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Comment on The Spatiotemporal Analysis of Rainfall Variability in the Sana'a Basin, Yemen: An Integrated Remote Sensing and GIS Approach

Khaled Ismail M. Al-Shami and Abdulla A. Noman

Water and Environment Center, Sana'a University, Sana'a, Yemen

*Corresponding author: mrwan87@yahoo.com

1. INTRODUCTION

I read with great interest the recently published paper by Quriaa et al [1]. (2026) on the spatiotemporal analysis of rainfall variability in the Sana'a Basin. While the authors tackle a critically important topic for Yemen's water security, a rigorous methodological review reveals foundational errors that compromise the reliability of the study's results. This comment focuses on two primary fatal flaws: (1) a severe physical and temporal impossibility regarding the utilization of the Tropical Rainfall Measuring Mission (TRMM) dataset and (2) an inadequate statistical approach to handling missing data through mean imputation. As established by Little and Rubin (2019), mean imputation artificially underestimates variance, distorts the probability distribution of the dataset and erases natural statistical covariance [2]. In hydrological modeling, this bias is particularly severe because it dampens extreme events, such as hyper-arid spells and localized flash floods [3]. In a basin characterized by high spatial heterogeneity, where orographic lifting dictates precipitation, these flaws systematically misrepresent the true spatiotemporal rainfall patterns. This comment outlines these limitations and provides explicit technical recommendations for their correction.

2. THE PHYSICAL AND TEMPORAL IMPOSSIBILITY OF TRMM DATA (2015–2024)

The authors explicitly state in their methodology that they utilized TRMM satellite precipitation products to drive or validate their spatial mapping for the continuous period from 2010 to 2024. This assertion introduces a direct physical impossibility. According to official technical documentation from the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA), the TRMM spacecraft ceased data collection in April 2015 and re-entered the Earth's atmosphere on June 15, 2015 [4]. Therefore, no physical TRMM data were available for 2015–2024. Mapping a continuous spatiotemporal rainfall trend up to 2024 using a decommissioned satellite platform represents a severe data provenance error. Blending disparate satellite grids without formal cross-calibration alters spatial rainfall gradients and artificially shifts the apparent wet/dry boundaries across sub-basins.

Recommendation for Correction:
To correct the satellite timeline while preserving a continuous, high-resolution 2010–2024 temporal scope, spatial analysis should transition entirely to the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) dataset. CHIRPS features a high spatial resolution (0.05 ° × 0.05 °), making it exceptionally well-suited for capturing the complex orographic rainfall patterns of the Sana'a Basin. Local empirical evidence confirms this adjustment, as demonstrated by Al-Falahi et al. (2020) in regional hydroclimatic evaluations across the highland regions of Yemen. CHIRPS exhibits a superior ability to capture local convective mechanisms and offers gridded rainfall estimates that align closest with actual ground-station observations [5].

3. METHODOLOGICAL FLAWS IN MISSING DATA HANDLING: THE FAILURE OF MEAN IMPUTATION

To address the data scarcity common in conflict-affected regions, the study under review resorted to the "mean imputation" method, replacing missing gauge records with the average rainfall from the same station or from nearby locations. Although simple, applying mean imputation to spatiotemporal climate data introduces a catastrophic statistical bias. As established by modern statistical missing-data theory (Little & Rubin, 2020), mean imputation artificially reduces the natural variance of the dataset, truncates the frequency of extreme events and destroys spatial covariance [2]. In the arid and semi-arid terrain of the Sana'a Basin, precipitation is heavily driven by isolated, convective, and high-intensity episodic storms. By smoothing these convective peaks into a historical average, spatial interpolation models (e.g., IDW or Kriging) generate highly distorted maps that over-stabilize the spatial water balance.

Recommendation for Correction:

To preserve the true variance and extreme variations characteristic of the region, mean imputation must be discarded in favor of modern stochastic or model-based gap-filling frameworks using:

- Multiple Imputation by Chained Equations (MICE) models missing values by capturing the joint spatial distribution of neighboring stations, drawing simulated values from a predictive distribution that preserves the natural variance and spatial covariance matrix of the rainfall field.
- Alternatively, data gaps can be filled using highly localized gridded products such as Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data, which are specifically built for complex terrains and blend station observations with satellite imagery to maintain accurate daily and monthly spatiotemporal rainfall patterns.

4. SUMMARY OF METHODOLOGICAL DISCREPANCIES AND RECONSTRUCTIVE FIXES

Section / Flaw	Impact on Spatiotemporal Rainfall Interpretation	Recommended Technical Remedy
TRMM Misapplication (2015–2024)	Introduces uncalibrated multi-satellite data shifts, distorting the long-term precipitation gradients across subbasins.	Replace TRMM with a continuous 2010–2024 CHIRPS dataset, leveraging its validated proximity to observed Yemeni gauge data (Al-Falahi et al., 2020).
Single Mean Imputation	Artificially flattens convective storm peaks and hyperarid spells, leading to homogenized, unrealistic spatial rainfall distributions.	Replace with Multiple Imputation (MICE) or space-time Kriging conditioned on the CHIRPS background matrix to preserve extreme patterns.
Trend Quantification	Inaccurate statistical variance overstates the significance (p-values) of computed temporal trends.	Re-run the Mann-Kendall trend tests and Sen's slope estimators strictly on the newly reconstructed, high-variance dataset.

5. CONCLUSION

In conclusion, while the structural intentions of Quriaa et al. (2026) are commendable for filling regional data gaps, the baseline inputs of their model suffer from a critical physical anomaly and an oversimplified data-reconstruction strategy. In a highly sensitive, water-stressed basin, such as Sana'a, relying on smoothed variances and misaligned satellite timelines can lead to fundamentally flawed water management policies and incorrect engineering designs for flood protection or artificial recharge structures. We urge the authors to clarify their data sources, apply the recommended cross-calibration and stochastic imputation techniques, and re-evaluate their spatiotemporal rainfall dynamics to ensure a scientifically defensible foundation for basin water resource planning.

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