Drought and households’ adaptive capacity to water scarcity in Kasali, Uganda
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ABSTRACT

The world is experiencing variability in precipitation, increased temperature, drought frequencies and intensities. Globally, approximately four billion individuals experience water scarcity due to drought. In Uganda about 10% of the population in the southern and northern parts of the country experience drought related water scarcity annually. This study aimed at assessing drought and households’ adaptive capacity (AC) to water scarcity during drought in Kasali. This was done through determining drought trends from 1987 to 2017, assessing the impact of drought on water availability and the AC of households to manage water scarcity. Droughts were assessed based on the Reconnaissance Drought Index (RDI). The results show a decrease in the average annual rainfall, and the seasons of March-April-May (MAM), January-February (JF) while the seasons of September-October-November-December (SOND) and June-July-August (JJA) show an increase in rainfall trend. The average maximum and minimum annual and seasonal temperature increased significantly by between 0.56 and 1.51 °C. The minimum temperature increased more than the maximum temperature. Kasali experienced one extreme dry year and four moderate ones between 1987 and 2017. Above 70% of the households spend longer hours collecting water during dry years than wet years. The AC of households to water scarcity was low and drought negatively impacted water availability.

Key words | climate change, communities, Kasali, vulnerability, water scarcity

HIGHLIGHTS

• We analysed temperature, rainfall and drought for the 1987–2017 period in Kasali.
• RDI was used to analyse drought since it is more sensitive compared to other indices.
• The annual minimum and maximum temperature increased by 0.4 °C and 0.2 °C per decade respectively from 1987 to 2017.
• We used financial and economics, infrastructure and institutions, knowledge and information, technology and innovation and social resources as indicators of adaptive capacity.
• Kasali was found to have a low adaptive capacity and it experienced five moderate to extreme drought events for the 1987–2017 period.
INTRODUCTION

Increased temperature on the Earth’s surface leads to changes in frequency and distribution of rainfall and droughts (Ghebrezgabher et al. 2016). Drought is an atmospheric event associated with insufficient availability of water for a long time in a given geographical area (Shamshirband et al. 2020). Drought is a complex climate change risk whose intensity and severity has risen globally in the past two decades causing adverse impacts on water resources, vegetation, people and their livelihoods (Gleick 2014; Masih et al. 2014). For instance, between 2002 and 2010, Australia experienced an extended period of droughts which affected ecosystems in its largest river system, Victoria and Murray-Darling Basin (MDB), and left thousands of people grappling with water scarcity (Leblanc et al. 2012). This drought was believed to have been the main cause of global apparent reversal in intensification of the water cycle that was observed in the subsequent years (Huntington 2006). Several studies have shown droughts in all the continents, with Africa having the highest number of drought events (Masih et al. 2014; EM-DAT 2019).

In Africa, The Greater Horn of Africa (GHA) and southern Africa regions were severely affected by droughts in the last one and half decades (Olufemi 2017). The GHA has experienced multiple droughts with varying onsets, duration and intensities. For example between 2009 and 2011 the region suffered the most severe drought due to its duration and intensity (FAO 2013). Climate change is undoubtedly becoming serious in the sub-Saharan African countries with studies showing increased annual temperatures and reduced mean annual precipitations in the GHA (Amjath et al. 2016). Drought has been severe in this region since the 1970s, and it has resulted in crises for millions of people together with their livestock and the situation has worsened due to climate variability and change (AfDB 202). The impact of drought on the hydrological system is less known. This is because of the human and physical feedback loops influencing the behaviour of the resources, being more at a local than a regional scale (Ghebrezgabher et al. 2016). This remains a pressing issue which has to be studied because some adaptation strategies to water scarcity may result in mal-adaptation (Olufemi 2017). Drought has increased water scarcity in sub-Saharan Africa (Olufemi 2017), for example in early 2018 the city of Cape Town was hit by one of the worst drought periods in its history which led to water scarcity. During the last months of 2017 in Cape Town, the water reservoirs in the dams dwindled to so low a level that approximately 3.7 million metro area residents of Cape Town city risked experiencing a ‘Day zero’ situation where residents’ taps would be switched off as a way of conserving water (Wolski 2018).

In Uganda, water scarcity due to drought poses the greatest threat to the rural population. Around 4.5 million people (or 10% of the population) are affected by water scarcity each year, mainly in the south-eastern and north-eastern regions of Uganda (World Bank 2019). Droughts in Uganda are a recurrent hazard and the country experienced notable drought events in the years 1967, 1979, 1987, 1999, 2002, 2005, 2008, 2010 and 2017 (World Bank 2019). The severe droughts affected many water resources in the country (NEMA 2010). Climate projections indicate that conditions will become even more severe in the 21st century (Hertel & Rosch 2010). Therefore, adverse impacts of drought will
continue to pose threats to Uganda in future amidst the growing population and economy and increasing urbanization (Kilimani et al. 2015). The experiences of the local communities, their AC and risks need to be understood for proper measures to be put in place. This study seeks to address this gap in knowledge through determining the impact that drought has had on water quantity and assessing the AC of households to withstand such impacts.

In determining drought, various indices have been developed in the last 30 years to monitor the various droughts – agricultural, meteorological, hydrological, and socio-economics. Many studies have indicated that the Reconnaissance Drought Index (RDI) was useful for hydrological studies because it has been recognized as a more sensitive and conservative index (Shokoohi & Morovati 2015; Tigkas et al. 2015). RDI also accounts for potential evapotranspiration (PET) and rainfall, unlike other indices, and therefore could potentially be useful in analysing droughts in tropical countries where PET is an important climatic factor. These data requirements are ideal for developing countries which monitor few climatic parameters. Combining drought information with a community household survey (HHS), Focus Group Discussions (FGD) and Key Informant Interviews (KII) provides robust tools to understand the community’s experiences and assess the AC of households of Kasali.

**STUDY AREA**

The study area is in Kasali sub-county, southern Uganda (Figure 1) located between latitude 31° 28’ 0” and 31° 35’ 0” east and longitudes 0° 34’ 0” and 0° 42’ 0” south. The

[Figure 1: Map of Kasali sub-county showing the five parishes (Buziranduulu, Gayaza, Kigenya, Kyakonda and Nkenge), rivers, wetlands and water points.]
climate of the study area is governed by the passage of the Inter Tropical Convergence Zone (ITCZ) and influenced by convective rainfall influenced by the proximity to Lake Victoria (Muhiru et al. 2015), thereby experiencing a moderate rainfall distribution throughout the year with longer rains taking place between March and May and shorter rains between October and November, receiving a mean annual rainfall of 1180 mm. The dry months are January–February and June–August (GOU 2013). The mean annual maximum temperature of Kasali is around 25 °C. The minimum temperature in the east (17.5 °C) is higher than the west (15 °C) (GOU 2013). The relative humidity ranges between 80 and 90% in the morning and 61–66% in the afternoon for the months of January–May. In June–August, the morning relative humidity decreases to around 77% and the same applies to the afternoon, which decreases to around 57% (GOU 2013).

The sub-county has a number of considerable geomorphologic features comprising plateaus, highlands, hills, flatlands, rivers, lakes and wetlands (NEMA 2010). Most parts of Kasali have a high plateau with an average elevation of about 1,500 m above sea level. The hills are separated by narrow valleys consisting of papyrus wetlands. The region is part of the Lake Victoria catchment consisting of four main rivers and associated wetlands which include Kisoma, Kase Mugiri, Nakogongo and Katengo (Figure 1). These are the main water sources for the residents (NEMA 2010).

The vegetation of the study area can be broadly classified into three major divisions, which include savannahs, swamps, and forests, all supporting different ecosystems. (GOU 2019). The sub-county has a total population of 25,700 (GOU 2013). It is composed of five parishes and 37 villages. The parishes are: Buziranduulu (seven villages), Gayaza (eight villages), Kigenya (eight villages), Kyakonda (six villages) and Nkenge (eight villages). The study was conducted in three parishes of Gayaza (Kyampigi, Luti), Kigenya (Lwengwe, Kisubi) and Nkenge (Kyango-Bigavu, Nkenge) and six villages (Figure 1).

**METHODOLOGY**

**Data collection**

Both primary and secondary data were used in this study. The primary data was collected using a household questionnaire (HHQ), FGD and KIs, while secondary data (monthly temperature and rainfall) for 1987–2017 was acquired from Uganda National Meteorological Authority (UNMA).

HHSSs were undertaken to gather information on impacts of past droughts on water availability and assessing the AC of households. A total of 195 questionnaires were administered to the household heads or any other adult found in the household in the three parishes (Gayaza, Kigenya and Nkenge). The sample size was determined using Cochran’s equation as shown in Equations (1) and (2):

\[ n_0 = \frac{z^2 p (1 - p)}{e^2} \]  

where \( n_0 \) = sample size; \( z = 1.96 \) for 95% confidence level; \( p \) = estimated proportion of population (assumed to be 50% or 0.5); \( e \) = margin of error (assumed to be 0.07).

Therefore, \( n_0 = \frac{1.96 \times 1.96 \times 0.5(1 - 0.5)}{0.0049} \)

\( n_0 = 196 \)

Adjusted Sample (S) = \[ \frac{n_0}{1 + \left(\frac{n_0 - 1}{P} \right)} \]  

where \( P \) (the population of Kasali sub-county) is 25,700:

\[ \frac{196}{1 + \left(\frac{196 - 1}{25700} \right)} \]

Therefore (S) = 195

The distribution of the questionnaires was such that two villages were selected in each of the three parishes making a total of six villages. Sixty-five households were interviewed in each parish. The questionnaires were administered proportionally in the selected villages based on their population. The list of all the households in different villages was identified through collaboration with the respective local council leaders (village leaders). The standard questionnaires for HHSs were composed of both the qualitative and quantitative parts. The qualitative part included collection of data to assess the impact of drought on water availability. The quantitative part of the questionnaires consisted of a five-point Likert scale which was used to collect data on the indicators of AC to water scarcity in the households (see Supplementary material S1 for the questionnaire). The scale ranking is from 1 to 5...
where 1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree and 5 = strongly agree.

Three FGDs were conducted, one in each of the three parishes. These helped to collect information about the impacts of drought on water availability at the community level. Each FGD consisted of five women, five men and five youths from the 195 households. The FGDs were organized with the help of the local council administrators in the villages. They were guided by structured questions and were administered with the help of the field assistants who helped the respondents with translation.

Two KIIs were conducted with the district Agricultural and Environmental officers using guided questions. The aim was to collect additional information on the impact of drought on water availability in households. These KIIs also enabled cross-checking respondents’ information from the villages.

**Data analysis**

**Climate data and statistical analysis**

Monthly precipitation, and maximum and minimum temperature data from October 1987 to September 2017 for Rakai Meteorological station was sourced from Uganda National Meteorological Authority (UNMA). One meteorological station was used. To understand the current water resource threats in the study site it is necessary to find out the existence of a trend in rainfall and temperatures. The Mann–Kendall non-parametric test is commonly used for identifying trends in climate data because of its insensitivity to outliers, high degree of quantification and wide range (Shokoohi & Morovati 2015). The Mann–Kendall tests whether to reject the null hypothesis (H₀), i.e. ‘no trend’, or accept the alternative hypothesis (H₁), i.e. ‘the trend exists’. We further quantified the changes in temperature by conducting regression analyses because they assume a normal distribution. Normal probability plots were also drawn to check for violations of the assumptions prior to conducting the analysis (see Supplementary Figure S1).

**Reconnaissance drought index (RDI)**

RDI requires precipitation and PET data (Tigkas et al. 2015). Most meteorological stations in developing countries, including Uganda, do not usually record evapotranspiration values (Moazenzadeh et al. 2018). Therefore, PET was determined using Hargreaves’s method, using the minimum and maximum monthly temperature (Tigkas et al. 2015). Data from October 1987 to September 2017 (rainfall calendar) was prepared using Microsoft Excel before being entered into the Drought Index Calculator (DrinC) to calculate the initial RDI value.

The RDI is expressed in three forms: the initial value \( a_k \), normalized and standardized RDI. \( a_k \) is presented in an aggregated form using a monthly time scale and may be calculated on a monthly, seasonal or annual basis. \( a_k \) of RDI is calculated for the \( i\)th year in time basis of \( k \) (months) as follows (Tigkas et al. 2015):

\[
 a_k(i) = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} PET_{ij}}, \text{ ~} i = 1(1) N \text{ ~and ~} j = 1(1) k
\]

where \( P_{ij} \) and \( PET_{ij} \) are the precipitation and potential evapotranspiration respectively in the \( j\)th month of the \( i\)th year, and \( N \) is the total number of years. The normalized form \( RDI_n \) is computed using the following equation:

\[
 RDI_n(i) = \frac{a_k(i)}{\bar{a}_k} - 1
\]

in which \( \bar{a}_k \) is the arithmetic mean of \( a_k(i) \).

By assuming that the lognormal distribution is applied, the following equation can be used for the calculation of RDI:

\[
 RDI_y(i) = \frac{\ln(a_k(i)) - \bar{y}}{\sigma_y}
\]

in which \( y(i) \) is the \( \ln(a_k(i)) \), \( \bar{y} \) its arithmetic mean and \( \sigma_y \) is its standard deviation. The drought classifications according to RDI values are shown in Table 1.

**AC analysis**

The main indicators influencing the AC of households to water scarcity during drought were selected based on Abaje et al. (2015); these included assessing financial
and economic resources (FE), infrastructure and institutions (II), technology and innovation (TI), knowledge and information (KI) and social resources (SR). The (AC) of each selected village was calculated using Equation (6):

\[
AC = \frac{FE + II + TI + KI + SR}{5}
\]

with the interval of 0.5, the upper cut off point was determined as 3.00 + 0.5 = 3.50 and the lower limit as 3.00 – 0.5 = 2.50 (Abaje et al. 2015). The classification of the AC of the households is classified as low AC between 0.0 and 2.49, moderate AC between 2.50 and 3.49, and high AC between 3.50 and 5.00 (Table 2).

We used the \( \chi^2 \)-test to assess if there were differences in AC across the six villages and also if there was a difference in travel time between the dry and wet season between the villages.

### RESULTS AND DISCUSSION

#### Rainfall

The annual monthly average rainfall for the period 1987–2017 for Kasali is shown in Figure 2. The results show that Kasali sub-county has a bimodal rainfall distribution with long rains being observed between March and May (MAM) and short rains between September and December (SOND). The study site has two dry seasons, the long season occurring in June-July-August (JJA) and the short dry season occurring in January–February (JF). May is the wettest month and receives the highest amount of rainfall averaging 178.43 mm (standard error, \( SE \pm 12.33 \)) and the driest month is July with a long-term average rainfall estimated at 27.15 mm (\( SE \pm 3.6 \)).

#### Temperature

The average monthly minimum and maximum temperature for the 30-year period (1987–2017) for Kasali sub-county is shown in Figure 3. April and May had the highest minimum temperature of 17.1 °C. The coldest month is July with a minimum temperature of 15.6 °C. The overall monthly minimum temperature was 16.5 °C. February is the hottest month with an average temperature of 29.0 °C. May had the lowest maximum temperature of 27.4 °C and also received the highest amount of rainfall. The overall monthly average maximum temperature for Kasali sub-county was 28.0 °C.

### Table 1 | Drought classification based RDI values

| RDI values | Classification   | RDI values | Classification   |
|------------|-----------------|------------|-----------------|
| 2.00 and above | Extremely wet | -1.00 to -1.49 | Moderately dry |
| 1.50 to 1.99 | Very wet | -1.50 to -1.99 | Severely dry |
| 1.00 to 1.49 | Moderately wet | -2.00 and less | Extremely dry |
| -0.99 to 0.99 | Near normal |           |                 |

Source: Abaje et al. (2015).

### Table 2 | Classification of AC

| Mean score | Level of AC |
|------------|-------------|
| 0.00–2.49  | Low AC      |
| 2.50–3.49  | Moderate AC |
| 3.50–5.00  | High AC     |

Source: Abaje et al. (2015).
Table 5 shows the summary of maximum and minimum temperature changes in Kasali sub-county for the period of 1987–2017. The results show that the increase in the minimum temperature was higher than the increase in maximum temperature. The annual average minimum temperature increased by 1.24 °C while the annual maximum average temperature increased by 0.65 °C. This means that the annual average minimum temperature has been increasing by 0.04 °C per year, and the annual maximum temperature has been increasing by 0.02 °C per year. The highest increase in the maximum temperature was registered...
In the 30-year study period there has been one extremely dry year, four moderately dry years and one extremely wet year, two very wet years, one moderately wet year, and 21 near normal years (Figure 4). The year 1991–1992 was extremely dry and 1988–1989, 1999–2000, 2008–2009, 2016–2017 were moderately dry. The extremely wet year was observed in 1997–1998. Very wet years were registered in 2000–2001 and 2006–2007 and moderately wet in 2007–2008. The rest of the years were near normal (refer to Figure 4).

Table 6 lists the drought incidence as calculated based on RDI and compares to historic documented droughts by other researchers.

Impact of drought on water availability in households in Kasali sub-county

The impact of drought on water availability was determined through analysing the time taken by household members to collect water from the source during wet and dry years. There was a statistical difference in the dry season ($\chi^2 = 6.3 \ p = 0.04$) in terms of time spent collecting water in the six villages, while in the wet season there was no statistical difference in time used in the six villages ($\chi^2 = 3.5 \ p = 0.17$).

During wet years, 19% of the households in Kasali sub-county spend more than 1 hour collecting water, while 16%...
spend 1 hour and the majority, 65% of the households, spend less than 1 hour collecting water. However, during drought years, the majority of the households (85%) spend more than 1 hour collecting water, while 12% spend up to 1 hour and only 3% spend less than 1 hour. The percentage of households spending more than 1 hour during dry years (85%) is considerably higher than that in wet years (19%), meaning that drought has a negative impact on the availability of water to the households (Figure 5(a) and 5(b)).

### Time spent by households collecting water during dry and wet years

The time spent collecting water by each village during both wet and dry seasons differs due to their relative geography that determines water availability and water quality (refer to Supplementary material S2a for statistical significance). Nkenge had the largest percentage of households which spent more than 1 hour followed by Kyango-Bigavu, Kisubi, Luti, Kyampigi and Lwengwe with 100, 90.3, 90.3, 87.1; 83.9 and 71.0% respectively. Lwengwe had the largest percentage of households which spent 1 hour followed by Kyampigi, Luti, Kisubi, Kyango-Bigavu and Nkenge with 29.0, 16.1, 12.9, 9.7, 6.5 and 0.0% respectively. Kyango-Bigavu had the largest percentage of households that spent less than 1 hour (3.2%) and the other villages registered that none of its population spent less than 1 hour collecting water (Figure 6(a)).

Figure 6(b) shows the time taken by households to collect water during dry years. From the results, Kyango-Bigavu

### Table 6 | Drought classification based on RDI

| RDI values | Drought classification | Years | Incidence and source |
|------------|------------------------|-------|----------------------|
| 2.00+      | Extremely wet           | 1997–1998 | 1997–1998 (GHOA): (Ghebrezgabher et al. 2016) |
| 1.50–1.99  | Very wet               | 2000–2001, 2006–2007 | 2006–2007, 2000–2001 (Uganda): (Ghebrezgabher et al. 2016; World Bank 2019) |
| 1.00–1.49  | Moderately wet         | 2007–2008 | 2007–2008 Uganda: (Ghebrezgabher et al. 2016) |
| -1.00 to -1.49 | Moderately dry     | 1988–1989, 1999–2000, 2008–2009, 2016–2017 | 2016–2017, 2008–2009, 1999–2000 (Uganda): (World Bank 2019) |
| -1.50 to -1.99 | Severely dry        | None | |
| -2.00 and less | Extremely dry      | 1991–1992 | 1991–1992 (GHOA): (Ghebrezgabher et al. 2016; Brietzke & Caputo 2019) |
Figure 5 | Pie chart showing the percentage of households’ time used in collecting water in (a) dry and (b) wet years in Kasali sub-county.

Figure 6 | (a) Time taken for households to collect water in dry years in villages of Kasali sub-county. (b) Time taken for households to collect water in wet years in the six villages of Kasali sub-county.
(Nkenge) has the largest percentage of households that spend more than 1 hour (32.3%), followed by Nkenge (Nkenge), Lwengwe (Kigenya), Kisubi (Kigenya), Kyampigi (Gayaza) and Luti (Gayaza) at 29.0, 16.1, 12.9, 12.9 and 12.9%, respectively (Figure 6). Kisubi has the largest percentage of households which spend 1 hour (22.6%) followed by Lwengwe, Kyampigi, Kyango-Bigavu, Luti and Nkenge at 19.4, 19.4, 19.4, 16.1 and 0.0%, respectively. Nkenge has the largest percentage of households which spend 1 hour (74.2%) followed by Luti, Kyampigi, Lwengwe, Kisubi and Kyango-Bigavu at 71.0, 67.7, 65.5, 65.5 and 48.4%, respectively (Figure 6(b)).

The three parishes selected for the study have a total of 26 water points which include boreholes (nine), shallow wells (10), water pumps (three) and protected well (one) (Figure 1). Kigenya parish has the highest number of water points (15) and Gayaza has the lowest number of water points (three).

**Indicators of AC to water scarcity in the villages of Kasali sub-county**

The analysis indicated variation of AC across the villages and also among the five adaptive interventions, but it was not statistically significant (refer to Supplementary material 2B). Table 7 summarises the AC of the six villages of Kasali sub-county. The overall AC of Kasali sub-county is low (2.08) and is driven by low values with the largest contributor to this low AC being technology and innovative resources (1.58), financial and economic resources (1.70), infrastructure and institution resources (1.98) and knowledge and information resources (2.04). The largest asset for the villages to deal with adaptation is social resources (3.08). All villages have high social resources except for Kisubi.

Only the two villages of Kyango-Bigavu and Nkenge in the study have moderate AC. The other four villages, Lwengwe, Kisubi, Kyampigi and Luti, are poorly adapted to deal with water scarcity. Social resources has the highest mean score of AC (3.08) whereas other indicators of AC have low mean scores (see Table 7).

**Drought trends**

This study sought to understand the occurrence and frequency of drought in the 30-year period between 1987 and 2017 and also understand the AC of the community in Kasali sub-county. The results indicate declines in annual, long wet season (MAM) and short dry season (JF). However, analysis of the long dry season of JJA and short wet season of SOND indicates a slight increase in rainfall, though this was not statistically significant. Both the minimum and maximum temperatures increased significantly between 1987 and 2017. The increase in annual minimum temperature was more (1.24 °C) than the maximum temperature (0.65 °C). These changes in climatic variables have a significant impact on water resources availability in the study site.

Four moderately dry years and one extremely dry year occurred in Kasali between 1987 and 2017. Based on this finding the area has not been ravaged by droughts because there are exceedingly high near-normal rainfall years (21 events) compared to either dry (five events) or wet years (four events). The moderate dry years occurred between the range of 7–10 years (1988–1989, 1999–2000, 2008–2009, and 2016–2017). In the earlier years, a drought

| Indicators of AC               | Kyango-Bigavu | Nkenge | Lwengwe | Kisubi | Kyampigi | Luti | Average AC |
|--------------------------------|---------------|--------|---------|--------|----------|------|------------|
| Infrastructure and institutions resources | 2.57          | 2.23   | 1.97    | 1.87   | 1.57     | 1.67 | 1.98       |
| Technology and innovation resources          | 1.56          | 2.45   | 1.56    | 1.56   | 1.35     | 1.01 | 1.58       |
| Social resources                             | 3.45          | 3.25   | 3.23    | 2.45   | 3.63     | 2.47 | 3.08       |
| Financial and economic resource               | 2.34          | 1.98   | 1.43    | 1.43   | 1.97     | 1.02 | 1.70       |
| Knowledge and information resources           | 3.35          | 3.23   | 1.23    | 1.45   | 1.99     | 1.01 | 2.04       |
| AC                                            | 2.65          | 2.63   | 1.88    | 1.75   | 2.10     | 1.44 | 2.08       |
occurred about once in 10 years, however, in recent times the frequency has reduced to every seven years. Additionally, one extreme drought was registered in 1991–1992. Severe and extreme droughts are normally influenced by the Indian Ocean Dipole (IOD) and La Nina periods (Shilenje et al. 2019). The La Nina periods are brought about by a decrease in the sea surface temperature (SST) in the eastern and central parts of the Pacific Ocean while IOD occurs as a result of irregular oscillations of the SST of the Indian Ocean. A negative phase of IOD and La Nina periods are associated with dry conditions in East Africa (Shilenje et al. 2019). The study area also experienced very wet events in 2000–2001 and 2006–2007. These two recent events of increased rainfall and a drought in 2016–2017 can have a significant role in water resources recharge (wells and boreholes), rivers and ponds, and how local communities can either benefit or be impeded by these resources (Mubiru et al. 2015).

Impact of drought on water access

Spending more than 1 hour collecting water is considered a vulnerability because water is collected more than once and this translates to household members wasting a lot of time which could have been used to carry out other essential activities such as household tasks, farm work and taking care of the family. The burden of fetching water falls on women and children, especially girls. Water collection by children can take time away from their education. In Kasali, the percentage of households spending more than 1 hour (85%) can easily increase to 97% considering the 12% who spend 1 hour to collect water. On the contrary, only 19% spend more than 1 hour collecting water during the wet years. Taking a longer time to collect water is an indicator of water insecurity which can also lead to food insecurity and adverse health outcomes in households (Macdonald et al. 2009; Hunter & MacDonald 2010).

At the village level, both access to water and the time spent to collect water vary. In the dry season the majority of villages (five out of the six) have more than 85% of their households spending more than 1 hour to collect water. One village in particular, Nkenge, has all the households spending more than 1 hour to collect water. The only village that has a moderate water access is Lwengwe because about 29% of its households could access water within 1 hour. Many households reported having unsustainable means of storing water for future use which leads to water scarcity. These findings are consistent with a study in Kaliro district in eastern Uganda where it was found that household members, especially women, struggle in accessing water during drought as a result of the drying up of nearby water sources like wells and river beds. This means that they have to walk miles in search of water (LWR 2017).

Some parishes such as Nkenge have six water points (three boreholes and three shallow wells) and Gayaza has three water points (two boreholes and one shallow well). However, these sources are vulnerable to drought, for example the wells dry up during drought and boreholes become defunct due to over usage. The respondents indicated that the water from these water sources have reduced their flow due to a decrease in the water table during dry years. This also contributes to the length of time households spend while collecting water during drought. Households spend a shorter time collecting water during wet years because seasonal water sources such as ponds and wells are recharged by rains. Furthermore, households harvest water during wet years. Similar studies conducted on water scarcity have found that households access water much more easily during wet years (Dessalegn et al. 2013; Mubiru et al. 2015). As shown in this study the drought cycles are becoming shorter, therefore the impact on local communities will be large unless they come up with adaptation strategies that will help overcome these hurdles.

AC of Kasali

The overall AC of Kasali is low (2.08) from the five indicators of AC we assessed (financial and economic resources, infrastructure and institutions, technology and innovation, knowledge and information and social resources). Of these, the highest asset is social resources (3.08). The study area faces repeated and frequent stress periods because of droughts and a further increase in temperature that puts more pressure on the system due to increasing human and animal water needs. Adger (2005) observed that a social network establishes better communication and collective actions, especially during times of
stress. These networks include women and men’s groups, saving schemes, youth groups, farmers’ groups and religious groups. Members in these groups share knowledge about a given crisis such as drought and how they can overcome it. Collectively they can access drought resistant seeds and share among themselves. They also have irrigation projects and collectively rehabilitate wells and boreholes so that access to water is maintained.

Interestingly, though Nkenge Parish has the highest number of households requiring more than 1 hour to collect water, the villages therein (Kyango-Bigavu and Nkenge) have a moderate AC to deal with water scarcity, while the other four villages in two parishes (Lwengwe, Kisubi, Kyampigi and Luti) are poorly adapted to deal with water scarcity though only 71–90% of the households need more than 1 hour to collect water. We highlight that due to frequent long walks to collect water during dry periods the Nkenge households have developed a strong social network to cope. Nevertheless, there is a low AC in the financial and economic resources, infrastructure and institutions, technology and innovation, knowledge and information in the study area. The most important development indicators in rural Africa are infrastructure and institutions such as schools, hospitals, markets and others. Brien et al. (2004) point out that communities with well-developed infrastructure and institutions adapt better to drought than those without. The second important aspect is knowledge and information which is also poorly developed in the four villages (Lwengwe, Kisubi, Kyampigi and Luti). Cutter et al. (2003) points out that lower knowledge and information capacity affects an individual’s ability to understand warning and recovery information. Without infrastructure, knowledge and finance, technology and innovations, it becomes difficult to manage adaptation of any sort.

Kasali, having a low financial and economic resource, cannot afford better and sustainable adaptation strategies to water scarcity during drought. A recent report by the World Bank (2019) observed that the majority of residents in Kasali sub-county have a low income. The low income of an individual limits his/her membership to social groups that would have acted as security for accessing loans and diversification of his/her economy for better income (Abaje et al. 2015). In addition, technology and innovation was very low in some of the villages. A key feature of AC is the ability of the system to access new technologies, build and integrate innovations and also support new practices (Yohe & Tol 2002; Sorre et al. 2017). None of the five indicators are independent of each other, each supports the others, and therefore to increase the households’ AC, all the indicators should be boosted. Studies in southern and western Africa (Cape Town, South Africa and Kaduna State, Nigeria), have indicated that rural villages have a moderate AC. This is because their residents have diversified economies and better access to climate information which improves their knowledge, infrastructures, social resources, technology and innovations compared to Kasali (Abaje et al. 2015; Munashe & Hamisai Hamandawana 2018). This observation should therefore be a benchmark for authorities in Kasali to improve the household’s AC. Financial and economic resources rank significantly higher in both South Africa and Nigeria compared to Kasali (Munashe & Hamisai Hamandawana 2018). This probably means that the economy is a very important indicator of AC in rural villages.

Other countries such as Malawi are boosting communities’ AC through improving access to science and analysis for adaptation decision making, establishing effective governance systems for adaptation, identifying, promoting, and piloting actions that increase climate resilience (Maguza-tembo et al. 2017).

Though some structural measures have been carried out in Nkenge and Kyango-Bigavu villages to adapt to water scarcity, for example piped water systems have been installed, this requires higher capital investment and therefore only a few households can afford it (Shankar 2018). In Kisubi, Lwengwe, Kyampigi and Luti, rainwater harvesting in plastic tanks or Ferro-cement cisterns is carried out to collect water for domestic use. This has been aided by government, NGOs like Danish International Development Agency (DANIDA), World Division and World Bank, especially among women’s groups in the area (Mubiru et al. 2015). Other interventions include tree planting to increase atmospheric water vapour for rain formation. The government also committed to supplying water to Kasali and in the 2016/2017 financial year, the Ministry of Water and Environment pledged to construct a water supply and sanitation system in Kasali to supply water to the villages in Kasali sub-county (GOU 2019).
Possible interventions that were pointed out by the key informants to improve the AC to water scarcity include ensuring disaster preparedness through improving the water infrastructure by the construction of water valley dams to enable households to easily access water for their domestic use, diversification of sources of livelihood in order to improve households’ economy, construction of more boreholes, improve the knowledge and information capacity of residents, encourage diversified income generating projects to improve their income and financial resources.

CONCLUSIONS AND RECOMMENDATIONS

In analysing the climate of Kasali between 1987 and 2017 we have found that the annual minimum and maximum temperatures have increased by 1.24 and 0.65 °C respectively. The RDI has proved a useful tool to assess drought in Kasali. Our study reveals that the region has experienced five moderate to extreme drought years in the 30-year period (1987–2017). These droughts and other dry spells in the region result in water scarcity leading to more than 85% of the households requiring more than 1 hour to collect water contrary to only 19% in the wet seasons. The average time spent while collecting water in Kasali during dry years (1 hour) is higher than the UN goal of 30 minutes. The fact that residents need more than 1 hour to collect water during the wet seasons means that there is a shortage of water supply and there is a need for the government to develop more water access points that will help the residents to spend less time and increase their resilience to climate change impacts.

Additionally, we find that the overall AC of Kasali is low. Nkenge parish (Kyango-Bigavu and Nkenge villages) have a moderate AC whereas Gayaza (Kyampigi, Luti) and Kigenya (Lwengwe, Kisubi) parishes have a low AC. The indicator that ranks high is social resources while the others (infrastructure and institutions resources, technology and innovation resources, financial and economic resource, knowledge and information resources) are low.

Water insecurity impacts on other sectors of the community such as food security, health and livelihoods and the ability of the country to achieve its UN Sustainable Development Goals. A number of recommendations should be taken up by the government and relevant authorities in charge to improve the AC of Kasali, for example developing drought early warning systems and in light of that dissemination of information to sensitize households and increase the knowledge and information, developing some water supply such as drilling deeper boreholes that can be relied on during droughts, and encouraging diversification of livelihood activities so as to increase the incomes of the community and adapt the community to future climate changes.

This study looked at historical changes in climate on an annual scale, therefore there is a need to promote studies in long-term predictions of climate parameters such as drought occurrence, intensity and frequency, start and end of crop seasons on both an annual and seasonal scale. The meteorological department needs to invest more in collecting localized climate data using automatic instruments so that more localised bottom-up vulnerability assessments can be conducted (Declan et al. 2019). There is a need to build simplified tools that the community can use for early warning and climate projections (Olaka et al. 2019). This will educate and also develop a knowledge base to deal with climate change. Further, as shown in this study the community needs financial help. It is recommended that as these communities are impacted by climate change, there is a need by the government of Uganda to access the climate fund (Climate Access Fund and Green Climate Fund) and use this to develop the infrastructure, market and financial base to improve the well-being of these communities in dealing with climate change.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Abaje, I. B., Sawa, B. L., Iguisi, E. O. & Ibrahim, A. A. 2015 Assessment of rural communities' adaptive capacity to climate change in Kaduna State, Nigeria. J. Environ. Earth Sci. 5 (20). Available from: www.researchgate.net/publication/293331409.
Adger, W. N. 2003 Social capital, collective action, and adaptation to climate change. *Econ. Geogr.* 79 (4), 387–404. Available from http://www.clarku.edu/econgeography

AfDB 2012 Solutions for a changing climate. *The African Development Bank’s Response to Impacts in Africa* 1, 42. Available from www.afdb.org

Amjath, B. T. S., Krupnik, T. J., Aravindakshan, S., Arshad, M. & Kaechele, H. 2016 Climate change and indicators of probable shifts in the consumption portfolios of dryland farmers in Sub-Saharan Africa: implications for policy. *Ecol. Indic.* 67, 850–858. https://doi.org/10.1016/j.ecolind.2016.03.030.

Brien, K. O., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Brien, K. O., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H. & West, J. 2014 Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environ. Change* 14, 303–313. https://doi.org/10.1016/j.gloenvcha.2004.01.001.

Brietzke, P. H. & Caputo, P. 2019 Horn of Africa. *Afr. Stud. Rev.* 46 (4), 11. https://doi.org/10.25307/524355.

Cutter, S. L., Carolina, S., Boruff, B. J., Carolina, S., Shirley, W. L. & Carolina, S. 2003 Social vulnerability to environmental hazards. *Soc. Sci. Q.* 84 (2), 261. Retrieved from https://doi.org/10.1111/1540-6237.8402002.

Declan, C., Nicholls, J. R., Brown, S., Tebboth, M., Neil, A. W., Ahmad, B., Biemans, H., Crick, F., Lutz, A., Safra de Campos, R., Said, M., Singh, C., Zaroug, M., Ludi, E., New, M. & Wester, P. 2016 The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. *Nat. Clim. Change* 9 (7), 503–511. https://doi.org/10.1038/s41558-019-0502-0.

Dessalegn, M., Nigussie, L., Tucker, J., Nicol, A. & Calow, R. 2013 Struggles with Local Water Security in Ethiopia Mengistu. *Voices from the Source*, January, 35.

EM-DAT 2019 The International Disasters Database. Centre for Research On the Epidemiology of Disasters – CRED. Available from: www.emdat.be/

FAO 2013 Drought. *FAO Land and Water*, Vol. 1. Rome, Italy. Available from: www.fao.org/nr/aboutnl/en.

Ghebrezgabher, M. G., Yang, T. & Yang, X. 2010 Climate change, agriculture, and poverty. *Appl. Econ. Perspect. Pol.* 32 (3), 355–385. https://doi.org/10.1093/aep/ppq016.

Hunter, P. R. & MacDonald, A. M. C. R. 2010 Water supply and health. *PLoS Med.* 7 (11), 97. https://doi.org/10.1371/journal.pmed.1000361.

Huntington, T. G. 2006 Evidence for intensification of the global water cycle: review and synthesis. *J. Hydrol.* 319 (1–4), 83–95. https://doi.org/10.1016/j.jhydrol.2005.07.003.

Kilimani, N., Heerden, J. V. & Bohlmann, H. 2015 Water taxation and the double dividend hypothesis. *Water Resour. Econ.* 10, 68–91. https://doi.org/10.1016/j.wre.2015.03.001.

Leblanc, M., Tweed, S., Van Dijk, A. & Timbal, B. 2012 A review of historic and future hydrological changes in the Murray-Darling Basin. *Glob. Planet. Change* 80–81, 226–246. https://doi.org/10.1016/j.gloplacha.2011.10.012.

LWR 2017 *East Africa Drought*. Vol. 1. Kampala. Available from: https://reliefweb.int/sites/reliefweb.int/files/resources/20170221_EARO_Drought_Draft_SitRep_LB.pdf.

Macdonald, A. M., Survey, B. G. & Calow, R. 2009 What impact will climate change have on rural groundwater supplies in Africa? *Hydrol. Sci. J.* 64, 690–703. https://doi.org/10.1623/hysj.54.4.690.

Maguza-tembo, F., Maguza-tembo, F., Mangison, J., Edris, A. K. & Kenamu, E. 2017 Determinants of adoption of multiple climate change adaptation strategies in Southern Malawi: an ordered probit analysis. *J. Dev. Agric. Econ.* 9 (1), 1–7. https://doi.org/10.5897/JDAE2016-0753.

Masih, I., Maskey, S., Mussa, F. E. F. & Trambauer, P. 2014 A review of droughts on the African continent: a geospatial and long-term perspective. *Hydrol. Earth Syst. Sci.* 18 (9), 3635–3649. https://doi.org/10.5194/hess-18-3635-2014.

Moazzenadeh, R., Mohammad, B., Shamshirband, S. & Chau, K. 2018 Mechanics coupling a firefly algorithm with support vector regression to predict evaporation in northern Iran. *Eng. Appl. Comput. Fluid Mech.* 12 (1), 584–597. https://doi.org/10.1080/19942060.2018.1462476.

Munasinghe, R., Deressa, T., Thibault, P., Turton, B., Yallop, L. & Sobrado, J. 2017 An integrated analysis of climate change impacts on the water balance in the Murray-Darling Basin. *Global Planet. Change* 151, 1–9. https://doi.org/10.1016/j.gloplacha.2017.05.007.

NEMA 2010 *State of the Environment Report for Uganda*. Kampala. Available from: www.nemaug.org.

Olaka, L. A., Ogutu, J. O., Said, M. Y. & Oludhe, C. 2013 Projected climatic and hydrologic changes to Lake Victoria Basin Rivers under three RCP emission scenarios for 2015-2100 and impacts on the water sector. *Water (Switzerland)* 11 (7), 10–22. https://doi.org/10.3390/w11071449.

Olufemi, A. F. 2017 The impact of drought on Africa. *Hitachi Europe Ltd* 66 (7), 28–34. Available from: www.hitachi.com/rev/archive/2017/r2017_07_fl/p28-34_GIR.pd.

Shamsirband, S., Hashemi, S., Salimi, H., Asadi, E., Shadkani, S., Kargar, K. & Chau, K. 2020 Mechanics predicting standardized streamflow index for hydrological drought...
using machine learning models. *Eng. Appl. Comput. Fluid Mech.* **14** (1), 339–350. https://doi.org/10.1080/19942060.2020.1715844.

Shankar, A. 2018 Drought impact and adaptation strategies in the mid-hill farming system of western Nepal. *Environments* **5** (101), 12. https://doi.org/10.3390/environments5090101.

Shilenje, Z. W., Ongoma, V. & Njagi, M. 2019 Applicability of combined drought index in drought analysis over North Eastern Kenya. *Nat. Hazards* **99**, 379–389. https://doi.org/10.1007/s11069-019-03745-7.

Shokoohi, A. & Morovati, R. 2015 Basinwide comparison of RDI and SPI within an IWRM framework. *Water Resour. Manage.* **15**, 11–14. https://doi.org/10.1007/s11269-015-0925-y.

Sorre, A. M., Kurgat, A. & Sorre Bernard, R. M. 2017 Adaptive capacity to climate change among smallholder farmers in Busia County, Kenya. *IOSR-JAVS* **10** (11), 40–48. https://doi.org/10.9790/2380-1011014048.

Tigkas, D., Vangelis, H. & Tsakiris, G. 2015 Drinc: a software for drought analysis based on drought indices. *Earth Sci. Inform.* **8** (3), 697–709. https://doi.org/10.1007/s12143-014-0178-y.

Wolski, P. 2018 How severe is Cape Town’s ‘Day Zero’ drought? *Significance* **15** (2), 24–27. https://doi.org/10.1111/j.1740-9713.2018.01127.x.

World Bank 2019 *Disaster Risk Profile Uganda*. World Bank, Washington, DC, USA. Available from: www.gfdrr.org/en/publication/disaster-risk-profile-uganda.

Yohe, G. & Tol, R. S. J. 2002 Indicators for social and economic coping capacity – moving toward a working definition of adaptive capacity.pdf. *Global Environ. Change* **12**, 25–40. Available from: www.elsevier.com/locate/gloenvcha.

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