

ASSESSING SPATIO-TEMPORAL DROUGHT DYNAMICS USING A SATELLITE-DERIVED COMPOSITE INDEX

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River flow dynamics are significantly influenced by the spatiotemporal variability of drought, underscoring the necessity of thorough frameworks for drought monitoring. Accordingly, to evaluate the effects of meteorological drought on river discharge in the Giriulla sub-basin of the Maha Oya River Basin, this study proposes a Composite Drought Index (CDI) for the period 2015–2023. The 1-month Standardised Precipitation Evapotranspiration Index (SPEI-1), together with Vegetation Condition Index (VCI), Temperature Condition Index (TCI), and Soil Moisture Condition Index (SMCI) derived from MOD13A3.061 Normalised Difference Vegetation Index (NDVI), MOD21C3.061 Land Surface Temperature (LST), and SMAP L4 Root Zone Soil Moisture data, respectively, were integrated into the CDI. Principal Component Analysis (PCA) was employed to derive the CDI by identifying the optimum weightings for each indicator, ensuring that the most significant indicators provide a proportionate contribution and thereby enhancing the accuracy of drought characterisation. The robustness and appropriateness of the CDI for tracking drought conditions were validated through the application of multiple statistical techniques, including the Kolmogorov-Smirnov (KS) test, Pearson's Correlation Coefficient ($R = 0.73$), and Root Mean Square Error ($RMSE = 0.69$). The Hydrologic Engineering Centre-Hydrologic Modelling System (HEC-HMS) was utilised to further examine the hydrological impacts of drought circumstances. The division of the Giriulla River basin into four sub-catchments allowed a thorough evaluation of the effects of spatial drought variation on river discharge. The association between drought severity and river flow dynamics was assessed using discharge simulations from the HEC-HMS model in conjunction with the regionally averaged CDI. Analyses examined both specific discharge and the relative contribution of each sub-catchment to total basin flow under varying drought conditions.

The results demonstrated a significant impact of drought on river flow dynamics across the basin. Upstream regions were more sensitive than downstream areas, and specific discharge decreased significantly as drought severity increased in all four sub-catchments. The corresponding exponential coefficients indicated that the sub-catchment in the upstream was roughly 75% more sensitive to drought than the sub-catchment in the downstream. According to the link between sub-catchment drought anomalies and contribution to total discharge, wetter sub-catchments contributed more to high flows, but some sub-catchments maintained relative baseflow contributions even in drier conditions. Longer flow path sub-catchments showed buffered baseflow responses, underscoring the function of catchment features in adjusting effects of hydrological dryness. These results underscore the critical role of hydrological structure and connectivity in modulating the effects of spatial drought variability on river flow. Hydrological modelling combined with drought indices derived from remote sensing provides a potent method for assessing the impact of spatial drought variation on river systems. In the context of basin-scale hydrological management, this study highlights the necessity of spatially explicit drought monitoring and offers a useful paradigm for managing water resources and climate resilience strategies.

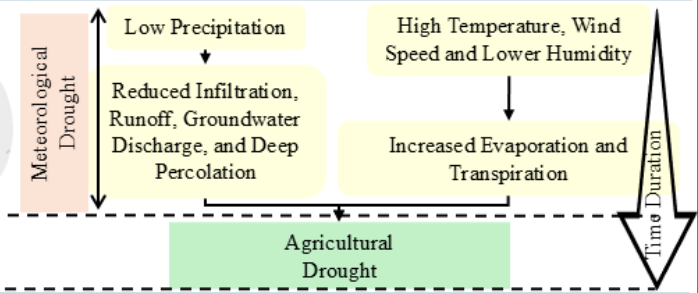
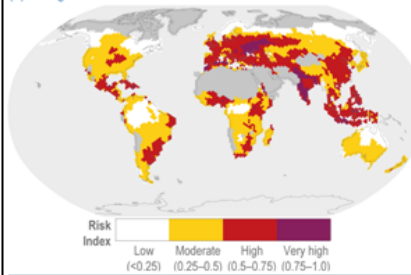
Keywords: HEC-HMS, Meteorological drought, PCA, Soil moisture, SPEI-1

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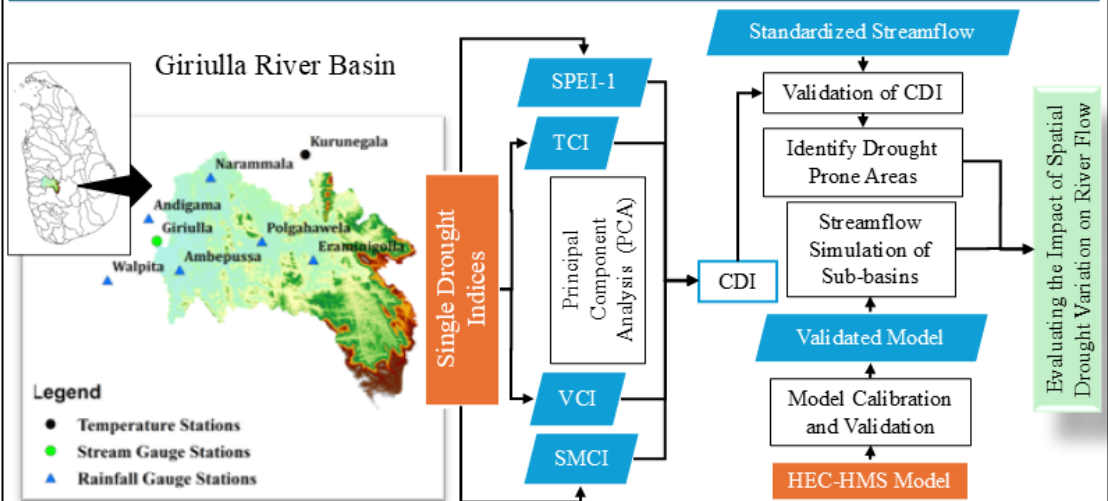
Evaluating Spatio-temporal Drought Impacts on Basin Hydrology Through a Geospatially Integrated Composite Index

Background

(d) Drought risk

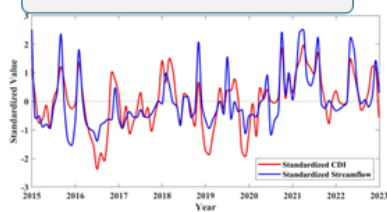


Methodology

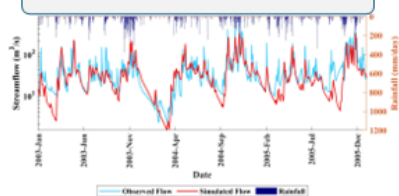


Results

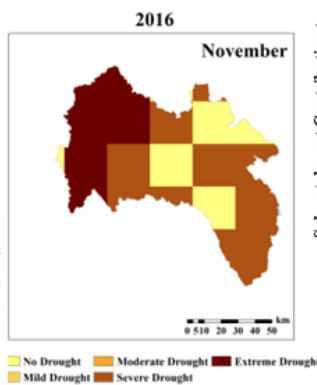
Validation of CDI



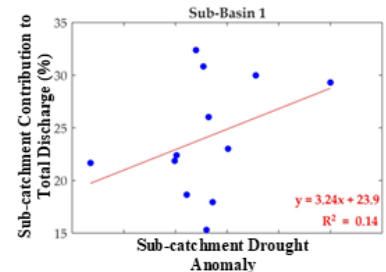
HEC-HMS Model Calibration



Spatial and Temporal Variation of Drought Severity



Impact of Spatial Drought Variation on River Flow



Sub-catchments with longer flow paths and larger catchment sizes show less sensitivity in baseflow contribution to drought anomaly.