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Effects of climate change on water savings and water security from rainwater harvesting systems

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ABSTRACT

Climate change presents major uncertainties in future safe water access especially in rural communities that are already faced with water insecurity. For Uganda, rainwater harvesting has become a major adaptation strategy to ensure the attainment of safe water access for all. However, climate change effects on rainwater harvesting potential remains largely unexplored. Therefore, this paper assesses climate change effects on water savings and water security from rainwater harvesting systems for Kabarole district, Uganda. The top performing Global circulation models (GCMs), used in this study included; MIROC5, BCC-CSM-1-M, CNRM-CM5, ACCESS1-0, HADGEM2-ES and HADGEM2-CC using projections for 2025–2055 (2040s) and 2060–2090 (2070s) periods. Seasonal analysis used the 4 seasons for Uganda, namely; the 2 dry seasons of December, January, February (DJF) and June, July, August (JJA) and the 2 rainy seasons of September, October, November (SON) and March, April, May (MAM). Although there are conflicting model predictions, generally, the models agree that water savings and security will reduce in DJF and MAM and increase in JJA and SON seasons. MAM rain season will be most affected with water savings and security projected to reduce by more than 50% in the 2070s period. Therefore, households should harness the increased water savings in JJA and SON to cater for the predicted reduction in water savings in MAM and DJF seasons especially for the 2070s period. A larger tank of 5 m^3 along with at least 50 m^2 roof size combined with a low cost household water treatment is thus recommended.

1. Introduction

The sustainable development goal 6 targets that by 2030, safe water should be affordable and accessible for all (UNDP, 2015a,b). For many developing nations, achieving this target will be a challenge especially with the increasing population and projected climate changes. Therefore, decentralised water supply systems are increasingly becoming important c water supply systems especially for rural areas. This is because of the inadequacy of the central public water supply systems to reach to remote rural areas, which are often the most affected. Consequently, for most developing countries, rainwater harvesting is gradually becoming an important potable water source to improve household water security (Musayev et al., 2018). Rainwater harvesting systems comprise of a catchment harvesting surface, a storage volume and a guttering system that connects the catchment area to the storage volume (Wallace et al., 2015). The practice has been conducted for over 4000 years for both potable use and irrigation of food crops (Londra et al., 2015). Depending on the local needs and resource availability, different countries have different purposes for rainwater. Developed countries mostly use rainwater for non-potable needs such as irrigation, laundry and toilet flushing, and among others as reported in Sweden (Villarreal and Dixon, 2005), Australia (Muthukumaran et al., 2011; Rahman et al., 2012; Van der Sterren et al., 2012), Canada (Despins et al., 2009), Spain (Domènech and Saurí, 2011) and the United States (Jones and Hunt, 2010; Rostad et al., 2016). In developing countries however, rainwater is normally used for potable purposes like drinking, cooking and personal hygiene as reported in Namibia (Sturm et al., 2009), Nepal (Domènech et al., 2012), South Africa (Kahinda et al., 2007), Uganda (Kisakye et al., 2018) and Brazil (Ghisi, 2006). Therefore, depending on the purpose of the water, the quantity and quality needs for the harvested rainwater greatly varies from country to country. Many studies on rainwater harvesting have focused on rainwater systems design using historical rainfall data (Bashar et al., 2018; Imteaz et al., 2015, 2012, 2011; Montalto et al., 2010; Rahman and Hajani, 2014). However, with projected climate change, water savings and water security from rainwater harvesting systems may be

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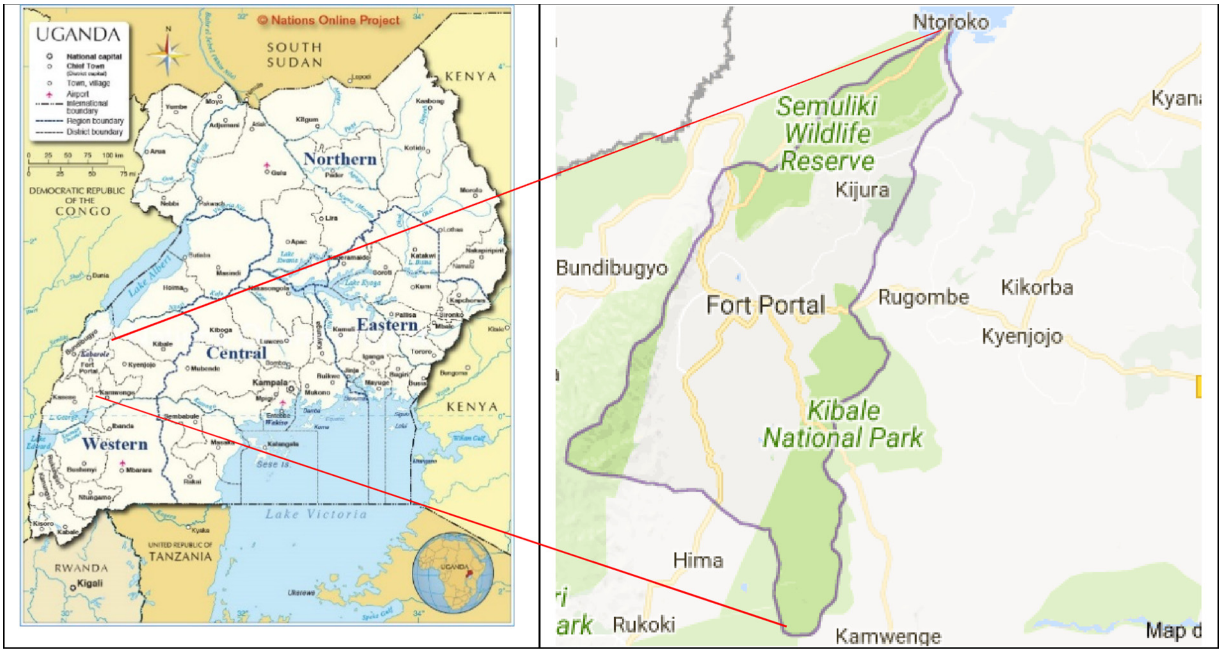

Fig. 1. Kabarole district location on the Ugandan map (Based on Google maps).

negatively affected especially for developing countries.

For East Africa, General Circulation Models (GCMs) suggest a 10–20% increase in rainfall and a shift in rainfall distribution is expected (Toulmin, 2009). For instance, an increase in rainfall is expected between December to February and a reduction from June to August (Toulmin, 2009). In Uganda, the effect of climate change on seasonal rainfall is predicted to be more important than changes in annual rainfall (Kisakye et al., 2018). Specifically, seasonal rainfall is predicted to increase by almost 100% while total annual precipitation is predicted to increase by only less than 10% for the RCP4.5 scenario. The changes will be greatest for December, January and February season (Akurut et al., 2014; Rautenbach et al., 2014). Most GCMs suggest a drier dry season and a wetter wet season for Uganda (Akurut et al., 2014; Hisali et al., 2011; Rautenbach et al., 2014). In an effort to mainstream domestic rainwater harvesting as a conventional water source, Uganda developed a rainwater harvesting strategy in 2005. However, for rainwater harvesting to be realistic for Uganda, projected changes in rainfall due to climate change need to be incorporated in future policy formulations.

Some studies have explored the effect projected changes in rainfall would have on rainwater harvesting systems (Alamdari et al., 2018; Kahinda et al., 2010; Kisakye et al., 2018; Musayev et al., 2018; Rahman et al., 2016; Wallace et al., 2015). In their study Kahinda et al. (2010) evaluated water security variation with climate change using a daily water balance model incorporating roof size, daily demand and storage volume. The study concluded that water security will increase by 5–20% for a 0.5 m^3 tank volume for some regions in South Africa. The study however uses annual rainfall changes as opposed to seasonal changes. In developed nations like Australia, climate change impacts on rainwater harvesting systems have been extensively covered (Rahman et al., 2016; Wallace et al., 2015). In Australia, Rahman et al. (2016) evaluated the performance of a rainwater harvesting system for non-potable demand using a daily time step. Wallace et al. (2015) demonstrated developed design curves for different reliabilities using projected rainfall from different GCMs using a daily water balance algorithm. Both studies suggest a reduction in rainwater savings, reliability and water security for Australia with the greatest impact experienced in the dry season. While Rahman et al. (2016) relied on a single GCM, Wallace et al. (2015) used a total of 11 top performing GCMs. Wallace et al. (2015) developed design curves, which communities can use to design rainwater harvesting systems for a given reliability. To the best of our knowledge, only one study has evaluated climate change effects on rainwater harvesting systems for Uganda. Kisakye et al. (2018) developed design requirements for rainwater harvesting systems of varying reliabilities considering climate change for Kabarole district, Uganda. The study reports that the reliability of rainwater harvesting systems will greatly increase during the SON season and reduce during the MAM season for the 2055–2090 period (Kisakye et al., 2018). The study however only focused on rainwater harvesting systems' reliability and only presents water security for one roof size of 30 m^2 and yet water savings and water security greatly varies with roof area and water demand. Therefore, climate change effect on water savings and water security for different roof sizes and demand levels ought to be explored.

Consequently, this paper compares water savings and water security between the observed scenario (based on historical data) and the 6 different GCMs for 2025–2055 and 2060–2090 periods. Kabarole district, in western Uganda was considered as a case study because it has one of the highest rainfall in the country and thus considered to have high potential for rainwater harvesting. Seasonal analysis used the four (4) seasons for Uganda, namely; the two (2) dry seasons of December, January, February (DJF) and June, July, August (JJA) and the two (2) rainy seasons of September, October, November (SON) and March, April, May (MAM). According to Kisakye et al. (2018), using seasonal analysis for designing rainwater harvesting systems ensures that the worst case scenario is incorporated in the systems' design making it more sustainable. The implications of the results on rural households is also presented.

2. Methodology

2.1. Study area

Kabarole district is part of the seven (7) districts that make up the Rwenzori region in the mid-western part of Uganda as shown in Fig. 1. Other districts include, Kasese, Kamwenge, Kyenjojo, Ntoroko, Bundibugyo and Kyegegwa districts. Fort portal, the main district headquarters is located 318 km from the Ugandan capital, Kampala. The district land area is 8319 km^2 (MFCD, 2000) and the landscape comprises of undulating hills with over 53 crater lakes mainly used for