



Spatio-temporal dynamics of meteorological and agricultural droughts: A multi-seasonal analysis of Vegetation Health and Climate Indices Using Google Earth Engine

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Abstract

Seasonal analysis of VCI, TCI, VHI, and SPI reveals that vegetation health is driven more by accumulated soil moisture and thermal stress than by immediate rainfall, as consistently low SPI correlations (≤ 0.50) suggest. The monsoon season produced the strongest vegetation coupling (VCI-VHI: 0.91), and pre-monsoon VCI proved a reliable predictor of winter conditions ($r = 0.98$), supporting nine-month-ahead drought forecasting for water resource and agricultural planning.

Introduction

The purpose of the research is to assess drought dynamic in Imphal-Nambul River Sub-basin using multi source remote sensing data. The research objective is to quantify seasonal agricultural and meteorological drought over the study period and analyze the key factors on drought event.

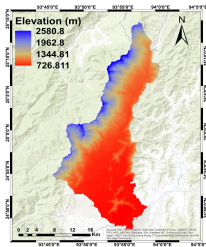


Fig. Elevation map of the study location

Data and method

Data	Source
CHIRPS	https://app.climateengine.org/climateEngine
Sentinel-2	https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S2_SR_HARMONIZED
Landsat-8	https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LC08_C02_T1_L2

$$VCI = \frac{EVI_i - EVI_{min}}{EVI_{max} - EVI_{min}} \times 100$$

Where, EVI_i is the value for a certain period
 EVI_{max} and EVI_{min} are the max. and min. values for whole time series data of EVI
 LST_{max} and LST_{min} are the max. and min. values for whole time series data of LST

$$TCI = \frac{LST_{max} - LST}{LST_{max} - LST_{min}} \times 100$$

$$VHI = 0.5 \times VCI + (1 - 0.5) \times TCI$$

$$SPI_{ijk} = \frac{P_{ijk} - \bar{P}_{ij}}{\sigma_{ij}}$$

Results

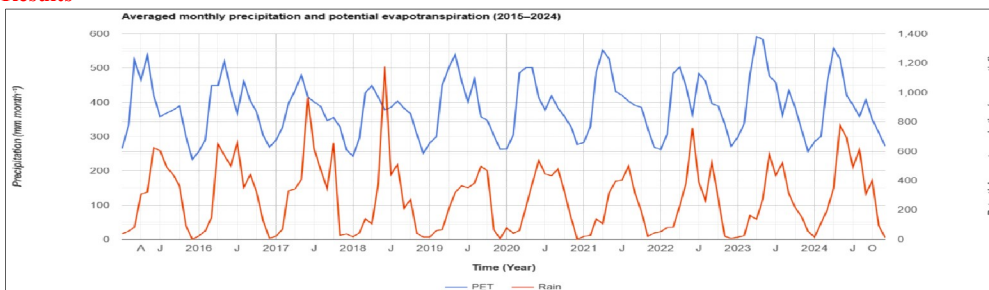
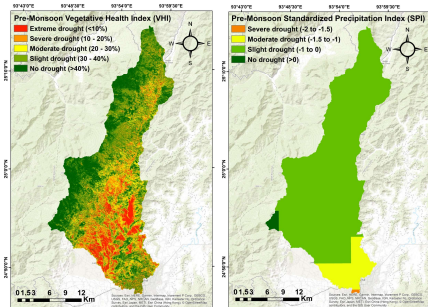
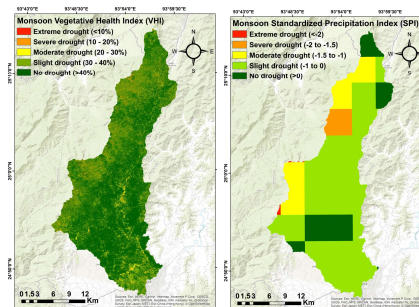


Fig. Precipitation and PET average monthly variation of the study region (2015 to 2024)

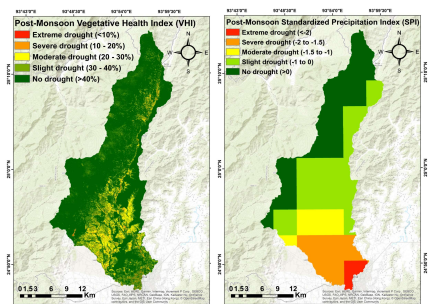
Drought trend in Pre-Monsoon (VHI & SPI)



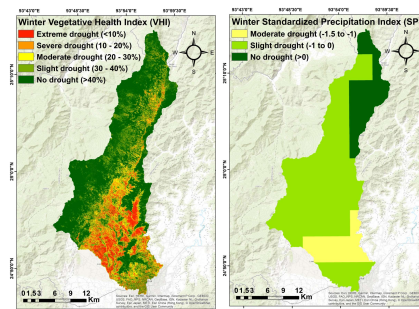
Drought trend in Monsoon (VHI & SPI)



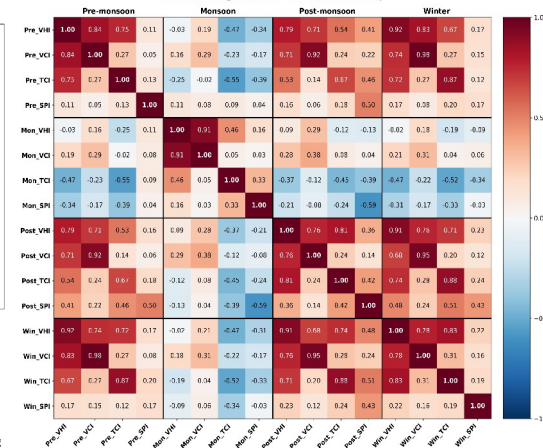
Drought trend in Post-Monsoon (VHI & SPI)



Drought trend in Winter (VHI & SPI)



Seasonal Drought Indices – Correlation Heatmap



Conclusion

- Vegetation-based indices, particularly VHI and VCI, demonstrated strong cross-seasonal consistency across pre-monsoon, post-monsoon, and winter seasons, with correlation coefficients reaching as high as 0.98, suggesting that drought-induced vegetation stress persists uniformly during non-monsoon periods.
- The Standardized Precipitation Index (SPI) remained largely independent of vegetation stress indices across all seasons.
- This research recommends that future studies should integrate hydrological drought indices to provide a more comprehensive representation of drought conditions.

References

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