SWAT model improvement for discharge process in paddy fields

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Background

- Paddy fields is the major land use in Monsoon Asian countries.
- However, it is difficult to apply hydrological models like SWAT for watershed management, because irrigation water use in paddy fields is too complicated to illustrate hydrological processes.
- SWAT is applicable for the simulation of observation data, but uncertainty is large then evaluation on land and water management is difficult.
- This uncertainty is coming from model structure that is not match with paddy hydrological process.

Objectives

- To improve surface discharge process in SWAT both pothole module and new development module
- To understand lateral flow process in small scale paddy plots with observation data

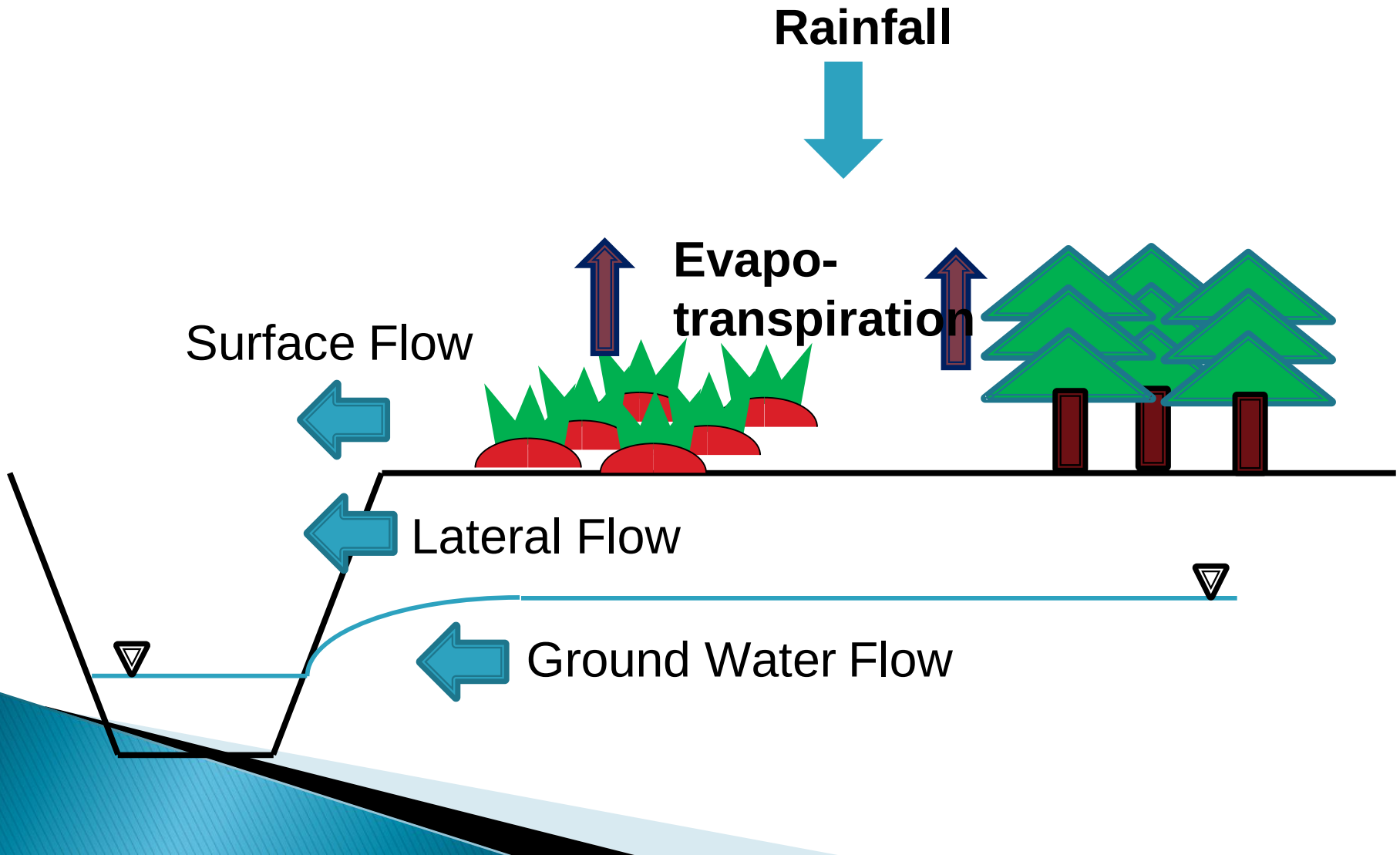
Methods

- Analysis on water & nutrients budget in paddy plots
- Implementation on pot hole option and uncertainty analysis
- Analysis on lateral flow process, and consider implementation idea

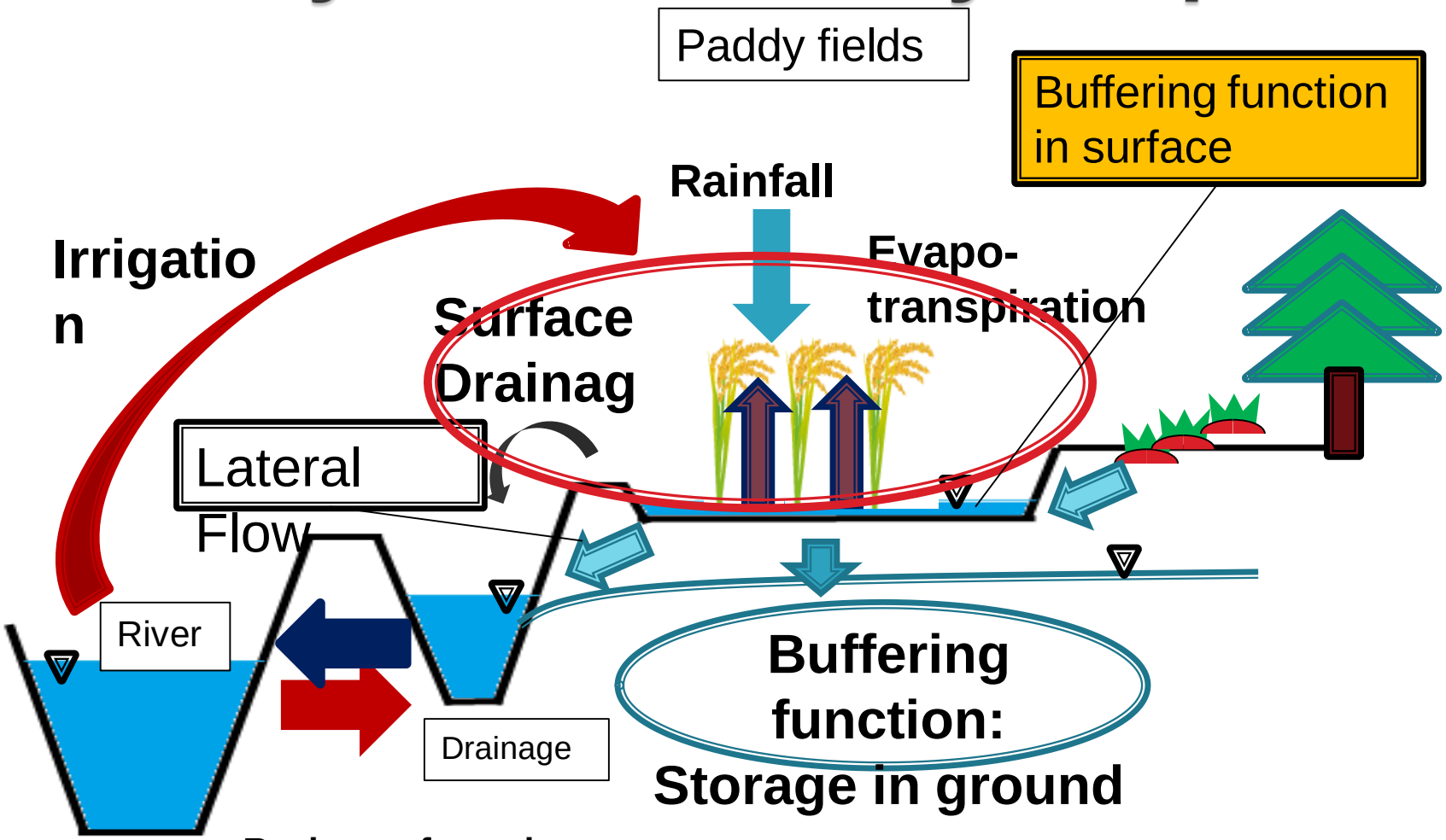
SWAT application to paddy fields

- Surface flow
  - Xie and Cui, 2011
    - Pot hole module application to paddy
  - Boulange et al., 2014
    - Surface discharge on pesticide
- Ground water flow
  - Kim et al., 2003
    - SWAT-MODFLOW combination
- Surface and Lateral flow
  - Kang et. al. 2006.
  - Sakaguchi et al. 2014
    - Modified pothole module for paddy application

General Hydrological process

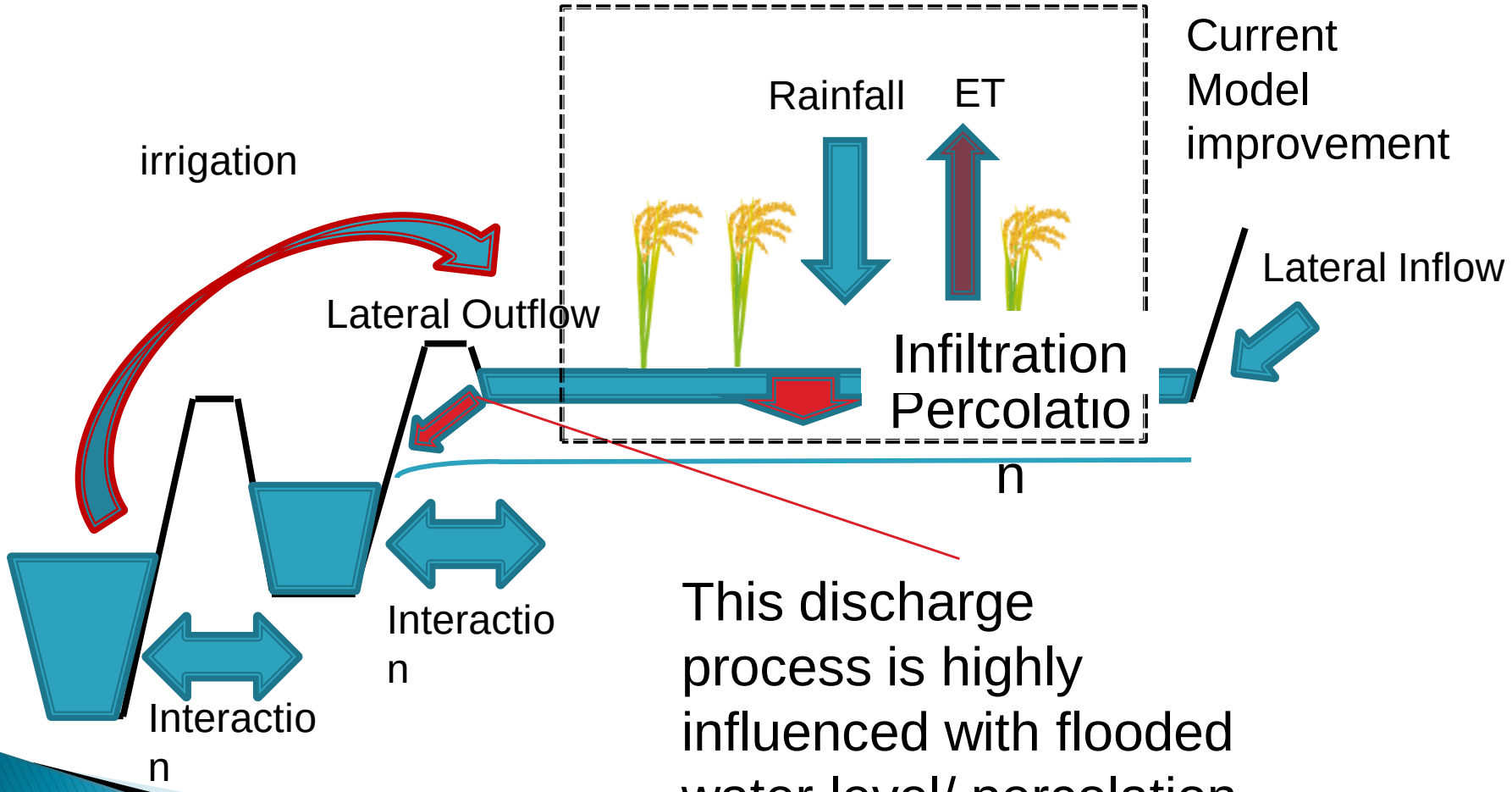


Paddy-Watershed hydro-process



Recharge from river
Discharge from background land use

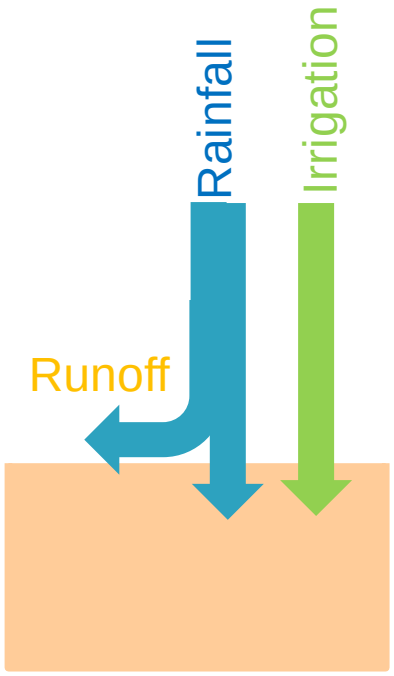
Actual surface-lateral process



This discharge process is highly influenced with flooded water level/ percolation rate

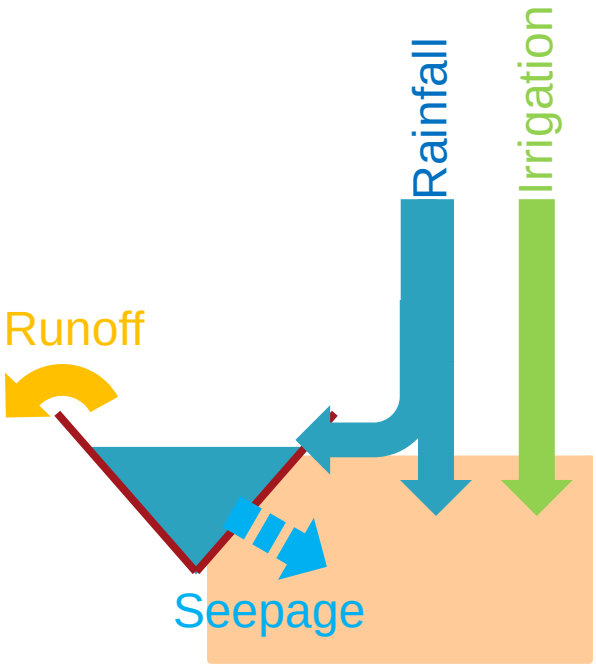
Current proposed model in paddy fields

Quick response



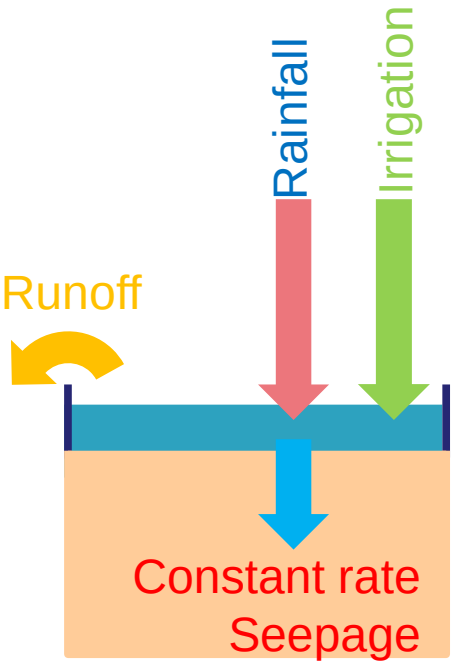
- Runoff as fraction of rainfall

Slower response



- Runoff as overflow
- Cone shaped
- Seepage when moisture below field capacity

Medium response



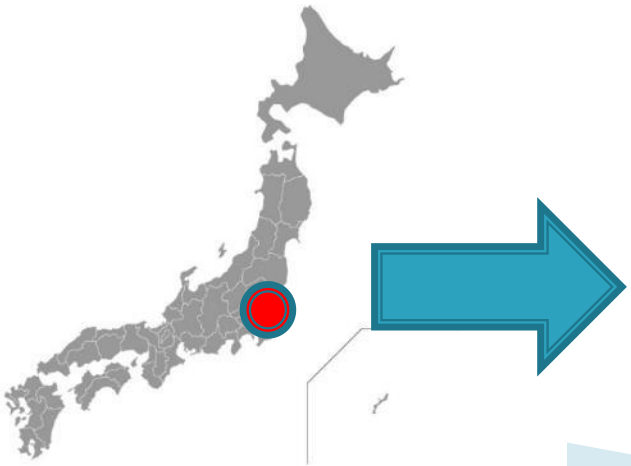
- Runoff as overflow
- Rigid shaped
- Seepage until saturation

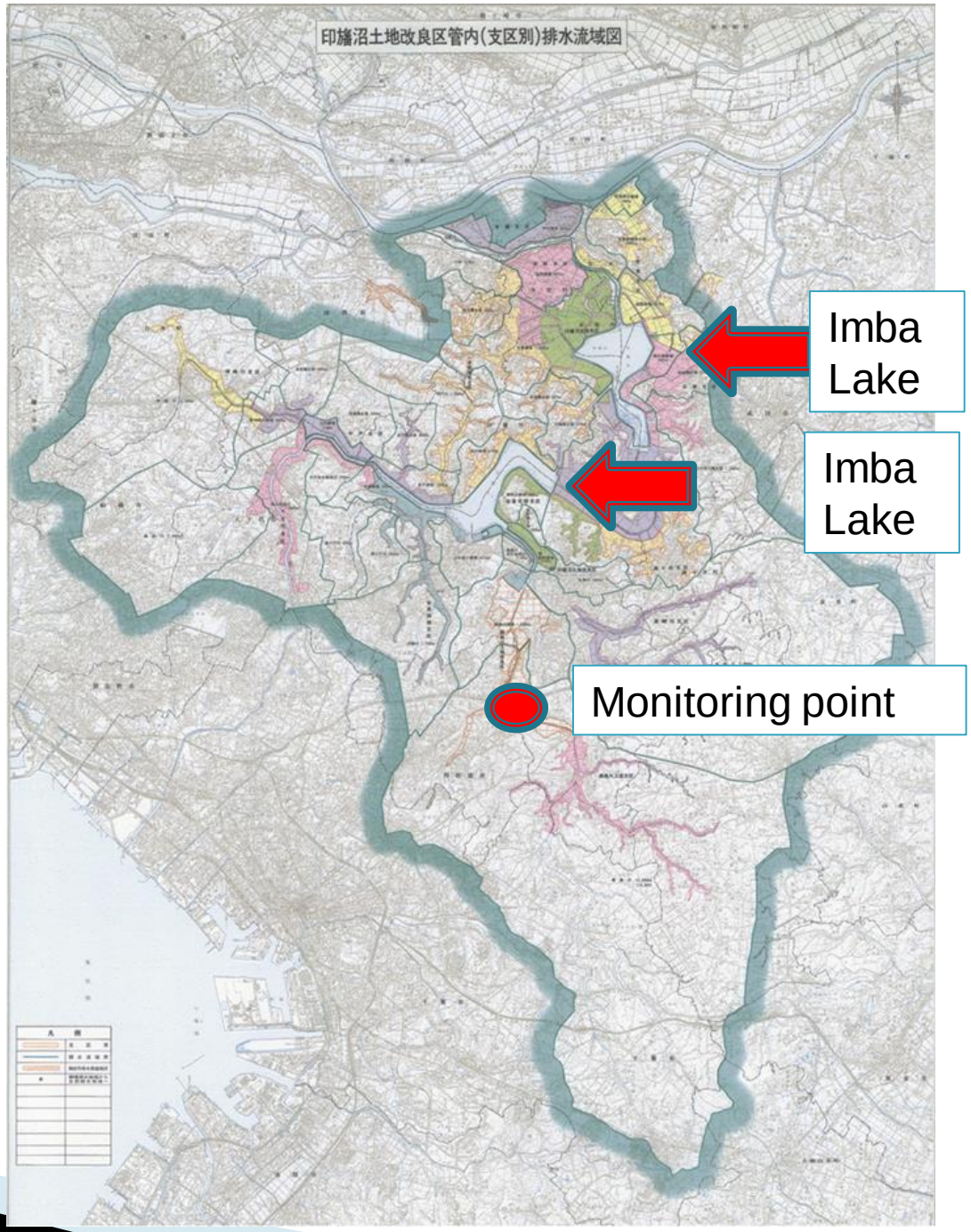
Modification by Sakaguchi et al. (2014)

SWAT (CN) | **SWAT (pothole module)** | **Paddy field**

Study area

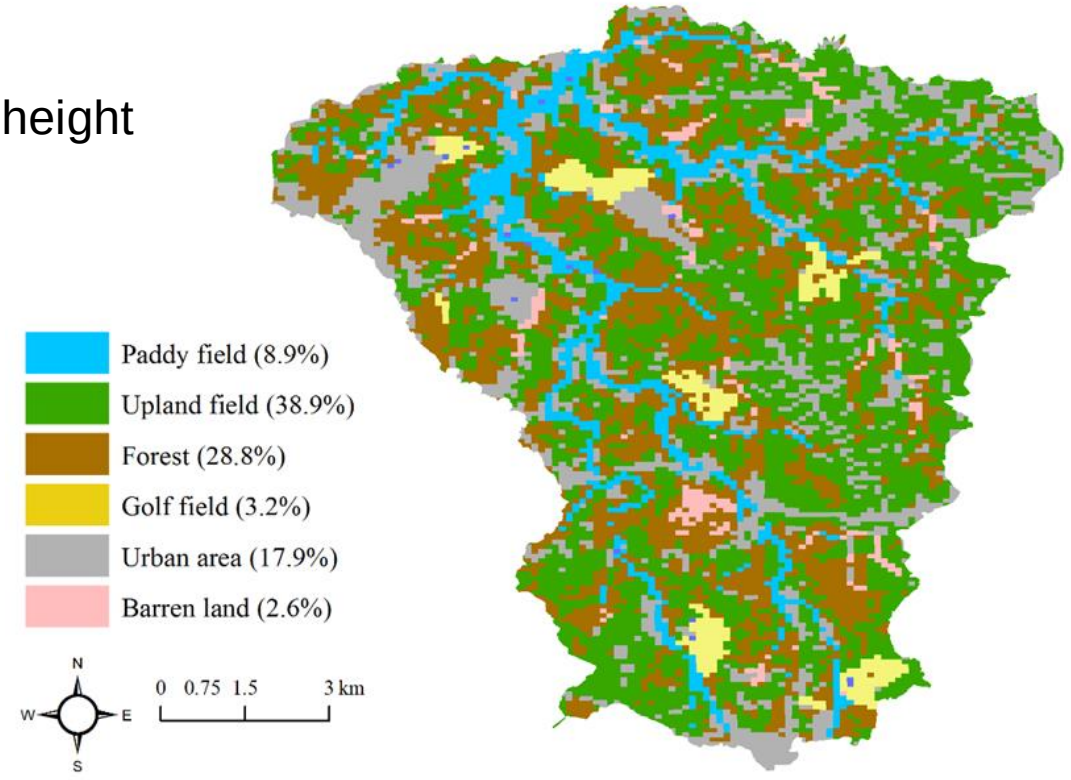
- Location: western of Tokyo, in Chiba prefecture.
- Basin area 494km^2
- Population 769,000
- Enclosed water body
- Multi purpose water resources



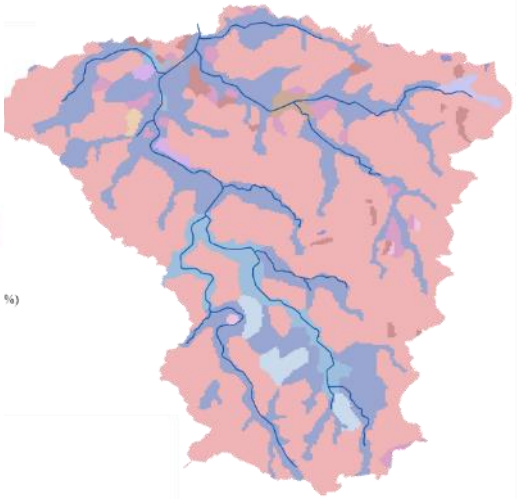


Application for evaluation
Study Area:Kashima river basin

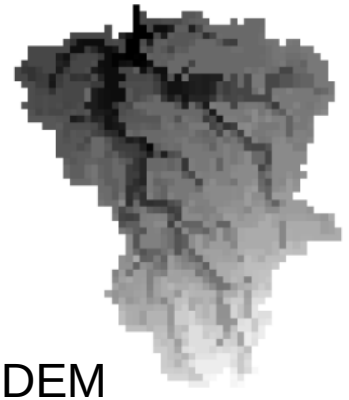
166 km2
7m-40m height



Land use data



Soil data



DEM

Features on study area

- Landscape, Landuse, and soil data show quite similar distribution.
- Soil data in deep layers are uniform in whole watershed, but surface soil layer is difference.
- Paddy fields are located in along the riverside, and generate soil for long term rice cultivation.

Monitoring system

◆Continuous monitoring
Water level, water quality (daily sampling)

Index
pH
Electric Conductivity (EC)
Suspended Solid (SS)
Total Nitrogen (T-N)
Total Phosphorous (T-P)
Nitrate Nitrogen (NO3-N)

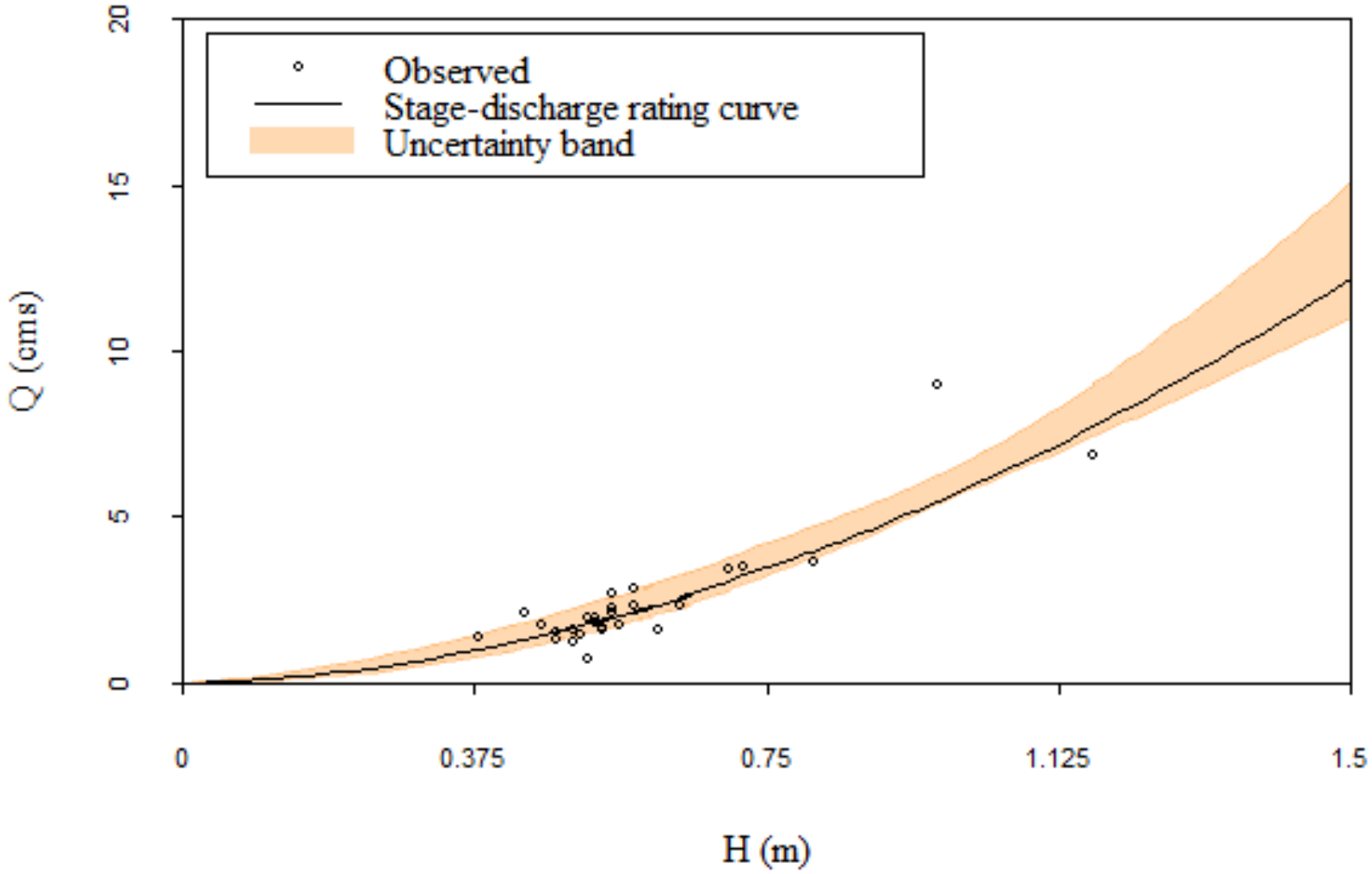
Hydrological measurement
Water depth
Discharge (Rating curve)
Water depth logger
Weather data (Evaporation estimation)

Develop Rating Curve

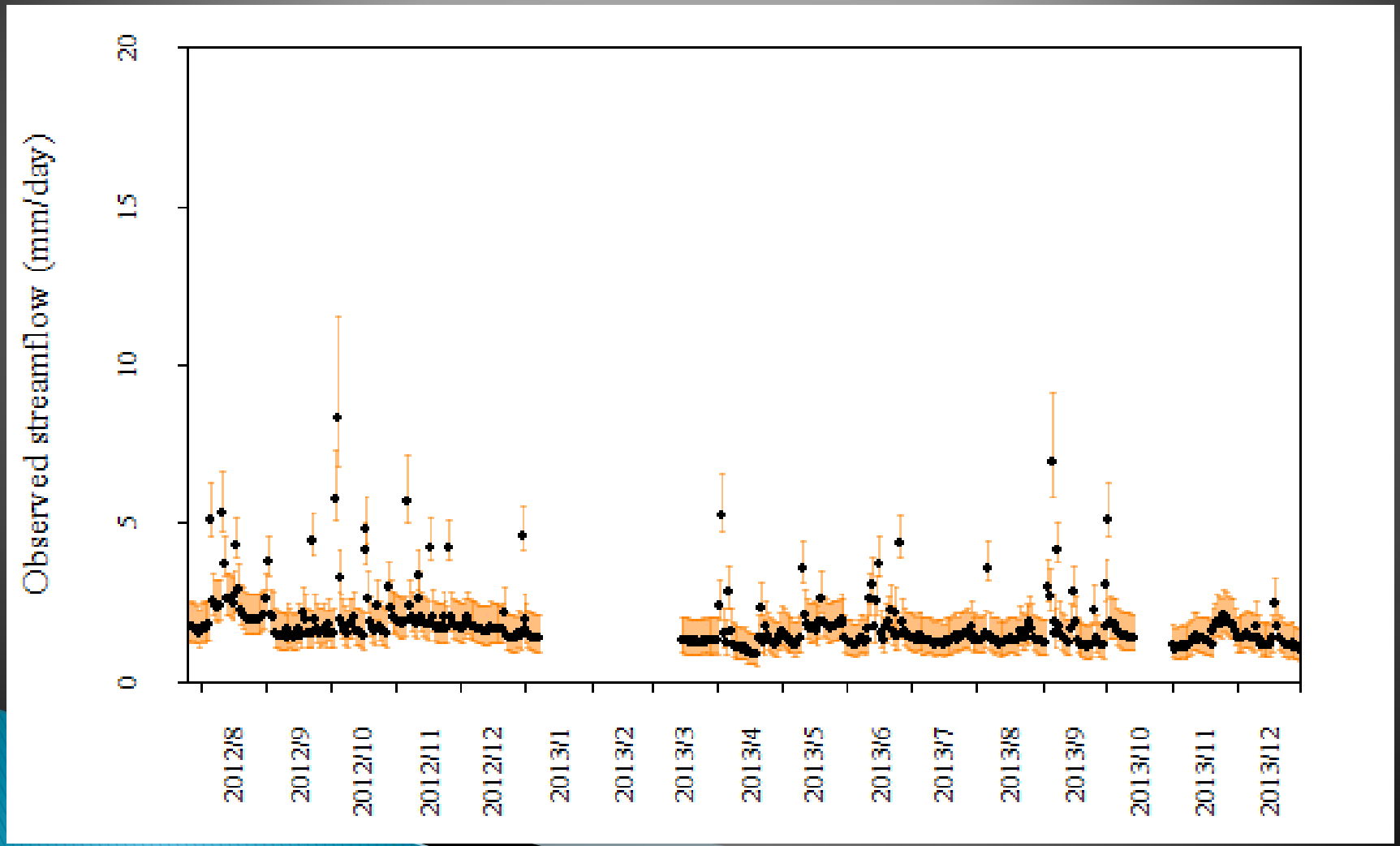
Water pressure gauge

$$Q=aH^{b}$$

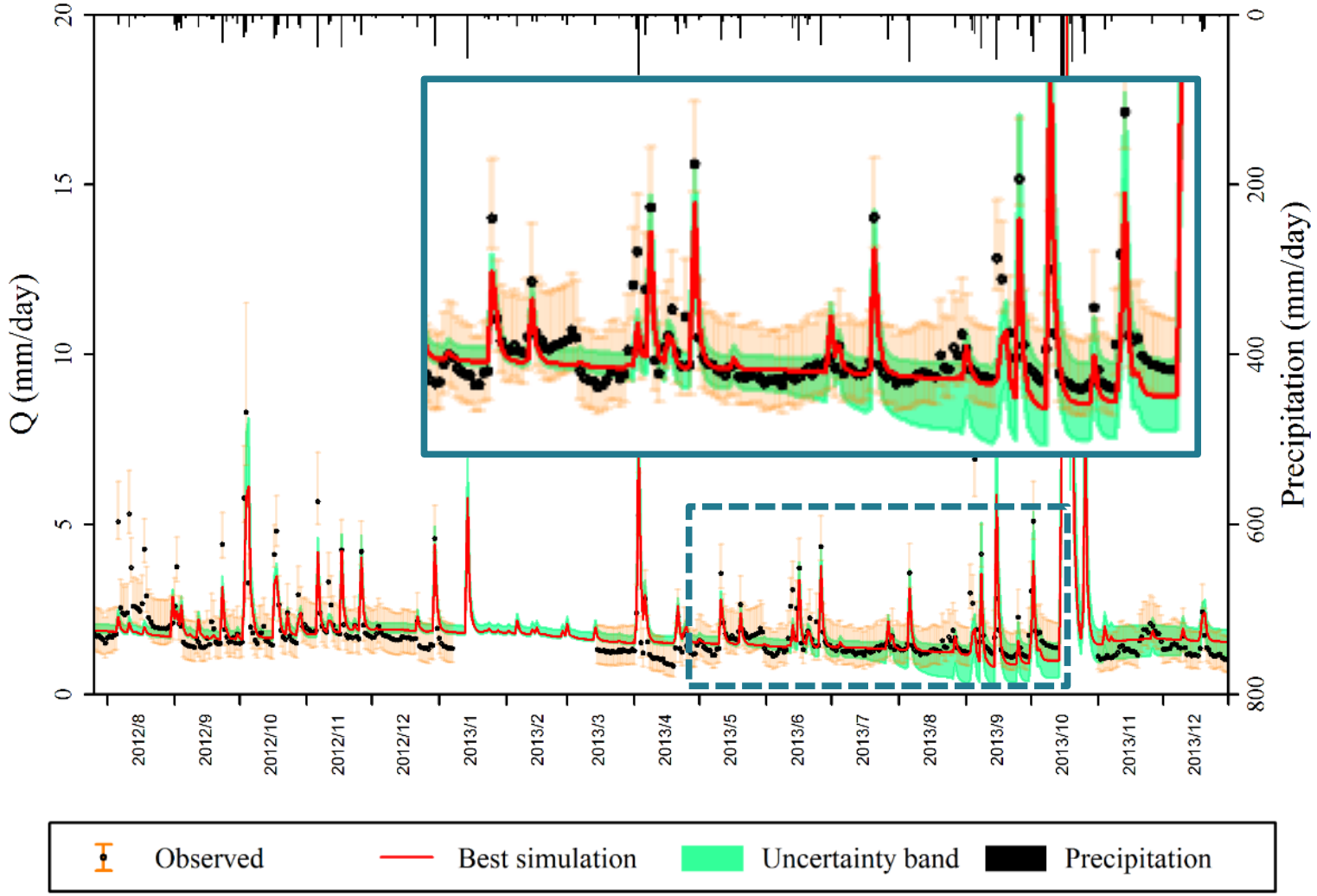
Observed data and uncertainty in SUFI2



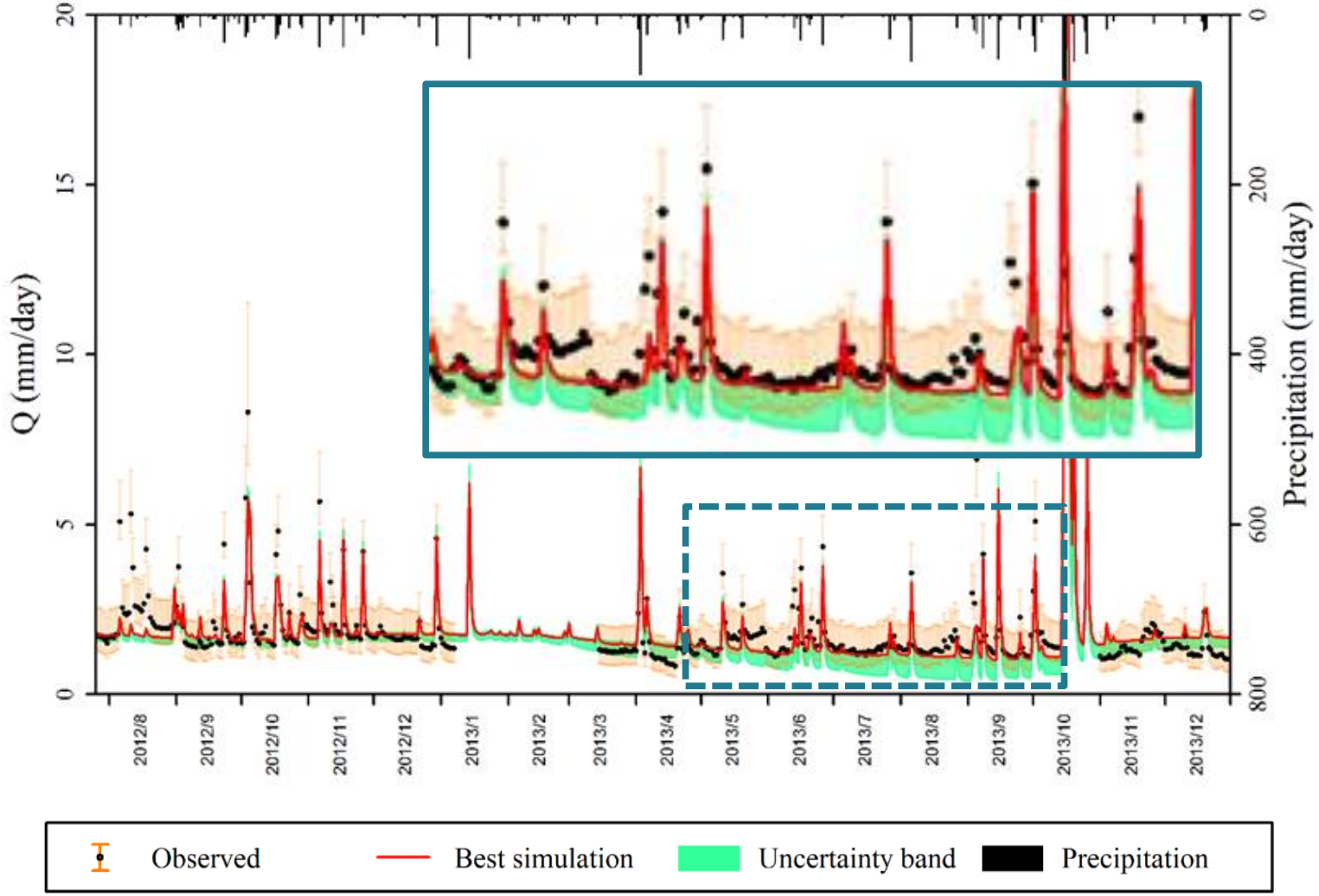
Uncertainty band in observatory data



Calibrated model (Curve Number)

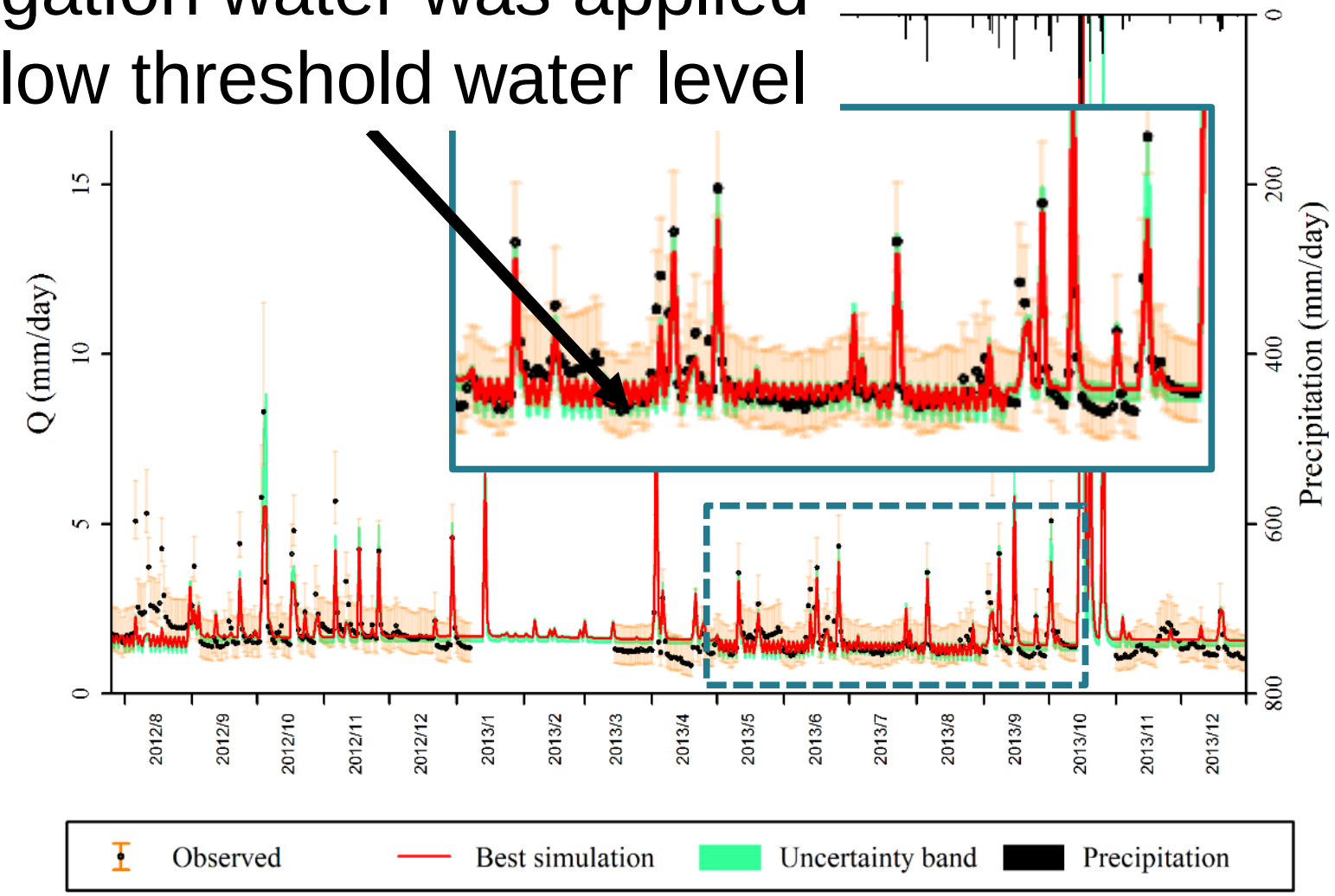


Calibrated model (Pothole)



Calibrated model (Modified based on pothole)

irrigation water was applied below threshold water level



How much observed data bracketed by the uncertainty band?

How narrow the uncertainty band?

How large the error?

Is there any systematic underestimation/ overestimation?

How the simulation can represent the dynamic change of observed data?

Model	p-factor	r-factor	RSR	NSE	PBIAS
SWAT with CN	93%	0.73	0.71	0.5	0.7%
SWAT with pothole	88%	0.54	0.69	0.5	-3.8%
Modified SWAT	88%	0.43	0.70	0.5	-0.5%
Satisfactory criteria	> 50%	< 1	< 0.7	> 0.5	-25% ~ 25%

Uncertainty of observed data can be explained well by simulation

Relatively small error

Simulation fit the dynamics of observed data

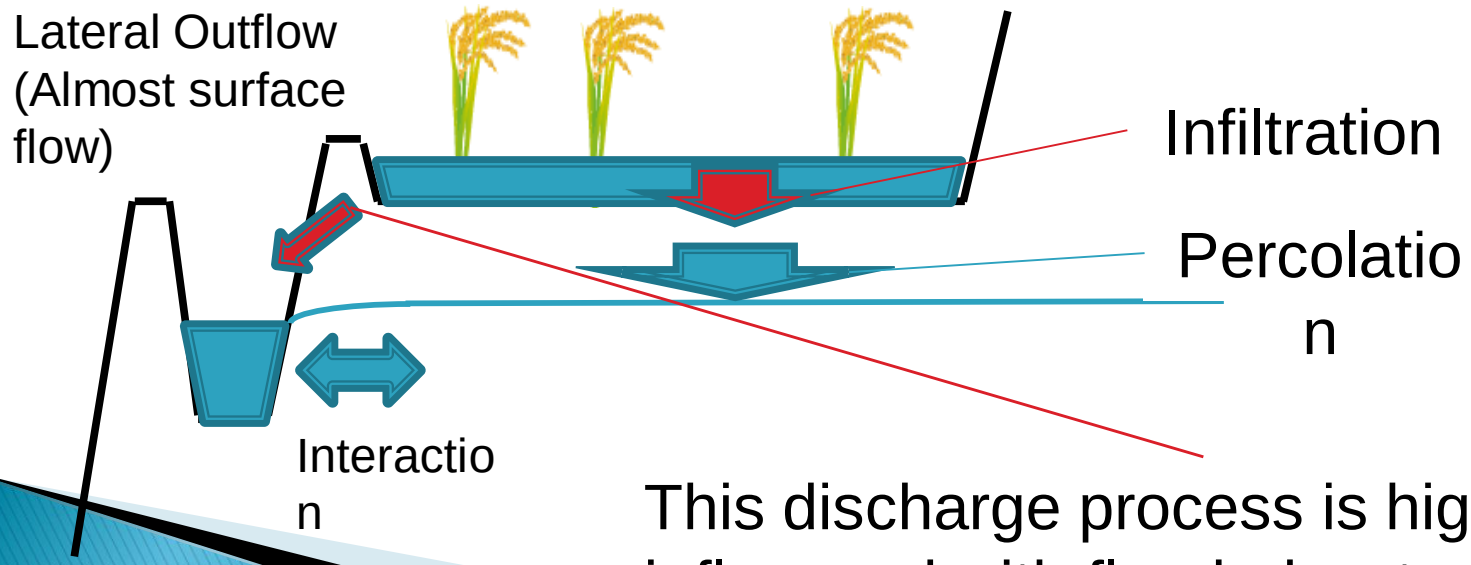
No over/under-estimation

Why NSE was not improved?

- Model improvement was focused on a surface process.
- Discharge from surface water buffered temporally and small, then, perpetual fluctuation was represented.
- In actual discharge process, lateral flow from paddy fields would be more crucial factor.

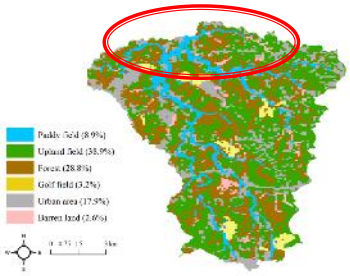
Further implementation on surface and lateral flow process

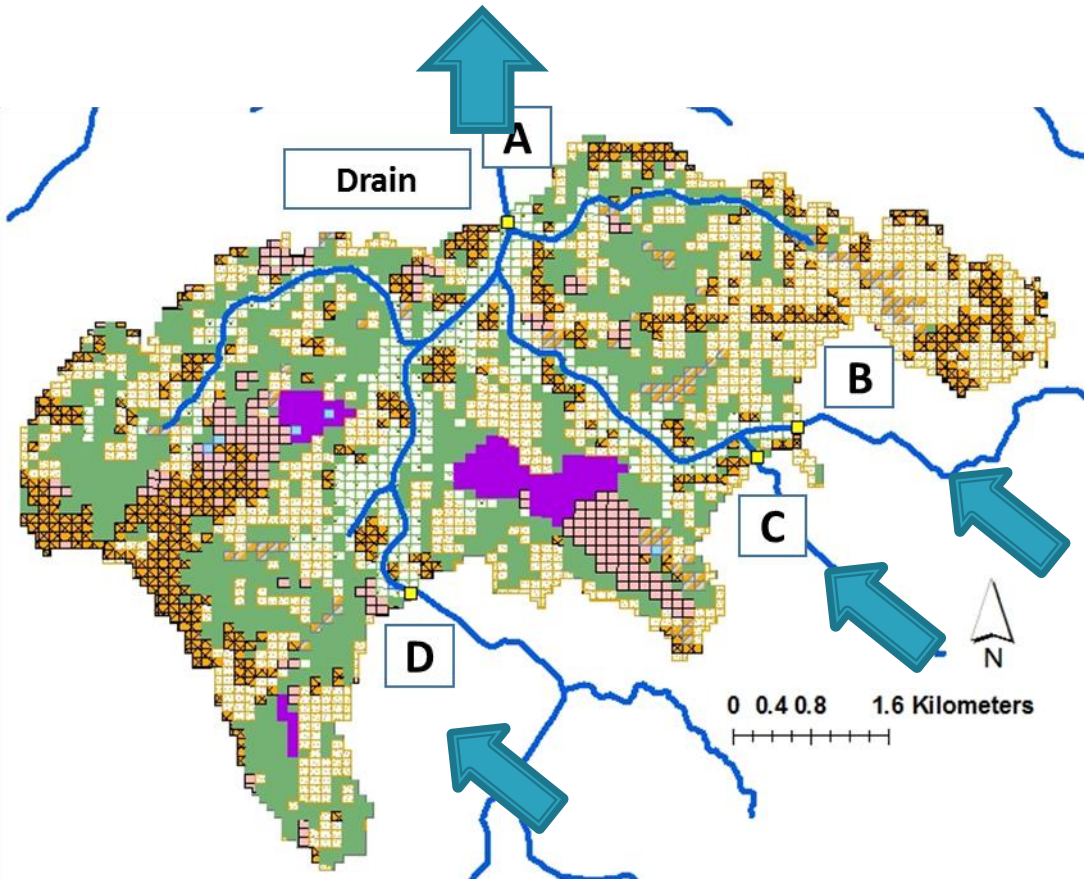
- Currently, infiltration rate was settled as static
- As a real process in paddy, infiltration process is influenced with percolation and lateral flow



This discharge process is highly influenced with flooded water level/ percolation rate

Water balance in paddy block

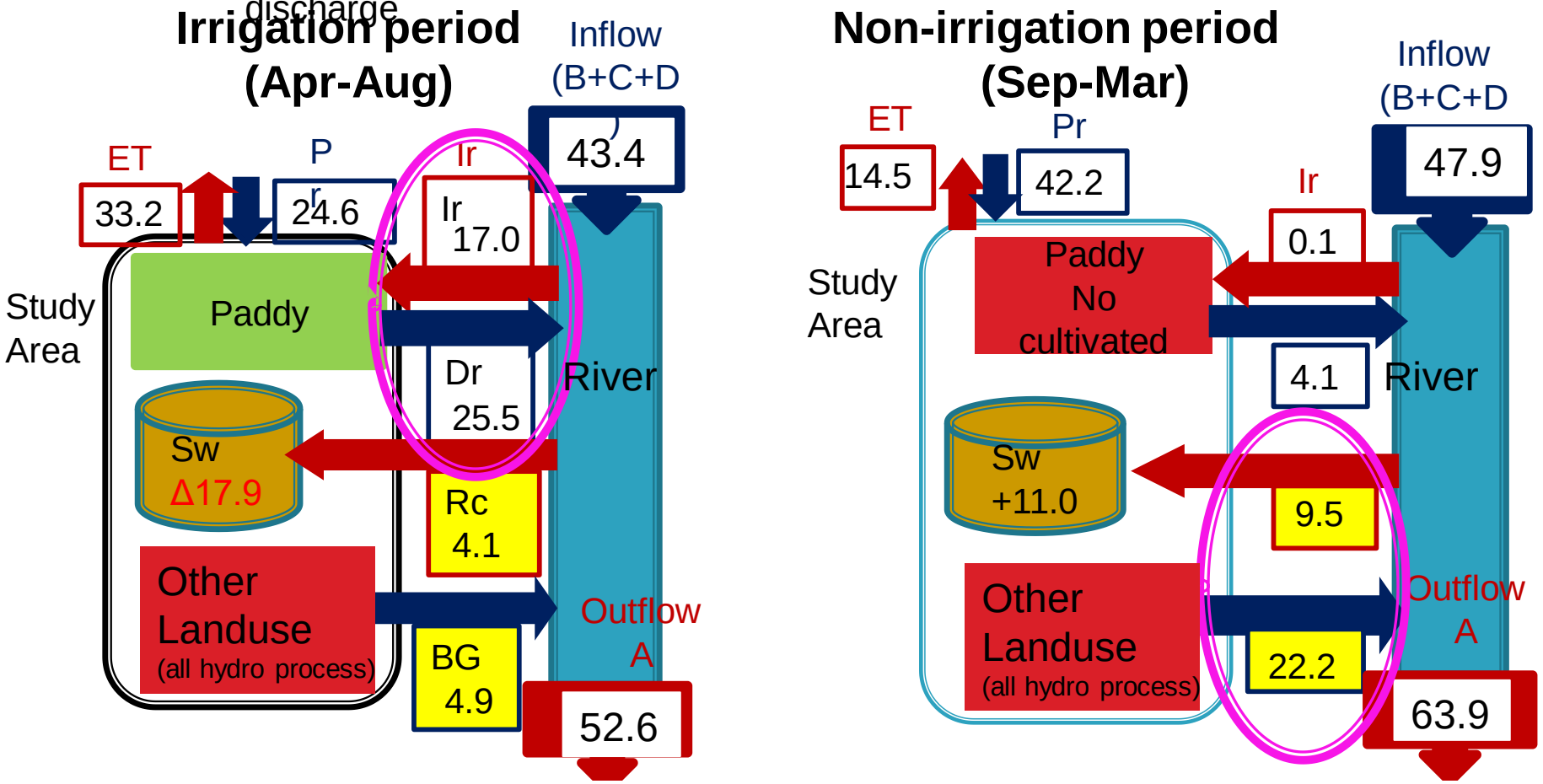




Water balance (2013)

unit: $10^5 m^3$/month

ET:Evapotranspiration, Pr:Rainfall, Ir:Irrigation, Dr:Dranage, Sw:Basin storage, Rc: Recharge from river BG: Background discharge



◆Water Balance Equation

Basin scale $Q(Rc)-Q(BG)-Q(Dr)+Q(P)+Q(Ir)-Q(ET)=\Delta Sw$

River scale $Qin\ (B+C+D) - Qout\ (A) - Q(Ir) - Q(Rc) + Q(BG) + Q(D) = 0$

Assumption in lateral flow process

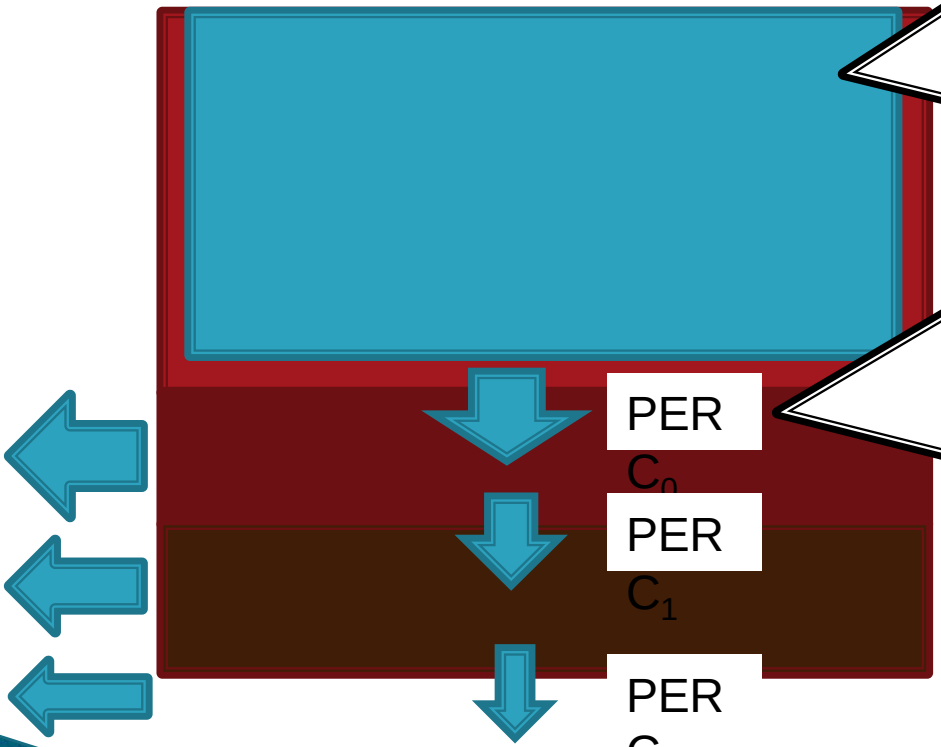
Paddy fields: (under development)

- Infiltration (flood to soil) is less than percolation (soil to soil), then, lateral flow is increased.
  - lateral flow in open condition would be discharged within 1-several days.

Background landuse: (not consider yet)

- It would be increased ground water level, then, background discharge process would be prevented.
  - In condition of paddy filed along riverside location, ground water **travelling time** would be longer in irrigation period.

Current Development of SWAT-Paddy



Surface flooding

- Water and material balance sub-models are developed .
- Flood depth control activities
- Puddling, as the tillage operation under the flooded condition, was developed.

Percolation

- Percolation ($PERC_1$, $PERC_2$, …) from a soil layer to the next layer is limited to a value lower than the value of $PERC_0$,

Lateral Flow

- In pothole module, lateral flow from surface layer were excess
- This implementation would be effective increase discharge from multiple layers

SWAT application in paddy fields Discussion & Conclusion

1. Surface buffering process was considered
   - Pothole module, implementation pothole module are not enough for fully understanding on hydro process
2. High ground water level would be influenced with percolation and lateral flow
3. Paddy fields location along riverside would possibly delayed ground water discharge from background landuse.

MARCO Satellite International Workshop
—Adoption and adaptation of SWAT for Asian crop production systems and water resource issues—
International SWAT-Asia Conference IV (SWAT-Asia IV)

Date: **October 19–23, 2015**

Venue: Tsukuba Bioscience Hall (TBH), Japan

Abstarct submit: end of August (250-350 words)

Organized by:

Monsoon Asia Agro-Environmental Research Consortium (MARCO), National Institute for Agro-Environmental Sciences (NIAES),

Japan International Research Center for Agricultural Sciences (JIRCAS) *(to be confirmed)*

Location of TSUKUBA

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