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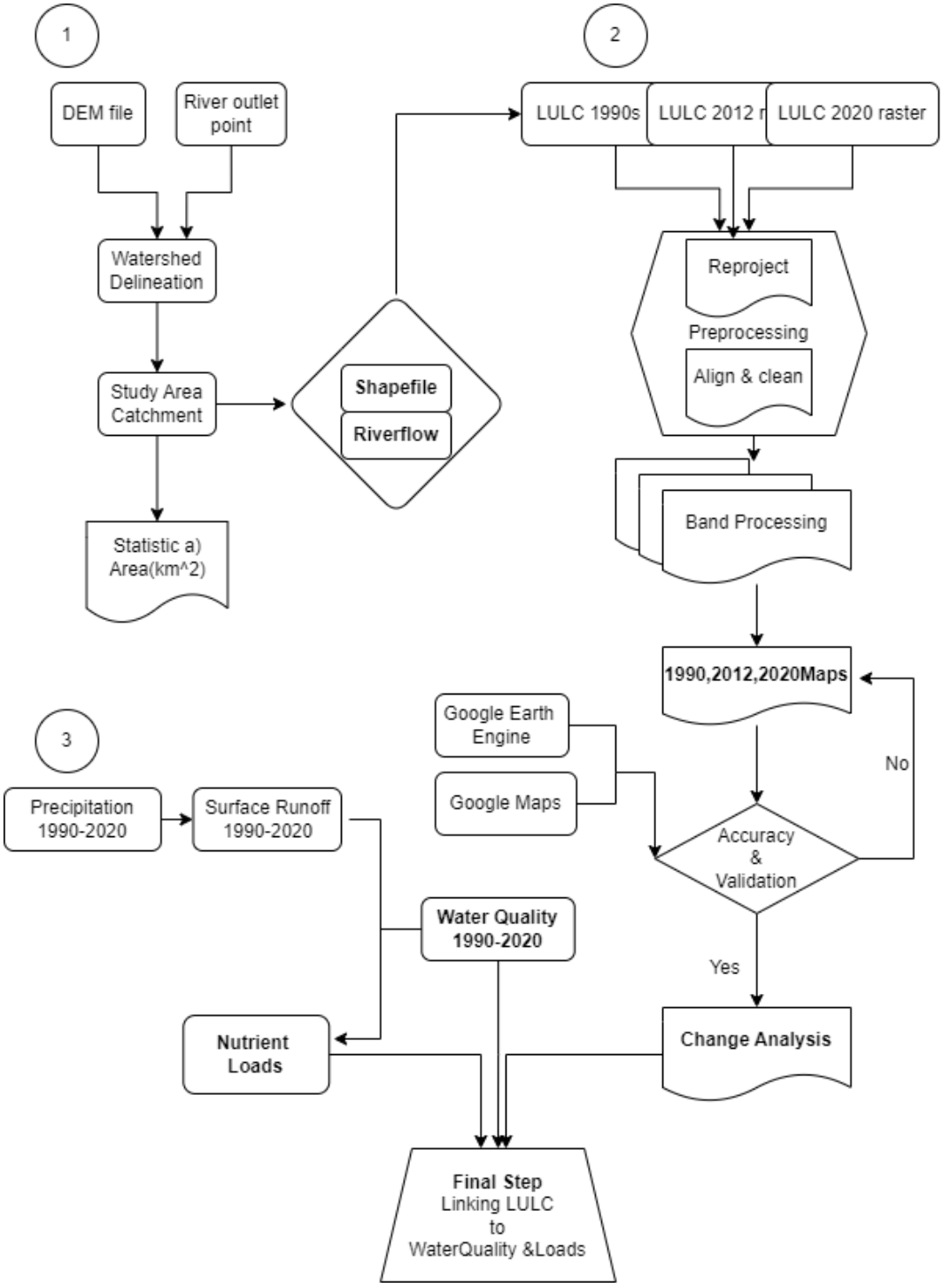
Introduction

Water quality degradation due to commercial agricultural activities is a global concern, particularly in arid regions. Under such climate conditions and increased population, irrigation is essential for crop production and food security. Agricultural fields alter the hydrological processes of water infiltration and runoff, facilitating the transfer of nutrients into the water bodies. Nutrient pollution from such sources is termed nonpoint source pollution (NPS). High sediment and nutrient concentrations are highlighted as the main problem in water streams and originate from agricultural landscapes. Due to change in land policies in late 1994, the threat of the Land Use Land Cover change (LULC) may have impacted water quality in the Orange River basin. However there is limited research or policy intervention.

Methodology

Fig 1.



Study area

To define the area of study for which the pollutant loads are calculated, the extent of the watershed was needed. The outlet point and DEM file were considered for a watershed delineation. The size of the study areas depends on the delineated watershed. The watershed for

the Richie Klipdrift water monitoring station (Lat -29.42, Long 24.6) was then delineated using a DEM file and selected as a case study for agricultural land use change analysis and its relation to water quality to represent the entire basin. The total surface area of the study area is 27,016.18224 km2 and covers the Riet River and the Modder River. The area covers two different rivers, Riet and Modderriver. The watershed consists of four water monitoring stations, two of which are in the study area's upper and lower sections. The positions of the stations gave the perfect overview and assumption of the water quality situation in the upper and lower Orange River basin.

Fig 2.

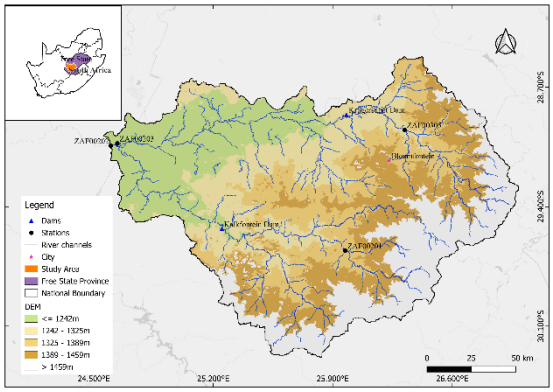


Figure 1. Type your title here.

Description:

This figure illustrates the delineated study area (Riet-Modder River) watershed. The study area is situated in the lower Orange River basin in Free State Province. It consists of four water monitoring stations (ZAF00201, ZAF00202, ZAF00203, and ZAF00305) and key land cover features (Bloemfontein city and Dams) that may influence the nutrient concentrations in the area.

Results

Fig 3.

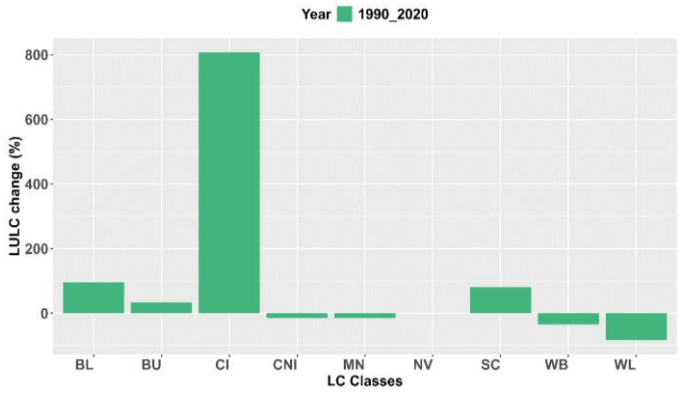
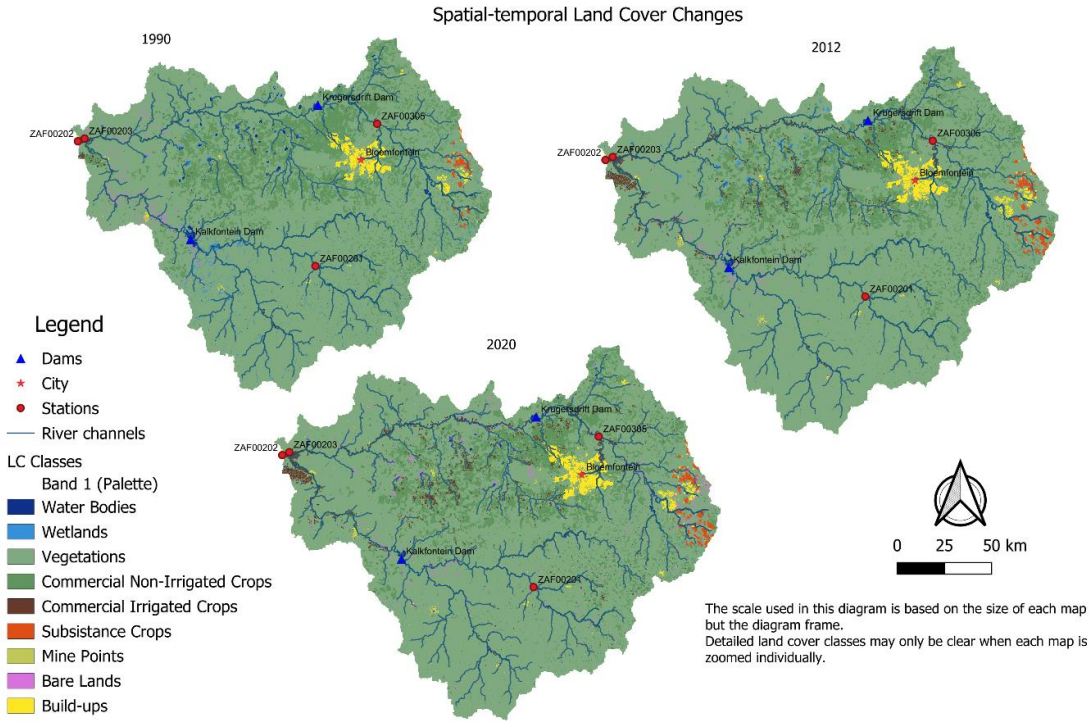


Fig 4.



Description:

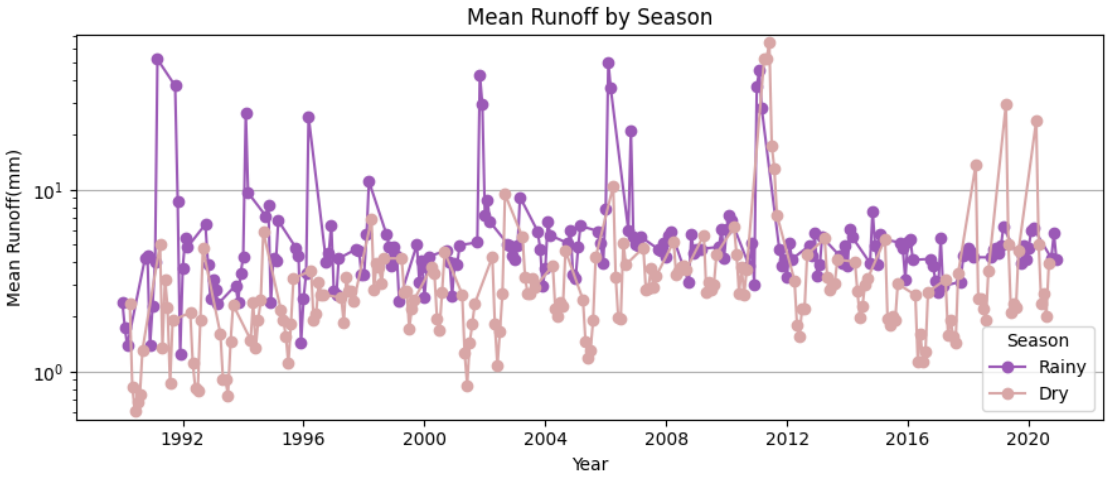
The bar chart (Fig3) illustrates the percentage change in Land Use Land Cover (LULC) classes between 1990 and 2020 while Fig 4 shows the spatial temporal land cover distribution over the study period. The LULC classes include BL (Bare Land), BU

(Built-Up), CI (Cropland/Intensive Agriculture), CNI (Cropland/Non-intensive Agriculture), MN (Mangroves), NV (Natural Vegetation), SC (Shrubland/Grassland), WB (Water Bodies), and WL (Wetlands).

Observations:

- Commercial Irrigated land shows the most significant increase, with a dramatic rise of approximately nine folds. This suggests a major expansion of agricultural activities, probably driven by climate change and increased demography. A notable increase in subsistence croplands was evidenced, which indicates the impacts of land reforms on local communities.
- Water bodies and wetlands exhibited negative changes, indicating a reduction in these vital ecosystems over the study period. This decline could be attributed to increased agricultural lands and climate change.

Fig 5.



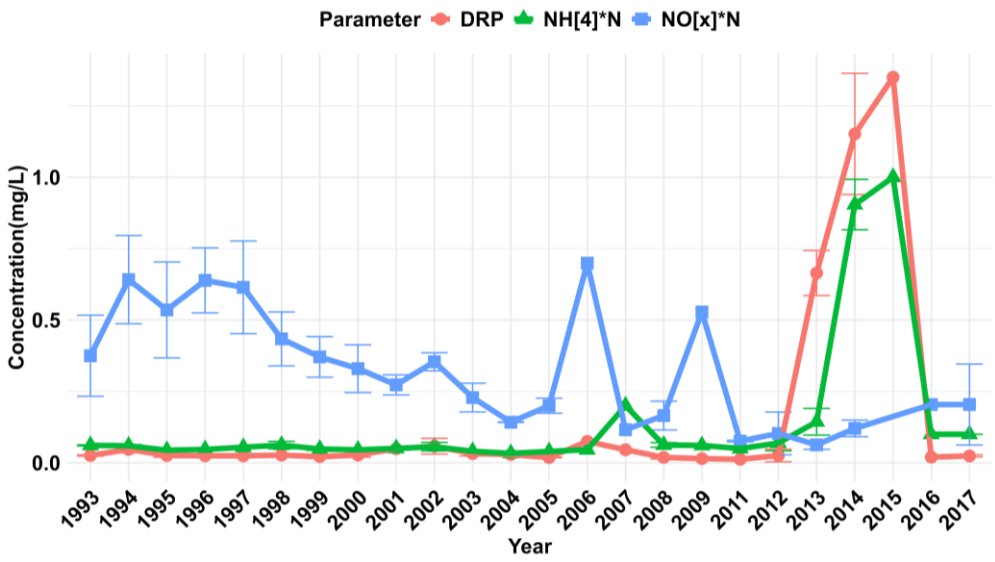
Description:

The line graph shows seasonal variation in mean runoff for winter (dry) and summer (rainy) seasons from 1990 to 2020.

Observations:

- Rainy season runoff exhibited significant peaks in specific years, such as 1992, 2004, and 2012, indicating extreme weather events or heavy rainfall.
- Dry season remained relatively low throughout the period but showed occasional spikes, likely due to hydrological changes or changes in water management practices.
- Changes in discharge/runoff likely influences the nutrient loads and concentrations in a river system.

Fig 6.



Description:

The line chart tracks the concentrations of Dissolved Reactive Phosphorus (DRP), Ammonium Nitrogen (NH_4-N), and Nitrate/Nitrite (NO_x-N) from 1993 to 2020. Error bars represent standard deviations.

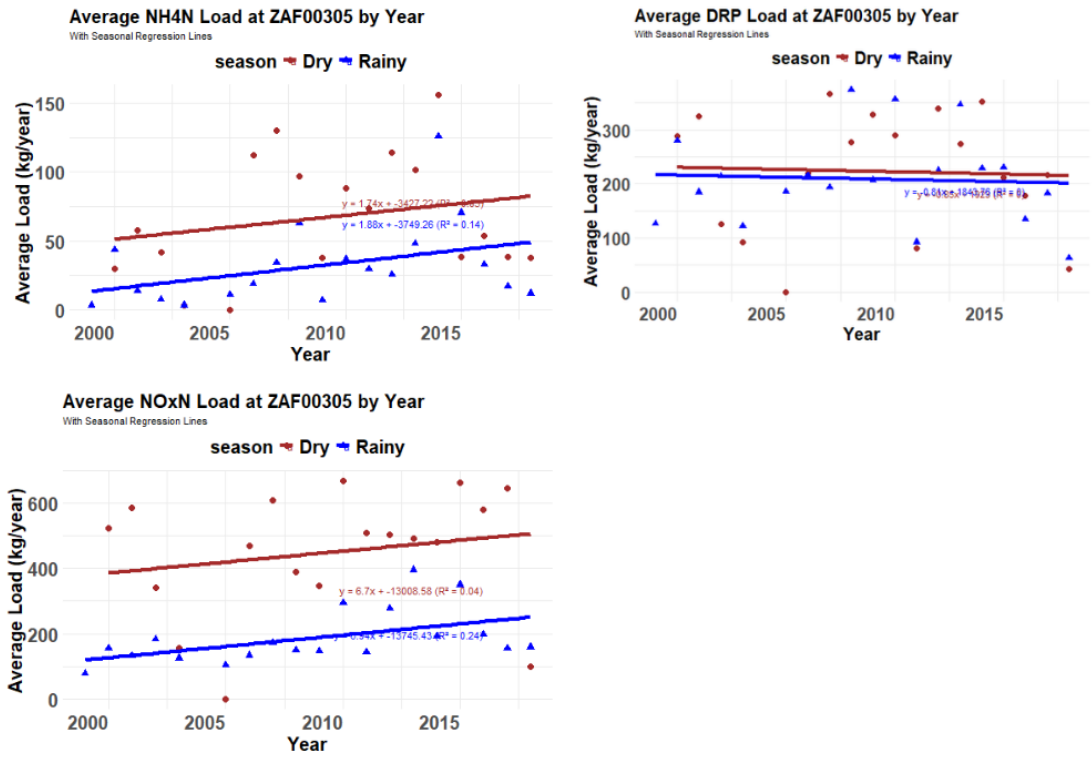
Observation:

- NO_x-N concentrations declined from 1993 to 2008 but exhibited sharp spikes in subsequent years. The fluctuations may reflect shifts in nitrogen management practices, especially in fertilizer management.

- NH_4-N concentrations were relatively low throughout but notably increased between 2013 and 2016.
- DRP levels were consistently low, with a sharp rise after 2013.

The trends suggest potential agricultural practices or wastewater management changes influencing nutrient loads. Based on the Mann Kendell test analysis, NO_x-N concentrations and load trends reduced over the study period while NH_4-N and DRP increased.

Fig 7.



Description:

Fig 7 illustrate the nutrient hotspot in the Riet-Modder River watershed at the monitoring station adjacent to the Bloemfontein city based on loads concentrations.

Observation:

- NH_4-N, NO_x-N and DRP showed the highest concentration at ZAF00305 compared to the other three stations under study.
- Nutrient concentrations at this station were higher in winter seasons than in summer seasons.
- NO_x-N and DRP concentrations at this station were higher than the standard concentrations recommended by the Department of Water and Sanitation (DWS).

This hotspot may suggest the influence of urban wastes and snow melt on the spike of nutrient concentrations.