Comparative assessment of different gridded meteorological datasets in SWAT modelling of the Apayao-Abulug River Basin (AARB), Apayao, Philippines

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Challenge: “Data Poverty”

- **Philippines**
  - Freshwater plays a role in development
    - 421 principal rivers
    - 140 critical watersheds
    - 221 lakes
    - 18 major river basins

- **Pertinent datasets**
  - Streamflow from DPWH
  - Meteorological data from PAGASA and DOST-ASTI

- **A degree of disjunct in access and distribution of pertinent data for hydrological studies**

Alternative: Use of satellite-based, blended, and reanalysis gridded meteorological datasets

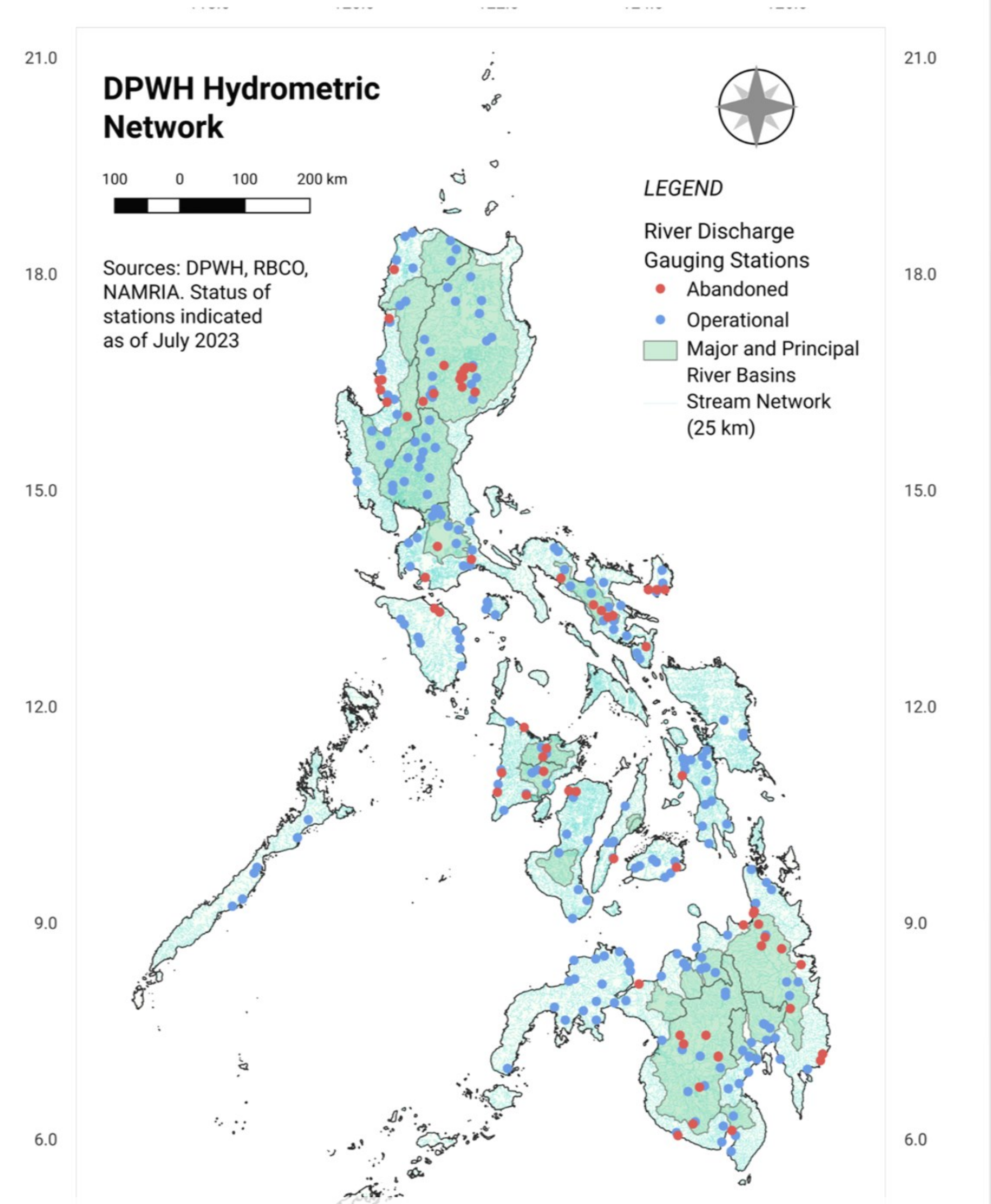


Figure 1. DPWH Hydrometric Network Prepared by R.C. Cornelio, July 2023 (E-Hydro Lab, 2023) https://pages.upd.edu.ph/ehydrolab/research

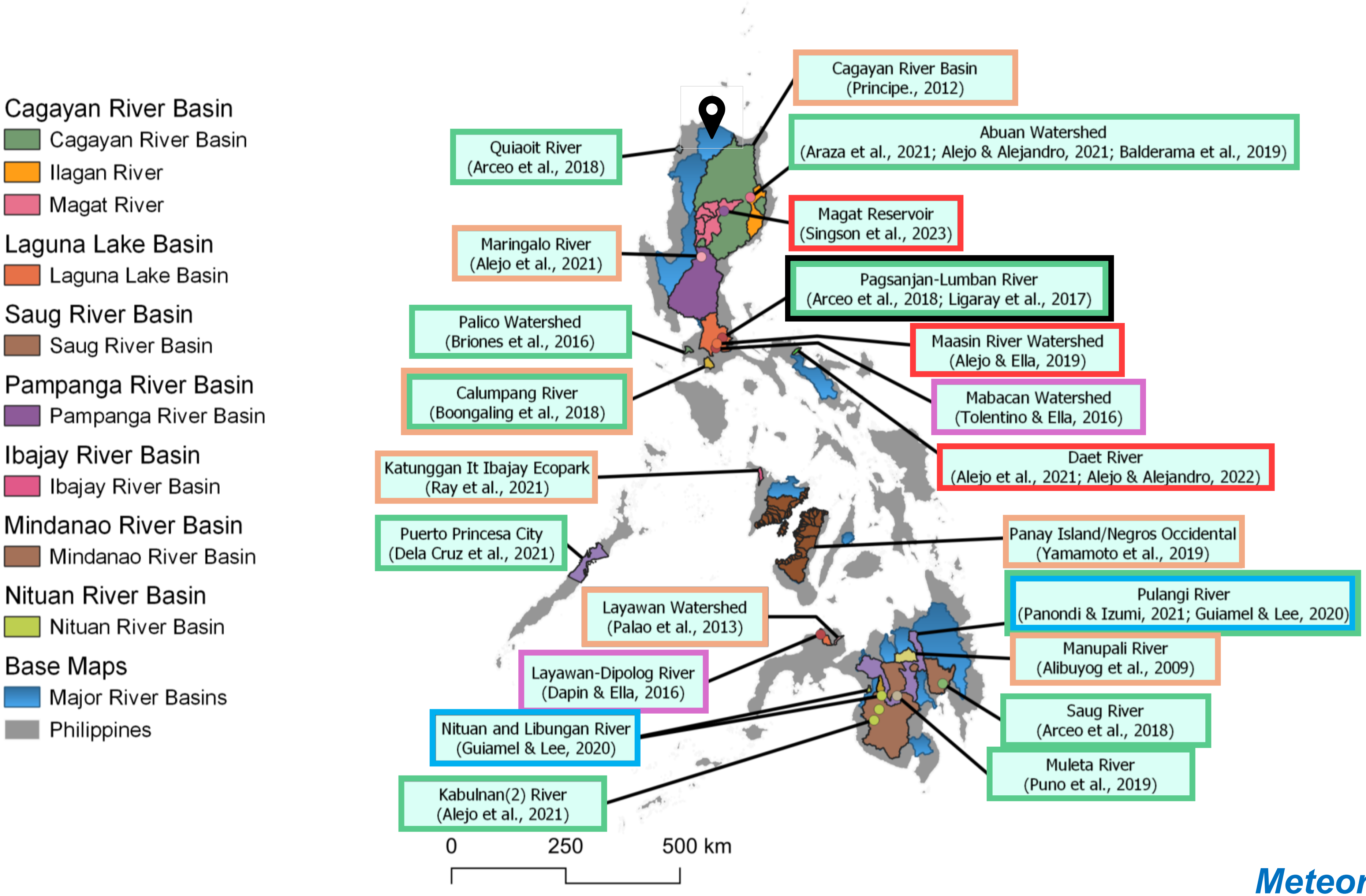


Figure 2. Map of published literature of SWAT studies in the Philippines.

Streamflow and sediment transport

Pollutant transport

Hydropower utilization

Role of forest cover and climate on runoff regulation

Calibration/ meteorological data

Demand based problems

Meteorological data is a common limitation in studying Philippine RBs

Apayao-Abulug River Basin (AARB)

9th longest river in the Philippines

280,290.31 ha

Northern Luzon:

Calanasan, Apayao to Abulug, Cagayan

Headwaters: Mt. Magna, Calanasan

Gauging station: Abulug, Cagayan and Nagan, Pudtol, Apayao

High flood vulnerability

Climate Type: III, II, and I

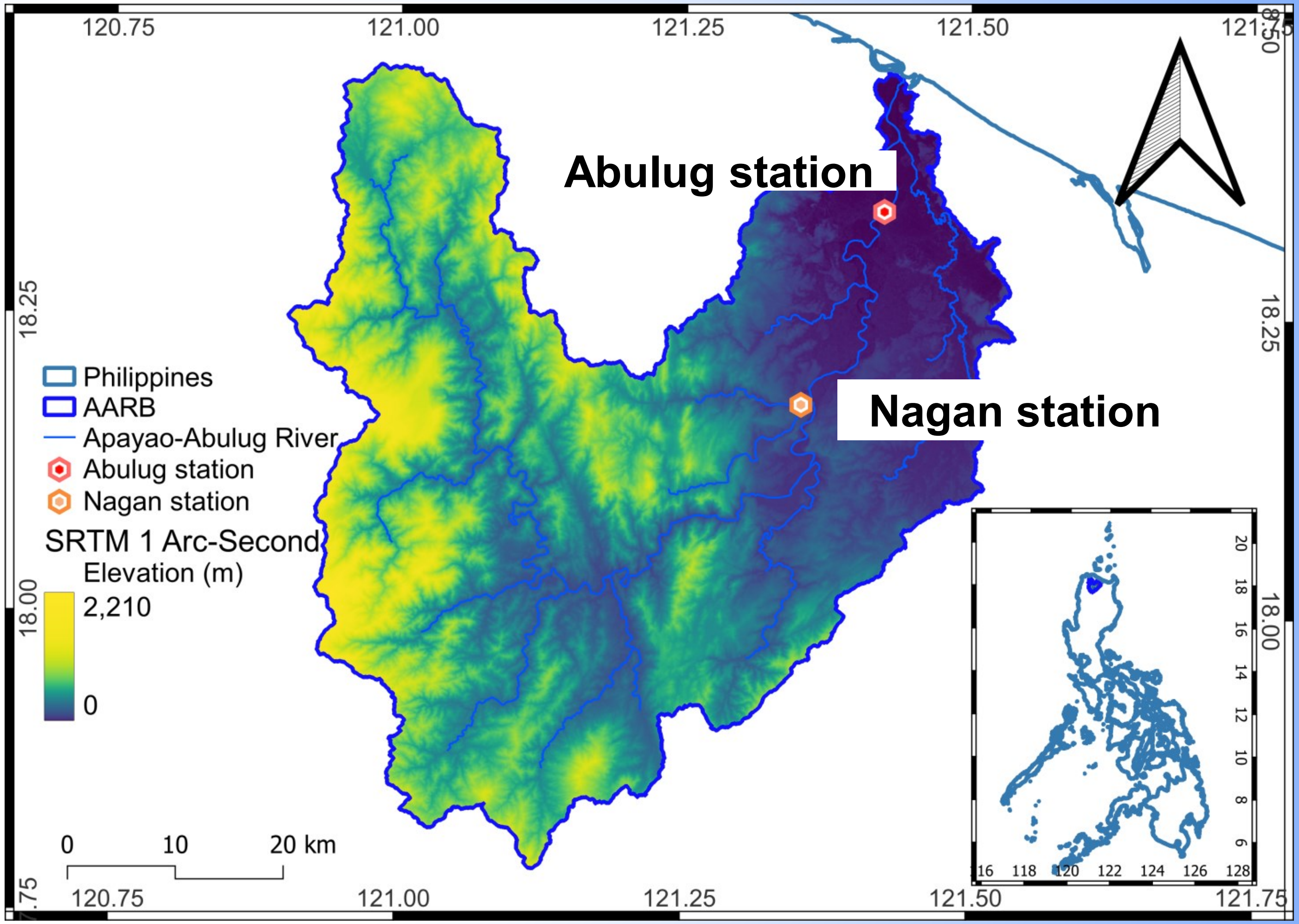


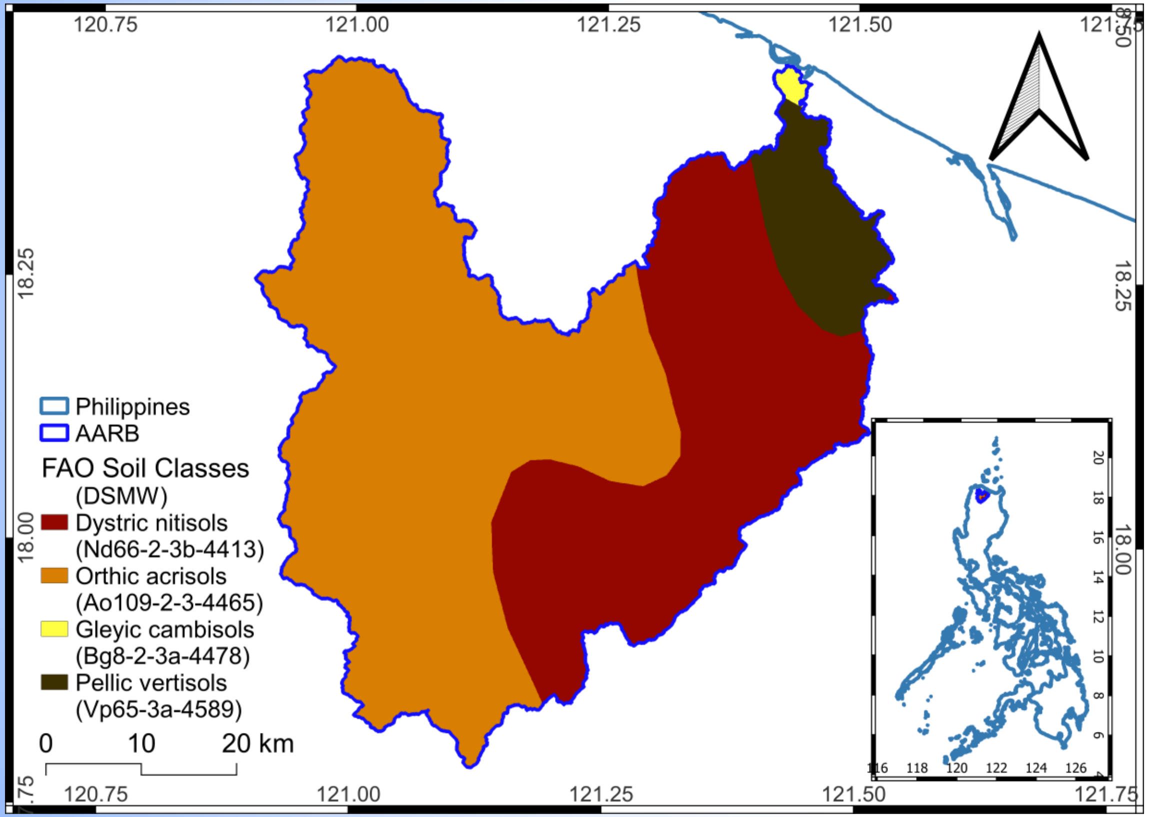
Figure 3. The Apayao-Abulug River Basin (AARB) Digital Elevation Map.

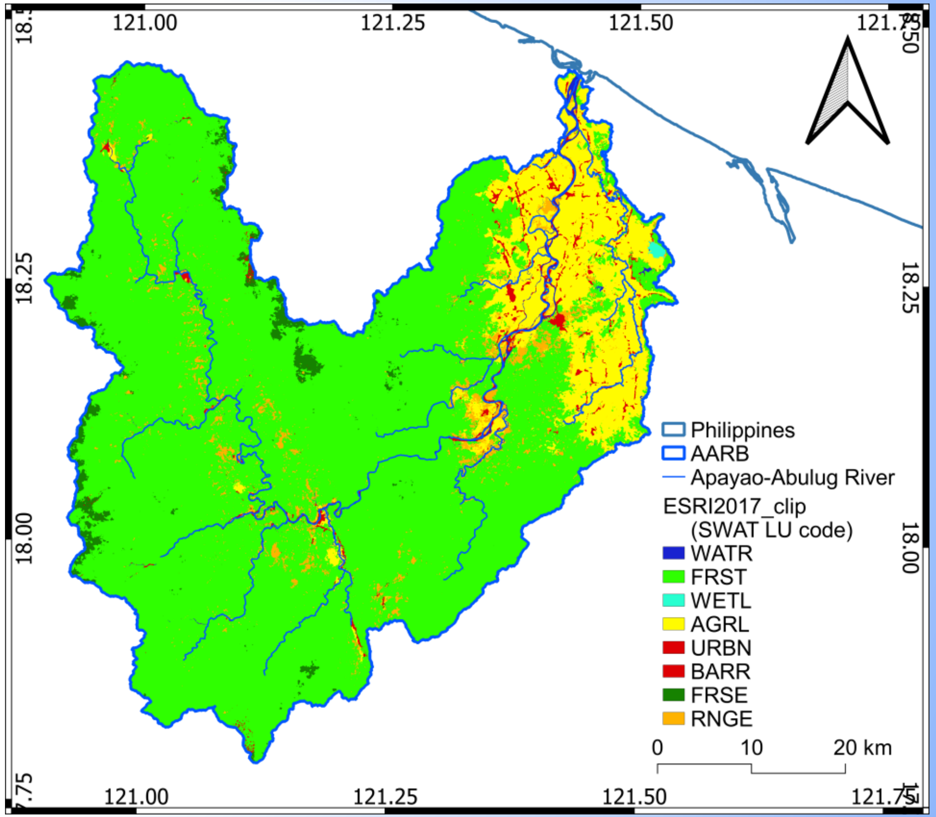
Objective

Evaluate the applicability of different gridded meteorological datasets to the SWAT hydrologic modeling of the data scarce river basin of the Apayao-Abulug River Basin (AARB), a critical river basin in Northern Luzon, Philippines.

Methodology

Spatial maps





Soil Map (FAO DSMW) **ESRI 2017 LULC map**

Figure 4. Soil and land use-land cover data used in the SWAT models of AARB.

Gridded precipitation products

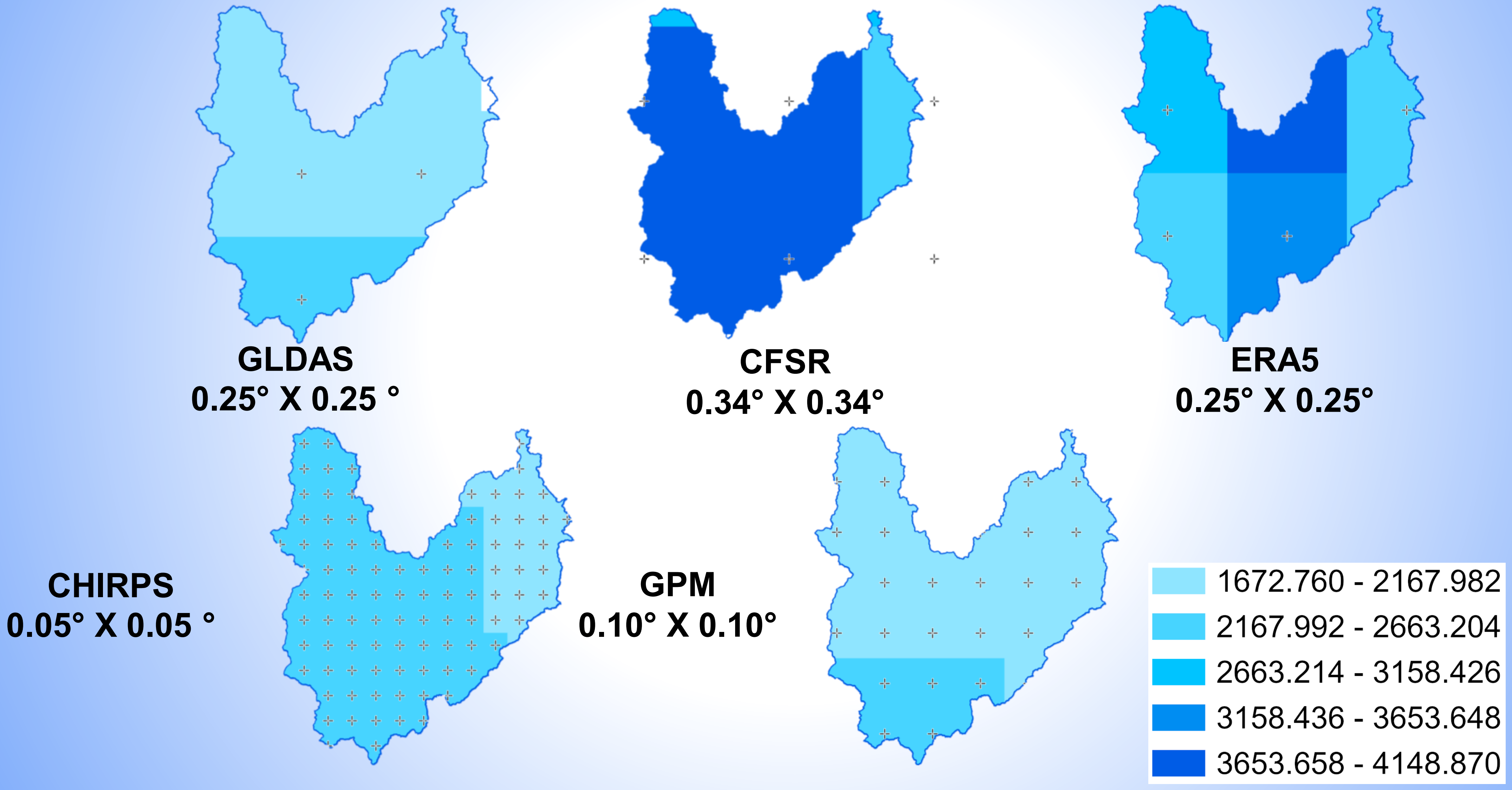


Figure 5. Mean annual precipitation estimates of the AARB from different gridded meteorological datasets.

Results

Precipitation climatological averages

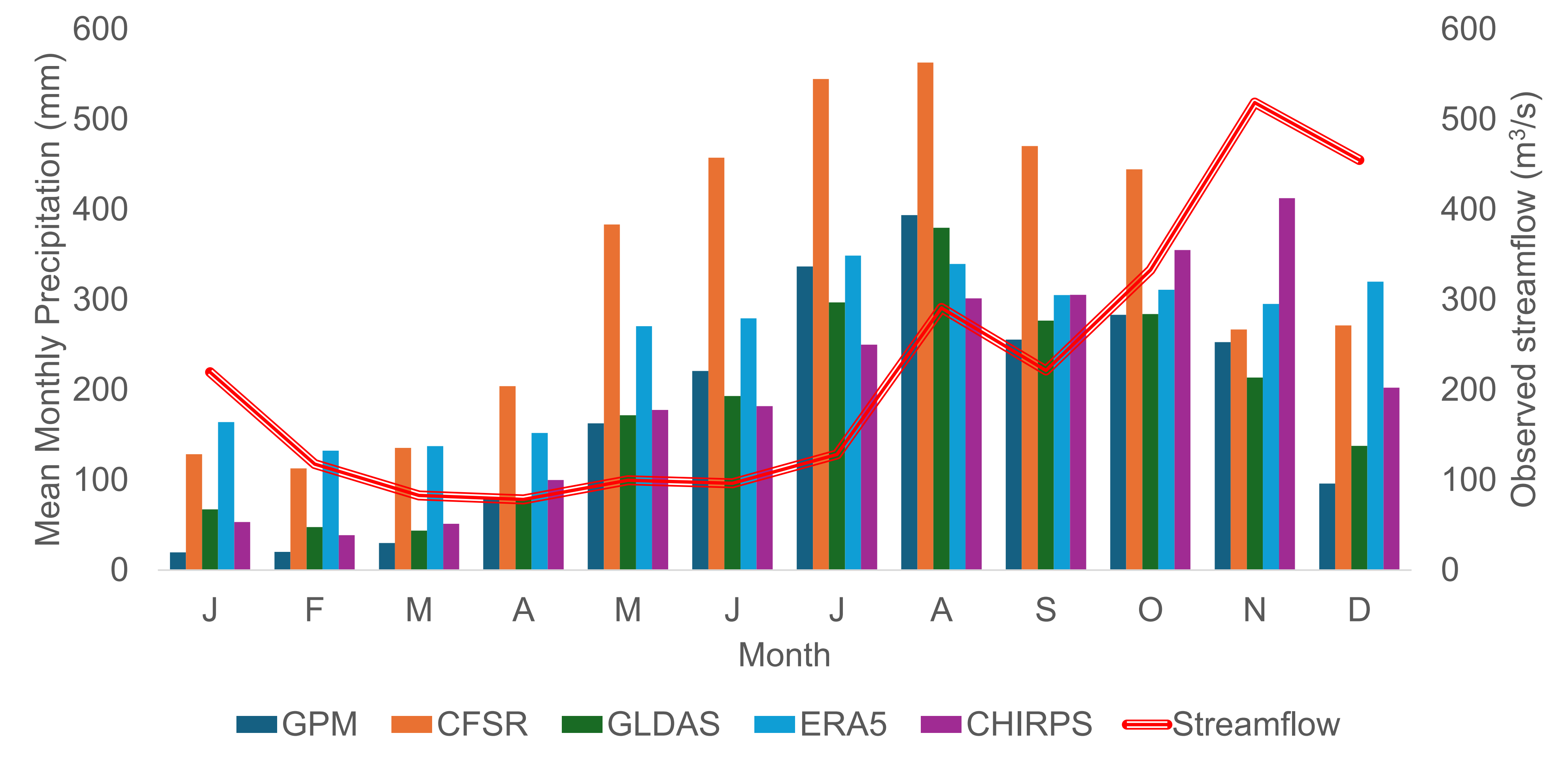
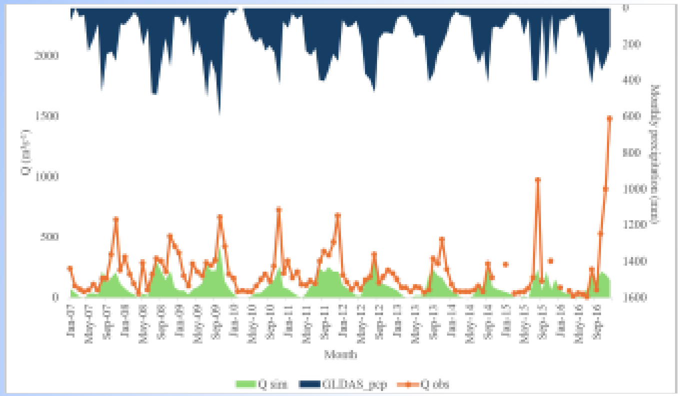
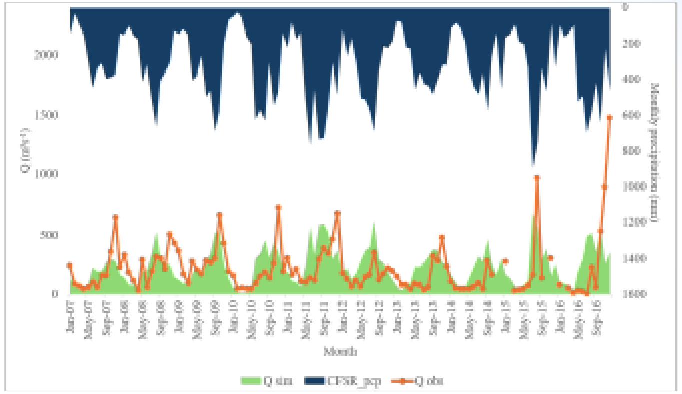


Figure 6. Estimated average monthly precipitation within AARB from 5 different RA datasets and climatological average streamflow in the basin.

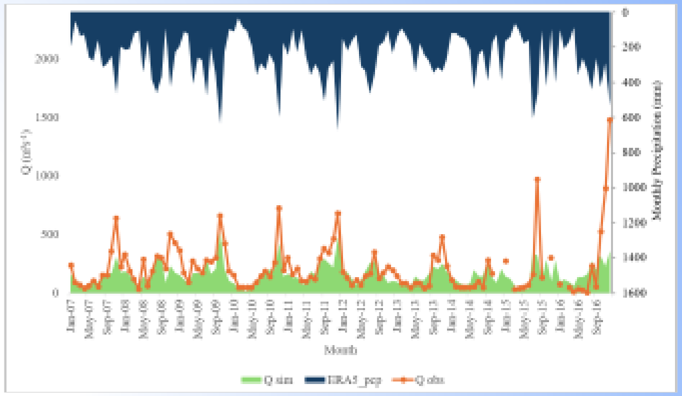
Initial performances



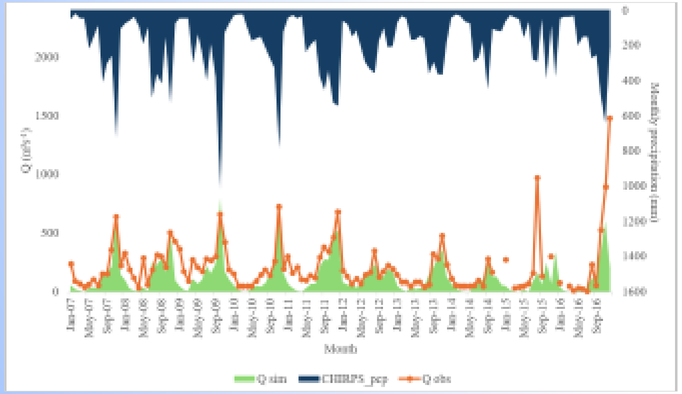
GLDAS NSE = 0.05
$R^2(R)$ = 0.38 (0.61)



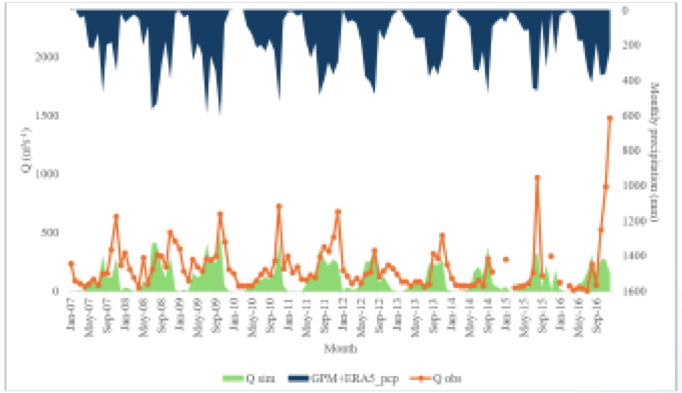
CFSR NSE = 0.07
$R^2(R)$ = 0.18 (0.42)



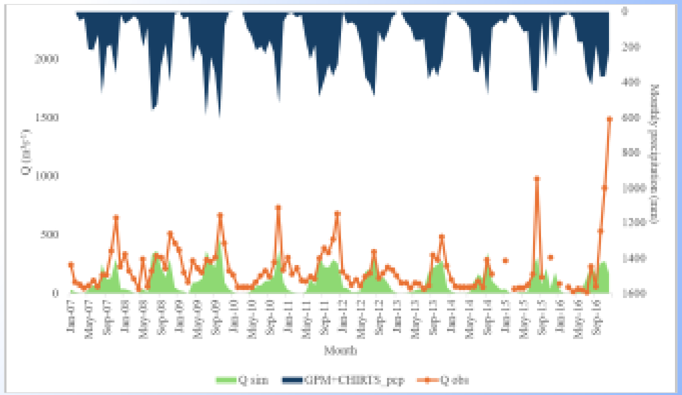
ERA5 NSE = 0.38
$R^2(R)$ = 0.53 (0.72)



CHIRPS-CHIRTS NSE = 0.32
$R^2(R)$ = 0.48 (0.70)



GPM+ERA5 NSE = 0.06
$R^2(R)$ = 0.26 (0.51)



GPM+CHIRTS NSE = 0.10
$R^2(R)$ = 0.35 (0.59)

Figure 7. Hydrographs of 6 default monthly SWAT simulations of the AARB using 2016 ESA CCI LULC and different precipitation and climate data.

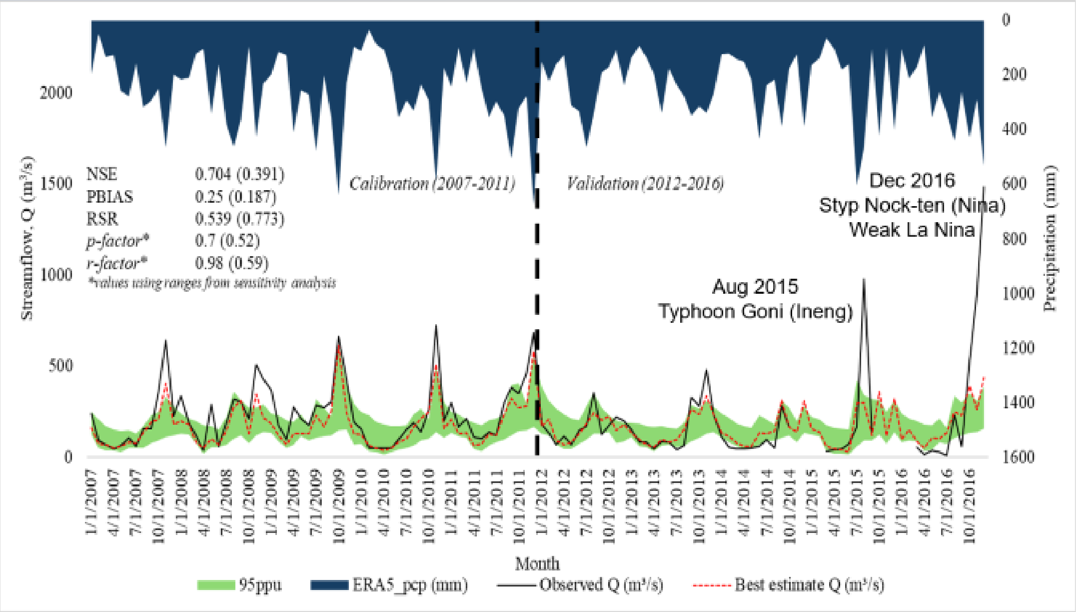
Calibration and validation

- 20,000 simulations over 2 model setups
- Best calibration signal: **ERA5 driven model**

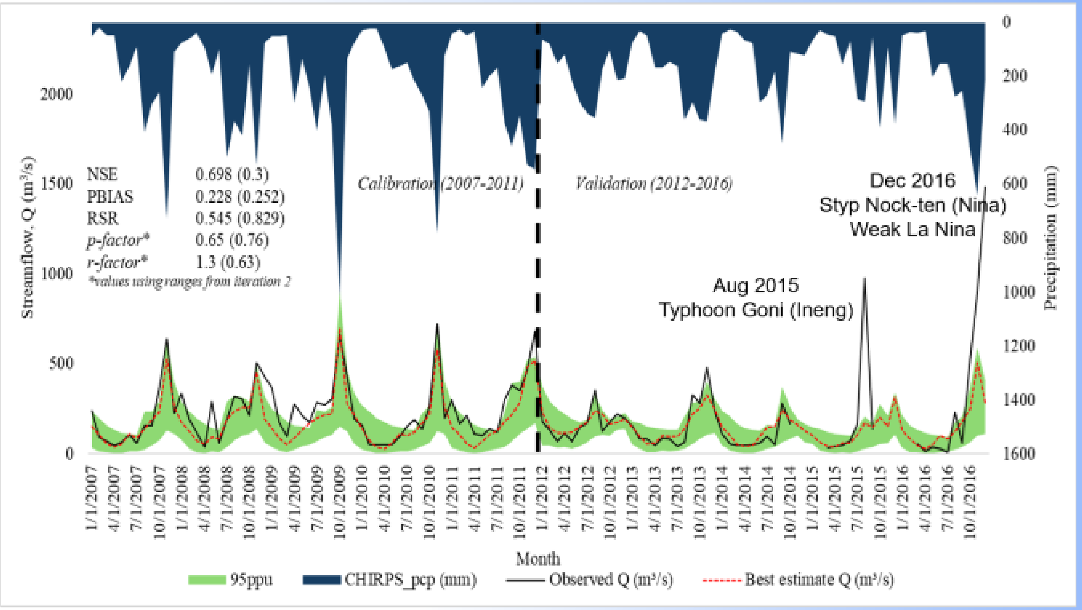
Table 1. Table of best deterministic and stochastic SGOFs from the ERA5 and CHIRPS-CHIRTS driven models.

Meteorological data	**NSE**		**PBIAS**		**RSR**		***p-factor****		***r-factor****	
	cal	*val*	*cal*	*val*	*cal*	*val*	*cal*	*val*	*cal*	*val*
ERA5	0.704	0.391	0.250	0.187	0.539	0.773	0.700	0.520	0.980	0.590
CHIRPS-CHIRTS	0.698	0.300	0.228	0.252	0.545	0.829	0.650	0.760	1.300	0.630
** values extracted from iterations with best stochastic SGOFs*										

Calibrated hydrographs



ERA5



CHIRPS-CHIRTS

Figure 8. Calibrated hydrographs of the ERA5 and CHIRPS-CHIRTS driven SWAT models.

- Models show marginal performances using NSE
- CHIRPS-CHIRTS driven models show better stochastic performance than ERA5
- ERA5 driven models struggle to capture both streamflow lows and peaks especially during validation period

SWAT and the SEA region

Table 2. Results of SWAT studies in SEA using ERA5 and CHIRPS-CHIRTS datasets.

Basin	Dataset	Result	Authors
Apayao-Abulug River basin	***GLDAS, CFSR, ERA5, CHIPS-CHIRTS, GPM, Interpolated***	***ERA5 and CHIRPS-CHIRTS models are equifinal > GPMv07, GLDAS, CFSR (streamflow and water balance components)***	***Current study***
Maringalo, Daet, Abuan, Kabulnan river basins	CHIRPS-CHIRTS	Surface runoff and streamflow suitability (streamflow)	Alejo et al., 2021
Kelantan river basin, Malaysia	APHRODITE, CHIRPS, ERA5-Land, NASA POWER	APHRODITE; NASA POWER > ERA5-Land temperature data (streamflow and drought indices)	Du et al., 2025
Lower Lancang-Mekong river basin, China	Gauge, IDW data, TRMM, CHIRPS	TRMM and CHIRPS (streamflow)	Luo et al., 2019
Tonle Sap basin, Vietnam	APHRODITE, ERA5, TRMM, IMERGv6, CPC, SA-OBS	IMERGv6>TRMM>APHRODITE>ERA5 (streamflow and ET)	Ang et al., 2022

Mean annual water balance

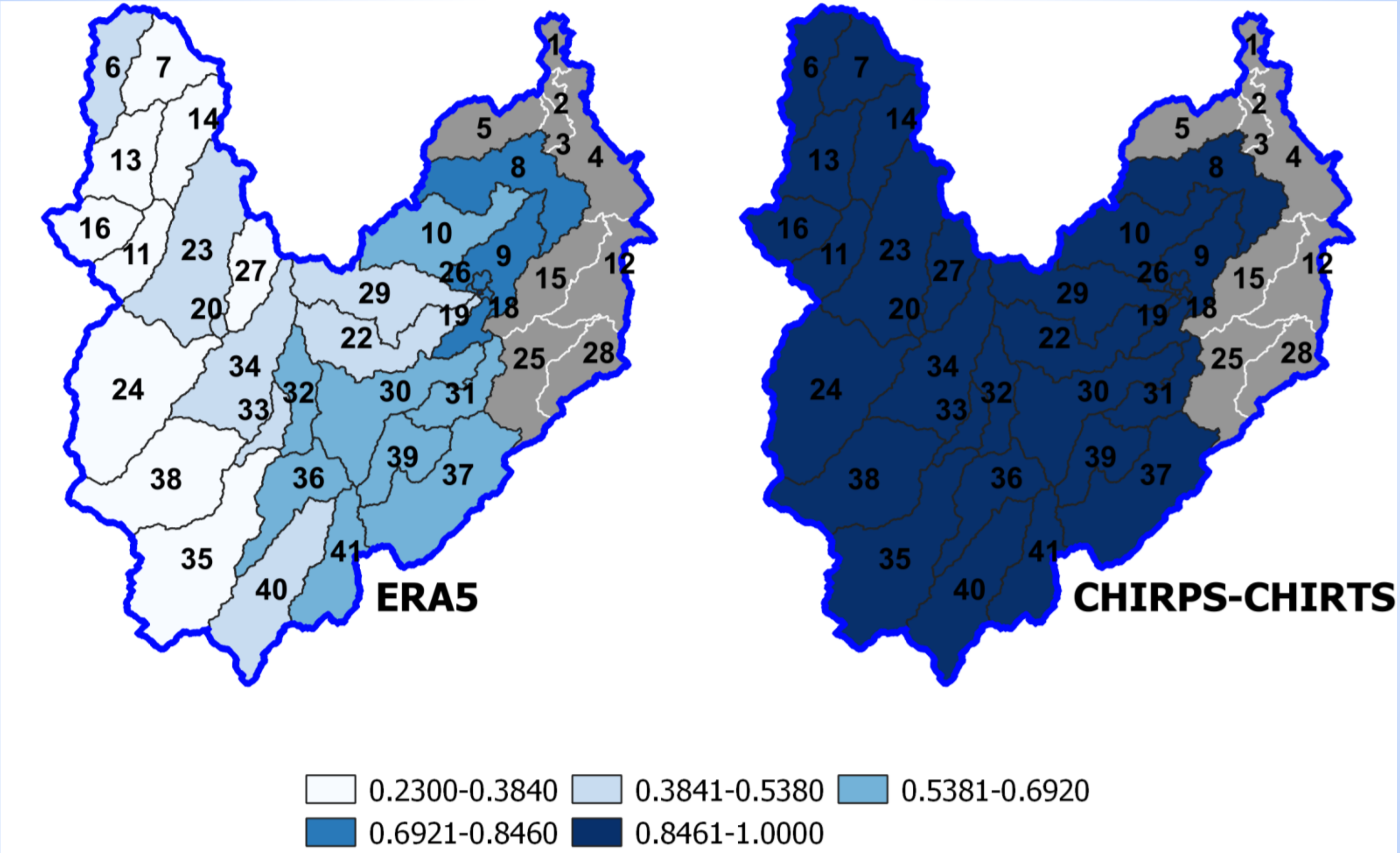


Figure 9. Annual surface runoff ratios to total flow.

↑ Surface runoff ↓ Infiltration

- Realistically improbable for a forested basin

Mean annual water balance

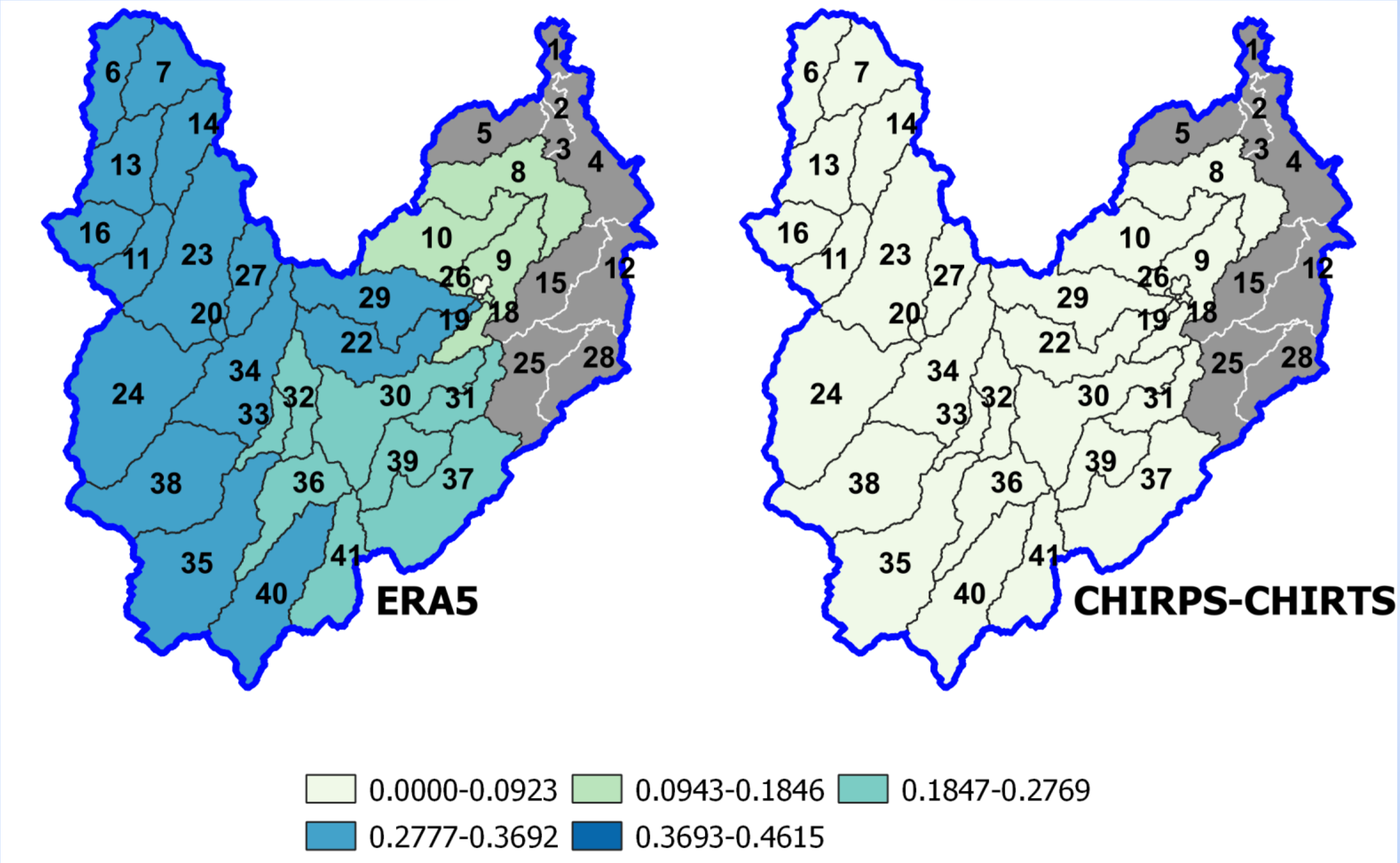


Figure 10. Annual groundwater ratios to precipitation.

- CHIRPS-CHIRTS driven model significantly limited

Percolation, Groundwater flow, and Lateral flow

Mean annual water balance

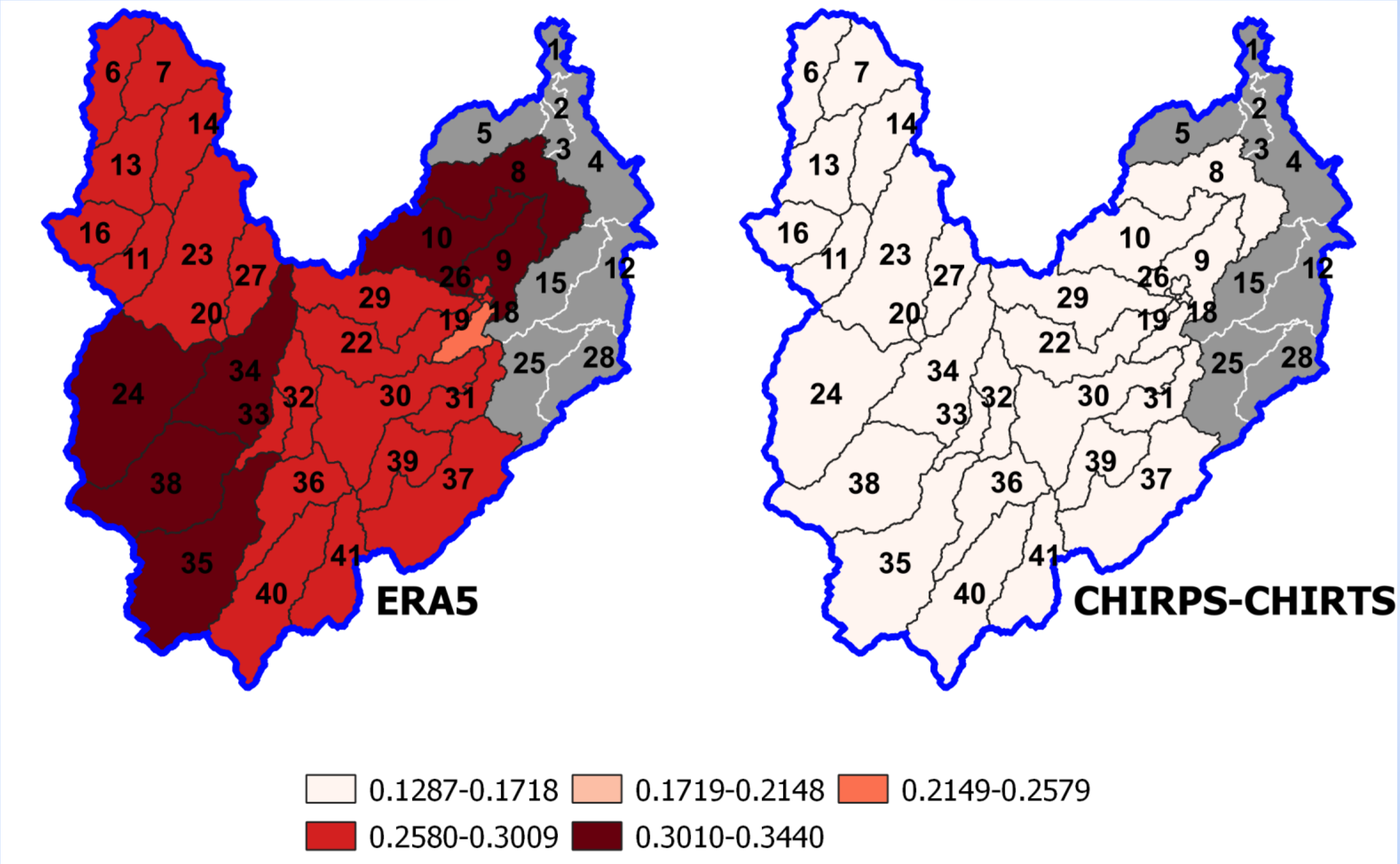
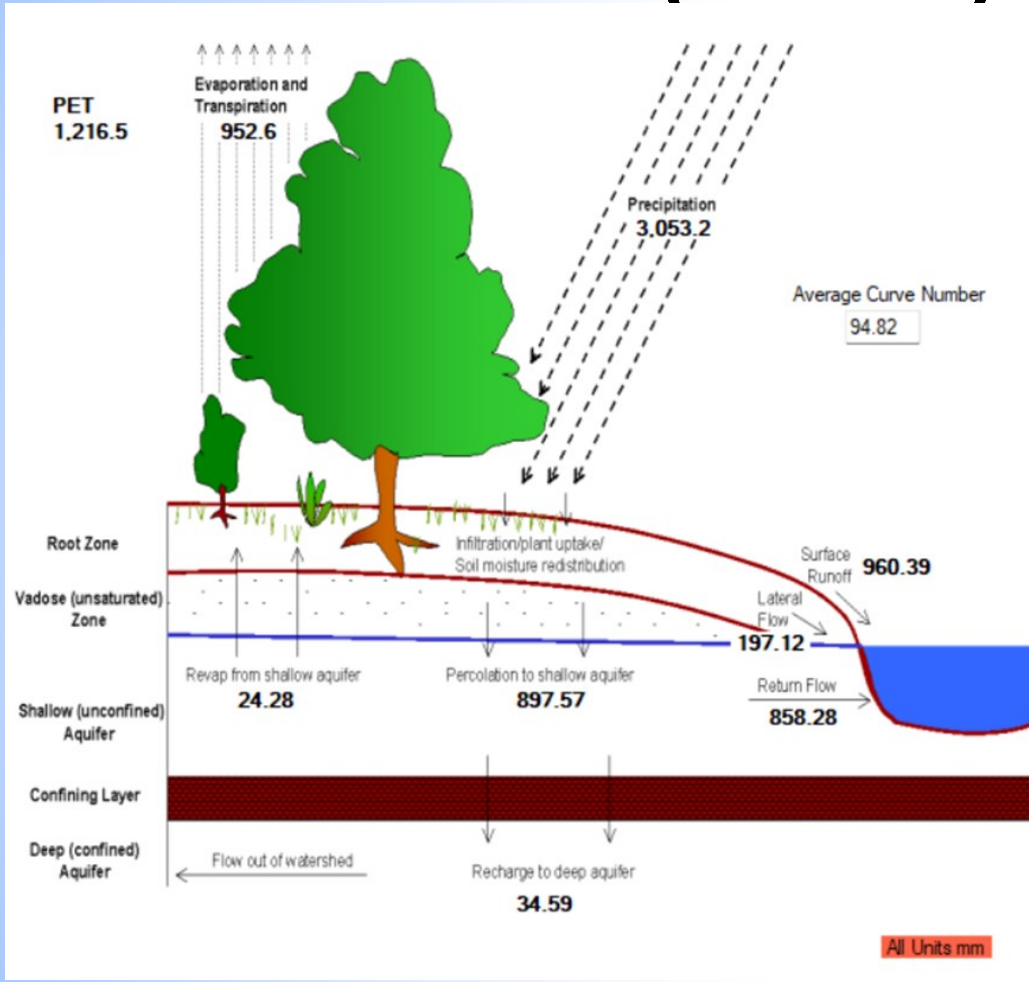


Figure 11. Annual actual evapotranspiration ratios to precipitation.

- CHIRPS-CHIRTS driven models significantly limit

Actual evapotranspiration

Fitted model (ERA5)



- Annual basin precipitation: **3,053.2 mm/year**

Surface runoff 47.64% of total flow

Deep aquifer loss rate: 1%

Actual evapotranspiration = 31% of precipitation

- ✓ 78.31% of annual demand (PET)
- ✓ Monthly range 32.67%-98.2% of PET

Baseflow = 52.36% of total flow

- 12.11%-81.78% monthly contribution

Figure 12. Water balance of the fitted SWAT model for AARB using the ESRI 2017 LULC map and ERA5 dataset.

Fitted model

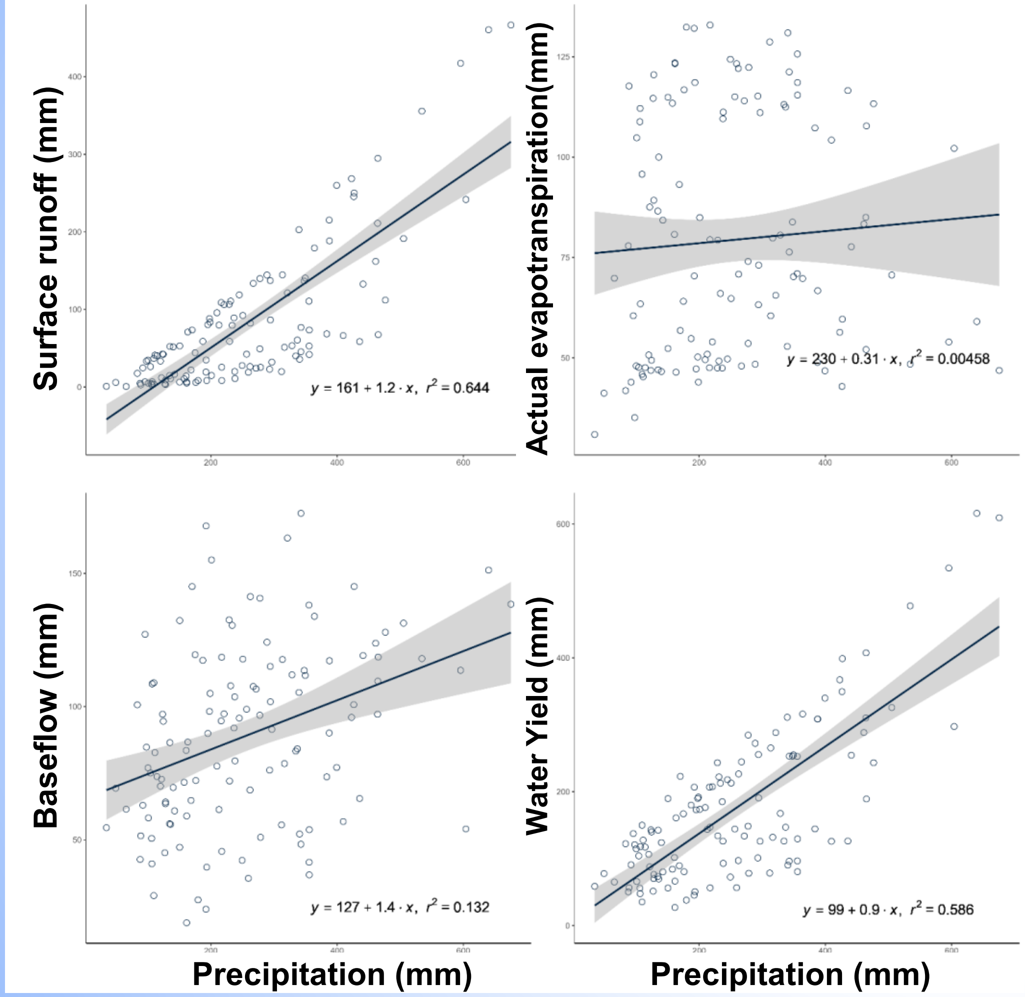
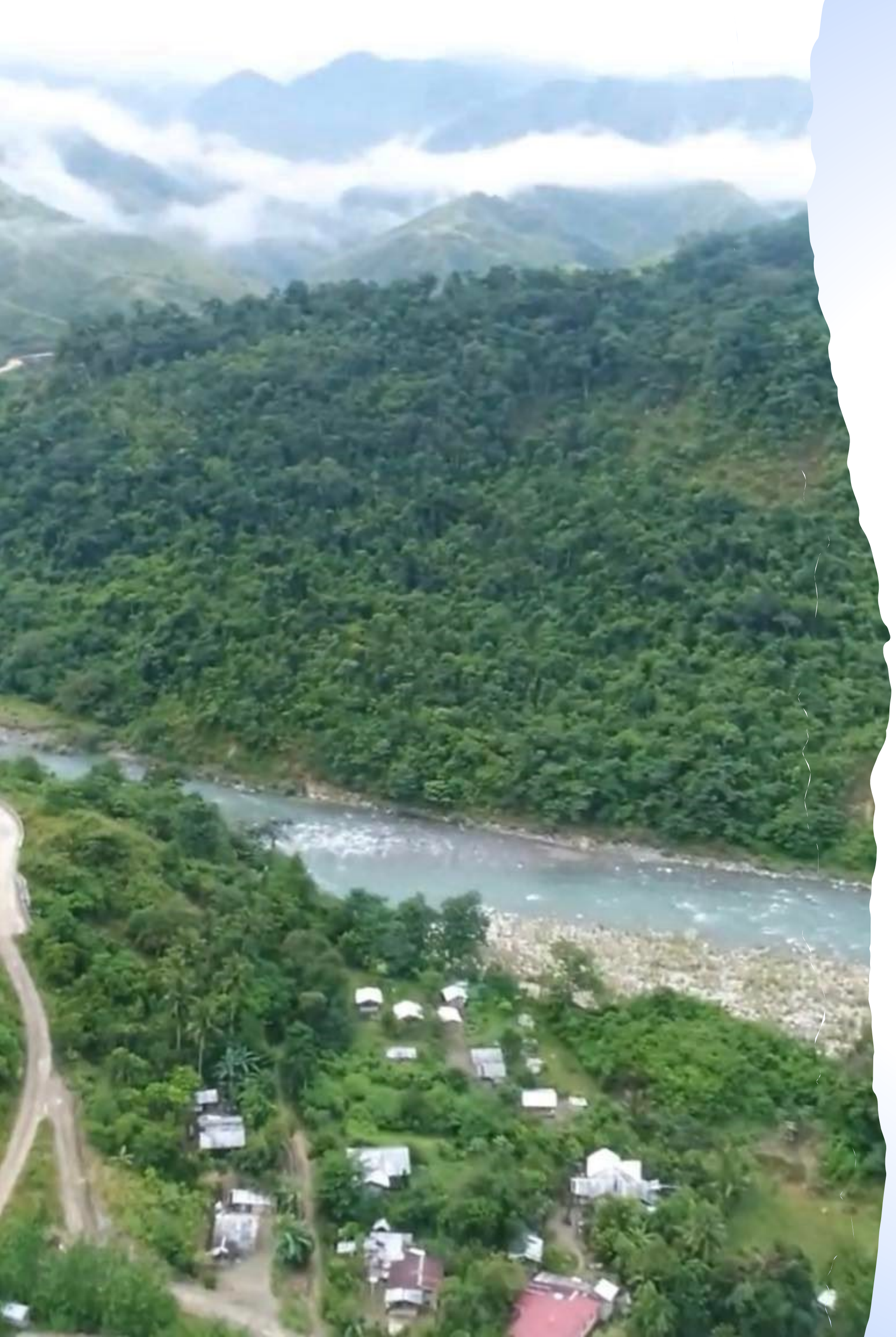


Figure 13. Scatter plots of monthly precipitation with surface runoff, actual evapotranspiration, baseflow, and water yield.

- Correlation with ERA5 precipitation data
  - $R_{SURQ} = 0.802$ ($R^2 = 0.644$)
  - $R_{WYLD} = 0.766$ ($R^2 = 0.586$)
  - Baseflow and AET have weak correlations
- AET *($R = 0.0678$ ($R^2 = 0.00458$))*
  - ✓ Canopy free water, soil evaporation, plant evapotranspiration, surface water evaporation
- Baseflow (*$R = 0.363$ ($R^2 = 0.132$)*)
  - ? Poor soil and channel alluvium hydraulic conductivities, low recession factor, moderate-long groundwater delay



Conclusions

- **ERA5** and **CHIRPS-CHIRTS driven models produced *satisfactory and equifinal models for the AARB*** among different gridded meteorological data
- Validation struggled due to **uncaptured extreme precipitation events**
- CHIRPS-CHIRTS driven models significantly limit key water balance components in the AARB.

Thank you very much!

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