EVALUATING THE IMPACT OF DROUGHT SPATIAL DISTRIBUTION ON RIVER FLOW DYNAMICS USING REMOTE SENSING DATA

P.V.R.P. Madhumal [1,*], H.G.L.N. Gunawardhana [1]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Drought is a complex and challenging weather-related disaster with significant economic, social, and environmental impacts. Traditional drought monitoring, which primarily relies on ground observations, often falls short due to limited spatial coverage and data scarcity. Most existing drought indices focus on a single variable, which may not adequately capture the full scope of drought conditions. To address this, integrating multiple parameters from remote sensing data presents a promising approach, providing spatially distributed and real-time information for a more accurate and comprehensive drought analysis.

This study aims to utilize multiple remote sensing parameters to provide a comprehensive analysis of droughts in the Padiyathalawa catchment area, a dry zone river basin in Sri Lanka covering 171 km². Three satellite-derived indices, namely the Vegetation Condition Index (VCI) and Temperature Condition Index (TCI), derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data, and Standardized Precipitation (SP) from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), were integrated using Principal Component Analysis (PCA) to derive a Combined Drought Index (CDI). In this analysis, Principal Component (PC) one, capturing 58% of the total variance, was used to develop the CDI. Validation showed a strong visual correlation between the normalized CDI and river flow over time. However, the Kolmogorov-Smirnov (KS) test revealed that the CDI needs improvement, as it does not fully capture streamflow dynamics during significant rainfall events. Despite this, the CDI effectively reflected seasonal variations, indicating dry conditions from June to August and wetter periods influenced by the northeast monsoon.

Using the Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS), the area was modelled as a semi-distributed system with five sub-catchments, based on the spatial variation of drought in developed 1 km resolution CDI maps. Model calibration was conducted for the period 1999-2005, followed by validation from 2005-2010, employing the Nash–Sutcliffe model efficiency coefficient (NSE) and mean relative absolute error (MRAE). The results indicated that the HEC-HMS model effectively simulated streamflow, with NSE values of 0.78 and 0.92, and MRAE values of 0.86 and 2.44. However, the model exhibited limitations in simulating low-flow conditions, failing to accurately represent discharges below 0.1 m³/sec. Further analysis of drought-prone areas identified by the CDI was performed using the HEC-HMS, incorporating hypothetical drought scenarios.

The study found that river flow decreases as drought severity intensifies, with the impact lessening in sub-catchments farther from the catchment outlet. It highlights the potential of integrating remote sensing data, PCA, and hydrological modelling for effective drought assessment, benefiting farming communities and decision-makers in understanding drought severity on river flow and taking necessary action.

Keywords: Combined drought index, HEC-HMS, Principal component analysis, Temperature condition index, Vegetation condition index

* Correspondence: madhumalpvrp.19@uom.lk

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INTEGRATING REMOTE SENSING DATA WITH HYDROLOGICAL MODELING FOR DROUGHT ANALYSIS

1. Background

Traditional drought Indices → Most rely on one variable → Insufficient to accurately represent complex droughts

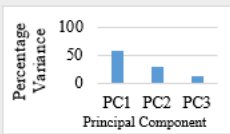
Ground observations → Lack of spatial coverage; Data quality issues; Data scarcity

Aim: As a solution this study develops a **Combined Drought Index (CDI)** from three remote sensing parameters to analyse drought effects on river flow.

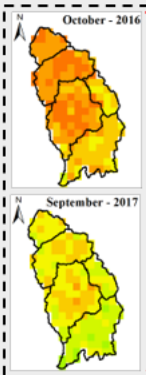
2. Methodology

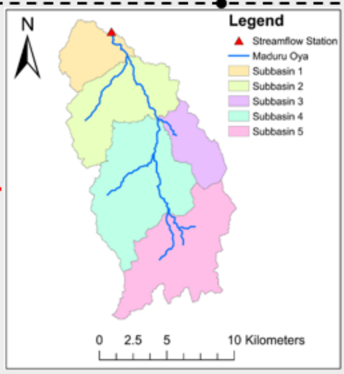
Derived 1 km resolution maps for selected satellite indices. → **Principal Component Analysis (PCA)** → CDI → Validate and calibrate **HEC-HMS model**

Satellite sources: **Temperature Condition Index, Vegetation Condition Index Standardized Precipitation**



Principal component 1 was considered in developing CDI.





Study area (**Padiyathalawa upper catchment**) was divided into **5 sub-catchments** based on CDI maps.

Calibration:
NSE:0.78
MRAE:0.86

Validation:
NSE:0.92
MRAE:2.44

Simulated hypothetical drought scenarios to assess drought impact on river flow.

3. Results & Conclusions

Developed CDI was able to **capture seasonal variation** within the catchment.

As the **distance from the outlet to the centroid of the sub-catchment increases, the drought's impact on total river discharge decreases.**