Assessing the effect of rainfall data scarcity on daily streamflow simulation in spatially heterogeneous watersheds

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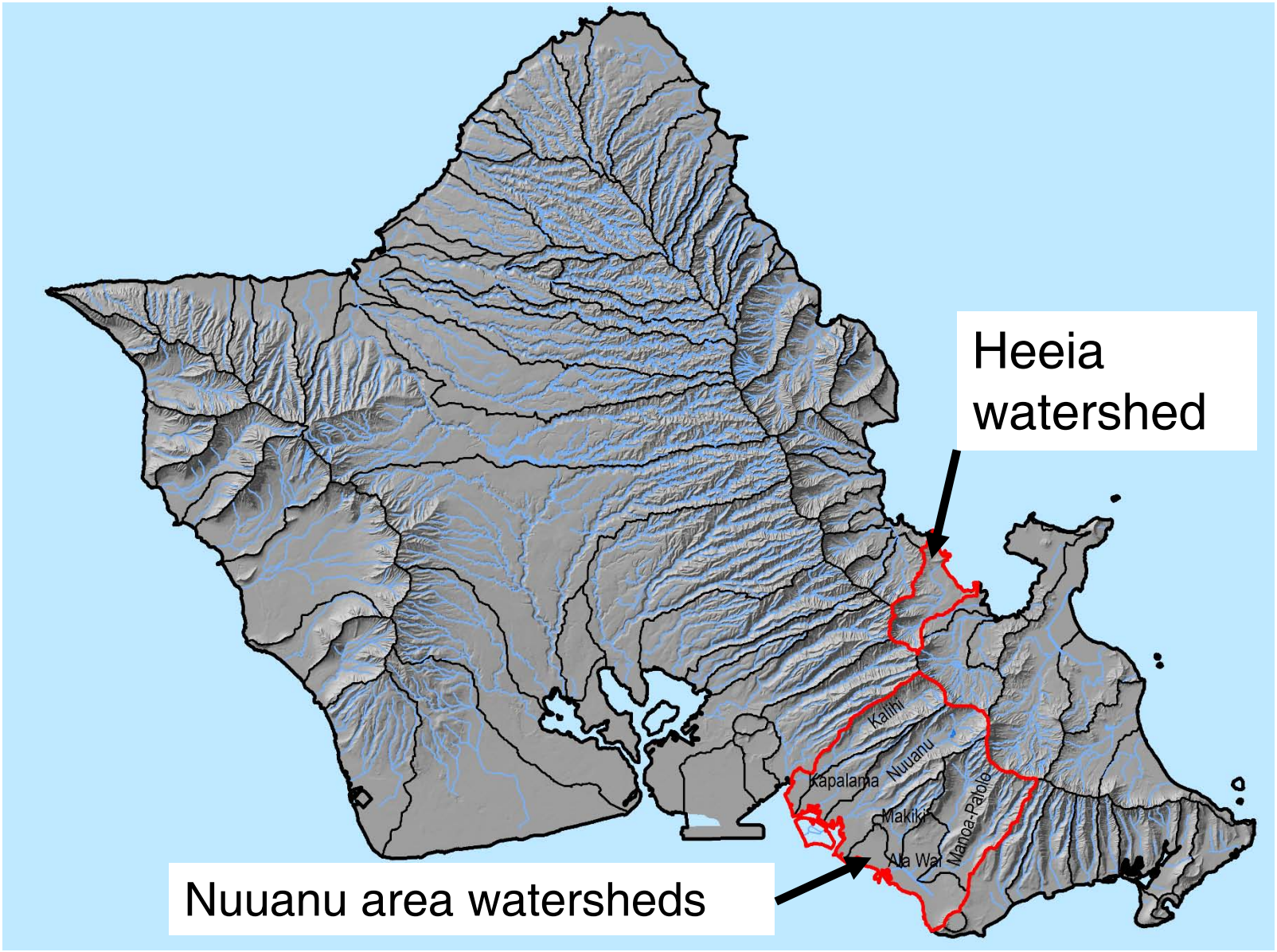
Problem/research questions

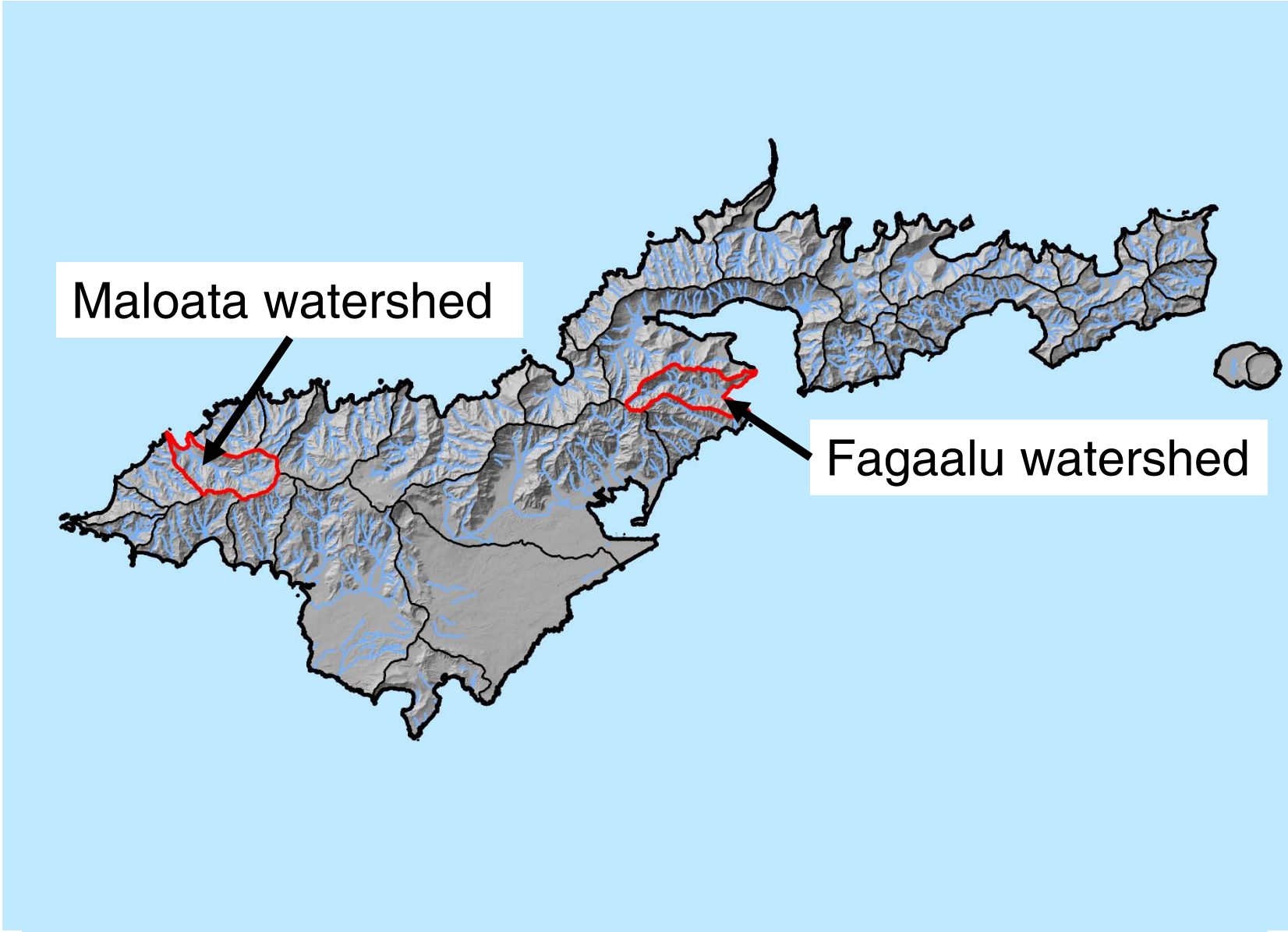
- High rainfall spatial variability in Pacific Islands
- Mean annual rainfall ranges **200 to 10,000** mm over the Hawaiian Islands (Giambelluca et al, 2013)
- Decrease in number of rain gauging stations
- Can we use rainfall data from neighboring watersheds for ungauged watersheds in spatially heterogeneous rainfall patterns?
- How do rainfall data scarcity affect watershed model performance compared to relatively well gauged watersheds?

Study area (Oahu island)



- Small scale watersheds with unique hydrological features, soil types, topography, & highly variable climate conditions.

Study area (American Samoa)



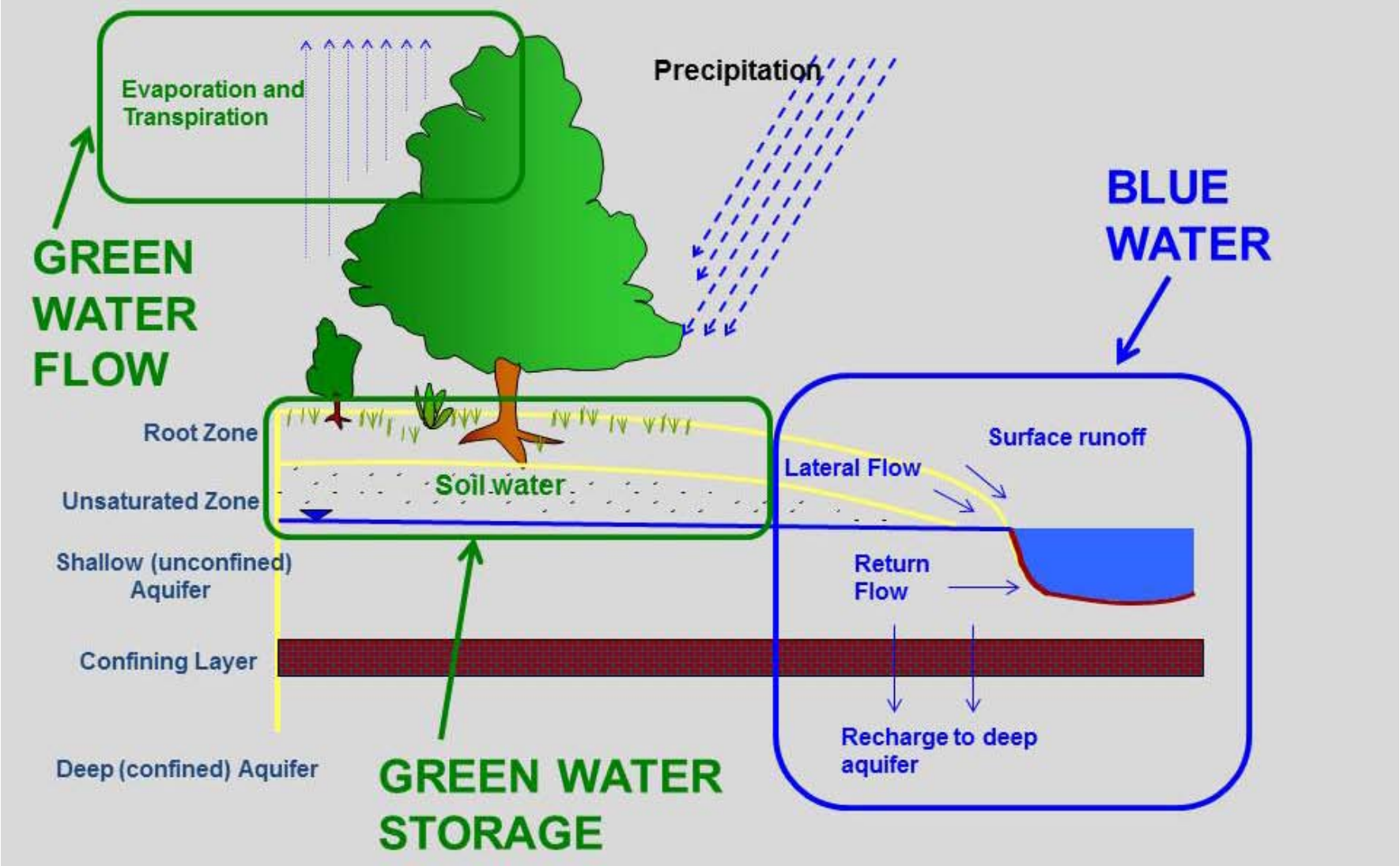
- Small scale watersheds with unique hydrological features, soil types, topography, & highly variable climate conditions.

Objectives

- To develop watershed model for:
  - Heeia watershed: environmental twist
  - Nuuanu watershed: water conservation twist
  - Fagaalu watershed: environmental twist
- To assess the effect of rainfall input on watershed model performance in spatially heterogeneous watersheds

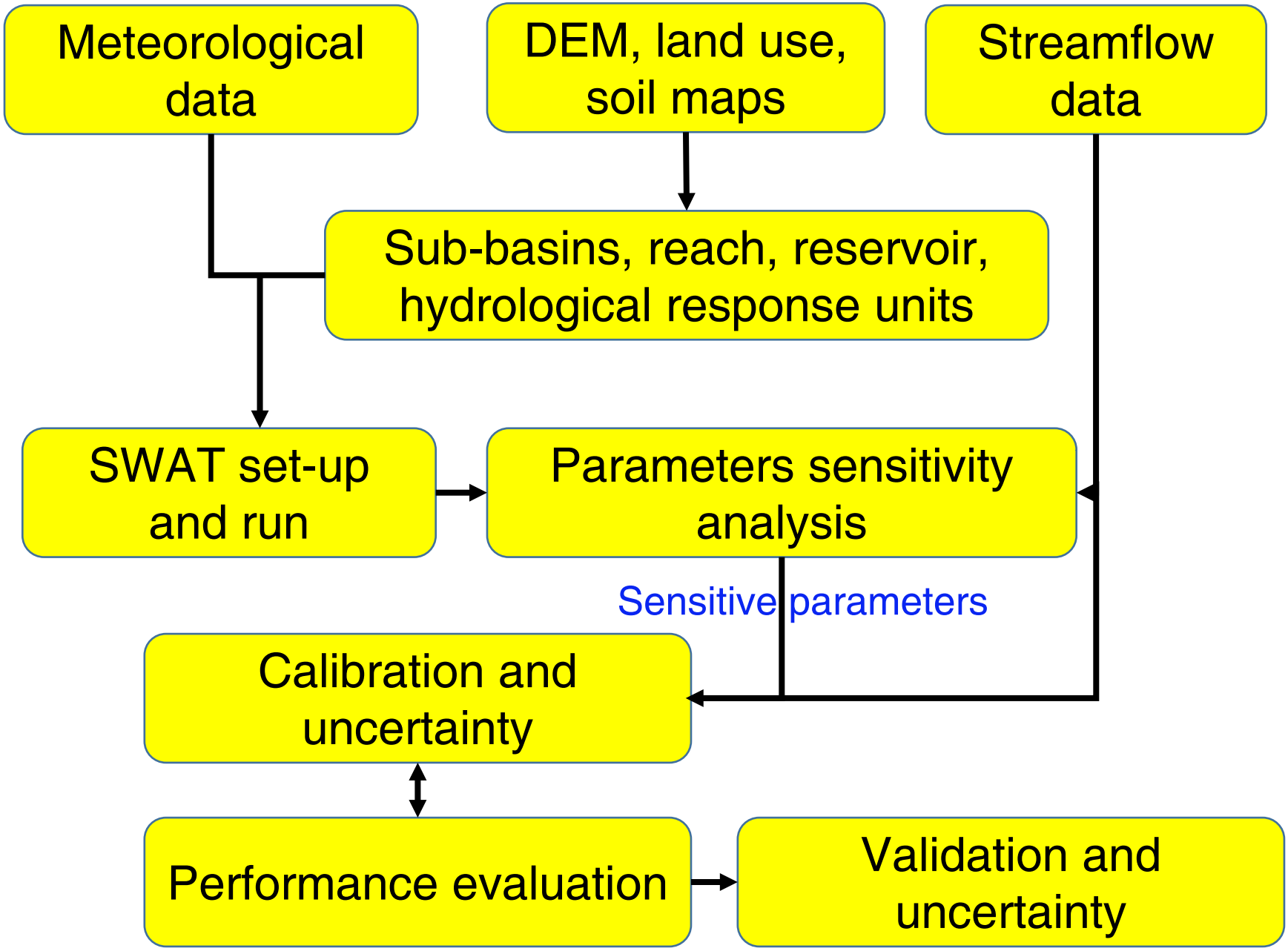
Approach

Utilize the model Soil and Water Assessment Tool (SWAT)

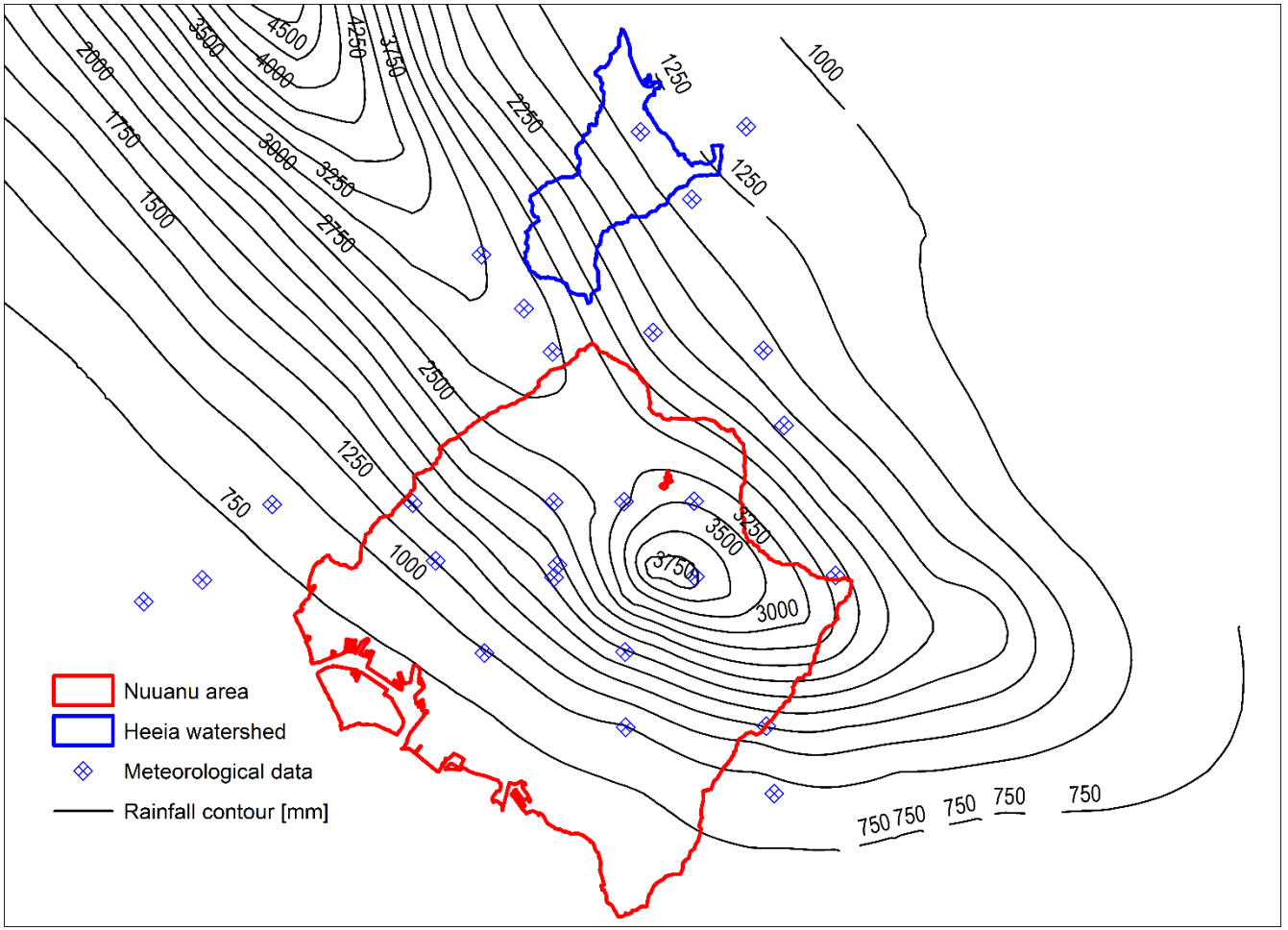


Soil-water-plant interaction processes and water balance

SWAT modeling approach

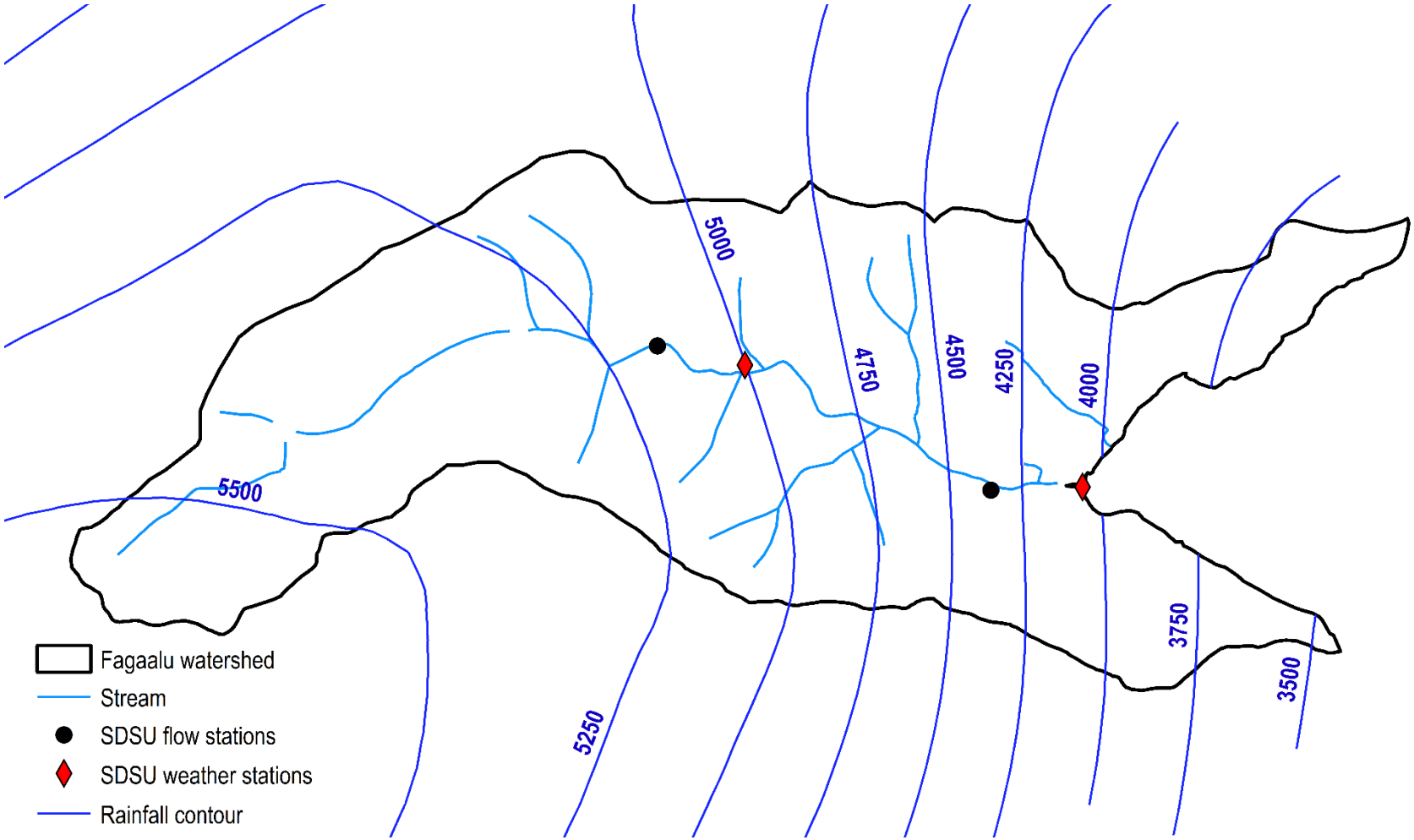


Hydro-meteorological (Oahu watersheds)



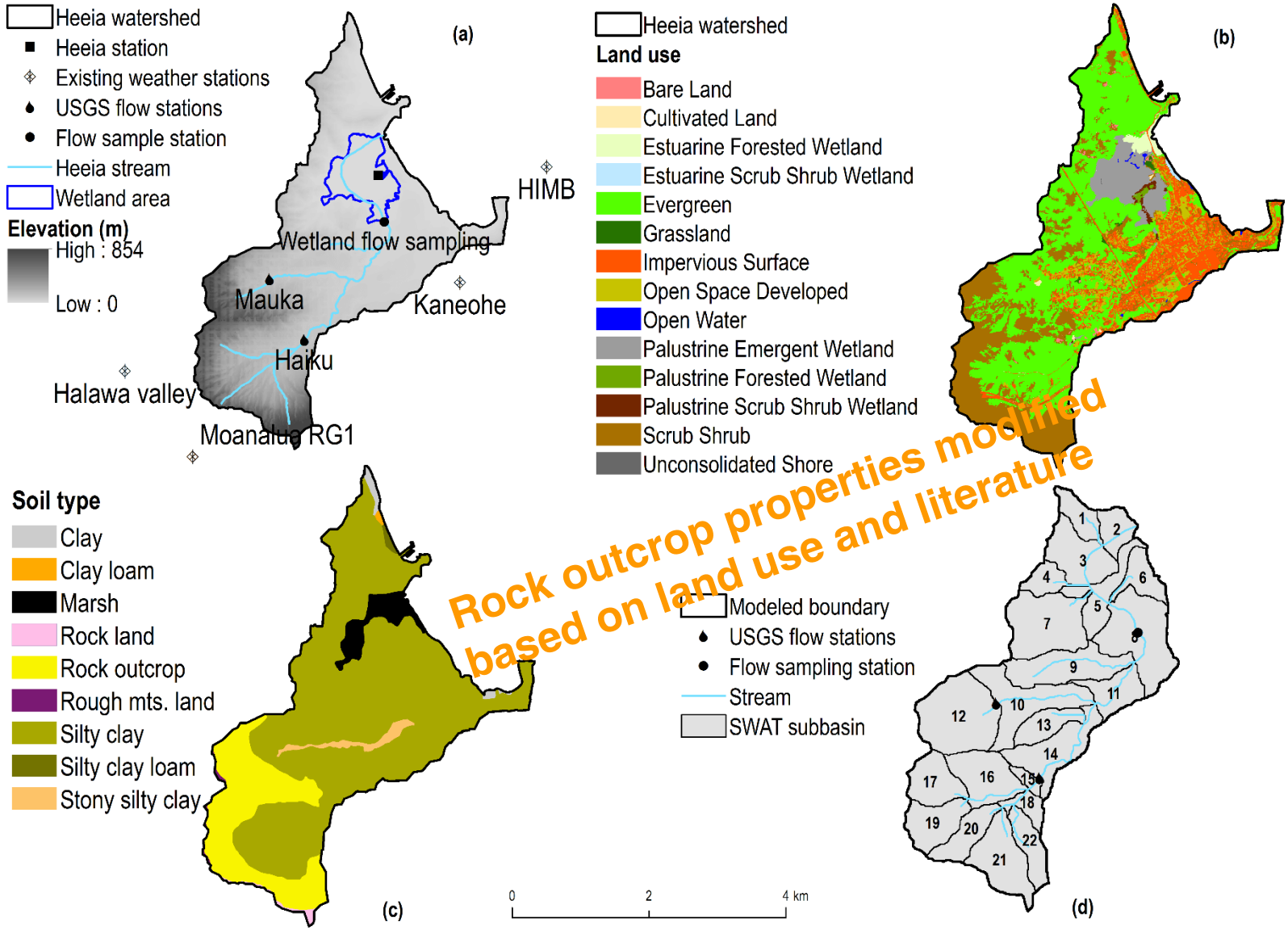
- **Missing values:** filled based on contour maps, nearby stations, correlation and interpolation techniques for ungauged sites

Hydro-meteorological (Fagaalu)

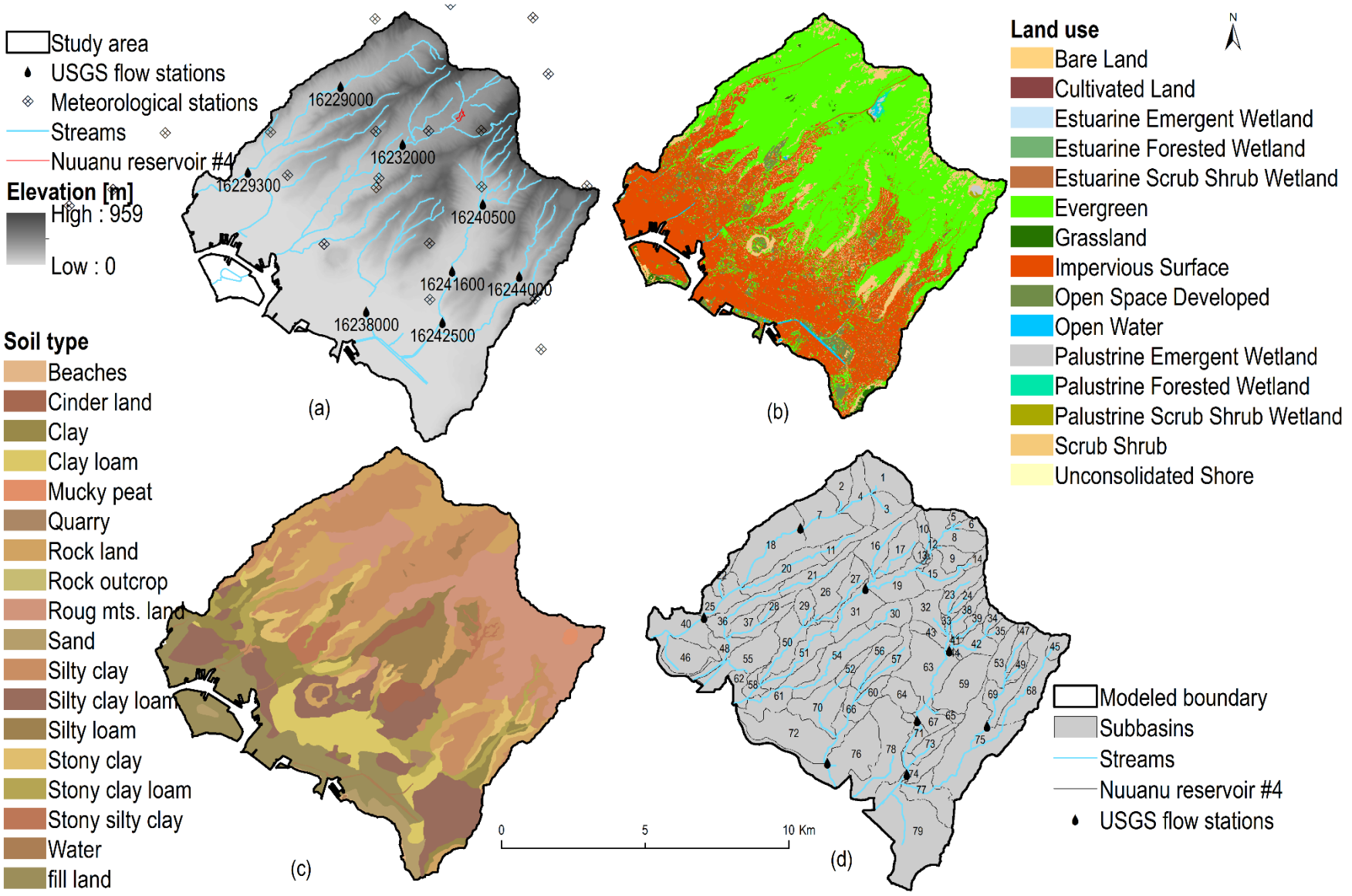


- **Missing values:** filled based on contour maps, nearby stations, correlation and interpolation techniques for ungauged sites

Data and SWAT development Heeia watershed



Data and SWAT development for Nuuanu area

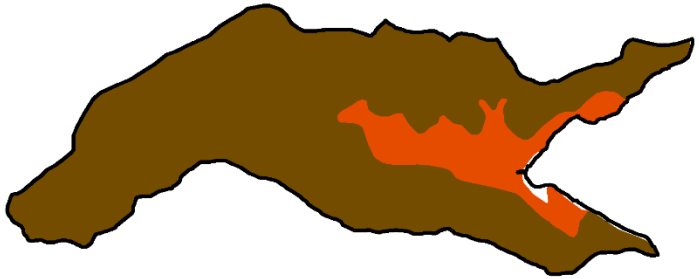


Data and SWAT development for Fagaalu

Faga'alu watershed

Land use C-CAP 2010

- Bare Land
- Cultivated
- Developed Open Space
- Evergreen Forest
- Grassland
- Impervious Surface
- Scrub/Shrub
- Water

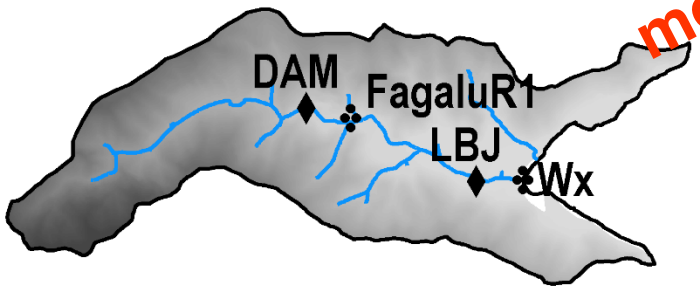


Faga'alu watershed

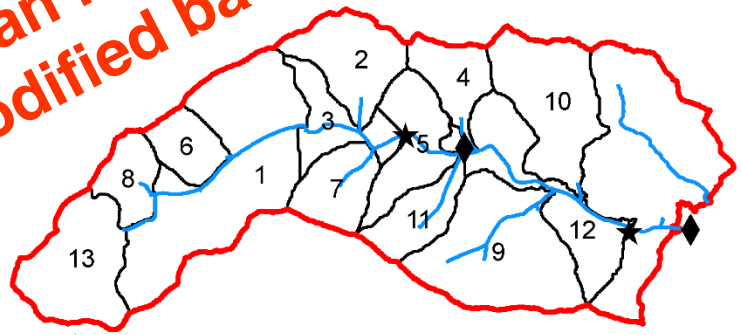
SSURGO soil type

- Fagasa
- Urban land

Urban land soil properties modified based on land use type



- SDSU weather stations
- SDSU flow/sediment stations



- SDSU weather stations
- SDSU flow/sediment stations
- SWAT boundary
- SWAT sub-basins

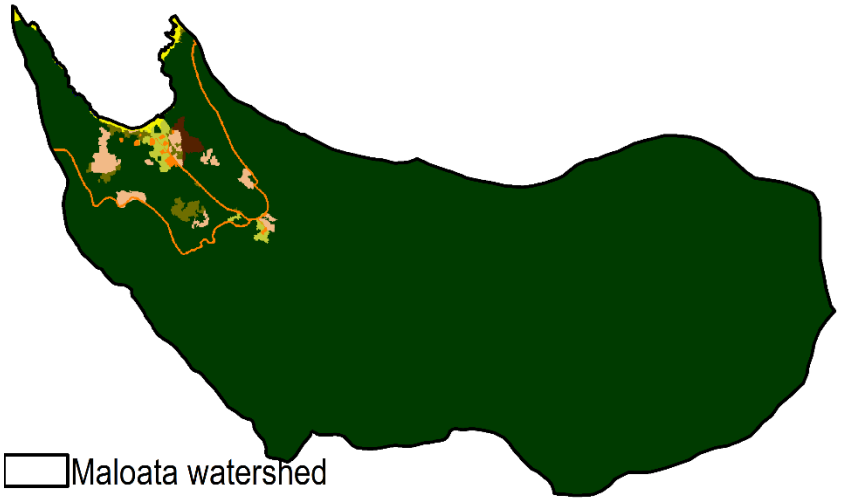
Elevation [m]

High : 651

Low : 0

0 1.75 3.5 Km

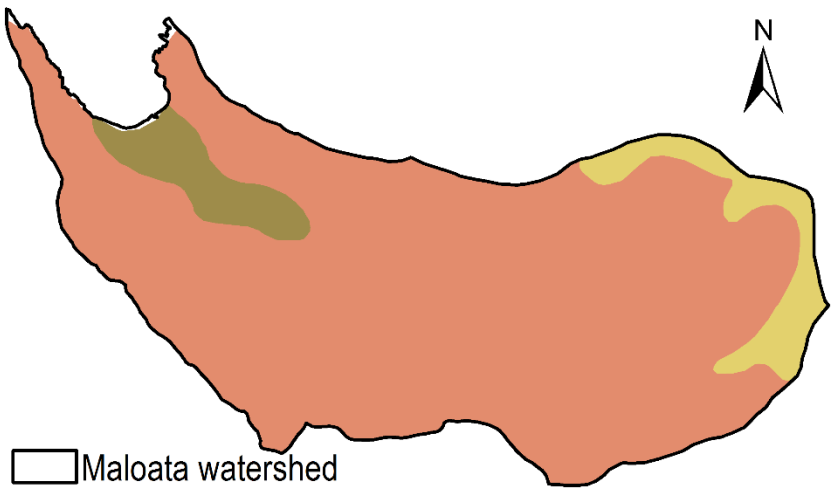
Data and SWAT development for Maloata



Maloata watershed

Land use C-CAP 2010

- Bare Land
- Cultivated
- Developed Open Space
- Evergreen Forest
- Grassland
- Impervious Surface
- Scrub/Shrub
- Water

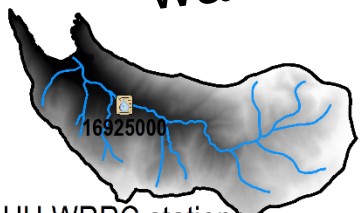


Maloata watershed

SSURGO soil type

- Aua
- Fagasa
- Oloave

All climatic data derived from neighboring watersheds

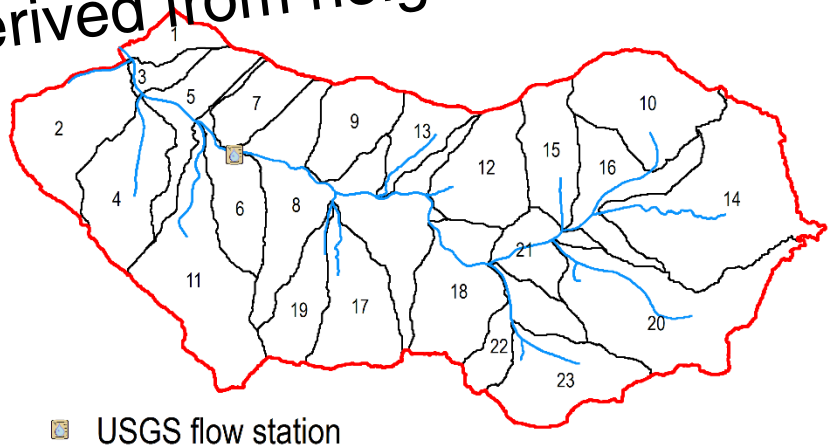


- UH WRRC stations
- NCDC stations
- USGS flow station

Elevation [m]

High : 393

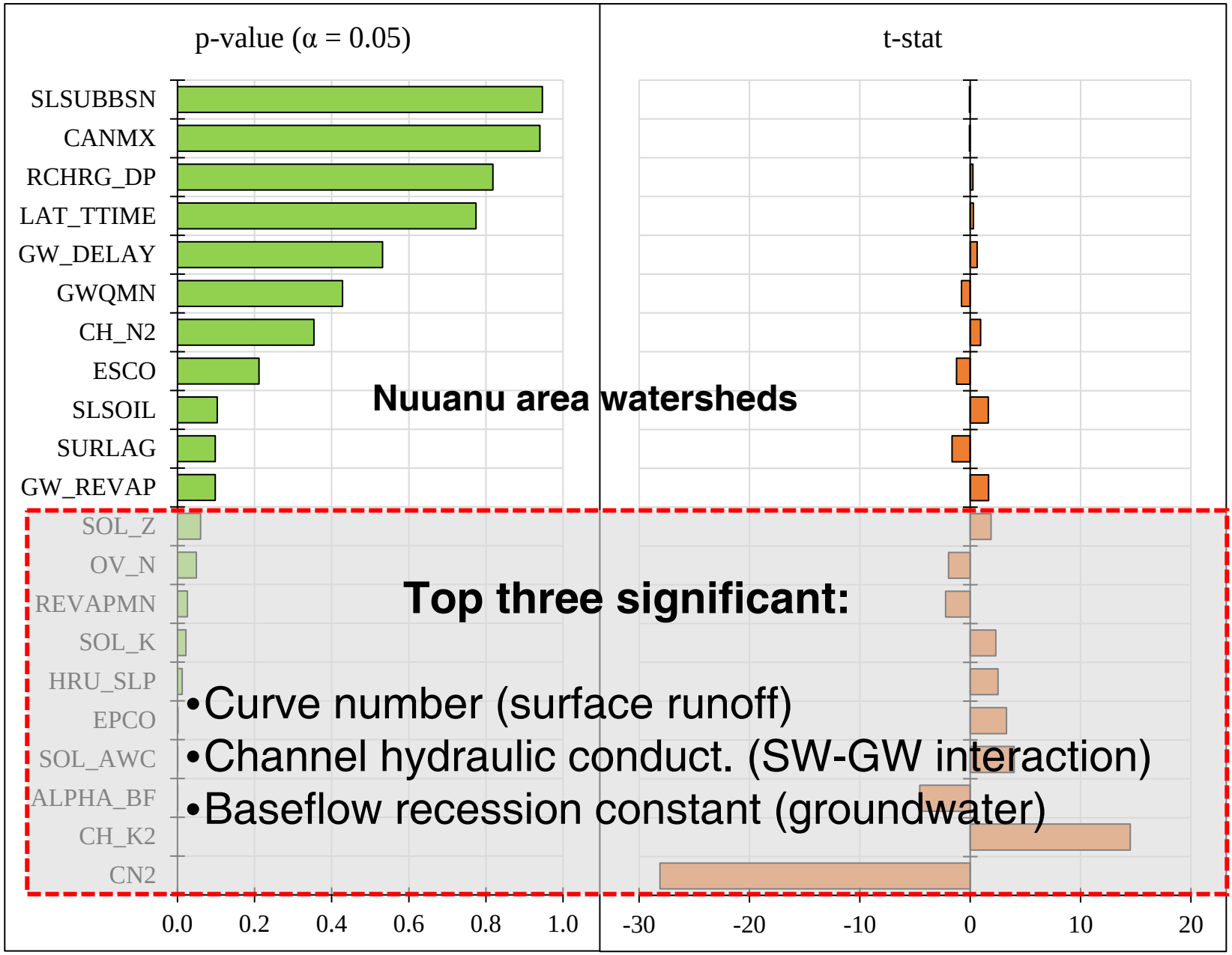
Low : 0



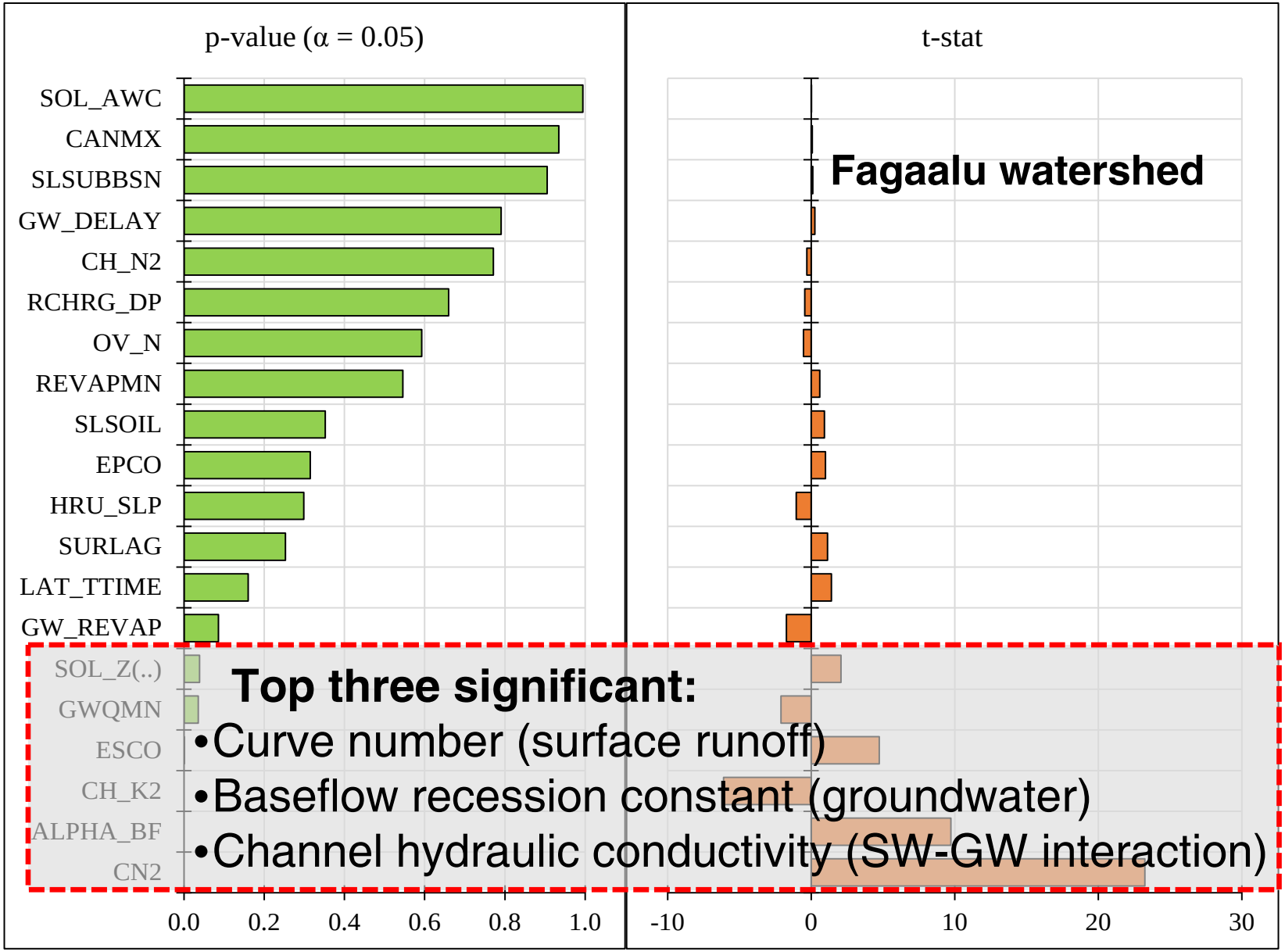
- USGS flow station
- stream
- SWAT_boundary
- SWAT sub-basins

0 1.5 3 Km

Sensitive parameters for Oahu

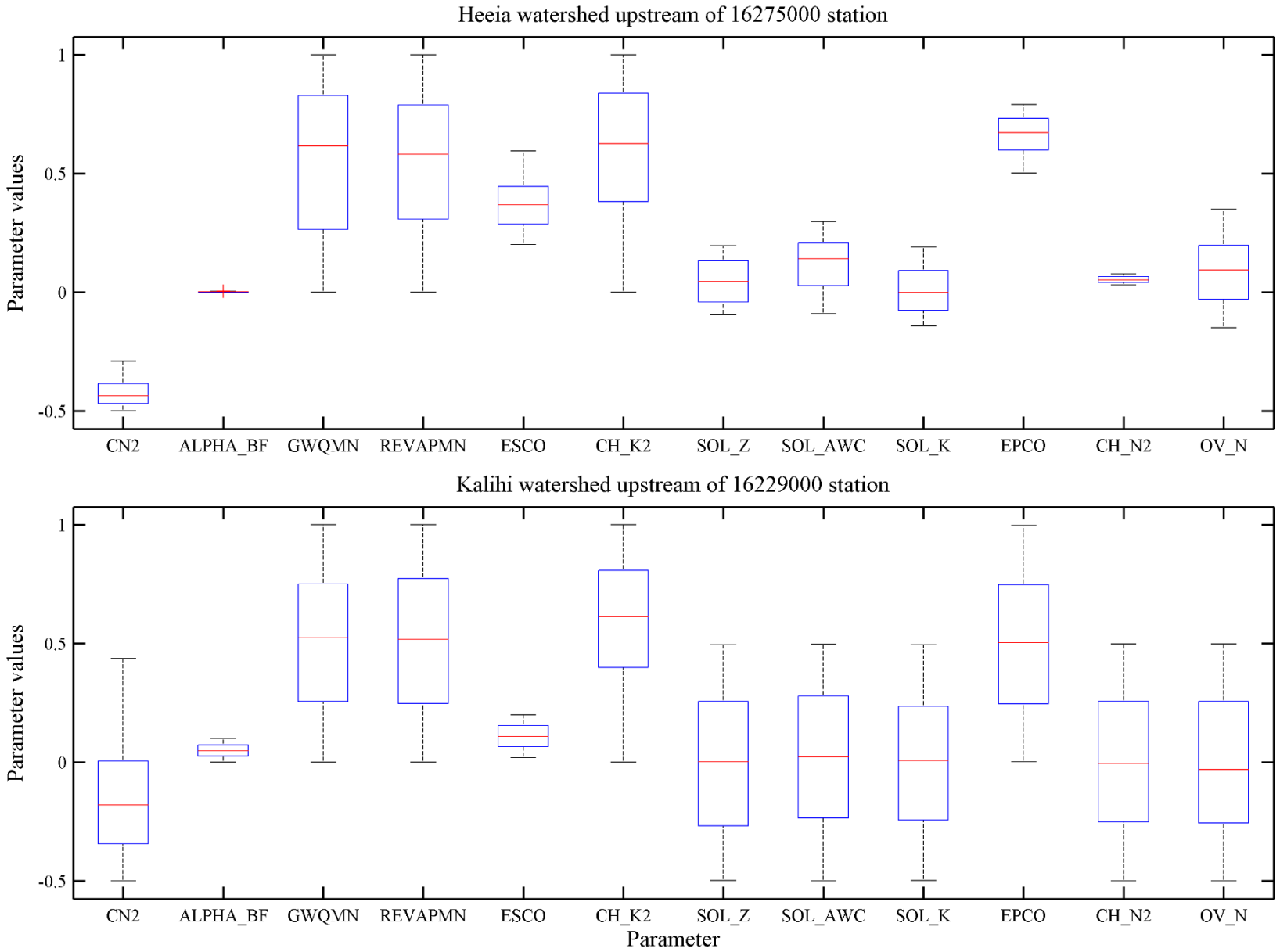


Sensitive parameters for American Samoa



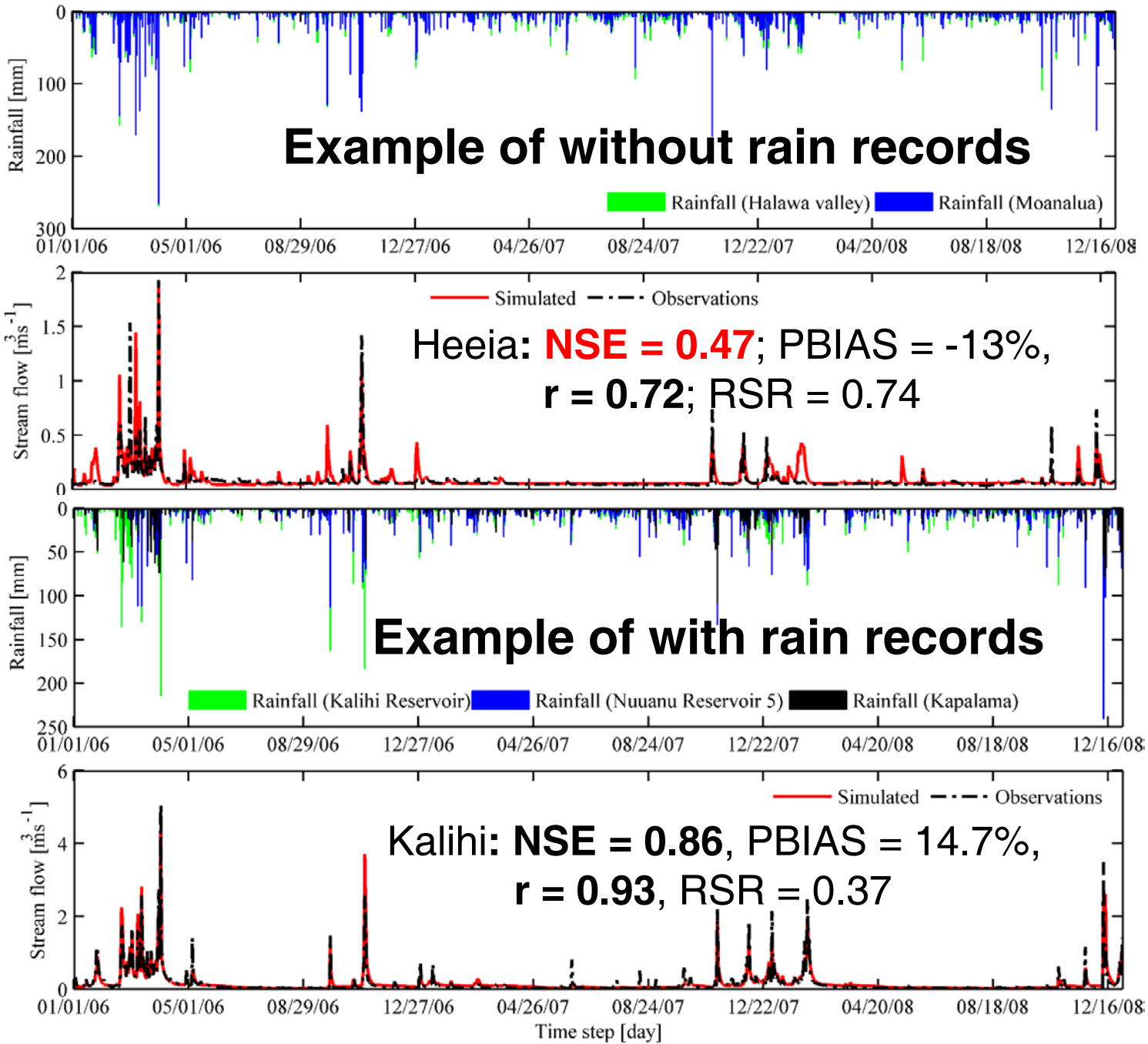
•Top 3 sensitive parameters are the same for Oahu and Am Samoa

Calibrated SWAT parameter values

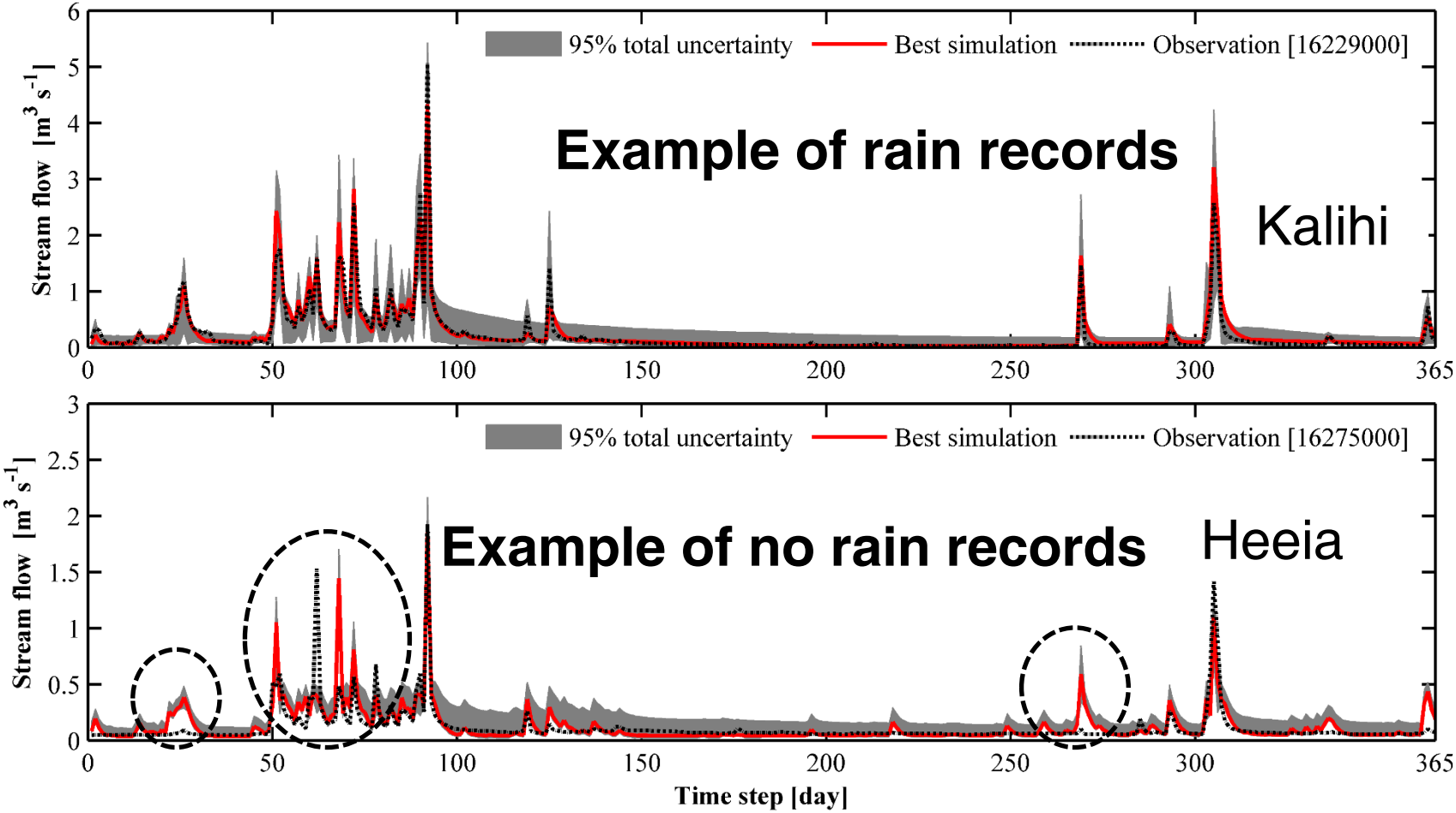


- Good solutions (NSE $\geq$ 0.2, Heeia, $\geq$0.5, Kalihi) parameter values

Observed streamflow well represented with rain records

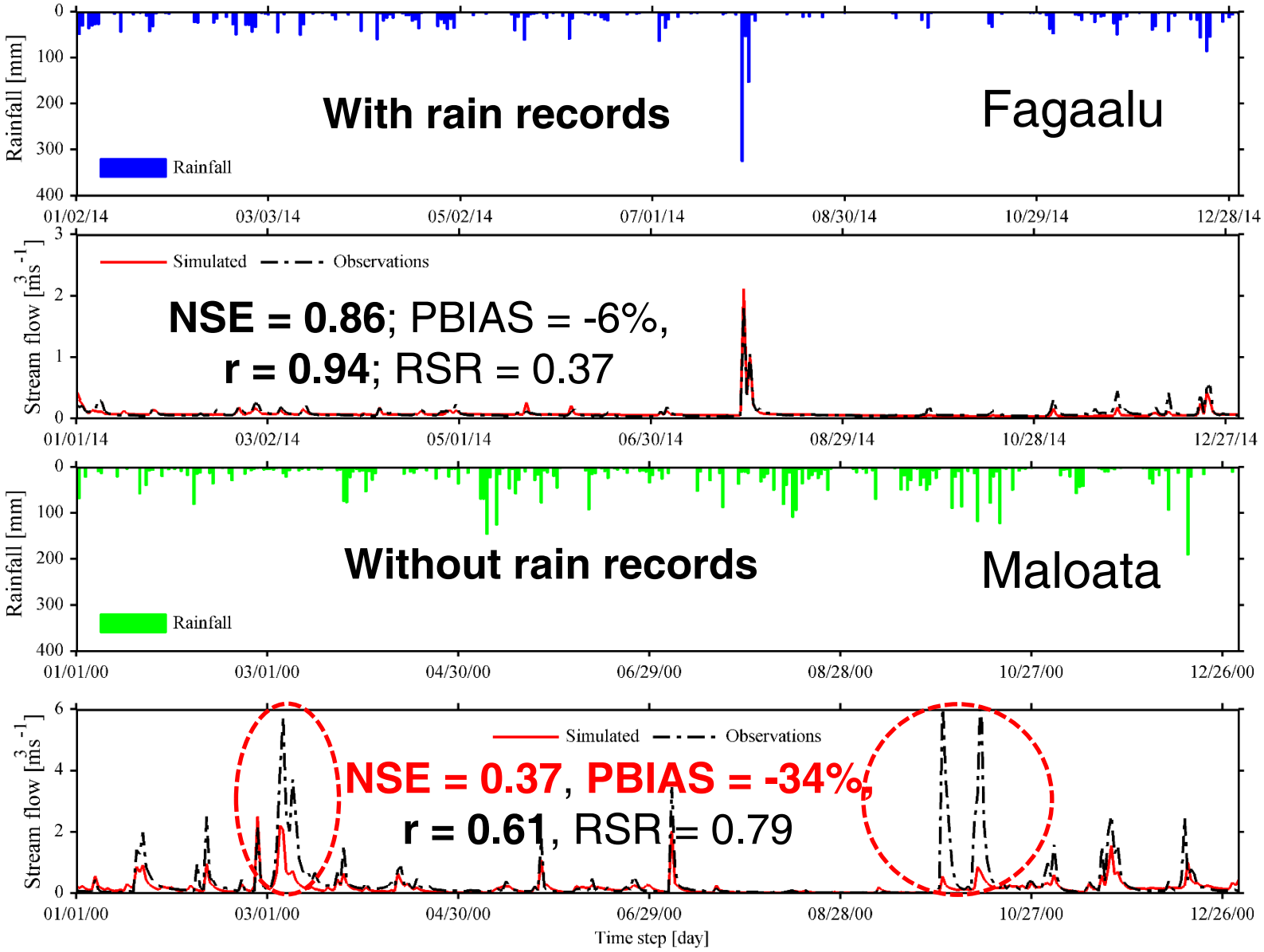


Use of rainfall data within watershed improves SWAT model performance



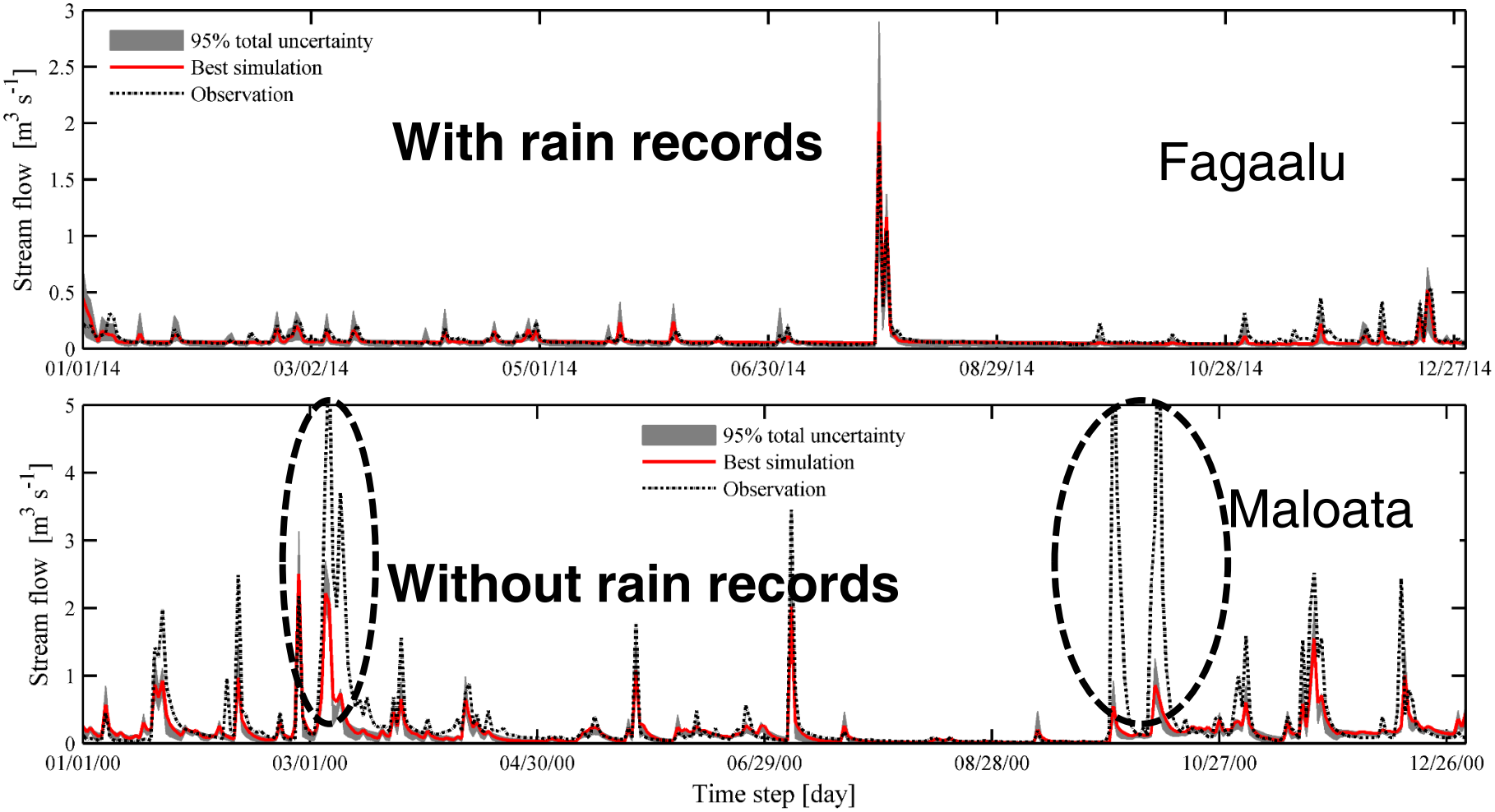
- Rain records: P-factor = 0.83 to 0.93; r-factor = 0.72 to 0.84
- Without rain records: p-factor = **0.41** to 0.76; r-factor = 0.89 to **1.18**

Temporal variability of observed streamflow sufficiently captured for watershed with rainfall data



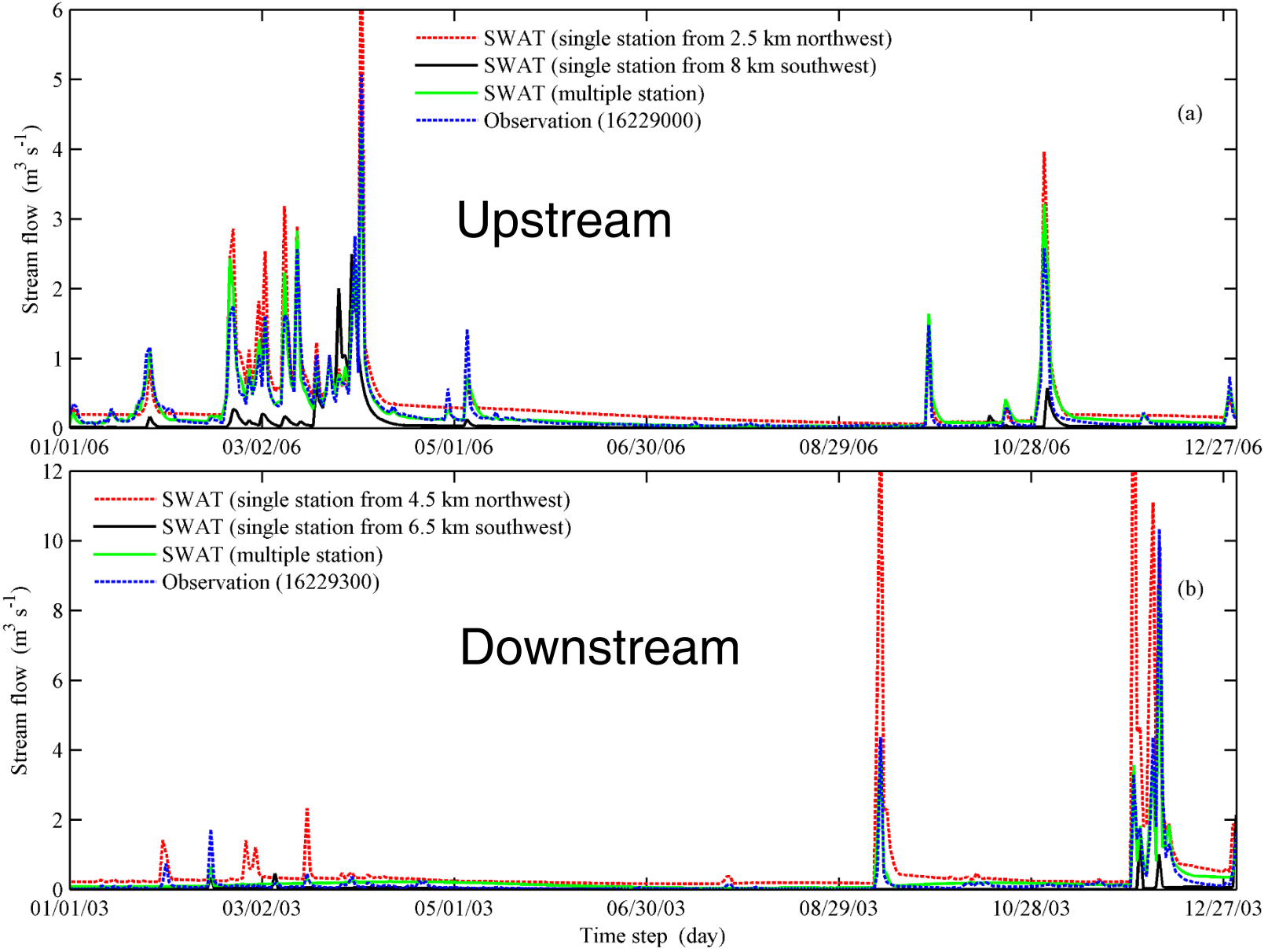
- Peak flows missed for Maloata watershed, low NSE

95% prediction uncertainty did not sufficiently bracket observations for ungauged watersheds



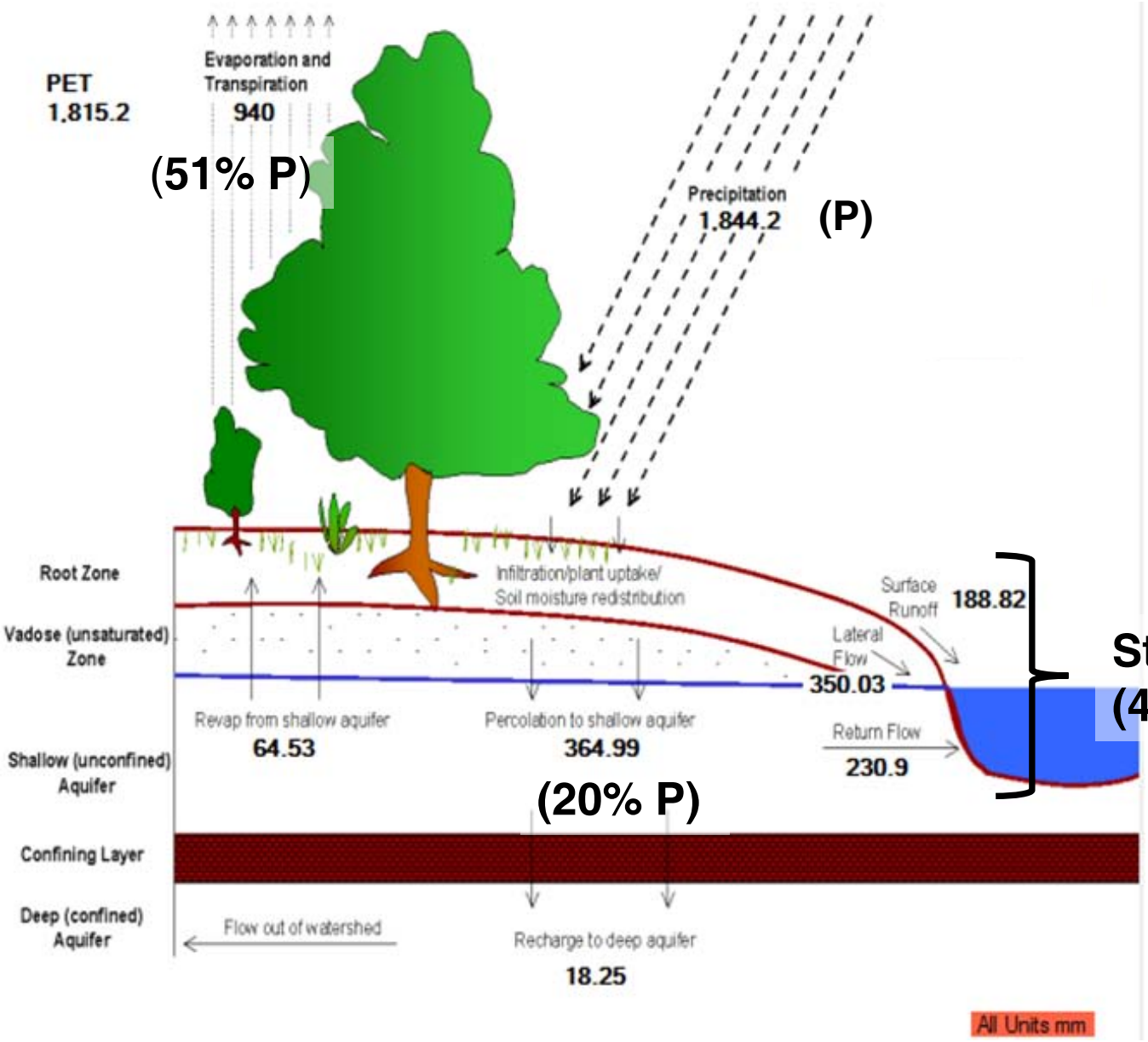
- P-factor, is **0.87** for Fagaalu, but only **0.38** for Maloata watershed
- Most of the observations brackets when rainfall data within watershed is used, but results reasonably acceptable

Multiple rain-gauges improve model performance



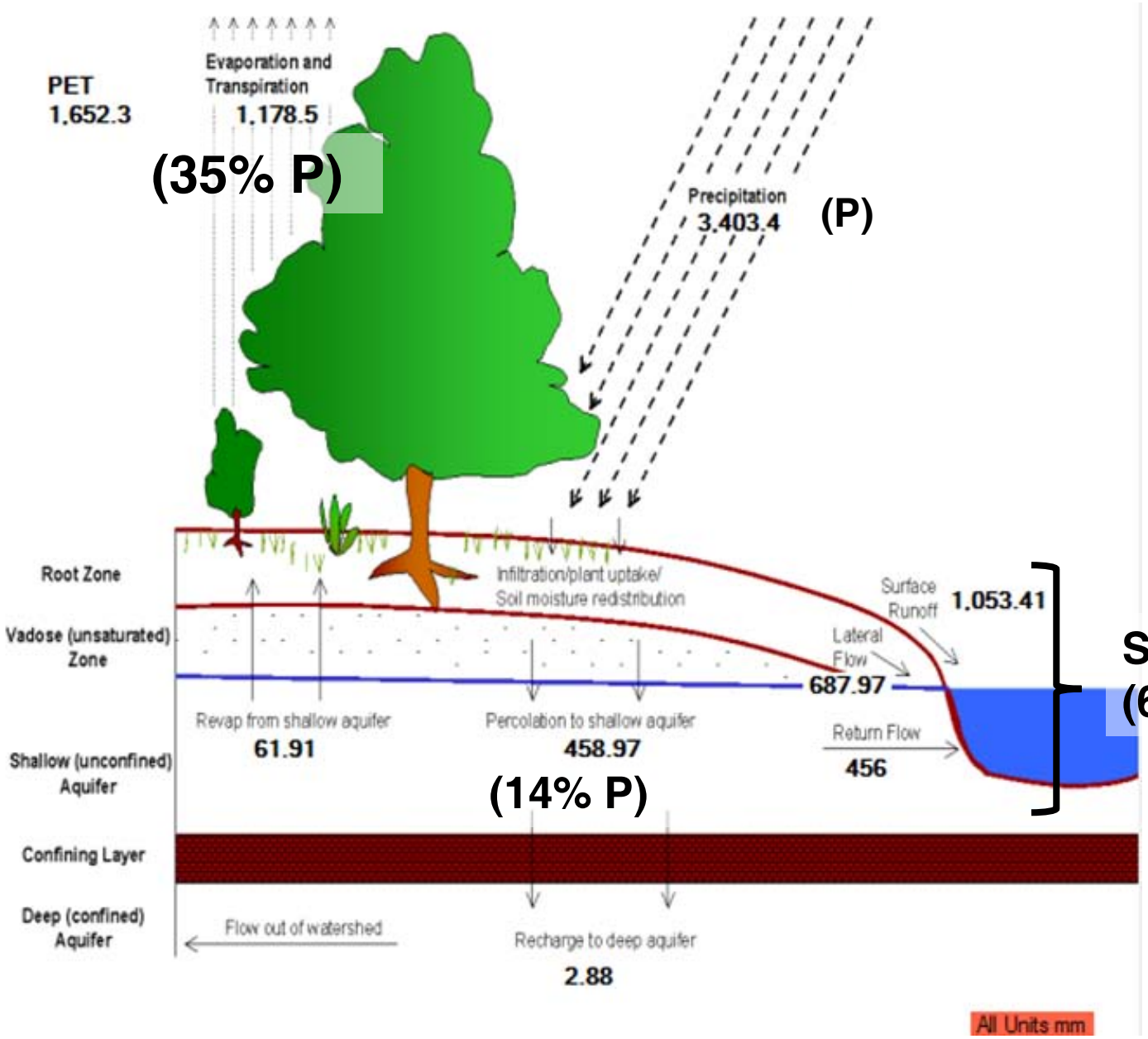
- Use of multiple rain gauging stations well represents hydrographs.

The Nuuanu area annual water budget



- ET and recharge consistent with previous studies

The Fagaalu annual water budget



- ET inline with Izuka et al, 2007 Tafuna-Leone Plain

Conclusions

- SWAT applicability tested for rain gauged and ungauged watersheds;
- Use of rain records within watershed improved model performance by capturing local climate spatial variability;
- SWAT performed less for watersheds without rain records, but results were reasonably acceptable;
- **With methods to resolve data scarcity issues and careful statistical evaluation criteria**, data from neighboring areas can be used for watersheds without rain records.

Acknowledgements to: