

Review Article

# Impact of Climate Change in Wheat Yield and Water Productivity-Review

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## Abstract

Climate change is linked to many catastrophic events and causes many disasters for people around the world. We cannot say that just those impoverished countries are impacted by the worsening effects of climate change, when wealthier nations continue to lose billions of dollars and thousands of lives year. This review work's primary goal was to determine how climate change affects crop water requirements and productivity while also offering recommendations. Numerous books and papers, both published and unpublished, were reviewed as part of the methodology. The outcome showed that the impact of climate change will vary by region and could be either good or unfavorable. In some regions of the world, raising the temperature by just one degrees Celsius may significantly reduce wheat yield productivity, but in other regions, it will enhance yield and water productivity. According to those studies, despite an increase in yield and water productivity, the high levels of carbon dioxide in the environment will cause the quality to deteriorate. Additionally. According to the reports, depending on various situations and horizons with sowing dates as well, the water need for wheat production will fall by 10% to 32% as a result of temperature increases. Researchers also underlined that water productivity will occasionally decline if mitigating efforts are not made to address the effects of climate change.

## Keywords

Climate Change, Wheat, Wheat Yield, Water Productivity

## 1. Introduction

Even though they haven't realized it yet, climate change has become a major cause for international organizations and national leaders to band together in search of answers. Numerous extreme events are linked to climate change, which also leads to numerous calamities for people worldwide. Human activity is the primary cause of climate change, particularly in developed nations. However, this does not imply that developing nations do not contribute to the case; rather, their share is far smaller than that of wealthy nations. Even though wealthy and industrialized nations are the main sup-

plier, impoverished nations are severely impacted by the impact.

Since the wealthy continue to lose billions of dollars and thousands of lives year as a result of the worsening effects of climate change, we cannot claim that only those poor countries are affected. [1, 2] According to research by Wang et al., the concentration of CO<sub>2</sub> in the atmosphere will cause a 2.5-4.5°C increase in temperature if the current climatic trend continues. The effects of climate change don't stop with rising mean temperatures; they also increase crop transpiration and

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evaporation from soil and water bodies, which could lead to a drop in agricultural productivity from heat stress. [3]

The majority of African nations are increasingly depending on developed nations to supply their needs, including food. Despite the fact that most of them have abundant natural resources, climate change is causing them to be dependent. Water availability is drastically declining, rainfall is varying and not consistent, which has made it difficult for developing nations whose economies mostly rely on agriculture. [4] The goal of bringing developing nations into middle-income society will remain a theory that cannot be validated in a lab setting if communities, organizations, and governments at all levels fail to collaborate to maintain a better solution for this issue.

The change in climate is becoming paramount obstacle on agricultural production, availability of fresh water for crop production and access to food. If it continues as we are observing now, food insecurity in majority part of the world will be unavoidable. While we are talking about mean temperature rise due to climate change, we are talking about the possible increment in crop water requirement and decreases the water productivity of crop production in general of course with considerable decrement of days of crop growth stage.

Many studies show that the rise in maximum and minimum temperature will have different impact with respect to regional difference and geographical location. The same studies give emphasis on precipitation variation and its effect on crop water requirement as well as on water productivity. Some of them conclude that, if the climate change goes with the same pattern as it does before and now, producing sufficient amount of food for fast growing population number will be tough.

Research works that had been done in different parts of the world like Italy, Iraq, Morocco, Zimbabwe and US America too show almost similarity with their result and they stated the rise in temperature will increase the crop water demand and it will leads to diminution in water productivity because the agricultural production will show decrement in the future unless adaptation and mitigation methods take place especially in some critical part of the world like arid and semi-arid areas. [4-9]

According to different scholars' findings on the impact of climate change on agricultural production; the escalation in temperature and CO<sub>2</sub> in the atmosphere would have negative impact on yield production and water availability as well as water productivity for the future. As Naveen stated the reduction in production may hit up as high as 45% for cereals. [10] The influence may reach to the extreme point unless we find better solutions with strong commitments to apply. The main aim of this review is to generate information about the current status of climate change and its impact on agricultural crop production as well as on water productivity on some crops and give suggestion for stockholders who have responsibility to handle the future plan of the next generation. The main aim of this review work was to identify the impact of climate change on crop water requirement and crop productivity; to suggest adaptation strategies and management plans

for policy makers, and to generate information about climate change and its impact on agricultural crop production with respect to crop water requirement and water productivity.

## 2. Methodology

The methodology used for this seminar paper was a review of research studies that were previously conducted which are published and unpublished papers. Comparisons and synthesis of online historical data and reports of different institutions have been reviewed and presented.

## 3. Review Result

### 3.1. Crop Production and Climate Change in Agriculture

Increasing world population is putting agricultural demand under stress because the increasing number and demand for food is not matching in quantity as well as in quality. As UN report indicated population number in 2050 and 2100 will be 9.8 and 11.2 billion respectively. [11]

Climate change has high potential to affect agricultural production. As CABI climate change series book explained the climate change doesn't show the same effect on the environment and food production across the world. Areas with mid to high latitude will may beneficiary from temperature rise and in other hand locations of low altitude would be negatively affected. [12] Abadi strengthen this idea as he indicated in his report the projection on the productivity of crop with the change in climate will show slight increasing in quantity with the latitude of mid - high and mean local temperature rise of 1°C to 3°C and would decrease at the area of low-tropical and dry land with mean temperature of 1°C to 2°C. [4]. Similarly, study done in Morocco shows that the rise in temperature will have positive impact on production and water productivity of wheat though the quality of the yield may decrease due to reducing the content of plant nutrient which can be caused by high concentration of carbon dioxide (CO<sub>2</sub>) in the atmosphere. [8] Xei *et al.* strengthen this fact on their study result. [13] But it's not always true because Naveen Kumara stated that at the end of the century the cereals product reduction will be 20-45% for maize, 5-50% for wheat and 20-30% for rice. [10] Other study by Wang *et al.* stated that wheat production in the future will decrease due to climate change. The change will be different from region to region. For instance, the world largest wheat producer China had lost 1- 10% due to 1°C temperature rise in Southern China though 1-13% rose in the Northern part of the country based on baseline production year of the experiment (1981-2009). The same thing in France, which is the fifth largest producer of wheat will loss 3.5-12.9% of production in medium term from (2037-2065) and also winter wheat production would be decreased by 14.6-17.2% by the end of the century. [3]

The rise in temperature due to climate change can cause decreasing water availability in the soil due to evaporation aggravation. As a consequence, the food insecurity will arise since number of populations is snowballing but crop production is in the opposite direction. Especially in developing countries this will be a serious problem which requires high

attention in order to handle it. As Mall *et al.* studied climate change will have positive and negative impact on crop production according to the regional difference and adaptation strategies. According to the summary the climate change will hit almost the whole Africa in their crop production. [14] The following figure gives strong evidence about their result. [21]

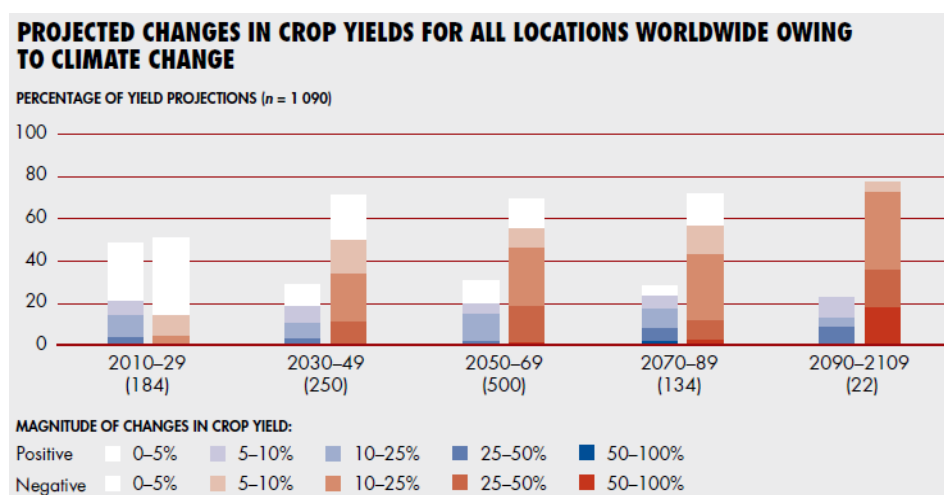


Figure 1. Projected crop yield for worldwide owing to climate change. (Source, FAO 2016- State of Food and Agriculture.).

### 3.2. Impact of Climate Change in Ethiopian Agriculture

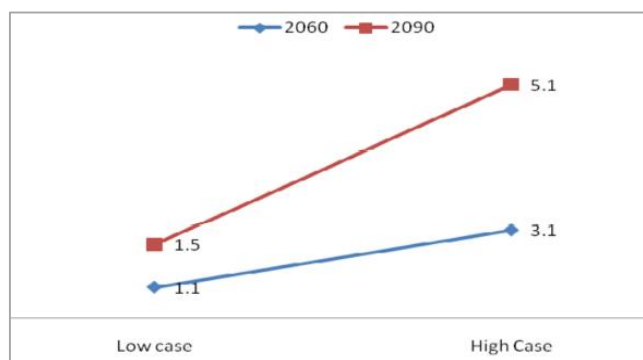
Ethiopia is one of the developing countries with approximate population number of 111M and agriculture is the milestone of economic activity. About 85% of the population lives in rural area leading its life through agricultural practices.

And also the agriculture is main source of employment in Ethiopia since around 80% of the population is part of agricultural activity. According to United Nation reports Ethiopia will become in the top ten of the most populated country in the world which implies the agricultural productivity need to have more emphasis if we are thinking of becoming among a member of middle-income countries before the end of 2030 [11, 15, 1].

Table 1. World population growth from 1950-2100. (Source; Pew Research Center; 2019).

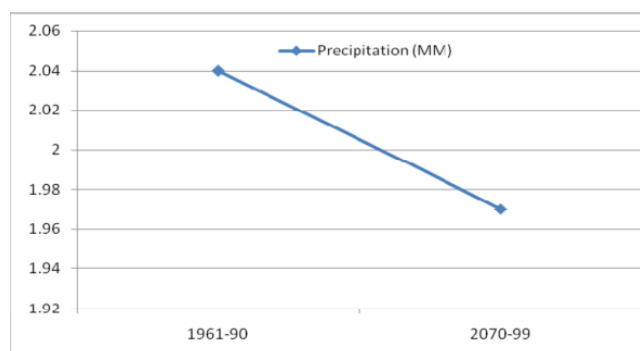
1950		2020		2100	
Country	P.N (MI)	Country	P.N (MI)	Country	P.N (MI)
China	554	China	1,439	India	1,450
India	376	India	1,380	China	1,065
U. S. A	159	U. S. A	331	Nigeria	733
Russia	103	Indonesia	274	U. S. A	434
Japan	83	Pakistan	221	Pakistan	403
Germany	70	Brazil	213	D. R. Congo	362
Indonesia	70	Nigeria	206	Indonesia	321
Brazil	54	Bangladesh	165	Ethiopia	294
UK	51	Russia	146	Tanzania	286
Italy	47	Mexico	129	Egypt	225

As studies show the mean temperature of Ethiopian climate is increasing significantly for the last many decades. Amare in his work said that Ethiopian mean temperature raised by  $1.3^{\circ}\text{C}$  from (1960-2006). Climate change didn't affect the temperature only but also the availability of precipitation in the country level. This made it hard for smallholder farmers who are very dependent on rain-fed agriculture due to variation in precipitation and yearly crop production is decreasing from time to time and becomes difficult to satisfy daily need for food. [2, 16, 1]



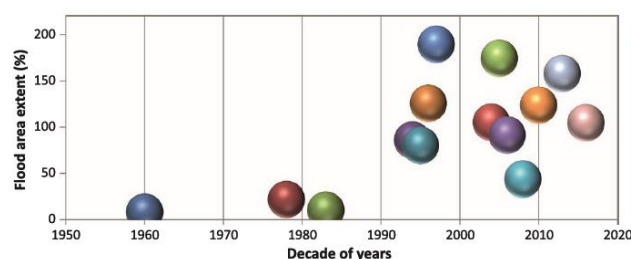
**Figure 2.** Evaluation of temperature rise in Ethiopia (Source; Amare, 2015).

From the above graph we can observe that for the next 80 years or more the temperature in Ethiopia will increase for sure. That means the crop production and water availability for food production will not stay as it is now. Due to significant evaporation brought on by the high temperature, the stream's flow may fluctuate or vary, which would result in a national shortage of water for irrigation crops. The population of Ethiopia is expected to quadruple by the end of the century, according to projections, therefore crop output will need to expand significantly in order to meet the population's need for food [17]. Amare also presented the variation of precipitation for the next decades and it indicated that the amount of precipitation the country receive will be decreased from 2.04 to 1.97mm in (1961-1990) and (2070-2099) respectively. [2]



**Figure 3.** Variation of precipitation rate from 1961-2099, (Source; Amare, 2015).

The reduction in crop production and variation in precipitation are taken as a serious problem of climate change in Ethiopia, it is also plain fact that it is becoming core reason of frequent drought and flooding in national level. As history and documentation narrates, the country has been exposed for extreme events of flood and drought. Reports indicate that every single decade in Ethiopian history there is at least one drought event and many flood phenomenon. There are several indications of this, like the 2020 flood that resulted from an unanticipated amount of rainfall and the flood from the Awash River and its watershed, killing numerous people and destroying thousands of acres of farmland before the crop was even harvested. In Ethiopia's past history, flooding has occasionally been worse and has expanded in extent. The main source of those flood events is climate change, which results in surprise floods from unpredictable or predicted but very uncertain precipitation type, even though other reasons, such as deforestation, urbanization, terrain, and steep slopes in the area, also play key role. [18] As Surafel *et al.* studied these two extreme events (drought and flood) affect the nation one after the other and many passes in difficult situation to overcome afterward effect.



**Figure 4.** Frequency and area distribution of flood event for the last six decades. (Source; Surafel *et al.* 2019).



**Figure 5.** Flood in awash river basin (afar regional state) in 2020. (Source; floodlist.com).



### 3.3. Crop Production and Climate Change in Ethiopia

For the last numerous decades crop production is decreasing due to different reasons nationwide. These includes; climate change, decline in fertility of the soil, shortage of rainfall availability, lack of improved varieties which can give better yield production, lack of mechanization in smallholder level and weak commitment for the adaptation of new technologies those can overcome the effect of all these factors. It's clear that weak farm land management and water in the field is part of cause for the production reduction. Though all these have impact in reduction of crop yield but the studies give a concrete evidence climate change is the paramount cause for the reduction in crop yield [17, 1, 10, 9].

Ethiopia is losing huge amount of production on the agricultural land due to sudden flood and other times cause of less precipitation on critical crop growth stage. The best example for this case in 2020 Ethiopia had lost 60,000 hectares of crop and farm land as the government reported. [19]

As of my experience farmers with farm land less than 0.5ha are struggling to cultivate their land on off season months which is the most crucial stage of crop development around North Showa. Therefore, the production would be less even up to not covering the production cost.

This is the story of many farmers that their crop production is very dependable on rainfall or small-scale irrigation schemes. Stream which are the source of many small-scale irrigation schemes during the off-season period shows sign of drying on this specific period because the season which is known as Belg in Ethiopian agricultural Calander which had been the best bridge between spring and dry season is becoming unsustainable or sometime it causes damage with unpredictable huge rainfall appearance. This is not the only problems but during summer (Jun - Sep) there is flood at most of Ethiopian regions and it causes soil erosion, land degradation of the top soil which is very fertile and full of nutrient for crop growth will be eroded. As a result, production is decreasing especially in areas which exposed for frequent flood event. [10]

### 3.4. Climate Change and Crop Water Requirement

#### 3.4.1. Effect of Climate Change in Crop Water Requirement

In global level the change in climate caused various changes in crop production process. Due to temperature rise the length of crop season have shown shortening. Though it differs according to planting time. The temperature rise results early maturity of crops so that they can resist the effect of the stress which have been caused by climate change. [8] The study also analyzed that the decreasing of length in crop season will cause for reduction of water requirement in wheat production. Based on twenty (20) (1991-2010) years data for

their study site early and late sowing dates reduced by 11% and 10% (17 and 13), respectively in 2050. While with the extreme scenario in 2090 horizon the reduction may reach up to 32% and 26% for early and late sowing date, respectively. According to their finding, water requirement reduced by 21, 15 and 13% from initial values of 353, 382 and 404mm for early, intermediate and late sowing date, respectively which clearly shows the reduction of water requirement of wheat production for the site. Certainly, declination of crop season length is not the only reason but also improvement in stomatal regulation of the crop to adjust with the scenario change due to climate variation. According to other study on Boro rice conducted in Bangladesh, crop evapotranspiration has decreased at a high rate over the past three decades, resulting in an 11% (on average, -4.4mm/year) decrease in irrigation requirement due to the crop's shortened growth stage as a phenological response to temperature rise. The result indicated that the reduction in irrigation water requirement will continue and it may reach up to 1.6% lesser than now in 2050 and 7.4% in 2080 with extreme scenario presented though the daily water requirement shows increment with reference to (1980-2013) base data. [20] Other studies controversy with these ideas and indicated increasing in water requirement due to temperature rise and the cause for the difference might be that the use of different equation as Elhoussaine *et al.*, used Hargreaves equation to analyze the crop requirement and others used different empirical formula. [8]

As daily water requirement of specific crop determined with the following numerical formula, temperature change due to climate change is very crucial point in crop water requirement analysis.

$$ETc = ET_o * Kc$$

Where, ETc is the daily crop evapotranspiration (mm/day), ET<sub>o</sub> is the daily reference evapotranspiration demand of the climatic condition (mm/day), and K<sub>c</sub> is constant and it is daily crop coefficient. Casolani *et al.* from Italy who studied on climate change and crop water requirement, the change in temperature (T<sub>max</sub> and T<sub>min</sub>) and in precipitation will have significant effect on crop water requirement in spite the effect has different degree of significance from region to region. According to their report, in some area the rise in T<sub>max</sub> has high effect on crop water requirement while in other area T<sub>min</sub> has more impact. The study also reported variation in precipitation will have negative effect and the effect is highly significant [5]. Other research report from Zimbabwe shows the same result as of Italy. It reported that increasing in temperature will affect the crop water requirement since it is the determinant factor of crop water requirement calculation and analysis. [6] Chowdhury *et al.* mentioned in their study that, in Saudi Arabia the increment in temperature will absolutely increase the crop water requirement in their study area (arid region). [7] Those studies also considered sensitive parameters and it shows the change in these parameters will affect the

analysis of crop water requirement and its amount in the future scenarios. Most studies related to climate change and crop water demand are concentrated on cereal crops which indicated that additional studies should be done in order to have better mitigation plan for future climate change adaptation technologies for other type of crops in general.

Generally, from these studies we can understand that, the water amount that needed to produce specific crop now a day will show variation in the future as a result preparation need to be considered. Hence, the rise in temperature causes the rise in reference crop evapotranspiration (ET<sub>o</sub>) it will also affect the crop water requirement based on planting date and geographical location. As plants are very sensitive for moisture stress, if there is shortage of water during their growth period significant loss of yield is unavoidable the same is true for water productivity. [9, 4]

### 3.4.2. Effect of Climate Change on Water Productivity

The word water productivity indicates that the ratio of yield above the ground to the water applied for the growing season. As of the definition the dominant factor for water productivity is the yields that have been harvested. If the yield shows decrements while the applied water remains constant the water productivity will show decreasing pattern. The change in climate is causing rise in temperature and evapotranspiration and the water demand to produce crop will increase in the future as literatures indicated. Due to shortage of season length in crop production as a result of high CO<sub>2</sub> concentration and high temperature in different regions and locations the grain yield will decrease. This is due to shortage of time in flowering stage as the stage is critical to have more yield at the day of harvesting. As Abadi mentioned the water productivity will decrease if adaptation and mitigation takes place as strategy to overcome the future impact of climate change. [4, 1] But this is not always true because Elhoussaine *et al.* on their study in morocco in Mediterranean region with base of historical data of (1991-2010) found increasing in water productivity for wheat and the cause was due to increment in photosynthesis process and high CO<sub>2</sub> concentration since wheat is C<sub>3</sub> plants and it's favorable for its production. They reported that the water productivity increased by 93% from initial values of 2.1, 1.6 and 1.3 kg/m<sup>3</sup> for early, intermediate and late sowing, respectively, at the end of the century for all climate scenario depending on sowing date. [8] The result indicated that as of other parameters water productivity and water requirement due to climate change has different impact based on the regional difference and latitude of the location as explained in the above subtopics.

## 4. Climate Change and Adaptation Strategies

Selection of improved crop varieties: introducing improved

varieties of crop is one way of mitigation for the purpose of climate change adaptation. Varieties which use less water while giving high yield production should be considered as a solution for water shortage and precipitation variability in the future. In improving of genotype of the crop, producing new variety which has an ability to resist diseases and pests caused by climate change and high temperature rise can be achieved. This achievement may help to reduce the effect of climate change on crop. [4, 10]

Improving water use efficiency: water use efficiency can be improved by introducing the most recent and productive way of irrigation method selection. Selecting more water conservative way of irrigation in areas with low water potential highly affected by climate change is a mandatory action in order to bring sustainable crop production and feed the nation.

Proper management of water during extreme conditions: the major problem now a day in crop production is lack of proper management on water using. Especially in Ethiopian condition farmers use excess amount of water to produce limited yield production without considering the consequence of their action on the future water availability and sustainable production. Water is the most expensive natural resource which needs extra care and planning management so that it can give what we are looking for. Harvesting it while it's abundant and use it whenever there's shortage should be used as one mechanism to overcome when extreme conditions like drought occurs and when there is shifting of seasons due to climate change effect. [4]

Recycling and reuse of waste water for irrigation: incorporating waste water management with irrigation technology practices will improve crop productivity and water productivity too. Recycling waste water from different sources can be used as source of water for irrigation practice and the same time we can save our rivers and streams from damage caused by untreated waste water disposal from industries, service giving sectors too.

Land use management: instead of abandoning the land when it shows the sign of salt accumulation and loss of its fertility characteristics continues, follow up should be considered from the beginning to avoid such event. And reclamation of lands which are already abandoned due to salt accumulation can be used by improved varieties with high resistant ability for salt and also ability to absorb the accumulation so that the land can be used for different crop production.

## 5. Conclusion and Recommendation

### 5.1. Conclusions

The major findings of this review are;

- 1) Climate change and increasing world population number are putting agricultural demand under stress.
- 2) Climate change is causing rise in mean temperature with varies range in different part of the world and also is

increasing CO<sub>2</sub> concentration in the atmosphere.

- 3) The rise in temperature is affecting the agricultural production of many countries.
- 4) Rise in temperature in high latitude region will be beneficiary while areas with low latitude will struggle with its negative impact.
- 5) Agricultural production is at risk due to climate change and variation in precipitation.
- 6) The crop water requirement will show different property with respect to topography and geography of different areas. In some part of the world region will increase while in other area it will show decrement in amount due to various reasons.
- 7) In most of world area water productivity will increase due to shorted length of crop season.

## 5.2. Recommendations

As we know climate change is not a single day process but gradual and takes overall the world. Even though each country doesn't contribute the same amount of cause for the climate change but everyone is suffering without discrimination. We all know that developed countries are the main source of climate change but it doesn't make developing countries out of responsibility as they have their own share in the process. Therefore, everyone needs to work together at least to minimize the effect so that everyone have secured food system to feed ones population. In addition to this working on different technologies and mitigation as well as adaptation needs to be considered. Especially, for the sector of agriculture adaptation and adaptability is an important task to overcome the vulnerability to climate change. Since we can't control the climate and as well as nature, we have to adapt our self with it. It is pure logic that the decrease in greenhouse gas emission by itself will not automatically stops the global warming of climate change as it takes to clean the already stored greenhouse in the atmosphere many years in the future. Because it is gradual process to see its effect on our environment while rising, therefore it will take time to avoid its negative consequences or results in the future too. So, it is up to us to create fresh and clean environment, which is free of greenhouse gases for the next generation. The following points can be used as mitigation methods;

- 1) Enhancing rainwater harvesting technologies and improving irrigation methods into more water conservative ways.
- 2) Introducing new varieties for smallholder farmers as well as commercial farms which can give more yield with adapting in changing environment and climate so that the production will become more sustainable.
- 3) Applying only required amount of water for the specific crop is other method for increasing water productivity and yield production.
- 4) Proper planning and management of water resource would help to minimize the negative impact of climate

change in agricultural production.

During preparing for this seminar, I tried to refer related papers and journals from Ethiopia as much as possible amazingly there are limited in number and only focused on reviewing instead of model analysis and see different scenarios in the future impact due to climate change on agriculture, water availability and productivity as in other countries. In this area other African countries are better than Ethiopian working with models and determining the future preview of their production and demand in order to feed their growing populations and policy makers are very close to researchers and their output so that they can prepare best strategies and policies to overcome the upcoming challenge caused by climate change.

It's recommendable to work with models and available data so that we can be prepared to any extreme events and phenomena which is the major problem of Ethiopia.

Policy makers need to give emphasis for research results especially on natural resource based one and agricultural outputs and have to try to prepare plans, strategies and management techniques as the country is still dependent on agricultural production whether for foreign exchange or local market as well as its GDP growth.

## Abbreviations

IPCC	Intergovernmental Panel on Climate Change
NASA	National Aeronautics and Space Administration
CABI	Centre for Agriculture and Bioscience International
UNDESA	United Nation Department of Economic and Social Affairs

## Author Contributions

Mahlet Wogu Amdneh is the sole author. The author read and approved the final manuscript.

## Conflicts of Interest

The author declares there is no conflicts of interest.

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