Response to Reviewer #1

Review comments on "Flow regime change in an Endorheic basin in Southern Ethiopia" by Worku et al.

Worku et al. used 29 indicators of hydrologic alteration (IHA), climate and land cover change to study the changes in the natural flow regime in the Omo Gibe basin in the Southern Ethiopia. This is an interesting and much required study for this basin. Similar studies are also required for other basins where in situ data are scarce or unavailable. The research presented in this study is very relevant to this journal. This study is well structured and well presented. However, I have few concerns on how results are analyzed and conclusions are drawn. Below is the list of comments and concerns that have to be addressed.

We would like to thank the reviewer for the compliment, as well as for the thorough review of the manuscript. We have considered each comment carefully and in this document provide our response to each. Reviewer's comments are included in bold for easy reference. Where we have made changes to the manuscript we have included the changed text in this document. These are marked in red. Line numbers indicating where the text has been changed refer to those in the original manuscript.

1. The major conclusion for this study is that dry season flows are increasing in the Omo-Gibe basin. Authors have analyzed stream flow trends from 12 stations and the results indicated that only 2 station show significant increasing trend (Table 3). How can authors conclude that overall trend in dry season flows are increasing when 10 out of 12 stations does not show significant increase in trend?

Authors' response:

We agree with the comment that when considering only the indicator of Dry Season Flow only two out of 12 stations showed a significant positive trend, making a conclusion on the increase of the indicator of "Dry Season Flow" difficult. However, there are multiple indicators that reflect on the magnitude of dry season flows. Table R1 below summarises the indicators that are relevant to the magnitude of low flows (dry season, 7-day minimum flow and BFI), showing also the number of stations with significant trend in each of the homogenous regions. This shows that there are regions that showed a more positive trend (region 1 and 4, both humid regions) and regions that did not show any trend (region 2 and 3).

We have revised the manuscript to make it clearer how we have reached our conclusion (page 1320 line 26).

Of the 17 indices considered, mainly those representing low flow magnitude, such as dry season flow, 7-day minimum flow, BFI and dry season FDC were found to show significantly positive trend, particularly in regions 1 and 4. Indices related to frequency of low flows in regions 1 and 4 also show a significantly decreasing trend, which reflects the increase in magnitude of low (dry season) flows.

Table R1: Number of stations showed significant positive trend at 5% significance test

Hydrological Indices	Region 1 (4 stations)	Region 4 (3 stations)	Region 2 (3 stations)	Region 3 (2 stations)

Dry season flow	1	1	0	0
7-day min. flow	2	2	1	0
BFI	2	2	0	1
FDC (Dry season)	3	2	0	2

2. It is hard to understand which stations are showing significant trend (by geographic location) and which stations are not. Can you identify stations with ids in Figure 1 and then discuss the results in trends so that readers can relate where significant trends are observed and how is the LCLU changing in those regions?

Authors' response:

We agree that it is not easy to interpret the geographic distribution of stations with positive/negative trends. We have included a map of the stations, with symbols showing the direction and the significance of the trend. As it is difficult to include symbols for all 17 indicators, we have grouped indicators showing trend in low flows and in high flows. We have included this as an additional figure, as Fig 1c. This has also been updated based on the following comment to indicate the availability of data at stations.

3. Authors indicate that they have used stream flow data from 32 gauging stations (shown in Figure 1) which have records ranging from 14 to 46 years. It is not clear, which station has how many years of data. It would benefit readers if you can show in Figure 1 by classifying gauging station in Figure 1 by different colours based on the number of years of data available.

Authors' response:

We have updated the map in figure 1 to show the stations with length of the available recorded data in the revised manuscript. The flow data of all stations in the basin are categorised as being available from the 1960s, 1980s and 1980s, with different icons used in the map for each category. In addition, the stations with good quality and (almost) gap free data that were used for the Natural flow regime analysis are denoted as NFR-stations (The updated figure is included in this response letter). We will edit Fig.1 in the revised manuscript.

4. Are the multi-year data (stream flow) from each station used in this study continuous without any data gaps? How did you handle if the data available was not continuous and has data gaps? How did you handle such situation while dealing trends?

Authors' response:

It is mentioned in the manuscript that there are 32 stations in the basin, but only some of these have a long data record. We used only 12 stations for the trend analysis that had good quality data with only few data missing. Where there was missing data in these, we used multiple regression to fill missing data by data from nearby station in the same homogenous region. We will clarify this in the revised manuscript as follows (page 1306):

We have analysed the quality of data for randomness, independence or persistence (autocorrelation) and consistency both for streamflow and rainfall. We used only those stations which satisfied these criteria and had data without or with only few gaps. Where there were small gaps we used multiple regression to fill missing data using stations from the same homogenous regions

5. Author indicated that ... "from each region the stations with the best data in terms of quality and record length in excess of 20 years were selected for characterizing the natural flow regime and variability. For most stations the period of record available spanned from about 1982 to 2008, with the exception of the stations at Abelti and Asendabo, where data was available from 1963 and 1967 respectively." The MK trends results would change based on the length of the data used. For example, MK trend result for a data (1982-2008) could show significant positive trend but may show a different trend when data with different time period/ length (1963-2008) is used. So, I am wondering if the time period for each station or length of the data is different, how we can inter compare trend results from one station to another.

Authors' response:

We agree that there may be an effect on the result due to the use of a different time periods, we have repeated the analysis for the same period (1982-2008) for all stations and checked the trend if there is any change on result. This showed that there are some slight differences of Sen's slope and Z (significance test), but overall it does not affect the significant test results, i.e., almost all the trend direction or significance remain the same as shown on Table 3A below. Numbers marked in yellow are those that have changed. We will edit the revised manuscript to reflect that we now used data for the same period as follows (page 1306):

For most stations the period of record available spanned from the early 1980's to 2008 and while data from some of the stations spanned from 1960's and 1990's to 2008, we used a common data period from 1982-2008 for all stations for the analysis.

6. Moreover, the time period of analysis or length is not same for all the variables in this study. For example, stream flow used is from 1982-2008; Rainfall from 1970-2008; Temp (1970-2008); ET (2000-2008); Water levels (1992-2008). How can we compare trends for these variables when the period of analysis is different? Authors should redo entire analysis by choosing a particular time period for all variables. Say 1982-2008. In case data is not available for at least 20 years, a different data set or variable should be used.

Authors' response:

As in the previous comment we agree that the different time periods for different variables in the trend analysis may affect the result. We have repeated the analysis for the common period of time as the reviewer suggests and will incorporate changes in the revised manuscript. We have analysed this for stream flow for the period of 1982-2008 as explained in response to comment number 5. We have also reanalysed the rainfall and temperature data for the same period and the results will be included in the revised manuscripts as shown in Table 4 and 5. However, for the ET and lake levels there is inadequate ground measured data in the basin. The remotely sensed ET and Lake level data is not available for the full period from 1982 to 2008. Table 4 and 5 have been edited as shown below. Numbers marked in yellow are those that have only changed slightly, but not significantly; numbers marked in green are those that have changed in magnitude and direction of trend but not significantly and those that marked by pink colour have significant change.

We will edit the revised manuscript in section 2.2, page 1307:

For this analysis we used data from 1982-2008, the same period for which streamflow data was available.

7. Page 1313, lines 27-29, authors indicate that P, PET, AET were analyzed for 70 spatially distributed points. However, previous research (Velpuri et al., 2013, Remote Sensing of Environment) indicates that point based estimates of P, PET, AET have more uncertainty than spatially averaged estimates. Moreover, daily point based estimates have lot more noise that can influence trends. Authors should use spatially averaged estimates instead of point based estimates.

Authors' response:

We have indeed used 70 spatially distributed points for P, PET and AET across all of five homogenous regions in the study area. These were subsequently averaged over each of the regions to determine the dryness index of the regions as shown on Fig. 2. This has been clarified in the manuscript.

The dryness index (DI=PET/P) and the evaporative index (EI=AET/P) were calculated using the mean annual value of PET, AET and precipitation (P) (mm/year) calculated at 70 spatially distributed points that represent all LULC. PET and AET were sampled from the 1 km^2 MODIS images, while values for P were determined using inverse distance weighting. The spatially distributed points were subsequently averaged over each homogenous region.

8. It is hard to believe the results of land cover change analysis unless both the land cover data are thoroughly validated. Both the LULC datasets used in this study are generated using different input datasets and different classification algorithms. Most often comparisons of such datasets do not agree with each other. How much of change do you attribute to the difference in data sources? Don't you think, if 83% of increase in grassland and cropland due to conversion of FL, GL and WL is real, it should show significant increase in flows from majority of the stations?

Authors' response:

We agree that the consistency of the land cover maps is an important issue. In the revised manuscript we have included additional detail on how the land cover information was validated to the extent possible. The following clarification was added to section 2.

The two original land cover maps differ in sources of satellite data, resolution and processing algorithms. This could lead to erroneous interpretation of land use change between the two periods. A limited validation of the LULC maps was carried out through site visits to areas that remain unchanged in the two maps (water area, bare land and highland forest areas), and a good agreement was found with the classes shown in the two maps, though there were some small differences in area coverage. Additionally the changes in LULC found in the maps corroborated with changes in land use reported in other basins in Ethiopia (Rientjes et al., 2011).

9. In the current manuscript, the discussion on the trends in IHA parameters for the 12 stations is presented as a whole. Instead, the trends in IHA parameters for the stations falling within a region vs LCLU change happening in the region should be examined to see the cause and effect of LULC change on each parameter trends. What I mean is that table 3 should be separated by regions. Then

comparison should be made with the parameter trends (significant or not) vs the amount of LCLU change.

Authors' response:

To clarify the spatial variability of the trends we now include a figure which shows the stations and trends in the different regions (Fig. 1c). The symbols used show the significance and direction of the trends found. We used Table 3A and 3B to summarise the results of 17 parameters of 12 stations, divided per region (Note that based on comments from reviewer 2, we have decreased the number of indices to 17).

We have added the following clarification in section 4.1:

Trends in the natural flow regime were observed to vary spatially across the basin. Humid regions 1 and 4, which were dominated by FL, WL, WG and SL, show more significant positive trends in low flow magnitudes compared to the dry sub-humid regions 2, 3 and 5 (Fig 1C), which are dominated by CL and GL. In the regions 1 and 4, FL, WL, WG, SL decreased by 64-73%, but CL and GL increased by 123-261%, whereas in regions 2, 3 and 5, CL and GL increased by ranges of 21-38% only.

10. In section 2.2 add discussion on Evapotranspiration (PET and AET) and land cover datasets used.

Authors' response:

We will include additional discussion on Evapotranspiration and land cover dataset used on revised manuscript as follows in section 2.2:

Land use land cover (LULC): For the analysis of change in LULC, and possible links to the natural flow regime analysis, we used two sets of land cover data that coincide with the period of data of streamflow. These are the global land cover of NASA/NOAA Pathfinder Land (PAL) data set of 1981-1994 of 1 Km resolution from the Advanced Very High Resolution Radiometer (AVHRR) produced by the University of Maryland Department of Geography (UMDG) (Hansen et al., 1998) and the dataset of 2009 with a resolution of 300 m produced by the European Space Agency (ESA, 2010).

Potential and Actual Evapotranspiration (PET and AET): we used MODIS16 (Mu et al., 2011) remote sensed data of 1 km^2 resolution which is available for the time period from 2000-2010 at a monthly time step. This is to investigate possible trends in actual evaporation (AET) and potential evaporation (PET), and to understand if these reflect the trends found in the temperature data. The MOD16 ET datasets are estimated using the algorithm described by Mu et al., (2011). This algorithm is based on the Penman-Monteith equation (Monteith, 1965). It considers the surface resistance as an effective resistance to evaporation from land surface and transpiration from the plant canopy. The data was obtained through FTP (ftp://ftp.ntsg.umt.edu/pub/MODIS/Mirror/MOD16/)

11. Page 1305, Line 1, uses just 5% significance level instead of two significant levels.

Authors' response:

We will use only the 5% significant level as recommended and have revised the manuscript as "...at the 5% two tail significance level." For clarity, this can be found on page 1309 rather than 1305.

12. Page 1307, selection of homogenous regions should be numbered as an individual section (2.3?)

Authors' response:

We will correct this as suggested in the revised manuscript.

13. Page 1309, Lines 24-25, MOD16 is actual ET dataset. Does it provide potential ET data? Provide the link from where you downloaded the data.

Authors' response:

Yes, MOD 16 data set has both actual and potential evapotranspiration data. The Brief Introduction to MODIS Evapotranspiration Data Set (MOD16) by Mu et al. 2011 describes the data as follows: "The MOD16 global evapotranspiration (ET)/latent heat flux (LE)/potential ET (PET)/potential LE (PLE) datasets are regular 1 km^2 land surface ET datasets for the 109.03 Million km^2 global vegetated land areas at 8-day, monthly and annual intervals. The dataset covers the time period 2000-2010."

The link to the data is: ftp://ftp.ntsg.umt.edu/pub/MODIS/Mirror/MOD16/, which is also included in the manuscript in the data availability section.

14. In table 3, can you classify all the indices into five categories as in Table 2. For easy comparison, please maintain the number for each indices same as in Table 2.

Authors' response:

We have updated Table 3 as suggested and the revised version as will be included in the manuscript is shown below.

15. Can you provide p-value in tables 4, 5, and 6?

Authors' response:

We will include the p value in the revised manuscript. The revised version of Table 4, 5 and 6 are found below.

16. Why have the authors presented flow duration curves (Figure 4) for pre-1995 and post 1995? This type of classification is not performed for IHA parameter trend analysis or for climate variable analysis. Then, why here? Although probability of exceedance has increased for post-1995 data, it could be due to climatic variability. It is not correct to draw conclusion that this increase in the probability (for 8 years) is due to land cover change.

Authors' response:

The objective of this paper is to analyse trends in streamflow, and subsequently if trends are detected to identify the possible drivers. These trends are assessed through trends in the IHA indicators over the selected time period. As the flow duration curve aggregates flows over time it in itself can indeed not be used to detect trend. However, by dividing the period in to roughly two halves and analysing the FDC over the two periods we can see if there are any changes to the FDC that corroborate trends found in the other indicators. We agree that it is incorrect to draw conclusions on land cover change on changes to the FDC alone, but suggest that the changes to the FDC contribute to drawing such conclusions in combination with trends identified in other IHA indicators. Our conclusions were not based solely on the change to the FDC, and we have revised the text to ensure this is clear.

In section 3.1, "... to analyse if there are any clear deviation changes to the distribution between the two periods, and if these corroborate trends found in other indeces."

In section 3.3, "The trends found in the IHA indeces, such as for the 7-day minimum flow, as well as changes to the dry season FDC between the first and second parts of the periods analysed reflect this increase in runoff. This would suggest the dominance of LULC change in the changing distribution of runoff over changes due to the climate effect."

17. Figure 5 indicates that mean annual dry season rainfall for Omo-Ghibe is decreasing. This is in contrast with the conclusion of the study that dry season flows are increasing. How do you explain this?

Authors' response:

Thank you for your comment. Indeed in Fig.5 there is some suggestion that areal rainfall of the basin (dry season) averaged over the whole basin may be decreasing. This trend was, however, not found to be significant for most stations as shown in Table 4, except at two stations. We agree that a significant decrease would seem to be in contrast with the conclusion on the increasing dry season flows. However, as discussed, the change in flows, in particular for lower flows during the dry season are also impacted by the actual evapotranspiration, which is related to multiple factors; including availability of water, land cover, and temperature.

We have not made any amendments to the manuscript in response to this question

18. Did you analyze the trends in the Lake Turkana inflow (Figure 6) obtained from Abera, 2012?

Authors' response:

We did analyse the trend of inflow to Lake Turkana from the model results of Abera, 2012. The period available is, however, too short (seven years) to reliably analyse trends.

We have added a short sentence in section 3.4 to clarify:

The relatively short period for which the results of Abera, 2012 were available meant that a reliable analysis of trends could not be carried out.

19. Several sentences in the manuscript are confusing mainly due to poor choice of words. I would recommend a thorough English review.

Authors' response:

Thank you the reviewer for your recommendation, we will carefully go through the revised manuscript and improve as required.

20. It is difficult to understand that temperature in the basin is showing significant increase whereas PET trend is not showing any increase. Can you explain why? Provide more information on how PET data was derived.

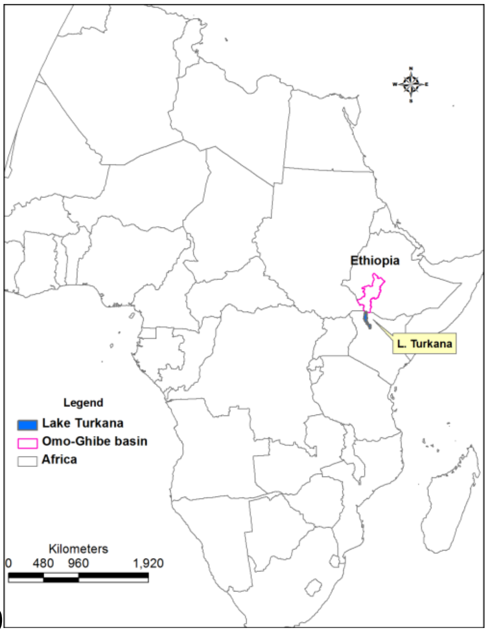
Authors' response:

Thank you for your comment. One could indeed expect that as temperature increases then evapotranspiration will also increase. This was, however, not the case in this analysis, which seems counterintuitive. As explained on page 1314 line 6-13, the land use/land cover changes, in combination with temperature changes result in the changes to evapotranspiration being more complicated. In humid areas, LULC have a more dominant effect on potential evapotranspiration than does temperature change, while in an arid region changes to the climate will have more effect than LULC change (Yang et al., 2012;Tomer and Schilling, 2009;Zhang et al., 2001). It is well known that forest land has a higher evapotranspiration than cropland and grassland (Zhang et al., 2001), which means conversion of land use from forest/wood land to grass/cropland will decrease evapotranspiration.

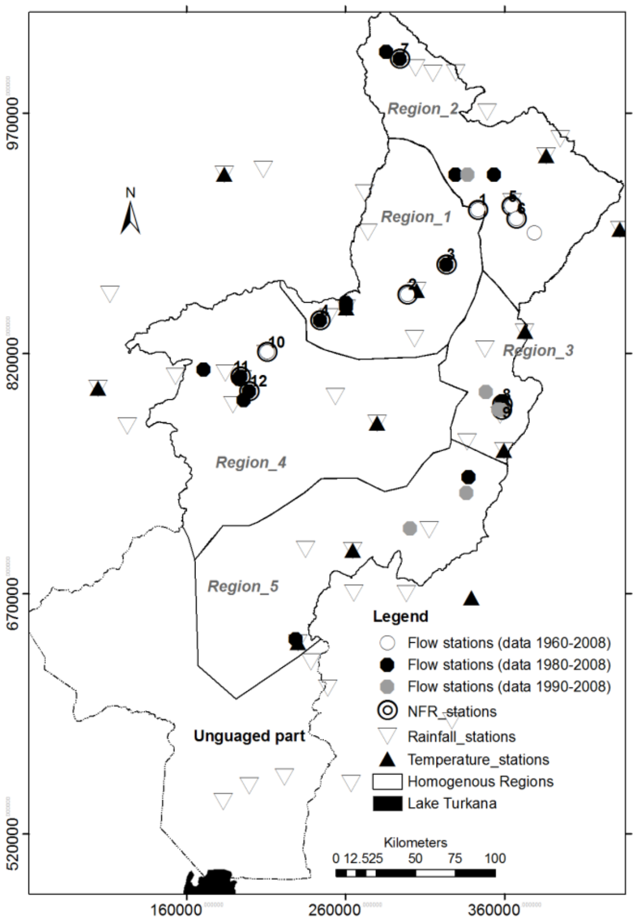
We derived potential evapotranspiration from the 1km^2 resolution MODIS 16 product (Mu et al., 2011). This uses a combined energy balance and aerodynamic method or Penman-Monteith equation (Monteith, 1965).

We have added a small sentence to make this clearer in section 2.4.1 (revised 2.5.1) on page 1309 as:

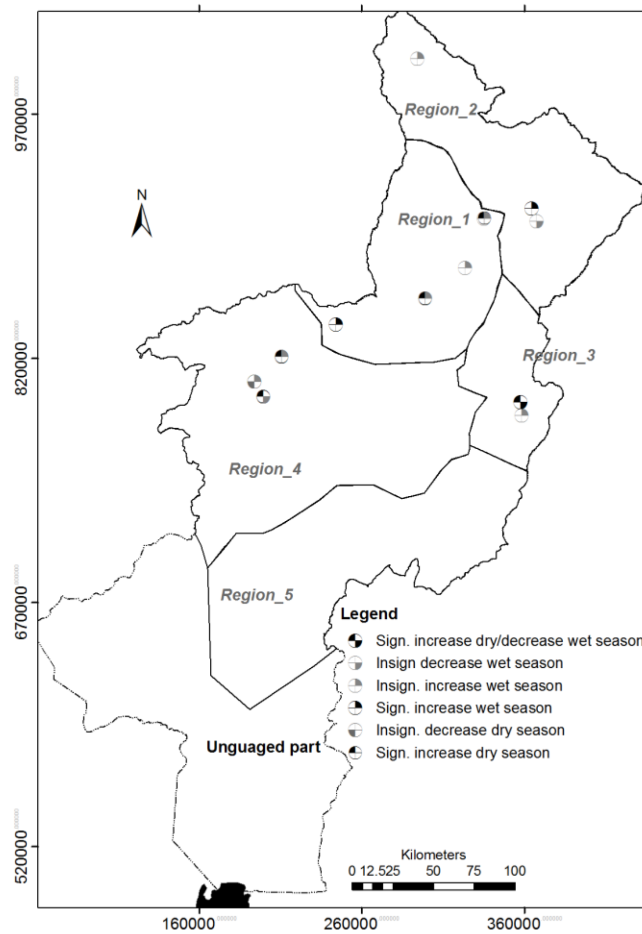
MODIS 16 evapotranspiration data uses a combined energy balance and aerodynamic method or Penman-Monteith equation (Monteith, 1965) based on remote sensed information (Mu et al., 2011).



a)



b)



c)

Fig.1 (a) Africa and Ethiopia map (MoWR, 2011), (b) Homogenous regions and gauging stations based on their length of record year and stations used for NFR analysis, rainfall and temperature stations,
(c) NFR trend of dry and wet season (sign. increase dry is for significant increase dry season flow; insign. decrease wet season is for insignificant decrease wet season flow).

Table 1: 17 Hydrological indices analysed at 12 stations and the number of stations that show a generally increasing or decreasing trend, as well as the number of stations at which the trend is significant at the α=5%.

	(1)	(2)	(3)	(4)	(5)
S.No.	Hydrological Indices	General increasing	Significant increasing @ α=5%	General decreasing	Significant increasing @ α=5%
	Magnitude				
1	Annual flow	8	2	4	1
2	Dry Season flow	9	2	3	0
3	Wet Season flow	6	2	6	1
4	7-day minimum flow	7	4	4	1
5	7-day max. flow	8	2	4	2
6	Base flow Index	8	5	4	0
7	FDC (Annual)	8	7	4	3
8	FDC (Dry season)	6	5	6	4
9	FDC (Wet season)	6	3	6	3
	Timing				
10	Date of min. flow	3	0	9	2
11	Date of max. flow	2	0	9	0
	Duration				
12	Ext.Low flow duration	2	0	9	0
13	High flow duration	4	1	7	2
	Frequency				
14	Ext.Low flow frequency	2	1	7	4
15	High flow frequency	5	1	2	1
	Flow Variability				
16	Low pulse count	3	0	6	2
17	High pulse count	5	2	2	0

Table 3A: Main hydrological indices trend and its significance level for all data in the range of 1982-2008 compared to longer period of data (1960s-2008), the bold figure shows significantly changed with 5 % significance level.

Hydrological Indices	REGION1								Region 2								Region 4			
	Abelti 1960s		Abelti 1980		Asendabo		Asendabo 1980		Megecha		Megecha 1980		Wabi		Wabi 1980		G.Shebe		G.Shebe 1980	
	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z	Sen's slope, (trend)	Z
Annual	0.88	1.11	26.37	1.15	0.09	0.49	3.06	1.33	-0.03	**2.19**	-0.12	0.417	0.16	0.98	1.65	0.584	0.01	0.01	5.18	1.32
Dry Season	0.7	**2.10**	19.11	**2.38**	0.11	1.66	2.69	1.83	0.01	0.04	-0.13	0.580	0.03	0.3	0.36	0.21	0.05	0.41	1.20	0.58
Wet Season	1.59	1.11	33.85	1.10	-0.19	0.6	5.34	0.63	-0.11	**2.41**	-0.02	0.042	0.58	1.3	5.00	0.770	-0.08	0.18	6.84	1.27
7-day min flow	0.23	**2.72**	7.42	**3.615**	0.07	**3.36**	**1.47**	**3.294**	0.01	**3.91**	-0.03	1.290	-0.02	1.18	-0.10	0.560	0.04	0.48	-0.07	0.09
7-day max flow	1.54	0.55	29.80	0.353	-0.19	0.3	3.30	0.417	-0.41	**2.83**	-1.96	1.760	2.06	0.84	28.70	0.770	0.6	0.61	3.35	0.210
Base flow Index	0.01	**2.19**	0.03	**2.65**	0.01	**2**	**0.03**	**3.75**	0.01	1.11	-0.01	0.830	-0.01	1.11	-0.01	0.056	0.01	1.93	-0.02	0.49
FDC (Annual)*	<0.0001	8.4	<0.0001	5.518	<0.0001	4.7	<0.0001	5.82	0.01	-2.55	0.287	1.06	0.89	-0.14	0.080	-1.751	<0.0001	5.03	<0.0001	6.84
FDC (Dry)*	<0.0001	14.7	<0.0001	19.29	<0.0001	8.4	<0.0001	8.27	0.003	-2.97	<0.0001	5.05	-1.43	0.15	0.131	-1.510	<0.0001	-3.98	0.16	-1.42
FDC (Wet)/*	0.023	2.3	0.590	0.539	0.28	1.07	0.001	3.361	0.016	-2.41	0.176	1.35	0.14	-1.46	0.008	-2.632	0.27	1.1	0.53	0.63
Date min flow	-0.42	0.78	-7	-0.617	-0.36	0.94	-3.00	-0.499	-1.83	**2.36**	-3.00	-0.208	-0.88	1.02	0.00	0	-0.91	1.55	-2.50	-0.37
Date max flow	0.01	0.04	-2	-0.639	-0.19	0.68	-4.00	-0.521	-0.31	1.07	-4.00	-0.79	-0.46	1.25	-3.50	-0.77	-0.5	0.74	-8.50	-1.24
Ext.Low flow duration	-0.17	0.86	-5.20	-3.620	-0.19	1.73	-5.20	-1.91	0.08	0.53	0.57	0.38	-0.22	0.42	0.81	0.65	-0.1	0.4	-0.0010	-0.18
High flow duration	0.01	0.05	-0.92	-0.370	-0.18	0.94	-3.57	-2.25	0.12	1.83	-0.06	-0.06	-0.15	1.34	-1.36	-0.96	-0.03	0.27	-1.300	-0.63
Ext.Low flow frequency	-0.03	1.99	-1.00	-2.940	-0.06	**2.03**	-2.00	-2.83	0.1	3.01	1.00	1.44	0.08	1.83	1.00	1	-0.14	**3.14**	-1	-2.15
High flow frequency	0.01	0.05	0.00	0.085	0.07	**2.34**	1.00	1.82	0.01	0.28	0.001	0.103	0.01	0.34	0.00	0.28	0.01	0.36	0	0
Low pulse count	-0.05	**2.14**	0.00	-0.820	-0.06	1.58	-1.00	-1.03	0.05	1.1	1.00	1.896	0.11	1.45	1.00	0.72	0.01	0.73	-0.001	-0.32
High pulse count	0.06	2.02	1.00	1.950	0.01	1.36	1.00	1.22	0.01	0.17	0.001	0.103	0.09	0.99	0.00	0.023	0.01	1.29	0	0

Table 2B: 17 Hydrological indices analysed at 12 stations and the number of stations that show a generally increasing (column A) or decreasing trend (Column C), as well as the number of stations at which the trend is significantly increasing (column B) and significantly decreasing (column D) at the α=5%.

S.No	Hydrological Indices	Region 1 (Id-1,2,3,4)				Region 2				Region 3				Region 4				Summary	
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	Total B	Total D
	Magnitude																		
1	Annual	3	1	1	0	2	1	1	0	1	0	1	0	2	0	1	0	2	0
2	Dry Season	4	1	0	0	2	0	2	0	2	0	0	0	3	1	3	0	2	0
3	Wet Season	3	1	1	0	2	1	1	0	1	0	1	0	3	0	0	0	2	0
4	7-day min flow	4	2	0	0	1	0	0	0	2	0	0	0	2	2	1	0	4	0
5	7-day max flow	4	1	0	0	2	1	1	0	1	0	1	1	2	0	1	0	2	1
6	Base flow Index	4	2	0	0	0	0	3	0	2	1	0	0	2	2	1	0	5	0
7	FDC (Annual)*	3	3	1	1	2	1	1	0	1	0	1	1	3	3	0	0	7	2
8	FDC (Dry)*	2	2	2	0	1	1	2	1	2	2	0	0	1	1	2	0	6	1
9	FDC (Wet)/*	3	1	1	0	2	1	1	1	1	1	1	1	3	1	0	0	4	2
	Timing																		
10	Date min flow	0	0	4	0	0	0	2	2	2	0	0	0	1	0	2	0	0	2
11	Date max flow	2	0	2	0	0	0	3	0	0	0	2	0	0	0	3	0	0	0
	Duration																		
12	Ext.Low flow duration	1	0	3	1	3	0	0	0	0	0	2	0	0	0	3	0	0	1
13	High flow duration	0	0	4	3	1	0	2	0	1	0	1	0	1	1	2	0	1	3
	Frequency																		
14	Ext.Low flow frequency	2	0	2	2	3	0	0	0	2	0	0	0	3	2	0	0	2	2
15	High flow frequency	3	0	0	0	2	0	0	0	1	0	1	1	1	0	1	0	0	1
	Variability																		
16	Low pulse count	2	0	1	0	2	0	1	0	1	0	1	0	0	0	3	1	0	1
17	High pulse count	4	0	0	0	2	1	0	0	0	0	2	0	2	0	0	0	1	0

Table 3: Rainfall trend (Sens's slope) in the dry and wet season and the significance level test (Z and P) for trends in the five homogenous regions with the α=5 % significance level for 21 stations and Lake Turkana

Season	**Dry Season**				**Wet season**		
Regions	**Stations**	**Sen's slope**	**Z**	**p**	**Sen's slope**	**Z**	**p**
Region 1	Asendabo	0.11	0.92	0.36	-0.12	-0.49	0.63
	Chekorsa	0.25	1.46	0.14	-0.16	-0.44	0.66
	L.Genet	0.04	0.30	0.76	-0.01	-0.05	0.96
	Jimma	0.15	0.59	0.56	0.07	1.91	0.06
Region 2	Butajira	0.12	0.63	0.53	0.38	**2.23**	0.03
	Gedo	-0.31	**-2.58**	0.01	-1.87	-4.91	<0.0001
	Weliso	-0.09	-1.08	0.28	-0.06	-0.33	0.74
	Welkite	-0.21	-0.96	0.34	-0.09	-0.42	0.68
Region 3	Areka	0.03	0.19	0.85	-0.285	-0.68	0.50
	Bele	0.01	0.10	0.92	-0.65	-0.83	0.41
	Hosana	0.085	0.06	0.95	-0.02	-0.12	0.91
	Walaita	0.19	0.97	0.33	0.44	1.36	0.17
Region 4	Bonga	-0.02	-0.10	0.92	0.25	0.46	0.65
	Mizan	-0.02	-0.06	0.96	-0.22	-0.94	0.35
	Sokeru	-0.05	-0.39	0.69	-0.37	-1.11	0.27
	Tepi	0.01	0.02	0.98	-0.665	**-2.17**	0.03
Region 5	Beto	0.3	**1.78***	0.07	0.81	**1.78***	0.07
	Jinka	0.08	0.69	0.49	0.07	1.35	0.18
	Kemba	0.035	0.10	0.92	-0.485	-0.78	0.44
	Keyafer	0.18	0.65	0.52	0.63	1.20	0.23
	Konso	-0.13	-0.90	0.37	-0.165	-0.42	0.67
Lake Turkana•			**2.11**				

Table 4: Monthly minimum, maximum and mean temperature trends (Sen's slope), and its significance at α=5 % significance level test (Z and p) for 13 stations and on Lake Turkana in the study area

	Selected Stations	Maximum Temperature			Minimum Temperature			Mean monthly Temperature		
Regions		Sen's slope	Z	p	Sen's slope	Z		Sen's slope	Z	p
Region 1	Jimma	0.054	**3.86**	0.0001	0.026	**4.18**	<0.0001	0.036	**4.93**	<0.0001
	Asendabo	-0.023	-1.94	0.053	0.076	**3.81**	0.0001	0.022	**2.71**	0.007
Region 2	Welkite	0.25	**5.09**	<0.0001	0.056	**3.36**	0.0008	0.153	**5.14**	<0.0001
	Weliso	0.029	**3.40**	0.0007	0.076	**3.49**	0.0005	0.059	**3.78**	0.00016
	Butajira	0.08	**4.22**	<0.0001	0.025	0.001	1.000	0.046	1.8	0.056
Region 3	Hosana	-0.013	-1.56	0.119	0.063	1.38	0.168	0.012	**2.48**	0.013
	Walaita	0.25	**3.4**	0.001	0.069	**4.0**	0.0001	0.072	**4.19**	<0.0001
Region	Sokeru	0.015	0.84	0.399	0.026	1	0.315	0.007	1.11	0.268

4	Chira	0.282	**2.37**	0.006	0.053	**3.89**	0.0001	0.053	**3.42**	0.00062
	Tepi	0.024	**2.90**	0.0037	-0.036	-1.33	0.184	-0.006	-0.73	0.464
Region 5	Jinka	0.026	**3.48**	0.0005	0.024	**2.04**	0.04	0.023	**4.54**	<0.0001
	Sawla	0.045	1.80	0.071	0.025	1.32	0.186	0.022	1.63	0.104
	A.Minch	0.016	**2.16**	0.031	-0.054	**-2.46**	0.014	-0.014	-1.68	0.093
Lake	Turkana	0.08	**2.50**	0.01	0.29	**2.04**	0.04	0.17	**2.40**	0.02

Table 5: Remotely sensed data from MODIS16 actual- and potential evapotranspiration trend and significance test at 5 % in the homogenous regions of the study area and climate class based on UNEP 1997 Aridity Index (UNEP, 1997)

Regions	Actual Evapotranspiration		Potential Evapotranspiration		Aridity Index (P/PET)	Climate class
	Z	P	Z	P		
Region1	-2.2	0.03	-1.27	0.18	0.85	Humid
Region2	0.89	0.42	-1.99	0.048	0.53	Dry sub-humid
Region3	-1.3	0.17	-0.76	0.47	0.58	Dry sub-humid
Region4	-2.9	0.04	-2.63	0.006	1.01	Humid
Region5	0.15	0.81	-0.76	0.47	0.57	Dry sub-humid
Un-gauged	1.56	0.06	-0.71	0.49	0.24	Semi-Arid

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