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The Effect of Climate Change on Yield and Quality of Wheat in Ethiopia: A Review

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1. INTRODUCTION

The changing climate is one of the biggest threats to agriculture during the years ahead (Kajla *et al*., 2015). Climate change refers to a period of time where a country or region goes through changing weather or temperature patterns than what is accustomed. Not only that, but it also refers to changes in seasons over long periods of time. Notably these changes have become more drastic in recent years, mainly due to global warming. Climate Change Refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC TAR2001).

Climate change is expected to increase future temperatures, potentially resulting in reduced crop production in many key production regions (Tack *et al*., 2015). Climate change is a serious threat to crop productivity in regions that are already food insecure(Knox *et al*., 2012). Climate change represents a significant challenge for delivering grain of consistent quality in the future due to the complex interactions of atmospheric CO2, changing temperature and rainfall patterns on yield and quality(Nuttall *et al*., 2017). Climate change is a global environmental threat to all economic sectors, particularly the agricultural sector(Abid *et al*., 2015). Global warming is the process of the Earth's surface and overall temperatures rising due to the amount of greenhouse gases being emitted into the atmosphere by humans(Hendrix, 2012). Recent global climate change has made this situation more serious. The expected changes in the climate could strongly affect the wheat production worldwide(Kajla *et al*., 2015). Climate change is a serious threat to crop productivity in regions that are already food insecure (Knox *et al*., 2012).

Africa is widely held to be highly vulnerable to future climate change and Ethiopia is often cited as one of the most extreme examples, with reference to the famines of the 1980s to warn of the disasters that may result from anthropogenic climate change(Conway & Schipper, 2011). The climate in Ethiopia is generally associated with tropical monsoon-type behavior, experiencing significant June-September rainfall, yet measurably cooler in its high plateau and Central Mountain range elevations(Paul *et al*., 2008). In Ethiopia the distribution of rainfall varies over the diverse agro-ecological zones that exist in the country(Zerihun, 2013). Ethiopia's rain-fed agriculture based economy is highly sensitive to climate fluctuations(Alemayehu, 2015). Ethiopia's agricultural sector, with cereals as the major food crop, is especially vulnerable to the adversities of weather variability and climate change and is characterized by poor productivity(Oumer, 2016). Climate change impacts on crop yield are different in various areas, in some regions it will increase, in others it will decrease which is concerned with the latitude of the area and irrigation application(Yinhong *et al*., 2009). The level of increase in climatic factors is dependent on the anthropogenic radiative forcing; the anthropogenic energy emissions influencing the energy system of the earth(Cathrine, 2014). Climate change is likely to influence food-producing capacity in many areas.

Cereals in Ethiopia are particularly important to the country's food security as they are a principal dietary staple for most of the population; they also comprise about two-third of the agricultural GDP and one-third of the national GDP and are a source of income for a majority of the people(Oumer,2016). Wheat has played a fundamental role in human civilization and has contributed to improving food security at global and regional levels. Meeting this demand is very challenging and is complicated by factors including: climate change; increasing drought/water shortages; soil degradation; reduced fertilizer supply and increasing costs; increasing demand for bio-fuels; and the emergence of new virulent diseases and pests that attack wheat crops(Tadesse *et al*., 2016).

Climate change affects wheat production by increasing both abiotic stresses (heat, drought, cold, salinity and water logging) and biotic stresses (aggressive diseases and insect pests). Climate trends over the past few decades have been fairly rapid in many agricultural regions around the world, and increases in atmospheric carbon dioxide(CO_2) and ozone (O_3) levels have also been ubiquitous(David and Sharon,2012). The effect of climate change is also affecting the quality of wheat as increasing CO_2 may negatively affect protein quality and content and increasing temperatures can negatively affect grain size(Tadesse *et al*., 2016). Rising atmospheric CO_2 concentrations provide some counteracting tendencies to the otherwise negative impacts of rising Temprature and reduced soil moisture(David and Sharon,2012). Thus, studying how climate change affects agriculture and how agriculture responds to a changing climate is important, since agriculture invariably influences the poverty reduction efforts of agrarian economies.

2. LITERATURE REVIEWS

2.1. Climate risk and food security in Ethiopia

Climate change is causing variability in weather factors such as precipitation, temperatures and soil moisture, and sometimes increased temperatures and prolonged droughts, which have compromised production of food crops in Ethiopia(Oumer, 2016). Water scarcity can cut production and adversely impact food security. Population and income growth will increase the demand for irrigation water to meet food production requirements and household and industrial demand(Munir *et al*., 2010).

About 70% of the world's current freshwater withdrawals are used for agriculture, rising to over 90% in most of the world's least-developed countries. Carbon dioxide also causes ocean acidification, which makes it harder for small shellfish to form the calcium carbonite shells they need to grow with implications rising up the food chain, threatening the availability of food from the seas as well(Report, 2016). A decrease of up to 30% in world food production due to effects of climate change on agriculture is generally predicted (IPCC 2007). Ethiopia's economy is highly exposed to climate variability and extremes.

Agriculture forms the basis of the economy supporting roughly 42% GDP and 85% employment (Byerlee *et al*., 2007). The nature of Ethiopia's agriculture, primarily rain-fed, means that production is sensitive to fluctuations in rainfall. Chronic food insecurity affects 10% of the population; even in average rainfall years these households cannot meet their food needs and rely partly on food assistance(Conway & Schipper, 2011). Climate change may affect agriculture and food security by altering the spatial and temporal distribution of rainfall, and the availability of water, land, capital, biodiversity and terrestrial resources(Munir *et al*., 2010). According to Assefa *et al*. (2008), small- scale, rain fed, subsistence farmers and pastoralists are the most vulnerable groups to climate changes in Ethiopia.

2.2. Climate change impacts on water use efficiency of wheat

Wheat can tolerate lower water supplies, but usually yields are lower when exposed to water stress(Tadesse *et al*., 2016). The upper limit of wheat yields is 10-12 t/ha and wheat water productivity is about 2 kg/m^3 of net water use, which is only attainable under favourable conditions and good management (Passioura and Angus, 2010). In developing countries, wheat yields are still low compared to developed countries and the wheat productivity per unit of water can be as low as 0.5 kg/m^3 (Periera *et al*., 2002). Wheat yields drop with water stress and good water management is critical to enhancing wheat productivity especially in water scarce regions(Tadesse *et al*., 2016). As water scarcity is increasing in many parts of the world, the need to increase wheat water productivity/water use efficiency is crucial, especially in developing countries where there is still great potential for improvement. As this is also associated with food security, increasing wheat production per unit of water is a top priority policy concern for countries who are net importers of wheat and who depend on wheat as a staple food crop(Tadesse *et al*., 2016). Climate change is expected to cause an increase in rainfall intensity in some areas, which is likely to increase runoff and reduce infiltration into the soil. This will negatively impact rain-fed wheat soil water availability. The low adaptive capacity coupled with other environmental factors including precipitation variability, population pressure, natural resource degradation and water quality and supply will continue to harm the agricultural sector. With regard to water resources, any changes in hydrological balance such as change in runoff due to climate change may limit surface water supply for irrigation which is already in high demand and may force shifting to poor quality groundwater resources(Tewodros, 2013). Climate change could impact on rainfall and runoff and the availability of water for irrigation in many regions and countries in the world(Munir *et al*., 2010). A decline in rainfall along with an increase in temperature will increase crop water requirement due to high evapotranspiration while less rainfall will increase crop net irrigation water requirements. As a result, the already existing water scarcity problem will exacerbate in many regions and countries, and affect food production(Munir *et al*., 2010).

2.3. Climate change effects on yield and yield components of wheat

Year-to-year climate variability affects the growth, development, and yield of crops(Salinger *et al*., 1995). Higher temperatures and CO_2 levels will likely change the wheat growth patterns and duration by shortening the growth cycle and altering the phenological stages(Tadesse *et al*., 2016). Increased CO_2 levels reduce stomatal conductance and transpiration rates(Gunther *et al*., 2002). However, higher early spring temperatures and fewer frost days may improve the early growth and vigor of the plants. With higher CO_2 levels, plants may transpire less. A combination of increased temperature with increased atmospheric levels of CO_2 will modify crop water use patterns, affecting the soil water status and the moisture uptake by the crops(Tadesse *et al*., 2016). Rising temperatures will decrease the length of grain-filling period of wheat and other small grains (Chowdhury and Wardlaw, 1978). Rising temperatures and changes in rainfall patterns have direct effects on crop yields, as well as indirect effects through changes in irrigation water availability(Nelson *et al*., 2009).

Pushpalatha *et al*. (2008) observed that rubisco activity decreased in wheat plants with a reduction in the photosynthetic rate when wheat plants were exposed to high temperatures. Increases of temperature above 25 to 35^{o}C, common during grain filling of wheat, will shorten the grain filling period and reduce wheat yields(Hatfield *et al*., 2011). When these temperature increases are extrapolated to the global scale a 5.4% decrease in wheat yield per 1°C increase in temperature is expected (Lobell and Field, 2007). Exposure to 36/31°C temperatures for only 2 to 3 dates before anthesis created small unfertilized kernels with symptoms of parthenocarpy, small shrunken kernels with notching, and chalking of kernels (Tashiro and Wardlaw, 1990).

2.4. The impact of climate change on wheat production

Global agriculture is facing the probable impact of global warming (Harold, 2015). Global warming is likely to bring local shifts in temperature and in the amount and seasonal distribution of precipitation. It is also likely to result in more extreme weather such as droughts and periods of heavy precipitation. Such changes can affect plant growth, the spread of pests and diseases, and water availability in both positive and negative ways(Doll & Baranski, 2011). Recent studies suggest that the production of major commodities has declined since 1980 due to global warming (Lobell *et al*., 2011). It is estimated that, given current warming trends in sub-Saharan Africa, the production of major cereals could decline by as large as 20% by mid-century (Schlenker and Lobell , 2010). The poor who depend on agriculture for their livelihoods and are less able to adapt will be disproportionately affected (World Bank 2007). A recent study estimates the annual costs of adapting to climate change in the agricultural sector to be over USD 7 billion(Nelson *et al*., 2009).

Valizadeh *et al*.(2014)reported that wheat production in the future will be affected by climate change and will decrease; to reduce these risks, the impact of climate change mitigation strategies and management systems for crop adaptation to climate change conditions should be considered. Temperature and CO_2 influence plant growth and development through their effects on stomatal opening and rate of physiological processes. Higher temperatures speed up the biochemical reactions and also increase transpiration losses. Stomatal conductance declines with increasing CO_2 concentration for crop which fix and reduce inorganic CO_2 into organic compounds (C3 plants)(Olivier Abayisenga, 2015).

Rising atmospheric CO_2 concentrations provide some counteracting tendencies to the otherwise negative impacts of rising Temperature and reduced soil moisture(Lobell & Gourdji, 2012). This seems to benefit more in terms of dry matter production from a higher CO_2 level, due to higher leaf expansion, increase in the photosynthetic rate per unit area, increase in water use efficiency and increase in photorespiration rates (Warrick *et al*., 1986). First, higher CO_2 has a fertilization effect in C3 species such as wheat, rice, and most fruit and vegetable crops, given that photorespiratory costs in the C3 photosynthesis pathway are alleviated by higher CO_2(Lobell & Gourdji, 2012). The lack of expected rainfall has also lead to water and pasture shortage within the country, which is absolutely one of the biggest problems(Hendrix, 2012). Farmers sensitivity to changing climate and the way they perceive the notable changes in rainfall and temperature condition and its impacts on crop production (Tewodros, 2013).

2.5. Effect of climate change on sustainable wheat production

Climate change affects wheat production by increasing both abiotic stresses (heat, drought, cold, salinity and water logging) and biotic stresses (aggressive diseases and insect pests). With the current climate change effects, it is anticipated that new pests and diseases will emerge as already exemplified in the recent epidemics of stripe/yellow rust across the Central & West Asia and North Africa and the Ug99 stem rust epidemic in East Africa countries (Solh et al.,2012). Changes in precipitation patterns, caused by climate change, will increase the likelihood of short-term crop failures and long-term production declines(Bekele *et al*., 2011). Any temperature increase will increase rates of evapotranspiration, possibly leading to a deficit in the water balance and posing a major challenge to rain fed agriculture(Habtamu *et al*., 2012). Changes in precipitation have more severe and determining consequences for crop production and yield stability depends on the optimum distribution of precipitation during the vegetative phenophases(Jolánkai *et al*., 2016).

2.6. Effect of climate change on the Quality of wheat production

Grain quality is influenced by genetics, management and environment. Maintaining grain quality of wheat under climate change is critical for human nutrition, end-use functional properties, as well as commodity value(Nuttall *et al*., 2017). Hatfield *et al*. (2011) have summarized research on grain quality related to protein content. In short, low nitrogen levels in soil are known to reduce grain quality in wheat, and this is further exacerbated in high CO_2. It is widely recognized that grain quality declines with increase in atmospheric carbon dioxide, so increases in grain yield (weight) do not necessarily indicate increases in global production of grain protein.

Kimball *et al*. (2001) reported that grain quality reduced due to low nitrogen is further reduced by high concentrations of CO_2. At low nitrogen levels, protein content was reduced by 39% under elevated CO_2 compared to a 33% reduction under ambient CO_2(Takle, 2011). Blumenthal *et al*. (1991) showed that there was a highly significant positive correlation of grain protein with hours above 35°C during grain filling, and negative correlations with dough strength and loaf volume. Randall & Moss (1990) showed that dough strength increased with temperatures up to 30°C, but decreased for even short periods above this.

2.7. Climate change impacts on food security and nutrition

Climate change is perhaps the most serious environmental threat to the fight against hunger, malnutrition, disease and poverty in Africa, mainly through its impact on agricultural productivity(Enete *et al*., 2016). Climate change increases child malnutrition and reduces calorie consumption dramatically. Thus, aggressive agricultural productivity investments are needed to raise calorie consumption enough to offset the negative impacts of climate-change on the health and well-being of children(Nelson *et al*., 2009). Although agriculture contributes to excess greenhouse gases in the atmosphere, it is possible to reduce emissions and even remove carbon dioxide from the atmosphere through specific land management practices(Doll & Baranski, 2011).

(Nelson *et al*., 2009)reported that, the impacts of climate change on agriculture and human well-being include: 1) the biological effects on crop yields; 2) the resulting impacts on outcomes including prices, production, and consumption; and 3) the impacts on per capita calorie consumption and child malnutrition. The biophysical effects of climate change on agriculture induce changes in production and prices, which play out through the economic system as farmers and other market participants adjust autonomously, altering crop mix, input use, production, food demand, food consumption, and trade.

Jolánkai *et al*.(2016) reported that weather impacts may have direct or indirect influence on the performance of agricultural production and food industry. The present problems are various, however, they can be sorted into two major groups: (1) factors that can be related to climate change processes like water scarcity, drought, meteorological extremities (temperature anomalies– frost, heat days, duration of unfavorable periods; precipitation – heavy rains, hail storms, land slide; air – storms, high wind, alterations of radiation and its postulates, (2) economic, social, and policy problems, that may have negative impact on the adaptability to meteorological factors in general and climate change processes in particular regarding food and agricultural production.

2.8. The future challenges of climate change on wheat production

The world faces an enormous challenge over the coming decades, as a combination of environmental change and a growing population makes food security harder to achieve(A J Challinor *et al*.,2010). Changes in mean temperatures can shorten the time to maturity of a crop, thus reducing yield. Experimental studies have also shown that even a few days of temperature above a threshold value, if coincident with anthesis, can significantly reduce yield, through affecting subsequent reproductive processes (Wheeler *et al*., 2000).

The nature of Ethiopia's agriculture, primarily rain-fed, means that production is sensitive to fluctuations in rainfall. Chronic food insecurity affects 10% of the population; even in average rainfall years these households cannot meet their food needs and rely partly on food assistance(Conway & Schipper, 2011). Recognizing the multiple drivers of change in Ethiopia, and how the challenges to enhanced well-being compound the adverse effects of climate variability and change will be crucial to taking effective action to reduce vulnerability to climate change in Ethiopia. A better understanding of what causes vulnerability will also help us interpret the results from climate models and the implications for society(Conway & Schipper, 2011).

Future climate change conditions are likely to be characterized by increased frequency of extreme events, such as heat waves, hail storms, excessive cold, heavy and prolonged precipitation and droughts, with negative impacts on crop yields. Extreme weather events such as heavy rain, hail storms and flooding can physically damage crops, while extremely wet conditions in the field can delay planting or harvesting. Prolonged droughts lead to outright crop failure. Compared to scenarios that only consider mean climate change, increased frequency of extreme events may lead to unexpected, earlier and larger impacts on agriculture with significant consequences for food production (FAO, in press). Therefore preparing agricultural systems to withstand increased climate variability is an essential component of appropriate adaptation responses (Rosenzweig *et al*., 2002).

Broadly speaking, adapting to changes in the mean climate will require farmers to: i) adapt management; ii) choose other more robust crop varieties; iii) select other crops; and iv) modify water-management practices. Such changes will come as a result of scientific knowledge and field experience. If widely adopted, these adaptations singly, or in combination, have the potential to offset negative climate change impacts and take advantage of the positive. It has been stressed that most farm-level adaptation responses may counterbalance impacts at low-to-medium temperature increases, allowing for coping with up to 1-2^{o}C local temperature increases, an effect that can be seen as 'buying time' (Howden *et al*., 2007).

SUMMARRY AND CONCLUSIONS

In respect of the above review it can be concluded and suggested that Climate change will be especially detrimental to crop production in cropping systems where soils have been degraded to a point where they no longer provide sufficient buffer against drought and water stress. These problems cannot be addressed by improving genetic adaptation to water or drought stress alone and will require agronomic interventions. Therefore, Practices that reduce soil evaporation include zero or minimum tillage, early and vigorous crop cover and keeping crop residues on the soil surface. Manage rainwater to prevent potential flooding, water logging, erosion, and nutrient leaching under increased rainfall; improving adaptations mechanism to climate change for agricultural sectors such as the resilient variety, cropping pattern, cropping system, irrigation techniques, sustainable land management, early warning, research, subsidies, supply of inputs etc. through support of the Government. The country should be trying to develop coping mechanism against natural hazards like floods, droughts, etc. The second strategy is to selecting the appropriate wheat variety for the conditions in the field and associated within a good cultural practices are important.

RECOMMENDATIONS

A few years ago, Dr. Norman Borlaug, the agronomist's father of the Green Revolution and Novel Peace Price Laureate 1970, stated: One of the most serious challenges that humanity will be faced with during XXI century, will be to develop the capacity to produce enough food for humanity but conserving the environment at the same time. Hence, the Ethiopians agriculture is believed to be suffering from severe climate change (examples of El-nano 2015), so that it will be more likely to adopt an aggressive policy toward climate change mitigation. Appropriate and consistent, government policies needed to provide an enabling environment for the development of the cereal sectors. A good funding of the agricultural research and extension institutions and leading to effective Agricultural technological development and diffusion mechanisms are important. To reduce uncertainties in global impacts, better estimates of rates of global warming and responsiveness of crop yields to warming and CO_2 (and their combination) would be particularly useful. At last but not least; Countries should include climate change effect agenda into their mainstreaming for the developmental plans and the climate change adaptation plan road map for the crop (cereals crop) should be developed.

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