Trend detection in river flow series and shifts in flood timing across Kenya

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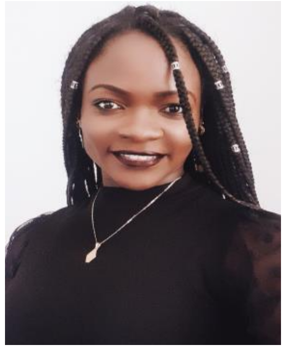

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EGU22– 26/05/2022

Presentation Outline

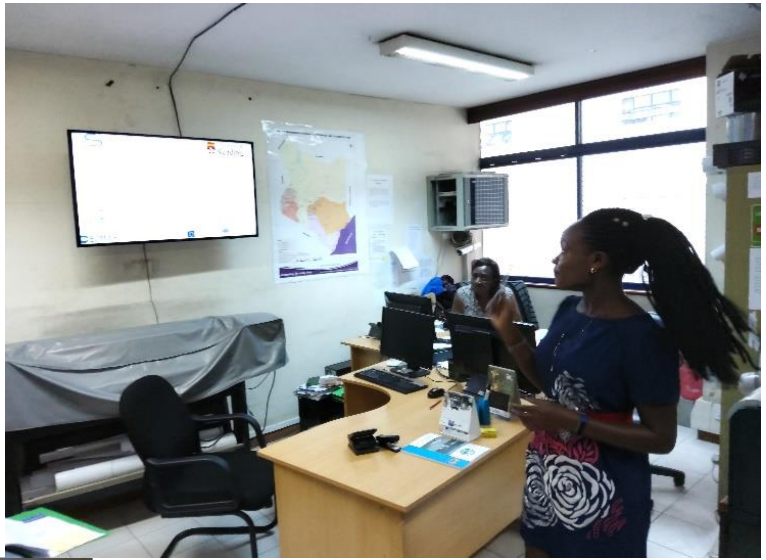
- Research motivation
- Research background in Eastern Africa and Kenya
- Research in the context of flooding
- Aims and objectives
- Study area
- Data and methods
- Key results
- Summary and conclusion

Motivation of the Research

Kenya Met Service,

23rd & 24th Sep 2019

- Flood forecasting sector has not been explored fully due to some limitations: data, resources and personnel



Kenya Water Authority , 26th & 27th Sep

- Science based evidence will provide insights & information on modelling & forecasting to key stakeholders, useful to Flood Early Warning (FEW) and risk reduction

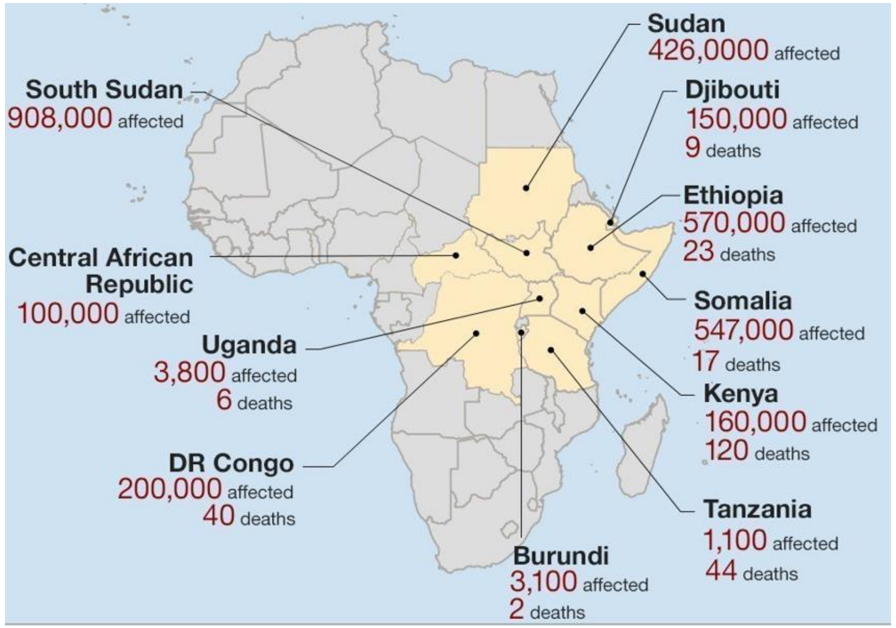
- Key question addressed – What can be done to improve flood forecasting amidst data scarcity issues?

Background on Flood Risk in Eastern Africa

- Flood occurs annually during the rainy seasons (March-May “**long rains**” and Oct-Dec “**short rains**”)

- Flooding in Eastern Africa is remarkable in terms of **duration, scale, and severity**. By late **April, the 2022** floods had killed more people than COVID-19.

https://medium.com/@icpac/recurring-floods-in-eastern-africa-amidst-projections-of-frequent-and-extreme-climatic-events-for-30d20d0d6f76



Source: OCHA

Flood Risk in Kenya

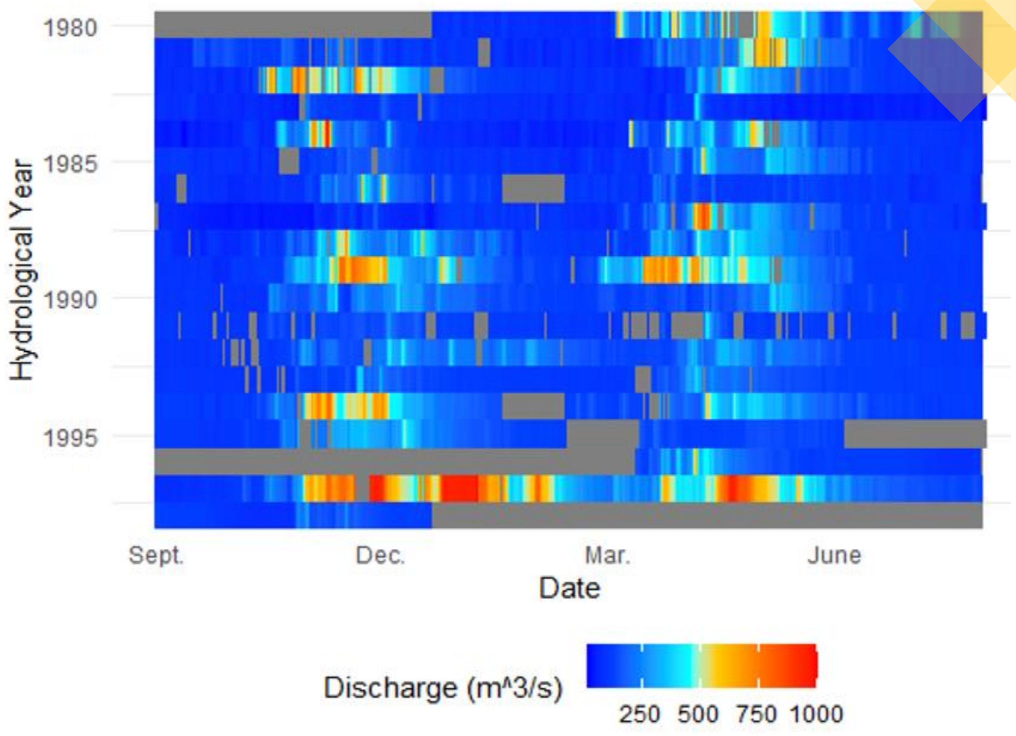
- Kenya is among the highest climate risk countries in the world (Global Climate Risk Index, 2020)

- The common climate and weather extremes are particularly droughts and floods (Eckstein et al., 2019)

- Major flood events occur roughly every two years on average (Emergency Events Database (EM-DAT)

- The typical population of people affected per event is approximated to be 70,000 (Parry et al., 2012)

- Between 1964 - 2019, Kenya recorded 18 major flood events, with 1961, 1997–1998, 2002, 2003, 2006,2010, 2012, and 2018 recording particularly high impact flood events, and declared national disasters



Annual discharge pattern for Nzioa river in Western Kenya

- High discharge occur during the wet seasons

- There is a large annual variation in river discharges

Research Context

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- Flood timing, magnitude and frequency are useful in informing the trends in river flooding
- Research has shown evidence in a shift in flood timing in East Africa, but still no much clarity in trends in flood magnitudes
- Causes of historical flood trends is still unclear due to a limited understanding of regional variations in flood-generating mechanisms, land use changes, reservoir constructions and uncertainty in projections

- Flooding is classified among the most detrimental natural hazards worldwide
- With the changing climate there is expected increase in flood risk globally
- For Kenya, flooding is the most common climatic extreme and the leading hydro-meteorological disaster
- Major flooding events in the past decades have proved a question whether or not they are effects of changing climate….

……and so need for analysis

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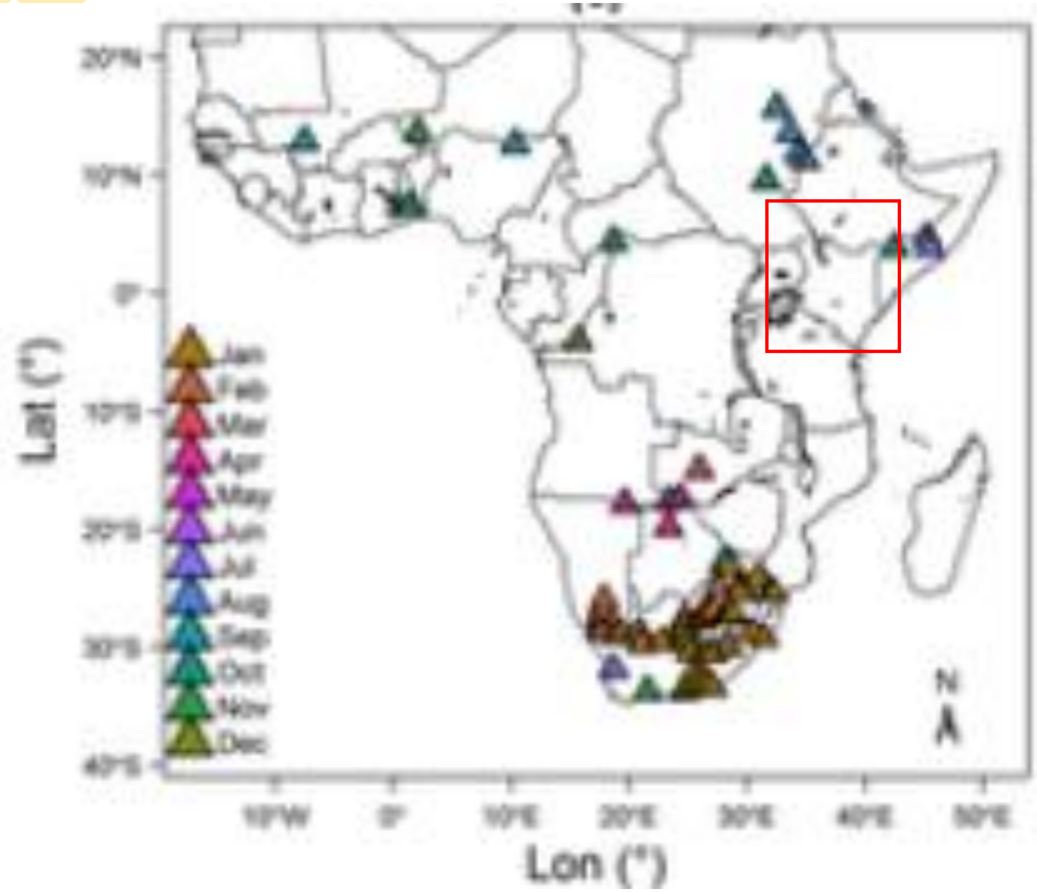
Research Context



Ficchi & Stephens 2019

- Trend analysis can be used to investigate whether there is any support for **increase** in river floods and droughts in observational flow data
- Understanding variability in flood timing and seasonality is important for water resources planning and management
- Thus, the need to assess the trends and changes in annual flood timing and seasonality at country basis due to the stark differences between the river basins

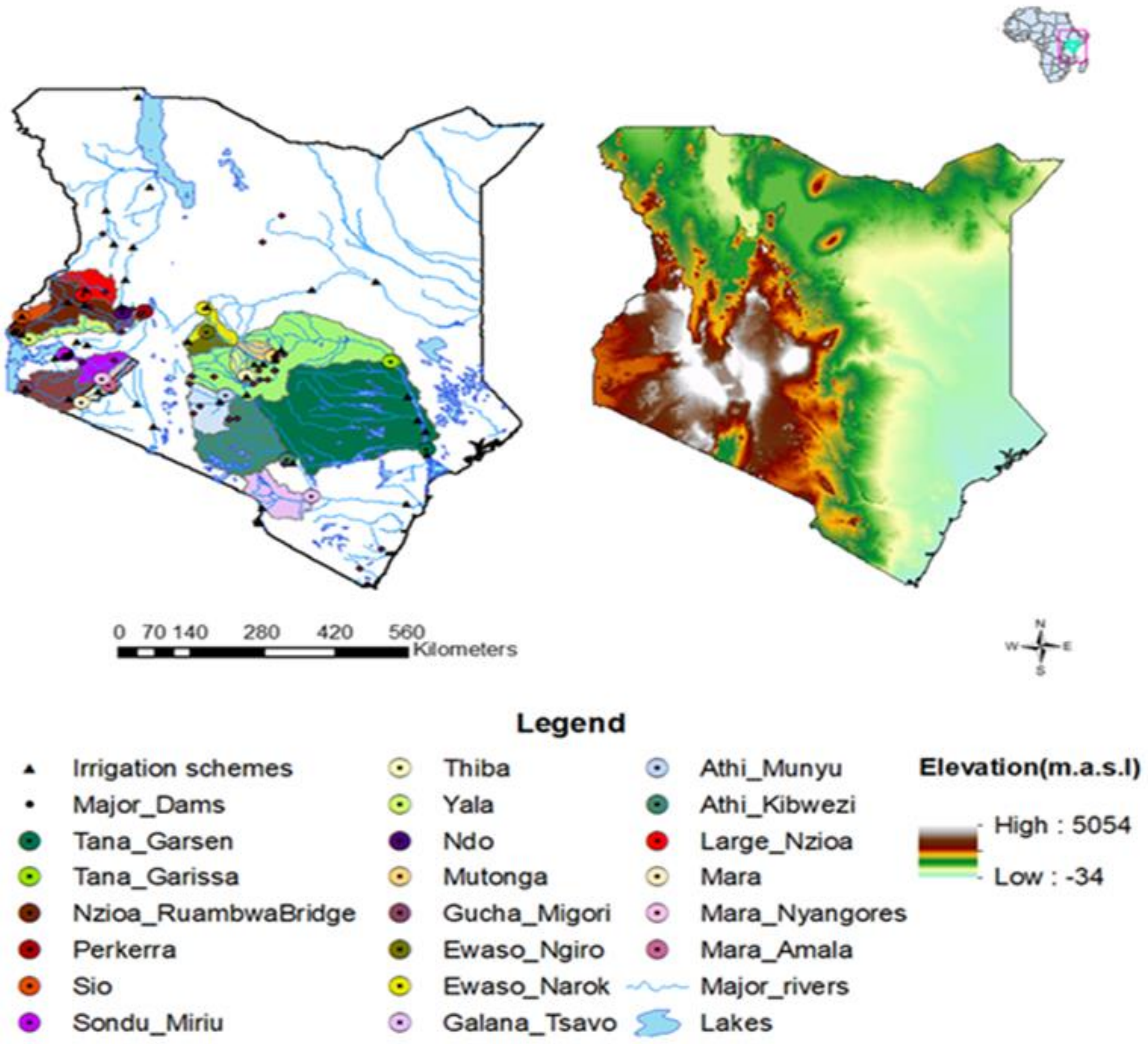
Research Aim

To detect the evidence of statistically significant flood trends across Kenya where flood-based farming systems and livelihoods are extensive. High flow indices are derived from river flow discharge series: AMAX, and POT indices using different magnitude and frequency thresholds

Research Questions

- What are the trends in flood magnitude and frequency across Kenya for the period 1981–2016**?**
- What is the sensitivity of the detected trends to the selection criterion used to define different flood peak series?
- What are the characteristics of country scale seasonality in flooding?
- What are the changes in seasonality and flood timing of the annual floods across Kenya?

Study Area



Study catchments, with the location of the outlet river gages used in this study and the main irrigation schemes and major dams across Kenya (left) and topography of Kenya (right)

The study is undertaken in **19 Kenyan catchments** with good and satisfactory streamflow data records

Kenya lies astride of the equator at longitude 34°E–42°E and Latitude 5°S–5°N and along the quasi-meridional western edge of the Indian Ocean at the eastern side of Africa

Kenya and flooding problems

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- Kenya receives enhanced rains in March-May (long rains) and October-December (short rains), key in driving floods

Flood event	Peak discharge (m3/s)	Start date for heavy rain	Days after peak flow when discharge < 50% of peak discharge	Flood duration
28Nov1961	935	23Nov1961	3	9 days
13Dec1961	731	09Dec1961	5	10 days
19May1962	559	16May1962	3	7 days
03May1963	596	10Apr1963	16	40 days
26Nov1977	538	11Nov1977	9	25 days
23Apr1988	517	13Apr1988	1	12 days
11Aug1988	528	29Jul1988	5	19 days
19Aug1988	531	29Jul1988	4	26 days
09May2002	510	28Apr2002	8	20 days
10Nov2008	546	03Nov2008	6	14 days
04Dec2011	576	29Nov2011	9	15 days
10May2013	569	29Apr2013	13	25 days

- Flooding in Kenya occurs annually

- The annual average economic loss approximated at 5.5% of GDP (Connor, 2015) from damages to roads, water systems, buildings, and communication networks; direct costs of treatment for waterborne diseases; and crop and livestock loss (Warner et al., 2018)

Data and Methods

We use observed river discharge data for the period 1981-2018

Station code	River Name	Station Name	Area (KM^2)	First & Last year of record	Record length (years)	Amount missing (%)
1EF01	Nzioa	Ruambwa	12643	1981-2018	38	13.6
1BD02	Nzioa	Large Nzioa	3878	1981-2011	31	28.8
1LA04	Mara	Mara	2977	1981-2015	35	77.7
1LB02	Mara	Amala	695	1981-2017	37	25.6
1LA03	Mara	Nyangores	697	1981-2017	37	15.5
1FG02	Yala	Yala	2700	1981-2019	39	59.6
1KB05	Gucha	Gucha_Migori	6310	1981-2015	35	47.8
2EE07A	Sio	Sio	1011	1981-2018	38	18.1
1JG04	Sondu	Sondu_Miriu	3444	1981-2018	38	64.4
5AC10	Ewaso	Ewaso_Ngiro	1837	1981-2019	39	35.0
5BC04	Ewaso	Ewaso_Narok	2597	1981-2018	38	26.5
4G01	Tana	Garissa	3269	1981-2018	38	14.2
4G02	Tana	Garsen	80760	1981-2016	36	58.2
4DD02	Tana	Thiba		1981-2014	34	64.1
4EA07	Tana	Mutonga		1981-2016	36	44.2
3DA02	Athi	Munyu	5689	1981-2017	37	21.6
3G02	Galana	Tsavo	6560	1981-2015	35	59.6
2EE07A	Turkwel	Perkerra	371	1985-2005	21	50.1
2C07	Turkwel	Ndo	897	1981-1993	13	47.2

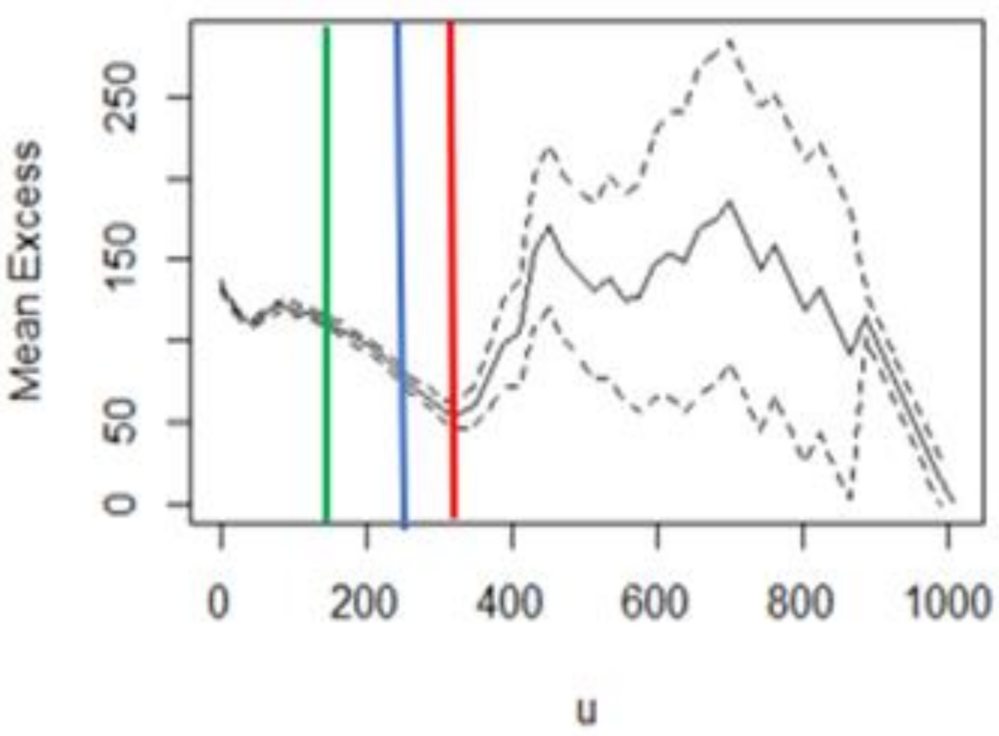
- We assess the **trends** via the monotonic **Mann-kendall trend test** and the magnitude of the slope via Sen's slope estimator

For 19 representative stations across Kenya

For Extreme Value Analysis: Fitted Generalised Eextreme Value (GEV) distribution on the annual maxima and Generalised Pareto Distribution (GPD) on Peak Over Threshold values of observed discharge

Data and Methods

Mean Residual Life Plots



Seven high flow representative indices were derived

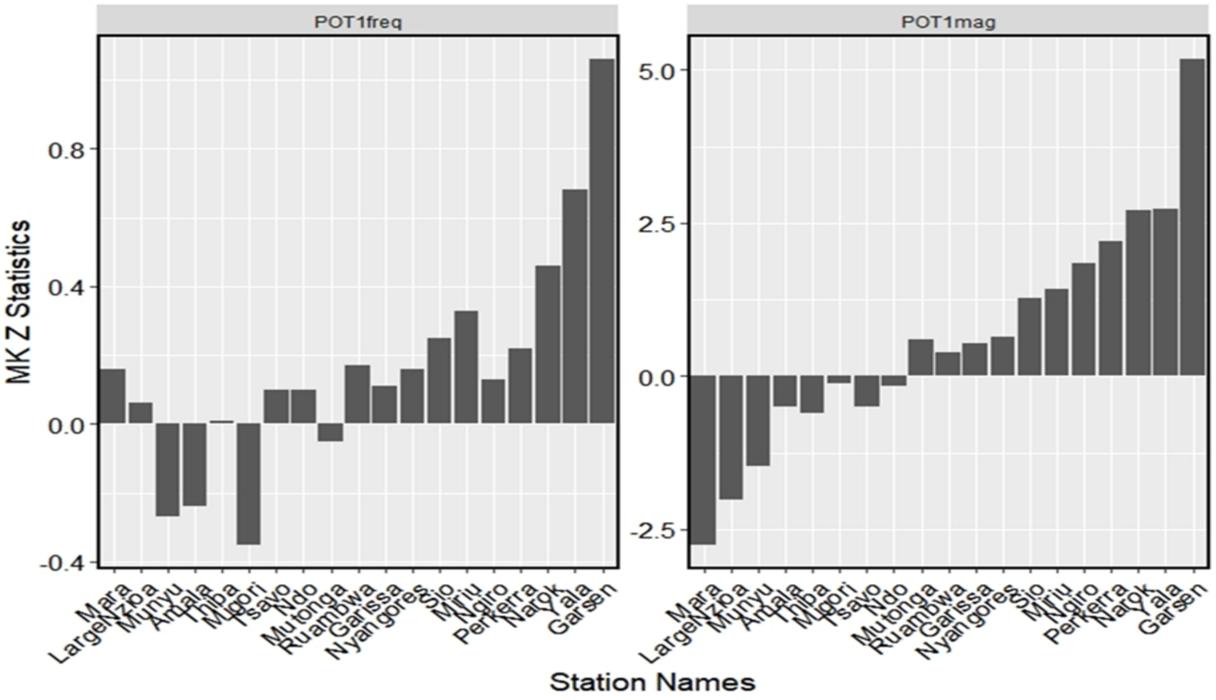
- Using observed river discharge data for the period 1981-2018, we derived indices to assess trends

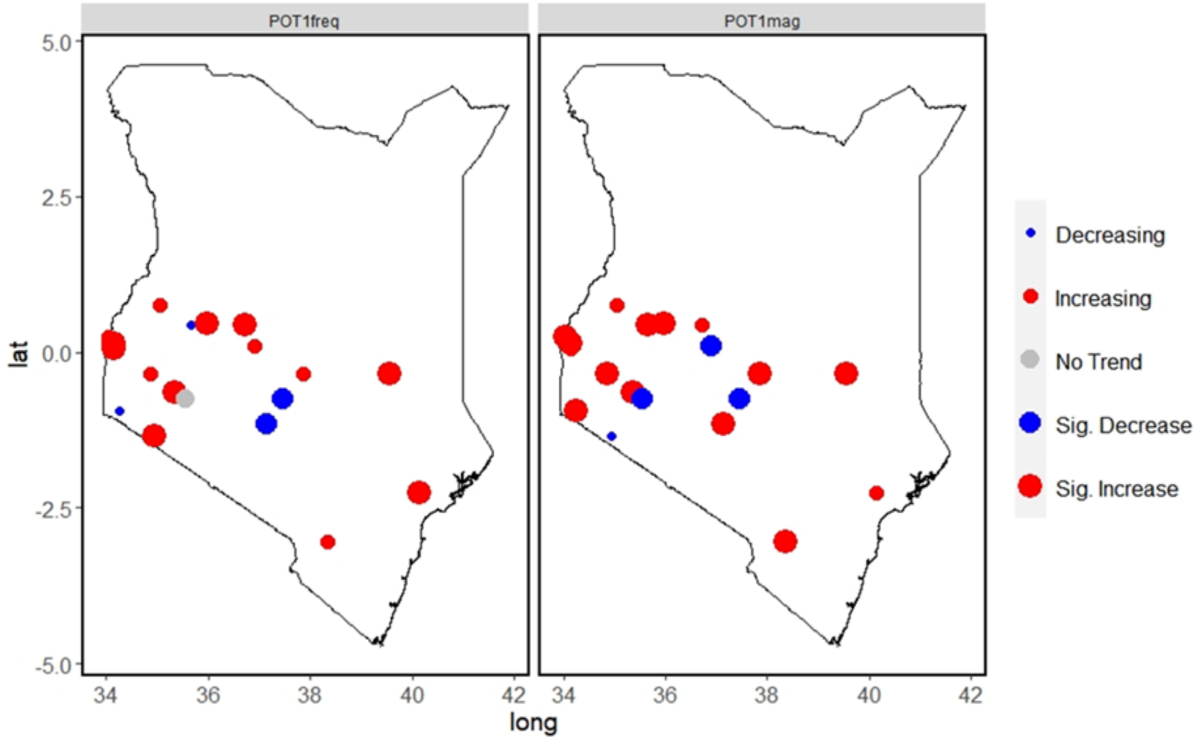
- Amax considers only the largest of several large observed flows in the series
- Peak-over-threshold (POT) series considers a sequence of independent daily mean river flows that surpass a certain threshold:-
  - POT3 corresponds to events with a probability exceedance of 70% of the flow.
  - POT5 corresponds to events with a probability exceedance of 50% of the flow.

- Flood frequency indices that were derived from counting the number of POTs that occur each year (POT3freq and POT5freq)

Key Results:- Trend Analysis

Peak Over Thresholds





- Positive trends in POT1 flood magnitude are found for 11 and negative trends for 8 stations respectively
- The number of stations exhibiting statistically significantly trends is higher in the POT1mag than in AMAX.
- Consistent pattern in the flood change in some catchments depicting significantly increasing trends in both the MAX and POT1mag series

Key Results:- Trend Analysis

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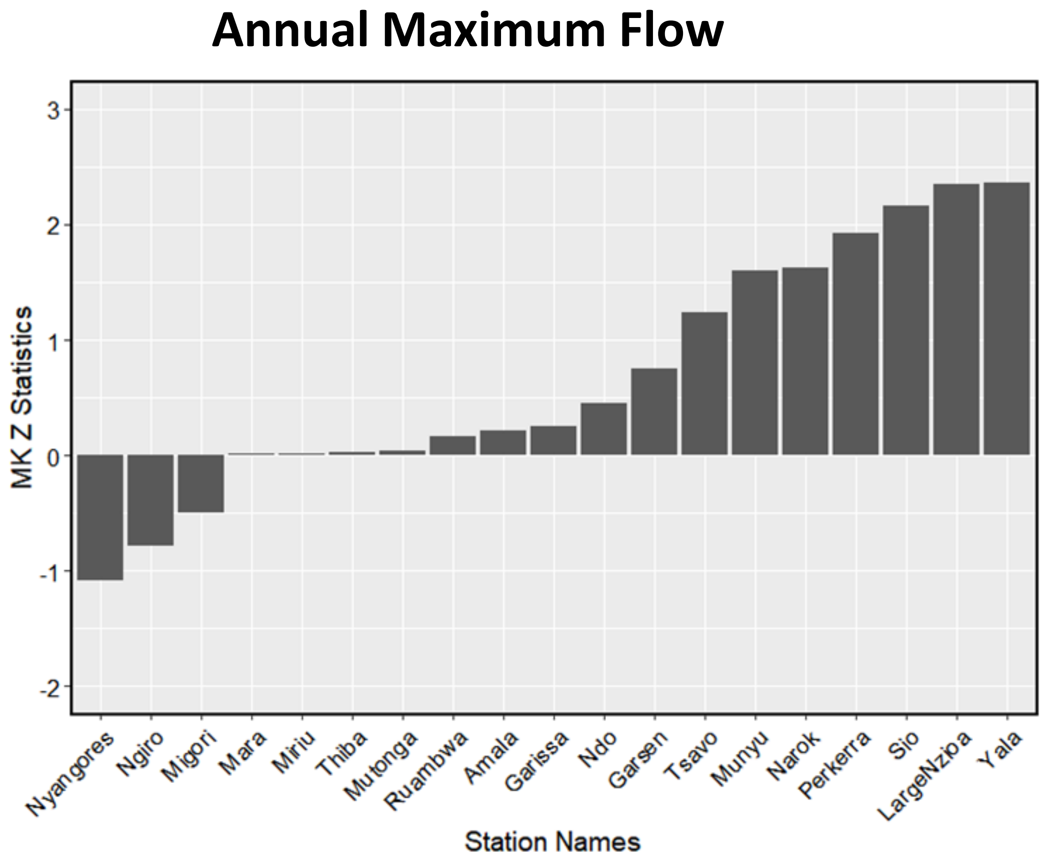

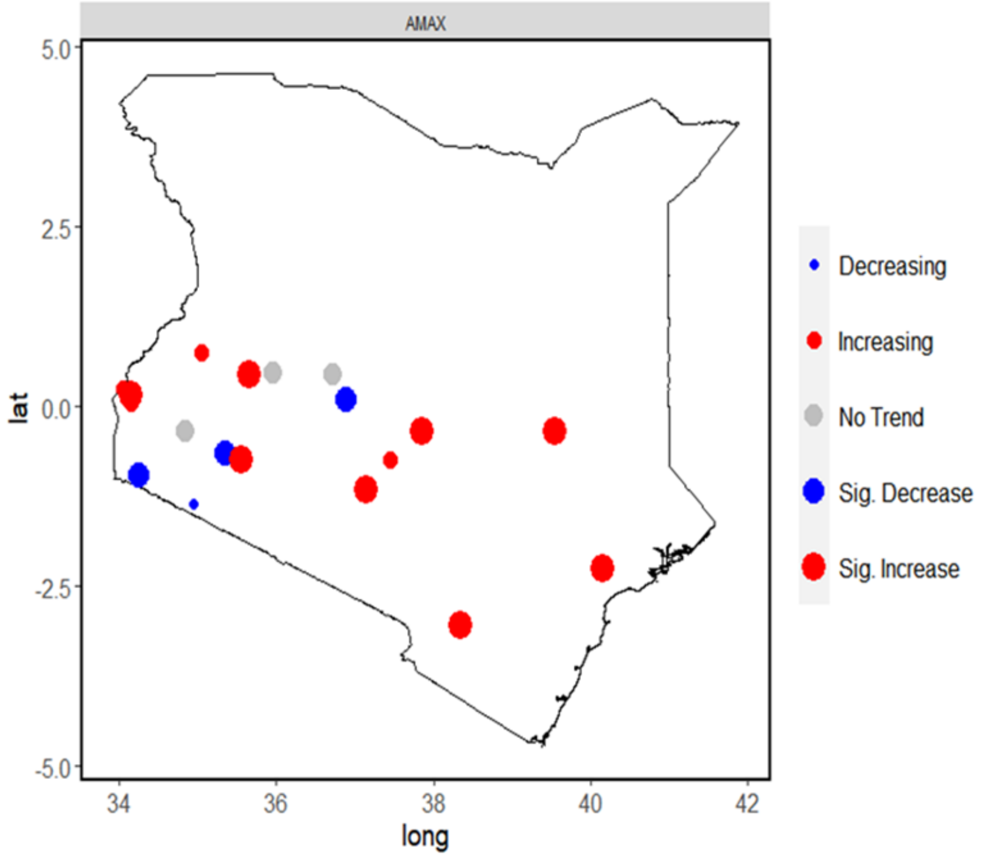

- Heterogeneity in the trend calculated for the 36-years.
- Dominant positive trend across 12 stations in the AMAX and only 3 stations (Nyangores, Ewaso-Ngiro and Gucha-Migori) show negative trends

- Statistically significant positive and negative trends at 10% confidence interval in the AMAX series are detected in 12 out of 19 stations

Key Results:- Extreme Return Values

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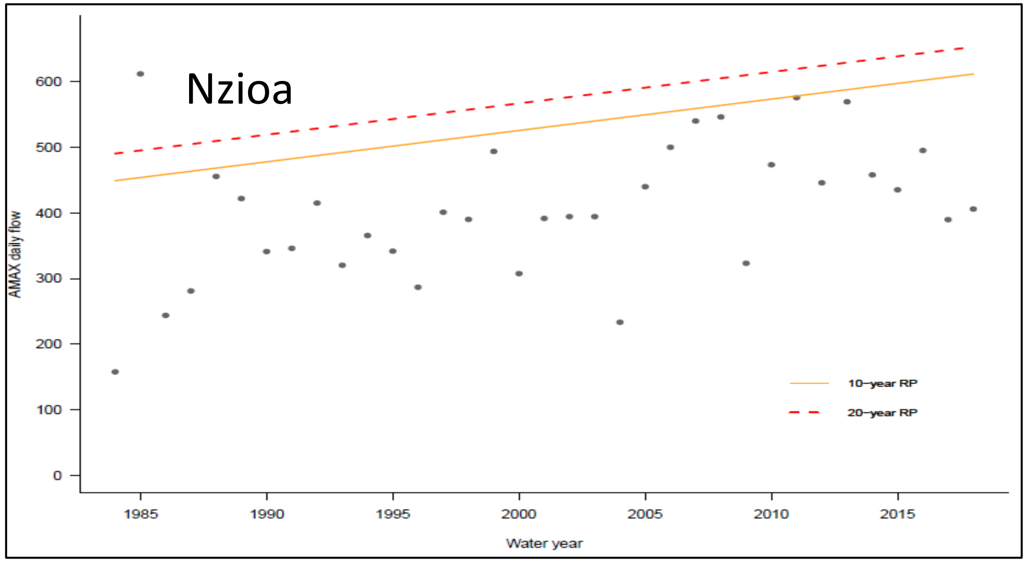
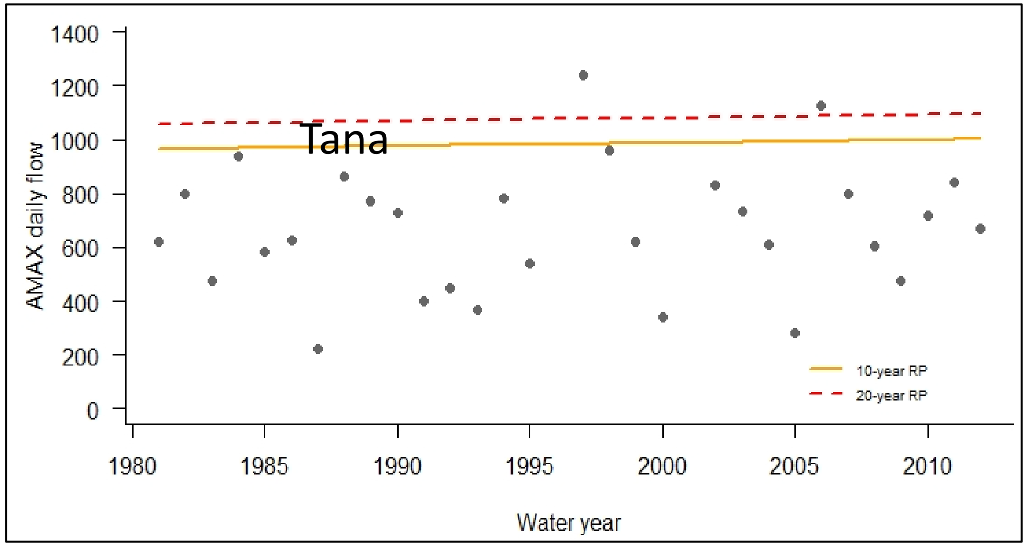




Trends in 10 & 20 years return period for Nzioa (top) and Tana (bottom) rivers

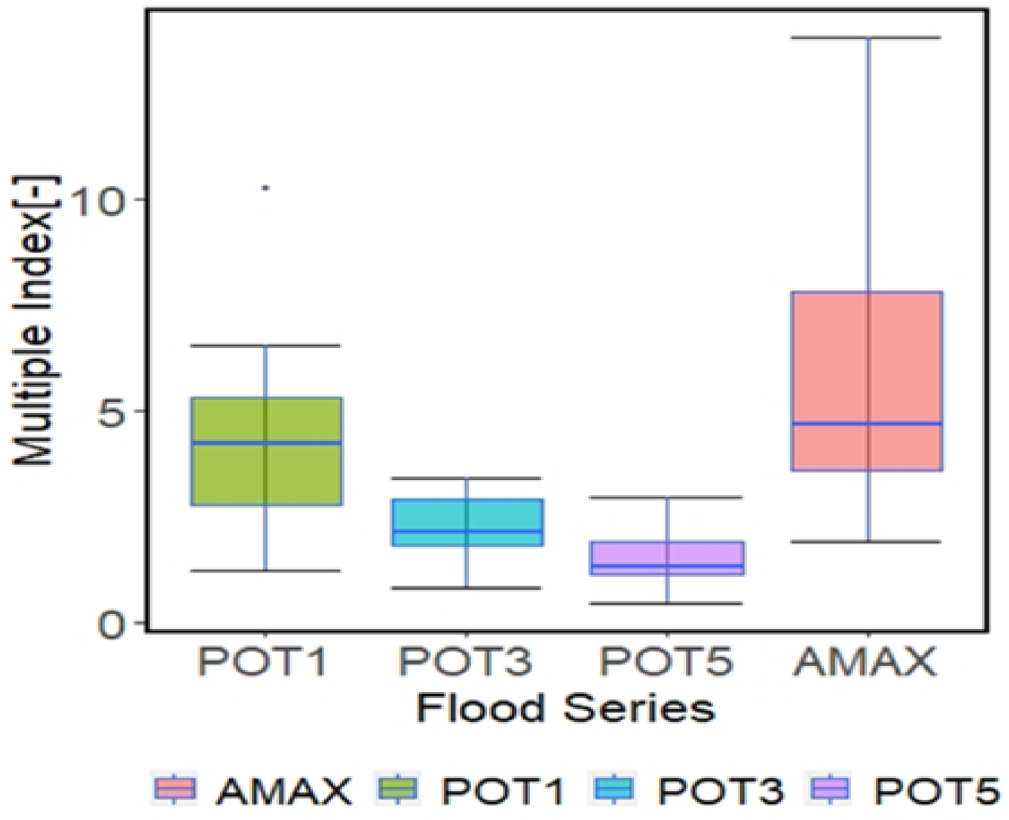
- A marked (and significant) positive trend is found in the annual maxima (or extreme return values) especially for Nzioa

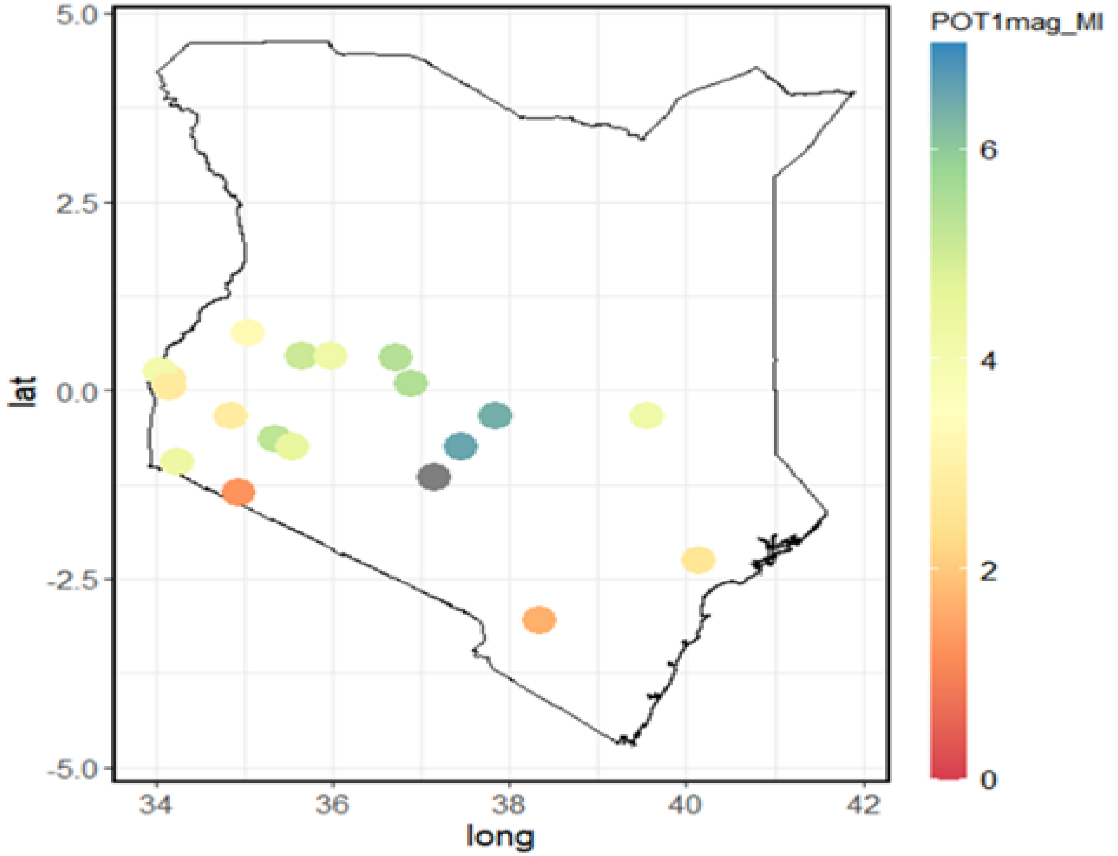
Station	Coefficient of change in time for the location parameter
Nzioa	4.88
Tana	1.36

- Coefficient is estimated to be positive and significantly different from 0 at the 5% significance level

Key Results:- Sensitivity of trends to different POTmag

Multiple Index (MI)

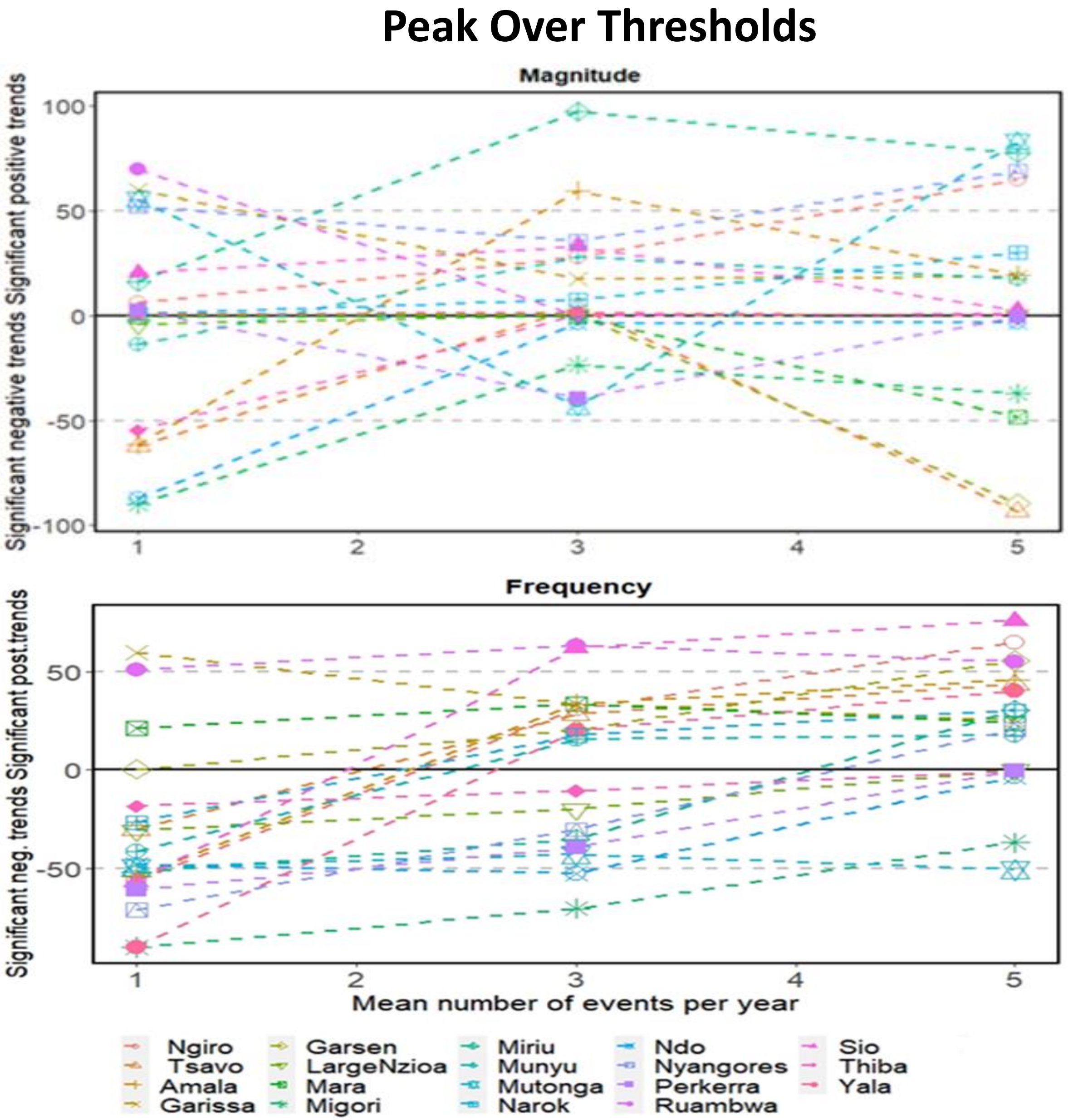




- AMAX MIs most significant, followed by the MI of the POT1mag series as well as the remaining POT series, & smallest MIs are derived for the POT6mag flood series

- MI values are relatively higher in the small sized arid and the semi-arid catchments e.g., Ewaso-Ngiro, Ewaso-Narok, Perkerra and Mara.

Key Results:- Sensitivity of trends to different POTmag



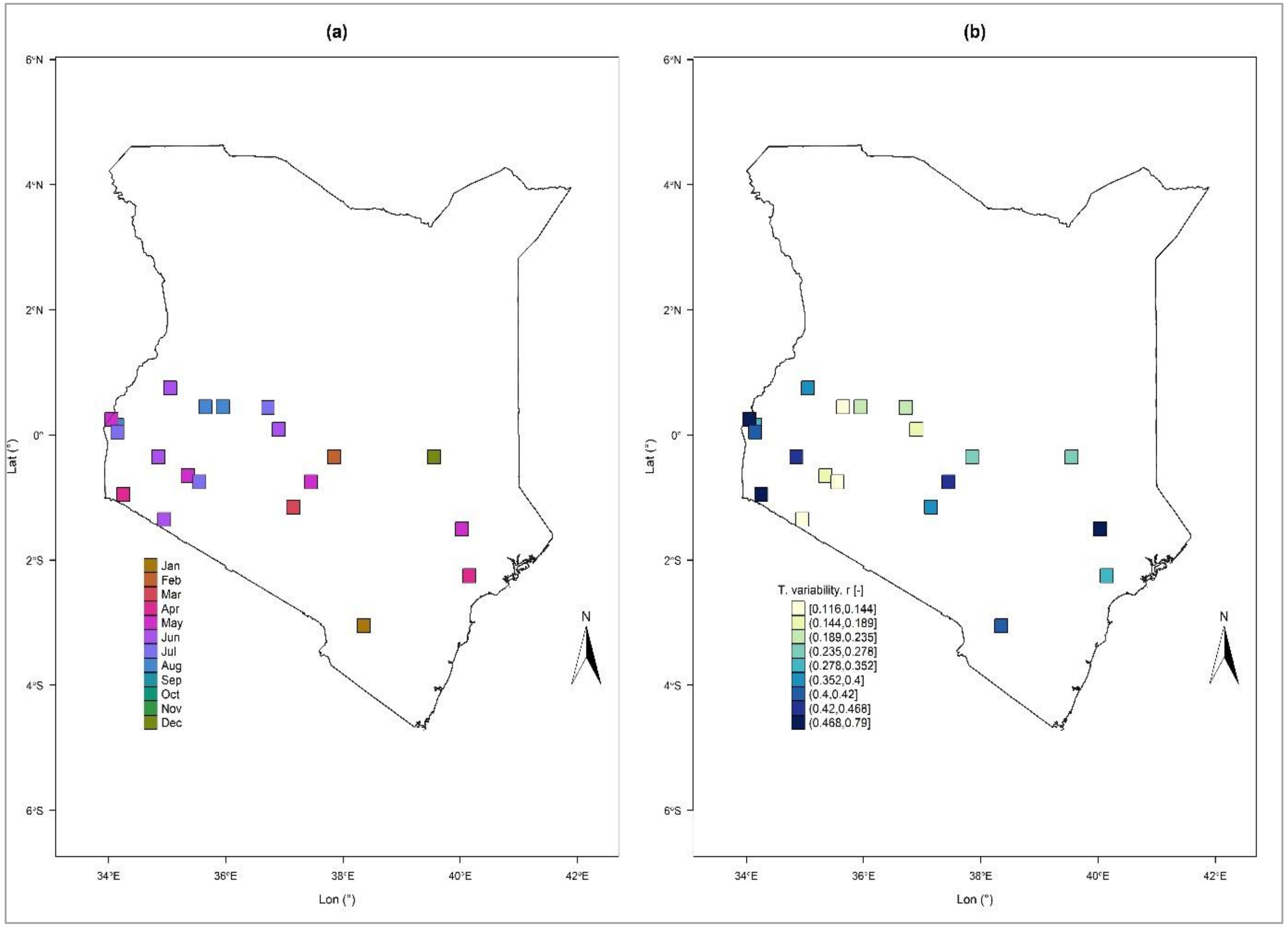
- Half of the stations show significant positive and negative trends for high λ. More than half of the stations show significant positive trends for λ = 3 and λ = 4.

- Trend results show high sensitivity to thresholds for flood frequency series.

- There are notable significant trends detected in the POTfreq series across most of the stations for increasing value of λ

Key Results:- Flood timing across Kenya

Flood timing & seasonality



Floods seasonality timing(left) and predictability (right) across Kenyan catchments

- The occurrence of the annual flood in is around the months of March, April, May, November, and December, coinciding with the occurrence of the 'long rains' (March – May) and the 'short rains' (October – December)(panel - a).

- Predictability is high (r > 0.4) in most of the stations whose annual floods occur during the short and long rains, whereas values of r < 0.4 can be seen in the stations in which the flood timing is around the dry months of June, July, and August (panel –b).

Take home

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- For both the **flood magnitude index** series, there are generally slightly more stations showing a significant positive trend than a significant negative trend
- There is a larger number of both **negative** and **positive** significant trends in the annual maximum flood series, than in the peak-over-threshold magnitude series
- The trend magnitudes may be explained in way these index series are constructed
- **Significant trends** on annual maximum values for 10 and 20 years return periods for select stations
- **High sensitivity** of the results of the trend analysis to different **exceedance thresholds** in terms of both magnitude and frequency, with the later showing higher sensitivity across the stations.
- **Predictability** is high ($r > 0.4$) in most of the stations whose annual floods occur during the short and long rains

THANK YOU FOR YOUR ATTENTION

Happy to take Your Questions & Comments

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