Assessment of Rainfall Spatial Representation using Hydrological Modelling for the Angat River Basin, Philippines

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Rainfall spatial representation is a major source of uncertainty in rainfall–runoff modeling. In tropical river basins, including those in the Philippines, convective storms and complex topography generate strong spatial variability, limiting the direct applicability of point-based rainfall observations when basin-average rainfall is required for hydrological simulation (Abdelmoneim et al., 2025).

Although satellite and gridded rainfall products are increasingly available, hydrological assessments in the Philippines have largely focused on rainfall impacts at basin outlets, landfall locations, or regional scales, with limited attention to how rainfall representation and hydrological response vary across spatial aggregation scales. Recent studies emphasize tropical cyclone behavior and regional rainfall impacts (Racoma et al., 2025) but do not explicitly examine how rainfall spatial structure influences sub-basin hydrological response. This limitation is particularly relevant for reservoir-regulated systems such as the Angat basin where water availability and allocation depend on spatially distributed inflows rather than outlet-scale signals alone.

To address this gap, the study examines multiple rainfall products across spatial scales, then uses the best-performing dataset for hydrological assessment with HEC-HMS, while rain gauge data are retained as the reference.

The study focuses on the Angat River Basin, a multi-purpose system supporting domestic water supply, irrigation, flood control, and hydropower. Rainfall products are evaluated across the Pampanga River Basin, while hydrological modeling and validation focus on the Bustos sub-basin and Angat Reservoir. (**Fig. 1**).

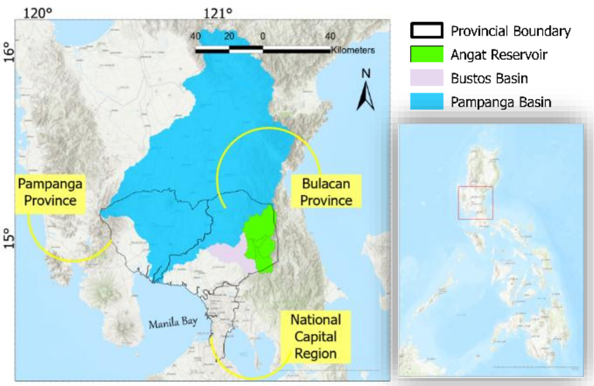
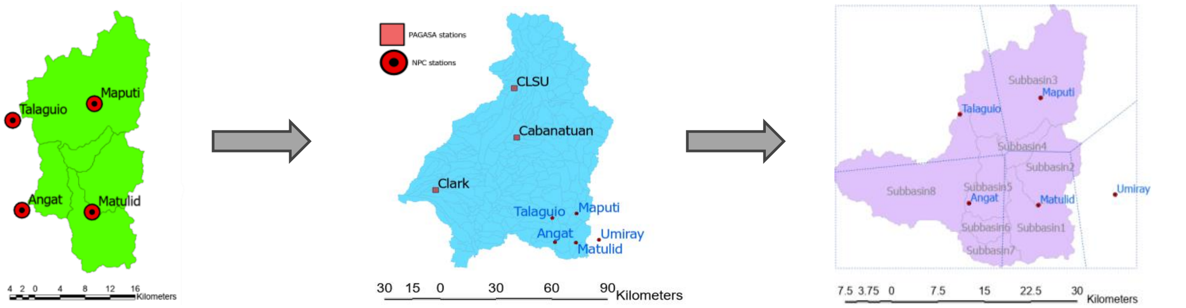


Fig. 1. Study area and data coverage for rainfall evaluation and hydrological modeling in the Angat–Pampanga system.



(1) Basin-wide point-based evaluation (2) Basin-wide point-based evaluation (4) Local station-scale evaluation

(3) Basin-wide ClimGridRR-Ph-based evaluation

Fig. 2 Conceptual workflow of rainfall product evaluation across spatial scales, from station-based analysis to subbasin-average rainfall inputs for HEC-HMS simulations.

This study assesses the suitability of multiple rainfall products for hydrological modeling using a four-level evaluation framework: (1) station-scale point analysis, (2) basin-wide point-based evaluation under limited gauge coverage, (3) basin-wide assessment using ClimGridRR-Ph as spatially continuous rainfall forcing, and (4) subbasin-average evaluation consistent with the rainfall input structure of the HEC-HMS model (**USACE, 2021**) **(Fig. 2**), with Thiessen-weighted rain-gauge rainfall used as the reference benchmark.

Although rain-gauge rainfall performs well at station and event scales, it is sensitive to gauge density and spatial representativeness. Thiessen-weighted rainfall performs best for event-scale simulation **(Fig. 3)**, reproducing peak timing and magnitude during intense storms (NSE = 0.63; KGE = 0.82), corresponding to approximately 120% higher NSE and 48% higher KGE than ClimGridRR-Ph (NSE = 0.29; KGE = 0.55). However, its performance varies across sub-basins due to localized rainfall and uneven gauge coverage. In contrast, ClimGridRR-Ph provides spatially continuous and coherent rainfall fields with more stable sub-basin runoff simulations, making it more suitable for consistent rainfall–runoff and reservoir inflow modeling using HEC-HMS.

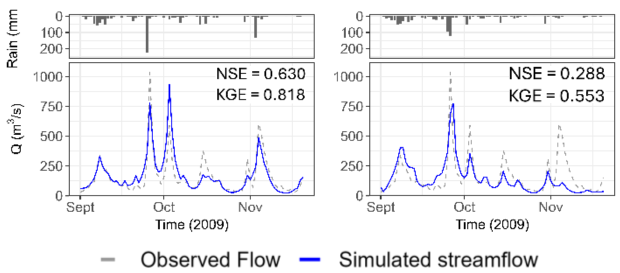


Fig. 3. (left) Thiessen-weighted rain-gauge; (right) ClimGridRR-Ph; streamflow hydrographs with rainfall hyetographs for selected 2009 flood events.

Both datasets capture similar basin-scale precipitation gradients; However, ClimGridRR-Ph yields more consistent runoff indices and annual flow patterns across sub-basins (**Fig. 4**). These results highlight that rainfall datasets should be applied according to modelling scale, with rain gauges suited for event-scale flood dynamics and ClimGridRR-Ph better aligned with sub-basin and long-term hydrological and reservoir operation analyses under data-limited conditions.

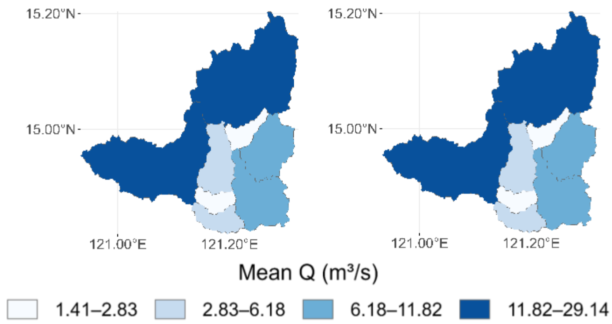


Fig. 4. (left) Thiessen-weighted rain-gauge; (right) ClimGridRR-Ph; Sub-basin mean simulated discharge

This study addresses rainfall spatial representation for hydrological modeling in the Angat River Basin. Results show that Thiessen-weighted rain-gauge rainfall is most suitable for event-scale flood simulation, while ClimGridRR-Ph provides more spatially consistent performance at the sub-basin scale, making it appropriate for hydrological and reservoir operation modeling under data-limited conditions. Other satellite products exhibit lower hydrological reliability.

References

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