Applying SWAT to a Watershed Containing Paddy Fields

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Scenery of a paddy field in winter

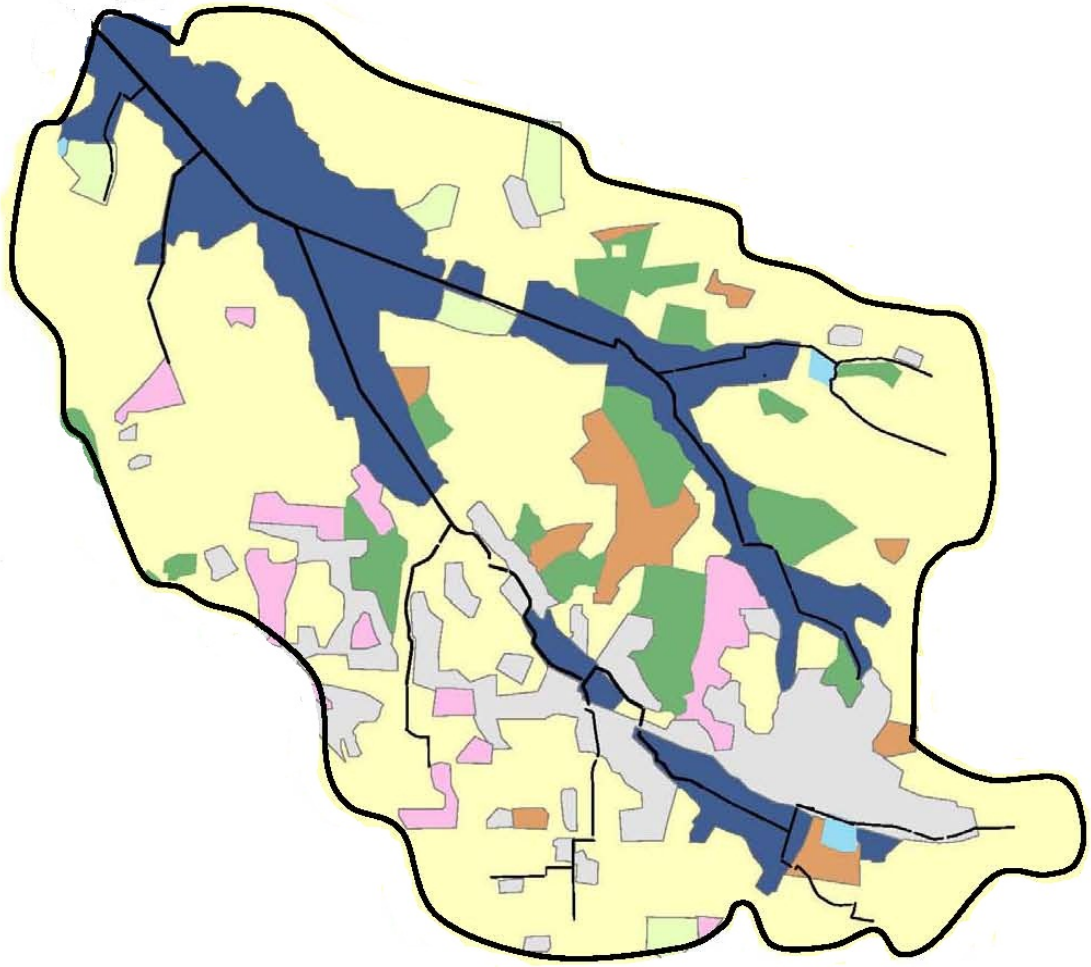
Objectives

- SWAT is becoming popular in Monsoon Asia.
- Many researchers have applied SWAT to watersheds containing paddy fields in Monsoon Asia.
- The objectives of this presentation are;
  - To validate SWAT for use in paddy cultivation area
  - To direct a course of SWAT improvement for paddy area

Methodology

- We applied SWAT to a small watershed containing paddy fields.
- Using the Green-Ampt infiltration method.
- We applied SWAT as mechanistically as we could.
  - Soil data from SolphyJ
  - 10-minute rainfall data
  - Daily paddy irrigation data
  - Roughness of paddy fields area
  - Canopy storage of crop, tree, house
  - Tuned growth parameters of each crop
  - Hydrological properties of rivers and ponds
  - Validated warming period
  - Slope length of paddy HRU
  - Two paddy irrigation methods

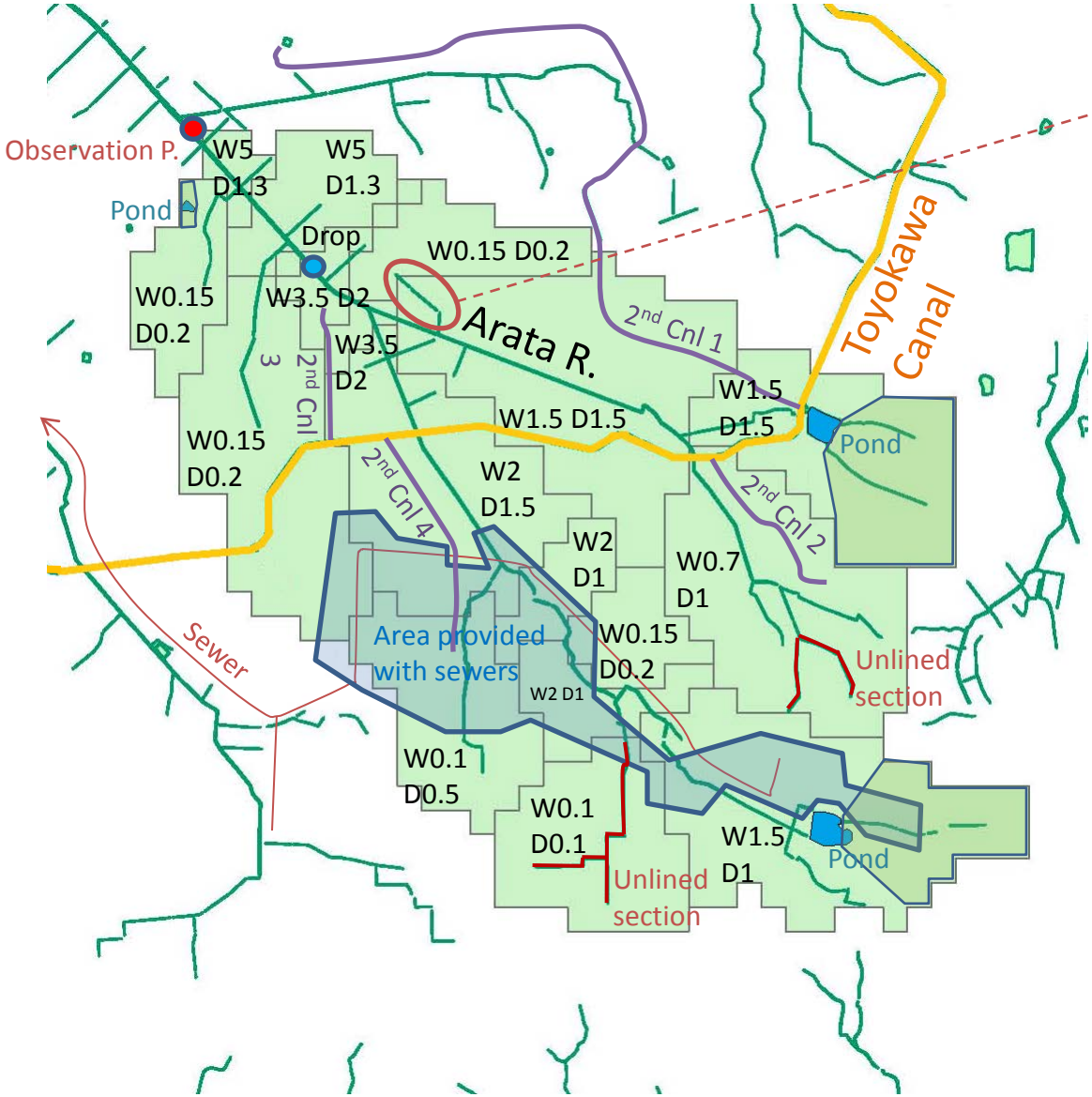
Land use



1 km

- 56.4% Upland fields
- 18.0% Paddy fields
- 10.7% Urban areas
- 6.3% Forest
- 3.6% Tea
- 3.1% Orchards
- 1.4% Grasslands
- 0.5% Ponds

Hydrological network

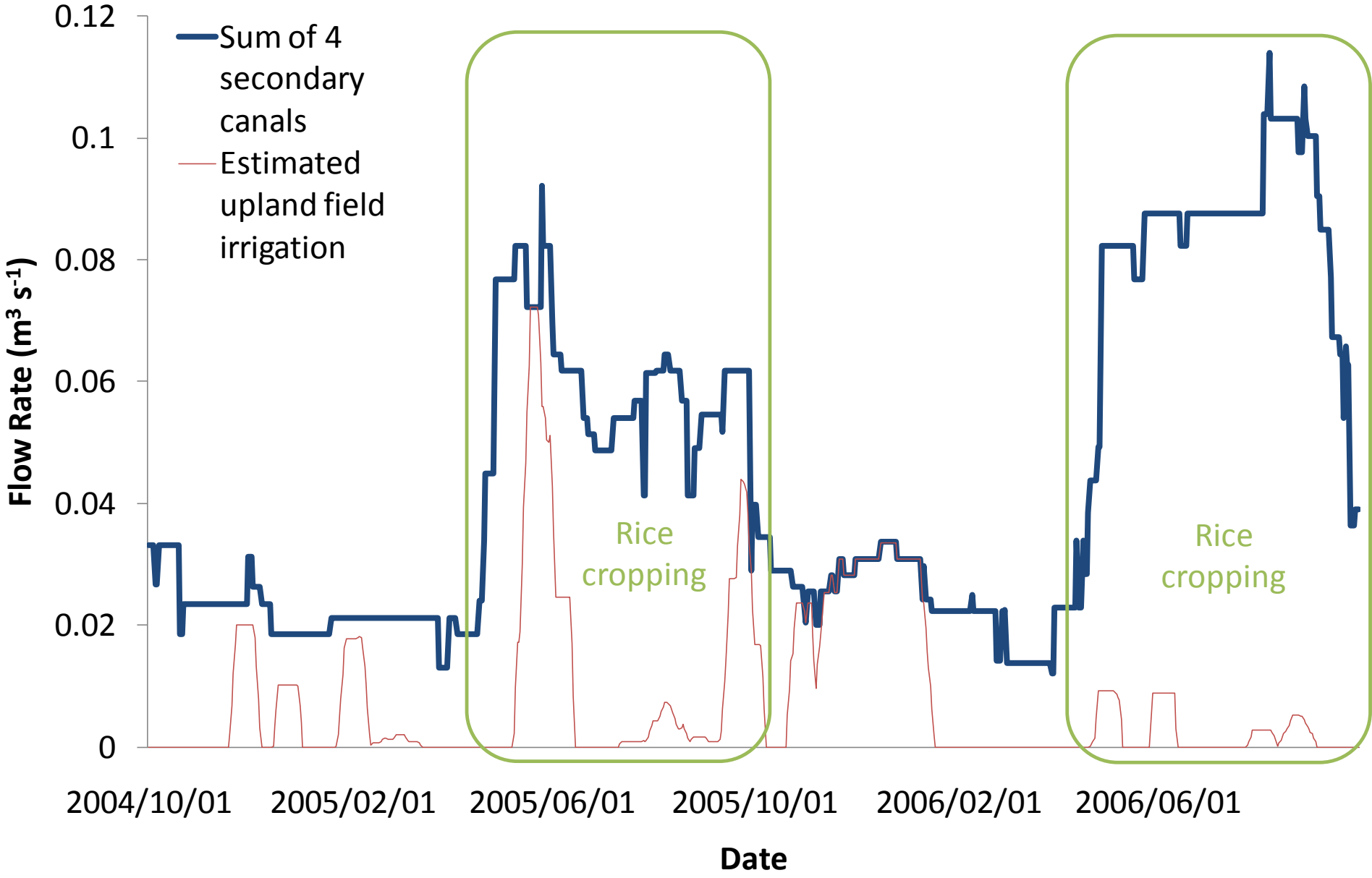


Paddy drainage canal

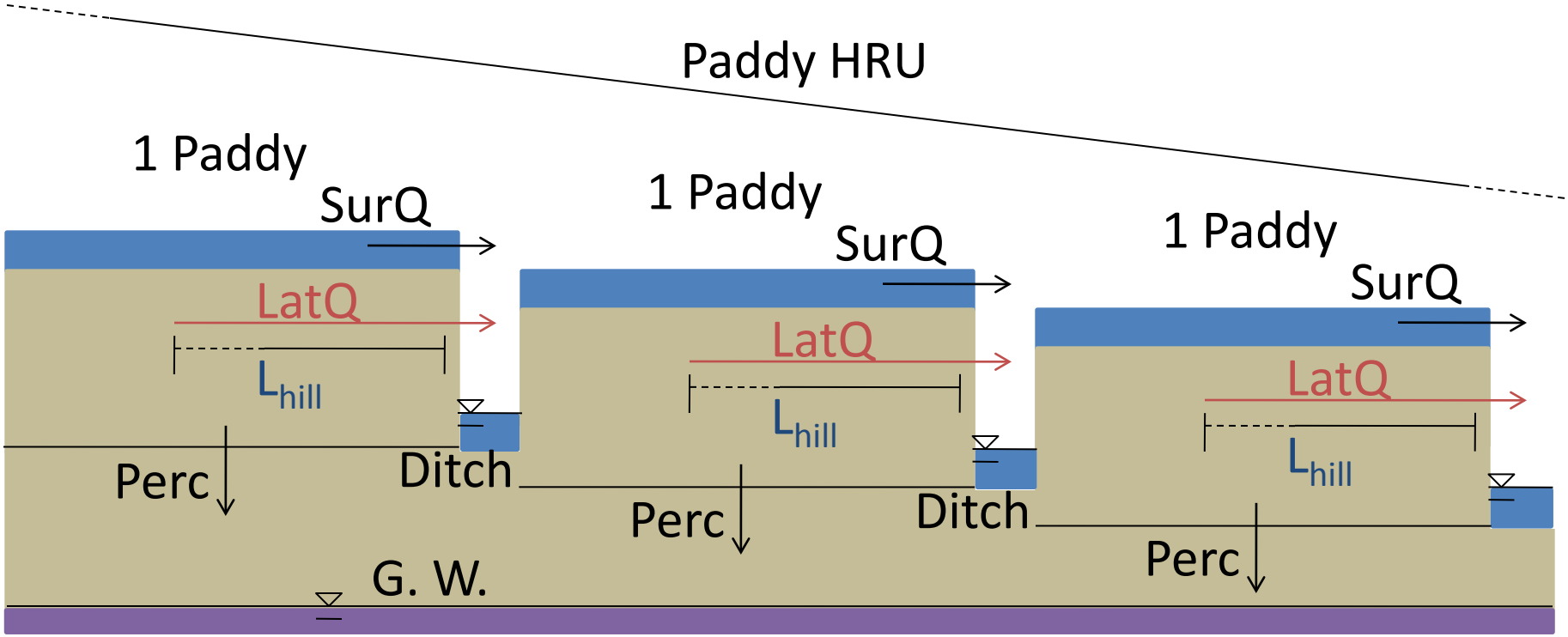
W: Width of river (m)
D: Depth from bank to bed of river (m)

1 km

Daily irrigation data



Slope length of paddy HRU



- $Q_{lat} = (Q'_{lat} + Q'_{latstor,i-1})(1 - \exp[-1/TT_{lag}])$
- L_{hill} for a paddy field HRU was assumed to be equal to 1/2 of the paddy field's length.

Irrigation methods to paddy HRU

1) POTHOLE method

   Stores water on soil surface

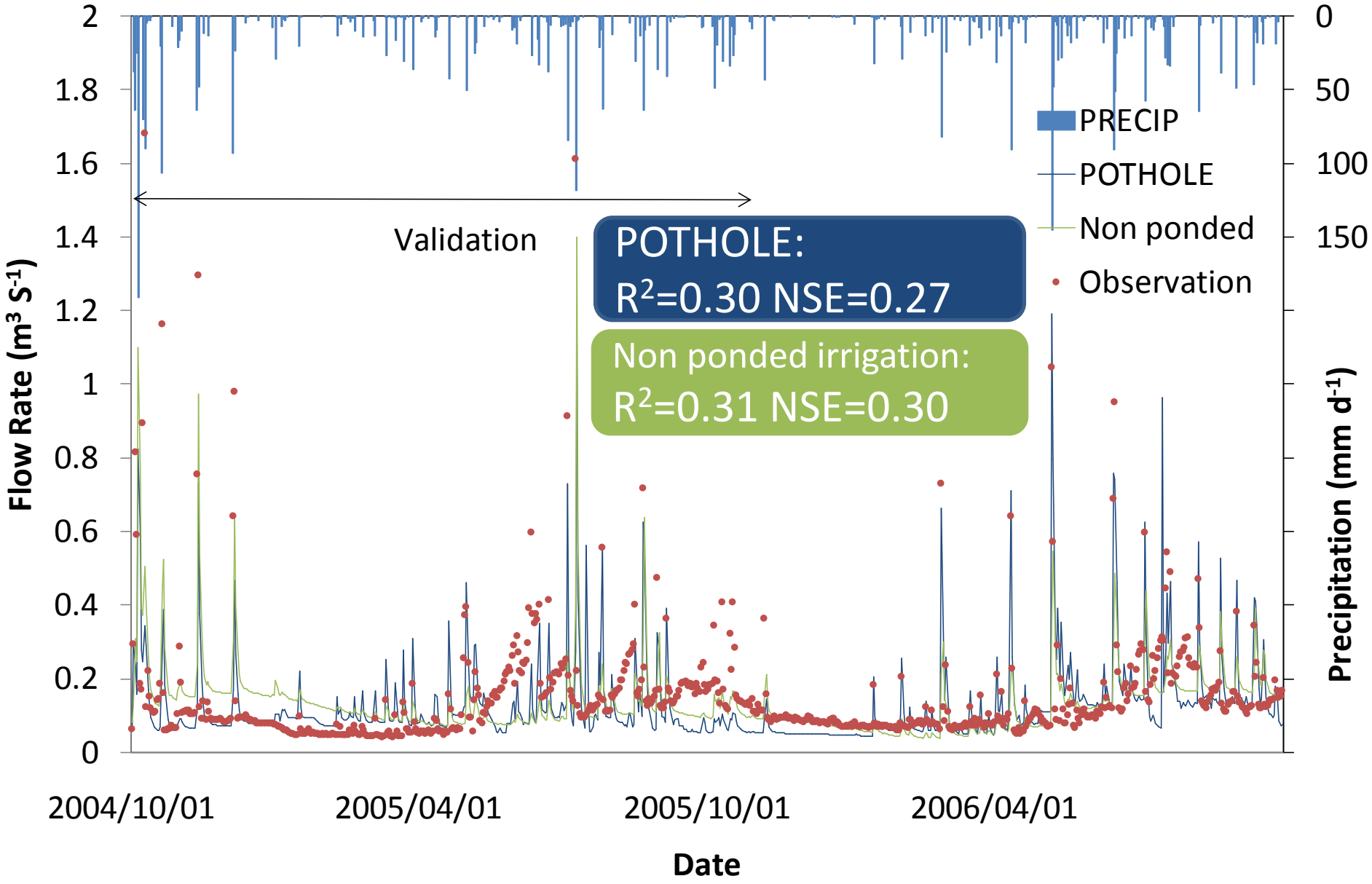
   – Height of weir
   – Ponding period
   – Mid-season drainage period
   – Daily irrigation data

2) Non-ponded irrigation method

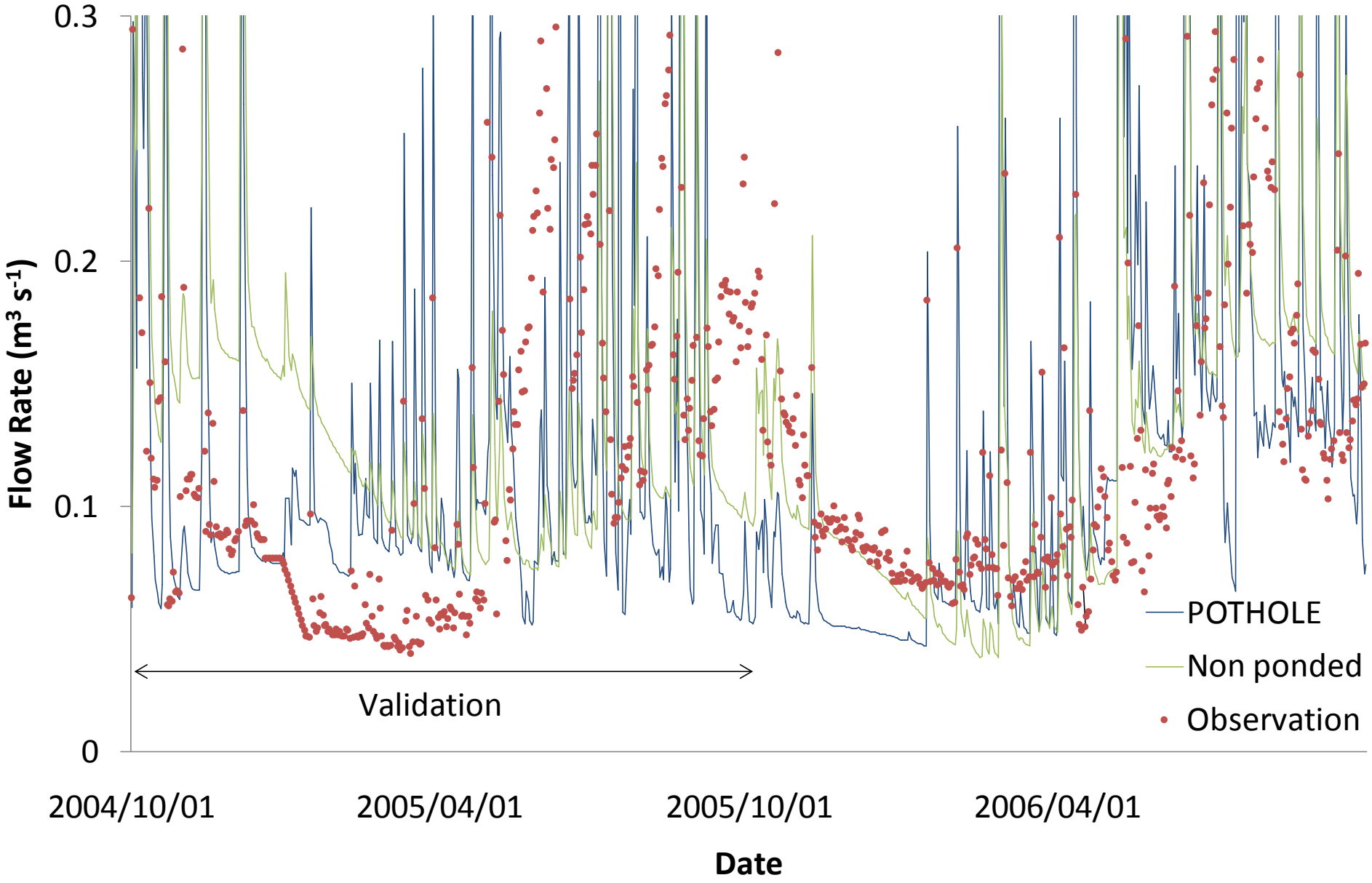
   Normal uplands irrigation

   – A large amount of water flowing into HRUs is equivalent to treating these HRUs as paddy fields
   – Simple & many SWAT papers for irrigated paddy fields
   – Daily irrigation data

Results

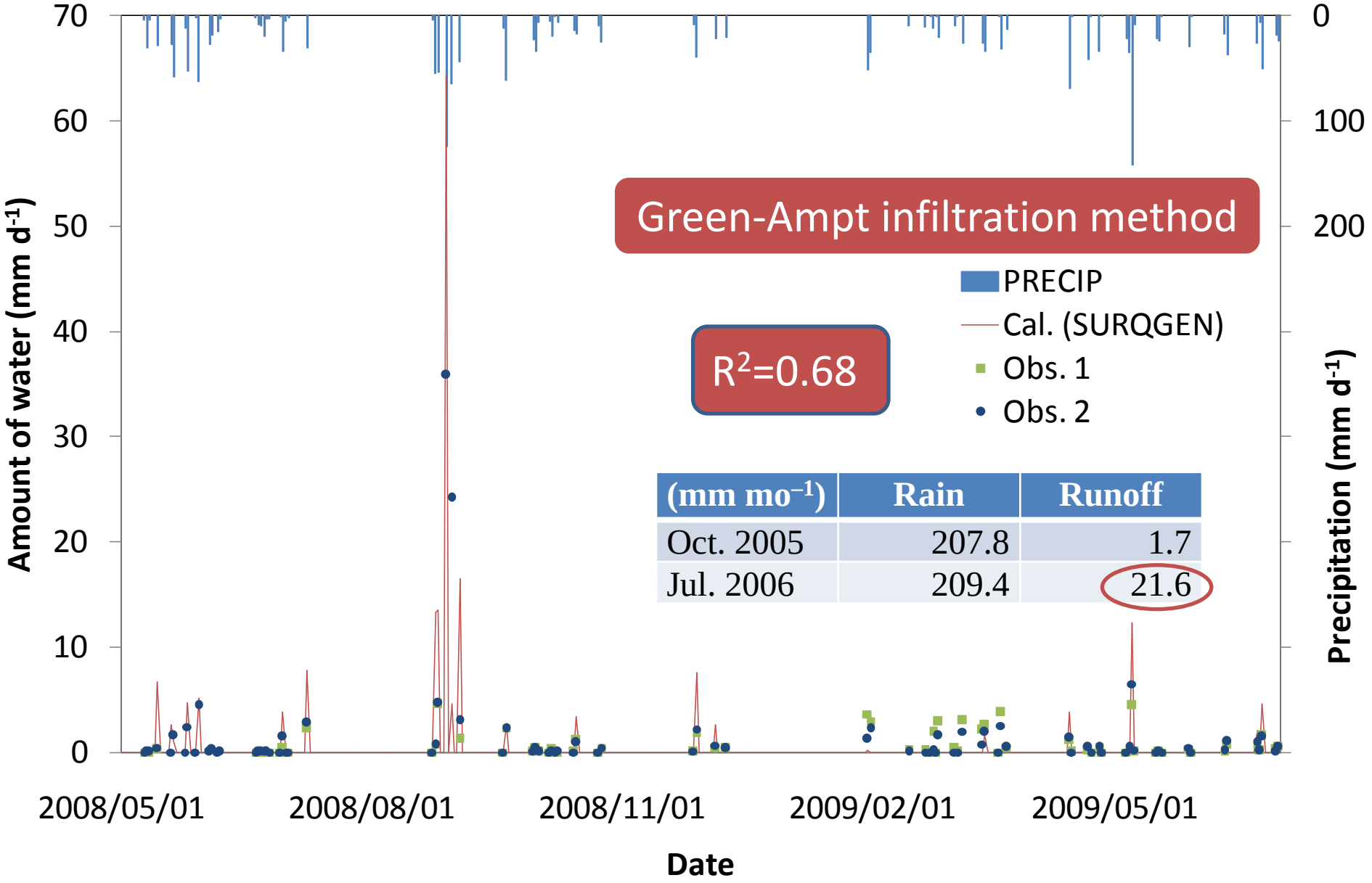

Validation
POTHOLE:
R²=0.30 NSE=0.27
Non ponded irrigation:
R²=0.31 NSE=0.30
PRECIP
POTHOLE
Non ponded
Observation
Flow Rate (m³ S⁻¹)
Precipitation (mm d⁻¹)
Date
2004/10/01
2005/04/01
2005/10/01
2006/04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
50
100
150

Base flow


0.3
0.2
0.1
0
Flow Rate (m³ s⁻¹)
Validation
POTHOLE
Non ponded
Observation
2004/10/01
2005/04/01
2005/10/01
2006/04/01
Date

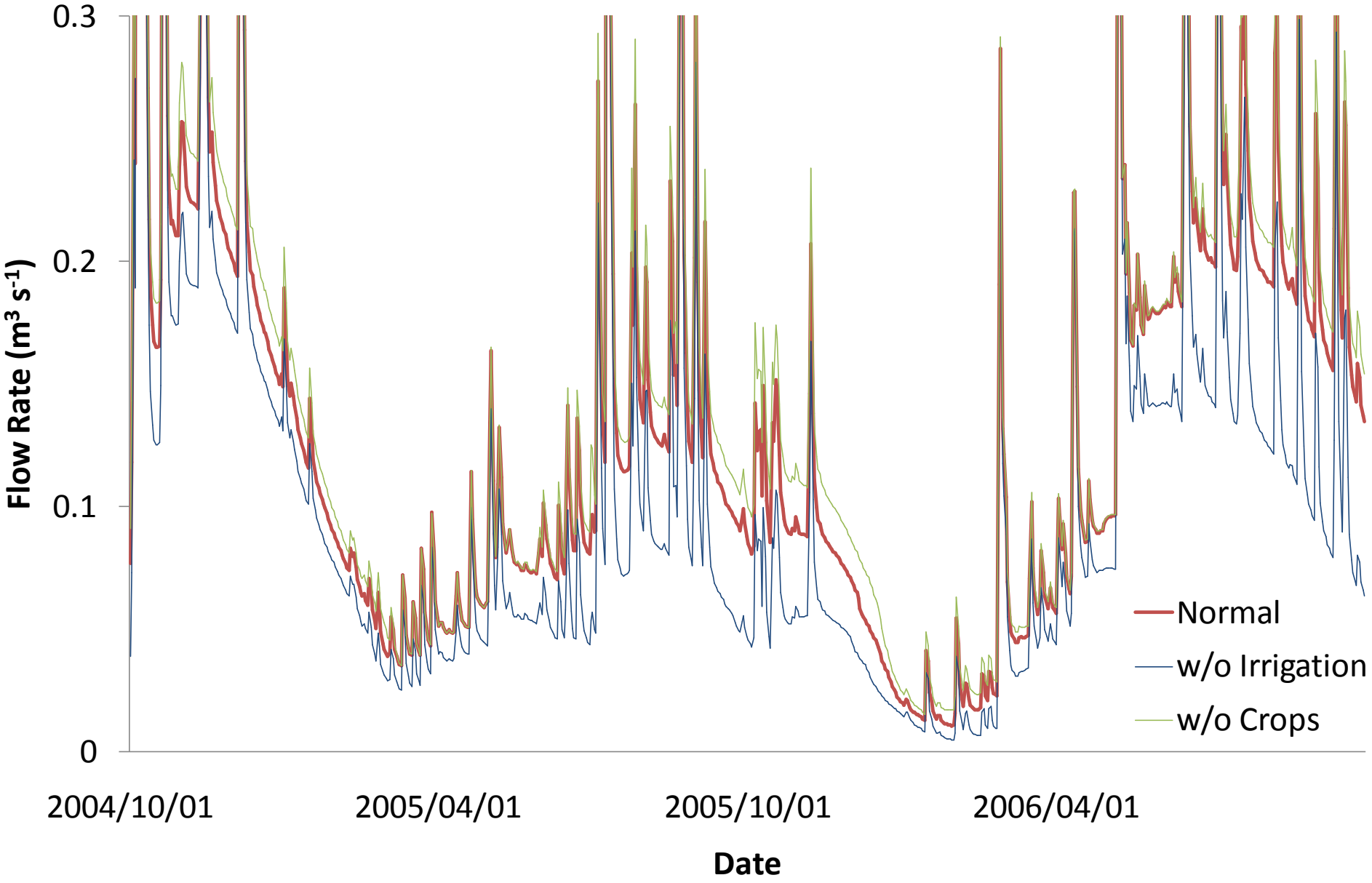
3. Results

Surface runoff



(mm mo^{-1})	Rain	Runoff
Oct. 2005	207.8	1.7
Jul. 2006	209.4	21.6

Effects of irrigation and crops

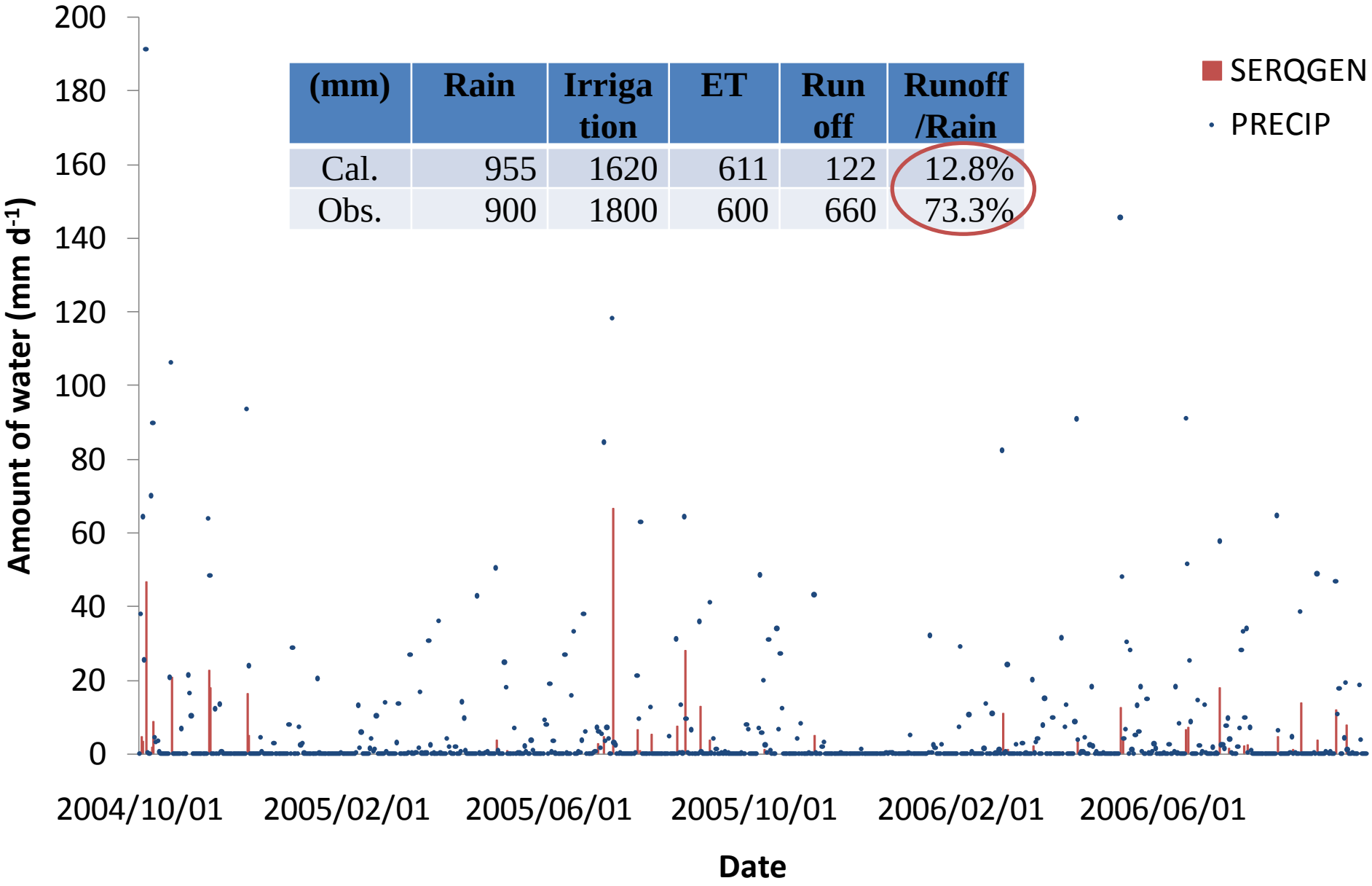


POTHOLE

- The percolation from the soil profile into the aquifer (PERC) ≈ 0 mm/d
- The groundwater flow from the paddy field HRUs to reach (GWQ) ≈ 0 mm/d
- Because…
  - Seepage from POTHOLE to soil profile (V_{seep}) stops if SW ≥ FC, so SW keeps FC under ponded condition
  - No mobile water ($SW_{ly,excess}$) in each soil layer if $SW_{ly} \leq FC_{ly}$, so percolation among each soil layer stops
  - Therefore, SW ≥ FC, and seepage = 0

Non-ponded irrigation

(mm)	Rain	Irrigation	ET	Run off	Runoff /Rain
Cal.	955	1620	611	122	12.8%
Obs.	900	1800	600	660	73.3%

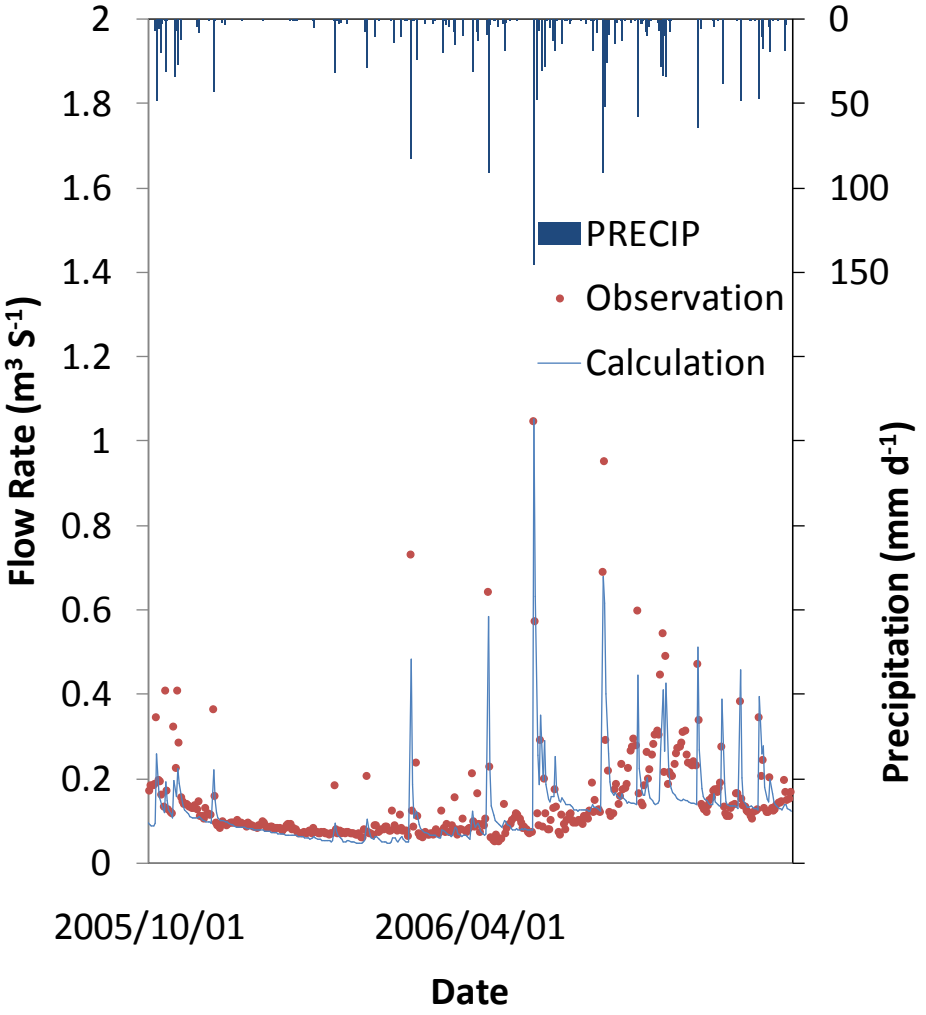


Conclusion

- We confirmed that the water balance in paddy field HRUs in SWAT differs from the observed water balance.
- And, this difference appears to be responsible for the low correlation between observed and calculated river flow rates in a watershed containing paddy fields.
- Thus, before using SWAT to simulate other targets in a watershed that contains paddy fields, it is first necessary to improve the hydrological process algorithm for paddy field HRUs.
- In addition, the hydrological process in paddy field HRUs affects not only the river flow rate but also other targets such as nitrate concentration.

Recent progress

- “Pothole” and “Irrigation” codes were modified.
- A base flow related parameter “GWdelay” was estimated using the HYDRUS.
- NSE increased to 0.77 in calibration period and 0.62 in validation period.



Other problems of current POTHOLE

- “Release” doesn’t make Pot_vol to 0, so released POTHOLE (paddy HRU in winter) doesn’t calculate the surface runoff generation routing.
  - If Pot_vol < infinitesimal, then go to surface routing
  - Measure: Always make POTHOLE impounded or crop something after “Release”
- “Released” becomes “Impounded” on January 1st
  - Measure: Impose “Release” on every January 1st
- Flood on January 1st from “Released” POTHOLE in every year
  - Measure: Always make POTHOLE impounded or delete peak flow