Comparison of Precipitation Trends and its Effect on Lake Water Levels Using Satellite Altimetry: A Case Study of Lakes Kainji and Shiroro

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Abstract

Water levels in lakes is a determinant of water availability for optimum water resources planning and ecosystem functioning. This study examines the surface water fluctuations in Kainji and Shiroro Lakes between 2008 and 2022 (14 years) using satellite altimetry. The purpose is to monitor the effect of precipitation, as an indicator of climatic variability on the water levels in the lakes considering their use for hydropower generation and flood control .From the observed values, there was no significant difference in water levels with the highest recorded at Kainji Lake as 138.84m and the lowest as 125.77m, however, there was significant difference in the area coverage with the highest value as 1311.16km^2 and lowest value as 761.15km^2.Same trend was noticed for Shiroro Lake where the highest water level was 381.92m and lowest as 356.97m; there was a marked difference in area coverage with the highest area being 361.61km^2 and lowest 104.36km^2 . A further analysis was done to assess the spatiotemporal trend of the rainfall at the Kainji and Shiroro Lakes from rainfall data derived from TAMSAT. Using Mann Kendall (MK) and Spearman's rho tests for the 14-year period, trend analysis for the Kainji Lake showed a slight positive trend for precipitation at a 5% significance level; with mean annual rainfall of 1137. 7mm.At the Shiroro Lake, there was no positive trend at a 5% significance level. The mean annual rainfall recorded was 1318.6m.

Key Words: Precipitation, Significance level, Mann Kendall, Rainfall, Trend

COMPARISON OF PRECIPITATION TRENDS AND ITS EFFECT ON LAKE WATER LEVELS USING SATELLITE ALTIMETRY:A CASE STUDY OF LAKES KAINJI AND SHIRORO

BY

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INTRODUCTION

- In all hydrological systems, precipitation (in different forms) has been found to be a major driver/component; In humid regions, water losses are usually through direct precipitation (Cretaux et al.,(2011).
- Precipitation trends help to reveal recurring patterns as well as differences that can aid in the understanding of water fluctuations, to enable proper planning and forecasting, and to ultimately prevent extreme events such as droughts and floods as a result of climate change.
- Lakes on the other hand are viewed as perfect proxies for climate change and their monitoring has aided in observing trends that has helped in the understanding of climatic parameters (Cretaux et al.,(2006). This monitoring has been made possible since 1993 by the use of satellite altimetry with the introduction of the Topex/Poseidon, Jason 1,2 and 3 missions where pulses are sent to lake water surfaces from radar altimeters and the height difference is measured.
- The Kainji dam is the largest of the dams on the River Niger, the Shiroro Lake was created from the River Kaduna, which is a tributary of the River Niger. The Lakes Kainji and Shiroro were created for the purpose of hydro-electric power generation, flood control and fishing, these purposes have not been fully achieved due to water fluctuations in the lakes, hence this study.
- The lake water levels should not be confused with the depth as the Lake water level is measured in relation to a reference point; usually the mean sea level which is taken as 0
- The choice of the two lakes is due to their similarities based on their usage for hydropower generation. Their differences based on their sources and their sizes were also reasons for comparison to determine if there are unique climatic controls on water level fluctuations in the two lakes

THE STUDY AREA

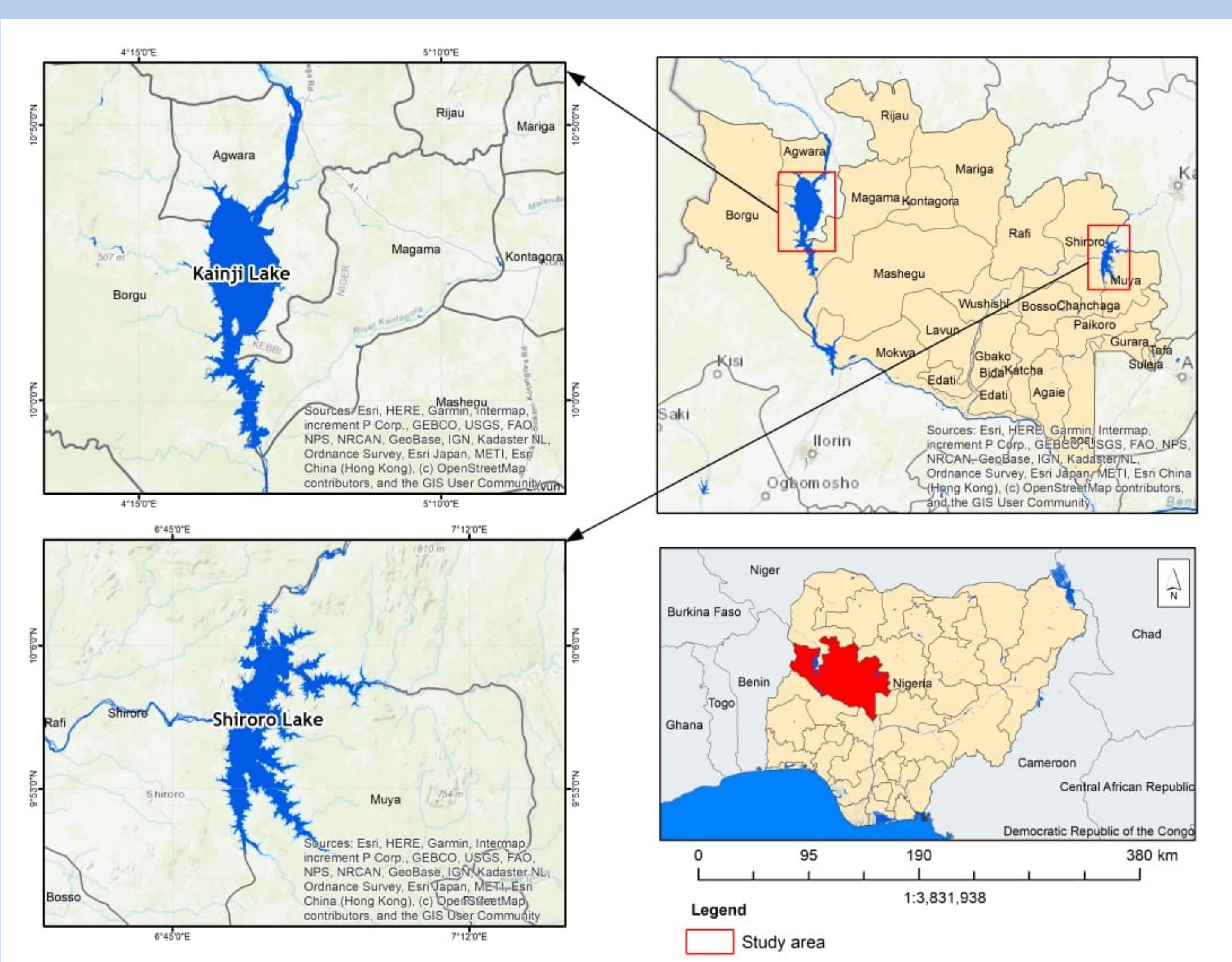

Fig 1: Lakes Kainji and Shiroro, North Central Nigeria

METHODOLOGY

- Rainfall data for Lakes Kainji and Shiroro were obtained from Tropical Applications of Meteorology using SATellite and ground-based observations (TAMSAT).A trend analysis (Mann Kendall was performed using the Excel Stat software 2023 to determine if there were positive trends in the rainfall data.
- The Mann Kendall is a non-parametric test which involves accepting an alternative hypothesis (H_a) which indicates the presence of a monotonic trend and rejecting the null hypothesis, (H_o) which indicates that no monotonic trend was present.
- The processed data for Lake Water Levels for the 14 year period was derived from hydroweb, the satellite tracks where the data was obtained for Lake Kainji are :Topex Poseidon, Jason 2,3 and sentinel 6A on track 135 respectively.Envisat and saral altika on track 874 respectively.(see fig 3)For Lake Shiroro, it was obtained from Jason 2,Jason 3 and sentinel 6A on track no 20 respectively. The water levels data collected were averaged into yearly data for the 14year period.

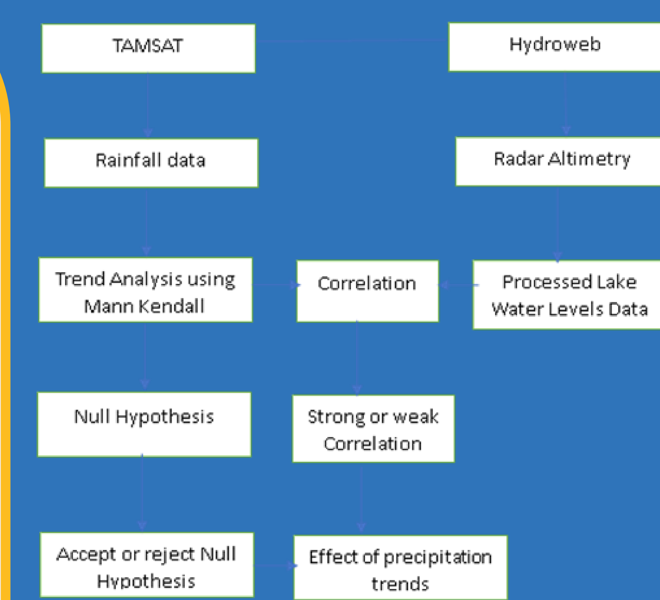

Fig 2:Work flow for the study

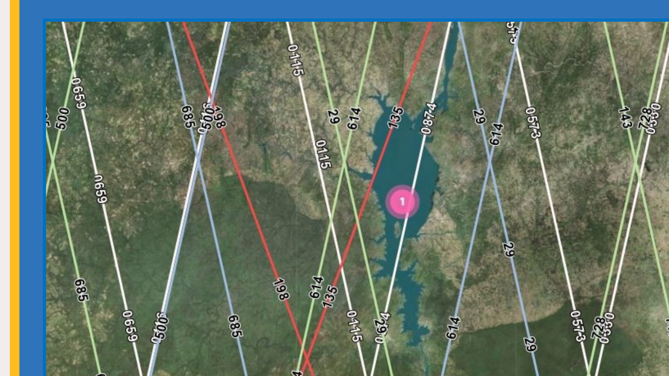

Fig 3:Radar altimetry tracks for Lake kainji

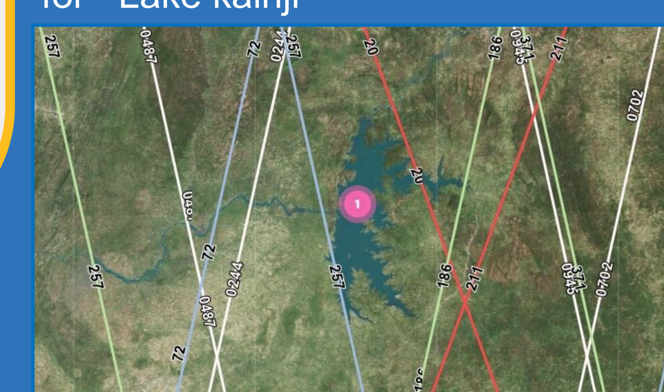

Fig 4:Radar altimetry tracks for Lake Shiroro

RESULTS

- From the trend analysis, the null hypothesis was accepted albeit a slight positive trend for Lake Kainji was noticed from the Sen's slope estimator with a positive Z value for Kendall's tau (see fig 8a).The same trend was noticed for the Lake water levels, as the null hypothesis was also accepted, with a slight positive trend noticed from the Sen's slope estimator. For Lake Shiroro, the Null hypothesis was also accepted with no positive trend noticed and a negative Z value (see fig 8b) Correlation analysis between rainfall and Lake water level showed a very weak correlation for Lake Kainji and a weaker relationship was seen for lake Shiroro.
- The slight positive trend for Lake Kainji might be as a result of the Lake being an endorheic Lake. Endorheic lakes are usually shallow as in this case and they are largely affected by inflow parameters such as rainfall, temperature, hence they are strong indicators for climate change.

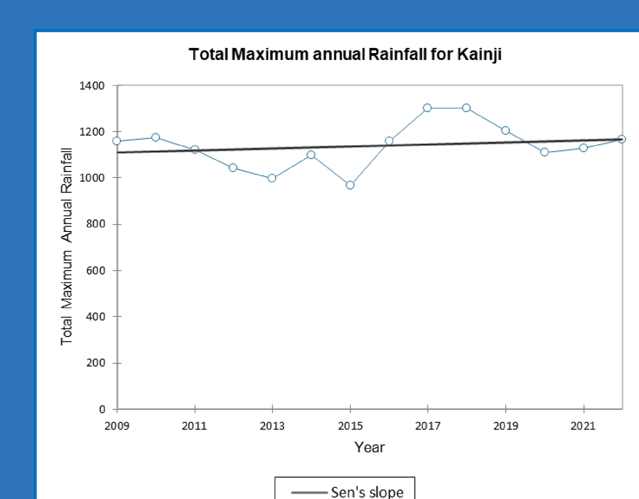

Fig 5:Sen's slope graph for rainfall at Lake Kainji (Note positive trend)

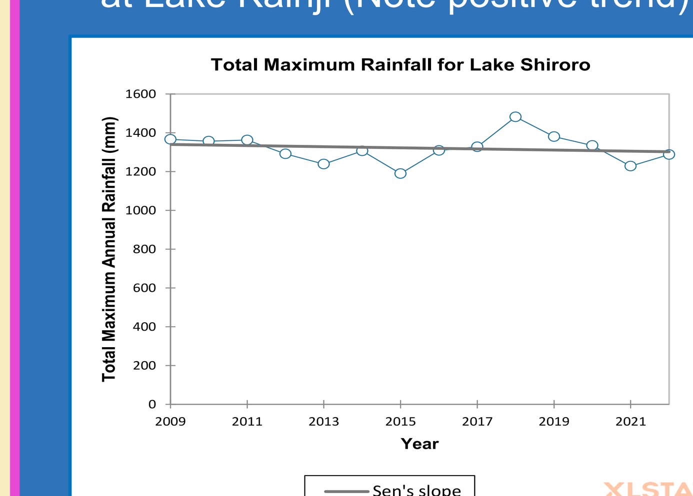

Fig 6 :Sen's slope graph for rainfall at Lake Shiroro (Note negative trend)

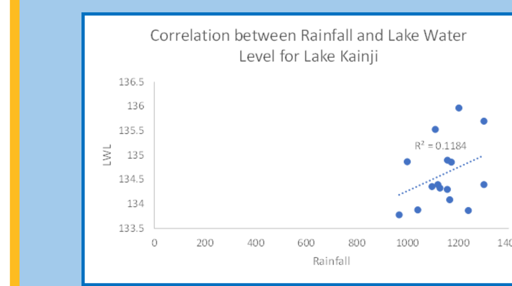

Fig 7:Correlating Rainfall and LWL for Lake Kainji

Kendall's tau	0.155
S	14
Var(S)	332.667
p-value (Two-tailed)	0.476
alpha	0.05

Fig 8a

Kendall's tau	-0.121
S	-11
Var(S)	333.667
p-value (Two-tailed)	0.584
alpha	0.05

Fig 8b

Kendall's tau	0.133
S	12
Var(S)	332.667
p-value (Two-tailed)	0.546
alpha	0.05

Fig 8c

Kendall's tau	-0.209
S	-19
Var(S)	333.667
p-value (Two-tailed)	0.324
alpha	0.05

Fig 8d

Figs 8a and8b :Summary statistics (Mann Kendall) for rainfall in Lakes Kainji and Shiroro respectively

8c and 8d:Summary statistics (Mann Kendall) for LWL in Lakes Kainji and Shiroro respectively

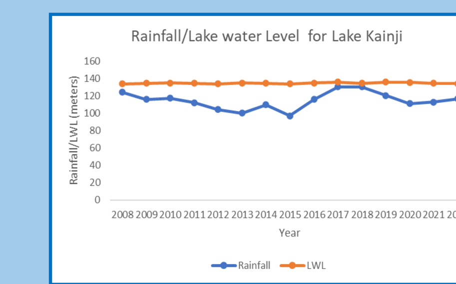

Fig 9: Rainfall and LWL plot for Lake Kainji

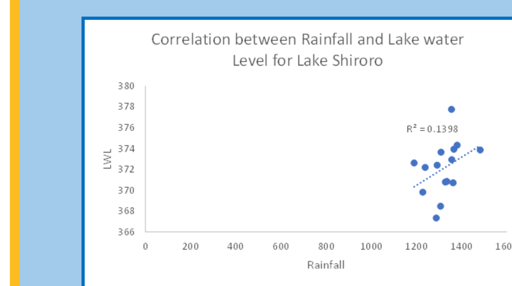

Fig 10:Correlating Rainfall and LWL for Lake Shiroro

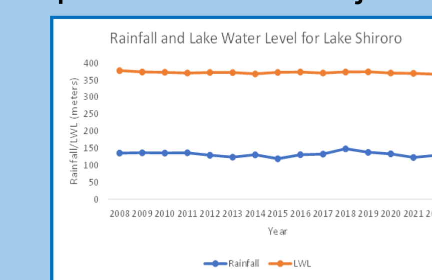

Fig11: Rainfall and LWL plot for Lake Shiroro

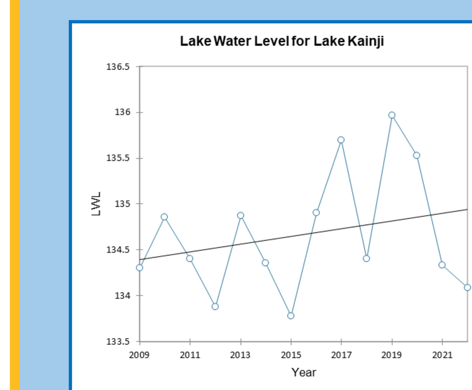

Fig 12:Sen's slope graph for LWL at Lake Kainji (note positive trend)

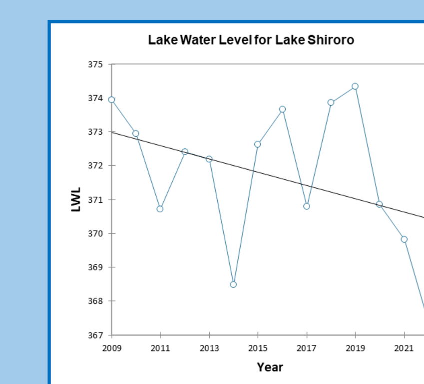

Fig 13:Sen's slope graph for LWL at Lake Shiroro (Note negative trend)

CONCLUSION

The effects of precipitation trends on Lake water levels for Lakes Kainji and Shiroro are similar albeit with a slight difference for Lake Kainji where there is a slight positive trend. Validation with insitu data can provide more insights into the dominant climatic and hydrological factors that affect the lake water levels. This further investigation is more recommended for Lake Kainji which is a shallow lake and a slight positive trend was noticed for the slope of rainfall and Lake water level during the trend analysis conducted.

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