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REVIEW ON: IMPACT OF CLIMATE CHANGE ON CROP WATER REQUIREMENT IN ETHIOPIA

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Abstract: The broad objective of this paper was to review and to give information for different users on impacts of climate change on crop water requirements and changes in water availability for irrigation in Ethiopia. Specifically, the review sought to assess climate change impacts and future climate change projections mainly on crop water requirement and other production systems in Ethiopia and selected countries using different literatures. Adaptations and mitigation strategies of Climate Change impacts are also reviewed. The results of the review had shown that climate variability is expected to increase the mean minimum and maximum temperature in future due to warmer atmospheric conditions, high evaporation and transpiration, as a results the demand of crop water requirement and demand of net irrigation amounts will be increase and it is expected more critical in the future. Addressing the issues is therefore imperative in terms of adaptation and coping mechanisms.

Keywords: Adaptation, Climate change, Crop water requirement, Ethiopia and Evaporation.

1. INTRODUCTION

1.1. Background

Nowadays, it has been widely agreed that climate change is already a real phenomena and is one of the global issue that would affect the sustainable development of many regions. Although the degree of the impact and its distribution is still debatable, many scientists, economists and policy makers agree that the world is facing a threat of global warming (Balling, 1992).The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and natural climate variability observed over comparable time periods" (Solomon, 2016). Although responsibility for the causes of climate change rests primarily with the developed and industrialized nations, the expenses of climate change will be bear most directly by the poor .

Change in the green house gases (GHGs) concentration due to human activities are the dominant cause of global warming that has taken place over the last half century (Balling, 1992). It has been estimated that doubling of the atmospheric concentrations of green house gases by the end of the century relative to preindustrial level is going to raise the mean global temperature by a range of 2–5.8^{C} changing the global climate with a doubling of the CO2 concentration in the atmosphere, annual precipitation to decrease on average by 30% by the year 2050 and it is expected to increase the intensity and frequency of extreme weather events (IPCC, 2007). Accordingly, this hot weather results water from plants evaporate to the environment highly and leads plant wilting. Climate change is already causing loss of life, damaging property and affecting livelihoods in many parts of the world, and it is expected to continue to do so in the future. Scientific evidence indicates that due to increased concentration of greenhouse gases in the atmosphere, the climate of the

Earth is changing; temperature is increasing and the amount and distribution of rainfall is being altered (Houghton *et al.*, 1996).

Though climate change poses devastating impacts in both developed and developing countries, the developed world are not committing their pledges to reduce green house gases emission (GHG), however. As a result, fixing the global temperature below 2^{o}C by 2020 is less likely to be achieved in the years to come (IPCC, 2007). Among the developing countries Ethiopia is one of the most vulnerable countries to climate variability. Because, the agricultural sector which contributes more than 45% of GDP, 80% to labor force and 85% to foreign exchange earnings is highly susceptible to climate change and is expected to have significant impacts on the economy of the country. A failure of rains and the occurrence of drought or consecutive dry spells during the growing season leads to crop failure, which in turn leads to food shortage. The ever increasing population in the country leads to increased food demand and as result demand for water also become increase. More than 95% of crop production which is rainfall dependent has been produced by small holders and subsistent farmers who have less capacity to adaptation of climate change (MoFED, 2006, Shimelis, *et al.*, 2011).The crop water requirement of different crops and water resources variability in the country is also one of the most sensitive issues to changing climate. On the other hand, Ethiopia's contribution to the global green house gases emission (GHG) is limited due to its lower economic activity (Amare, 2015).

In particular, changes to irrigation water quality, quantity and availability will be an impact of ongoing climate change in many areas (Solomon, 2016). In addition, as a result of the increased water scarcity and drought due to climate change, extensive water use for irrigation is expected to occur in the context of increasing competition between agriculture and other sectors of the economy (Jimenez, *et al.*,2014). Recent climate change impact assessment studies have indicated that changes in rainfall and increase in temperature are causing stresses on agricultural water as well as human health, and likely to continue to progress negatively in the future (IPCC, 2007).

1.2. Statement of the Problem

Today climate change is a big issue in any part of the world and affects all human activities. Agricultural practices are affected by climate change, particularly in those countries which are dependent on rainfed agricultural systems. A major effect of climate change is likely to be alterations in hydrologic cycles and changes in water availability for irrigation. Impacts of climate change on world aggregate net irrigation and crop water requirements are significant. As climate variable increases, the atmosphere air gets warmers, thus the warm air accelerates the evaporation from soil moisture. According to Milano *et al. (*2013), the combination of increasing temperature and decreasing precipitation could cause more intense and more frequent drought periods as well as induce a net decrease in freshwater availability. Similarly, climate change leading to increased surface temperatures, melting of snow and glaciers, rise in sea level and an increase in extreme weather events such as droughts and floods, can significantly affect water resources. The agricultural sector an integral part of the mixed farming system of Ethiopia is facing adverse impacts from climate variability, extremes and is one of the most susceptible sectors to climate change, with irrigation sector being the most climate sensitive economic area. Climate change adversely affect various aspects of irrigated areas including in rise of crop water demands due to high evaporation, transpiration as well as pests, and diseases.

Coping with climatic variability is certainly not new for African farmers, but the problem is that existing coping mechanisms may not match with the level of prevailing challenges that are likely to be faced in the future. For example, current climate variability is already imposing a significant challenge to Ethiopia by affecting crop water demand, poverty reduction, as well as by causing natural disasters (NAPA, 2007). Because climate change is global, concerns about its impact on agriculture in developing countries have been increasing and some attempts have been made to estimate this impact (Mendelsohn and Tiwari, 2000). Though this effort is growing, so far not much research has been done in Ethiopia both at local and national level as well as farm level adaptations that gives special emphasis on the impact of climate change on irrigation and/or crop water requirement. Accordingly, little is known about how climate change may affect the country's irrigation activity. This seriously limits policy formulation and decision making in terms of adaptation and mitigation strategies (Temesgen, 2007). Addressing these issues is therefore imperative in terms of crop and field management. Within this in mind, this review is proposed to identify impact of climate change on crop water requirement in Ethiopia.

2. IMPACT OF CLIMATE CHANGE

2.1. Impact of Climate Change on Crop Water Requirements (CWR)

Present water shortage is one of the primary world issues, and according to climate change projections, it will be more critical in the future. At present, nearly 80% of the world's population is exposed to high levels of threat to water security (Vorosmarty *et al*., 2010), and the increase of world population will have a significant impact on water usage for food. Under a pessimistic low yield scenario, De Fraiture and Wichelns (2010), estimated that 53% more crop water consumption is due to climate change and 38% more land are needed to achieve food production goals in 2050. It is known that global warming increases the evaporation of water into the atmosphere and changes the patterns of major airstreams and ocean currents such as El Niño and La Niña. This in turn alters the distribution of precipitation, so some regions experience greater rainfall and flooding while others become more prone to droughts.

Nowadays, the irrigated area has expanded to over 270Mha worldwide, about 18% of total cultivated land (Fischer *et al.*, 2007). However, as a consequence of increasing water scarcity and drought, resulting from climate change, considerable water use for irrigation is expected to occur in the context of tough competition between agribusiness and other sectors of the economy (Mancosu *et al*., 2015). Agriculture is the largest user of water among human activities: irrigation water withdrawal is 70% of the total anthropogenic use of renewable water resources. An estimated 50% of agricultural water withdrawals reach the crops - the remainder is lost in irrigation infrastructures and evaporating from irrigation canals due to warmer temperature. In recent years, rising temperatures, more variation in summer and winter temperature, erratic rainfall and prolonged droughts, along with steady growth population pressure have resulted in reduced supply and increased cost of irrigation water and other pressures on irrigated crops (Bruinsma, 2003).

In addition to the direct impacts of climate change on crop production, there is concern about future agricultural water requirements *vis-a-vis* water availability under the combined effects of climate change, growing population demands, and competition from other economic sectors under future socioeconomic development. Many researchers have been incorporated climatological cycle and its variability into the water resources system modeling in the recent past. Change on climate could affect the metrological parameters and which directly lead to change in irrigation water requirement in agriculture (Behera *et al.*, 2016).

2.2. Impact of Climate Change on Critical Areas in Ethiopia

2.2.1. Water resources and the environment

The economy of Ethiopia mainly depends on agriculture, and this in turn largely depends on available water resources. A major effect of climate change is likely to be alterations in hydrologic cycles and changes in water availability. The main consequence of changes in water resources for agricultural production is increased demand for water due to increases in crop evapotranspiration response to increased temperatures and increasing the water requirement for irrigation.

Ethiopia covers 12 river basins with an annual surface flow of 122 billion m^3 (75% drains to the neighboring countries),a relatively large volume. Even though, the country has huge water resources, due to lack of water storage capacity, inappropriate water use mechanism and large spatial and temporal variations in rainfall due to climate change, there is no enough water for most farmers to produce more than one crop per year and this leads frequent crop failures due to dry spells and droughts. Considering the above resource, Ethiopia is considered as the water tower of Eastern Africa. This is factually true when considering half of the country, particularly the western and South Western part of the country. However, as long as this resource is not available for productive and economic purpose during particular seasons of the year does not show economic availability and the country is considered as economically water scarce (Seleshi *et al.*, 2014). Especially the Eastern and North Eastern part of the country is also having a double challenge of having both physical and economic scarcity due to spatial and temporal variations in rainfall.

Figure 1: Effect of moisture on Maize

Being one of the very sensitive sectors, climate change can cause significant impacts on water resources, certain components of the hydrological cycle and this will have important effects on irrigation development. Even if Ethiopia is also known as a water tower of east Africa, today many rivers and lakes become shrinking in size due to the decrease in river flow and some small streams dry up completely, and finally the magnitude of flow of the medium to large rivers will decrease significantly (Solomon, 2016).

Results indicate that climate change is likely to increase water resource scarcity in Ethiopia. For instance the scenarios developed for Lake Ziway from the years 2001-2099 showed that despite the increasing trend of climatic variables, the increase in precipitation seems to be obscured by increases in temperature and hence, the total average annual inflow volume into Lake Ziway might decline significantly. This is likely to drop the lake level up to two third of a meter and shrink the water surface area up to 25 km^2. Therefore, in Lake Ziway, runoff is likely to decrease in the future and be insufficient to meet future demands for water of the ever increasing population (Lijalem, 2007).

Climate change has also several impacts on the environment in addition to the disruption to water resources we have just described above. Increased heavy rainfall as a result of climate change can cause soil erosion, crop damage and water logging, which makes the land difficult or impossible to cultivate for agriculture in general and for irrigation in particular. It is estimated that Ethiopia loses more than 1.5 billion tons of fertile soil each year through heavy rain and flooding and this aggravates the problem of food security in the country like shown in Figure 2.

Figure 2: Active land degradation as a result of soil erosion in Northern Ethiopia

(Source: Impacts of Climate Change in Ethiopia. http://www.open.edu/openlearncreate/mod/)

2.2.2. Impact of climate change on crop water requirement in Ethiopia

Crop water requirement (CWR) is the total quantity of water, regardless of its sources, required by the crop in a given growing season (from the time it is sown to the time it is harvested) for compensating the evapotranspiration loss plus water used for digestion, photosynthesis, transportation of minerals and foods and also for structural support. Crop water requirements can also be defined as 'the depth of water needed to meet the water loss through evapotranspiration of a crop. The values of ETc (crop evapotranspiration) and CWR (Crop Water Requirements) are identical, whereby ETc refers to the amount of water lost through evapotranspiration and CWR refers to the amount of water that is needed to compensate for the loss (Savva and Frenken, 2002).

Climate is one of the most important factors determining the crop water requirements needed for optimal growth and yield. An increase in irrigation water demand, particularly in irrigated areas, is projected because of climate change (Cisneros *et. al.*, 2014). Climate variables like temperature and precipitation are the important determinants of crop productions. At mid to high latitudes, crop yields may increase for low levels of change in temperature, but will decline at higher levels of temperature change (Solomon, 2016). Thus, in future the mean minimum and maximum temperature are expected to increases. As a result the demand of crop water requirement will be increase in future.

According to Hopmans and Maurer (2008), the prediction of climate change impact on crop growth and crop water demand (ETc) or seasonal potential crop ET is calculated as;

$$ETc = Kc * ETo$$

Where *ETo* is daily reference ET (mm), *Kc* is daily crop coefficient and the consideration of future changes in potential crop evapotranspiration (*ETc*) rates is caused by (i) increased atmospheric CO2 levels and (ii) increased air temperatures.

For instance an experiment on impact of climatological parameters on crop water use of maize and sorghum at Adami-Tulu Jido-Kombolcha woreda, Central Rift Valley of Ethiopia clearly shows that maximum temperature, minimum temperature and sunshine hours has positive correlation with ETc of both Maize and Sorghum. The results show that in future crop water use of both selected crops will increase in the study area. Here, it is easily noticeable that maximum temperature has the highest coefficient of correlation with ETc. The value of maximum temperature is affecting ETc more for both crops as compared to the sunshine hours, relative humidity and wind speed. Rainfall and minimum temperature do not perform significant association with ETc. The implication of this result is that; the higher maximum temperature affects the ETc of Maize than Sorghum (Gemechu, 2016). The experiment further describes the future ETc of Maize and Sorghum rise in crop evapotranspiration in all future periods (2020 and 2050) when compared to base period 1984-2013. In the period 2020 and 2050, Maize will shows increment in crop evapotranspiration by 15% and 34% respectively. In case of Sorghum, in the period 2020, it shows negligible increment (1%) in crop evapotranspiration and may increase by 37% in 2050. Generally, the results show that in future years the crop water use of both the selected crops will increase in the study area. The reason for this may be due to increase in air temperature and decrease in relative humidity in future years (Gemechu, 2016).

Similarly a model was simulated for estimating crop water use of maize and sorghum using CROPWAT model based on ten-year crop and metrological data at Adama and Miesso. The results showed that the water used by crops in both these districts was far less than actually needed, with pronounced effects on the simulated yield reduction percentage. The results show a decrease in yield of 40–70% as a result of the increase in evaporation rate. This yield reduction is caused by climate change effect. Increased evaporation because of higher temperatures combined with the reduction in rainfall and lower water availability in the soil means that the supply of water does not match the demand. This affects the overall condition of plants and their yield (Kidane *et al.*, n.d.). The reduction in yield might be due to the early cessation of rain fall which do not complete the growing period of the crop combined with extended dry spells within the growing season in the study area. This indicates the current rainfed cultivation demands supplementary irrigation due to climate change.

Hydrochemical constituents of irrigation waters can have a significant negative effect on crop productions and soil fertility. With increased evaporation due to global warming combined with reduction in rainfall may lead to stress in water availability and quality. When the temperature warmer and warmer there is high evaporation from the soil surface and this leads accumulation of salt on the ground. If salinity increased beyond the safe threshold of a crop, the crop yield will decline linearly with increase in salinity (Mass and Hoffman, 1976).

2.3. Impact of Climate Change on CWR in Selected Countries

Results indicate that climate change is likely to increase water scarcity around the globe, mostly in regions that already suffer under present conditions, such as the southern Mediterranean, the Middle East, and Sub-Saharan Africa. Within this context, even fewer studies have specifically addressed future regional and global changes in irrigation water for agriculture. Doll and Siebert (2001), developed a global irrigation model by integrating simplified agro-ecological and hydrological approaches. Doll (2002), used this framework to investigate global impacts of climate change and variability on agricultural water irrigation demand by comparing the impacts of current and future climate on irrigated cropland. She found that changes in precipitation, combined with increases in evaporative demands, increase the need for irrigation worldwide, with small relative changes in total, about + 5-8% by 2070 - depending on the general circulation model (GCM) projection - and larger impacts, about + 15%, in Southeast Asia and the Indian subcontinent.

An experiment on Paddy in Taiwan also shows that, due to the rising temperature, the estimated evapotranspiration will increase in the cropping seasons in the future. Meanwhile, estimated crop water requirement would increase 36.0% and 15.2% in the 1st and 2nd seasons respectively. A comparison between (2004–2011) and the future (2046–2065) in this region clearly shows that climate change would lead both rainfall and the temperature to rise; this would cause crop water requirement to increase during cropping seasons in the future (Lee, 2014).Similarly under future scenarios of crop irrigation needs in Western Mediterranean Region, the total annual rainfall slightly decreased (−7%) and the total annual evapotranspiration of the irrigated crops increased by between +5% (alfalfa) and +7% for Italian ryegrass + silage maize (Nguyen and Mula, 2016).

Moreover, in semiarid regions, where Egypt is located, more pressure will also be put on water resources distribution between economic sectors under climate change, especially agriculture. Reduction in the amount of allocated water for irrigation, increase in water requirements for crops, and yield reduction under climate change conditions will worsen food security situation in Egypt. For instance, the effect of climate change was more pronounced on maize as a high water demanding crops and the applied irrigation amount for these crops is expected to increase in all governorates under climate change in 2040 by 10 - 19%. Research on the effect of climate change on season length also indicated that it could be reduced by 7–12 days in this country and the water requirements for wheat will also increase by 2–19% depending on governorate location (Khalil *et al.*, 2009; Ouda *et al.*, 2009). The reduction in growing season is that most plants grow faster under elevated CO2 even under stress conditions (Ainsworth and Long, 2005).

The reason for this is that, Predicted increases in air temperature may result in faster plant development and therefore shorter growing seasons. These higher temperatures shorten the life cycle of grain crops, resulting in a shorter grain filling period, so the plants produce smaller and lighter grains, culminating in lower crop yields and perhaps poorer grain quality (Hopmans and Maurer, 2008).

Table 1: Applied irrigation water for wheat under current climate, water requirements in 2040, and percentage of increase (PI %) in Middle Egypt.

Middle Egypt Governorate	Applied irrigation under current climate (mm)	Water requirements under climate change (mm)	PI (%)
Giza	556	664	19
Fayoum	516	594	15
Beni Swief	544	644	18
El-Minia	531	631	19

Source: Hopmans and Maurer, 2008.

2.4. Future Climate Change Projection in Ethiopia

According to World Bank's climate projections model, global warming leads to rainfall variability with a rising frequency of both severe flooding and droughts. Economy-wide impacts of climate change studied by the World Bank indicated that the GDP losses are significant. The model highlights the high degree of vulnerability of Ethiopian agriculture and infrastructure to the climate shocks of the future (World Bank, 2006). Ethiopia is currently facing the effects of severe droughts caused by partial and in some areas total failure of the two main rainy seasons. Worsened by El Niño, this drought is threatening wide parts of the country with famine. Official reports of December 2015 stated that 10.2 million people were in need of emergency assistance (Peters *et al.*, 2016).

Ethiopia's mean annual temperature is also showing a significant warming trend. Future projections show that the mean maximum temperature will increase by 2-2.3^{0}c until 2030 and by 2.2-2.7^{0}c until 2050 while the mean minimum temperature will rise by 0.8-0.9^{0}c until 2030 and 1.4-1.7^{0}c until 2050 (Peters *et al.,* 2016), and that these will increase evaporation and soil moisture deficits both in the near and the long term. Furthermore, precipitation is projected to decrease from an annual average of 2.04 mm/day (1961-1990) to 1.97 mm/day (2070-2099), for a cumulative decline in rainfall of 25.5 mm/year (NAPA, 2007). As the number of rainy days decreases, dry spells become more sever in their impacts and result in crop moisture stress in the growing season. According to Shimelis (2011), a dramatic reduction in precipitation or increase of actual evapotranspiration would cause soil moisture stress in the country. The resulting negative agricultural water balance would reduction both rain-fed and irrigated agriculture productivity.

2.5. Can Climate Change May Help Ethiopia?

Despite the many disastrous impacts of climate change, there are some regions of the globe that might benefit from hotter temperatures. Reports of a team of researchers from Virginia Tech have predicted that water availability in the Blue Nile Basin of Ethiopia may increase in coming decades due to global climate change. While climate change will continue to cause untold problems, nuances in climate-induced weather events could benefit the Blue Nile Basin with increased rainfall in the area. It could also lead to increased crop production, spur massive hydroelectric power projects, and foster irrigation development in the region. The research team report also indicates "for all the catastrophic impacts of climate change, there are some silver linings, that climate change may be the catalyst Ethiopia needs to become a food-exporting country."(Available at https://phys.org/news/2016-10-climate-ethiopia-country-access.html#jCp)

Figure 3: Water gushes over falls in the Blue Nile River Ethiopia.

2.6. Adaptations and Possible Solutions to Climate Change

2.6.1. Adaptation and mitigation Strategies

Global environmental changes and increased climatic variability demands adaptation options and ways to minimize risks (Getachcew, 2010). Efforts to develop adaptation strategies for agricultural water management can benefit from understanding the risks and adaptation strategies proposed to date. This understanding may assist in developing priorities for the adaptation of water resources for irrigation. As indicated by Solomon (2016), adaptation describes a set of responses to the actual and potential impacts of climate change to moderate the harm or take advantage of the opportunities that climate change may bring. Hence the adaptation options should focus on increasing water utilization efficiency and water availability and on ensuring better management.

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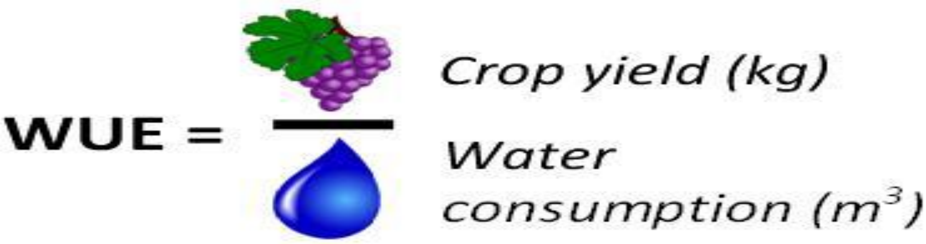
With regard to irrigation water management, climate change adaptation may include: implementation of appropriate irrigation water management practices, adoption of efficient irrigation systems (e.g. drip irrigation systems) and awareness creation on efficient water utilization, implementation of water pricing and water recycling, development of effective rainwater harvesting technologies, adoption of varieties and species of crops with increased resistance to heat stress and drought and appropriate use of groundwater resource as climate change adaptation tools, enhancing stakeholder participation in water development and climate change adaptation.

Figure 4: Efficient water utilization (NPA, 2007).

Similarly, use of deficit irrigation, conjunctive use of surface and groundwater, desalinization, water harvesting and natural resource conservation are also adaptation strategies and measures in response to climate change impacts on water availability and irrigation requirements (Iglesias and Garrote, 2015). Increased impacts of climate change and variability also make the rural agrarian people to practice various adaptation and coping strategies. These include mainly indigenous knowledge and wide variety of skills developed outside the formal education over a long period of time among the rural communities (Mongi *et al.*, 2010). In addition to this mitigation of green house gases (GHGs) is essential to slow the impact of climate change. This is mostly the issue of developed world being they release mere GHGs from their industries.

2.6.2. Improving water use efficiency and productivity

The slogan 'more crop per drop' calls for improving the efficiency or the productivity of water use to meet future global food demand as well as reducing the excessive wastage of water (Lankford, 2006). Nowadays, many strategies are implemented to improve water productivity, starting with the optimal choice of irrigation system, followed by the application of the proper irrigation scheduling in terms of both timing and quantity of water applied and concluding with the choice of the best crop management with regards to the soil and climate conditions. Improved irrigation use efficiency is also an important tool for intensifying and diversifying irrigated agriculture, resulting in higher economic yield from irrigated farmlands with a minimum input of water. Finally an increase in water productivity ameliorates gains in crop yield, while reducing the amount of irrigation water contributing to unrecoverable losses.



2.6.3. Reusing of waste water

The shortage of water can be augmented from wastewater utilization after suitable treatment (FAO, 2012). Some of the techniques like artificial recharge and use of unconventional water (reuse of wastewater after recycling) are effective solutions to minimize the impact of such problems. The unconventional water can play a major role in the management of water resources and agricultural activities in dried and semi dried areas. Recycling and reuse of wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes and replenishing a groundwater aquifer (groundwater recharge) can help in minimizing the impact of climate change on crop yield and water resources. Recycled water for irrigation requires less treatment than recycled water for domestic purposes and till date no documented case of human health problems has been reported by the use of unconventional water for irrigational purposes (Misra, 2014).

3. SUMMARY AND CONCLUSIONS

In summary**,** the main findings of this review are outlined below.

- Climate change is the current threats and global issue that would poses devastating impacts, extreme events (drought and related shocks) in both developed and developing countries and Ethiopia is one of typical example.

- Climate change is already causing loss of life, damaging property and affecting livelihoods in many parts of the world, and it is expected to continue to do so in the future.

- Globally the impacts of climate change on increasing crop water requirements could be nearly as large as the changes projected from socio-economic development in this century.

- The results of crop model simulations demonstrated that the increased temperature scenarios may induce an increased demand for irrigation of crops because of heat stress in future.

- Different investigations indicate that, climate variability is expected to increase the mean minimum and maximum temperature in future; as a result the demand of crop water requirement will be increase in future. Although higher temperature shorten the life cycle of grain crops and resulting in a shorter grain filling period, the plants produce smaller and lighter grains and this results in over all yield reduction, however**.**

- Although Ethiopia's contribution to the global green house gases emission (GHG) is limited, climate variability including droughts and higher temperatures, are a major challenges to expand irrigation development of the country. As a result, crop failure is the most common consequence of changing climate in Ethiopia.

- Water management for irrigation is becoming increasingly complex. Therefore, to meet the increase water demand and to increase yield for future, water resources management should be necessary, in which policy maker, planner and water user like farmers, investors should participate. As a result future demand and supply can be balanced and this leads to minimize the negative impact of climate change.

- Finally, the review indicates that the risk of water shortage for future irrigation demand in Ethiopia needs further study. Also, more work is needed on quantifying uncertainties in projected climate impacts, adaptation and mitigation can and should play an important role in reducing the impacts of climate change on irrigation water resources, globally and regionally. The adaptation options should also be focus on increasing water utilization efficiency and water availability and on ensuring better management.

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