Distribution and Partitioning of Water Balance Components in Peru along a Variety of Landscapes from the High Andes to the Amazon Rain Forest: Insights from a National-Scale Analysis

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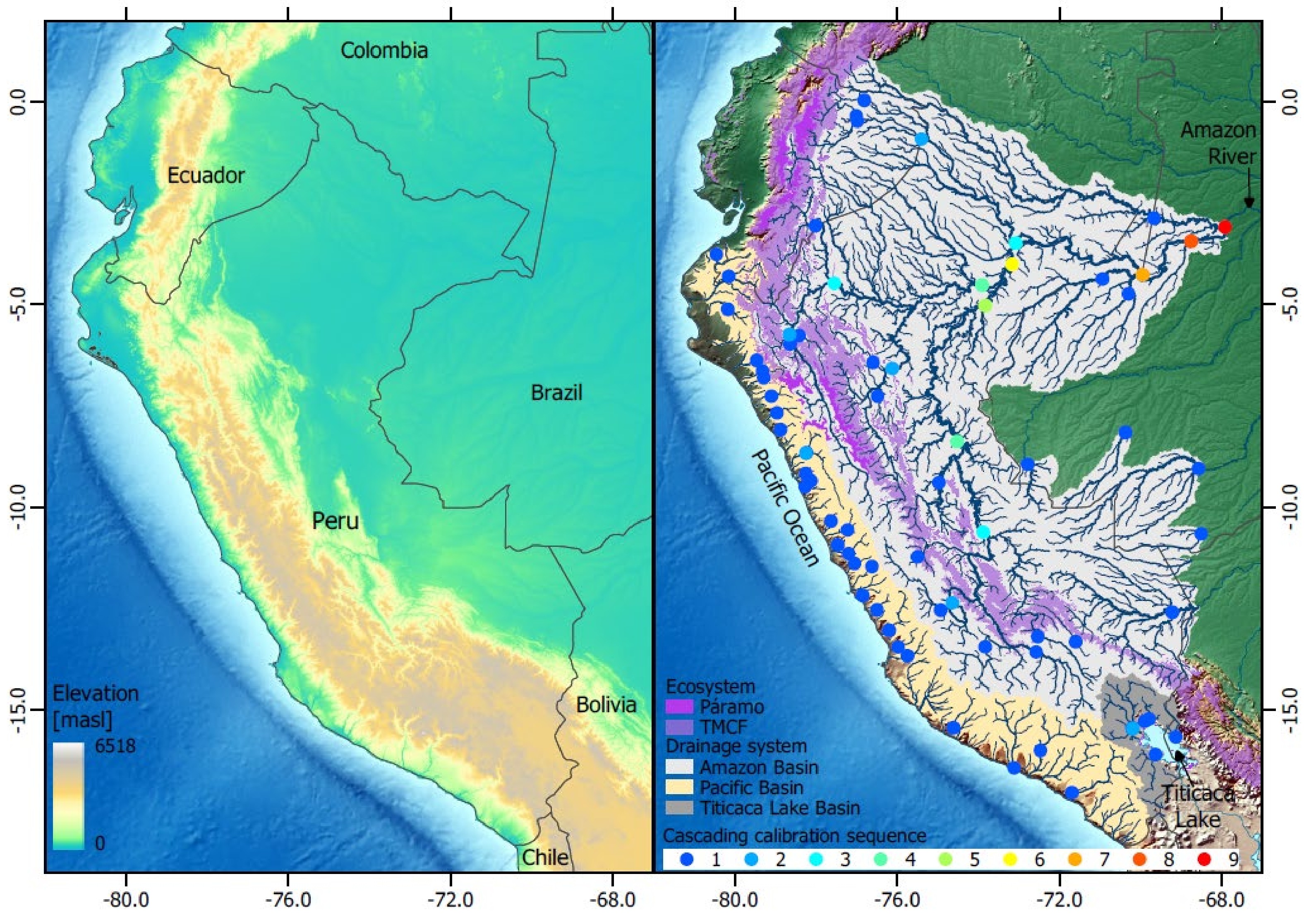
Objective

To analyze the distribution of water balance components in Peru at a national scale using the Soil and Water Assessment Tool (SWAT)

How is precipitation partitioned into various components, including evapotranspiration, water yield, and streamflow?

How is the partitioning of water yield into surface runoff, lateral flow, and return flow from both shallow and deep aquifers?

Study area



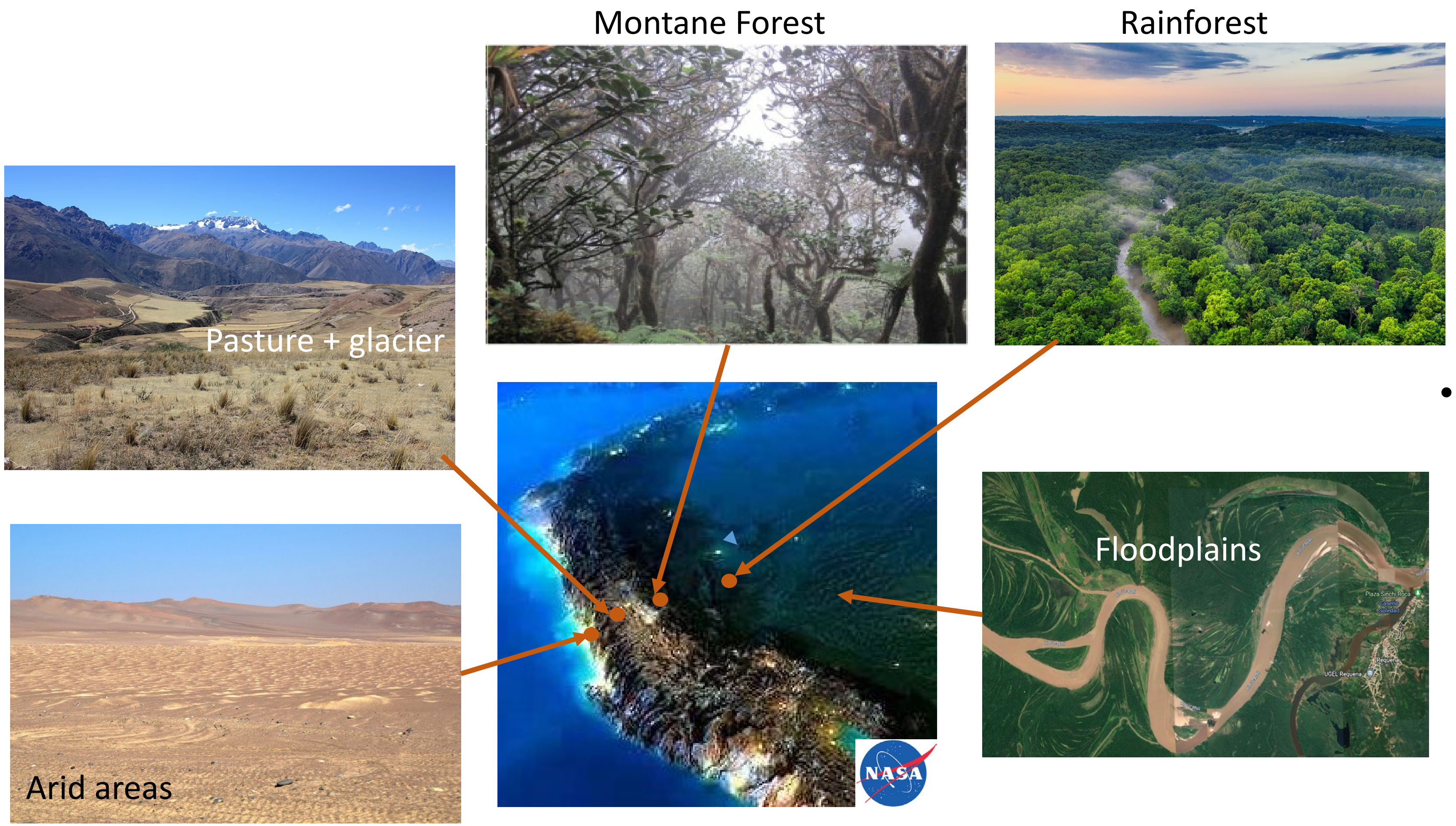
Streamflow stations (72)

Model setup
Area: 1.6 Million km^2
2675 subcatchments
6843 HRUs

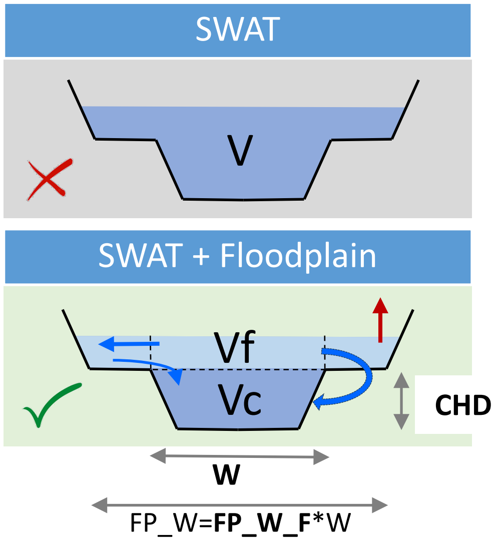
Data

Data type	Resolution	Description/source
Spatial data		
Elevation	90 m	Surface elevation (m a.s.l.) from Multi-Error-Removed Improved Terrain (MERIT; Yamazaki et al. 2017)
Land use	100 m	Land use classification representative for the year 2015 obtained from Copernicus Global Land Service (Buchhorn et al. 2019)
Soil	1000 m	Soil parameters for SWAT based on the Harmonized World Soil Database version 1.21 soil data (Abbaspour and Ashraf Vaghefi 2019)
Soil thickness	1000 m	Soil thickness data (Pelletier et al. 2016) were used to implement variable soil thicknesses at hydrological response units (HRUs)
Groundwater table depth	1000 m	Groundwater table depth data (Fan et al. 2013) were used to constrain soil thickness in shallow water tables across the rainforest region
Hydro-meteorological data		
Precipitation	Daily/0.1° (1981 – 2015)	Rain for Peru and Ecuador (RAIN4PE; Fernandez-Palomino et al. 2021a,b)
Temperature	Daily/0.1° (1981-2016)	Gridded temperature (maximum and minimum) dataset for Peru (Huerta et al. 2018) as provided by SENAMHI (ftp://publi_dgh2:123456@ftp.senamhi.gob.pe/)
Solar radiation	3-hourly/0.1° (1983-2018)	Long-term monthly averages of solar radiation based on the global surface solar radiation data (Tang et al. 2019; Tang 2019) were used
Streamflow	Daily/0.1° (1981 – 2015)	Streamflow data were obtained from Peruvian ANA, SENAMHI, and HYBAM project

SWAT model for Andean and Amazonian catchments

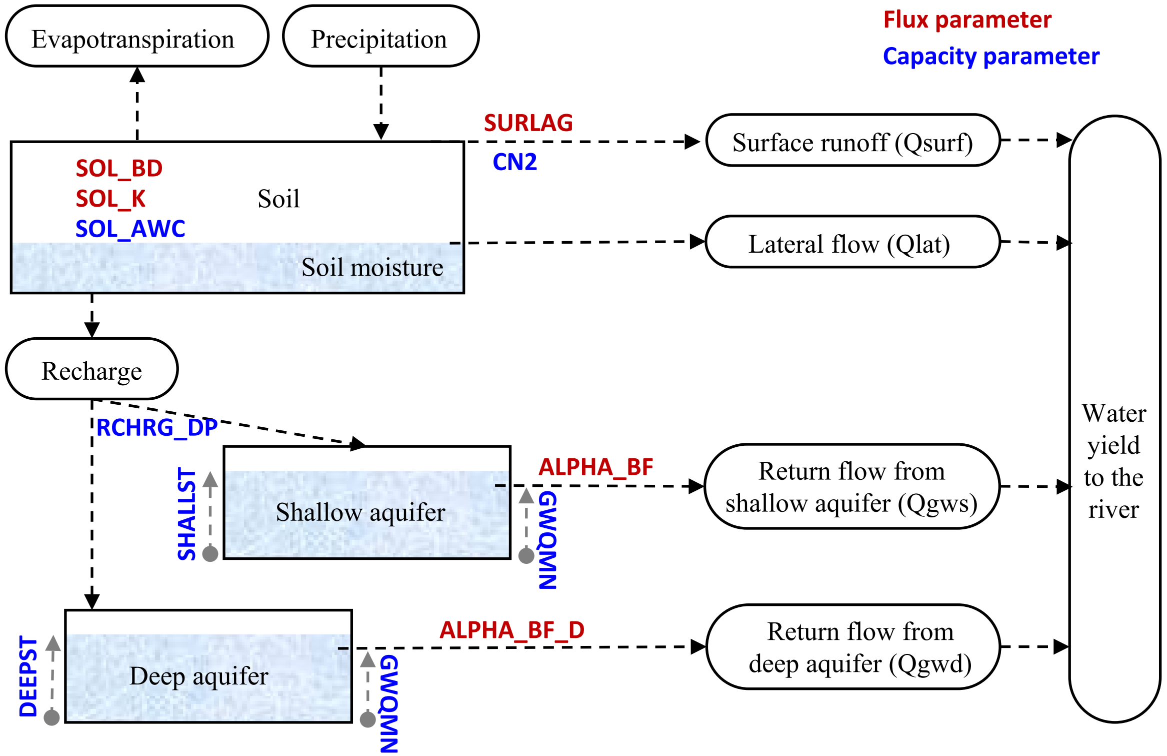


- **SWAT for tropical ecosystems (Alemayehu et al. 2017)**
- **Inclusion of river–floodplain dynamics**



Cross section geometry (Paiva et al. 2011):
$W = 0.8054 Ad^{0.5289}$ $CHD = 1.4351 Ad^{0.1901}$

SWAT model structure and parameters for calibration



Parameters [range]…………..impact

SWAT parameters (7)

SOL_AWC (r) [–0.8, 0.8]……………ET

GW_REVAP (v) [0, 0.2] ……………..ET

SURLAG (v) [0.1, 2] …………………..Q

GW_DELAY (v) [1, 100] ……………..Q

RCHRG_DP (v) [0, 1] …………………Q

GWQMN (v) [500, 1000]……………Q

ALPHA_BF (v) [0.01, 1] ……………..Q

Floodplain parameters (3)

CHD (r) [-0.1, 0.5]……………………..Q

FP_W_F (v) [1, 5]……………………….Q

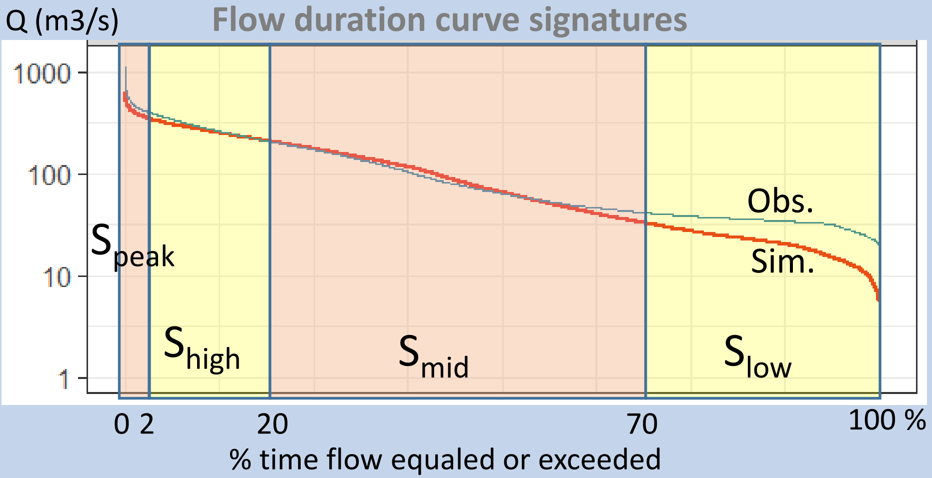
CH_K2 (v) [0, 50]……………………….Q

✓ In Andean catchments, activating Qgwd was crucial for accurately simulating the river flow during the extended dry season, which can last up to 6 months.

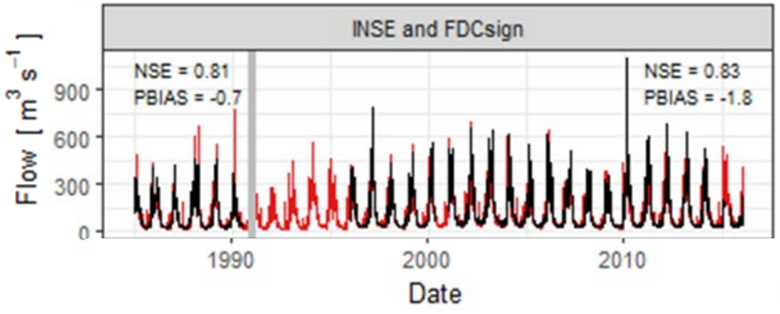
SWAT model calibration

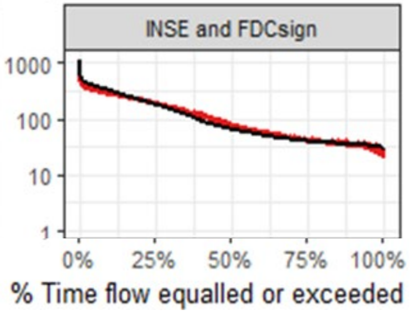
- **Multi-objective calibration (BORG algorithm)**
- **Objective functions:**

> ➢ $\text{Max}(\log\_NSE = 1 - \frac{\sum_{i=1}^{n}\left(\ln(S_i) - \ln(O_i)\right)^2}{\sum_{i=1}^{n}\left(\ln(O_i) - \ln(O_p)\right)^2})$

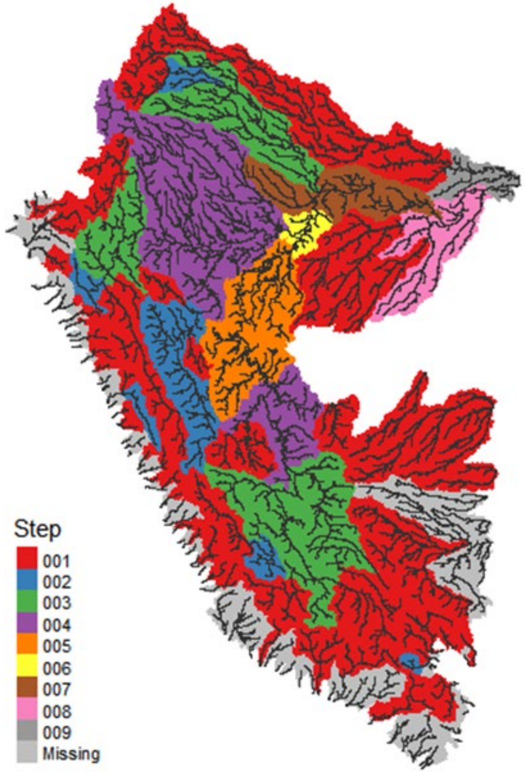


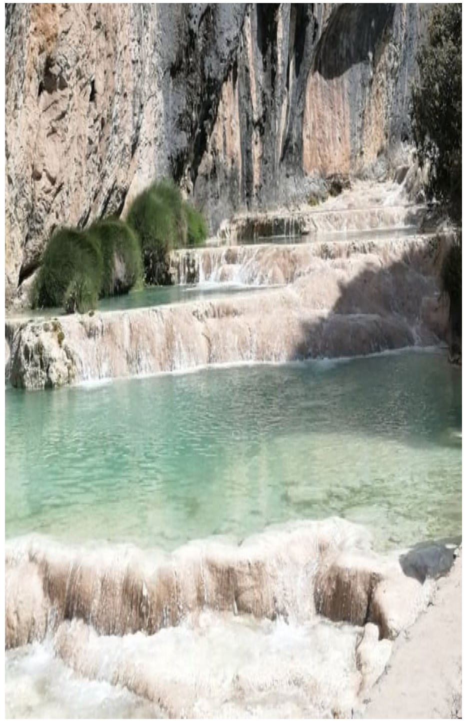
> ➢ $\text{Min}(FDC_{sign} = \frac{1}{4}(|S_{peak}| + |S_{high}| + |S_{mid}| + |S_{low}|))$





- **Cascading calibration approach (72 Q stations)**





Model run (1.6 Million km², 2675 sub-catchments, 6843 HRUs): 1 min.yr⁻¹

Total calibration time using traditional tool

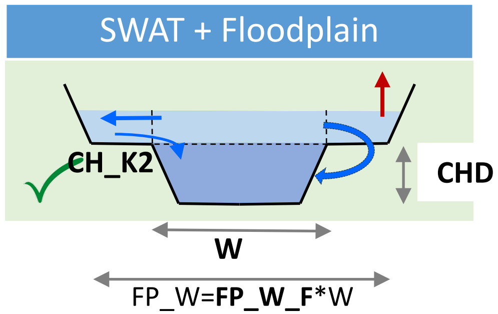
~500 days
(10yrs*1000sim*72gauges)

For me?

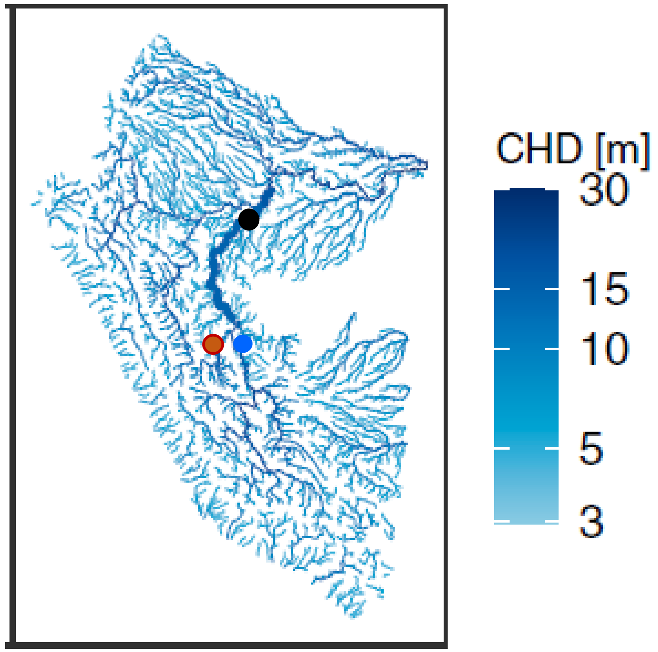
HPC

~5 days

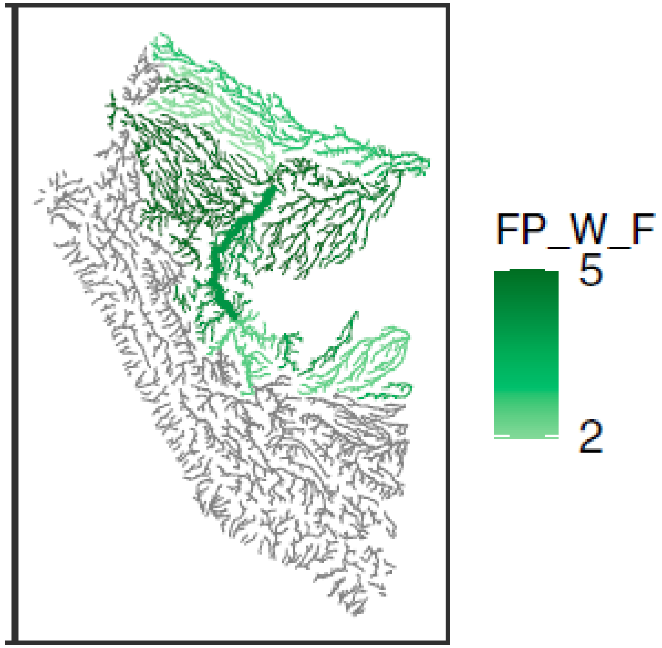
Calibrated SWAT-floodplain parameters



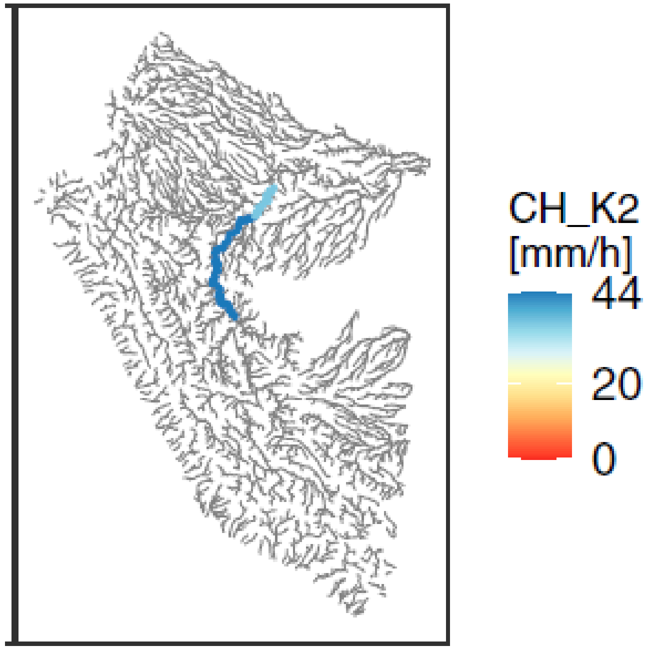
Main channel depth (CHD)

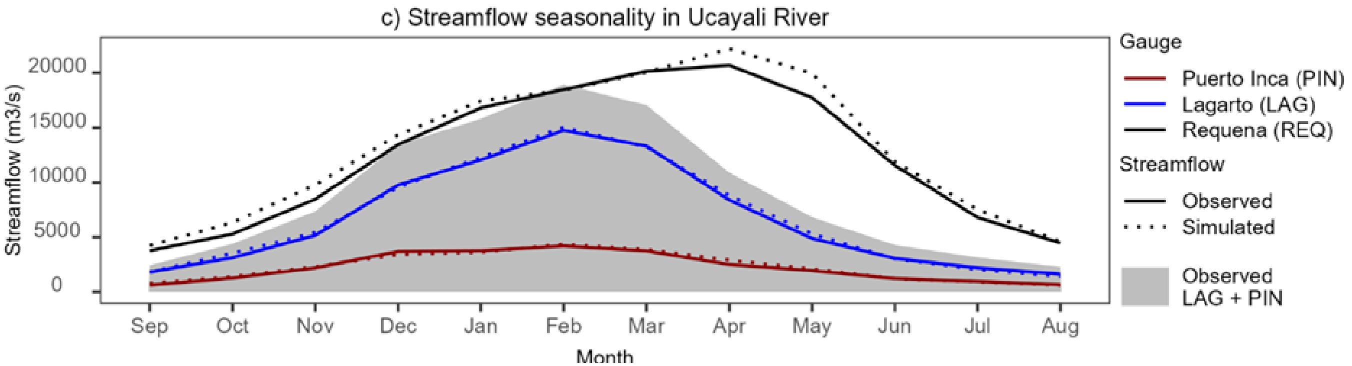


Ratio of floodplain width to bankfull width (FP_W_F = FP_W/W)

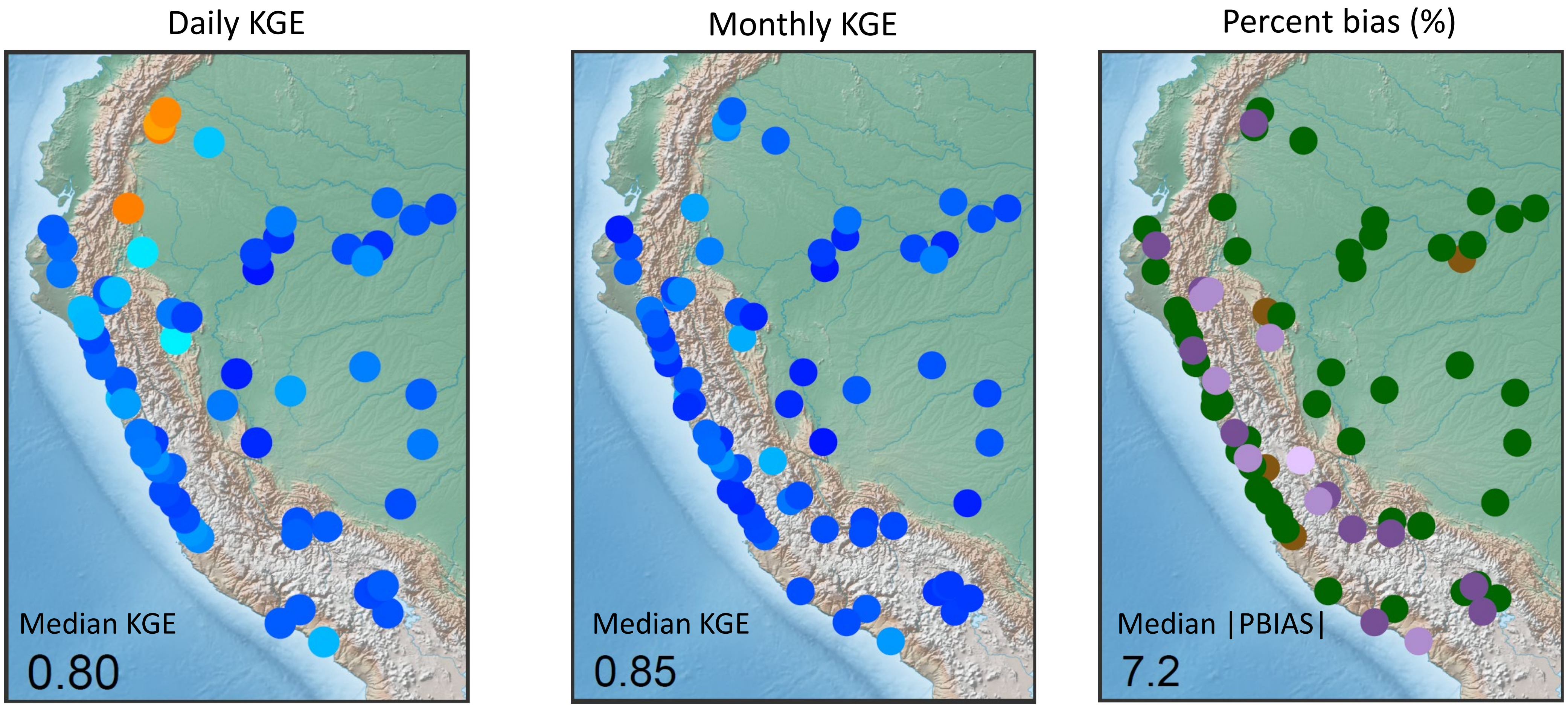


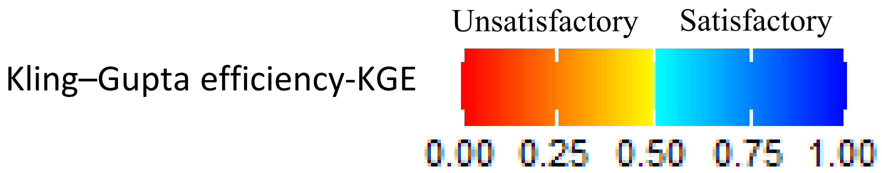
Hydraulic conductivity of floodplain (CH_K2)





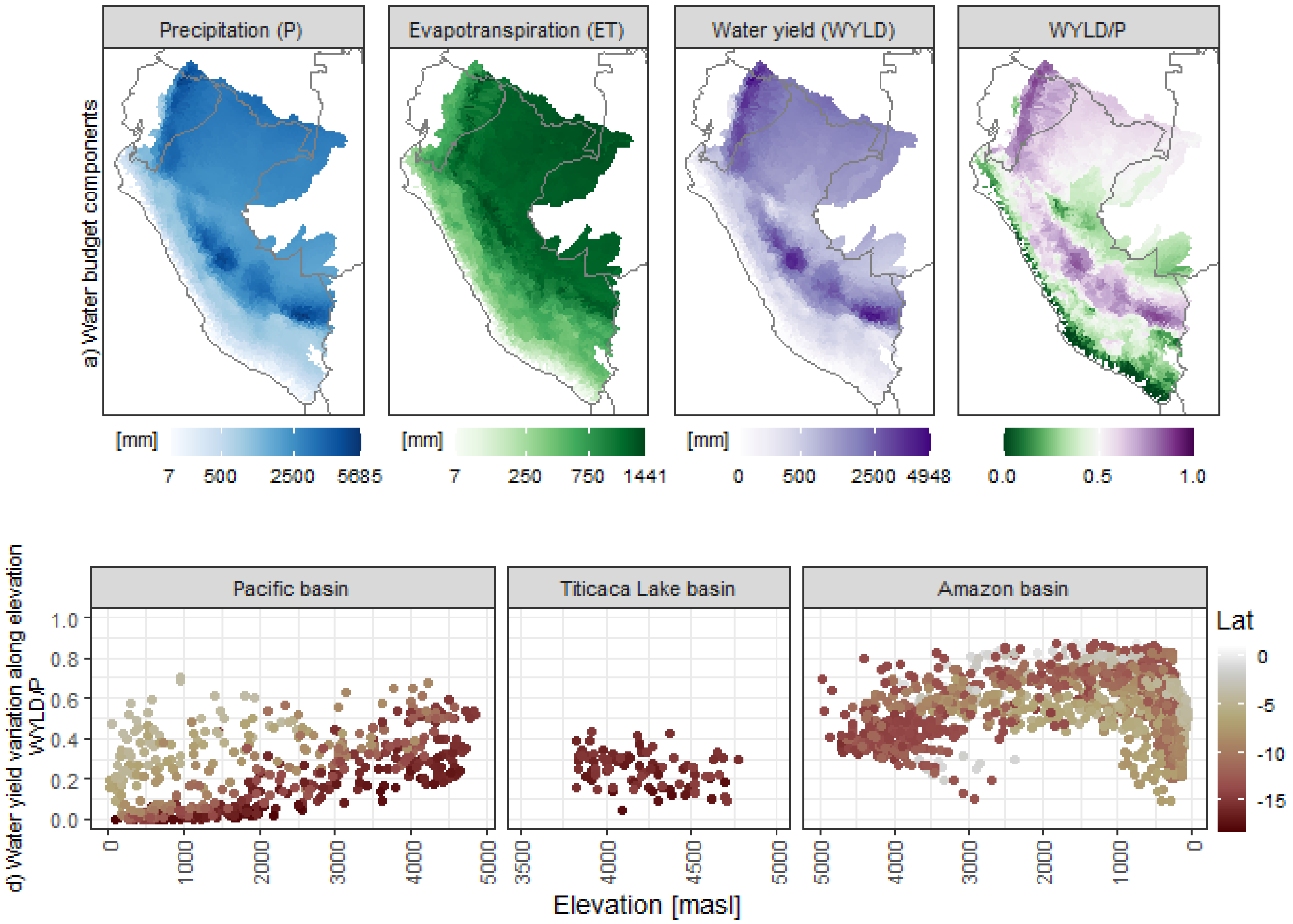
SWAT model performance for streamflow simulation





PBIAS values between -10 to 10 shown in green points indicate good model performance in achieving the water budget closure

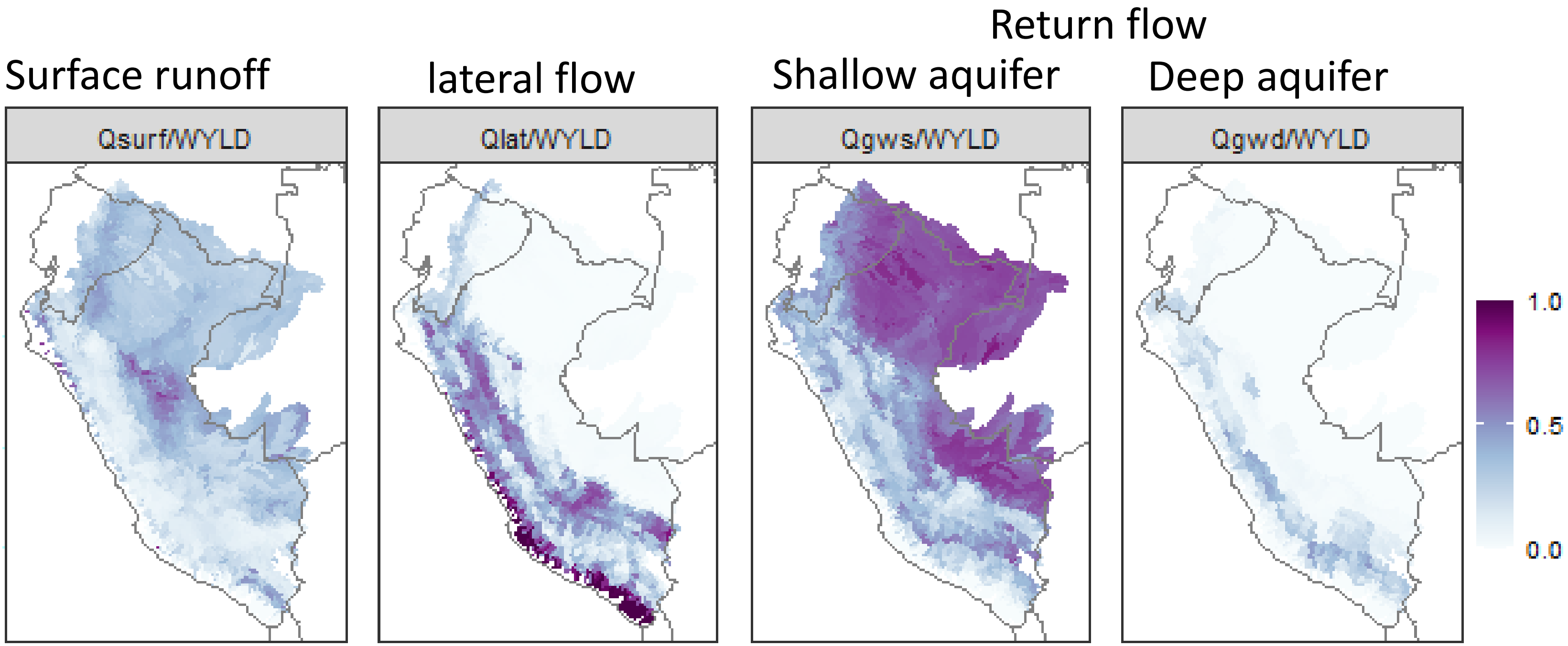
Distribution of water budget components



- Water balance components shows increasing patterns from west to east
- Notable hotspots of precipitation and water yield along the Amazon-Andes transition region (500-2000 masl)

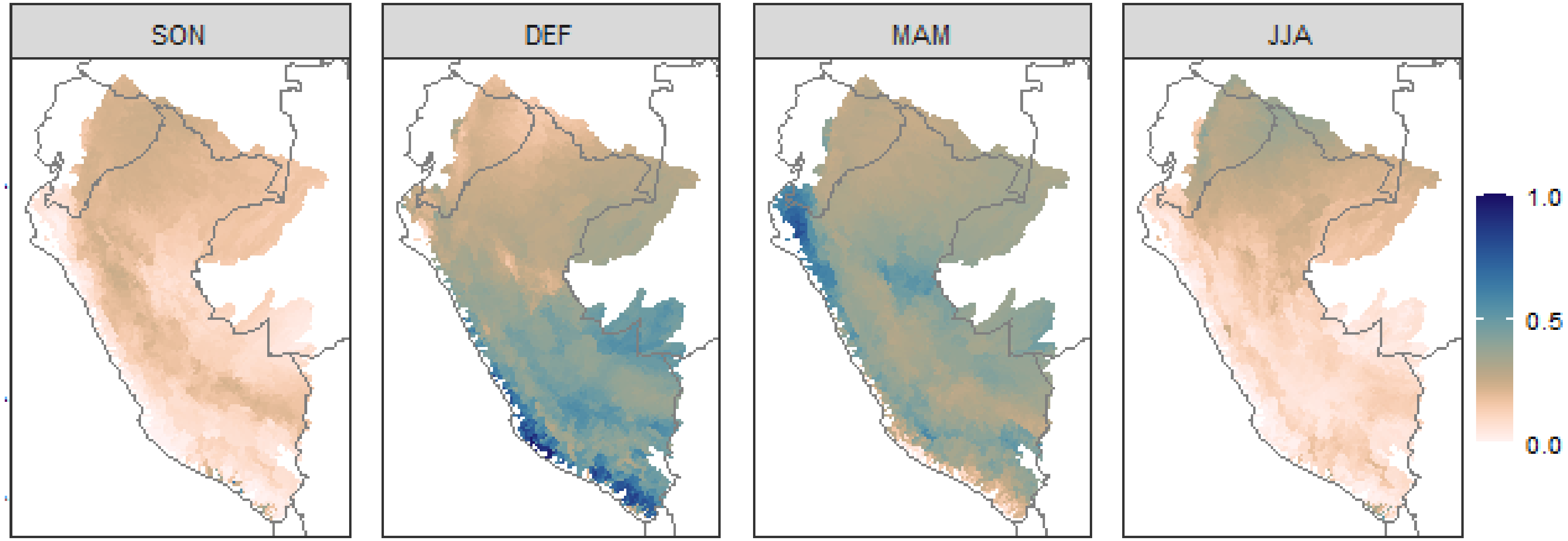
- In the Pacific Basin, water yield increases with elevation and latitude
- In the Amazon Basin, water yield follows a unimodal curve with a peak in the Amazon-Andes transition region

Spatial and vertical distribution of water yield components



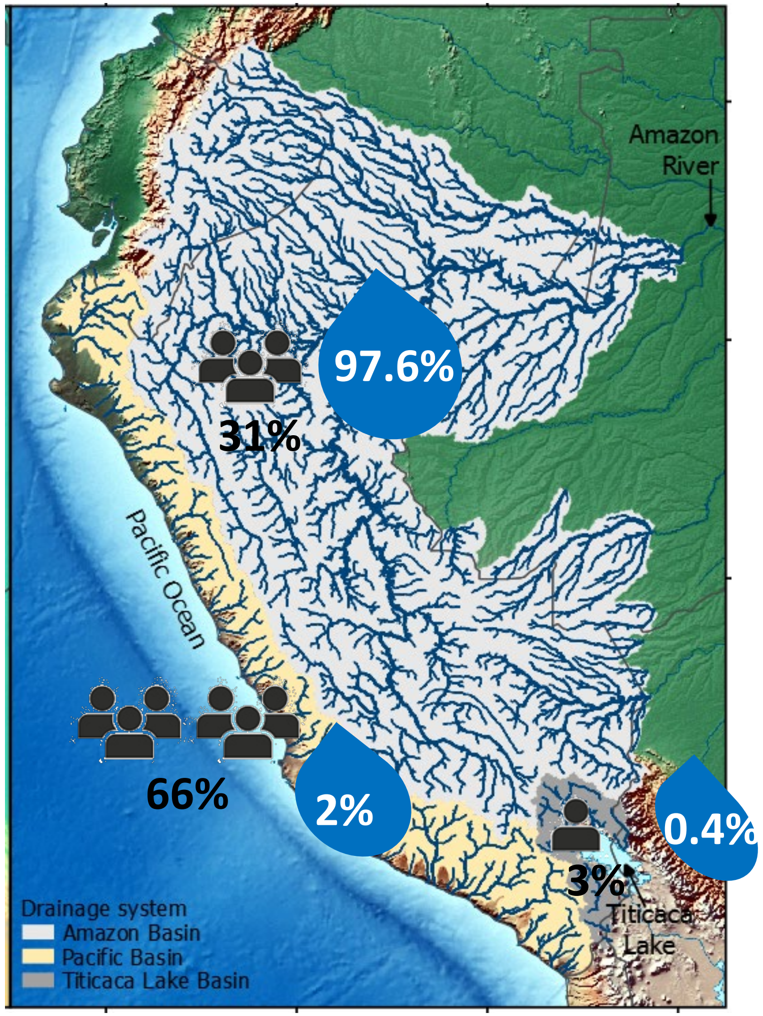
- Return flow from the shallow aquifer (Qgws), emerges as the primary contributor to water yield in Amazon lowland catchments
- Andean catchments exhibit a complex system with multiple sources, including lateral flow (Qlat) and return flow from both shallow (Qgws) and deep (Qgwd) aquifers.
- The return flow from deep aquifers plays a crucial role in regulating the baseflow regime in Andean catchments, ensuring substantial discharge during the extended dry season.

Seasonal water yield distribution



- In the Ecuadorian and northern Peruvian Amazon, water yield follows a weak annual cycle
- Southern catchments, including both Andean and lowland areas, experience a strong annual cycle, with high yields during December-May and low yields during June-November

Total freshwater resources in Peru



Water resources availability
58,934 m3/s

Population
33 Millions

Uneven water availability across the three large drainage systems

I would like to invite you to my presentation tomorrow!

09:00 - 10:30	**Session G3: Climate Change Applications** Preben Hornung Stuen, Building 1422	Moderated by Hans Thodsen, Aarhus University, Denmark
09:00 - 09:20	**Carlos Antonio Fernandez Palomino** Climate Change Impact on Water Budget and Hydrological Extremes Across Peru	

I also invite to view my previous presentation, which serves as the foundation for my current and upcoming presentation

13:00 - 14:30	**Session B3: Hydrology** Preben Hornung Stuen, Building 1422	Moderated by Pedro Chambel-Leitao, Hidromod, Portugal
13:00 - 13:20	**Carlos Antonio Fernandez Palomino** Assessing the Impact of Precipitation Input Errors on Model Parameters and Water Budget Components: Insights from Countrywide Hydrological Modeling in Peru	

THANKS