WANGARI MAATHAI INSTITUTE FOR PEACE AND ENVIRONMENTAL STUDIES

Journal of Sustainability, Environment and Peace

Homepage: http://www.jsep.uonbi.ac.ke

ISSN: 2663-4627

Impact of Rainfall Variability on Surface Water Resources in Homa Bay County, Kenya

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Article history:
Received: 08 April 2019
Received in revised form: 25 April 2019
Accepted: 2 May 2019
Available Online: 15 May 2019

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Key words:
SWAT
surface water
Rainfall
Climate
Lake Victoria basin

ABSTRACT

Changes in the Lake Victoria basin rainfall regime has far reaching environmental, hydrological and socio-economic effects to the more than 30 million people living around the lake. Lake Victoria basin water balance has rainfall as the main input, contributing about 80% of the input. Rainfall variability therefore plays a key role in the availability of surface water resources in the Lake Victoria basin. The objective of this study was to establish the relationship between Climate Variability and spatial distribution of Surface Water Resources in Homa Bay County. The rivers Kibuon, Tende and Riana are studied. Secondary data sets including climate data which are both in-situ and proxy data were sourced from Kenya Meteorological Department and the Global Weather Database for the period 1986-2012. River discharge data for 30 years spanning from 1983 to 2013 was obtained from Water Resources Authority while the Soil and Water Assessment Tool model (SWAT) was used in the estimation of weather variables including precipitation, temperature, wind speed, relative humidity and solar radiation. Correlation, regression and time series analysis which largely relies on the SWAT model output data were used to determine the relationship between climate variability and surface water resources in relation to availability, distribution and Yield of surface water systems. Impacts of variability in rainfall and temperature trends on surface water resources was discovered in distribution and quantity of water yield These findings will be useful in management of water resources within Homa Bay county and also aid in planning based on rainfall forecasts to avert water crisis scenarios in the county.

1. Introduction

Water is an essential resource for all livelihoods on the earth surface. The availability of surface water resources continues to decline in many parts of the world. In the opinion of IPCC (2007), fluctuations in the hydrological cycle affects both the ground and surface water supplies through fluctuating amount, frequency and intensity of rainfall. Oguntoyinbo & Odingo (1979) documented that the hydrological cycle through fluctuating temperature, rainfall, wind speed, humidity and solar radiation and the interactions results in diurnal, seasonal and interannual rainfall in a region such as Lake Victoria basin (Ogallo 1988; Mutai et al 1988) and the end results include variation of river discharge patterns (UNDP, 2006). The hydrological regime of any surface on earth is influenced by the terrain, climatic condition, land cover- land use system and population growth and all these affects surface water supply systems, flood structure, reservoirs and spillways in general (Moss & Parker, 1987; Hulme,1990; Ominde and Juma, 1991; Kundzewicz et al, 2008; McGrane, 2016).

Please cite this article as: Omondi O. C., J. I. Ndolo, I. A. Nyandega and C. Ang'u (2019). Impact of Rainfall Variability on Surface Water Resources in Homa Bay County, Kenya. *J. sustain. environ. peace 1(3) 84 –90*

The relationship between surface water resources and climate variability is complex (Gleick, 1998, 1999, 2000; WARPO, 2005). Even though there is a wide spread consensus that climate variability is real (Ermine et al., 2001, IPCC, 2001), there is need for increasingly new evidence in different and new areas. Climate variability affects the availability of surface water resources and this occurs in many different scales over time (Mitchell et al., 1966; IPCC, 1996) through manifestations of weather patterns in terms of frequency, magnitude and distribution (KMD, 2010; Kundzewicz et al., 2007). Assessment of the impact of Climate variability which is a vital natural phenomenon that influences many economic activities is therefore also important for surface water resources. Climate system is generally linked to the environment, hydrological cycle, and atmosphere and is considered a key component in the determination of rainfall (UNEP / GOK 2000).

Availability and distribution of surface water depends on the management of the already available quantities.

Homa Bay County which lies within Lake Victoria south water catchment area accounts for 3.0% of the total water resources in Kenya (WRA, 2011). Lake Victoria basin is one of the most important natural resource regions in Africa, providing services such as fishing, agriculture, transport and most importantly water supply for varied uses (Ntiba et al, 2001). Rainfall is the most important input in a regional water balance and is also influenced by temperature patterns (Flohn and Burkhardt 1985; Nicholson and Yin 2002; Tate et al 2004) and this has a significant impact on the availability and distribution of surface water resources in both inland and coastal areas. The increasing population in Homa Bay due to improved standards of living implies an ever-increasing demand for water uses for agriculture, domestic and industrial purposes. The devolved unit has brought about a rising affluence in developing towns and urban setups within the County with a larger number of persons in the area who adopt water intensive kind of lifestyles including car wash activity, watering gardens, infrastructural development and rapidly developing economy that requires more demand for water among others.

Shifting rainfall and temperature certainly impacts on the availability, distribution, quantity and supply of surface water resources. Fluctuating rainfall amount is catastrophic even to future distribution of surface water resources in Homa Bay County and needs to be addressed alongside management and conservation strategies. This paper focuses on the impacts of spatial-temporal daily rainfall, temperature and stream flow variability on water resources in Homa Bay County of Kenya. The main objective of this study was therefore to establish the relationship between Climate Variability and spatial distribution of Surface Water Resources in Homa Bay County. The study sought to determine the extent to which daily rainfall totals and temperature conditions affect daily river volume flows and how the daily rainfall totals and mean temperature relates to availability of surfaces water resources in Homa Bay County. Homa Bay County (Figure 1) is located in the western part of Kenya within the Lake Victoria basin. The county experiences a modified equatorial type of climate. It covers an approximate area of 3,342.2km^2 of which approximately 1.227 km^2 is covered by surface water resources.

A number of factors contribute to the variability in Climatic conditions in Homa Bay including synoptic scale factors such as wind systems all year round. Rainfall variability refers to the degree to which the amount of rainfall varies and its impact on the availability, distribution and quantity of water resources for varied uses (EPA, 2012). The weather of Homa Bay varies spatially over time and within short distances.

Lake Victoria region has a modified equatorial climate with relatively modified temperature and fluctuating rainfall totals. Rainfall in Homa Bay (figure 2) varies from 250mm to 800mm per annum and is influenced by the movement of the ITCZ. The area also exhibit variability in potential evapotranspiration depending on the altitude, relief and nearness to the Lake Victoria and this impacts the surface water resources in terms of availability and distribution.

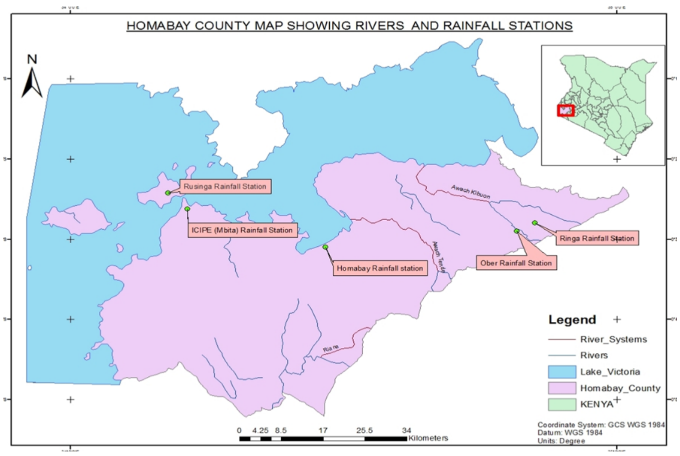

Figure 1: Map of Homa Bay county
Source: Author 2018

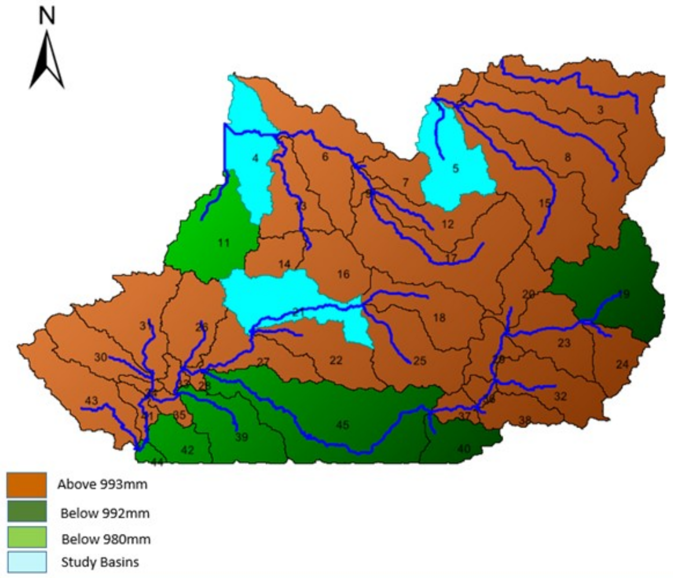

Figure 2: Annual average rainfall (Sub-basins 4, 5, and 21) in Homa Bay county
Source: Author, 2018

Rainfall variability is also linked to sea surface temperatures (Nicholson and Yin, 2002), Lake Victoria for this study and the subsequent weather patterns. According to Mutai et al (1998), the rainfall regime of Homabay County is moderated by the Lake Victoria and its topographical influences. Seasonality and interannual variability of rainfall is also occasioned by the interconnection between ITCZ, El Nino/South Oscillation, winds and extra tropical weather systems (Ang'u et al., 2016; Ogallo, 1998; Mutai et la, 1998; Nicholson and Yin, 2002) and in concurrent that the wind patterns, pressure belts and effects of the ITCZ modifies the climate variability of a region (Mukabana and Piekle 1996).

The population of Homa Bay county based on the projection of Kenya Population and Housing Census (2009) was 1,177,181 in 2017 with an area of approximately 3154.7km with a population density of 373 persons per km2. The population is expected to rise to 1,423,435 by the year 2022 thereby increasing demand for water especially along the emerging urban centre in Homa Bay, Sindo, Mbita and Oyugis as a result of devolution.

2. Methodology

The hydrology of Homa Bay County is made up of underground aquifers, rivers, wells, springs and is also a complex hydrological system that originates from the Kisii highlands and flows through to Lake Victoria. The Major Rivers include; Awach Kibuon, Awach Tende and Riana which together with their tributaries drain into Lake Victoria. The area is Swampy in Lambwe valley and parts of kochia, Kabondo and Kabondo Kasipul. The only outflow from Lake Victoria is the River Nile. Vegetation and land cover determines the hydrological abstraction, surface runoff volumes through different ways such as intercepting rainwater, evapotranspiration mechanisms and human activities including deforestation, ploughing along the contours. Within the County are patches of Savanah and modified equatorial forest along Kodera, Wire, Homa, Lambwe, Gembe and Gwasi hills

Agriculture is the main economic activity in Homa Bay. Areas around Kasipul, Kabondo, Rangwe and Ndhiwa have favourable climate and fertile soils for production of maize, sugar cane, Potatoes, Bananas and Pineapples. Due to variable rainfall and temperature conditions in the area that cannot support rain fed agriculture an improved household food security irrigation scheme has been established at Oluch kimira in Kochia. In Suba north and south ICIPE has also intensified programs supporting drought resistant varieties of Millet, Sorghum and Sunflower crops. This indicates the magnitude of water stress both for agricultural and household uses. Grassland cover is found in Ruma National park. Some of the gazetted forests include Gwasi and Wire, Non gazetted forests are found in Ruri hill, Gembe hill, Homa hill, Asego hill, Kodera and Mfangano Island. The lake shores consist of aquatic vegetation cover and play a vital role in the formation of rainfall and temperature modification; control surface runoff; and soil water infiltration which affect the water balance.

The various Agro ecological zones (figure 3) in the study area indicate the climatic variability relationships with various land uses. According to the Kenya soil survey climatic zoning Method, the area falls in the zones I-IV (table 1, Sombroek et al,1982). This means that Homa bay experiences variation in the potentiality for rainfed agriculture depending on the zones. The area of study is classified in terms of agro climatic potentiality of high, medium and low potential areas in relation to rainfall amount, the low potential area is located along the lake littorals.

2.1 Soil and Water Assessment Tool (SWAT)

SWAT is a hydrological model used to simulate the physical processes within a watershed including precipitation, evapotranspiration, surface and ground water flow to determine different scenarios affecting hydrological responses. The data sets used in SWAT outlines different characteristics of the basin such as land use land cover, soils, topography, climate and the general hydrological scenarios within the study area.

This model integrates Data sets within the GIS interface (Arc View Map Window) and presents them in tabular format and map information series. The main concepts in the model processes include simulation of the hydrological cycle and the water balance and the results being the water yield.

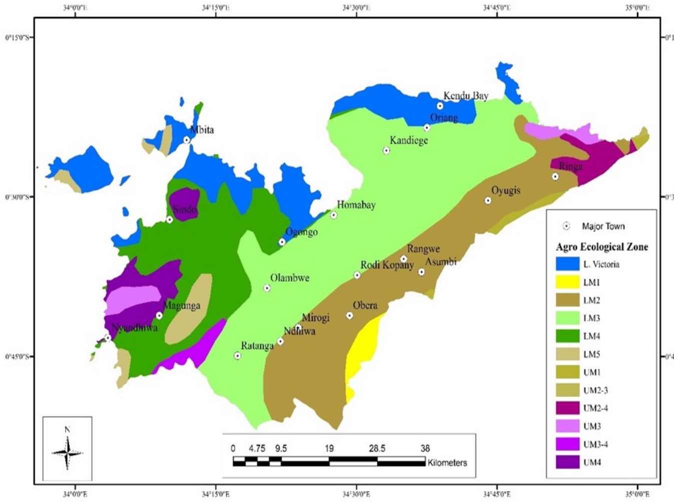

Figure 3: Agro Ecological Zones in Homa Bay County
Source: International Livestock Research Institute (1983).

Table 1: Key to Agro Ecological Zones

Zones	Agricultural potential	Amount of rainfall (mm/year)	Approximate evaporation (mm/year)
I	Very high	Over 1200	1200-2000
II	High	900-1600	1300-2100
III	High-medium	700-1400	1400-2200
V	Medium	600-1100	1500-2300
VI	Marginal	400-800	1600-2400

Source: Modified from Mungai (1984)

2.1.1 Data

This paper relies on the SWAT hydrological model outputs for Homa Bay County. The rainfall product used include the observed long-term daily rainfall and temperature. Simulated weather data used include precipitation, temperature, wind speed, relative humidity and solar radiation and measured river discharges for Awach Kibuon, Awach Tende and Raina rivers for a 30-year period (January 1983 to December 2013). Other data include terrain, soil, land use and land cover data. Rainfall and temperature records were obtained from Kenya meteorological Department while the hydro meteorological data was obtained from the Water resources management Authority (WRA). Simulated weather data was retrieved from the Global Weather Data geoportal website. The Terrain (DEM) was extracted from the Shuttle Radar Topographic Mission within the USGS site while soil. All the data sets were customized to SWAT format and subjected to inconsistency checks and in case of missing records, inbuilt interpolation procedures in SWAT was done and the data calibrated.

Land use and land cover data was obtained from the universal FAO geoportal land cover database with a spatial resolution of 1km. The land use data was coded to match with the SWAT land uses and the land use patterns in Homa Bay County as shown in table 2.

Since the model requires soil properties for the basins, a user table for soil was generated so that the universal FAO soil types are altered to match with the soils in the SWAT database and the FAO Kenya soil types to avoid errors during delineation and creation of HRU in the process of modelling the watershed.

Table 2: Land Use Data

FAO Coding	SWAT Equivalent	Land Use Symbol	FAO Kenya Land Cover
210	11	WATR	Water Bodies
60	41	FRSD	Open Broad Leaved Deciduous Forest
50	41	FRSD	Closed Broad Leaved Deciduous Forest
100	43	FRST	Closed To Open Mixed Broad Leaved/Needle Leaved Forest
130	51	RNGB	Closed To Open Shrubland
14	83	AGRC	Rainfed Cropland
30	85	AGRL	Mosaic Vegetation/Cropland
20	85	AGRL	Mosaic Cropland Vegetation
120	43	FRST	Mosaic Grassland/Forest-Shrubland/Grassland
190	21	URML	Artificial Areas
140	71	RNGE	Closed To Open Grassland
110	43	FRST	Mosaic Forest-Shrubland/Grassland
143	71	RNGE	Open Grassland
15	71	RNGE	Rainfed Herbaceous Crops
90	41	FRSD	Open Needle Leaved Deciduous Forest
40	42	FRSE	Closed To Open Broadleaved Evergreen/Semi Deciduous
200	31	SWRN	Open Areas

Source: Author (2018)

2.1.2 Digital Elevation Model

Digital elevation model of (30m×30m) resolution was extracted from the Shuttle Radar Topographic Mission within the USGS site and projected to UTM, Spheroid WGS 84 in Zone 36. This is necessary in accounting for water distribution and accumulation in the soil in relation to the topography. Slope was classified into five classes (figure 4) to help map depression, valley and lowlands and quantify the surface water storage, calculate the drainage network and density and their relationships to soil permeability and relief including land use patterns. The relationship is thus compared to availability and distribution of water resources in the study area within and across the slope.

2.1.3 Data Analysis

Data sets including daily rainfall and temperature totals (minimum and maximum), daily river volume flow were subjected to spatial analysis and interpretation. SWAT model was used to determine river volume flows in all channels and in estimating floods and low flows from simulated and in-situ measurements. In preparation for the actual SWAT data analysis, various software which are compatible within (Arc GIS 10.2.2 package) were downloaded from the SWAT web portal and installed in readiness for the data analysis.

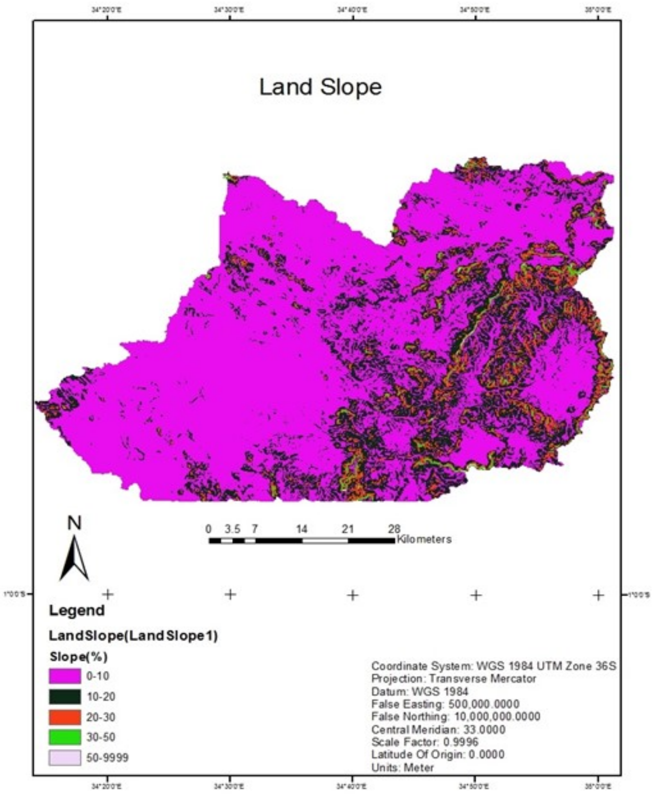

Figure 4: Land Slope
Source: Author (2018)

Other Statistical analyses in SPSS including the Correlation and regression analysis for rainfall temperature and Water yield were also carried out. The model set up is a process and begins with the delineation of the watershed by incorporating a projected digital elevation model (DEM) to enable complete terrain analysis, basin boundary delineation and definition of stream network .The main reason for the specified DEM set up was to model water flows downstream by showing slope, aspect and altitude which is indicated by the z direction and identification of streams starting with the flow direction, flow accumulation and final stream network definition.

Catchment boundaries, sub catchments and stream networks are clearly identified to quantify soil moisture and flow trends including the catchment responses. Streams and outlets were then generated and sub basin characteristics calculated. An overlay of Land use, soils and slope shape files is subsequently done to produce different sub basin files.

More spatial variables were added into the system including soil types and their derived characteristic, land use land cover to help in determination of the outputs such as stream discharge, water yield, evapotranspiration and groundwater recharge and transfer. Weather data generated from the global weather data base and observed rainfall and temperature data sourced from Kenya Meteorological Department for six identified rainfall and meteorological stations were incorporated into SWAT to generate weather input files.

Different input tables were successfully written including; configuration file, soil, weather generator, sub soil, HRU/drainage, main channel, ground water, water use, management, soil channel, pond, stream channel, septic, operations water shed and finally waste water shed file datum respectively. The SWAT input tables were edited and saved in the database for analysis. The GIS spatial overlay technique of SWAT project was set up including the major components such as Automatic watershed delineation, HRU analysis and report writing, creation of various input tables, editing of input tables and saving SWAT simulation, SWAT run and finally SWAT calibration was done.

To determine the rainfall variability and daily surface flows, SWAT model is used to establish the hydrological characteristics of the study area, the SWAT Outputs are then subjected to statistically analysis and interpretation including correlation and linear regression to establish the extent to which rainfall variability impacts on river volume flows in Homa Bay County. The basin characteristics are then determined in terms of water yield.

3. Results and Discussion

3.1 Rainfall and daily river volume flows

It is evident that irregularity in temporal rainfall trend exists throughout the period 1986-2012 with 2004 and 2009 having the lowest annual flows recorded (figure 5). The general flow within the sub basin depicts a relationship between the Riana river flow and rainfall trends as shown in figure 5.

The months of February and April experiences high rate of both the surface flow and water yield despite the rainfall amount being low. This is attributed to the fact that River Awach, River Tende and River Riana are permanent rivers and all originate from the Kisii highlands that receive relief rainfall in most months of the year. The offset of the main rainy seasons is from mid-March to early April and continues to the month of June, however, there is no marked end of the rainy season. Land use / land cover affects water availability and distribution in the study area across all the sub basins. The percentage of available water is found to be higher in area covered by agricultural land close grown and agricultural land generic. However, water stress is approximately higher in the residential mid low settlement, Range-bush (RNGB) and in the Forest deciduous (FRSD) across the region which could be attributed to climate variability.

Surface water resource availability is impacted by the hydrological cycle which is also affected by climate variability (Oki & Kane 2006). The major components of the hydrological cycle which affect the water resources include river discharge and rainfall which were also analysed in this study due to their role in availability and replenishment of water resources (Masihet et al., 2011). The river discharge in the study area indicates a seasonal and inter annual variability. High discharge in Kibuon, Tende and Riana rivers was witnessed in March, April and May. This can be attributed to high amount of rainfall during that period. Low discharge on the other hand is experienced in the months of October, November and December.

In all the sub basins the daily river discharge has a strong relationship with the water output, and using rainfall and discharge data is appropriate in establishing the relationship that exist between climate variability and water resources.

3.2 Relationship between Rainfall totals, Mean Temperature and availability of Surface Water Resources

Homa Bay experiences a bimodal rainfall pattern similar to most parts of eastern Africa with more interannual variability from October to December (UNEP, 2000). Variability in rainfall influences the availability and distribution of surface water resources in Homa Bay and the fluctuating surface water availability and distribution in terms of river flows. Increased temperature has positive influence on rainfall and evapotranspiration thus affecting river discharge and distribution of surface water resources.

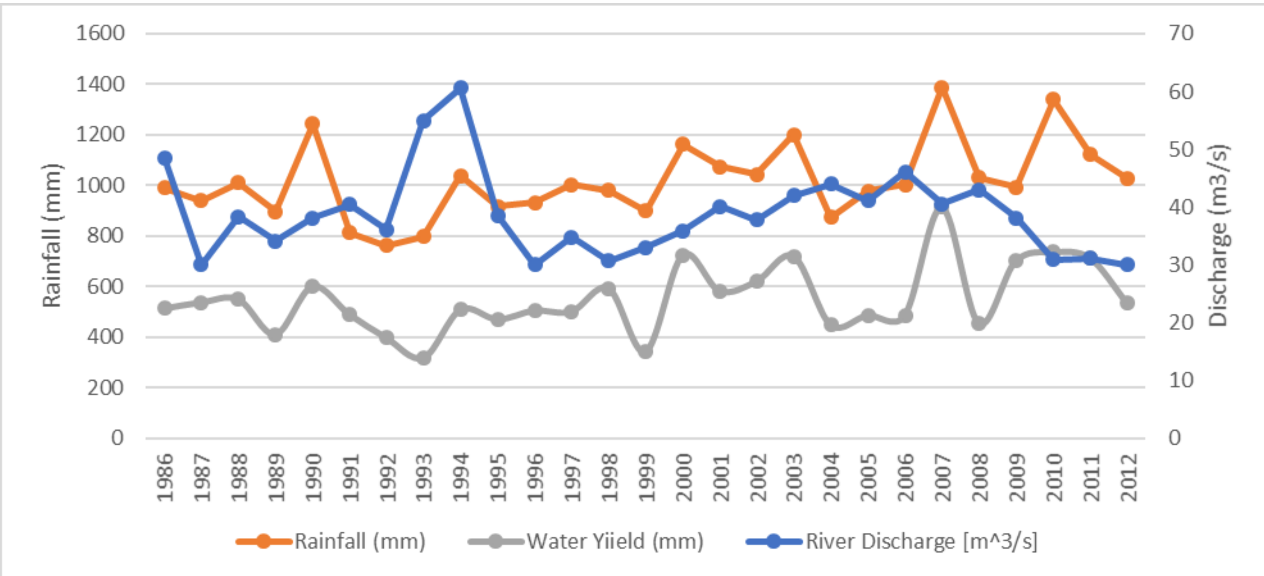

Figure 5: Rainfall and Water Yield at Riana River
Source: Author (2018)

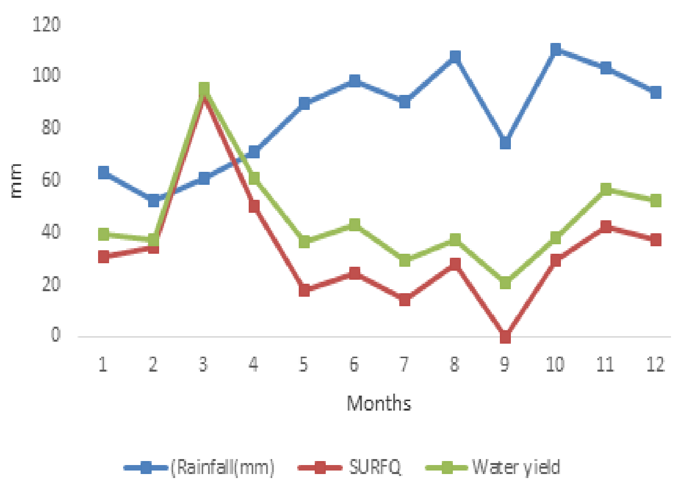

Figure 6: Basin values for Rainfall, SURFQ and Water Yield

Source: Author (2018)

This concurs with the study by Kumar et al. (2006) who indicated that the unpredictable nature connected with rainfall and temperature are vital components of the atmospheric systems which impact on water availability through alteration in water storage, evaporation and run -off.

Rising temperature increases evapotranspiration leading to a decline in soil moisture and water resources in areas such as Sindo, Mbita and Magunga. The monthly average rate of evapotranspiration in the study area depends on the trends in rainfall, evapotranspiration rate which also increases with decreasing river discharges.

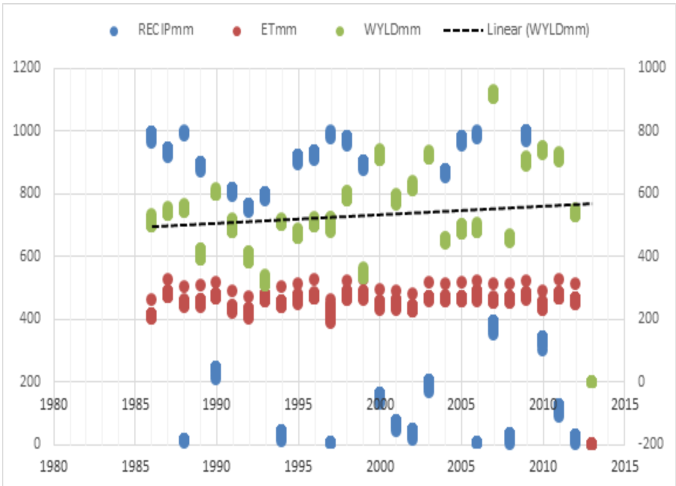

Figure 7: Rainfall, Temperature and Water Yield
Source: Author (2018)
PREC (mm) - Precipitation
ET (mm) -Evapotranspiration
WYLD (mm) - Water yield

Table 3: Statistical Correlation for Rainfall, Evapotranspiration and Water Yield

	Rainfall (mm)	Water Yield (mm)	ET (mm)
Rainfall (mm)	1	.898**	.781**
Water Yield (mm)	.898**	1	.610**
ET(mm)	.781**	.610**	1

**. Correlation is significant at the 0.05

Source: Author (2018)

Table 4: Regression for Rainfall, Evapotranspiration and Water Yield

***. Significance at the 0.05*

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	-7.768	9.778		-.794	.427
Rainfall (mm)	.749	.013	1.082	58.808	.000**
ET (mm)	-.445	.035	-.236	-12.812	.000**

Source: Author (2018)

In the month of March, the rainfall amount is low with increased water yield due to low evapotranspiration rates. This implies that the water levels in the aquifers drains into the wells leading to high water yields. The month of June is associated with high rainfall, high evapotranspiration and high potential evapotranspiration with low water yield. A lot of water is lost into the atmosphere through evapotranspiration. Other factors affecting water yield include geology, soil moisture, soil chemical composition and winds and this compares well with studies by Tao et al. (2011) that the major climatic factor that determine the availability of water include rainfall, temperature and evaporation which is influenced by average radiation, wind speed and humidity in the atmosphere.

The results of rainfall and temperature assessment conducted indicates that a significant relationship exists between climate variability and water yield (table 3 & table 4) which is being influenced by spatial and temporal variability in rainfall, temperature and River discharge Conditions within the study area in the period 1980 to 2015 (figure 7).

3.3 Rainfall and Surface Water conditions in Homa Bay County.

Homa Bay County exhibits quite high variability in monthly and annual rainfall especially in Kibuon, Tende and Riana basins. Rainfall amount varied from a low of 800mm to 1400mm per annum (pa) in most stations. The variability manifests itself in terms of fluctuating rainfall totals that causes fluctuations in river discharges and surface flows. This impacts surface water availability, distribution and quantity of Water Yield. The inter- annual and seasonal climate variability causes fluctuations in water resources temporally and spatially in terms of availability, distribution and eventual water yield. The variability in the total amounts of rainfall and temperature has a significant influence on the availability and distribution of water Yield within 0.89 as coefficient of correlation between rainfall and water yield, and 0.61 between water yield and evapotranspiration within the period 1983 to 2013. The fluctuating rainfall trends in the study area creates the seasonality of streams and some rivers. This causes water stress for domestic, agricultural, urban and industrial uses. Within the study area rainfall and temperature plays a major role in impacting on surface water yield hence needs to be addressed since climate friendly policies and mitigation strategies would help improve the water sector and the general economy.

The analysis of impacts helps in recommending for water conservation strategies, groundwater basin recharge, inter-basin water transfer from high to low potential zones, better soil and water conservation strategies, and controlling the use of products contributing to global warming in the region.

4. Conclusions and Recommendations

The SWAT model is an effective tool to simulate the hydrological conditions of an area. This involves the use of different data sets including the DEM, Soil map, Land use land cover map, Climate data and the in-situ measurements. This study adopted the SWAT model in establishing the link between climate variability and the distribution of surface water resources. The study concludes that rainfall in the Lake Victoria basin exhibits variability which impacts the Riana river discharge and availability of surface water resources in Homa Bay. Temperature influences precipitation and evapotranspiration and therefore has a bearing on surface water resources in Homa Bay. Climate driven fluctuations in surface water availability within Homa Bay county affects the sectors of the economy that depend on water resources. This study provides insight into the spatial and temporal characteristics of rainfall in Homa Bay County and its relationship with river Riana discharge which affects the availability, distribution and quantity of water resources in Homa Bay County. These findings will be useful in management of water resources within Homa Bay County and also aid in planning based on rainfall forecasts to avert water crisis scenarios in the county.

References

Ang'u C., Muthama N. J., Mutai B. K. (2016). Aerosol optical depth patterns associated with urbanization and weather in Nairobi and Lamu. J. Meteorol. Related. Sci. vol 8 pg26-40 http://dx.doi.org/10.20987/jmrs.2016.02.803

Gleick, P. H. (1998). Water in crisis: paths to sustainable water use. Ecological applications, 8(3), 571-579.

Gleick, (2000). Potential consequences of climate variability and change.

Gleick, P.H., (1999). The World's Water: The Biennial Report on Freshwater Resources 1998-1999. Island Press, San Francisco Global Policy Forum. (2009) Shrinking of Lake Chad.

Hulme, M. (1990). Rainfall changes in Africa: 1931–1960 to 1961–1990. International Journal Of Climatology.

IPCC (1997). IPCC Adaptation Experts' Meeting Report. Amsterdam, the Netherlands, 20-22 March 1997IPCC (2013). Approved summary for policymakers. IPCC AR4, WG2 Fresh water resources and management.

IPCC (1996). Climate Change 1995: The Science of Climate Change. Cambridge University Press, Cambridge.

Kumar, K. Rupa, A. K. Sahai, K. Krishna Kumar, S. K. Patwardhan, P. K. Mishra, J. V. Revadekar, K. Kamala, and G. B. Pant (2006). "High-resolution climate change scenarios for India for the 21st century." Current science

Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Doll, P., Kabat, P., Jimenez, B., ... & Shiklomanov, I. (2007). Freshwater resources and their management.

Kundzewicz, Szwed, M., Karg, G., Pińskwar, I., Radziejewski, M., Graczyk, D. and Kędziora, A. (2008). Climate change and its effect on agriculture, water resources and human health sectors in Poland

Mukabana, JR., Piekle, RA. (1996). investigating the influence of synoptic-scale monsoonal winds and mesoscale circulations on diurnal weather patterns over Kenya using a meso scale numerical model. Mon Wea Rev. 124:224–244

Mutai, CC., Ward, M.N, Colman, A.W. (1998). Towards the prediction of the East African short rains based on sea-surface temperature-atmosphere coupling. Int J Clim. 18:975 –997

Nicholson SE, Yin X (2002) Mesoscale patterns of rainfall, cloudiness and evaporation over the Great Lakes of East Africa. In: Johnson TC, Odada EO (eds) The limnology, climatology and palaeoclimatology of East African Lakes. Kluwer, Dordrecht, the Netherlands.

Ogallo, L. (1988) Relationships between seasonal rainfall in East Africa and the Southern Oscillation. Journal of Climatology, 8:31–43.

Ogallo, L. (1998). The spatial and temporal patterns of the East African seasonal rainfall derived from principal component analysis. International Journal of Climatology 9:145–167

Ominde, S. H., & Juma, C. (1991). A change in the weather: African perspectives on climatic change (No. 1). ACTS Press, African Centre for Technology Studies.

Tao, H., Gemmer, M., Bai, Y., Su, B. and Mao, W. (2011). Trends of streamflow in the Tarim River Basin during the past 50 years: Human impact or climate change Journal of hydrology

UNDP (2006). Beyond Scarcity: Power, Poverty, and the Global Water Crisis. Human Development Report 2006. United Nations Development Program, New York.