Journal of Climatology and Weather Forecasting 2022, Vol. 10, Issue 11, 001-009 Mini Review

Impacts of Climate Change on Water Yield of River Akokorio and Kapiri Sub-Catchments

Moses David Tumusiime[1]*, Andrea Ficchi[2], Alfred Owuor Opere[2] and Teddy Mwira[3]

[1]Uganda National Meteorological Authority, Kampala, Uganda University of Reading, UK
[2]University of Nairobi, Department of Meteorology, Kenya
[3]Makerere University College of Agriculture and Environmental Sciences Uganda

*Corresponding Author**

Moses David Tumusiime

Uganda National Meteorological

Authority, Kampala, Uganda

Email: tmoses2000@gmail.com

Tel: +256 782861768

Received: 22-Nov-2022, Manuscript No. JCWF-22-20640; **Editor assigned:** 23-Nov-2022, Pre QC No. JCWF-22-20640 (PQ); **Reviewed:** 26-Nov-2022, QC No. JCWF-22-20640 (Q); **Revised:** 27-Nov-2022, Manuscript No. JCWF-22-20640 (R); **Published:** 30-Nov-2022, DOI: 10.35248/2332-2594.22.10(11).374

Abstract

Lake Kyoga basin is largely under semi-arid characteristics with limited water resources and sensitive to climate change. Previous studies reveal that the region is prone to occurrence of extreme wet and dry climatic events. This research assessed the effect of the climate variability on water yield in Lake Kyoga basin. Daily rainfall data (1980 to 2014) was obtained from the Uganda National Meteorological Authority (UNMA). Land use data (2000 to 2015) was obtained from the National Forestry Authority (NFA) Uganda and processed using ArcGIS 10.1. Data on water levels and flow (1980 to 2014) was obtained from the Directorate of Water Resources Management Uganda and processed using Correlation Percentage Change (CPC) to examine changes in water storage and flow. The Mann Kendall (M-K) trend test tool was applied to establish the cumulative change in rainfall and flow. Open water and wetland areas reduced by 11% and 4%, respectively. A 3% negative change was observed in water levels of Lake Kyoga with exception of February and September that showed +3% from 1980 to 2014. The flow at Masindi port (out let of Lake Kyoga basin) was observed to decrease over time, contrary to increasing precipitation patterns. The water level for Akokorio and Kapiri sub basins were however observed to have increasing trends. Climate variability was found effective on to affect water yield in Lake Kyoga catchment, negative climatic observations and severe events were observed, and are expected to happen in the future. Mitigation methods should support the implementation of catchment management strategies in Lake Kyoga basin to sidestep the long-term forthcoming negative consequences of land use change which was observed as a major threat to the catchment.

Keywords: Climate change • Water yield • Land Use • Lake Kyoga

Introduction

Water yield and changes in climate of Lake Kyoga catchment; Communities depend on agriculture as the main economic activity which has been affected by climate change, and caused destruction of infrastructure by floods, landslides, mudslides and drought [1]. This chapter focuses on influences of climate change on water yield in Lake Kyoga catchment emphasizing on two sub-catchments [2]. Researchers proved that the climatic changes happening worldwide are the consequence of both anthropogenic and natural influence said it was further revealed that "changes of water quantity, quality and accessibility will be an influence of continuing climate change in numerous places of the environment" where water yield is most affected and the communities face the consequences of environmental degradation [3,4]. Communities in Lake Kyoga catchment are on tension after realizing that availability and accessibility of natural resources including forests, fertile land, and water are no longer adequate due to climate abnormalities experienced in this sub-region that led to low production of food and water scarcity. Some natural resources, such as soil and water, are essential for the existence of life which requires serious attention through monitoring and research especially water yield for purposes planning and improving community livelihood in L. Kyoga catchment [5,6].

Lake Kyoga catchment is characterized of two rainy seasons that affect water yield, the first season (from the month of October to December) and the second season (between March and May) while its dry period run from December to February. This lake is located wholly within Uganda but internationally connected via the Nile. It comprises of 2 major arms, Kwania and Kyoga, and over 30 smaller lakes separated from the main lake by swamps [7-9]. The lake's volume of ~8 km^3, most of the water input (82%) is from Lake Victoria, 9% from catchment inflow, and 9% from direct rainfall. Most (83.7%) of the water from the lake is lost through outflow of the Nile and 16.3% through evaporation. Therefore, monitoring water yield is critical for the purposes of implementing sustainable development goal including action to end poverty, protect the earth's environment and climate, and ensure that communities enjoy favorable environment.

Literature Review

The assessment is required for acknowledgement of the increasing problem that climate change is engaging on water yield aiming and identifying measures which can help to safeguard water resources. This will intend to meet the desires of decision-makers for scientific evidence on the relations amongst climate change and human living environment [10]. To achieve the intended objectives this study was organized with three core questions: How water quantity in Lake Kyoga changes with time? To what extent has climate variability affected water yield in Rivers [2,11]

Problem statement

Frequent severe wet weather events and prolonged dry spells was experienced in Lake Kyoga catchment caused destruction of infrastructure by floods, landslides, and mudslides and loss of lives. It has been theorised that climate change is accumulating fast and that upcoming extreme weather reports are likely to be more recurrent and dangerous than the present. The most population living in Lake Kyoga catchment have limited access to water and are exposed to climate variability, triggering an acceleration of water shortage, food insecurity and poverty especially in Karamojong north-eastern Lake Kyoga catchment [12].

According to Adhikari, "Abundant gaps in information occur in terms of clarifications and studies connected to water yield and climate change. In numerous cases and in various places, there is convincing scientific indication that climate change will posture serious encounters to the water structures in East Africa [13]. It is therefore noticed that improving the understanding of climate change linked to water yield is urgently required as information is inadequate especially with respect to water scarcity constraints in Lake Kyoga catchment mentioned in. North Eastern Uganda is under semi-arid characteristics with limited water resources and sensitive to climate change, previous studies revealed that "in most parts of Lake Kyoga catchment there is likely to be a rise in rainfall amounts, this escalation will be different as some parts will be undergoing a descending shift and the rest will have ascending trend with increasing occurrence of extreme wet and dry events", state therefore this research concentrated on assessing the influences of the changing climate on water yield and to advise the public with revised and favourable measures to alleviate water scarcity issues [14].

Water yield is defined as the amount of freshwater derived from unregulated flow (m^3s^{-1}) measurements for a given geographic area over a defined period of time. The freshwater flow (yield) is generated from a combination of base flow, interflow and overland flow originating from groundwater, precipitation. The water yield of a watershed may either be measured directly on a single outlet on the main stream or be calculated through empirical equations based on important physical properties of a particular watershed [15-17]

The general objective of this research was to "Investigate the impacts of climate change on water resources over River catchments for purposes of assessing water yield as well as identifying procedures which can be adopted to reduce pressure on limited water sources in the catchment. It was necessary to assess the status of water levels in Lake Kyoga basin and analyse the water yield of River Akokorio and Kapiri.

Significance of the study

Communities in North Eastern parts of Uganda have encountered serious challenges with limited, availability and accessibility of water structures as result of climate change. It was very critical for this research to examine how climate change triggered the influences on water resources in Lake Kyoga catchment for planning and purpose of water resources management as well as saving lives.

Climate change posed substantial socio-economic impressions in Uganda especially Eastern region with occurrence of overflows which left extensive infrastructure destruction, displacement and loss of livelihood. Drought too affected a substantial number of people estimated to 1.8 million over increased starvation, poverty, illness, death, asset damage and relocation all this related to water resources which required extensive study [18]. This research exposed the effect of climate change on water sources of Uganda specifically Lake Kyoga catchment aiming at providing valuable information to policy makers and stakeholders for planning adaptation strategies. This study contributes to the future planning and development of Uganda towards Government achieving its objectives of the third National Development Plan (NDP III), Vision 2040 and the Sustainable Development Goals which includes end poverty, protect the earth's environment and climate action.

Lake Kyoga catchment is the biggest watershed in Uganda which supports many ecosystems but has been constrained by natural hazards which could have been influenced by climate change and leading to water shortage in the sub-region [19, 20]. Therefore, it was of great importance for this research to carryout climate change impacts assessment on water yield to come up with solutions and guidelines for improving the community standards of living by applying stated adaptation and mitigation measures against climate change to water resources. Also proposing proper administration approaches for decision makers that will enable sustainable utilization of the water resources as a system to benefit the communities and the ecological systems [21,22]. For future Researchers to be updated on current situation in order to proceed with un-answered questions.

Description of the study area

The study area is River Akokorio and Kapiri sub catchments found in the eastern part of Uganda with in Lake Kyoga catchment. "Lake Kyoga is a big shallow lake located in the north of Lake Victoria, 914.0 m above sea level".

The drainage sub-basin of L. Kyoga shares the network of River Nile basin and major lakes in Uganda. Water flows from Lake Victoria through L. Kyoga on its system flowing from L. Victoria to Lake Albert, National Environment Authority (NEMA, 2010) report. Lake Kyoga area covers an open space of 2636.0 km^2, with an average altitude of 1034.0 m. [19,20]. The Kyoga catchment extends over 60000 km^2 which is approximately 25% of Uganda's total surface area of 240000 km^2.

The climatology of the area disclosed by (MWE-DWRM, 2011) report that Mean annual rainfall varies 989 mm at (Kakooge) weather station to 2,477 mm at (Buginyanya) weather station spatially and the average is 1,466 mm in the Basin (Figure 1).

Lake Kyoga catchment is located in Uganda covering Eastern and central parts of the country. Data from Hydrological stations and rainfall stations were analysed to present the discharge and water level measurements of the study area for the purpose of water yield assessment. This catchment is recharged by rainfall and inflow of rivers from different directions (North, East and South of catchment). The main inflow is from Victoria Nile which comes from Lake Victoria, Mpologoma and rivers from Mount Elgon and other rivers from the North including Akokorio and Kapiri.

Lake Kyoga catchment covers 15 Districts with several river sub-catchments but in this study only two sub-catchments (River Kapiri and River Akokorio) were considered for water yield assessment since they are major rivers originating from Karamoja a water scarcity sub-region and due to financial constraints and limited time we were unable to assess the whole catchment.

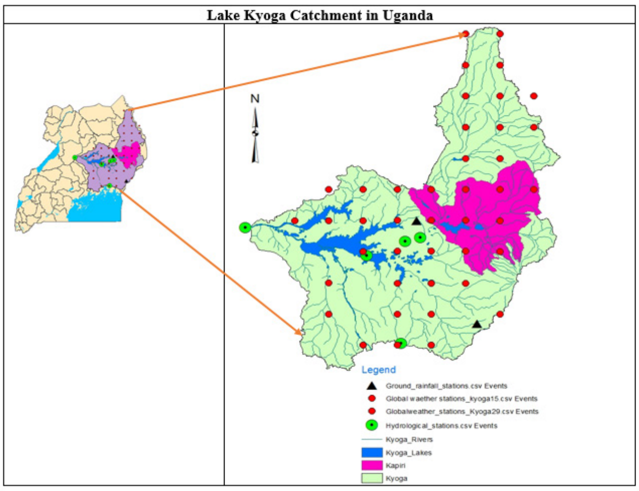

Figure 1. Lake Kyoga catchment showing hydrological rainfall stations.

Materials and Methods

Data gathering, processing and analysis are the most significant stages leading research on hydrological procedures in a catchment. Climate Forecast System Reanalysis dataset (CFSR)/ Global Weather Data (GWD) (Temperature and precipitation) from site [21] was downloaded (ANNEX 1) from GWD database and analysed for climate change assessment. Global Precipitation Climatological Project (GPCP) satellite precipitation and temperature information were gotten from 44 stations on the grid 34.06E:2.34N, 33.44E:2.03N, 33.75E:2.03N, 34.06E:2.03N, 33.44E:1.72N, 33.75E:1.72N …. etc. at a resolution of 25 km representing the catchment to enable observing rainfall characteristics and trends.

Assessing the effects of climate variability on water yield

This study examined the concurrency of high flows basing on average discharges from three river gauging stations (River Akokorio, River Kapiri and Kyoga Nile at Masindi port) were presented. Maximum flow points were extracted from XLSTAT2012 software under Man-Kendal component.

Based on annual flow data of Akokokrio River watershed from 1996 to 2016, the mean streamflow in this river was ranging from 28.411m^3/s to 313.572 m^3/s. The minimum was from 0.0 to maximum of 1266.316 m^3/s. Summary statistics for discharge from Akokorio River derived from XLSTAT2012.

Water stress was observed from this study and indicated minimum flow of 0.0 for all the months except September which indicates 0.777 m^3. For a water resource to reach zero minimum meaning that there is demolition of life, injuries and stress from extreme weather events like drought. To detect the influences of climate on water yield Mann-Kendal outputs gives clear evidence by showing extreme points above and below mean.

Discharge from River Akokorio was found to be unstable as the outputs from Mann-Kendal showed no trend for all months of the year excluding January is where trend was detected and the model tells us to reject H_0. On refusing the null hypothesis, the consequence is said to be statistically important as results specifies that the Null Hypothesis was rejected for only one month of January therefore positive trend was significantly observed.

The impacts of climate change on water yield can either be negative or positive to water yield performance. This research proved positive changes in water flow of River Akokorio in Lake Kyoga catchment as per out puts indicate in Figure 2.

River Akokorio is one of the major inflow rivers from northern parts of Lake Kyoga catchment, it was important for this research to analyze annual flow to detect abnormal situations in water yield while assessing evidence of climate change. The outputs reviled high flows and experienced flooding along Akokorio River most especially during 2005, 2006, 2010, 2011 and

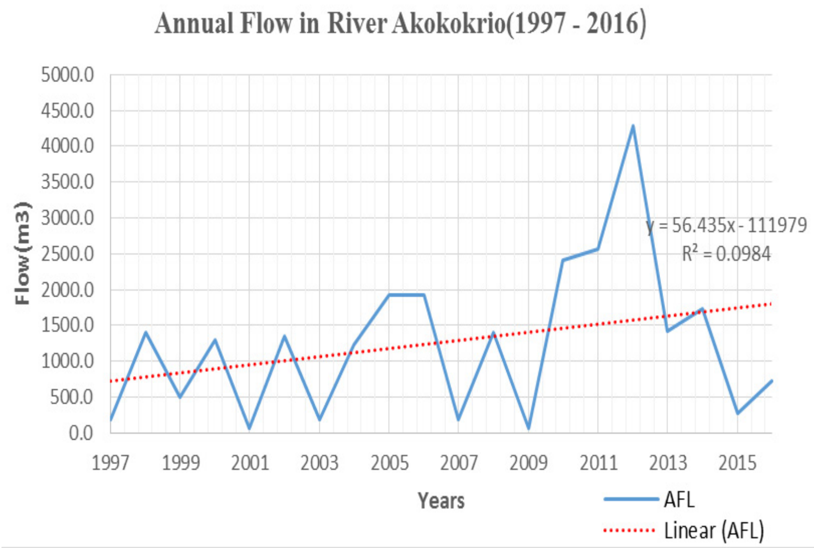

Figure 2. Fluctuations of water discharge in River Akokokorio (1997–2016)

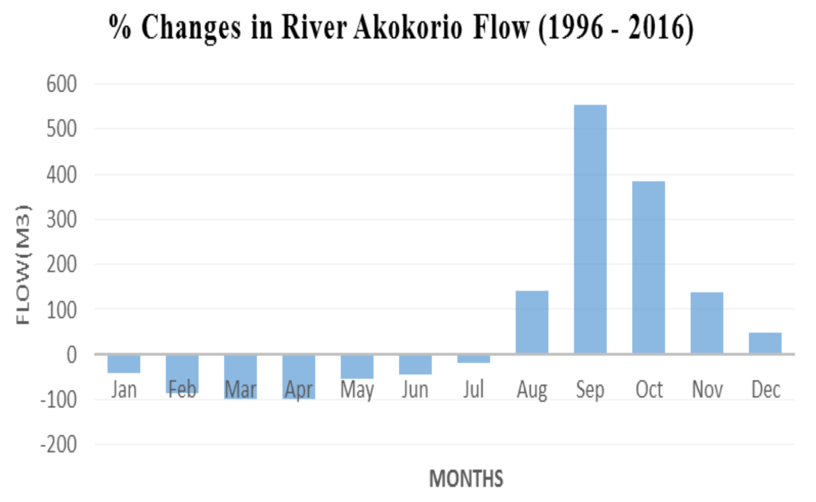

Figure 3. Percentage change of flow in River Akokorio (1996-2016).

2012 where 4288 m3 was observed to be the highest flow in 2012.

Considering the outputs from correlation percentage change (CPC) method, it was observed that water flow from river Akokokrio experienced negative changes from January to July with the highest reductions of 84 m^3, 97 m^3 and 97 m^3 in February, March and April respectively. The river experienced high flows which could have resulted into flooding during September and October as per demonstration of Figure 3.

Masindi port (Lake Kyoga outlet) is a hydrological observation point where average annual and seasonal water discharge from all together Lake Victoria sub basins and Lake Kyoga was calculated. Lake Victoria water shade contributes to Kyoga catchment, any alteration in the water system of Lake Victoria basin is replicated in the quantity of water established in Lake Kyoga waters. Therefore, Figure 4 indicates that total water discharge from all drainage sub basins were constantly reducing with time from 1970 to 1995 with a decreasing trend from 1200 m^3/s followed by an increasing trend with maximum flow of 5400 m^3/s in 1998 [23-26].

Positive and negative water yield from Lake Kyoga basin is anticipated to be affected by both human activities and natural factors contributing to climate change. Rainfall and Actual Evapotranspiration are the core drivers of alterations in water yield alongside through land use variations.

It is evidenced that annual water flow in Lake Kyoga catchment has been affected as at Masindi port-Figure 4 indicates both positive and negative events but there was missing data in 1994 which indicates zero flow. There was a great increase of flow from 1966 to 1969 as discharge increased from 40,000m^3/s to 53,430 m^3/s which could have been influenced by heavy rainfall that shifted a steady flow of 14 years since 1952 to 1966 and lasted for 3 years while discharging high flow of 33,430m^3/s [27-29].

Climate change affects water yield through different processes like high evaporation which induces hydrological cycle to generate extreme precipitation, high flow and development of flooding [30]. This analysis considered 25 satellite rainfall stations covering the entire catchment using Soil Conservation Service Runoff (SCSR) equation in order to calculate direct flow and to understand its impacts on water yield.

Soil Conservation Service Runoff (SCSR) equation:

Lake Kyoga catchment had only four observing stations which could not do much in estimating the status of out flow instead we considered using data from Global Weather Data (GWD) data base of 25 stations for proper estimation of direct flow and water yield from the catchment.

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)}$$

The out puts from SCSR method shows that all datasets show an was important in this study where by 25 rainfall stations with data from GWD considering study catchment area to calculate direct discharge. Due to limited number of rainfall stations in the catchment satellite data was used to observe the status of rainfall and its effects to water yield. SCS equation was applied to estimate annual water discharge results from the equation proved a decreasing trend as R^2. Figures 5 and 6 indicates a correlation significance of +3.1%.

An examination of the mean discharge was made by comparing observed data and simulated data sets for catchment outflows in the periods from 1968–2018. All results showed a relationship of trends with

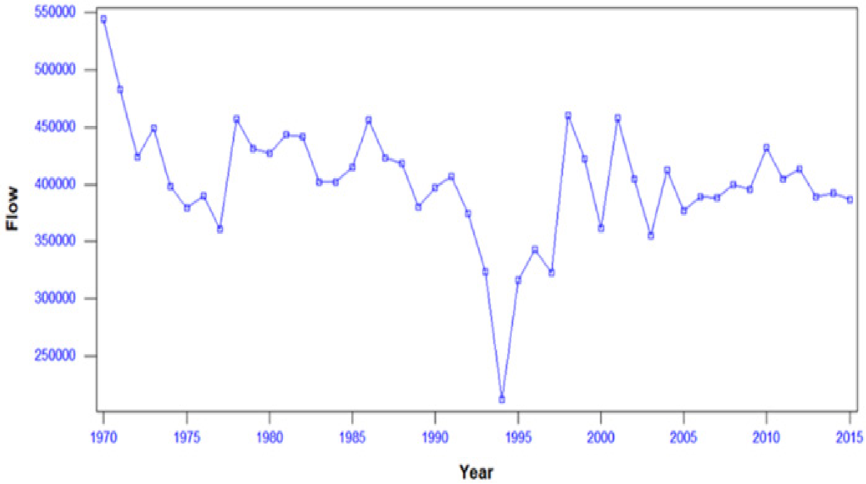

Figure 4: Average annual water yield at Masindi port (1970-2015)

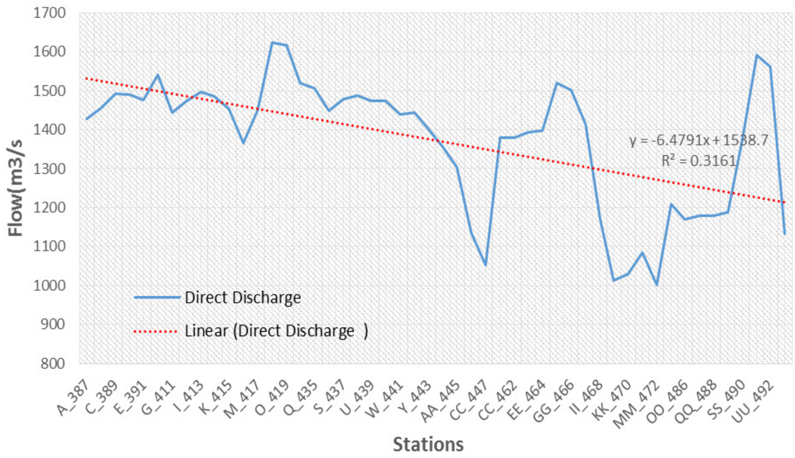

Figure 5. Water discharge for entire catchment (1961-2016)

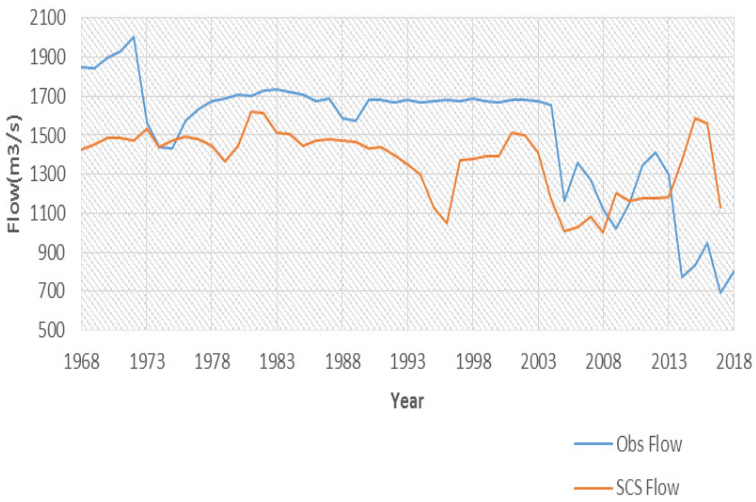

Figure 6. Observed flow Vs simulated from SCS (1968-2018).

exception of few years where contradictions in flow was observed as in Figure 7. For example, in 1972 observed curve showed an increase while SCS was constant, 1979 and 1996 proved a decreasing trend. There was a contradiction of flow in 2014 where both datasets showed different direction this could be the effect of inflow from Lake Victoria and different rainy seasons of both catchments which may require further investigations [31-35].

From Mann-Kendal statistics, it was observed that Akokorio river experienced zero flow during February, March, April, May and August identified as drought followed by high flows in June, July, October and November resulted floods in the catchment (Figure 8).

The summary statistics of discharge from Akokorio River includes minimum, maximum and mean which was extracted from ManKendal. This analysis was meant to discover how much maximum and minimum values are far from the mean for better planning of water use.

Discharge monitoring is avital factor for the valuation of climate change influence on water yield, this study observed that Akokokrio River experienced high flows during August and September with maximum flow of 1258 m^3/s that was very far from the mean which could not go away with flooding [36,37].

Monthly flow Averages were extracted from M-K tool while considering minimum, maximum, mean and standard deviation values for the purpose

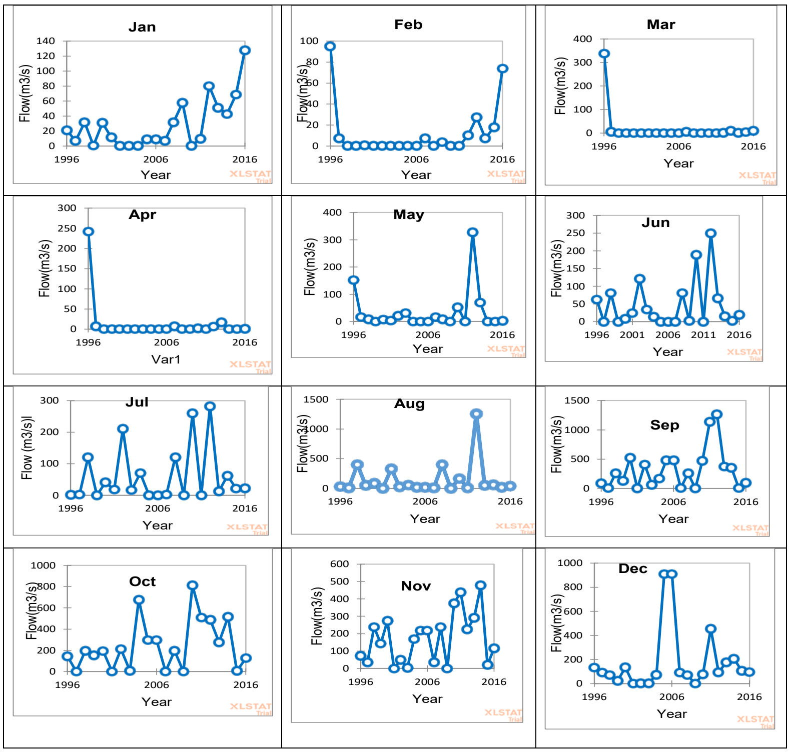

Figure 7. Monthly flow in River Akokorio from 1996 to 2016.

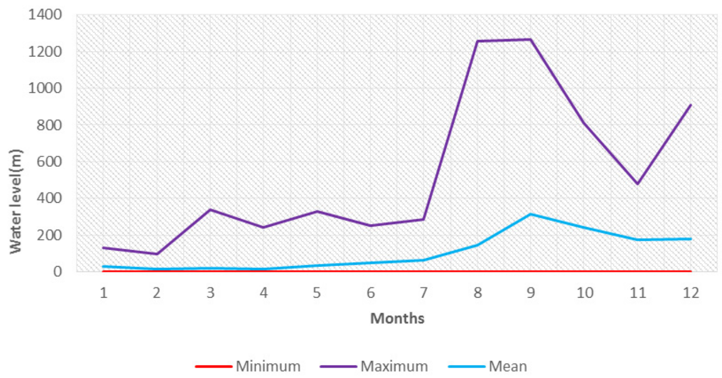

Figure 8. Minimum, maximum, and mean annual discharge from Akokorio River (1996 to 2016).

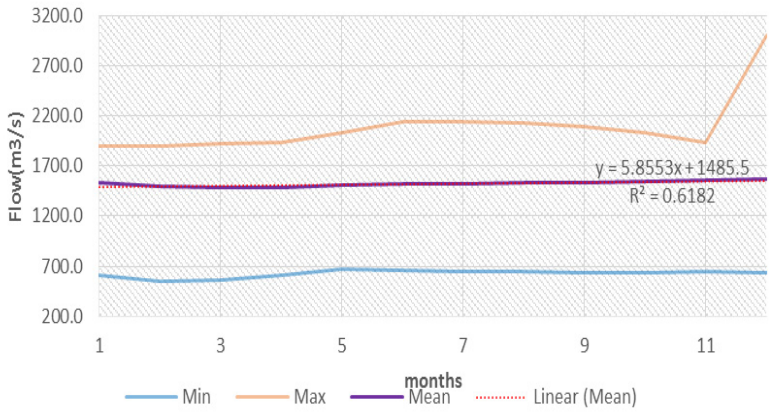

Figure 9. Relationship between mean, minimum and maximum flow at Masindi port.

of detecting changes in water yield where by a great change from the mean makes a big impact on water yield (Figure 9).

The outputs from Mann-Kendal trend test, justifies the relationship between mean, minimum and maximum flow, 1500 m^3/s, 611 m^3/s and 2000 m^3/s respectively for the evaluating influences of climacteric variations on water yield. This is important to know how far maximum and minimum are far from the mean for better planning of water use Figure 9. This study discovered that minimum was too far from the mean with a difference of -919.4 m^3 and maximum +370.5 m^3.

Following outcomes in in the M-K analysis gotten from Masindi port station, If the p value is less than the significance level α (alpha)=0.05, H_0 is rejected. Rejecting H_0 indicates that there is a trend in the time series, while accepting H0 indicates no trend was detected. On rejecting the null hypothesis, the result is said to be statistically significant. Results indicates that the Null Hypothesis was accepted for Masindi port station [38,39].

Detection in annual discharge for Lake Kyoga basin, an area encompassing the sub catchments of Kapiri and Akokorio. An analysis of two important parameters (Flow and rainfall) delivers stimulating insights on how they might impact water yield in this region. In this research M-K test results detected the negative trends because p-value is less than 1 for all the. Therefore, water yield from Lake Kyoga catchment was proved to have been reduced with significant level of 5%.

The physical plots from Man-Kendal justify that water yield at Masindi port was negatively affected. The most affected season was September, October, November (SON) with-1272 m^3/s, -1388 m^3/s, and -1351 m^3/s respectively compared to MAM season where annual water flow was; -1247 m^3/s, -1200 m^3/s, and -1053 m^3/s as presented in Figure 10.

Watershed monitoring and land use variation

ArcGIS is a popular tool amongst several watershed Hydrologists use as interested in learning the effect of agricultural activities and land use management and watershed monitoring containing river discharge and quality of water (Figures 11 and 12). This research applied GIS to analyse the state of water resources and land use variation area in Lake Kyoga catchment by considering temporal changes in open water and wetland areas.

The land use layer of 2000 indicates subsistence farmland with the highest coverage of 3.5 million hectares followed bush coverage of 1 million hectares [41-46]. However, the focused parameter was open water and wetland which directly affects water yield.

From Figure 13 the graph shows that there was a lot of land use practice which reduced bush coverage with 0.5 million hectares and some reduction of wetland coverage. However, subsistence farmland maintained its state as of the year 2000.

It is believed that any impact on wetland and open water area affects water yield, therefore this study realised a great change in these features Figure 14. From the Models out puts, it was observed that land use cover

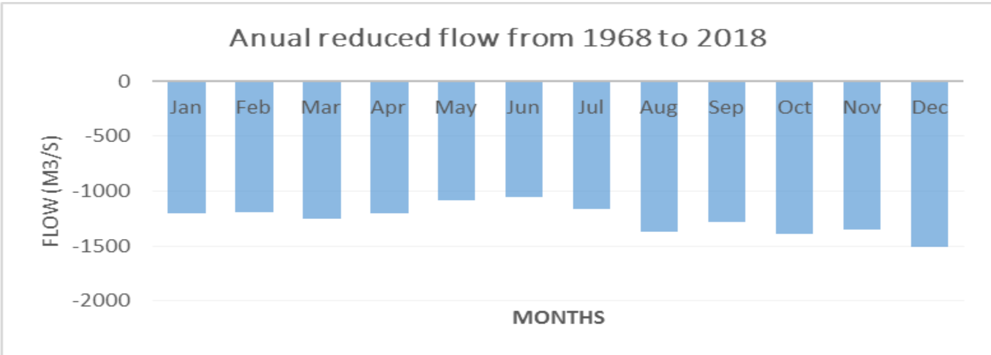

Figure 10. Annual reduced flow from Lake Kyoga at Masindi port (1968-2018) Water yield was observed to be reducing with time as all the months indicated negative change from 1968 to 2018 [40]. The month of December was found to be more affected as showed a decrease of 1508m^3

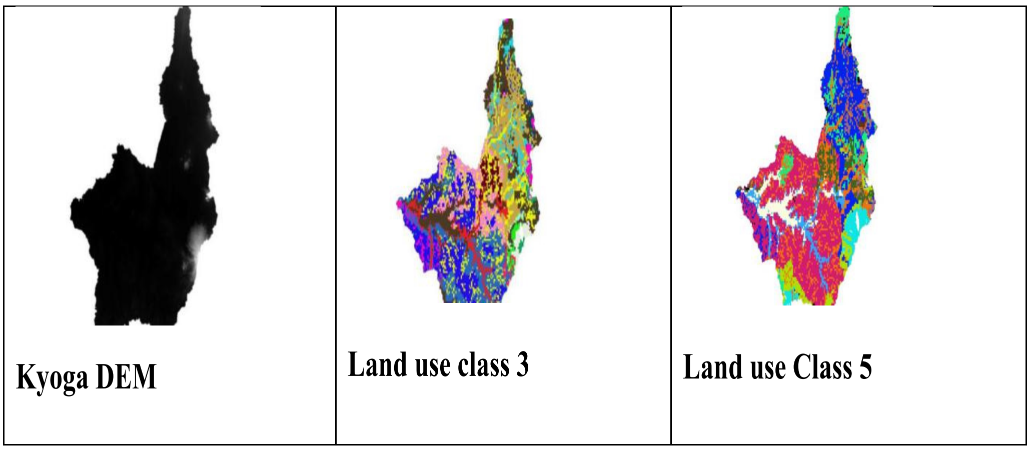

Figure 11. Lake Kyoga Land use: Source: UNMA 2020.

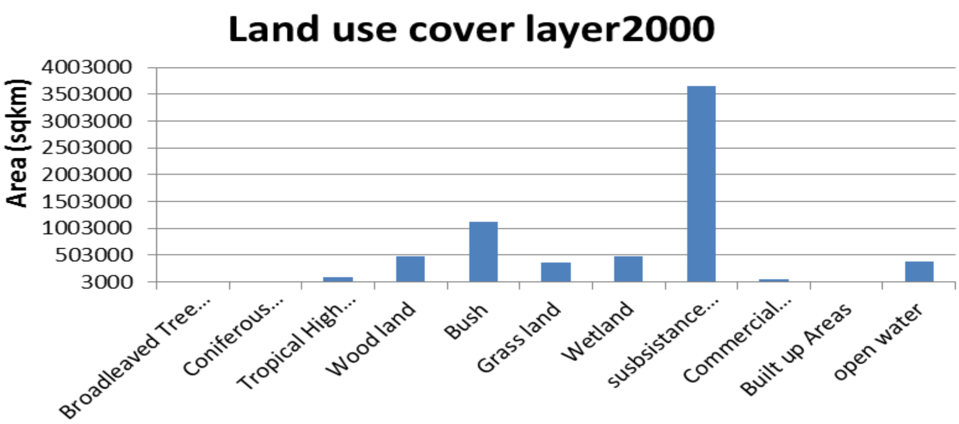

Figure 12. land use cover layer of year 2000 extracted from GIS tool.

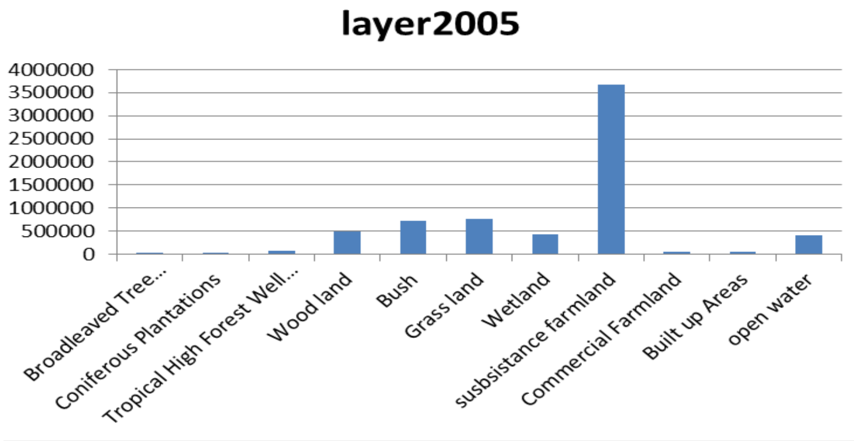

Figure 13. Land use cover layer 2005.

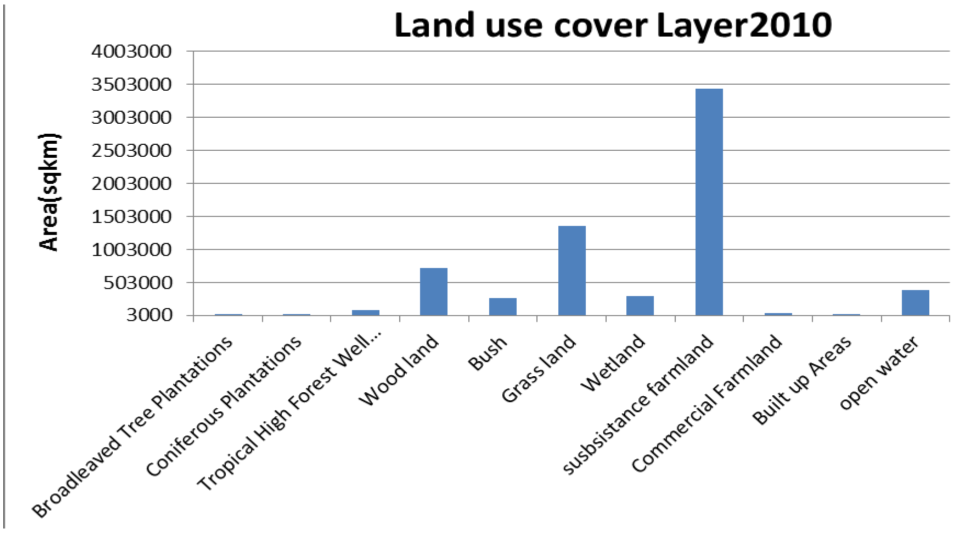

Figure 14. land use cover layer 2010.

in Lake Kyoga catchment greatly changed from 2000 to 2010. Where by wetlands reduced by 0.25 million hectares, open water 0.1 million hectares and bush coverage was reduced by 0.75 million hectares [47] (Table 1). All these are sources of water which can be examined to assess evidence of climate change and water yield.

Land use data for 10 years was obtained from National Forest Authority (NFA) as was only available during data collection.

To determine the changes in water storage, one must bear in mind that wetlands and open surface water are included in the equation. In this study a simple formula (L2010 – L2000=AC) was used to detect changes in land use layers obtained from GIS and expressed as follows;

1. L2010=layer2010
2. L2000=Layer2000
3. AC=Area change

Land use change per unit area was calculated using GIS tool from year 2000 to 2010 which later computed while considering values of previous layer minus values of current layer year2000' which indicated that bush cover was most affected with a decrease of -0.75 million hectares [48]. It was followed by wetland with a reduction of -0.25 million hectares. Land use was calculated in 5-year interval (2000, 2005, and 2010) but because to limited data 2015 was not accessible.

Using Geographic Information System (GIS), Land use categories were analysed focussing on open water area, wetland and Bush which are important in assessing evidence of climate change on water yield. Out puts indicates that there is a negative change of -32%, -4%, -11%, Bush, open water and wetland respectively [49,50]. However, some positive change was identified in grassland with +42% and woodland +11% of which could be due to afforestation and re-afforested that is being emphasized in

Table 1. Area changes per land use category.

Land use category	Area change from 2000 to 2010
Wetland	-0.25 million hectares
Open water	-0.10 million hectares
Bush	-0.75 million hectares
Wood land	+0.25 million hectares
Grassland	+1 million hectares

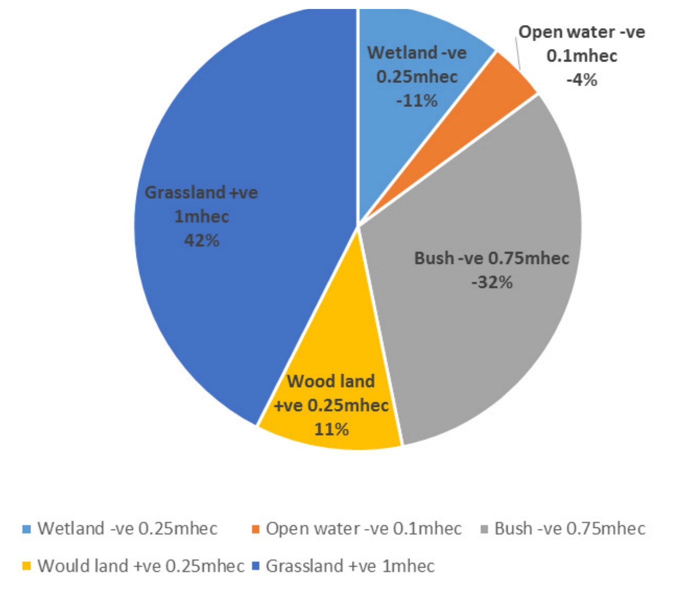

Figure 15. Land use change with area (2000 to 2015).

Uganda (Figure 15).

Recommendations

Improvement in research

Enhancement of climatological data gathering and analysis through establishment of more Meteorological Services in the country [16,51-53]. However due to the high doubt connected to climate change and variability, adequate and consistent data is important for research to improve on knowledge and awareness about climate Change. This can be done via establishment of meteorological stations as education on climate change would be grounded on more consistent information since this study was challenged by limited weather and hydrological stations. Since Lake Kyoga basin is recharged by different water resources including Lake Victoria, a comprehensive study is required to assess inlet waters from Lake Victoria into lake Kyoga.

Community development

Although results revealed increase of precipitation in most parts of lake Kyoga catchment, other parts especially Karamoja sub region experiences shortage of water. Improving adaptive capacities for helpless communities in drought prone areas particularly those in the semiarid and arid cattle corridor region to cope with the gradually frequent droughts. This is to allow them not only to be ready for seasons when rains fail, but also to mitigate the impact of droughts. This can be done via developing and encouraging suitable rainwater harvesting skills, water storage systems, and pasture creation among others [54].

Encouragement of small-scale irrigation systems to decrease on the surprise of droughts as utmost communities are poor and need cheaper systems. Government and other associates need to support research particularly at river catchment scale.

Conclusion

Results obtained from Addinsoft's XLSTAT2012 software performing the statistical Mann-Kendall test indicates negative changes in observed water levels and out flow of Lake Kyoga basin while precipitation data analysis proved positive changes within the entire catchment. This study revealed that there were sequential increasing trends in rainfall while general flow from the catchment was observed to be decreasing.

This research was carried out in order to get a better understanding of Lake Kyoga's hydrology, to discover the probable causes of the almost 2 m drop in the level of Lake Kyoga between 1963 and 2016. Simulation results indicate that approximately 6% of the drop in lake levels since 1963 can be credited to the effect of climate change and anthropogenic activities, although it must be noted that there is some uncertainty regarding the exact history, extent and impact of abstractions in the catchment.

Results from the analysis indicates that rainfall performance was increasing while water levels and flow over Lake Kyoga basin reducing with time which is contrary to the principle that "increase in rainfall should show significant increase on water storage" this incident in lake Kyoga catchment could have been caused by other factors including high evaporation rate, water abstraction for irrigation and impact of inlet from Lake Victoria. Most of the data analysed from rainfall stations indicate an increase in annual rainfall performance for example Soroti weather station rainfall was increased by 29% in 30 years while during MAM and SON seasons the trend also significantly rose to 5% and 19% respectively. This would mean positive effect on total water yield but surprisingly further analysis on discharge shows a decrease on observed water levels of Lake Kyoga Basin and its outlet at Masindi port.

This study displays that climatic changes and sector's influences on climate must be anticipated to affect the people of Uganda in a diversity way. Changes are not constant across the country as from the examination of land use cover layer change using ArcGIS to detect the impact of climate change results disclosed that there is a pronounced reduction in open water area with 0.10 million hectares equivalent to-4% also bush coverage reduced by 32% and wet land 11% for only 10 years. This implies that Lake Kyoga basin is on threat if its wetlands continue to reduce at that rate yet wetlands play a big role in water protection, source of food, biodiversity production and healthy environment.

Though negative impacts on open water were experienced, Uganda is still at greater risk of flooding and coexisting health impressions and infrastructure injuries generated from flow extremes. This research scrutinized changes in the occurrence of high flow events from observed flow records datasets varying from 1968-2018, while the water level dataset of 1948-2015 showed the variations of water levels in Lake Kyoga basin, river Kapiri and Akokorio results revealed that the sequential high flow of increasing trend in the 3 stations.

References

1. H Solomon, et al. "Evaluation of multiple climate data sources for managing environmental resources in East Africa." *Hydro Earth Sys Sci.* 22.8(2018):4547-4564. Alefa District Finance and Economy Office, 2021.
2. Zewdu T., et al. "Characterization and variability of Kiremt rainy season over Ethiopia." *Meteo Atmospheric Phys* 89.1 (2005): 153-180.
3. Endris, H. S., et al. Future changes in rainfall associated with ENSO, IOD, and changes in the mean state over Eastern Africa. Climate Dyn, 52(3–4), 2029–2053.
4. Merabtene, T, et al. "Assessment of seasonal and annual rainfall trends and variability in Sharjah City, UAE." *Advan Meteorol* (2016).
5. William R. *Global warming and agriculture: End-of-century estimates by country*. Peterson Institute, (2007).
6. Alefa Development Agriculture office District. Annual report. Maksegnit; (2021).
7. David B., et al. "Prioritizing climate change adaptation needs for food security in 2030." *Science* 319.5863 (2008): 607-610.
8. Elsanabary, et al. "Evaluation of climate anomalies impacts on the Upper Blue Nile Basin in Ethiopia using a distributed and a lumped hydrologic model." *J Hydro* 530 (2015): 225-240.
9. Woldeamlak B. "Rainfall variability and crop production in Ethiopia: Case study in the Amhara region." *Proceedings of the 16th international conference of Ethiopian studies*. Vol. 3. Trondheim, Norway: Norwegian Univ Science Technology, 2009.
10. Hope, S. R, and Kempe R. "Climate change and poverty in Africa." *Int J Sustainable Dev World Ecology* 16.6 (2009): 451-461.
11. Mekonnen Y, et al. "Assessing rainfall variability at Adwa District, Central Tigray, Ethiopia." *Int J Res Enviro Sci* 5.1 (2019): 1-5.
12. Akalu, S. D., et al. "The impacts of climate change on African continent and the way forward." *J Eco Natural environment* 7.10 (2015): 256-262.
13. Azeb W., et al. "Climate change impacts on potential maize yields in Gambella region, Ethiopia." *Reg Environmental Change* 21.2 (2021): 1-12.
14. Guhathakurta. P, and Elizabeth S. "Detecting changes in rainfall pattern and seasonality index vis-à-vis increasing water scarcity in Maharashtra." *J Earth System Sci* 122.3 (2013): 639-649.
15. Surabhi,M and Vinod K. H. "Mobile-based climate services impact on farmers risk management ability in India." *Climate Risk Management* 22 (2018): 42-51.
16. Meybeck, A. "Food and Agriculture Organization of the United Nations, & Organisation for Economic Co-operation and Development (Eds.). 2012.
17. Building resilience for adaptation to climate change in the agriculture sector: Proceedings of a Joint FAO." OECD Workshop, 2012.
18. Alhamshry, Asmaa, et al. "Seasonal rainfall variability in Ethiopia and its long-term link to global sea surface temperatures." *Water* 12.1 (2019): 55.
19. Diro, G. T., et al. "Teleconnections between Ethiopian summer rainfall and sea surface temperature: part I—observation and modelling." *Climate dynamics* 37.1 (2011): 103-119.
20. Vargas, R. "Vulnerability to drought and food price shocks: evidence from Ethiopia." *World Development* 96 (2017): 65-77.
21. Gemeda, D. O. "Climate change variability analysis in and around Jinka, southern Ethiopia. With special emphasis on temperature and rainfall." (2019).
22. Gebrehiwot T, B., et al. "Characterizing the spatiotemporal distribution of meteorological drought as a response to climate variability: The case of rift valley lakes basin of Ethiopia." *Weath Climate Extremes* 26 (2019): 100237.

23. Kabite, G., et al. "Spatiotemporal climate and vegetation greenness changes and their nexus for Dhidhessa River Basin, Ethiopia." *Envi Systems Res* 8.1 (2019): 1-24.
24. Wing H., et al. "Trends and spatial distribution of annual and seasonal rainfall in Ethiopia." *Int J Climatology: A J Royal Meteoro Socie* 28.13 (2008): 1723-1734.
25. Alemayehu A, and Woldeamlak B. "Trees and rural households' adaptation to Local environmental change in the central highlands of Ethiopia." *J Land Use Science* 13.1-2 (2018): 130-145.
26. Gezahegn A. "Long-term climate data description in Ethiopia" *Data in brief* 14 (2017): 371-392.
27. Girma E, et al. "Climate variability and small-scale farmer adaptation strategy in Setema-Gatira area of Jimmaa, southwestern Ethiopia." *Ame J biological envir stat* (2018).
28. Yibrah, M, et al. "Assessing rainfall variability at Adwa District, Central Tigray, Ethiopia." *Int J Res Environmental Sci* 5.1 (2019): 1-5.
29. Tujuba M, et al. "Rainfall seasonality and timing: implications for cereal crop production in Ethiopia." *Agri Forest Meteor* 310 (2021): 108633.
30. Stern, R. D., et al. "Analysing daily rainfall measurements to give agronomically useful results. I. Direct methods." *Experimental Agriculture* 18.3 (1982): 223-236.
31. Stern, R, et al. "INSTAT climatic guide." *Reading (UK): Univ Reading* (2006).
32. Mapunda, A., Chassama J., et al. "Livestock market data: Collection, dissemination and use in Tanzania." *Livestock Data Innova Africa Brief* (2011).
33. Yilma S and Zanke U. "Recent changes in rainfall and rainy days in Ethiopia." *Int J Climatology: A Journal of the Royal Meteoro Soc* 24.8 (2004): 973-983.
34. Conway, D. "The climate and hydrology of the Upper Blue Nile River." *Geogr J* 166.1 (2000): 49-62.
35. Park, A W, and Funk, C. "A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa." *Climate Dynamics* 37.11 (2011): 2417-2435.
36. Gemeda, et al. "Meteorological data trend analysis and local community perception towards climate change: a case study of Jimma City, Southwestern Ethiopia." *Envt, Develop Sustainability* 23.4 (2021): 5885-5903.
37. Barana, B, 2017. Spatial and Temporal Rainfall Trend Analysis: A Case Study of South Western, Ethiopia. Civil Environ Res.9(8) 2017.
38. Mirza, M.M.Q. (2003) Climate Change and Extreme Weather Events: Can Developing Countries Adapt? Climate Policy. 3 (3), pp. 233-248.
39. Radeny,, M., et al. "Indigenous knowledge for seasonal weather and climate forecasting across East Africa." *Climatic Change* 156.4 (2019): 509-526.
40. Guido, et al. "Farmer forecasts: Impacts of seasonal rainfall expectations on agricultural decision-making in Sub-Saharan Africa." *Climate Risk Management* 30 (2020): 100247.
41. Gebre, et al. "Trend and variability of rainfall in Tigray, northern Ethiopia: analysis of meteorological data and farmers' perception." *Academia J Research* 1.6 (2013): 088-100.
42. Hao, F., et al. "Temporal rainfall patterns with water partitioning impacts on maize yield in a freeze–thaw zone." *J hydrology* 486 (2013): 412-419.
43. Tujuba, M, et al. "Rainfall seasonality and timing: implications for cereal crop production in Ethiopia." *Agricultural Forest Meteo* 310 (2021):108633
44. Asfaw, A., et al. "Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin." *Weather Climate Extremes* 19 (2018): 29-41.
45. Dereje, et al. "Variability of rainfall and its current trend in Amhara region, Ethiopia." *African J Agricultural Res* 7.10 (2012): 1475-1486.
46. Abbink, G. J. *Ethiopian-Eritrean studies: a bibliography on society and history, 2010-2015*. African Studies Centre Leiden (ASCL), 2016.
47. Hansen, T., et al. Scaling up climate services for smallholder farmers: Learning from practice. *Climate Risk Management*, 2021: 1–3.
48. James, R, and Richard, W. "Changes in African temperature and precipitation associated with degrees of global warming." *Climatic change* 117.4 (2013): 859-872.
49. Woldemlak, B., and Conway, D. "A note on temporal and spatial variability of rainfall in drought prone Amhara regions of Ethiopia." *Int J Climatology* 27 (2009): 1467-147.
50. Wondimu K., et al. "Anthropogenic nitrate contamination of water resources in Ethiopia: an overview." *Water Supply* (2022).
51. Kassahun G, and Muchie Y. "Rethink the interlink between land degradation and livelihood of rural communities in Chilga district, Northwest Ethiopia." *J Ecology Envir* 42.1 (2018): 1-11.
52. Birhan S, and Nayak D. "Analyzing the perceived prioritized forest ecosystem services under the participatory management: A case of Maksegnit District, Amhara Regional State, Ethiopia." *Trees, Forests and People* 9 (2022): 100318.
53. Hundera, Mpandeli H S, et al. "Smallholder farmers' awareness and perceptions of climate change in Adama district, central rift valley of Ethiopia." *Weather and Climate Extremes* 26 (2019): 100230.
54. Tesfaye, K, et al. "Matching of crop and environment for optimal water use: the case of Ethiopia." *Physics Chem Earth, Parts A/B/C* 29.15-18 (2004): 1061-1067.

Cite this article: Tumusiime, M.D., et al. Impacts of Climate Change on Water Yield of River Akokorio and Kapiri Sub-Catchments. J Climatol Weather Forecast, 2022, 10(11), 001-009.