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Review on Impacts of Climate Change on Watershed Hydrology

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Abstract
The natural environment has been highly influenced by human beings since the industrial revolution that impact human activities. There is highly increase in global temperature and the amount and distribution of rainfall is being altered. When evaluated at a watershed level the effect is seen in terms of effect on atmospheric evaporation demand (change in potential evapotranspiration), changes in precipitation, change in vegetation composition and interception, changes on stream flow characteristics and groundwater storage and recharges.
Keywords: Climate change, watershed, hydrology

1. INTRODUCTION

The environment has been influenced by human beings for centuries. However, it is only since the beginning of the industrial revolution that the impact of human activities has begun to extend to a global scale. Today, environmental issue becomes the biggest concern of mankind as a consequence of scientific evidence about the increasing concentration of greenhouse gases in the atmosphere and the changing climate of the Earth. Globally, temperature is increasing and the amount and distribution of rainfall is being altered (Cubasch *et al.* 2001).

According to the International Panel on Climate Change (IPCC) Scientific Assessment Report, global average temperature would rise between 1.4 and 5.8°C by 2100 with the doubling of the CO_2 concentration in the atmosphere. Sea level rise, change in precipitation pattern (up to ±20%), and change in other local climate conditions are expected to occur as a consequence of rising global temperature (Cubasch *et al.* 2001). This is expected to have a potential impact on different sectors and natural process (IPCC 2001). Scientists have made estimates of the potential direct impacts on various sectors, but in reality the full consequences would be more complicated as impacts on different sectors are indirectly interrelated to one another (UNEP, 2005).

The recent occurrences hurricanes and flooding in different parts of the world and the very frequent drought in the African countries (including Ethiopia) may be manifestation of these changes. One of the very sensitive sectors that climate change can cause significant impacts on it is water resource; by resulting changes in the hydrological cycle. The change on temperature and precipitation components of the cycle can have a direct consequence the spatial and temporal water resource availability, or in general the water balance significantly (Hailemariam kiflu, 1999).

The IPCC findings indicate that developing countries, such as Ethiopia, will be more vulnerable to climate change and may have far reaching implications for various reasons, mainly the economy is largely depends on agriculture, large part is highly prone to desertification and drought. Climate change and its impacts are, therefore, a case for concern to Ethiopia. Hence, assessing vulnerability to climate change and preparing adaptation options is very crucial(NMSA, 2001).Since most climate change impact mitigation measures related to water resource are achieved at watershed level understanding the potential impact of climate change on hydrologic process at watershed scale is very crucial in management decision for watershed management experts.

This review paper also depicts the impact of climate change on watershed hydrologic process. The major issues assessed are climate change effect on atmospheric evaporation demand (change in potential evapotranspiration), changes in precipitation, vegetation composition and interception, changes on stream flow characteristics and changes on groundwater storage and recharges depending on researches and climate and hydrologic modeling case study results in different watersheds.

The Objective of this paper is to review the impact of increasing global climate change (increasing surface temperature) on the hydrology of a watershed based on climate and hydrological modeling case studies in different watersheds (river basins).

2. Over View of Climate Change

Climate change is considered as one of the biggest challenges of 21st century to the whole world will face. It is now widely accepted that climate change is already happening and further change is inevitable; over the last century (between 1906 and 2005), the average global temperature rose by about 0.74 ^{0}C. This has occurred in two phases, from 1910s to 1940s and more strongly from the 1970s to the present (IPCC, 2007).

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It is estimated that, for the 20th Century, the total global mean sea level has risen 12-22c m, this rise has been caused by the melting of snow cover and mountain glaciers (both of which have decline on average in both hemispheres) (IPCC, 2007). The IPCC also notes that observations over the past century shows, changes are occurring in the amount, intensity, frequency and types of precipitation globally (IPCC, 2007). IPPC also states the projected global surface warming lies within the range 0.6 to 4.0 ^{0}C at the end of next century (IPCC, 2007).

3. Climate Change In Ethiopia

Both instrumental and proxy records have shown significant variations in the spatial and temporal patterns of climate in Ethiopia. According to NMA (2006) the country experienced 10 wet years and 11 dry years over 55 years analyzed, demonstrating the strong inter-annual variability. Between 1951 and 2006, annual minimum temperature in Ethiopia increased by about 0.37°C every decade. The UNDP Climate Change Profile for Ethiopia (McSweeney *et al*., 2008) also shows that the mean annual temperature increased by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade. The temperature increase has been most rapid from July to September (0.32°C per decade). It is reported that the average number of hot days per year has increased by 73 (an additional 20% of days) and the number of hot nights has increased by 137 (an additional 37.5% of nights) between 1960 and 2006. The rate of increase was highest in June, July and August. Over the same period, the average number of cold days and nights decreased by 21 (5.8% of days) and 41 (11.2% of nights), respectively. These reductions have mainly occurred in the months of September to November (McSweeney *et al*., 2008)

The results of IPCC's mid-range emission scenario show that compared to the 1961-1990 average mean annual temperature across Ethiopia will increase by between 0.9 and 1.1°C by the year 2030 and from 1.7 to 2.1°C by the year 2050. The temperature across the country could rise by between 2.7 and 3.6^{0}C by 2080, unlike the temperature trends, it is very difficult to detect long-term rainfall trends in Ethiopia, due to the high inter-annual and inter-decadal variability. A small increase in annual precipitation is expected over the country (NMA, 2007).

4. Impacts of Climate Change on Watershed Hydrology

The projected changes in climate will have direct and indirect impacts on natural environment as well as on human societies. Hydrology and water resources will be affected, since they are closely linked to climate (Arnell 2003; Barnett 2005). Therefore, climate change may induce major changes in hydrological conditions. The most serious earth science and environmental policy issues confronting society is the potential changes in the earth's water cycle due to climate change (IPCC, 2008).The science community now generally agrees that the earth's climate is undergoing changes in response to natural variability, including solar variability, and increasing concentrations of greenhouse gases and aerosols. Furthermore, agreement is widespread that these changes may profoundly affect atmospheric water vapor concentrations, clouds, precipitation patterns, and runoff and stream flow patterns (IPCC, 2001).

Climate change impacts can vary between catchments even within relatively small areas due to local climate and catchment characteristics depending on which specific watershed process and response are sensitive to change because of difference in geophysical characteristic of watersheds (Arnell N.W., 2003). Thus, reliable estimates of climate change impact on hydrology are difficult to infer from large-scale results or by analogy from nearby locations. Therefore, modeling climate change impacts on hydrology in local and national scale is needed (Thornes J., *et al*. 2009).

The potential effects of a climate change on watershed hydrologic processes and its expected outputs specifically to different watersheds based on different case studies are discussed below.

4.1. Increased Atmospheric Evaporative Demand(Increased Evapo-transpiration)

Rising atmospheric CO_2 concentration affects the water balance through climatic changes and through changes in transpiration, vegetation structure and distribution (Huntington, 2008). Increasing temperature generally results in an increase in potential evaporation, largely because the water holding capacity of air is increased. According to IPCC (2007) referring to Chattopadhyary and Hulme, (1997) calculated increases in potential evaporation across a large watershed from GCM simulations of climate; found that projected increases in potential evaporation were related largely to increases in the vapor pressure deficit resulting from higher temperature, since evaporative demand is a function of air and surface temperature, solar radiation, humidity, and wind speed that could increase the atmosphere's ability to evaporate water (Huntington, 2008) and also increase if net radiation and wind speed increase (Spittle House, 2008). An increase in evaporative demand would significantly affect water resources through evaporative losses from water bodies, vegetation, and soils and through subsequent changes in water demands (Allen *et al*., 1998).

Kaicun, W. *et al.*, (2012) **on their modeling study** for years 1973 to 2008 **stated that** atmospheric evaporative demand increased in most arid and semiarid areas, indicating a decrease in water availability in those areas and will affect vegetation survival and growth through changes in water availability and fire risk. In Addition Spittle house (2008) estimated the magnitude of change in evaporative demand using existing weather station data and climate change model output for the two climate modeling B1 and A2 scenarios from the CGCM3; atmospheric evaporative demand that is calculated for months when the air temperature is above 0°C was increased at all locations. Gained that, increase in the length of time that air temperature remained above 0°C and an increase in the vapor pressure deficit (drier air) and conclude that by the 2080s, atmospheric evaporative demand will increase by about 8% under the B1 scenario and by 15–20% under the A2 scenario and will seriously affect water balance of the catchments. Similarly Ayten and Timothy (2012) found that higher temperatures and decrease in precipitation by the year 2100 in Mediterranean watersheds will lead to significant changes in vegetation cover, and water availability increasing evapo-transpiration rates in watershed systems.

Studies carried out on Lake Ziway watershed showed that the impact of temperature on the hydrological process by increasing evapo-transpiration seems to excel (Zeray, 2006). Haileyesus Belay (2011) in his study on selected 10 catchments of the Nile basin by developing a hypothetical scenario within the range of (-30 to +30 percent change) for both precipitation and potential evapo-transpiration have been investigated and shows that increment of potential evapo-transpiration in both future time series in all watersheds of upper Blue Nile. For the first time series: 2031-2040 in all watersheds higher increment is observed for Beles 10.66% and Sechi 6.86% but for Anger 3.56% and Neshi 3.54% .For the next time series: 2091-2100 higher increments are observed in all watersheds specially Beles 20.69% and Sechi 24.04% showing that increase in atmospheric evaporative demand with increasing surface temperature because of climate change will affect the water balance of watersheds by facilitating evapo-transpiration.

4.2. Change in Vegetation Composition Affecting Evaporation and Interception

Evaporation from the land surface includes evaporation from open water, soil, shallow groundwater, and water stored on vegetation, along with transpiration through plants (Eusebio I., 2008). The rate of evaporation from the land surface is driven essentially by meteorological controls, mediated by the characteristics of vegetation and soils, and constrained by the amount of water available. Climate change has the potential to affect all of these factors in a combined way (Ali E., 2012). Effects of climate extremes on vegetation can have both short-term and long-term implications for standing biomass, tree health and species composition. The more frequent occurrence of climatic changes may accelerate the replacement of sensitive tree species.

The term interception is used to describe the precipitation which is retained by, or absorbed into, the surface of the plant (bark, leaves) or litter and then evaporated directly back into the atmosphere(Soliman, S., 2009). The most accurate estimates of interception have come from studies which have quantified the losses for individual rainfall events on time scales of minutes to hours. Vegetation changes (e.g. from grassland to plantation) can have a significant impact on the amounts intercepted and ultimately on ground water recharge (David, 1998).

A change in catchment vegetation a result of climate change directly or indirectly may affect the catchment water balance. Several studies have assessed changes in biome type under climate change (Friend *et al*., 1997), Terrestrial vegetation influences water balance through the interception of rain and snow and the removal of water from the root zone as a result of plant transpiration and evaporation from the soil surface. As vegetation composition responds to climate change, so too will the amounts of water intercepted, evaporated, and transpired, thus altering snow accumulation and melt processes, water balance, groundwater recharge, and ultimately stream flow and mass wasting processes(IPPC, 2007).

Increases in temperature changes in atmospheric evaporative demand are likely to increase plant transpiration, assuming soil water is available. According to Spittle House (2003), transpiration from a coastal Douglas-fir forest in England could rise by 6% with an increase of 2° C and by 10% with an increase of 4° C. The projected changes in climate are sufficient to affect forest productivity and species composition (Barber *et al*., 2000). Changes may also occur in the form of forest die-off, alpine encroachment, and grassland expansion. (Breshears *et al*., 2005). Thus, changes to the amount of plant biomass on a site and the physiological characteristics of the new vegetation due to climate change will have an important effect on water balance in the future. A change in catchment vegetation directly or indirectly as a result of climate change therefore may affect the catchment water balance (Friend *et al*., 1997).

4.3. Precipitation

Theoretically an increase in heavy rainfall events can be expected in response to global warming. Satellite observation and theory indicates that the amount of perceptible water in the vertical column over the ocean increase, none linearly with increasing sea surface temperature. Thus the amount of water vapor available for rainfall is greater for higher base temperature typically of the tropics or warmer temperature due to enhanced green house condition. (P.H.Whetton.,et al.1999). An observed consequence of higher water vapor concentrations is the increased frequency of intense precipitation events, mainly over land areas. Furthermore, because of warmer temperatures, more precipitation is falling as rain rather (http://earthobservatory.nasa.gov /Features/Water/page4.php).

There is general agreement that many areas of currently high precipitation is expected to experience precipitation increases, whereas many of the areas at present with low precipitation and high evaporation, now suffering water scarcity, are expected to have rain decreases (IPCC 2007).

The hydrologic effects of climate change will have an important influence on all types of watersheds. The response of rain-dominated areas will likely follow predicted changes in precipitation (Loukas et al. 2002). In the Mediterranean region, continental precipitation is increased by 5–10% over the 20th century in the northern hemisphere and decreased in other regions (for example, North and West Africa and parts of the Mediterranean) increases in East African watersheds (IPPC, 2001; IPCC 2007). There is qualitative agreement with the results in Hulme et al. (2001).

In Ethiopia the temperature across the country could rise, whereas precipitation is expected to show some increase (NMA, 2006). Unlike the temperature trends, it is very difficult to detect long-term rainfall trends in Ethiopia, due to the high inter-annual and inter-decadal variability. According to NMA (2006), between 1951 and 2006, no statistically significant trend in mean annual rainfall was observed in any season. The results of the IPCC's mid-range emission scenario show that compared to the 1961-1990 annual precipitation show a change of between 0.6 and 4.9% and 1.1 to 18.2% for 2030 and 2050, respectively (NMA, 2006). The percentage change in seasonal rainfall is expected to be up to about 12% over most parts of the country (ICPAC, 2007).

Projections from different models in the ensemble are broadly consistent in indicating increases in annual rainfall in Ethiopia. These increases are largely a result of increasing rainfall in the 'short' rainfall season in southern Ethiopia. That is projected to change by 10 to +70% as an average over the whole of Ethiopian basins. Projections of change in the rainy seasons that affect the larger portions of Ethiopia are more mixed, but tend towards slight increases in the south west and decease in the north east. (C. McSweeney, 2003). Conway (2005) over the Nile basin indicates that with respect to future climate in Nile basin there is high confidence temperature rise leading to increase evaporation. However there is much less certainty about future rainfall because of low convergence in climate model projection in the key head water regions of the Nile.

Thesis presented by Hayileyesus Belay(2011) on Evaluation of climate change impacts on hydrology on selected catchments of Abbay basin based on the precipitation scenarios generated shows that, change of precipitation in percent for the first future time series: 2031-2040 with respect to the base period shows, the seasonal change of precipitation increase in most of the water shades; 7.41% at Sechi and higher reduction -6.51% at Muger is also observed in the same season, but higher increment value is observed for Chacha (7.71%) and Neshi (1.83%) watersheds. Higher reduction (-4.10%) is observed for Beles watershed in the same future time series (2031-2040). In most of the watersheds the monthly average rainfall in the two future time series:2031-2040 and:2091-2100 maximum variation of rainfall is observed on May, June, July, August months comparing with the base period:1991-2000 showing that the impact of climate change on precipitation distribution among different watersheds.

Ethiopia is historically prone to extreme weather events. Rainfall in Ethiopia is highly erratic, and most rain falls intensively, often as convective storms, with very high rainfall intensity and extreme spatial and temporal variability. Since the early 1980s, the country has suffered seven major droughts, five of which led to famines in addition to dozens of local droughts (Diao and Pratt, 2007). Survey data show that between 1999 and 2004 more than half of all households in the country experienced at least one major drought shock (UNDP, 2007). Major floods due to high rainfall occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996, and 2006 (ICPAC 2007).

From this it is possible to conclude that the increasing global surface temperature is seriously affecting the overall water balance of catchments particularly rain fall amount and distribution depending on the natural condition of the watersheds.

4.4. Altered Groundwater Storage and Recharge

Climate change affects the surface hydrology of landscapes (Thornes *et al*., 2009).The main concern raised by global warming is that climatic variations alter the water cycle; indeed, in many cases, the data show that the hydrological cycle is already being impacted (Huntingon, 2006; IPCC, 2007). Any variation in the regime and quantity of precipitation, together with variations in temperature and evapotranspiration, affects groundwater recharge. In general, groundwater recharge will increase in areas where precipitation is increased and vice versa. Ground water recharge will increase also in areas where permafrost thaws (Kitabata *et al*., 2006). Most of the consequences of changes in recharge will be detrimental (IPCC 2007).

Assessing the effects of climate change on groundwater is a difficult task because highly detailed subsurface information is required to develop quantitative models (Allen, 2009). Several of the hydrologic processes will influence changes in recharge fluxes; including increased atmospheric evaporative demand, changes in vegetation composition, snow accumulation and melt, and stream flow. Changes in the amount, timing, and form of precipitation (snow vs. rain) will all affect the rate and timing of groundwater recharge. Changes to stream flow will also affect groundwater recharge in locations where surface water is the main recharge source. Depending on aquifer size and depth, any changes in ground water hydrology caused by change in climate will likely occur more slowly than surface water changes (Burn *et al*., 2008).

Research in the Okanagan Valley(British) shows that direct (vertical) recharge along the valley bottom is driven largely by regional precipitation (e.g., frontal precipitation) rather than localized precipitation (e.g., convective storms) (Toews *et al*., 2009). When combined with future climate scenarios, peak recharges is expected to occur earlier in the year when evaporative demand is lower. The net effect is a minor increase in annual recharge for predicted future climate scenarios (Toews and Allen, 2009), which could possibly buffer higher water demand in hotter and drier winter months in some region.

Generally, variations in aquifer recharge not only change the aquifer yield or discharge, but also modify the groundwater flow network, e.g. gaining streams may suddenly become losing streams, and groundwater divides may move position. A paper by Wintar (1999) shows how climatic conditions affect the direction of groundwater flow and the relationship between superficial hydraulic bodies and shallow waters, at different scales. The most recent GCMs forecast showed a decrease in rainfall and, therefore, of groundwater recharge (IPCC, 2007). The combination of lower precipitation and higher evaporation in parts of the Mediterranean region is diminishing water levels in lakes and groundwater (UNESCO, 2006).

Some results reported by IPCC (2008) through a global hydrological model applied with four climate change scenarios (the ECHAM4 and HadCM3 GCMs with the SRES A2 and B2 emissions scenarios), the groundwater recharge decreased by more than 70 % for the south west Africa and north-eastern Brazil. Ground water recharge has a direct influence on the base flow of rivers, when the water table depth and groundwater decrease; the base flow is reduced fundamentally in dry seasons resulting in less water storage (Stewart *et al.* 2004) or groundwater storage.

Effect of Climate change on vegetation also affects groundwater recharge; with increased frequency and magnitude of floods, ground water recharge may increase, in particular in semi-arid and arid areas where heavy rain falls and floods are the major sources of groundwater recharge. Accordingly, an assessment of climate change impact on groundwater recharge should include the effects of changed precipitation variability and inundation areas (Kundzewicz, Z, *et al.* 2007).

The global scale estimates of climate change impacts to groundwater recharge developed by Döll and Florke (2005) based on calculations from the global hydrological model WGHM (Water Gap Global Hydrology Model), estimated diffuse recharge (1961–1990 baseline) at the global scale with a resolution of 0.5° by 0.5°. They then simulated the impacts of climate change for 2050s under a high (A2) and low (B2) greenhouse gas emission scenario. A comparison of the impact of climate change on groundwater recharge to the impact on total runoff generation from the land fraction of each cell (i.e. not considering the water balance of surface water bodies) shows a spatially very heterogeneous pattern, even though groundwater recharge, in WGHM, is computed as a fraction of total runoff from land. In most areas, however, the percent change in groundwater recharge is less than the percent change in total runoff generation from land. In some areas around the globe, (mostly small) increases of total runoff from land are coupled to (mostly small) decreases in groundwater recharge, and vice versa, which is also due to seasonal shifts. In areas with decreasing total runoff from land, the percent decrease of groundwater recharge is often higher than the percent decrease of total runoff from land (Döll and Florke, 2005). Climate change also affects the groundwater recharge rate.

Table 1: Global values of groundwater recharge, total runoff from land, total cell runoff and continental precipitation computed or applied by WGHM for the period 1961-1990 and the 2050s. The values for the future time period refer to the emissions scenario A2 as interpreted by the global climate model ECHAM4.

	1961 [A] (KM^3/a)	2050s ECHAM4,A)(B) [Km3/a]	Change between A and B [%]
Groundwater recharge	12882	13112	+1.8
Total runoff from land	38617	42062	+8.9
Total cell runoff	36621	39755	+8.6
Continental precipitation	107047	111572	+4.2

Source: Doll and Florke, 2005. Global-Scale Estimation of Diffuse Groundwater Recharge

4.5. Change in Stream Flow and runoff Characteristics

Stream flow characteristics mean and inter annual variability; of the river basins have far-reaching implications. Climate change can also alter flow regime and change nutrient and sediment budgets of watersheds (Ayten and Timothy, 2012).

Stream flow regimes are controlled primarily by seasonal patterns of temperature and precipitation, as well as watershed characteristics such as lake cover, and geology. The relative importance of climatic changes, therefore, will vary by region and depend on the current sensitivity of the hydrologic regime to regional temperature and precipitation changes. In addition, groundwater storage and release strongly control stream flow (particularly low flows) in some watersheds by affecting magnitude and timing of stream flow (Thompson, 2007; Tague and Grant, 2009).

The hydrologic effects of climate change will have an important influence on all types of watersheds. The response of rain-dominated areas will likely follow predicted changes in precipitation (Loukas et al. 2002). For example, increased magnitude and more numerous storm events will result in increasingly frequent and larger storm driven stream flow (including peaks) in the rainy season. Projected warmer and drier seasons also raise concerns about a possible increase in the number and magnitude of low flow days. Li et al., (2011) indicated that increase in temperature as a result of global warming may increase the soil loss. The increase in soil loss from the upper catchment will increase the sediment flux to the reservoir. The predicted increase in temperature causes increased evaporation losses, which in turn result in a decrease in stream flow.

According to study in the upper Mississippi river basin (North America) using regional climate model climate induced stream flow changes are inferred by evaluating differences produced by SWAT and when driven by future scenario and contemporary climates; annual average stream flow will increased by 50% because of climate change, with the largest increase occurring in spring and summer (Ayten Erol & Timothy O. Randhir, 2012). Surface runoff would be substantially reduced as a result of an increase in surface air temperature by 2°C accompanied by a 5–10% decline in precipitation during normal rainy season (Gruza *et al.* 1997). There is an increase in the risk of flooding in semi-arid and arid regions (Patz and Martens, 1996). On other hand researches in Mediterranean basin accentuated irregularity of stream flow with increased aridity. The flow regimes of smaller river basins are very sensitive to soil and land use changes, thereby increasing the irregularity of flows (Thornes, 2009).

Studies carried out in different African countries showed that Climate change has the potential to impose additional pressures on hydrology in Africa (Bates, *et al*., 2008). The impact of projected climate change on water resources across the continent is not uniform. An analysis of five climate models (CSIRO2, HadCM3, CGCM2, ECHAM and PCM) in conjunction with two different emissions scenarios, Strzepek and McCluskey (2006) showed that almost all countries in southern Africa, except South Africa will probably experience a significant reduction in stream flow. De Wit*, et al*. (2006) also using six GCMs, identified a critical 'unstable' area between Senegal and Sudan, separating the dry Sahara from wet central Africa and reported that a reduction in runoff in Southern African watersheds.

In the Nile Basin, Conway (2005) found that there is no clear indication of how Nile river flow would be affected by climate change, because of uncertainty in projected rainfall patterns in the basin and the influence of complex water management and water governance structures. Another study by Soliman *et al*. (2009) using ECHAM5 A1B scenario as downscaled by RegCM3 reported future increase in Blue Nile flow at El Diem by about 1.5% annually.

Demissie *et al,* (2013) in their study on Gibe catchment of south west Ethiopia using SWAT model indicated that; as climate changes, the average annual stream flow is predicted to decrease within the range of 1.3% to 3.5% for the future period of 2050s. Haddush Goitom *et al*. (2012) in their study on the Geba river also which is a tributary of the Nile showed the projected effect of climate change in daily mean river flow in each month between the future and baseline periods for the A2 and B2 climate scenarios simulated with the WetSpa model shows that there will be a significant decrease in river flow for both climate scenarios. The overall annual reduction in river flow accounts for 23.1%, 35.8% and 50.2% of the present river flow for the A2 climate scenario and for 26.1%, 36.6% and 42.7% for the B2 climate scenario in the 2020s, 2050s and 2080s respectively. Reduction in stream flow due to climate change has been confirmed by other studies in the region and is attributable to the decrease in precipitation and increase in PET.

Studies carried out on Lake Ziway watershed showed that despite the increasing trend of both climatic variables in the future, the increase in monthly average precipitation seems to be obscured by increases in monthly average temperature. The impact of temperature on the hydrological process by increasing evapotranspiration and thereby reducing the inflow volume seems to excel. As a result, the total average annual inflow volume into Lake Ziway might decline significantly up to 19.47% for A2a and 27.43% for B2a scenarios. The decreasing trend of the average annual inflow volume is mainly associated with the decrease in the Kiremt inflow volume by between 11.8 and 28.4% for the A2a scenario and between 16.5 and 27.8% for the B2a scenario (Zeray, 2006).

A study in the Gilgel Abbay river watershed indicates that the catchment is sensitive to climate change especially in rainfall and an increase of 2°C without change in rainfall; decreases the seasonal and annual runoff by 1.7 and 2%. However; if the change in temperature is changed by 20% rainfall reduction, seasonal and annual runoff will reduce by 33%. If the change in temperature is 4°C, the seasonal and annual runoff decreased by 3.3 % and 4% respectively. If the 2°C increase of temperature is occur simultaneously with rainfall reduction in 10% the seasonal and annual runoff will decreased by 17.7%. And it is concluded the Gilgel Abbay Catchments is more sensitive to change in rainfall than change temperature (Kedir, 2008). Assessment for Lake Tana sub basin on the basis of CCCM and GFCD3 UK89 climate change prediction model predicts a reduction of annual runoff by 18.2% and 12.6% respectively while GCM predicts wetter condition and as result of an increase in 2.5% in annual runoff (Tarekegn and Tadege, 2006).

More recently, Kundzewicz *et al*., (2004) and Svensson *et al*., (2004) analyzed trends in annual maximum flow and in peaks over threshold and annual low flows, respectively and found the following result.

Table 2 Annual maximum stream flow by continent for 195 stream gauging stations worldwide associated with climate change

Region	Number of stations	Number with increasing trend	Number with no trend	Number with decreasing trend
Africa	4	1	1	2
Asia	8	0	5	3
North America	3	0	3	0
South America	70	14	44	12
Australian pacific	40	1	34	5
Europe	70	11	50	9
Totals	195	27(14%)	137(70%)	31 (16%)

Source; kunduzewicz et al., 2004

Generally, the most recent and most comprehensive analyses of river runoff, which include newly, assembled observational records conclusion is that global runoff increased (4% increase in global total runoff per 1°C rise in temperature with regional variations as Bates, B.C.,*et al*.,2008 stated) during the 20th century. Average runoff has not changed in the majority of rivers, but year-to-year variability has increased (IPCC, 2013). At the global scale, there is evidence of a broadly coherent pattern of change in annual runoff, with some regions experiencing an increase in runoff (e.g., high latitudes) and others (such as parts of West Africa, southern Europe and southernmost South America) experiencing a decrease in runoff (Milly *et al*., 2005) for many catchment-scale studies.

5. Conclusion and Recommendation

Climate change is the biggest challenge to the whole world it is already happening and further change is inevitable. The IPCC scientific assessment report and other climate change researches showed that global average temperature would rise with increasing amount of carbon dioxide concentration in the atmosphere. In Ethiopia trend analysis shows there was an increase in temperature over the last 50 years with rainfall and temperature pattern change and variability with a sign of recurrent draught and flood events in the country.

The projected changes in climate will have direct and indirect impacts on natural environment as well as on human societies. Climate change may induce major changes in hydrological conditions like; sea level rise, change in precipitation pattern, change in stream flow characteristic, groundwater recharge and availability, change in vegetation composition affecting interception process, changes in evapo-transpiration process.

Climate change impacts can vary between catchments even within relatively small areas due to local climate and catchment characteristics depending on which specific watershed process and response are sensitive to change because of difference in geophysical characteristic of watersheds. Modeling climate change impacts on hydrology in local and national scale is needed to infer reliable estimates of climate change impact on hydrology.Those current modeling studies of climate change on watershed hydrology on different river basins conclude that there is atmospheric evaporative demand increased because higher temperatures indicating a decrease in water availability affecting vegetation survival and growth. Altered frequency and distribution precipitation events, with associated consequences, effects on groundwater recharge and discharge rates and stream flow characteristics mean and inter annual variability; of the river basins have far-reaching implications.

Generally since water is vital for the existence of life and overall process of the planet and is vulnerable to climate change impacts developing and testing probabilistic regional models to understand and predict key impacts of changes in water dynamics under a range of climate scenarios for the next few decades, developing appropriate science-based adaptation strategies to respond to and minimize the risks to human and natural systems caused by changes to the water cycle through the development of appropriate options at the watershed/river basin scale. Understanding the consequences of the changing water cycle for water-related natural hazards, including floods and droughts, and to improve prediction and mitigation of these hazards and improving predictions for the next few decades of regional precipitation, evapo-transpiration, soil moisture, hydrological storage and fluxes, and the requirement to quantify and narrow the uncertainty in predictions to develop adaptation mechanisms for current and future generation is crucial.

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