
Standardizing the rainfall (using equation (3), below normal deviation of rainfall years were like 1984, 1987, 1994, 1996, 2003, and 2007 while received above average rainfall in 1985, 1986, 1988, and 1991 (Figure 6). Disrupting or decreased amount of rainfall during the main rainy season (from June to September) reduces the National crop production by 90-95% in Ethiopia [7]. Agnew and Chappel [8] reported there have been four drought years in the Amhara region, two extreme (1984 and 1987), one severe (1990) and one moderate (1992) drought. In addition to this report, Woldeamlak [9] also reported that the year 1984 was a year of lowest rainfall record in the Western Ethiopia with the worst drought occurrence.

**Future climate change relative to baseline**

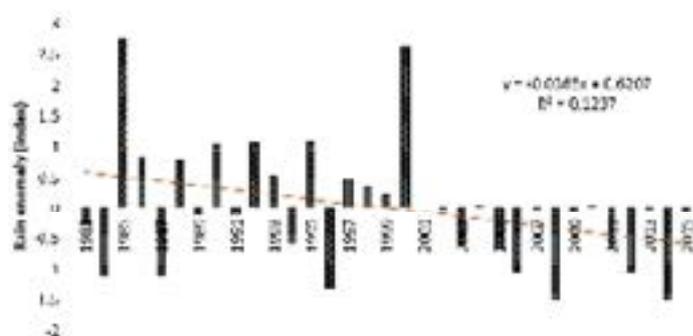
Future climate change relatives to the baseline period (1980-2009) are summarized in Table 4. The mean baseline annual rainfall was 1350 mm and the annual mean maximum and minimum temperatures were 26.5 and 10.4°C respectively. The projected of

**Table 4:** Future rainfall and temperature change relative to baseline period (1983-2015) in Adet, North Western Ethiopia.

| Variables   | CO <sub>2</sub> concentration (ppm) | RF (%)  | Max Temp (°C) | Min Temp (°C) |
|-------------|-------------------------------------|---------|---------------|---------------|
| Time slices | RCP 8.5                             | RCP 8.5 | RCP 8.5       | RCP 8.5       |
| 2030        | 432                                 | 2.47    | 1.04          | 0.93          |
| 2050        | 571                                 | 2.92    | 2.76          | 2.51          |
| 2080        | 801                                 | 5.36    | 4.69          | 4.73          |



**Figure 5:** Annual minimum temperature trend (1983-2015) in Adet, North Western Ethiopia.



**Figure 6:** Annual rainfall standardized in Adet, North Western Ethiopia.

both maximum and minimum temperatures using (equation (5)) are expected to increase in each time slice under RCP 8.5 scenario. On average, maximum and minimum temperatures are expected to rise by 1- 4.6°C and 0.93-4.73°C respectively in 2030 to 2080 time period. The rainfall also (equation (4)) will increase by 2-5% in 2030 to 2080 time period (Table 4). The positive change or increase in temperature indicates it will be warmer relative to the baseline. IPCC [36,37] indicated that large scale increase in average temperature in the mid and late 21<sup>st</sup> century. If the increasing temperature is not offset by adequate moisture, the intensity and duration of drought might increase, and results in failure of bread wheat production. For instance for each °C increase in mean air temperature during grain filling in wheat crop the duration of grain filling was shortened by 3.1 days and final kernel weight was reduced by 2.8 mg [38].

**Rainfall distribution**

Depending on the historical and future records rainfall data, the study area receives unimodal rainfall distribution during the main rainy season, in which the highest rainfall occurred from June to September. The projected rainfall has similar distribution with the historical baseline period (Figure 7). It should be noted that the slightly increase rainfall over the study area might not offset the negative impacts of temperature. The IPCC prediction on the level of precipitation showed a long-term increase in Ethiopia despite the short and medium term observation of frequent dry periods with extreme rainfall levels [39]. Flato et al. [38] noted, future climate projection is quite uncertain, the output depends on the number and type of GCMs used.

**Maximum temperature**

The average maximum temperature increase across the months from January until April and then decreasing up to July and finally rise from August to December (Figure 8). Similar pattern of projected maximum temperature is experienced with the historical baseline.

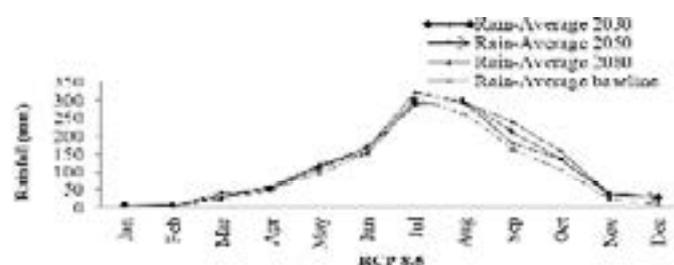
**Minimum temperature**

The average minimum temperature exhibits an increasing trend from January to April and stagnated for about four months, and then decline after July in all time slices (Figure 9). The increasing of temperature may have negative effect on yield production. For instance, for each °C increase in mean air temperature during grain filling in wheat, the duration of grain filling was shortened by 3.1 days and final kernel weight was reduced by 2.8 mg [39]. Wheat yield also has been predicted to decrease approximately 3-4% for each 1°C rise in temperature above 15°C during the grain filling period [40,41]. You et al. [42] also carried out research in China

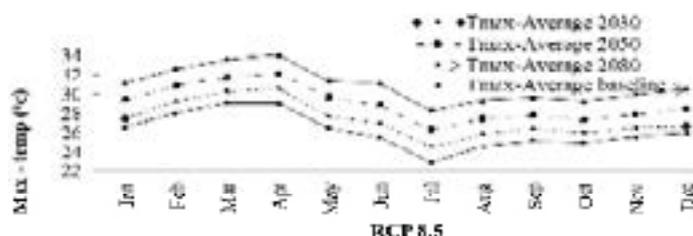
and found out that an increase in temperature of 1°C during the growing period may lead to wheat production reduction of 3-10%.

**Variability of grain yield**

For Tay wheat variety, the expected minimum yields are ranged between 22-30 qt ha<sup>-1</sup> while maximum yields are between 45-49 qt ha<sup>-1</sup> in time period of 2030-2080. On the other hand, 25% of yield results are ranged between 32-34 qt ha<sup>-1</sup> and 75% of the yield results are between 40-44 qt ha<sup>-1</sup> and less in time period of 2030-2080. Similarly, for Senkegna wheat 25% of yield results are expected in the range of 33-35 qt ha<sup>-1</sup>, and 75% of the yields are expected in the range of 44-45 qt ha<sup>-1</sup> in time period of 2030-2080 (Table 5). The variability of yields with the coefficients of variations ranged between 14-17% in time horizon of 2030-2080 showed less varied though the time period for both bread wheat varieties [43].



**Figure 7:** Projected annual rainfall distribution under RCP 8.5 scenario in Adet, North Western Ethiopia.



**Figure 8:** Projected annual maximum temperature under RCP 8.5 scenario in Adet, North Western Ethiopia



**Figure 9:** Projected annual minimum temperature under RCP 8.5 scenario in Adet North Western Ethiopia.

**Table 5:** Variability of grain yield (qt ha-1) for Senkegna and Tay wheat at different Slices under RCP 8.5 scenario in Adet, North Western Ethiopia.

| Statistical parameters   | Senkegna variety |       |       |       | Tay variety |       |       |       |
|--------------------------|------------------|-------|-------|-------|-------------|-------|-------|-------|
|                          | Baseline         | 2030  | 2050  | 2080  | Baseline    | 2030  | 2050  | 2080  |
| Minimum                  | 29.37            | 30.12 | 28.7  | 22.89 | 30.57       | 30.21 | 27.8  | 18.03 |
| 1 <sup>st</sup> quadrant | 33.26            | 32.96 | 33.47 | 34.75 | 32.89       | 32.66 | 33.26 | 33.48 |
| Median                   | 36.73            | 37.97 | 38.41 | 38.8  | 36.82       | 37.63 | 37.97 | 35.39 |
| 3 <sup>rd</sup> quadrant | 43.85            | 44.68 | 44.85 | 43.34 | 42.81       | 43.59 | 43.12 | 40.08 |
| Maximum                  | 51.15            | 50.26 | 50.36 | 49.57 | 49.13       | 49.77 | 49.05 | 45.42 |
| Mean                     | 38.79            | 39.18 | 39.68 | 39.11 | 38.2        | 38.81 | 38.47 | 36.1  |
| CV (%)                   | 16.7             | 17.2  | 16.7  | 15    | 15.6        | 16.7  | 15.5  | 14.9  |

### Change of wheat phenology

A yield gap analysis was done by using equation (6) and the results depicted in Figures 10 and 11. The days from planting to flowering and to maturity for the two wheat varieties are become shorten. Relative to the baseline, the anthesis and maturity days are expected to decrease by 5, 11 and 21% in 2030s, 2050s and 2080s for both wheat varieties (Figures 10 and 11). Abera [12] reported that the simulation days from planting to flowering and to maturity of Tay and Senkegna wheat varieties will be declined in the end of 2080. In line with this statement, the rise in temperature will increase the growth and development speed of the crops and leads to the shorter length period of grain filling [44]. On the other report, for each °C increase in mean air temperature during grain filling in wheat, the duration of grain filling was shortened by 3.1 days [38].

### Wheat yield change

The yield change in future climate relative to the baseline under RCP 8.5 emission scenarios are presented in Figure 12. The yield of Tay wheat is expected to increase by 0.5-1.3% in 2030 to 2050 but decreases by 3% in 2080s. The grain yield of Senkegna wheat will increase by 0.8-2.5% in all time slices. Future climate has positive impact on crop yield due to the elevated of CO<sub>2</sub> concentration increases photosynthesis and thereby increasing the carbohydrate pools of leaves and stems, and finally to grain yield [2]. Schulthess

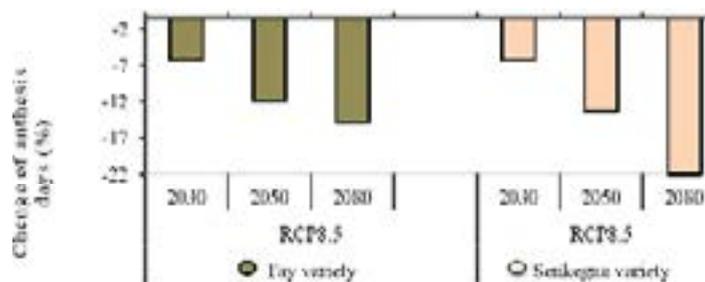


Figure 10: Change of anthesis days from the baseline in percentage for Tay and Senkegna wheat varieties in Adet, North Western Ethiopia.

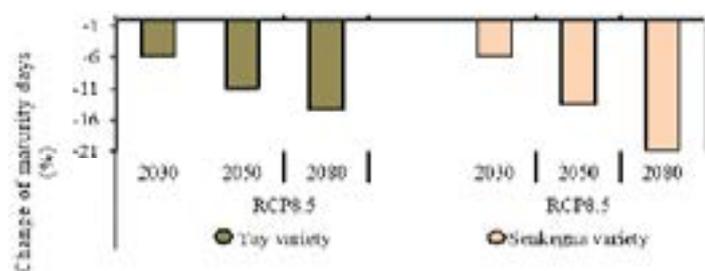


Figure 11: Change of maturity days from the baseline in percentage for Tay and Senkegna wheat varieties in Adet, North Western Ethiopia.

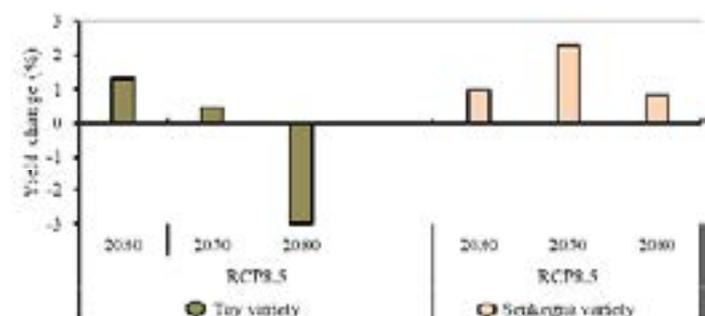


Figure 12: Grain yield change in percentage from the baseline period for Tay and Senkegna wheat varieties in Adet, North Western Ethiopia.

et al. [3] reported that temperature increase would result in yield reduction whereas increased the level of precipitation and CO<sub>2</sub> fertilization would have positive impact on the production of wheat in Europe. Gbetibouo and Hassan [4] also found that temperature increase would be havoc wheat productivity. These results suggest that an increase in temperature may offset the benefits of increasing CO<sub>2</sub> concentration on crop yield. Different outers used crop models for yield prediction and reported that future climate has positive and negative impact on wheat production. Lobell et al. [45] used CERES-Wheat model and found 25% increase in wheat production in the Mexico region. Guojo et al. [46] reported wheat production increase by 3.1% at low altitude by 4% at high altitude up to 2030s.

### CONCLUSION

The study output revealed that the rainy season over the study area was started in the 1<sup>st</sup> decade of June while the end date of rains was about in the 1<sup>st</sup> decade of November. The observed rainfall was decreased while both maximum and minimum temperatures showed increasing significantly (P<0.05). Climate projection revealed the increasing trend in temperature and rainfall in 2030 to 2080 time period. The positive change in temperature indicates it will be warmer than today in the study area. Although future climate changes have positive and negative impact on Tay wheat, the grain yield will increase relative to the baseline for both wheat varieties. On the other hand, the simulation days from planting to flowering and to maturity of the two wheat varieties become decline.

### ACKNOWLEDGMENT

I would like to address my thanks to the Ethiopian Institute of Agricultural Research for sponsoring my study and Haramaya University for admission to pursue a higher education toward MSc degree, Agro meteorology and Natural Risk Management in the School of Natural Resources Management program and Environmental Sciences. I would like also to Mr. Fasil Mekuanent at Melkasa Agricultural Research Center, and Mr. Muluken, at Adet Agricultural Research Center for his support during crop data collection.

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