Journal of Environmental Science and Engineering B 7 (2018) 18-27
doi:10.17265/2162-5263/2018.01.003

DAVID PUBLISHING

Quantity and Trends in Streamflows of the Malewa River Basin, Kenya

Musa Cheruiyot[1], Gladys Gathuru[2] and James Koske[3]

1. WWF Regional Office for Africa, Nairobi 62440-00200, Kenya

2. Department of Environmental Sciences, Kenyatta University, Nairobi 43844-00100, Kenya

3. Department of Environmental Education, Kenyatta University, Nairobi 43844-00100, Kenya

Abstract: Freshwater availability in sufficient quantity and quality is necessary for both people and nature. Environmental flow data is useful in the management and allocation of water resources. This study aimed at quantifying stream flows and their trends in the Malewa Basin rivers in central rift valley, Kenya. Daily stream flow data (1960-2013) in four gauges (2GB01, 2GB05, 2GB0708 and 2GC04) were subjected to exploratory data analysis, fixed interval method of baseflow separation and Mann Kendall trend test. The results shows that on average, the Malewa river at Gauge 2GB01 discharge (excluding abstractions) about 191.2 million cubic metres of water annually, equivalent to a discharge of 6.06 m^3/s. While discharges had not experienced a step change, huge annual fluctuations were noted suggesting periodicity with changes in climatic conditions. No trend was noted in annual stream data for the four gauges assessed. However, extreme low and high flows, median flows and baseflows for daily data showed either positive or negative trends. The baseflow index for daily flows showed trends: 2GB01 (Z = 4.519), 2GB05 (Z = -6.861), 2GB0708 (Z = -16.326) and 2GC04 (Z = 5.593). The findings suggest that Malewa rivers are likely experiencing effects of extreme climatic conditions and land cover changes. Land cover degradation seems to create conditions of increased flow, although the intensity varies from sub-catchment to another. The data also seems to suggest that stream discharge is much dependent on baseflows. There is need to regulate water use, improve soil cover and manage or adapt to the adverse effects of climate change.

Key words: Streamflow, baseflow, trend, discharge.

1. Introduction

Freshwater availability in sufficient quantity and quality is necessary for both people and nature. The concept of environmental flows has been the subject of study and consideration [1-5]. Environmental flow information guides on how water is managed and allocated to different competing uses. The need for improved water efficiency in the allocation has led to increasing focus on environmental flows or environmental water allocations [6], although national and international policies have not yet accounted for them [7]. Streamflow volumes and trends are important for decision making on water allocation. As reported by Kundzewicz, W. Z., et al. [8], changes in streamflow may occur gradually (a trend) or abruptly (a step change), and this may affect any aspect of the data in question [9].

Environmental flow assessments are conducted using different methods. According to Dyson, M., et al. [2], this may conveniently be grouped into four categories, namely hydrological rules, hydraulic rating methods, habitat simulation methods and holistic methodologies [10]. The Service Provision Index is an example of an environmental assessment approach that links environmental flows, ecosystem services and economic values [11]. This study aimed at quantifying stream flows and trends of the Malewa Rivers in central rift valley, Kenya. Such information was deemed useful in informing the allocation and management of competing water uses and also in the planning for restoration and or management of the water deficit.

Corresponding author: Musa Cheruiyot, MSc, research fields: environmental flows and landscape restoration.

2. Material and Methods

2.1 Study Area

The Malewa river basin (1,760 km^2) (Fig. 1) is located in the larger Naivasha basin within Nakuru and Nyandarua counties of the eastern Africa (Gregory) Rift valley, Kenya. Located at 36°05' E-36°42' E longitudes and 00°07' S-00°45' S latitude, it is administratively bordered by Nyeri and Muranga counties on the east. East of the study area is the Aberdares Mountains and Kinangop plateau. The topography of the study area ranges from about 1,900-3,990 m above mean sea level [12]. Soil types have been influenced by the topographical variation, volcanicity and geology [13]. The soils are predominantly of lacustrine, volcanic and lacustrine-volcanic origins [14, 15].

The area is positioned within a semi-arid type of climate, with a bimodal rainfall distribution. It is characterized by longer rainy season (March-May) and short rainy season (October-November), with February, July and December being the driest months [16]. Annual rainfall ranges between 600-1,700 mm, with the Kinangop plateau experiencing 1,000-1,300 mm [17]. Rainfall in the upper catchment exceeds potential evaporation in most parts of the year [18]. The mean annual temperature ranges from 16 ^oC to 25 ^oC and daily range from 5 ^oC to 25 ^oC [19].

Lake Naivasha (145 km^2) is drained by two main rivers: Malewa and Gilgil. The Malewa river with a dendritic drainage system has four streams, namely the Turasha, Kitiri, Mugutyu and Makungi. Its annual flow is estimated at 153 MCM (Million Cubic Metres) [20].

Agriculture, grassland, bush/scrub land and forest are the major land cover types [21]. The upper catchment (the Nyandarua range) is dominated by forests and cropland, the lower end by livestock grazing [22].

2.2 Data

Using ArcGIS 10.3.1, a 30 m by 30 m resolution Digital Elevation Model for Kenya projected into UTM (Universal Traverse Mercator) Zone 37 was used to delineate the drainage basin and stream network. After basin delineation, the study area was sub-divided into three sub-catchments, namely Turasha (Sub-catchment I), Upper Malewa (Sub-catchment II) and Lower Malewa (Sub-catchment III). Daily stream discharge data for the years 1960-2013 in four gauge stations i.e. 2GB01, 2GB05, 2GB0708 and 2GC04 (Fig. 2) was sourced from the Water Resources Management Authority.

2.3 Exploratory Data Analysis

Stream data for the four gauge stations were analyzed for volumes and trends in daily and annual flows. Using Microsoft Excel®, EDA (Exploratory Data Analysis) was done to estimate stream volumes and visualize trends in data. Using EDA, annual total flow, median flow (50th percentile) and daily flow (90th, 95th, 25th, 10th and 5th percentiles) were generated [9].

2.4 Baseflow Separation

Baseflows were established using the fixed interval method of baseflow separation. In this method, the lowest discharge in each interval (N) was assigned to all days in that interval by starting with the day of the period of record. After this, the bar is moved one interval (2N* days) horizontally and thereafter the process is repeated. Assigned values were connected to define the base-flow hydrograph [23]. This method was applied using BFI+3.0 program (a base-flow index calculation programme) developed based on Tallaksen, L. M. and van Lanen, H. A. J. [24] among others [25].

2.5 Mann Kendall Trend Tests

Using Microsoft Excel® based add-in XLSTAT statistical analytical software, MK (Mann Kendall) tests [26-28] were performed on annual and daily streamflow data to detect trends. Baseflow and baseflow index for the four gauge stations was also subjected to MK test to establish trends.

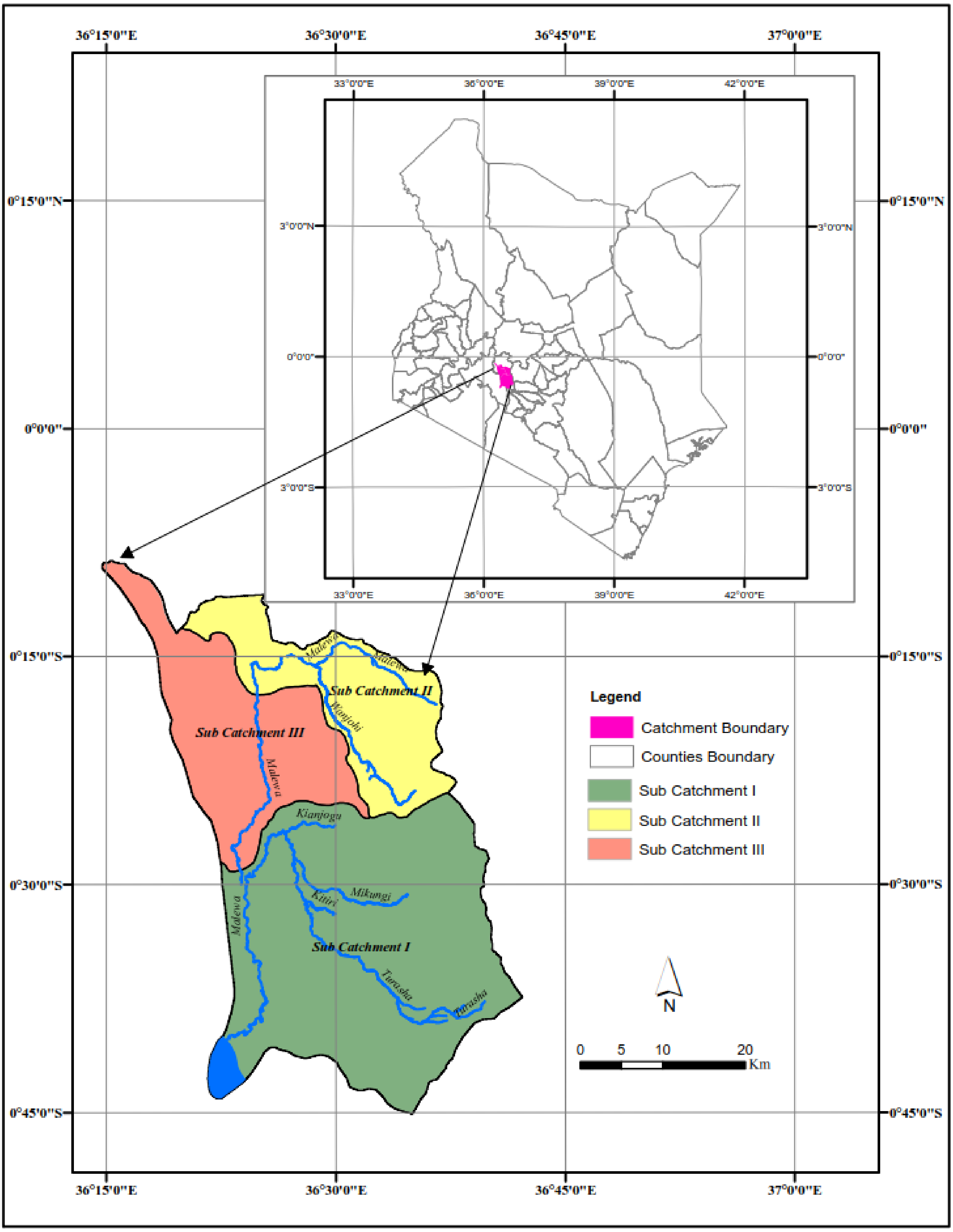

Fig. 1 Area of study.

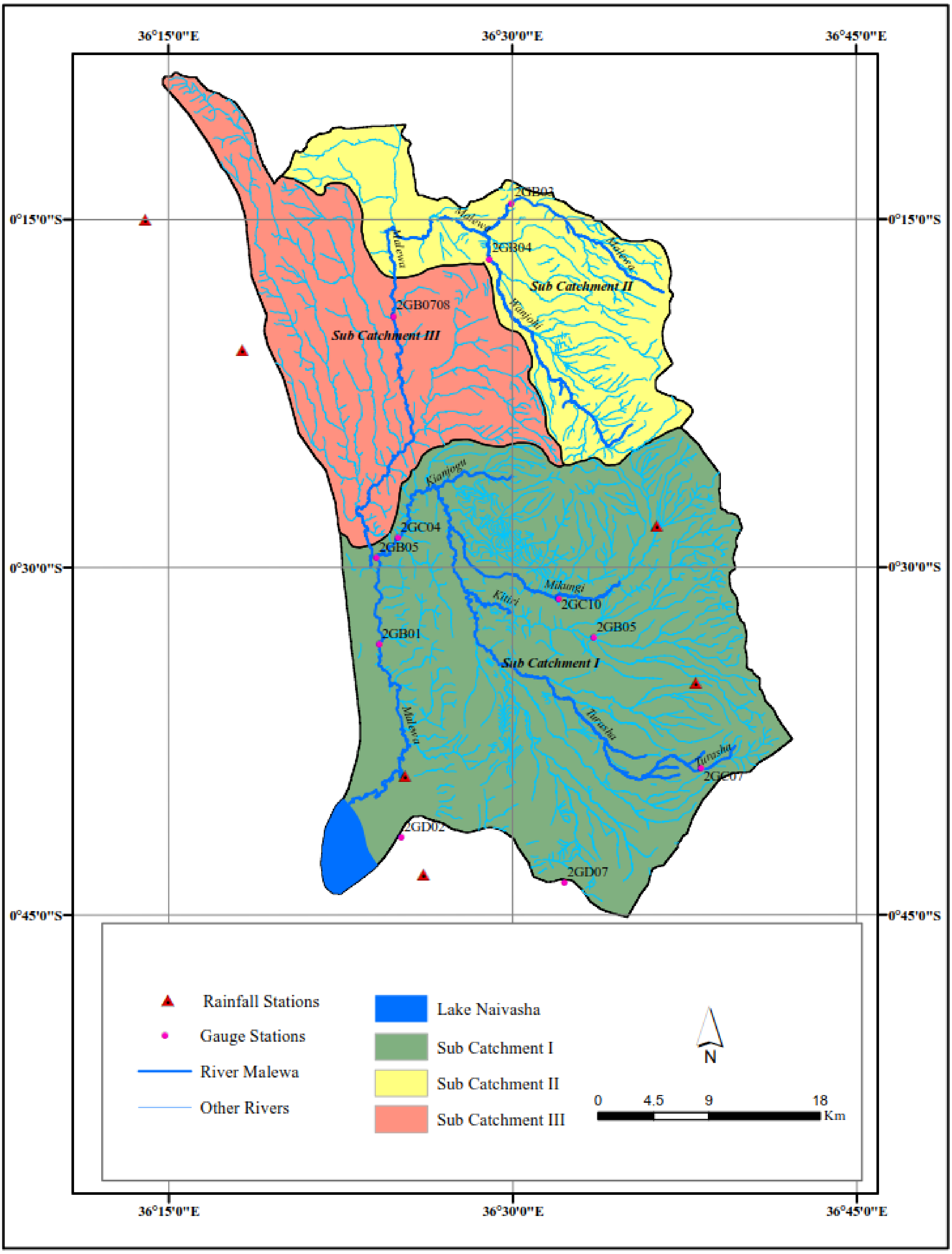

Fig. 2 Location of gauge stations.

3. Results

3.1 Trends in Daily and Annual Stream Discharges

The results show that on average the Malewa river at gauge 2GB01 discharges (excluding abstractions) about 191 MCM of water annually. This is equivalent to a discharge of 6.06 m^3/s. There were wide variations in minimum and maximum diurnal and annual flows recorded in all the four gauges. The daily and annual stream volumes and trends for the four gauges stations (1960-2013) are shown below (Table 1). The fluctuations in annual total flows for the four gauges are shown in Fig. 3.

Trends in streamflow (Q) level of the four gauge stations are shown in Table 2. The MK tests on annual streamflows (annual totals) for all the four gauge stations indicates no trend. All the four gauges except 2GB01 indicated trends in daily stream discharge. At 2GB01, the Z scores showed an increasing trend in streamflow at Q5, Q10, Q25, Q50, Q75, Q90 and Q95 levels. At Gauge 2GB05, trend was observed for daily discharge for all levels of flow examined. Increasing trend was observed for daily discharge values at Q10, Q25, Q75, Q90 and Q95. However, decreasing trends were observed at Q5 and Q50. At Gauge 2GB0708, trends was noted for all levels of daily flows except Q90. In this station, except for daily values, Q5 and Q95 indicating decreasing trends, all other levels showed increasing trends. No trend was observed for Q5, Q10, Q25 and Q75 at Gauge 2GC04. All the remaining levels (daily values, Q50, Q90 and Q95) showed increasing trends in streamflows.

Table 1 Daily (m^3/s) and annual (MCM) discharges at four gauge stations of Malewa rivers.

Gauge	Mean		Minimum		Maximum		SD	
	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual
2GB01	6.06	191.25	0.34	53.11	139.17	358.64	7.12	74.7
2GB05	3.37	106.37	0.25	28.63	115.42	235.68	5.58	47.04
2GB0708	2.25	70.89	0.00	7.55	144.35	186.06	6.10	45.62
2GC04	4.77	150.41	0.00	38.94	136.72	352.98	8.04	67.17

Daily data in m^3/s; Annual data in MCM.

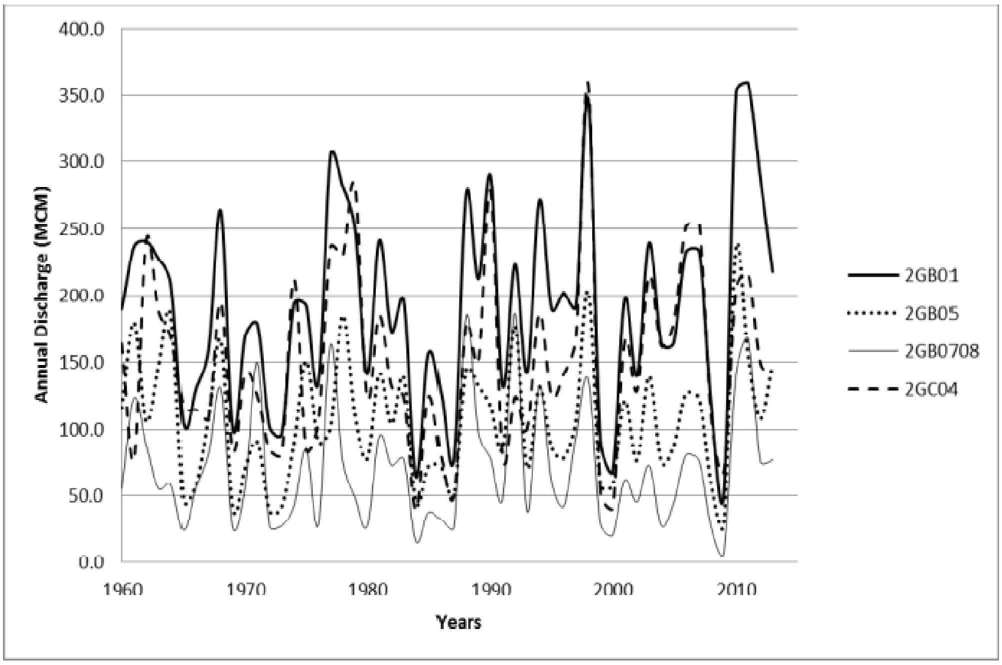

Fig. 3 Fluctuations in annual streamflows in four gauge stations of the Malewa rivers.

Table 2 Trends in streamflow characteristics of the gauge stations.

Q Metrics	2GB01	2GB05	2GB0708	2GC04
Annual totals	0.776 (0.438)	0.254 (0.800)	0.164 (0.870)	0.851 (0.395)
Daily discharge	-0.586 (0.558)	9.588 (< 0.0001)	-18.903 (< 0.0001)	2.318 (0.02)
Q5	2.924 (0.003)	-2.518 (0.012)	-2.376 (0.017)	0.912 (0.362)
Q10	3.781 (< 0.0001)	7.465 (< 0.0001)	2.064 (0.039)	1.176 (0.239)
Q25	5.978 (< 0.0001)	7.465 (< 0.0001)	6.619 (< 0.0001)	0.896 (0.37)
Q50	8.394 (< 0.0001)	-3.57 (< 0.0001)	7.831 (< 0.0001)	2.35 (0.019)
Q75	5.467 (< 0.0001)	4.636 (< 0.0001)	11.616 (< 0.0001)	0.342 (0.732)
Q90	4.234 (< 0.0001)	4.382 (< 0.0001)	0.188 (0.851)	2.116 (0.034)
Q95	4.166 (< 0.0001)	6.683 (< 0.0001)	-7.623 (< 0.0001)	2.495 (0.013)

Z-scores and *p*-values (brackets) in bold are significant at 0.05 level.

3.2 Trends in Daily and Annual Baseflows

The mean annual baseflows (MCM) of the four stations (1960-2013) were: 149.67 (2GB01), 72.38 (2GB05), 43.07 (2GB0708) and 100.47 (2GC04). The data also show wide fluctuations in diurnal and annual streamflows. The mean daily and annual baseflows are shown in Table 3.

As shown in Fig. 4, annual baseflows in the four gauge stations examined highly fluctuated over the last 43 years. There were no trends on daily baseflows for Gauge 2GB01 (Z = 1.113, p = 0.266). However, Gauges 2GB05 (Z = 13.903), 2GB0708 (Z = -16.326) and 2GC04 (Z = 6.368) showed increasing trends. Fig. 5 shows the BFI (Baseflow Index) fluctuations in the four gauge stations. The BFI for Gauge 2GB01 ranged between 0.76 and 0.90 (Mean = 0.85, SD = 0.03); 0.74 and 0.99 (Mean = 0.86, SD = 0.05) in Gauge 2GB05; and 0.74 to 0.92 (Mean = 0.82, SD = 0.04) in 2GB0708. Gauge 2GC04 had a BFI range of 0.68 to 0.84 (Mean = 0.79, SD = 0.03). All the four gauge stations show trends in BFI: 2GB01 (Z = 4.519), 2GB05 (Z = -6.861), 2GB0708 (Z = -16.326) and 2GC04 (Z = 5.593).

4. Discussions

It is evident that there have been huge annual fluctuations in streamflow. The fluctuations seem to suggest periodicity: a decrease in annual flows coincide with dry periods recorded such as that of 1965, 1969, 1973, 1984, 2000 and 2009. It is also indicative of extreme flows during the wet years of 1961, 1968, 1977, 1988, 1990, 1994, 1998 and 2010-2011. As such climatic variability seems to play an important role in the annual discharges. These fluctuations likely impacted decreased flow regime and increased scarcity of water during dry conditions; and intense rains and subsequent floods particularly in the absence of adequate vegetation cover.

Table 2 showed diversity in trends reflected as positive or negative changes. Overall, as shown in Gauge 2GB01, there seems to be no major changes in streamflow regarding both annual and daily total discharges. However, the data seems to suggest an overall increase in streamflow at low (Q75-Q95), median (Q50) and high flow (Q5-Q25) metrics of the watershed. The fewer the number of days in a year with greater flows recorded, the lesser the magnitude of positive stream flow trends. In the contrary, the more the number of days in a year with greater flows, the greater the magnitude of streamflow trends. However, median flows demonstrated higher magnitude of streamflow changes. Gauges 2GB05 and 2GB0708

Table 3 Daily and annual baseflows in the four gauge stations.

Gauge	Mean		Minimum		Maximum		SD	
	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual
2GB01	4.75	149.67	1.37	43.32	8.68	273.81	1.80	56.88
2GB05	2.30	72.38	0.82	25.85	4.91	154.90	0.94	29.53
2GB0708	1.37	43.07	0.18	5.69	4.69	147.76	0.85	26.80
2GC04	3.19	100.47	0.94	29.56	8.03	253.22	1.43	45.24

Daily data in m^3/s; Annual data in MCM.

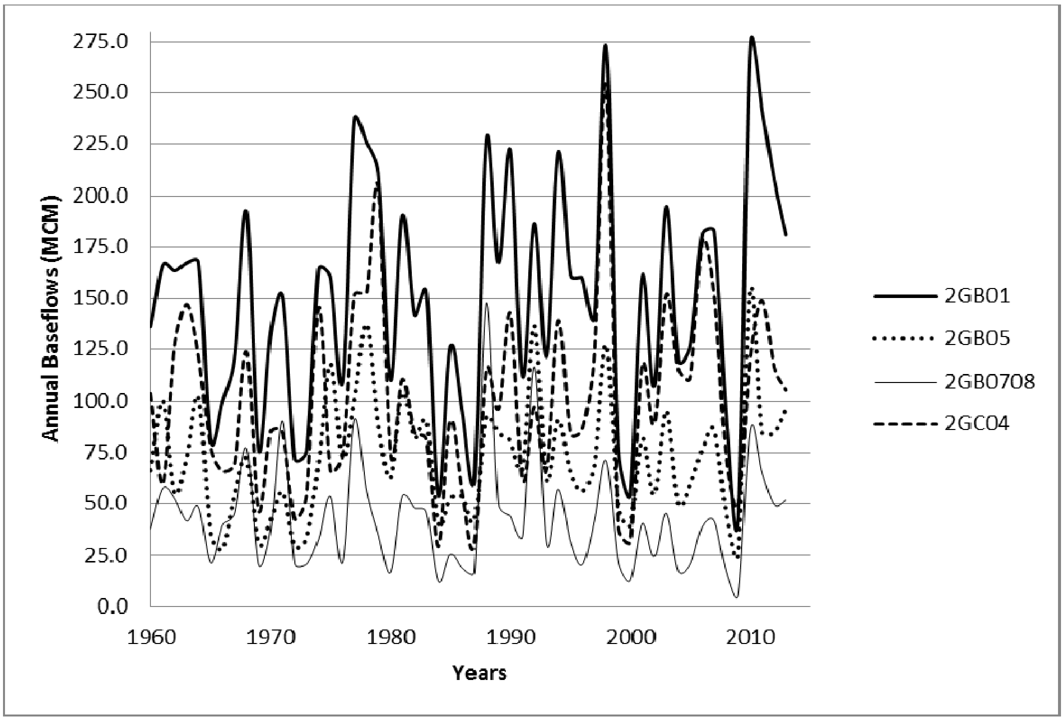

Fig. 4 Fluctuation in annual baseflows in four gauges of the Malewa rivers.

demonstrated a lot of diversity in either increasing or decreasing trend, while 2GC04 were either increasing or no trend at all. While 2GB05 and 2GC04 generally had an increase in daily streamflow, 2GB0708 had fluctuated changes in streamflow, with a positive change in Q10 to Q75. While no evidence exists to suggest a step change in discharge, the trends observed in all the four gauge stations but at different Q levels suggest that the Malewa rivers are experiencing effects of extreme climatic conditions and land cover change. These findings seem to suggest that degradation in land cover appears to create conditions of increased flow, although the intensity varies from sub-catchment to another. A big change in flow at 2GB0708 is difficult to interpret, although this may be due to inter-basin water transfer.

The contribution of annual baseflows to streamflow: 2GB01 (78%), 2GB05 (68%), 2GB0708 (61%) and 2GC04 (67%) seems to suggest that stream discharge for this area is much dependent on baseflows. The evidence that about 78% of the discharges are attributed to baseflows in 2GB01 shows that the hydrological regime is much dependent on ground water systems. Baseflow matched very well with stream flows as the results shows that no changes are happening at 2GB01 yet increases were observed at 2GB05 and 2GC04, while a decline was noted in 2GB0708. It is likely that water abstraction is a key factor experienced at the lower catchment where 2GB01 situates. Inter-basin water transfer could be

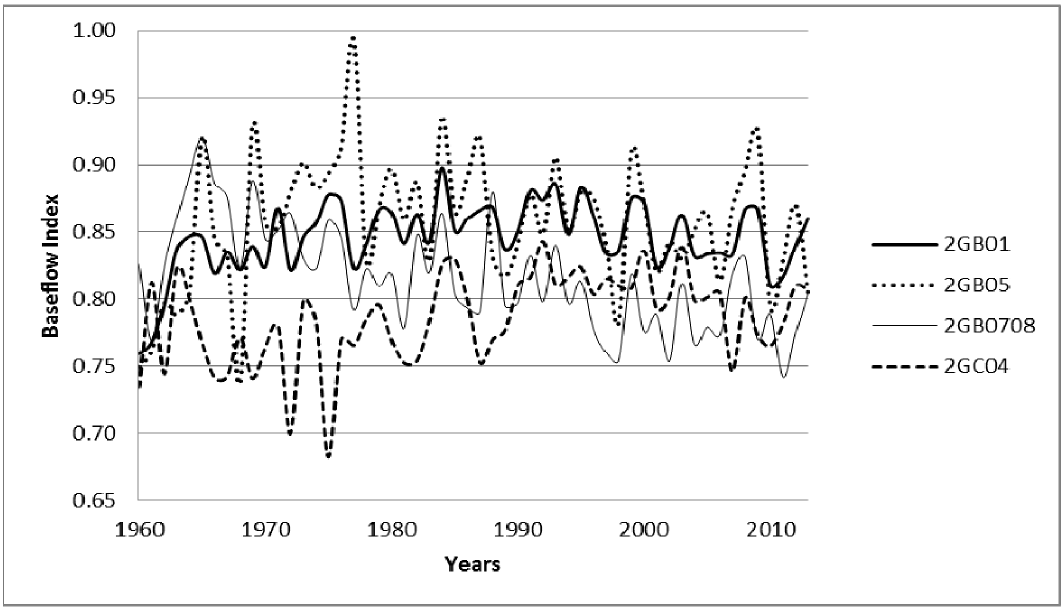

Fig. 5 Trends in baseflow index in the four gauge stations.

influencing reporting of decline at 2GB0708. Increased infiltration at 2GB05 and 2GC04 due to improved ground cover are likely factors driving enhanced baseflows. This is supported by BFI data showing increasing trends (2GB01 and 2GC04) and decreasing trends (2GB05 and 2GB0708).

As reported by Becht, R., et al. [29], the surface water inflow for the entire Malewa basin was 217 MCM over the period 1932-1997. The authors suggest that permits for river abstraction may have influenced the reported inflow. This is because the total permitted abstraction was then about 17% of the estimated surface inflows into the lake. As such, without abstraction, the Malewa inflow is much higher than reported. The findings from this study slightly differs from that reported by Everard, M., et al. [30] of an annual (153 MCM/year) and daily (4.84 m^3/s). However, as indicated by Åse, L. E., [31] and Becht, R., et al. [29], this varies from one study to another depending on the time period considered [32]. As regards trends, Kyambia, M. M., et al. [12] have reported significant increase in annual maxima at Gauges 2GB01, 2GB05, 2GB04 and 2GC04. The annual Q95 at 2GB01 and 2GB05 had increasing flows while a decrease was observed for annual Q90 and Q97 at 2GB04 and 2GC04 respectively. As such, this variation points to climate change realities in terms of increased intensity and frequency of flows and the need to respond through different adaptation actions. These findings are similar to one reported by this study, although the unit of analysis differs.

An increase in streamflow is usually attributed to rainfall. In the Mississippi river, an increase (1940 to 2003) in flow was caused by increased baseflow attributed to land use change driven by soybean cultivation. A conversion of perennial vegetation to seasonal row crops and accompanying agricultural activities decreased evapotranspiration and surface runoff, and increased groundwater recharge, baseflow, and thus streamflow [33]. Increase in winter baseflows in the Tahe River and Duobukuer River watersheds of north-eastern China may be due to enhanced groundwater storage and winter groundwater discharge caused by permafrost thaw. It could also be due to an increase in the wet season rainfall [34].

5. Conclusions

This study has established that the Malewa rivers are experiencing fluctuations in streamflows over the years. While no step change was detected, nor trend at the outlet, there are significant fluctuations in annual streamflows and baseflows suggesting periodicity. Daily discharge and baseflow index have shown trends, both positive and negative in flows. It is suggested that the Malewa rivers are likely experiencing effects of extreme climatic conditions and land cover changes. Land cover degradation seems to create conditions of increased flow, with varied intensities per locality. In addition to the effects of climate and land cover change, water abstraction, inter-basin water transfer and increased infiltration are likely reasons for fluctuating flows in discharge and baseflow. Stream discharge is much dependent on baseflows suggesting the influence of infiltration. These fluctuations likely impacted on decreased flow regime and increased scarcity of water during dry conditions; and intense rains and subsequent floods in the absence of adequate vegetation cover. This study has provided evidence of increasing and decreasing trends in extreme and median flow metrics. There is thus need to regulate water use, improve soil cover and manage or adapt to the adverse effects of climate change.

Acknowledgements

Authors would like to sincerely thank the Water Resources Management Authority for providing secondary streamflow data. Many thanks go to Messrs. Joseph Munyao and Dominic Wambua of the Water Resource Management Authority, and also Zachary Maritim and Reuben Soy for their help in the map production. Authors are also much grateful to Messrs. Daniel Koros and Peter Muigai for their logistical assistance in the field.

References

[1] Poff, N. L., Allan, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B. D., et al. 1997. "The Natural Flow Regime: A Paradigm for River Conservation and Restoration." *BioScience* 47 (11): 769-84. Accessed November 16, 2011. http://wec.ufl.edu/floridarivers/.

[2] Dyson, M., Bergkamp, G., and Scanlon, J. 2003. *Flow: The Essentials of Environmental Flows. Gland, Switzerland and Cambridge.* UK: IUCN.

[3] Arthington, A. H., and Pusey, B. J. 2003. "Flow Restoration and Protection in Australian Rivers." *River Research and Applications* 19: 377-95. doi:10.1002/rra.745.

[4] Brisbane Declaration. 2007. "Environmental Flows are Essential for Freshwater Ecosystem Health and Human Well-Being." In *Proceedings of the 10th International River Symposium and International Environmental Flows Conference, Brisbane*.

[5] Hirji, R., and Davis, R. 2009. *Environmental Flows in Water Resources Policies, Plans and Projects. Findings and Recommendations.* Washington DC: The International Bank for Reconstruction and Development/The World Bank. Accessed October 26, 2011. https://openknowledge.worldbank.org/bitstream/.

[6] Environmental Flows. Environmental Perspectives on River Basin Management. 2006. "Special Issue: Developing a Global Environmental Flows Network." *Newsletter* 3 (1): 4.

[7] Durrete, M. 2008. "Defining Environmental Flows for Sustainable Water Management. Knowledge Notes". Accessed April 28, 2017. https://www.scribd.com/document/.

[8] Kundzewicz, W. Z., Cecilia, S., and Thomas, M. 2004 *Trends in Flood and Low Flow Series.* Germany: Global Runoff Data Centre (GRDC).

[9] Jamaluddin, I. B. 2014. "Analysis of Trend in Hydrological System for Sungai Bernam Basin." Master thesis. University of Putra Malaysia.

[10] Arthington, A. H., Bunn, S. E., Poff, N. L., and Laiman, R. J. 2006. "The Challenge of Providing Environmental Flow Rules to Sustain River Ecosystems." *Ecological Applications* 16 (4): 1311-8.

[11] Korsgaard, L. 2006. "Environmental Flows in Integrated Water Resources Management: Linking Flows, Services and Values." Ph.D. thesis. Technical University of Denmark. Accessed October 26, 2011. http://citeseerx.ist.psu.edu/viewdoc/.

[12] Kyambia, M. M., and Mutua, B. M. 2014. "Analysis of Drought Effect on Annual Stream Flows of River Malewa in the Lake Naivasha Basin, Kenya." *International Journal of Current Research and Review* 6 (18): 1-6. Accessed December 17, 2016. https://www.ejmanager.com/mnstemps/45/45-1410974630.pdf.

[13] Sombroek, W. G., Braun, H. M., and van der Pouw, B. J. 1982. "The Explanatory Soil Map and Agro-climatic Zone Map of Kenya. Report No. EI. Scale 1:1,000,000." Nairobi: Kenya Soil Survey. Accessed December 15, 2016. https://library.wur.nl/isric/fulltext/.

[14] Girma, A., Rossiter, D. G., Siderius, W., and Henneman, I. R. 2001. *Soils of the Lake Naivasha Area, Kenya. Summary of investigations 1997-2000.* Technical Report for Soil Science Division, International Institute for Aerospace Survey & Earth Sciences (ITC). Accessed September 12, 2013. https://www.imarisha.le.ac.uk/sites/.

[15] Nagelhout, A. 2001. "Performance Analysis of Small Format Aerial Photography (SFAP) in Assessing Current Status and Trends in Wind Erosion: A Case Study in the Longonot-Kijabe Hill Area, Naivasha District, Kenya." Unpublished MSc thesis. Enschede, the Netherlands: ITC. Accessed April 28, 2017. https://ftp.itc.nl/pub/naivasha/ITC/Nagelhout2001.pdf.

[16] Kamoni, P. T. 1988. *Detailed Soil Survey of a Part of Quarantine Farm-National Husbandry Research Station, Naivasha, Nakuru District*. Nairobi: Kenya Soil Survey.

[17] Becht, R., Odada, O., and Higgins, S. 2005. "Managing Lakes and Their Basins for Sustainable Use: A Report for Lake Basin Managers and Stakeholders, International Lake Environment Committee Foundation." In *Lake Naivasha: Experience and Lessons Learned Brief.* ILEC. Kusatsu, Japan.

[18] Farah, H. O. 2001. "Estimation of Regional Evaporation under Different Weather Conditions from Satellite and Meteorological Data: A Case Study in the Naivasha Basin, Kenya." Unpublished PhD thesis. Wageningen University.

[19] Republic of Kenya. 2014. *Lake Naivasha Basin Integrated Management Plan 2012-2022*. Ministry of Environment, Water and Natural Resources.

[20] Arwa, D. O. 2001. "GIS Based Rainfall-Runoff Model for the Turasha Sub-Catchment Kenya." Masters thesis. International Institute for Geo-Information and Earth Science.

[21] Ogweno, L. O., Gathenya, J. M., and Home, P. G. 2010. "Impacts of Best Management Practices (BMPs) on Water Quantity and Quality of Malewa Basin." *JKUAT* 739-58.

[22] Muthawatta, P. L. 2004. "Long Term Rainfall-runoff-Lake Level Modeling of the Naivasha Basin, Kenya." Enschede, the Netherlands: ITC.

[23] Sloto, R., and Crouse, M. 1996. "HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis. Water Resources Investigation Report 96-4040." Lemoyne, Pennsylvania: US Geological Survey. Accessed March 23, 2016. https://water.usgs.gov/software/HYSEP/code/doc/hysep.pdf.

[24] Tallaksen, L. M., and van Lanen, H. A. J. eds. 2004. *Hydrological Drought: Processes and Estimation Methods for Streamflow and Groundwater*. Boston: Elsevier.

[25] Gregor, M. 2010. "BFI+ 3.0 User's Manual." HydroOffice. Accessed April 8, 2016. https://hydrooffice.org/.

[26] Mann, H. B. 1945. "Non-parametric Tests against Trend." *Econometrica* 13: 163-71.

[27] Kendall, M. G. 1975. *Rank Correlation Methods (4th ed.).* London: Charles Griffin.

[28] Gilbert, R. O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* New York: Wiley.

[29] Becht, R., and Harper, D. M. 2002. "Towards an Understanding of Human Impact upon the Hydrology of Lake Naivasha, Kenya." *Hydrobiologica* 488: 1-11.

[30] Everard, M., Vale, J. A., Harper, D. M., and Tarras-Wahlberg, H. 2002. "The Physical Attributes of Lake Naivasha Catchment Rivers." *Hydrobiologia* 488 (1-3): 13-25.

[31] Åse, L. E., Sernbo, K., and Syrén, P. 1986. "Studies of Lake Naivasha, Kenya and Its Drainage Area." Stockholm: University of Stockholm.

[32] Meins, F. M. 2013. "Evaluation of Spatial Scale Alternatives for Hydrological Modelling of the Lake Naivasha Basin, Kenya." Masters Thesis. University of Twente. Accessed July 24, 2014. https://www.imarisha.le.ac.uk/sites/.

[33] Zhang, Y. K., and Schilling, K. E. 2006. "Increasing Streamflow and Baseflow in Mississippi River since the 1940s: Effect of Land Use Change." *Journal of Hydrology* 324 (1-4): 412-22.

[34] Duan, L., Man, X., Kurylyk, B. L., and Cai, T. 2017. "Increasing Winter Baseflow in Response to Permafrost Thaw and Precipitation Regime Shifts in Northeastern China." *Water* 9 (1): 1-25. doi:10.3390/w9010025.