Environment Pollution and Climate Change

Weldegebriel and Gustavsson, Environ Pollut Climate Change 2017, 1:3
DOI: 10.4172/2573-458X.1000125

Review Article | OMICS International

Climate Change Adaptation and Mitigation Strategies Vis-À-Vis the Agriculture and Water Sectors in Ethiopia - Case Review/Study of the EPCC Project

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Abstract

This study is a case review of the Ethiopian Panel on Climatic Change (EPCC) project, particularly the EPCC First Assessment Report, with special emphasis on the Mixed Crop Livestock (MCL) system, along with the water sector as it relates to climate change adaptation and mitigation strategies in Ethiopia. A key finding of this study is that there currently exist serious, direct impacts of climate change to crops, livestock, and water as compared to other economic sectors in the country. Impacts of climate change to crop sector are in terms of decreasing in both productivity/yield and cultivable land (in some crops like maize shifted from lowland areas to highland areas; while, barley since it is a highland crops, due to climate change its cultivable land diminished and productivity decreased) due to high temperature and water deficit. Despite to some extent livestock are better off even with higher temperature, overheating may significantly harm livestock production. Meanwhile, the water sector of the country gets impacted negatively by climate change by decreasing soil water, ground water and stream flow due to high evapotranspiration in some areas. To alleviate these negative impacts of climate change, there are trends of adaptation and mitigation strategies practiced at both private and community bases. Some of the explored adaptation strategies are macro-level, micro-level (farm level) and 'No regret' adaptations options (adaptation options which provide yields with tolerable cost even in the absence of climate change). It also discussed that there are mitigation strategies to immune level of emissions from particularly the agriculture sector (i.e., from crop, mainly livestock and natural resources). Some of the mitigation strategies identified and reviewed are: reducing expansion of cultivated land through agricultural intensification (increasing productivity by reducing Green House Gas (GHG) emission: conservation agriculture, compost, wise use of inorganic fertilizers, proper crop management); improving animal productivity through breeding; feedlots practice by smallholder farmers; improving feed and feeding management; diversification toward lower emitting animal species (small ruminants); mechanization; manure management; afforestation/reforestation; agroforestry; soil and water conservation and land rehabilitation; and reducing rate of desertification. However, it also noted that there should be given prior emphasis to adaptation than mitigation particularly in developing world like Ethiopia since it is local, complex and process based but practical and applicable, despite the trend is now shifted to it. Nevertheless, prior to intervene and/or scale up any adaptation option, there should be done livelihood based vulnerability assessment with specific to each agro-ecology and gender in the country. Doing this assessment first means, it is now easy to device or scale up any adaptation options to the community in general and women in particular. This report major finding will be reached out and communicated to the wider community via various means. There by, it will hopefully be upgraded the lower level of community awareness to climate change issues in general so that climate smart socio-economic development and well-being will be maintained and/or sustained in the country.

Keywords: Climate change; Vulnerability; Adaptation; Mitigation; Agriculture; Water; Women

Introduction

The Ethiopian Panel on Climate Change (EPCC) established in February 2014 under the auspices of the Ethiopian Academy of Sciences (EAS), primarily to, inter alia, produce periodic assessments of climate change issues in Ethiopia. It is a sub-project of the "Environment Service and Climate Change Analyses Program (ESACCCAP)"project jointly run by the Ethiopian Academy of Sciences, the Climate Science Centre (CSC) and the Horn of Africa Regional Environment Centre and Network (HoA-REC&N) of Addis Ababa University with financial support from the Department for International Development (DFID) UK, the Danish Government and the Norwegian Government through the Strategic Climate Institutions Programme (SCIP) [1].

EPCC has produced its First Assessment Reports from the two Working Groups (WG) namely, WGI- the Physical Science Basis and WG II- Climate Change Impact, Vulnerability, Adaptation and Mitigation. The 2nd WG has five Sub-Working Groups: Agriculture and Food Security, Biodiversity and Ecosystem, Water and Energy, Health and Settlement, and Industry, Transport and Infrastructure). In addition to these, the Gender Task Force and Climate Policy and Institutional Framework are the other components of EPCC.

Ethiopia's per capita emission of less than 2 ton CO_2e (Carbon Dioxide equivalent) is low compared to more than 10 ton in the EU and more than 20 ton in the US and Australia. The country's total emissions of around 150 Mt CO_2e represent less than 0.3% of global emissions. The agriculture sector is one of the major contributors of GHG (Green

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Received April 26, 2017; **Accepted** May 23, 2017; **Published** May 30, 2017

Citation: Weldegebriel NW, Gustavsson H (2017) Climate Change Adaptation and Mitigation Strategies Vis-À-Vis the Agriculture and Water Sectors in Ethiopia - Case Review/Study of the EPCC Project. Environ Pollut Climate Change 1: 125. doi: 10.4172/2573-458X.1000125

House Gas) emissions in Ethiopia through the crop, livestock and natural resources carbon footprints (like as a result of soil degradation and land use change from forest land to agricultural land). For instance, there are 50% and 38% GHG emissions from the agriculture and forestry sectors, respectively [2]. Ethiopia intends to limit its net GHG emissions in 2030 to 145 Mt CO_2e or lower. This would constitute a 255 MtCO_2e or 64% reduction from the Business As Usual (BAU) emissions in 2030, which would otherwise become 400 Mt CO_2e with BAU in the same year [3].

Inversely, this has impacted the agriculture sector in a way that rainfall variability and associated yield reductions are estimated to cost Ethiopia around 38% of its potential growth rate and increase poverty by 25% [4]. Since the country's main-stay and/or economy are based on agriculture, climate change could negatively affect agriculture. Thus, it will ultimately reduce GDP by 3-10% by 2025 [5]. Results show that warmer temperature is beneficial to livestock agriculture, while it is harmful to the Ethiopian economy from the crop agriculture point of view. Moreover, increasing/decreasing rainfall associated with climate change is damaging to both (crop and livestock) agricultural activities.

Although Ethiopia is, relative to many African countries, richly endowed with water, the spatial and temporal distribution of water is highly uneven, making certain places and times of the year very dry and water scarce. The rivers of Ethiopia exhibit typical characteristics of tropical rainfall-dependent flow regimes. Hence, the spatial and temporal distribution of rainfall governs amount and intra-and inter-annual variability of water availability. This is due to mainly effected from the changing climate that is happening now around the globe. There by, the blessings of water have primarily positive implication to the agriculture sector among other economic reward to the country. If the changing climate causes negative connotation to the water sector of the country, it will definitely hamper to the country's GDP in one way or another [6]. Hence, adaptation and mitigation options or strategies need to be devised, implemented and/or scaled up the existing ones to offset the current and predicted impacts of climate change to the agriculture and water sectors of the country.

Despite such challenges on these sectors in the country, the level of awareness towards climate change impacts, possible adaptation and mitigation options still remained backward and/or infant stage particularly at the grassroots level. Consequently, through the case review/study of the First Assessment Reports of the EPCC and the two principal experts (key informants) interview, it is going to explore in depth the climate change adaptation and mitigation options, practices and strategies on the agriculture (with special focus to the Mixed Crop Livestock (MCL) System) and water sectors in Ethiopia. Thus, it is believed that awareness will be created about climate change impact, adaptation and mitigation on these sectors in particular to the wider public via this published report. This is why for the need to prepare condensed and summarized report on the aforementioned issues and sectors so that it will be consumed by experts and policy makers for further actions.

The major objective of the study will thus be:

- To review the climate change adaptation and mitigation strategies *vis-a-vis* the agriculture and water sectors in Ethiopia through case study of the EPCC project so that awareness will be created to the wider public in prospect.

The climate change perspective

Climate change is already having significant impacts in certain regions, particularly in developing countries, and on most ecosystems. Africa is a vulnerable continent to the impacts of projected changes because of widespread poverty which is a significant limitation to adaptation capabilities. The climate of the continent is controlled by complex maritime and terrestrial interactions that produce a variety of climates across a range of regions, e.g. from the humid tropics to the hyper-arid Sahara [7]. There is already evidence that Africa is warming faster than the global average, and this is likely to continue although the overall trend is geographically variable [8]. According to the IPCC [9], average temperatures in Africa are predicted to increase by 1.5 to 3°C by 2050 and will continue further upwards beyond this time. Over the next century, this warming trend and changes in precipitation patterns are expected to continue and be accompanied by a rise in sea level and increased frequency of extreme weather events. Such changes are expected to put huge pressure on the main economic activities and livelihoods of the people in the continent. For instance, projections indicate that the population at risk of increased water stress in Africa will be between 75-250 million and 350-600 million people by the 2020s and 2050s, respectively [9]. In addition, climate change is predicted to reduce the area of land suitable for rain-fed agriculture by an average of 6% and reduce total agricultural GDP in Africa by 2 to 9% [10].

Like many other developing countries of the world, Ethiopia is also experiencing climate change and its impacts. Model predictions for Ethiopia indicate not only a substantial increase in mean temperatures and an increase in rainfall variability but also a higher frequency of extreme events such as flooding and drought [6]. The country's geographical location within the tropics and extremes of topography in combination with the low adaptive capacity of the people and their resources result in a high degree of vulnerability to the adverse impacts of climate change. A strong link has been observed between climate variations and the overall performance of the country's economy, mainly due to the direct impacts of unreliable weather on agriculture and the links to other sectors of the economy [6], Working Group II Agriculture and Food Security).

In northern Ethiopia, Nyseen et al. [11] investigated land use and land cover change using a matched pair of photographs that date back to 1868 to assess the changes over the last 140 years. They found out that the landscape was already in a severe state of degradation with limited vegetation cover in 1868. Until the recent massive plantations, the northern highlands in general and Tigray in particular have been devoid of vegetation cover. A watershed scale investigation by Aynekulu et al. [12] indicated that 75% of the forest land had been converted into arable land over a period of 50 years. Studies carried out in the north-western highlands of Ethiopia indicate a considerable decline in the natural forest cover and expansion of cultivated land [13-15].

The increased frequency of extreme weather events which faced Ethiopia in the 20th century may be one major impetus for enhancing the visibility of climate change issues over the country. Thus, research activities dealing with finding the major causes of these increasingly occurring extreme and severe weather and climatic events in the country date from the 1980s onwards [16].

Generally, there were increasing trends of greenhouse gas emissions in the country in the period from 1990 to 1995. The relative comparisons of increase indicated that, CO_2 have increased by 24% while emission of CH_4 and N_2O increased by 1% and 119%, respectively. Aggregate greenhouse gases emissions in terms of CO_2 equivalents have increased by 12%. There is significant variation between years for the N_2O emission as compared to CO_2 and CO_2e, respectively. differently, CH_4 emission depicted very less significant difference between those years (1990-1995), i.e., remained constant throughout those years (Table 1) [17]. As it is scientifically proved

	1990	1991	1992	1993	1994	1995	% change 1990/1995
Carbon Dioxide (CO_2)	2,308	1,879	2,073	2,402	2,595	2,862	**24**
Methane (CH_4)	37800	38661	37320	37498	37968	38235	**1**
Nitrous Oxide (N_2O)	3430	4579	4705	4818	7440	7498	**119**
Total	**43537**	**45119**	**44098**	**44718**	**48003**	**48595**	**12**

Table 1: Greenhouse gases emissions for the period 1990-1995 in terms of CO_2-equivalent (Gg) in Ethiopia [17].

that N_2O is both in terms of age in the atmosphere and Global Warming Potential (GWP) higher than both CH_4 and CO_2. This implies that N_2O has significant contribution to the higher global warming which is ultimately after global warming leading to climate change. Thus, since N_2O major sources in developing countries like Ethiopia is from increasing usage trends of N based fertilizers for crop cultivation and livestock production/rearing, it mean a lot by contributing or increase of the globe warming potential.

Case studies indicate that Ethiopian agriculture is highly vulnerable (with large spatial and temporal variation) to the impacts of climate change because of high exposure and sensitivity of the sector to climate variability and change. It is also because low adaptive capacity of smallholder farmers [18-25]. The vulnerability of the agriculture sectors to impacts of climate change is exacerbated by non-climatic drivers such as inappropriate land use and land degradation, population pressure, subsistence farming, low technological innovation and application and poverty. It is also clear that the water sector in Ethiopia is highly vulnerable to climate variability and change with high demand to it due to population growth. Also diminished and/or dried surface and ground water as well because of the limited water infrastructure in the context of the high hydrological variability. Thus, Ethiopia is considered to be economic and technical water-scarce country. The low level of development of water infrastructure exacerbates the country's vulnerability to climate change [26].

As far as transboundary issue in relation to climate change is concerned, Ethiopia has 11 major transboundary rivers basins; among which Blue Nile is one of them. Kim et al. [27] estimated that 14% reduction of runoff will be expected with 3% increase in rainfall and 1.7°C rise in temperature; and 11% runoff reduction is expected with 6% increase in rainfall and 2.6°C increase in temperature by mid of the century. The same study notes that because of the increased runoff in the headwaters or upper streams to be expected from increased rainfall intensity, it will be less likely that downstream communities will suffer reduction of flow; even with increased water demands and population growth by mid of the century.

Methodology

The review specifically employed descriptive reviews so as to focus on findings and interpretations of each reviewed study [28]. It mainly focused on two major sectors, the agriculture (with special focus on the Mixed Crop-Livestock System) and water *vis-a-vis* climate change adaptation and mitigation strategies in Ethiopia. The review strictly followed to explore the case of the EPCC project (one of the projects carried out by the Ethiopian Academy of Sciences (EAS)) particularly First Assessment Reports of the Agriculture and Food Security, and Water and Energy (focusing water sector). Besides to the EPCC assessment, as supplement, other publications collections, internet research, library research have been used. It was also believed that key informant interview of two senior experts from Addis Ababa University has been materialized for triangulation purpose with the above mentioned reviewed materials.

Results

Agriculture

The farming system in Ethiopia can be classified into five major categories namely the highland mixed farming system, the lowland mixed agriculture, the pastoral system, shifting cultivation and commercial agriculture [29]. The highland areas (above 1500 m) constitute about 45% of the total area and are inhabited by four-fifth of the population. The highland areas also support about 70% of the livestock population. Thus, this sector has still remained high potential for GHGs emission as far as the mixed livestock system (both highland and lowland areas) is considered [17].

One of the major expected effects of climate change on crop production in Ethiopia is relocation of suitable area of production for different crops. Under warming scenarios, plant species are forced to relocate growing areas to remain within optimal thermal zone [30]. As species relocate habitat area, there may be net gain or loss of area of adaptation and production. In line with this, Ethiopian Panel on Climate Change (2015), Working Group II Agriculture and Food Security [31] showed that by 2020 the major cereal crops of Ethiopia such as maize, tef, sorghum and barley will loss over 14, 11, 7 and 31% of their current suitable area of production, respectively. For maize, tef and barely the loss will be expected to increase to over 18, 11 and 37% by 2050, respectively. This indicates that C4 species (maize, sorghum, millet and tef), which are originated in warm tropical environments will reach near to their upper limit of maximum temperature tolerance. A small increase in temperature over the present maxima will displace the crops from their current adaptation area and hence the areas used to be planted to these crops will be out of production (at least for the crops mentioned). Apart from C4 crops, C3 species, which are adapted to cool temperature, will be most affected by projected climate change (Table 2). This is because C3 crops like barley and wheat are grown over small areas in the highlands and relocation of growing areas upward along altitudinal gradient will further reduce suitable area available for the crops due to the natural decline in area available, with increase in altitude. As a result, wheat is also expected to lose significant area of its current production, including where rainfall is expected to increase [32]. By 2020, the predicted net percentage change in potential area of production to major crops under A2 scenario is lower than B2 scenario, but the reverse is true by 2050. This is mainly due to by 2020, A2 scenario is better off or benefited with continuous population growth rate but will have higher rate after 2050. By 2050 however, there will be continuous population

Crop	Predicted Net Change in Potential Area of Production (%)			
	2020		2050	
	A2	B2	A2	B2
Maize	−14	−21	−25	−17.7
Tef	−11	−12	−17	−11.2
Sorghum	−7	−12	−7	−3
Barley	−31	−36	−46	−37

Table 2: Predicted average change [%] in area of production of major crops at national level in Ethiopia in response to climate change projected using CCCMA, HadCM3 and CSIRO GCMs under the A2 and B2 emission scenarios [31].

growth A2 but with lesser/slower population growth rate coupled with better environmental protection, social equity and diverse technological changes for B2 thanA2. Thus, by 2050, the net percentage change of areas for major crops becomes lesser under B2 than A2 scenario.

However, another study on the impact of climate change on maize in Africa by 2050s indicated that an increase in maize area by 2.1-5.4% at a national level due to the expansion of maize to the highland areas compared to the baseline period, 2000s [33].

Despite climate change has positive impact to crop production with CO_2 fertilization; model predicted that it will cause seriously reduce yields of major crops in Ethiopia due to high temperature coupled with water deficit on mid and end of this century. For tef and wheat, there are decreasing trend in productivity on both mid and end of the century. However, in the case of maize, it seems a bit strange result in terms of productivity in contrast to the two crops mentioned above. There will be 10% yield increment prediction in mid of the century, but it is going to decrease very slightly (1%) by the end of the century, this will happen mainly due to maize (normally tropical/warm places crop) expand its territories by displacing other temperate crops (like wheat and barley). This means maize favoured off with higher temperature, but with extreme temperature and water deficit on its original/lowland place, it somehow disfavoured with slight productivity decrease (around 1%) by end of the century (Figure 1).

Climate change also has negative effect through reduction in net gain of revenue from crop, livestock and whole agriculture with increase of temperature and decrease of precipitation. For instance, there are decrease of net revenue with 1812 vs. 3039 of crop and a decrease of 274 vs. an increase of 368 ETB of livestock (this due to livestock are generally better off with increase in temperature) for a general 2.5°C vs. 5°C increase of temperature. This also reflected on the whole agriculture with 1035 decrease vs. 364 net revenue increase for the same temperature increase of both +2.5 and 5°C. However, there is significant shrinkage in net revenue to both crop and livestock with both 7% and 14% decrease of precipitation (Table 3) [34].

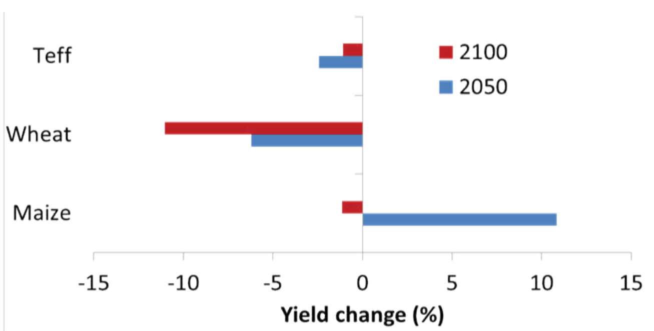

Figure 1: Predicted change in national crop productivity of major crops in Ethiopia in response to projected climate using CGCM2, RCM and HadCM3 GCMs under the A2 and B2 emission scenarios [31].

Climate Change Scenarios	Change in Per Capita Net Revenue (in ETB)		
	Crop	Livestock	Whole agriculture
+2.5°C Temperature	-1812	-274	-1035
+5°C Temperature	-3040	369	364
-7% in precipitation	-1609	-1113	-645
-14% in precipitation	-2677	-1833	-1142

Table 3: Change in per capita net revenue as a result of climate change on crop, livestock and whole agricultural activities in Ethiopia [34].

According to Dr. Belay[1], climate change adaptation is defined as in short as how to compatibly live with it; while that of climate change mitigation as minimizing GHG emissions in any way. In line with this, he also underscored some of the adaptation and mitigation strategies used in relation of agriculture/MCL system to climate change; he believed that there is no clear demarcation or boundaries between the two strategies rather they act as co-benefit. As per his explanation, for instance, soil and water management practices and conservation agriculture are adaptation strategies, but it could also be mitigation in the way that maintaining carbon cycle through sequestering carbon in the form of soil organic carbon. In the same manner afforestation and/or reforestation is usually mitigation strategies, but it could also be adaptation strategies if we specifically consider agroforestry for the agriculture sector.

However, agricultural adaptation to climate is not new in Ethiopia. There have been practices of adaptive strategies both at macro and micro-levels. To list some of the macro-level adaptations are like early warning and response mechanism, safety net programs, natural resource management based adaptation mechanisms, and weather-index insurance mechanisms. While that of the micro-level (farm level) adaptation strategies to the agriculture sector are changing planting dates, planting trees, adoption of drought tolerant and early maturing crops/varieties, increased use of soil and water conservation techniques and/or soil erosion prevention programs, diversification into non-farming activities, increased use of irrigation and/or use of irrigation techniques, the herd composition, applying different feed techniques, temporary or permanent migration, home-garden agriculture, and drawing down on livestock or savings. However, when it has been considered features of these strategies, two of the following points take attention, these are: first, there lacks clear evidence whether some of these practices are climate driven or not, and second the effectiveness of each strategy against climate change is not well documented.

'No regret options' are adaptation options that yield benefits even in absence of climate change and where the costs of adaptation are relatively low *vis-à-vis* the benefits of acting. These adaptation options strengthen resilience to current variability and future climate change. Most of these strategies are existing practices or part of existing policies, and many of them have yielded multiple benefits by increasing productivity and natural resource protection. Some of the suggested 'no regret adaptation options' are: soil and water conservation, sustainable land management, water harvesting and moisture conservation, small scale irrigation development, land rights certification, participatory forest management, agroforestry/homestead fruit production/small-scale plantations, sustainable management of dry land and sub-humid/low-land forests, protection and management of forest fires, biodiversity conservation and sustainable utilization, provision of practical and better agricultural extension, public welfare programs, early warning system, voluntary resettlement and provision of agricultural research and extension. Whereas, in the livestock sector specific adaptation strategies include: selection and use of adapted farm animal genetic resource, feed and feed system development and production system adjustment.

Meanwhile, some of the mitigation strategies identified from the EPCC's First Assessment Report on crop, livestock and natural resources are listed here as follows respectively: reducing expansion of cultivated

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land through agricultural intensification (increasing productivity by reducing GHG emission: conservation agriculture, compost, wise use of inorganic fertilizers, proper crop management); improving animal productivity through breeding (reduce GHGE by 6 Mt CO_2e per year by 2030); feedlots practice by smallholder farmers; improving feed and feeding management; diversification toward lower emitting animal species (small ruminants); mechanization; manure management; afforestation/reforestation; agroforestry; soil and water conservation and land rehabilitation; and reducing rate of desertification. Ethiopia has several means and potential to reduce its GHG emission from agriculture in the MCL system. This allows for environmental conservation and rehabilitation, sustainable production, benefit from the global carbon market, achieving the green growth strategy.

Water

Projections indicate that over the coming decades, expansion and intensification of agriculture, growth of urban areas, and extraction of natural resources will likely accelerate to satisfy demands of increasing numbers of people with higher standards of living like water demands [35]. Land use change in semiarid areas has often resulted in dramatic modifications of the water balance [36]. Land use change affects also water demand and thus, future water requirements and availability are tightly linked to land use [37]. Population growth and the dynamics of climate change will also exacerbate desertification, deforestation, soil erosion, degradation of water quality, and deplete on of water resources which in turn worsen the challenge of food security in developing countries, including Ethiopia [38].

A study conducted by Setegn et al. [39] over the northern highlands of Ethiopia revealed that the actual evapotranspiration (AET) will increase by 7-16.1% by 2045-2065 and will increases to 8.1- 16.9% by 2080-2100, negatively affecting soil water balance, ground water and subsequently stream flow (Figure 2). The change or the difference between mid and end of the centuries AET seem not a significant for which the northern highland temperature is relatively cooler than for example the rift valley (hotter) areas. This may be supported or depicted with the general principle of climate model prediction that relatively wetter and/or cooler areas gets more wetter and/or cooler; while, drier and/or hotter areas are become more drier and/or hotter than before. What so ever the case, AET will affect ground water and stream flow with maximum reduction of 30% and 15% by mid of the century and 12% and 25% by end of the century for A1B emission scenario, respectively. However, the soil water reduction is very less even below 1% since it means that the AET effect on soil water is lesser in both mid and end of the centuries. This is mainly due to climatic (relatively cooler areas) coupled with topographic nature (soil type is more of heavy clay soil, which lead to higher soil water holding capacity) of the areas. Soil water under A1B scenario is a bit lesser than A2 scenario. Since AIB scenario is a balance across all sources(where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies), the soil water decreases lesser than under A2 scenario, which assumes continuous population growth rate. While, soil water decrease under B1 scenario is by far lesser than A1B and A2 scenario since under B1, the population growth rate continue to grow until mid-century and after then becomes declined. The same analysis may also be true under B1 scenario for ground water and stream flow.

According to Prof. Tenalem[2], climate change adaptation defines as the response of various flora and fauna for better performance through a certain modification, accordingly to the changing climate. In line with this, he also underscored some of the adaptation strategies used in relation of water to climate change; these could be rearing and introducing various adaptable fish species in lakes; for scarce water-the community livelihood will be hampered seriously; hence, devising and engaging the community with alternative livelihoods; encouraging community rather than individual based adaptation, for instance, digging deep wells; using drought tolerant crops and early maturing varieties; construction of dams despite it is costly, enhancing and accessing drip irrigation for mass(this is also expensive for developing countries like Ethiopia if it is materialized especially at larger scale) are some to be mentioned.

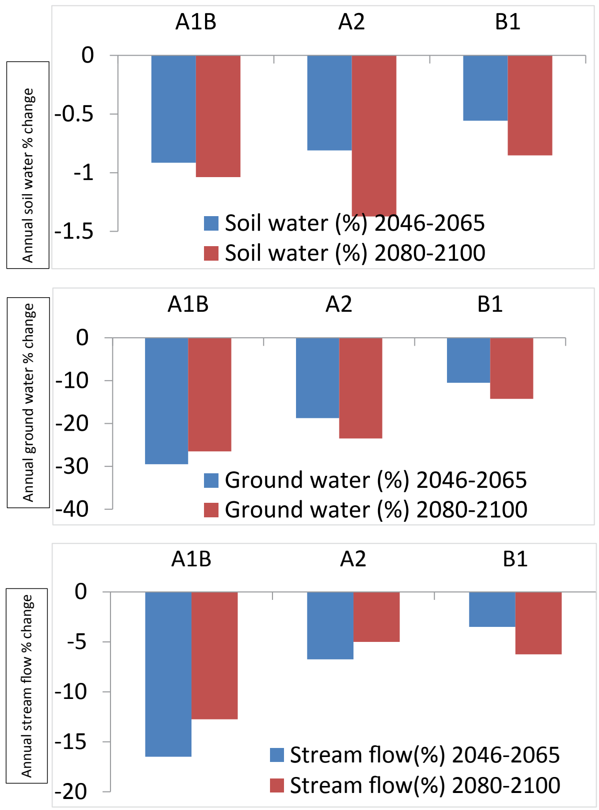

Figure 2: Projected annual percent change in soil water, ground water and stream flow due to changes in climate by 2046-2065 and 2080-2100 periods in the Northern Highlands of Ethiopia [39].

Likewise, adaptation strategies in the water resources sector at the country level should also include measures covering all the steps of the adaptation chain: prevention, improving resilience, preparation, reaction/ response, and recovery. Measures for prevention and improving resilience are related both to the gradual effects of climate change and to extreme events. Preparation, response, and recovery measures are mainly relevant for extreme events such as floods and droughts [40]. Adaptation should also include disaster risk reduction strategies that must be grounded in local knowledge and communicated broadly so that every citizen is aware about possible adaptation measures [9].

Measures of climate change mitigation through agricultural water management are mainly focusing on improving productivity to enhance more efficient use of resources and hence reduce losses (nutrient, water,

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energy, etc.) as well as increase biomass to enhance carbon sinks. Some of these measures include:

- Improving agricultural water management both in irrigated and rain-fed agriculture;
- Proper planning of timing and amount of fertilizer and water application as per the recommendations of the respective research centers irrigation agronomist department;
- Minimizing unproductive water use in agriculture;
- Use of more efficient and renewable energy sources in water management;
- Drainage and rehabilitation of waterlogged and saline irrigated areas to enhance productivity;
- Adapt where possible energy and water efficient irrigation methods;
- Use of renewable energy for water lifting and distribution;
- Rehabilitation of existing irrigation infrastructure and improved management practices to enhance efficiency so as to conserve water and water quality;
- Integrated soil fertility and crops management to enhance yield and water use efficiency; and
- Enhancing the capacities of irrigators through provision of services like: extension, research, credit, market information and the like.

Women's Climate Change Vulnerability, Adaptation and Mitigation from the two Sectors Perspectives

Economic role of women on both agriculture and water sectors in the country is very paramount; however, these two sectors are very vulnerable to climate change. Thus, women climate change vulnerability from adaptive capacity perspective is very clear. Women particularly women headed/unmarried and/or divorced women are generally the most vulnerable to climate change impacts [31]. As per Dr. Belay explanation, exposure, sensitivity and adaptive capacity are components of vulnerability. Sensitivity and exposure are equally imply to any social groups (men, women and children) of the community; while, if we consider adaptive capacity (it is a factor of wealth, infrastructure, access and control of resources, information, culture, law, education, etc.), women are definitely highly vulnerable than men. This is why women are vulnerable to climate change as far as adaptive capacity is concerned. Thus, since culture and other reasons are deprived women from education and other opportunities, then they become less aware about climate change and their adaptive capacity gets lowered, at the end they become highly vulnerable to climate change.

Besides, this may also be typically reasoned from some adaptive capacity barriers to adaptations which include: lack of climate information/awareness and technical knowledge; shortage of labor and land; low potential for irrigation; lack of financial capacity; lack of suitable crops/species (drought resistant) and improved seed; inadequate training and farmer capacity; and lack of understanding of adaptation process. For instance, if women to access certain adaptation and mitigation technologies from the extension service bureau, they will not have those technologies since they lack access to and control over resources, lack wealth and lack education and technical know-how. As a result, their adaptive capacity to climate change gets lowered. In other words, relatively they become more vulnerable to climate change than men [31].

Discussion

Adaptation might be proactive or reactive. Proactive adaptation is an adaptation that takes place to anticipatory climate stimuli; whereas reactive adaptation refers to an adaptation that takes place in response to already observed climate stimuli [41]. Adaptation may also take various forms such autonomous (private/collective) and/or planned (public sector) adaptation. Thus, most adaptation strategies in developing countries like Ethiopia in any sectors are reactive type with both private and collective forms.

The essentiality of agricultural adaptation in Ethiopia is self-evidenced by agriculture's multiple roles in the country. Food security, employment, income and significant portion of GDP are drawn from agriculture. Agriculture accounts about 41% of the GDP, 90% of the exports, and serves as the direct source of employment and livelihood for about 85% of the population [17]. What makes such overwhelming reliance on agriculture a serious problem is overdependence on rainfall which is by no means immune to climate change. According to IPCC, unless effective adaptation strategies are carried out timely, some African countries could lose up to 50% of yield from rain-fed agriculture by the year 2020 and access to food will be severely compromised in many African countries [42]. Ethiopia cannot be an exception given its overdependence on climate driven economy. Such impacts that significantly undermine the prominent role of agriculture in food production and economic growth predominantly signify the criticality of adaptation.

Similar to Dr. Belay statement, most of the empirical studies focused on adaptation strategies at micro-level as 90% of the national agriculture is accounted by small-scale farmers. But, it has to be understood that these adaptation strategies might not be purely driven by climate change as agriculture adaptation also occurs in the context of economic, technological, social, and political forces that are difficult to isolate. Determining when climate is the driving force behind adaptation behavior is difficult, and thus it is widely acknowledged that most adaptation practices serve multiple purposes and are strongly interrelated [43,44].

The cost of climate change adaptation in the water sector depends on the type and magnitude of future climate changes, drought and flood risk occurrences, and the level of initial water infrastructure in the country. Efforts to quantify economic impacts of climate-related changes in water resources are often hampered by lack of data, particularly in underdeveloped regions like Ethiopia and by the fact that the estimates are highly sensitive to different estimation methods and to different assumptions regarding how changes in water availability will be allocated across various types of water uses, e.g. between agricultural, urban or in-stream uses.

In agreement with Prof. Tenalem, in Ethiopia, the cost required for water management and water sector adaptation to climate change is expected to be very high due to the very difficult hydrology of the country characterized by extreme events and high inter-annual and seasonal variability and the poor water infrastructure development. Implementation of the water subsector climate resilience strategy, excluding costs for actions identified as 'cross-cutting' is estimated to cost USD 291 million. Another study estimates that climate change adaptation in the water sector will cost Ethiopia between USD 158 million and USD 258 million per year [6]. In addition to the financial cost, it is important to note that there are also many other factors, often categorized as physical, political, social and institutional, that limit or complicate adaptation responses and climate risk management activities in the water sector.

One of the components to vulnerability, adaptive capacity is the most responsible for women vulnerability to climate change impact. The impact of climate change made most women vulnerable to it. Thus, as Dr. Belay highlighted that livelihood based vulnerability assessment has to be made before suggesting or intervening any adaptation practices to the community at large and women in particular. Similarly, as per his comment, climate change vulnerability encompasses exposure (more of outside/external factors), sensitivity (biophysical/natural setup)-these two are commonly and equally imply to both sexes; however, adaptive capacity is a bit different from the two mentioned above, it is a function of several factors. This is where women vulnerability exhibited more than men. As a result, before devising and/or scaling up any adaptations options to the community in general and women in particular, who are engaged in the economy of both sectors, gender based and agroecology specific vulnerability assessment must be very crucial.

Some of the recommendations learned from this study as well as for further studies are summarized as follows:

- As per Dr. Belay suggestion, before introducing or intervening or scaling up any adaptation strategies with in the community, there should be done agro-ecologies and gender specific vulnerability assessment particularly livelihood based vulnerability assessment across the nation;
- As per Prof. Tenalem comment, community based adaptation strategies has to be encouraged and scaled up as far as cost and easing in reaching out anyone in the community is concerned;
- Women vulnerability to climate change impacts is a function of wealth, education and asses control over and possession on, information, etc.; hence, empowering women socioeconomically mean that we can build their resilience to climate change impacts;
- To raise awareness to anyone in the community about climate change impacts, adaptation and mitigation, capacity building particularly through various consecutive trainings about climate change issues to various level and class of the community are mandatory;
- Like the two discussed sectors (agriculture and water) in this study, similar efforts have to be extended to other sectors too like industry and energy since these are future potential opportunities to the economy and threats to climate change if not managed in advance in the country;
- Documentation of best practices;
- Dissemination of results so as to provide lessons to others and scaling up of these results to other sectors and locations.

Conclusion

Climate change is a serious threat to Ethiopia. It has paramount impacts on crop, livestock, water and to the economy in general in the country; as a result, this is hampering the well-being of the community in general. To curb this pessimistic situations in nationwide, either introducing new or scaling up the existing adaptation and mitigation strategies based on their agro-ecologies are very crucial. Indeed, addressing it timely needs greater emphasis.

However, there is confusion in prioritizing between adaptation and mitigation strategies in Ethiopia. For instance, when the country designed its Climate Resilient Green Economy (CRGE) strategy, first priority was given to mitigation despite later followed by adaptation. But, since adaptation is more of complex, local and process based, it should be given prior emphasis in the county as compared to mitigation strategies, which is relatively international and simple. Besides, what adaptation makes it complex is that it is a function of economy, politics, culture, etc. Thus, before intervening any adaptation options to the community, it has to be done first vulnerability assessment in the country. Among others, the most vulnerable sectors to climate change in Ethiopia are the agriculture and water sectors as they are inter-related each other.

Since most labour particularly women are engaged in these two sectors, livelihood based vulnerability assessment gets higher importance before introducing or scaling up any adaptation strategies across the nation. This will help any agent to device or scale up appropriate adaptation and mitigation strategies based on each specific agro-ecologies and gender. In line with this, upgrading the community level of awareness to climate change impacts, adaptation and mitigation options via various consecutive trainings will have significant added value so as collaboratively challenging to it.

The way forward

The impacts/effects of climate change are additional tips to socio-economic deprivation of the nation at large and the community in particular by seriously deteriorating their well-being. Thus, several CSOs and/or NGOs or INGOs have been making tremendous efforts to reduce the impact of climate change in the county. As a result, after finalizing this assessment study, an intervention and/or implementation project will soon be followed by any concerned body. It is believed that this assessment study together with this report findings will be used as input to improve community particularly women livelihood via addressing climate change effects in the country. Since the main backbone of the nation is agriculture which is laboured by close to 50% of women from the whole population, addressing climate change effects with appropriate adaptations and mitigation strategies of this sector would mean directly or indirectly dealing with poverty of this particular community.

One reputable study confirmed that by 2025 and 2045 with business as usual trend, climate change will cost Ethiopia 3% to 10% and 8% to 10% of GDP, respectively. This mean that additional burden in the strive of poverty reduction, despite the nation registering consecutively an average of 10% annual economic growth for the last recent decade, which helps the nation to record in reduction of absolute poverty from more than 44% to currently less than 25%. In short, climate change will be pillar limitation to the country in dealing with poverty. Thus, there must be a remedy to it before bringing significant catastrophes to the nation well-being.

This is why, among several attempts made by various CSOs and/or NGOs (including the EPCC project by EAS) and INGOs, the government of Ethiopia launched a national strategy named as Climate Resilient Green Economy (CRGE) in 2011. CRGE ultimately aims at zero net carbon emissions with putting the nation to middle income countries by 2025. Emanating from this strategy, policies were designed by Ministry of Environment, Forest and Climate Change (MoEFCC) and distributed them starting from the line ministries at federal level to regional, zone and district administrations to effectively execute these strategy and policies. Besides, planned and sequential trainings based on this report key finding and others have to be reached-out to policy-makers, academicians and grass root level community particularly focusing on women so as to maximize awareness and proper actions towards climate change in the country.

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