SAF-ADAPT

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RESEARCH BRIEF
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Mapping and Assessing Riparian Vegetation Response to Drought along the Buffalo River Catchment in the Eastern Cape Province, South Africa

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INTRODUCTION

Climate predictions forecast an increase in the frequency, duration, and severity of drought. Organisations such as the World Meteorological Organization (WMO) and the Centre for Research on the Epidemiology of Disasters (CRED) emphasise the severity of these climatic shifts as well as their implications for ecosystems, water resources, and human communities. Riparian vegetation - crucial for ecosystem regulation, rehabilitation, and pollution control - faces threats due to the anthropogenic impacts of increased drought frequency, intensity, and duration. This is particularly concerning in semi-arid regions where riparian vegetation controls the flow and effect of water as well as the transportation and deposition of sediments.

Understanding how riparian vegetation responds to drought is vital for effective conservation and water management practices, particularly in semi-arid environments such as the Buffalo River catchment in South Africa's Eastern Cape Province. Recent droughts in the region have adversely affected riparian vegetation and ecosystem health due to its aridity and hydrological complexity. However, comprehensive assessments of riparian vegetation dynamics at the micro-scale which account for topographic complexities, are lacking.

To address these gaps, this study integrates advanced multi-modal drought-related vegetation indices - including the Normalised Difference Vegetation Index (NDVI), Transformed Difference Vegetation Index (TDVI), and Modified Normalised Difference Water Index (MNDWI) - from Landsat and hydro-meteorological variables (precipitation and streamflow). These indices are used to analyse riparian vegetation change along the Buffalo River from 1990 to 2020 and the findings aim to inform future strategies for preserving riparian vegetation.

PROJECT SUMMARY

This study examined long-term drought trends in riparian vegetation cover from 1990 to 2020, focusing on the role of precipitation and streamflow. The results indicate that changes in riparian vegetation were primarily associated with reduced streamflow, although some areas showed precipitation variations due to drought.

KEY FINDINGS

- The study highlights the **frequency and severity of droughts** in the area, providing data to support provincial drought monitoring and risk assessment systems.
- NDVI and TDVI were **significant indices for detecting water-stressed vegetation** in river catchments.
- A moderate positive **correlation was found between precipitation and streamflow**. Precipitation increased significantly with little effect on vegetation trends, whereas streamflow had a more pronounced impact.
- The study **revealed inter-annual and inter-seasonal variations in drought stress**, demonstrating the dynamic and resilient nature of riparian ecosystems.
- Findings can guide policymakers on disaster preparedness and response, emphasising the **importance of managing recurrent drought in river ecosystems effectively**.

RESULTS

RIPARIAN VEGETATION DYNAMICS

Significant inter-catchment variations in riparian vegetation were observed along the Buffalo River between 1990 and 2020. TDVI values range from 0.59 to 0.7, with notable declines from 2015 to 2020. NDVI also exhibited decreased vegetation cover, particularly evident in the middle and lower reaches of the catchment. MNDWI analysis revealed extensive drought impact on water bodies, affecting dams, lakes, and streams.

PRECIPITATION, STREAMFLOW, AND VEGETATION TRENDS (1990 - 2020)

Analysis of precipitation data from 1990 to 2020 revealed wave-like precipitation fluctuations, possibly linked to the El Niño/Southern Oscillation (ENSO). Positive correlations were found between shorter-term precipitation and vegetation indices, while longer-term precipitation decreases were associated with reduced vegetation health. Streamflow dynamics clearly influenced vegetation trends, especially during dry years, underscoring the catchment's dependency on water availability for vegetation health.

STANDARDISED PRECIPITATION INDEX (SPI) PATTERNS

SPI analysis at three time scales (3, 6, and 12 months) identified drought patterns, revealing that dry years were associated with negative SPI values which impacted riparian vegetation health. Correlation analyses between SPI and vegetation series (NDVI, TDVI, MNDWI) revealed varying relationships, with longer-term drought indices showing stronger negative correlations with vegetation health. However, higher rainfall in wetter years did not necessarily equate to higher vegetation series, indicating spatially heterogenous rainfall distribution as well as natural variability in streamflow patterns.

METHODS

The Buffalo River catchment is situated in South Africa's Eastern Cape Province. Draining through the Buffalo River which enters the Indian Ocean in East London, the catchment has an average elevation of 1200 meters above sea level and its geology primarily comprises of marine sediments from the Beaufort Series. The catchment's landscape ranges from mountainous regions with forests to plains, with average minimum and maximum temperatures spanning from -3°C to 38°C respectively.

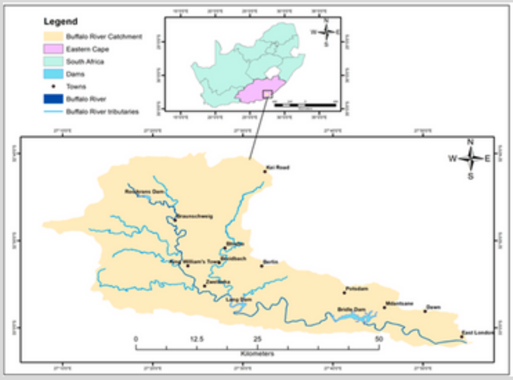

Figure 1. Map of Buffalo River catchment showing dams and its tributaries in the Eastern Cape Province, South Africa.

Satellite imageries from Landsat were used to measure the impact of drought on riparian vegetation changes along the Buffalo River catchment between 1990 and 2020 at a resolution of 30m. This was used in combination with Standardized Precipitation Index (SPI) values and streamflow data. NDVI, TDVI, and MNDWI were used to analyse the spatial and inter-annual characteristics of riparian vegetation's response to drought. The degree of correlation between the variables was determined by evaluating annual precipitation and streamflow.

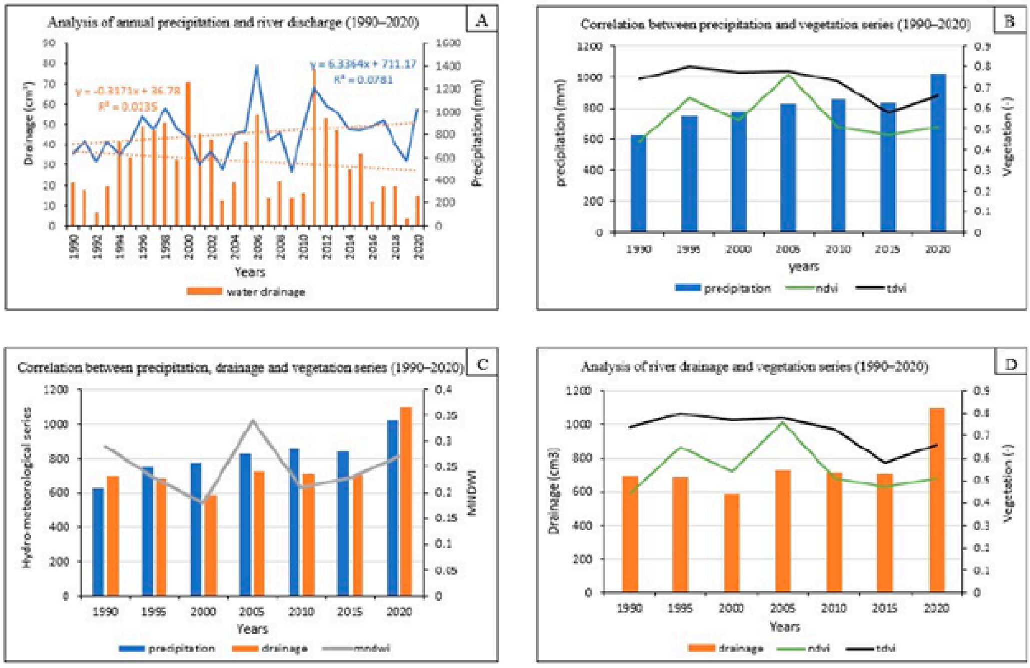

Figure 2. Correlation analysis between annual precipitation, streamflow, and vegetation between 1990 and 2020

Table 1 (A - C). Summary statistics results (1990 - 2020)

(A)

Variables	Precipitation	Streamflow	NDVI	TDVI	MNDWI
Precipitation	1				
streamflow	0.77	1			
MNDWI	0.58	0.55	1		
NDVI	0.13	0.47	0.48	1	
TDVI	0.24	0.18	0.71	0.48	1

(B)

	Precipitation and Streamflow	Precipitation and NDVI	Precipitation and TDVI	Precipitation and MNDWI
Coefficient (r):	0.77	0.58	0.47	0.24
N	7	7	7	7
T statistic	2.70	1.59	1.18	0.56
DF	5	5	5	5
p value	0.04	0.17	0.29	0.60

(C)

	Streamflow and NDVI	Streamflow and TDVI	Streamflow and MNDWI
Coefficient (r):	0.55	0.47	0.18
N	7	7	7
T statistic	1.49	1.18	0.41
DF	5	5	5
p value	0.20	0.29	0.70

DISCUSSION

HYDRO-METEOROLOGICAL INFLUENCE ON CLIMATE-RELATED VEGETATION SERIES

The study assessed riparian vegetation response to drought using multimodal drought related vegetation indices and hydro-meteorological data from 1990 to 2020. The vegetation series demonstrated clear spatial characteristics of drought in response to hydro-meteorological variations.

TDVI proved more sensitive than NDVI in detecting riparian vegetation change along the catchment. Reduced streamflow influenced vegetation changes, with dry seasons being largely influenced by inter-annual and inter-seasonal climate variability. Within the context of hydro-meteorological factors, precipitation and streamflow are identified as the primary drivers of riparian vegetation health.

Therefore, when one of these factors deviate from standard values, riparian vegetation can become stressed, leading to a decline in plant productivity. Vegetation did, however, demonstrate adaptive capacity in being able to recover under favourable conditions after prolonged periods of drought. This phenomenon was particularly prevalent in the upper reaches of the catchment. That being said, recurrent droughts adversely impacted agricultural resources and ecosystem resilience.

SPI DROUGHT CLASSIFICATION PATTERNS BETWEEN 1990 AND 2020

During the study period, some years experienced above-average rainfall, indicating positive SPI values which correspond to increased streamflow. The reverse was true of dry years. Positive SPI values correlated with increased streamflow and vegetation, while negative values indicated drought impacts. NDVI and TDVI showed a moderate positive relationship at different time scales, emphasising the influence of precipitation on vegetation dynamics. Higher-resolution data and larger datasets could enhance ecological process differentiation and the understanding of hydro-meteorological-vegetation relationships. Remote sensing-based models are recommended for further research to inform monitoring and management strategies.

CONCLUSION

This study assessed the long-term drought trends in riparian vegetation cover and the role of precipitation and streamflow between 1990 and 2020. Results suggest that changes in riparian vegetation were primarily linked to diminishing streamflow, although certain areas did experience variations in precipitation due to drought. The major conclusions are as follows:

- NDVI and TDVI were significant indices for detecting water-stressed vegetation in river catchments.
- There is a moderate positive correlation between precipitation and streamflow. Precipitation increased significantly with little influence on vegetation trends while the reverse is true for streamflow.
- Inter-annual and inter-seasonal variations in drought-stress highlight the dynamic and resilient nature of riparian ecosystems.
- This study provides valuable insights into the frequency and severity of droughts in the study area and results can be used to inform a provincial drought monitoring and risk assessment system.
- The assessment of drought disaster can inform guidelines for policymakers on disaster preparedness and response, underscoring the importance of effectively managing recurrent drought in river ecosystems.

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