Farmer's Perception about Water Demand and Availability in Koga Irrigation Project Under Climate Change

Berhanu B.[1], Haile A.T.[2*], Getnet K.[3] Amha Y.[4]

[1]Reasearch Consultant, International Water Management Institute, Addis Ababa, Ethiopia.

[2]International Researcher, International Water Management Institute, IWMI, Addis Ababa Ethiopia.

[3]Research Economist, International Water Management Institute, Addis Abba, Ethiopia.

[4]Climate Change, Adaptation and Food Security Researcher Fellow at Afrian Climate Policy Centre, Addis Ababa, Ethiopia

* Corresponding Author

Received: 29 June 2017 Accepted: 28 April 2018 Published: 09 May 2018

Abstract

Irrigation is certainly a means for farmers to adapt to climate variability and change. However, the impact of climate change on irrigated agriculture and possible options to deal with it still deserves more research. We therefore assessed farmer's perception on climate change and its impact on current and future water management in the Koga irrigation scheme in Lake Tana sub-basin, source of upper Blue Nile River. Farmers in Koga who used to entirely rely on rain fed agriculture stated that the major benefits of the scheme are multiple cropping, increased productions and profits, savings, children's school enrollment and in general better livelihoods. Despite these observed benefits more than half of the respondents expressed dissatisfaction with the current water allocation. Farmers are concerned that climate variability and change might exasperate the current water allocation issues. For example, hail strom was cited as one of the major climate stress in the region by 60% of respondent. Seven out of ten respondents felt a change in rainfall pattern (onset and variability) in the past 20 years. Slightly less than half of the farmers believe that temperature has increased over the past two decades. More than half of the farmers anticipate future water shortages due to climate change and sedimentation. Almost all of the respondents do not use other water sources during times of water shortage. The main reasons for not using additional source of water are long distance from river water, and long distance between existing hand dug groundwater wells and cultivated lands. About 38%, 12% and 12% of the respondents suggest respectively digging groundwater wells, rainwater harvesting and improved governance as better strategies to deal with future water shortage. Measures that will solve existing water allocation problems and enable farmers to better deal with the anticipated future water shortages will increase the resilience of the scheme.

Keywords

Koga; farmers' perception, water allocation, vulnerability and adaptation to climate change

1. Introduction

1.1 Background

There is undeniable scientific evidence about the increasing concentration of greenhouse gases in the atmosphere and its visible impact on the global climate system (IPCC, 2013). Over the period 1880 to 2012, the globally averaged combined land and ocean surface temperature data showed a warming of 0.85 °C (IPCC, 2013). However, the observed climate change and its associated impacts differed greatly across countries and regions. For instance, mean temperature over Ethiopia has increased by 1.3°C between 1960 and 2006 at a rate of 0.28°C per decade (McSweeney, 2010). The corresponding precipitation trend during the last 3-6 decades was not very clear, although its change is often implicated as a source of droughts and floods in eastern Africa countries including Ethiopia (Niang, 2014). The projected changes in average precipitation and temperature could also vary across regions. The IPCC Fifth Assessment Report (AR5), for instance, states that GCM projections of annual precipitation in the Upper Blue Nile basin (UBN) do not agree on the direction of precipitation change (Niang et al., 2014) while the average temperature is projected to increase by 2 to 5^{o} C by the end of this century (Elshamy et al., 2009). Such changes in r temperature are, therefore, expected to affect potential evapotranspiration (Elshamy et al., 2009), crop water requirement (McKenney et al., 1993) and socio-economic development (Fischer et al., 2007) in the region.

In order to adapt to the observed and projected climate variability and changes, farmers in UBN have been taking various measures including water harvesting, trees planting, early and late crop planting, terracing, crop diversification and others (Deressa et al., 2009; Salvatore et al., 2012; Tessema et al., 2013). To support such local initiatives, the government of Ethiopia is also responding to the changing climate in the region. For instance, the five large scale irrigation schemes[1], which are commissioned or under construction in the Lake Tana sub-basin, are among those bold government initiatives that are aiming at improving food security while reducing the vulnerability of local communities in the region to climate variability. Koga irrigation scheme is the first large scale irrigation project to be operational in the Lake Tana sub-basin. Its construction has been completed and become operational since 2009.

The Ethiopian government strategy to expand small and large scale irrigation schemes can be justified as an adaptation option as it increases farmer's resilience to climate change impacts (World Bank, 2006; Falkenmark and David, 2008; Misra, 2014). This is because irrigation helps to increase agricultural productivity by withstanding rainwater shortages (Kurukulasuriya and Rosenthal, 2003). Many researchers have also suggested that irrigation is one of the best possible means for farmers to adapt to climate variability and climate change (Cooper et al, 2008; Deressa et al, 2009; Mengistu, 2011; Haile et al, 2013). To this end, various African countries including Ethiopia are expanding irrigation to feed their ever growing population (Maddisson, 2006). However, most of such initiatives did not fully consider the impact of climate change on both demand and supply sides of the irrigation schemes. For instance, the current water demand and supply sides of the Koga irrigation scheme were estimated under the assumption of a stationary climate by undermining projected increased temperature and reduced stream flow for Lake Tana sub-basin (Abdo et al, 2009; Setegn et al, 2011;). Recent study by Berhanu and Haile (2015) also predicted a likely increase in future water requirement of Koga irrigation scheme under all representative concentration pathway scenarios (RCPs) to question the reliability of future irrigation water demand and delivery of this scheme.

In addition to the impact of climate change on the supply and demand sides of irrigation, farmers' perception about the impact of climate change on irrigated agriculture and possible options to deal with such impacts are important to ensure the sustainability of irrigation schemes (Koontanakulvong et al, 2014). This is because perception plays a great role in farmers' level of response to climatic change, choice of adaptation measures and how they will be affected by such changes. Therefore, there is a strong need to understand how farmers engaged in agriculture perceive and adapt to climate change. Such information is necessary for the process of adapting agriculture to climate change (Deressa et al, 2011), designing effective policies to support successful adaptation and enhancing our understanding of what factors shape their adaptive behavior (Abid et al, 2015; Mertz et al, 2009; Weber, 2010).

This study is focused on the case of Koga as an operational irrigation scheme to assess the perception of the benefiting farmers' about the impact of climate variability and change on irrigated agriculture (water demand and supply). The objectives are to: (i) understand farmers' perception about the existing water allocation in the irrigation scheme, (ii) evaluate farmer's perception about climate change and its impact on irrigation water demand and supply, and (iii) assess possible water management and adaptation options for irrigated agriculture. The findings from the study will serve as inputs to inform future water management as well as other adaptive initiatives in and around the Koga irrigation scheme. Since irrigated agriculture will continue to expand to feed the growing population in Ethiopia, the study will also generate valuable information on farmers' perception to make the upcoming irrigation projects more resilient to climate change.

1.2 Study Area

1.2.1 General characteristics of the study area

The Koga Dam is built on the Koga River at 11° 24′ 31″ North and 37° 9′ 39″ East coordinates with an elevation stretching from 1800 m above sea level (downstream area) to 3000 m above sea level (upstream area). It is situated in the Amhara regional state of Ethiopia at a distance of about 35 km south of Bahir Dar. Mean daily temperature of Koga watershed was 19 degrees Celsius from 1960-2003 and it received 1560 mm of precipitation annually on average during that same period. High rates of erosion are stimulated by high river flows that occur during the rainy period as a result of high precipitation and runoff (Reynolds, 2013). Almost 87% of the area consists of silty clay soils which are suitable for irrigation (Eriksson, 2013). The major land use/land cover features of the watershed before the start of the irrigation project were cultivated land, settlement, scrub-wetland, bush land, few remnants of natural forest trees and also some planted Eucalyptus trees around settlements (Gebrehiwot, 2010).

1.2.2 Koga irrigation project

Koga irrigation scheme is the first of the six large scale reservoirs1 that the Ethiopian government planned to construct in Lake Tana sub-basin with an aim of ensuring food security in the region and beyond. Figure 1 provides the location irrigation schemes in the Lake Tana basin. The construction work of Koga irrigation project was started in November 2004 and completed in May 2011. Parts of the scheme were operational since the dry season of 2009/2010 though the construction of some tertiary or quaternary canals was not fully completed. The Koga reservoir covers 1750 ha surface area with a storage capacity of 83.1 million cubic meters. The target irrigated area in the design report is 7004 ha with possible addition of 196 ha if water saving technologies are applied. However, the actual irrigated area during the dry season of 2013/2014 was 5830 ha covering 10,356 farm households.

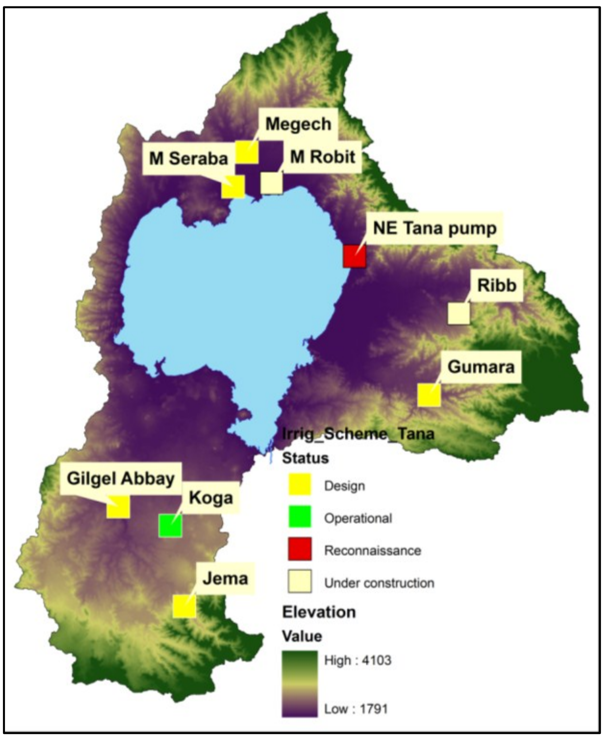

Figure 1. Irrigation schemes in the Lake Tana basin including location of the Koga scheme

The main canal of Koga irrigation scheme stretches 19.7 km. Its 11.95 km stretch follows the contour and the remaining 7.75 km stretch follows a ridge. Its irrigated land is divided into twelve irrigation units that are supplied by twelve secondary canals (they add up to a total length of 42 km). A number of tertiary canals with total length of 117 km divert water from secondary canals (tertiary canal head regulators) and deliver water to each tertiary blocks. Primary, secondary and part of the tertiary canals are built with a protective concrete lining. On the contrary, 783 km stretch of quaternary canals are unlined cut and fill canals, which are each designed to serve 8 to 16 hectares of land. Earth field canals off-take from quaternary canals and are designed to serve an area of 2 hectares per 12 hours irrigation time at a discharge rate of 30 l/s. The 12 hours period night storages capacities of the irrigation units are given in Table 1.

1.2.3. Crop production and /socioeconomic regime

The main crops cultivated within the scheme are wheat, maize, barley, potato and onion. During the dry season of 2013/2014, 70% of the irrigated area was covered with wheat which is the preferred crop by farmers as it requires long irrigation interval. The region's hybrid seeds enterprise that works with the Koga project farmers has cashed 22 million Ethiopian Birr (around 1 million US$) in the 2013/14 season. The rest of the irrigated area is mostly covered with vegetables such as onion, potato, cabbage and tomato which are destined to the local market. Rhodes grass is also being cultivated on the edges/borders of the primary, secondary the tertiary canals, water storage structures and periphery of the dam.

Table 1. Koga irrigation scheme night storages capacity

Irrigation Unit	Night storage capacity(m^3)	Irrigation Unit	Night storage Capacity (m^3)
Kudmi	20,006	Lasi	25,195
Chihona	35,593	Bered	24,728

Ambomesk	40,176	Anidenet	40,695
Adibera	30,986	Amarit	a
Tagel wodefit	37,727	Teleta	41,887
Inguti	19,200	Tekle Dib	44,614

a. The only block that does not have night storage

2. Methods

2.1. Key informant interviews

Ten key informant interviews (KII) were conducted during the first week of October, 2014. Prior to the field work, KII guide was prepared to facilitate the interview. The guide covered main issues relevant to the study, such as the benefits of the irrigation scheme, general operation of the scheme, water allocation and shortage problems, coping strategies to water shortage, perception on climate change and its impact on water resources and possible adaptation options to water shortage. The key informants included the Koga irrigation project management, the technical personnel (canal operators and agronomists), beneficiary farmers and representatives of the water users association. In order to acquire a wide range of information, the informants were selected as much as possible from the 12 different irrigation units.

2.2 Structured interview

Quantitative and qualitative data were collected using structured questionnaires. The questionnaire consists of 86 open and closed questions grouped in to six main sections: (i) irrigated farming; (ii) farmers' satisfaction; (iii) exposure and sensitivity to climate change impacts; (iv) current coping mechanisms; (v) anticipated exposure and adaptive capacity to climate change and (vi) assessing potential adaptation options. The survey lasted for about 30 to 40 minutes for each respondent. The questionnaire was prepared in English language but later translated in to the local language (i.e., Amharic). The accuracy of the Amharic translation was assessed by a local expert who did not participate in the preparation of the questionnaire.

In order to assess the level of understanding and difficulties associated with the interpretation of the questionnaires, the research team has trained three enumerators and helped them to conduct a pre-test survey. Once they were qualified to conduct an independent interview, a total of 93 randomly sampled farmers were surveyed from the 12 irrigation units of the Koga irrigation scheme. The number of surveyed households was limited to 93 since this was found sufficient to perform simple statistic estimation. The research team assessed the quality of the collected data on a daily basis and provided continuous feedbacks to the enumerators. A minimum of 7 farmers were interviewed per irrigation unit regardless of inaccessibility problem by vehicle (e.g., in the Lasi and Adeberra irrigation units). Both canal head and tail farmers of each unit were included in the survey. Overall, we can say that the respondents are representative of the entire irrigation scheme but still farmers' selection within the same irrigation unit was sometimes influenced by accessibility of their plots.

2.3 Statistical analysis

The quantitative data collected through the structured questionnaire were first checked for consistency and then digitized. The data were then analyzed using the Statistical Package for Social Sciences (SPSS). Descriptive statistics (min., max., mean, percentage and standard deviation) was used to analyze the collected data.

3. Results

3.1 Socio-economic profile of the respondents

Farmers benefiting from the Koga irrigation scheme have an average age of 40 years (Table 2(a)). Crop cultivation is the major livelihood strategy and source of income to these farmers. However, about 87% of the respondents are also involved in more than one income generating activities mainly in livestock rearing. Average land holding is 1.2 ha with a maximum of 4 ha. Most farmers with a large landholding stated that they cultivate only part of their land in each production season due to lack of labor and limited financial capacity to purchase agricultural inputs. Irrigation farming is a new activity in the area and almost all the surveyed farmers did not have any irrigation experience before the start of the Koga irrigation scheme in 2009. Tables 2(a) and 2(b) show the profile of the respondents, their irrigation experience,income information and landholding size.

Table 2(a). Respondents profile and irrigation experience

Sex		Age				Irrigation farming experience before the Koga project	
Female (%)	Male (%)	Min	Max	Mean	St. Dev.	Yes (%)	No (%)
25	75	22	70	40.75	11	3	97

Table 2(b). Respondents income information and land holding

Source of income				Number of activities generating incomes			Landholding			
Crop cultivation (%)	Livestock (%)	Petty trade (%)	Other (%)	One (%)	Two (%)	Three (%)	Min	Max	Mean	St.Dev.
100	87	5	3	13	80	7	0.25	4	1.18	0.77

3.2. Farmer's perception about the existing water allocation

Farmers stated that the irrigation scheme has brought multiple benefits to them. While they used to cultivate only once a year by relying on the rainy season, they are now cultivating at least twice a year (after the commissioning of the scheme). As a result of multiple cropping, farmers are able to improve their crop yield, income and livelihood (e.g. improved food diets, better houses and improved living standards). The improvement of income from their irrigated agricultural activities has helped them to save some money in a bank, which was not common in the area before the start of the project. As a result, children school enrollment has drastically increased since farmers are able to incur the cost of sending their kids to school. This has caused labor shortage in some households as kids were the once who helped them in farm activities.

Despite the multiple benefits of the irrigation scheme, about 57% of the respondents are not satisfied with the current water allocation. Their dissatisfaction is mainly related to the irrigation water amount and interval. The amount of the allocated water for >60% of the respondents is less than their actual water demand (Figure 2) as the allocation did not take into account the type and stage of crop. The current discharging rate at the Koga irrigation scheme is based on fixed flow (30 l/s for 12 hours to irrigate 2ha), which is levied during the design phase of the project. The discrepancy between water demand and supply has induced impact on the performance of their crops. According to the respondents, water shortage is causing decline in crop yield and increase in pest infestations in the area.

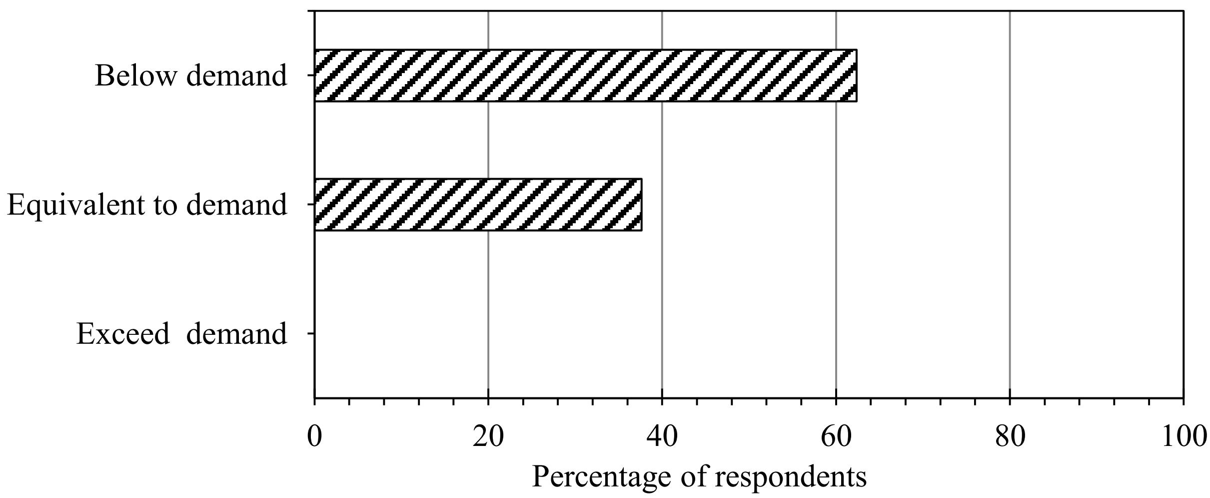

Figure 2. Farmer's perception about amount of allocated water compared to the irrigation demand

About 70% of the farmers stated that the current irrigation interval is too long to timely satisfy the water demand of existing crops (Figure 3). The average irrigation interval is 11 days but depending on the location of the irrigation unit it can go as short as 5 days and as long as 30 days. As a result, farmers are forced to make adjustments on their crop selection. They opted to less water demanding crops (such as cereals) rather than planting more profitable crops with frequent water demand (e.g. vegetables). Despite their dissatisfaction on the irrigation interval, majority of the respondents (~85%) consider the current water rotation as reliable as they received water on due date. However, farmers' complained that they are not benefiting from this irrigation scheme during the rainy season for instance in times of early rainfall offsets or extended dry spells although the reservoir was designed and build to store sufficient water for both seasons.

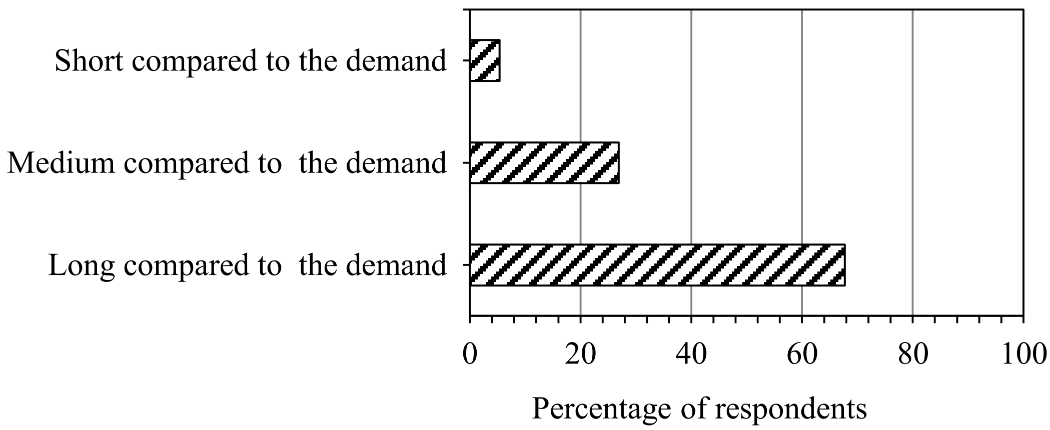

Figure 3. The actual irrigation interval compared to the required irrigation interval

3.3. Farmer's perception on historical climate variability and change

We assessed farmers' perception on historical climate variability and change with the assumption that farmers' perception towards these changes could affect their responses and provides useful inputs to understand the existing adaptive capacity. With regard to historical rainfall patterns, 70% of the respondents recognized changes in rainfall pattern over the past 20 years (Figure 4). Of these, almost 80% of them stated that the current onset of rainfall is earlier than before and offset. Appreciable percentage of the respondents (30.5%) had also noticed increased rainfall variability over the years. The number of respondents who reported a decrement in rainfall amount is greater than those who reported an increment. Most of the respondents generally said that rainfall has become less predictable and posed difficulties to schedule their agricultural activities based on their existing indigenous knowledge.

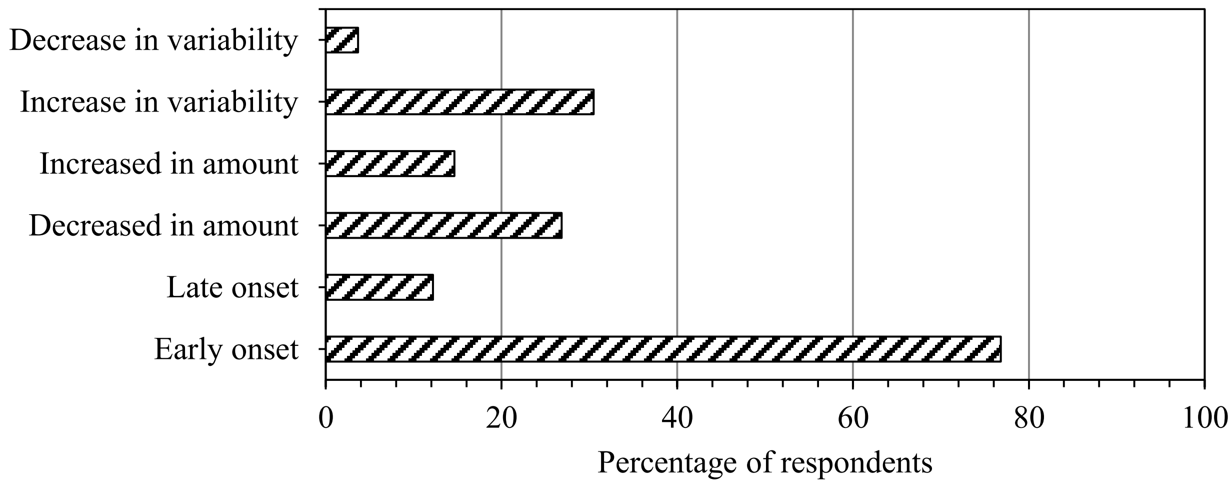

Figure 4. Farmers' perception of changes in rainfall in the last 20 years (% respondents)

Slightly less than half of the farmers believe that temperature has increased over the past 20 years (Figure 5). A rise in temperature is explained by an increase in crop water requirement, an increase in crop diseases and pest proliferation. However, about 13% of the respondents observed a decrease in temperature over the past 20 years while 14% did not recognize any change.

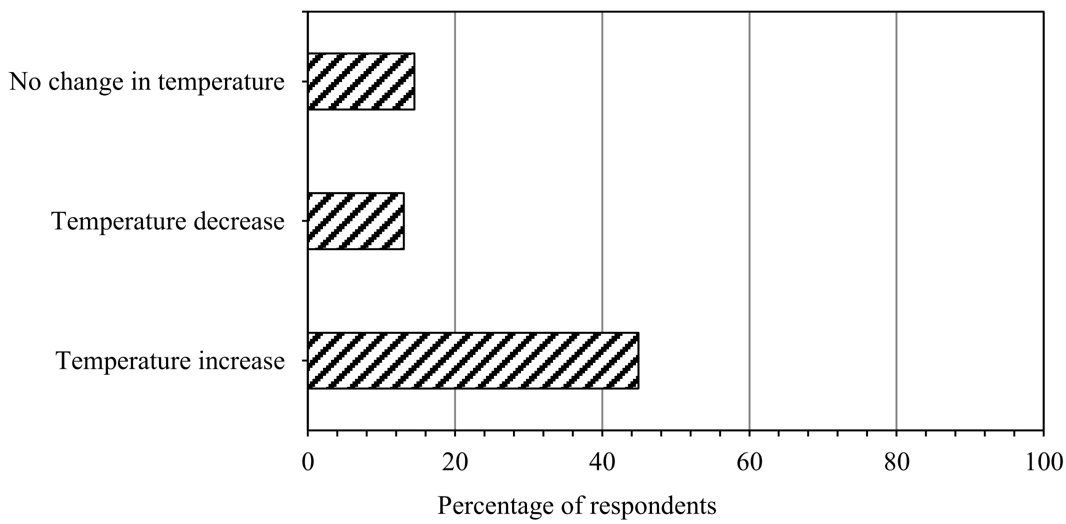

Figure 5. Farmer’s perception of changes in temperature in the last 20 years

Farmers’ perception about the major climate stresses in the last 20 years was also evaluated and 60% of the respondents considered hail storm as one of the major climate stresses in the study area (Figure 6). The unexpected hail occurrence may, sometimes, destroy the standing crops and left farmers with empty hands. For example, in 2014, most of the maize farms in Ambo Mesk irrigation unit were destroyed by hail (at maturity stage) and greatly affected farmers’ capacity to purchase agriculture inputs in the coming irrigation season. According to the respondents, flood is the next major climate stress followed by frost. Only less than 10% of the respondents consider drought as the major climate stress.

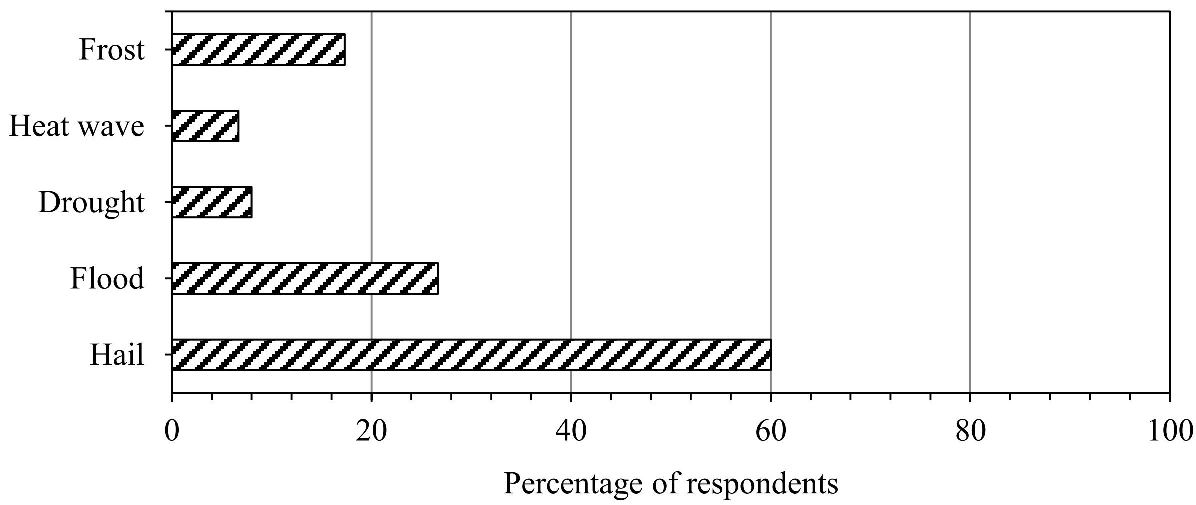

Figure 6. Farmers' perception of the major climate stresses in the last 20 years (% respondents

3.4. Farmers' perception on future climate change and associated impacts

Fifty eight percent of the respondents anticipate that irrigation water shortage in the future will affect their agricultural activities. However, most of them (54%) do not anticipate water shortage in the near future (within 5 years). Among those farmers who anticipate shortage, 58% and 35% of them fear that water shortage will occur in the meduim (5-10 years) and long term (>10 years) respectively (Figure 7). The rationale behind their perception is that the future irrigation water shortage will probably occur due to reservoir sedimentation and an increase of irrigation water use than changes in climate variables (Figure 8). Farmer's fear of increased water use in the future may be linked to increased awareness of the benefit of irrigated farming which may lead to very intensive irrigated agriculture activities. On the question "who will be more affected by future water shortage", nine out of ten respondents identified farmers at the tail reach of the scheme to be more vulnerable to climate change. They believe that these farmers are more prone to water shortage because they are located far away from the main reservoir and are susceptible to increased water loss along the canal. They also believed that poor water management does aggravate this situation. Therefore we can say that the serious problem right now could be unfair distribution of water and it will remain a major problem if not addressed (more than the impact climate change).

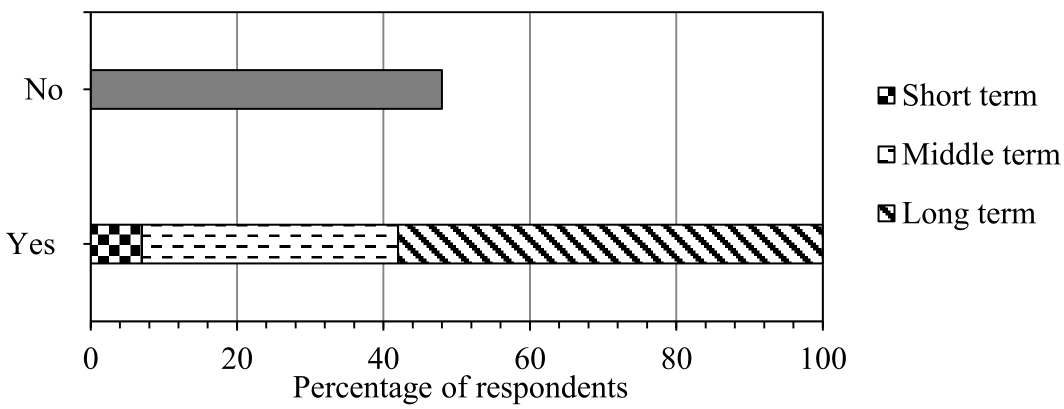

Figure 7. Percentage of respondents who anticipate irrigation water shortage in the future

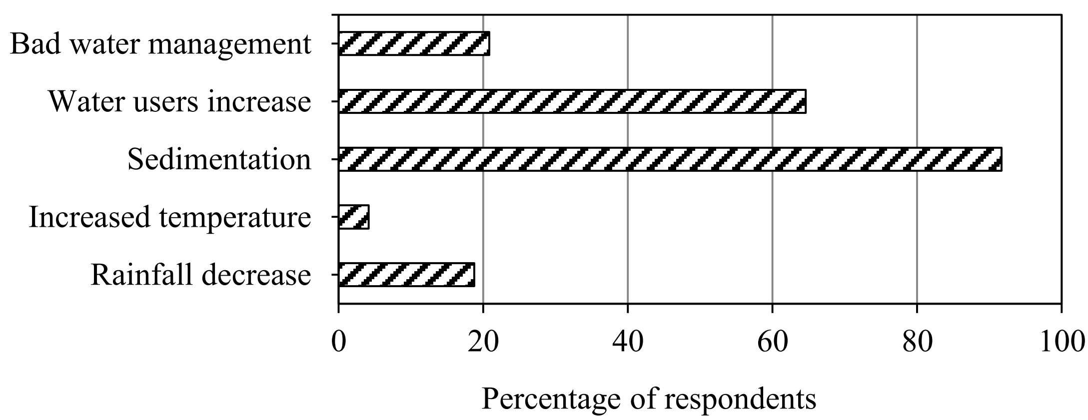

Figure 8. Farmers' perception on the possible reasons for future water shortage

Climatic factors do not seem to be farmers' biggest fears in Koga as they stated that temperature and rainfall variation will have limited impact in terms of water shortage. This is mainly due to their belief that they cannot do much with regard to climatic variables as it depends only on the "will of God" and they preferred to concentrate on factors that can only be managed by them. Comparatively, farmers are more concerned about the effect of decreased rainfall on future water shortage (19%) than increased temperature (4%).

3.5 Possible water management and adaptation options

About 97% of the respondents stated that they do not try to use additional sources of water other than the reservoir water during times of water shortage. This is an overwhelming large number particularly since many farmers were complaining about inadequate and infrequent water allocation. The main reasons for not using additional source of water are poor access to river water as determined by distance (28% of the respondents), and long distance between existing hand dug groundwater wells and cultivated lands (68%). Our key informants stated that they are shifting to less water demanding crops to deal with water shortages. Indeed, their major crop is wheat (70% of the cultivated area was covered with wheat during dry season 2013/2014), a cereal crop that does not require frequent irrigation and large amount of water. The cultivation of wheat is done in spite of vegetable crops which are much more profitable than cereals but demand short irrigation intervals.

Asked about the possible adaptation options for anticipated future water shortage, 38% of the respondents suggested that digging groundwater wells within their cultivated land can be a solution as long as they can use motor pumps to irrigate their land. Currently, 56% of the households have groundwater wells but they only use it for domestic water use, for livestock and to irrigate their backyard vegetables. For 12% of the respondents' rain water harvesting is preferred option to deal with water shortage. Another 12% of the respondents affirm the need for the government assistance in order to deal with future water shortage. Although few in number, some of them mentioned improving water use efficiency, reduction of reservoir sedimentation rate through soil and water conservation and reduction of the irrigated area in times of water shortage as possible adaptation options for Koga scheme.

4. Discussion and conclusion

Several irrigation infrastructures are under-construction in the Lake Tana sub-basin, which is considered as the growth corridor by the Ethiopian government. These irrigation infrastructures are expected to increase farmers' resilience to climate change by reducing their dependence on rain fed agriculture. However, the predicted climate change in UBN may have direct impacts on the irrigation water requirements, reservoir evaporation and inflow. According to Setegn et al. (2011) and Abdo et al (2009) , UBN region will experience an increased temperature and reduced stream flow to Lake Tana sub-basin that in turn challenge the sustainability of future irrigation schemes in the basin.

As farmers are the direct beneficiaries of the Koga irrigation scheme, it is important to consider their perceptions about the existing water allocation and water shortage phenomena. This study found that most beneficiaries are not totally satisfied by the existing allocation of the irrigation water and are concerned about the amount and interval of the supplied irrigation water. Currently, farmers are not able to plant profitable crops (like vegetables) as their water demand is larger or more frequent than the amount and frequency of water delivered by the scheme. The initial fixed flow rate of 30 l/s for a period of 12 hours on about a weekly basis is basically planned to irrigate 2 ha without considering the crop type or stage of crop development. Hence, the existing water allocation practice should be revised so that farmers' can shift from cereal cultivation to profitable crops like vegetables.

Farmers perceive hail as the major climate stress in Koga scheme. Hail frequently destroys standing crops. However, hail has not been given due attention in previous studies (Deressa et al, 2009; Deressa et al, 2011). They consider flooding as the second major climate stress. Heavy rainfall is the major cause of flooding in the area while the problem is exacerbated by poor drainage system of the irrigation scheme. Therefore, the concerned bodies need to thoroughly consider this climate stress and work to build viable shielding measures such as establishment of better drainage systems.

Climate change is happening and its impact is being felt by farmers within the Koga irrigation scheme. An increased variability of rainfall is making it hard for them to predict crop planting date using indigenous knowledge. Early rainfall offsets and rainy season with extended dry spells in Koga area had also contributed to significant decline in crop yield as it was the case in the 2015 rainy season. The success of the rainy season production in the area is crucial since the financial profit of the production in this season is used to purchase inputs for dry season. However, lack of irrigation water supply during the rainy season has been significantly affecting crop production although the irrigation scheme was designed and constructed to supply water in both seasons. Therefore, the possibility of using the irrigation water as supplemental irrigation should be considered to increase farmers' ability to better deal with climate shocks in the rainy season.

Farmers' perception on climate change may agree with climatic trends that were detected in meteorological records (e.g. Gbetibouo, 2009; Kasulo, 2012; Bryan, 2013). However, its reliability is often questioned as it is influenced by a number of social, economic and environmental factors (Nhemachena & Hassan, 2007; Deressa et al., 2009; Nhemachena, 2009; Deressa et al., 2010). In this study, more than half of the respondents noticed a rise in temperature in/around their area. Surprisingly, the majority of the respondents believe that changes in climatic variables (such as temperature and rainfall) will have less impact on the volume of water stored in the reservoir. Rather, sedimentation is their number one reason responsible for a significantly reduction in the actual amount of water stored in the reservoir. This findings is also in contrary to McKenney and Rosenberg (1993) and Fisher et al. (2007) findings who reported consequential effects of climate variables on the volume of water in the reservoir, crop water requirements, reservoir evaporation, crop disease and pest proliferation. Apart from sedimentation, farmers in Koga irrigation scheme linked future water shortage to an increased water use and bad water management that warrant improvement on the existing water management system to avoid/reduce probable cause of water loss.

With regard to Koga farmers' current coping mechanisms, in times of reservoir water shortage they are not using an extra source of water. Their current coping mechanism is only linked with the continuation of the cultivation of the crop that is known (even under rain fed condition) instead of experimenting with something with new possibly high yielding crops that are not indeed the most profitable crops. Therefore by shifting from vegetables to cereals crops their income decreases and this implies that their adaptation option incurs a cost. Adaptation measure often incur extra costs but some investments like the purchase of a water pump may become profitable in the case where the owner earns money by renting it out to other farmers (Kusters and Wangdi, 2013).

One of the objectives of this study was to identify viable adaptation options for anticipated future water shortage. Digging groundwater wells, rain water harvesting and assistance of the government are the major suggested strategies by Koga farmers. We believe that in order to be successful, future projects that will try to improve the resilience of Koga farmers to water shortage need to take farmers' suggestion into consideration.

The Koga irrigation scheme is a well-functioning irrigation system with some existing and forthcoming challenges with regard to its water allocation and its vulnerability to climate change. However, for better crop harvest, the fixed flow rate and long irrigation interval should be adjusted in accordance to the crop-water requirement demand. The irrigation project management should consider releasing reservoir water as supplemental irrigation in the rainy season particularly during early rainfall offsets and extended dry spell. This is needed to maximize the benefit from this big investment. Farmers in Koga should consider alternative water sources in times of irrigation water shortage (e.g., digging groundwater wells and use of motor pumps, rain water harvesting, etc) to increase the resilience of the irrigation scheme. Overall, measures that will improve farmer's capacity to better deal with water shortage should be implemented in Koga irrigation and other similar irrigation projects that are under construction or at design stages in the UBN basin. We particularly advocate improved water governance for better water allocation and suggest that future research needs to explore the implications of promoting rain water harvesting and groundwater abstraction to deal with irrigation water shortage.

Acknowledgements

Support for this study was provided by the European Communities' FP7 project IMPACT2C (Quantifying Projected Impacts Under 2°C Warming). We also acknowledge the support provided by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

References

Abdo, K. S., Fiseha, B. M., Rientjes, T. H. M., Gieske, A. S. M. and Haile, A. T. (2009) 'Assessment of climate change impacts on the hydrology of Gilgel Abay catchment in Lake Tana basin, Ethiopia', Hydrological Processes, 23, 3661–3669. doi: 10.1002/hyp.7363.

Abid M., Scheffran J., Schneider U. A., and Ashfaq M. (2015) 'Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan', Earth System 6, 225–243.

Aich, V., Liersch, S., Vetter, T., Huang, S., Tecklenburg, J., Hoffmann, P., Koch, H., Fournet, S., Krysanova, V., Müller, N., Hattermann, F. F. (2014) 'Comparing impacts of climate change on streamflow in four large African river basins', Hydrology and Earth System Sciences, 18, 1305-1321.

Berhanu B. and Haile A.T. (2015) 'Evaluating climate change impact on water demand of irrigation schemes in the Lake Tana basin using newly developed climate change scenario'. Proceedings of the 14th Symposium on Sustainable Water Resources Development, Arba Minch University Arba Minch, Ethiopia, pp. 29-30.

Bryan E., Ringler C., Okoba B., Roncoli C., Silvestri S. and Herrero M. (2013) ‘Adapting agriculture to climate change in Kenya: Household strategies and determinants’, Journal of Environmental Management, 114, 26–35.

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferawa, B., Twomlowc, S. (2008) ‘Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change?’, Agriculture, Ecosystems and Environment, 126, 24–35.

Deressa T. T., Hassan R. M., Ringler C., Alemu T. & Yesuf M. (2009) ‘Determinants of farmers’ choice of adaptation methods to climate change in the Nile Basin of Ethiopia’, Global Environmental Change 19, 248–255.

Deressa T. T., Hassan R. M. & Ringler C. (2010) ‘Climate change and agriculture paper: Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia’ Journal of Agricultural Science, 149, 23–31.

Deressa, T. T., Hassan, R. M., and Ringler, C. (2011) ‘Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia’, Journal of Agricultural Science, 149, 23–31.

Elshamy, M. E., I. A. Seierstad, and A. Sorteberg (2009) ‘Impacts of climate change on Blue Nile flows using bias-corrected GCM scenarios’ Hydrology and Earth System Sciences5, 1407–1439.

Ethiopian Panel on Climate Change (2015), First Assessment Report, Summary of Reports for Policy Makers, Ethiopian Academy of Sciences

Falkenmark, M. & David M. (2008) ‘Wake up to realities of River Basin Closure’, International Journal of Water Resources Development, 24:2, 201-215, DOI: 10.1080/07900620701723570.

Fischer, G., F.N., Tubiello, H., Velthuizen, V., and Wiberg, D.A (2007) 'Climate change impacts on irrigation water requirements: Effects of mitigation, 1990-2080', Technological Forecasting Social Change, 74, 1083-1107, doi:10.1016/j.techfore.2006.05.021.

Eriksson S. (2013) 'Water quality in the Koga Irrigation Project, Ethiopia: A snapshot of general quality parameters'. Department of Earth Sciences, Air, Water and Landscape Science, Uppsala University.

Gbetibouo G. A. (2009) 'Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa'. IFPRI Discussion Paper 00849.

Gebrehiwot, S. G., Taye, A., Bishop, K. (2010) 'Forest Cover and Stream Flow in a Headwaterof the Blue Nile: Complementing Observational Data Analysis with Community Perception', Royal Swedish Acedemy of Sciences.

Getnet, K. (2015). Profit and financial risk in the smallholder irrigated agriculture of Ethiopia. Research Report.

IPCC (2001) Climate change 2001: impacts, adaptation and vulnerability, contribution of working group II to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.

IPCC, 2013: Summary for Policymakers. In: Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kasulo V., Chikagwa-Malunga S., Chagunda M. and Roberts D. (2012) 'The perceived impact of climate change and variability on smallholder dairy production in northern Malawi', African Journal of Agricultural Research Vol. 7(34), pp. 4830-4837.

Koontanakulvong, S., Chaowiwat, W., Miyazato, T. (2014) 'Climate change's impact on irrigation system and farmers' response: a case study of the Plaichumpol Irrigation Project, Phitsanulok Province, Thailand' Paddy and Water Environment, 12(Supp. 2):S241–S254, DOI 10.1007/s10333-013-0389-8

Kusters, K. and Wangdi, N. (2013) 'The costs of adaptation: changes in water availability and farmers'

responses in Punakha district, Bhutan', International Journal of Global Warming, Vol. 5, No. 4,pp.387–399.

Kurukulasuriya, P. and Rosenthal, S. (2003) Climate Change and Agriculture: A Review of Impacts and Adaptations. World Bank Climate change series Paper no 91. Paper prepared and published for the Rural Development Group and Environment Department of the World Bank. 106 pp.

McKenney, M.S. and Rosenberg, N.J. (1993) 'Sensitivity of some potential evapotranspiration estimation methods to climate change', Agriculture and Forest Meteorology, 64, 81-110.

Mengistu D.K. (2011) 'Farmers' perception and knowledge of climate change and their coping strategies to the related hazards: Case study from Adiha, central Tigray, Ethiopia', Agricultural Sciences Vol.2, No.2, 138-145.

McSweeney, C., New., M., Lizcano.,G. and Lu., X. (2010) 'The UNDP Climate Change Country Profiles Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countrie', Bulletin of the American Meteorological Society, 91, 157-166.

Mertz, O., Mbow, C., Reenberg, A. & Diouf, A. (2009) 'Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel', Environmental Management 43, 804–816.

Misra, A.K., (2014) 'Climate change and challenges of water and food security', International Journal of Sustainable Built Environment.

Nhemachena, C. and Hassan, R. (2007) Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute. Washington DC, USA.

Nhemachena, C. (2009) Agriculture and future climate dynamics in Africa: Impacts and adaptation options. PhD thesis, University of Pretoria, South Africa.

Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart (2014) 'Africa. In: Climate Change: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects'. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press,Cambridge, United Kingdom and New York, NY, USA, pp. 1199-1265.

Okonya J.S., Syndikus K and Kroschel J. (2013) 'Farmers' Perception of and Coping Strategies to Climate Change:Evidence From Six Agro-Ecological Zones of Uganda', Journal of Agricultural Science; Vol. 5, No. 8.

Reynolds B. (2013) 'Variability and change in Koga reservoir volume, Blue Nile, Ethiopia., Examensarbete vid Institutionne för geovetenskaper, ISSN I650-6553 Nr 261.

Salvatore D.F., Köhlin G. and Yesuf M. (2012) 'Strategies to Adapt to Climate Change and Farm Productivity in the Nile basin of Ethiopia', Climate Change Economics:3(2). Download reference Doi:10.1142/S2010007812500091

Setegn, S. G., Rayner D., Assefa M. Melesse, Dargahi B., Srinivasan R., Anders Wörman (2011) 'Climate Change Impact on Agricultural Water Resources Variability in the Northern Highlands of Ethiopia. In Nile River Basin', Springer, 241-265 pp.

Tessema Y.A, Aweke C.S. and Endris G.S. (2013) 'Understanding the process of adaptation to climate change by small-holder farmers: the case of east Hararghe Zone, Ethiopia', Agricultural and Food Economics, 1:13. http://www.agrifoodecon.com/content/1/1/13

Weber, E. U. (2010) 'What shapes perceptions of climate change?' Wiley Interdisciplinary Reviews: Climate Change, 1, 332–342, 2010.

World Bank (2006) 'Managing Water Resources to Maximize Sustainable Growth: A Country Water Resources Assistance Strategy for Ethiopia'. World Bank, Washington, DC.