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Climate change and population growth impacts on surface water supply and demand of Addis Ababa, Ethiopia

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ABSTRACT

Addis Ababa is expected to experience water supply stress as a result of complex interaction of urbanization and climate change. The aim of this study is to investigate water demand and supply prospects for the City of Addis Ababa by applying the Water Evaluation and Planning (WEAP) hydrological model and using scenarios of population growth trends and climate change. The study method consists of trend analysis through collecting on water consumption & hydrological information and climate data of statistically downscaled acquired from Worldclim data center. Bias corrected climate model data of NIMR-HadGEM2-AO under a midrange RCP 4.5 scenario and RCP8.5, high emissions scenario was used for the study. The result shows that the projected population of Addis Ababa city using high population growth rate (3.3%) will be about 7 million by the year 2039. The climate change projections result under RCP 4.5 and RCP 8.5 scenarios on surface water supply shows that the level of reservoirs volume both Legedadi/Dire and Gefersa reservoirs will reduced in the projected years between the years 2023 and 2039. The result of the RCP 8.5 scenario with low population growth shows that the unmet water demand will be 359.54 million m^3 in 2039. The result of the RCP 4.5 scenario with low population growth shows that the unmet water demand will be 450.59 million m^3 in 2039. This indicates that the unmet water demand with the dry climate of RCP 4.5 climate change scenario is higher than RCP 8.5 scenario. The RCP 4.5 scenario with high population growth (3.3%) the unmet water demand is 130 million m^3 in 2030, 271 million m^3 in 2035 and 515.74 million m^3 in 2039. This indicates that the unmet water demand in both high population growth and the dry climate of RCP 4.5 climate change scenario will have big shortage of water in the city. The most effective management optioned are water tariff increasing, domestic water use technology efficiency improvement and water harvesting gives satisfactory result in mitigating un meet demand of climate change and population growth in the city.

1. Introduction

Studies indicate that extreme variability in water resources and significant decreases in stream-flow will be major threats across sub Saharan African countries in the coming decades (Saloua et al., 2012). Water resources are among the most vulnerable as they are

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directly exposed to climate change (Ellen and Jay, 2008; Raskin et al., 2009; Saloua et al., 2012). This is important as one of the major limiting factors of economic growth is the relative availability of water (Yahaya et al., 2014). Recent research shows that climate change will increase the pace of the global hydrologic cycle with accompanied rise in temperature, variability and changes in precipitation patterns (Saloua et al., 2012; Daniel, 2011). Changes in the frequency and intensity of precipitation invariably affect stream flow and the resultant storage volumes of reservoirs. For example, such changes manifest themselves in the form of increased intensity of floods or occurrence of severe droughts which severely affect the water resources at local and regional levels (Akiça, 2012). Human induced climate change affects the quality and quantity of global water resources and this necessitates changes in the way these resources are managed (Manjarrez et al., 2010). Sub-Saharan countries are among those most threatened by water stress, in view of the likelihood of extreme variability, seasonality, and decreasing stream-flows that are predicted to occur in the coming decades (Saloua et al., 2012). Drought in Sub-Saharan Africa is the dominant climate risk; it destroys the livelihoods of farming and pastoral communities and shatters their food security, whilst it also has a significant negative effect on GDP growth (UN-Water, 2012). On the other hand, floods impact on infrastructure, transportation, goods and service flows as well as clean water supplies and health negatively (Yahaya et al., 2014; FDRE Climate Resilient, 2011).

The urbanization rate in Sub-Saharan Africa is increasing (George et al., 2011). Addis Ababa is one of these fast growing sub-mega cities in recent times (AACPPO, 2014). As the administrative seat and political capital of Ethiopia, the city attracts the highest number of migrants from other parts of the country (ORAAMP, 2002)). As the supply of water must be assured for all, to meet the basic human needs, there is a need for progressive water supply planning and management system for the city in order to bring about fundamental changes in the ways water is currently used as well as distributed among different categories of users (Foster and Morella, 2011; AAWSA, 2012). The importance of demand-side management, in particular, is vital in view of the fact that the supply of water cannot be simply increased indefinitely to meet the otherwise increasing demands from the household, commercial, construction, industry and other sectors as well as the needs of the ecological reserves (Golini et al., 2001; Mulwafu et al., 2003; Buytaert et al., 2011).

Growth in population and economic activities as well as improvements in living standards of the population would entail increasing demand for water (Bell, 2015). In case of Addis Ababa, which is evolving into a mega-city, the construction boom including the expansion of condominiums and real estate housing developments, the expansion of manufacturing and service sector establishments that has occurred during the last decade, and the significant increase in its population that is expected to occur in the coming years presupposes a sustainable water supply planning and management (AACPPO, 2014)). As water resources are susceptible not only to these pressures but also to impacts of climate change; environmental managers, urban planners and policy makers need to find solutions for climate change and urban development impact and alternative water sources for the existing and future pressures (Eriyagama et al., 2010; Kirsten and Mark, 2011; Yahaya et al., 2014; Carter et al., 2015).

Climate related risks due to increased variations in climate and weather associated with extreme events have emerged as a key natural hazard of the 21st Century (IPCC, 2013; Hayhoe et al., 2013; Dastagir, 2015). Studies on both present climate variability and future climate change impacts-vulnerability and adaptation have predominantly been derived from Global Circulation model (GCM) outputs. GCMs are the most multifaceted tools currently available for simulating the global climate system (Randall et al., 2007).

The Global Circulation models (GCMs) are not only designed to understand climate processes and reproduce observations but they are also used to predict the future climate (Nimusiima, et al., 2014). However, the future climate depends upon several factors including anthropogenic activities. As a result, defining the possible pathways of different climate components dictated by their interactions under the influence of internal and assumed external factors (e.g., internal natural and external anthropogenic factors) are important for making future projections. This constraint led to definition of different scenarios under the Special Report on Emissions Scenarios (SRES) and Representative Concentration Pathways (RCPs). In the following, a brief review of the GCM experiments conducted under these scenarios is provided.

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has been carried out using a new set of scenarios that replace the Special Report on Emissions Scenarios (SRES) (Wayne, 2013). There are four pathways: RCP 8.5, RCP 6.0, RCP 4.5 and RCP 2.6. The RCPs are trajectories, based in greenhouse gas emissions, land use changes and aerosols, developed for use by the climate modeling community as a uniform basis for near-term and long-term experiments of climate modeling (Moss, 2010). Coupled with climate change, urbanization poses an added challenge to water resources around the world (Monireh et al., 2012; Larson et al., 2013; Zhou, 2014). Human induced climate change is expected to influence the quantity and quality of water resources and this require changes in the way water resources are handled (Sujoy et al., 2010). Since urban population is expected to grow increasing the amount of existing water supply to meet the rising demand. Studies shows cities have additional sources of water supply (like from the ground water) in order to maintain inhabited consumption levels (Alexander et al., 2010). Given the relationship between urbanization and water on the one hand and between climate change and water on the other, the goal of this work is therefore investigate the potential impact of climate change on urban water supply by taking the City of Addis Ababa as geographic study area.

2. Methodology

2.1. Study area

Addis Ababa was established in 1889. Addis Ababa city lies between 23°21′ N to 23.35°N latitude and 85°20′E to 85.33°E longitude (Tolon, 2008). Total area covered by the Addis Ababa city is 520 km^2. The city mean annual maximum temperature is about 24 °C, and the mean annual minimum temperature of the city is about 120 C. The mean monthly rainfall is high in July and August (about 260 mm). The mean annual rainfall in the city of Addis is about 1255 mm (NMA, 2007). Land use in the city indicate,