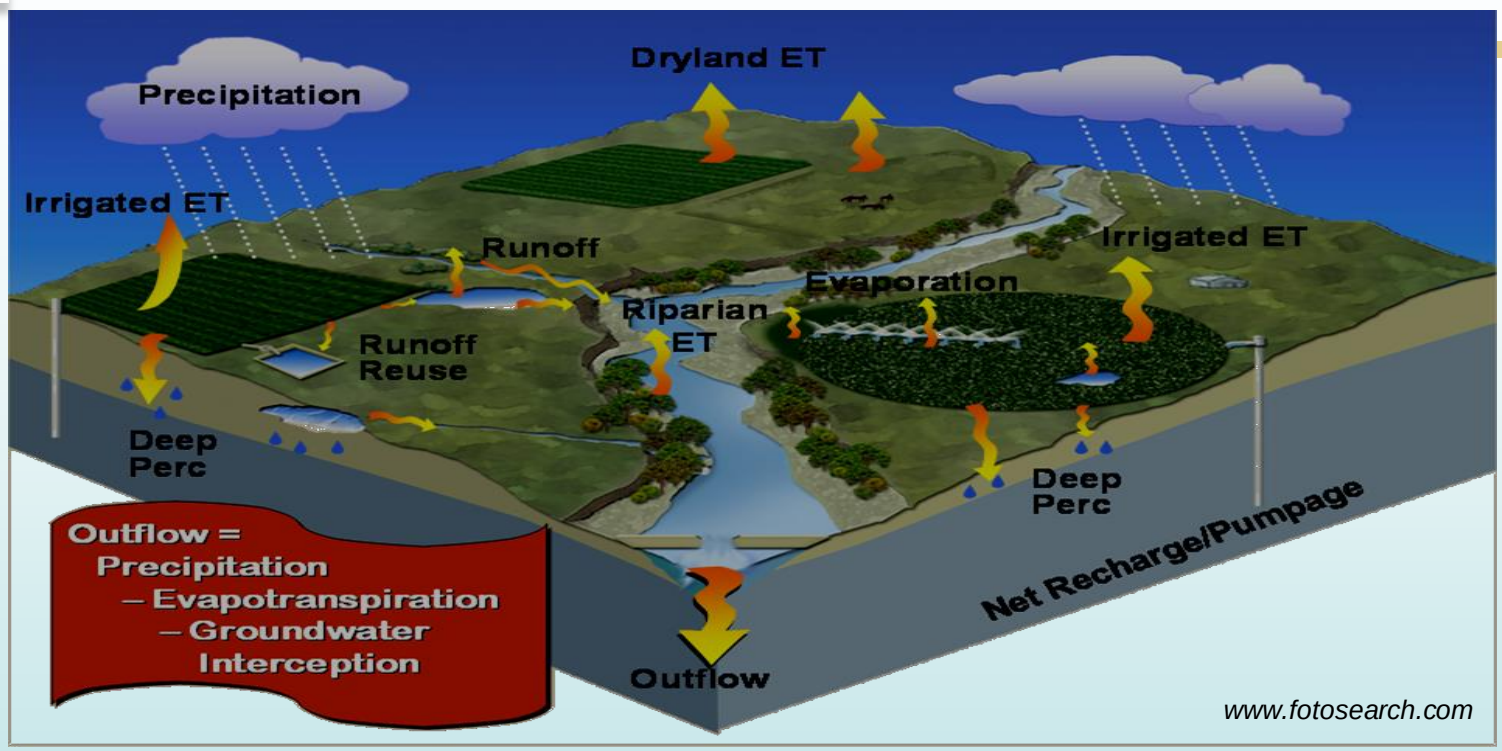
Development of an improved irrigation subroutine in SWAT to simulate the hydrology of rice paddy grown under submerged conditions



Balaji Narasimhan

Associate Professor

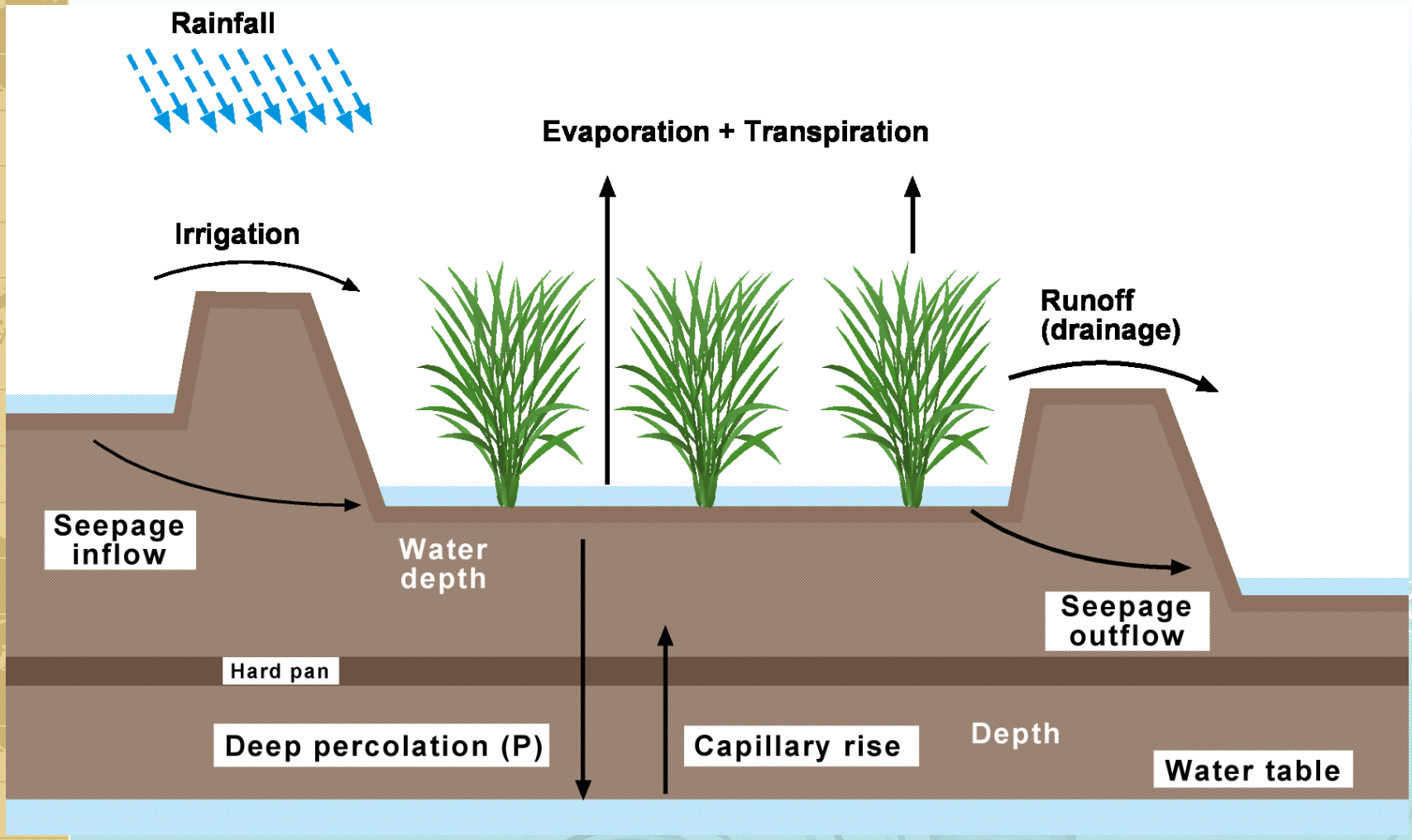
Department of Civil Engineering

Indian Institute of Technology – Madras

Co-authors

- V. M. Bindhu
  - Assistant Professor, VIT University, INDIA
- K. Karpagam
  - Research Associate, IIT Madras, INDIA
- Nithila Devi
  - Graduate Student, IIT Madras, INDIA

Field water balance lowland rice



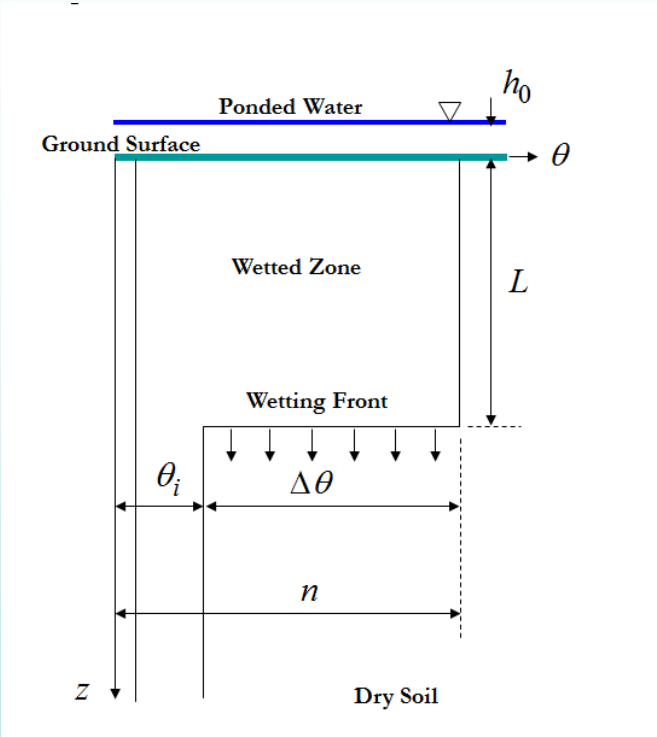
Source: IRRI

Rice Paddy representation in SWAT

- Modifications to Pothole module

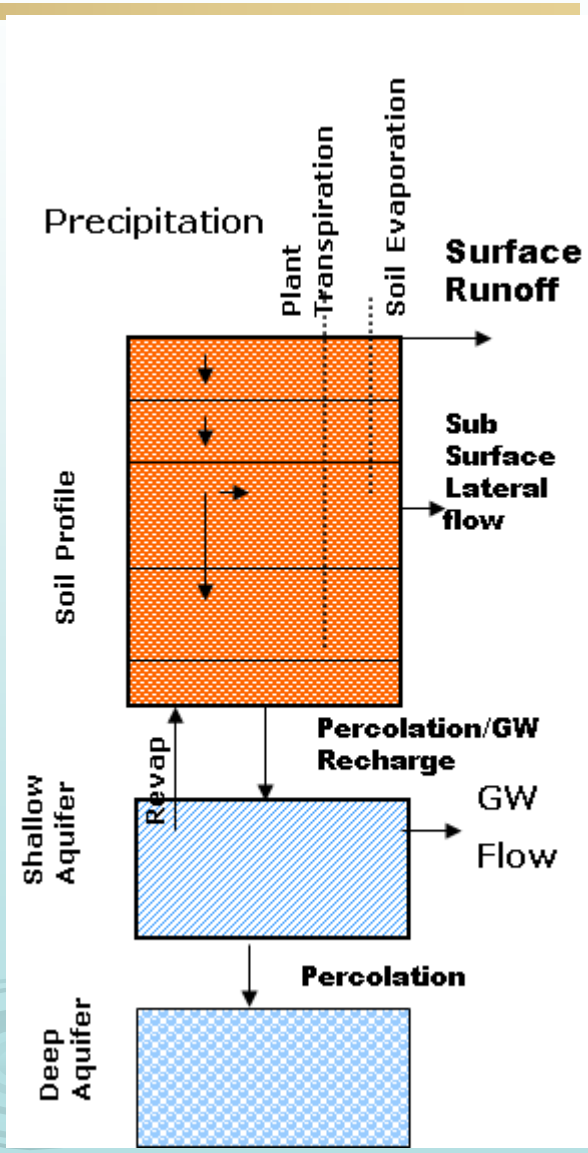
Features	Current	Modifications
Standing water	Is possible to a limited extent	Is possible
ET and crop growth	Evaporation from pothole is NOT accounted for while calculating water stress	Evaporation from pothole is accounted for while calculating water stress
Hard Pan layer	Not modelled; constant seepage rate	Two Layer Green-Ampt model; Variable seepage depending on saturation
Infiltration loss	Discharged to ground water; Does not contribute toward soil moisture	Contribute to soil moisture of first soil layer; Percolation out of the last layer contributes to ground water
Autoirrigation	Autoirrigation not possible based on ponded water level	Autoirrigation trigger is possible based on ponded water level
Irrigation Efficiency	Only total irrigation efficiency	Splitted into Conveyance efficiency and application efficiency; Loss due to conveyance efficiency is added to ground water recharge

Single Layer Green-Ampt model



$$f(t) = K\left(\frac{\psi\,\Delta\theta}{F(t)} + 1\right)$$

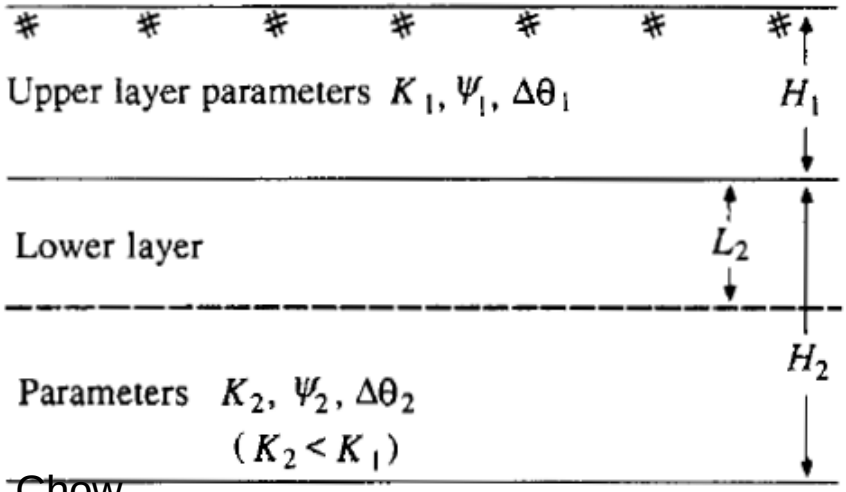
$$F(t) = Kt + \psi\,\Delta\theta\,\ln\left(1 + \frac{F(t)}{\psi\,\Delta\theta}\right)$$



Source: Ven T. Chow

Two Layer Green-Ampt model

- Hard pan assumed to have 1/5th the K_{sat} of plough layer
- Thickness – 10mm
- Insignificant storage

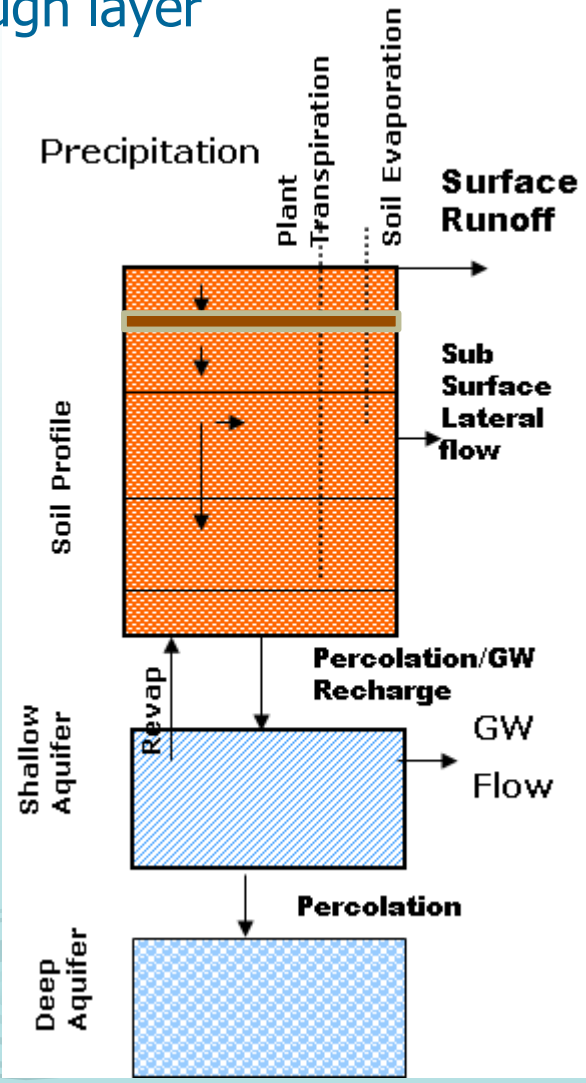


Source: Ven T. Chow

$$f = \frac{K_1 K_2}{H_1 K_2 + L_2 K_1}(\psi_2 + H_1 + L_2)$$

$$F = H_1 \Delta\theta_1 + L_2 \Delta\theta_2$$

$$L_2 \frac{\Delta\theta_2}{K_2} + \frac{1}{K_1 K_2}[\Delta\theta_2 H_1 K_2 - \Delta\theta_2 K_1(\psi_2 + H_1)] \ln\left[1 + \frac{L_2}{\psi_2 + H_1}\right] = t$$

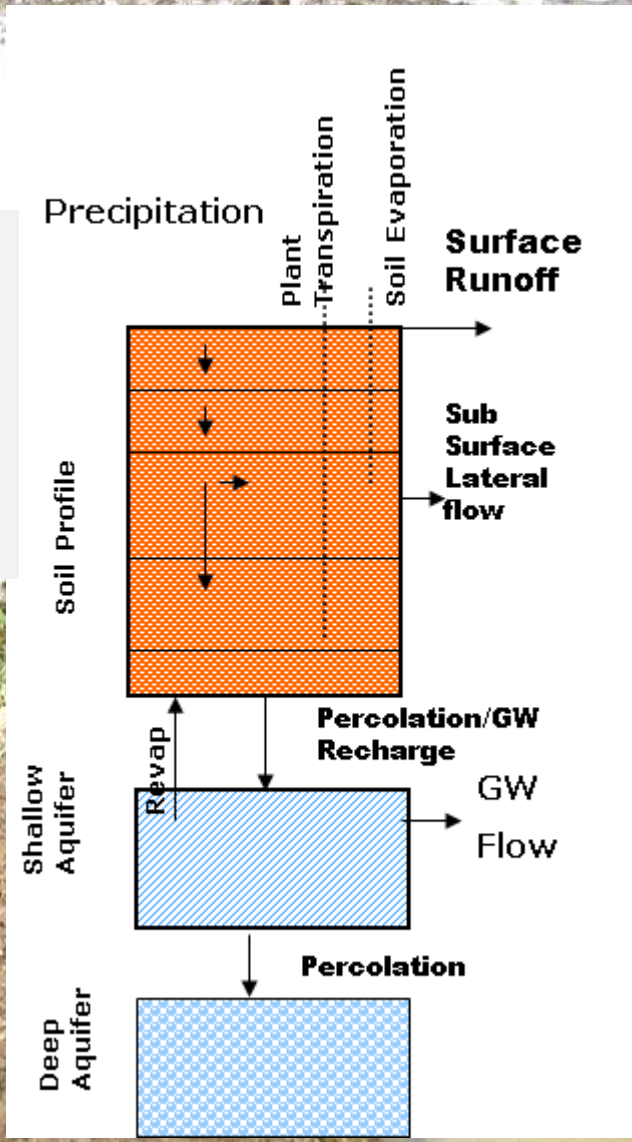


Irrigation efficiency ~ (conveyance efficiency X field application efficiency)=40%

Water diverted from source = Irrigation requirement / Irri. Eff

Water applied in the field = Water diverted from source X Conv. Eff.

Water lost in conveyance = Water diverted – water applied



	Earthen canals			Lined canals
Soil type	**Sand**	**Loam**	**Clay**	
Canal length				
Long (> 2000m)	60%	70%	80%	95%
Medium (200-2000m)	70%	75%	85%	95%
Short (< 200m)	80%	85%	90%	95%

Source: FAO manual

Irrigation methods	Field application efficiency
Surface irrigation (border, furrow, basin)	60%
Sprinkler irrigation	75%
Drip irrigation	90%

$$e = \frac{ec \times ea}{100}$$

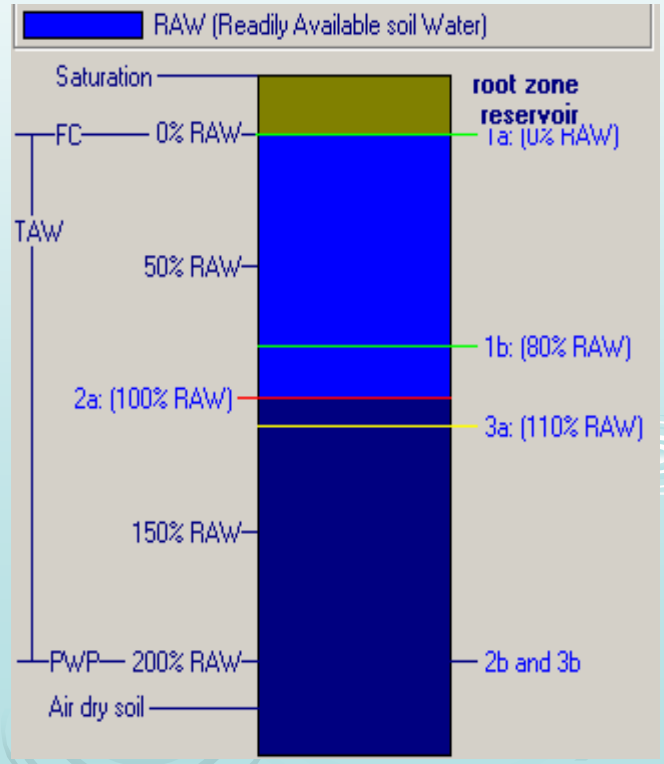
with

e = scheme irrigation efficiency (%)
ec = conveyance efficiency (%)
ea = field application efficiency (%)

A scheme irrigation efficiency of 50-60% is good; 40% is reasonable, while a scheme Irrigation efficiency of 20-30% is poor.

Auto Irrigation trigger

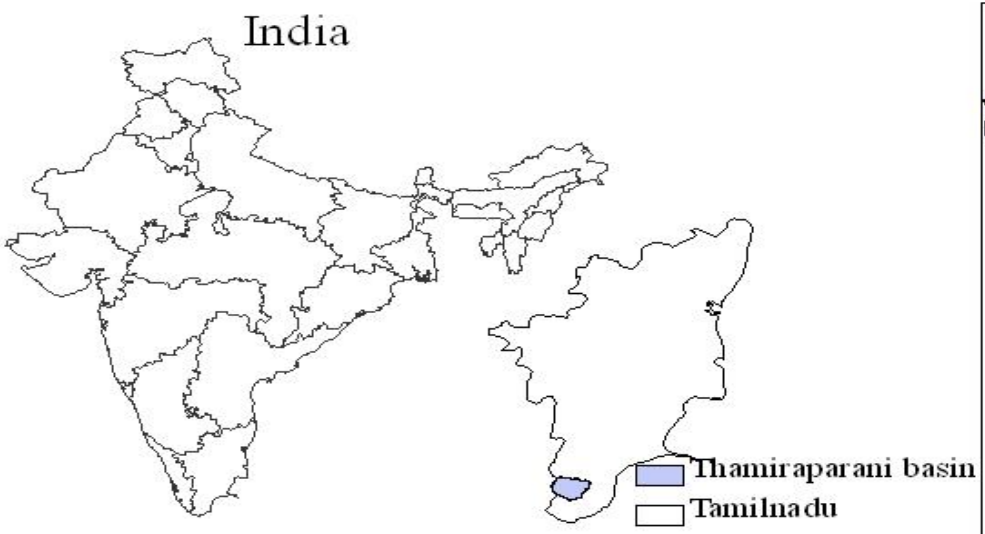
- Plant growth
  - Fraction of potential plant growth reduced due to water stress
- Soil water stress
  - 1 – Depletion. Fac
  - Depletion factor
    - SW/TAWC
- Ponded water level

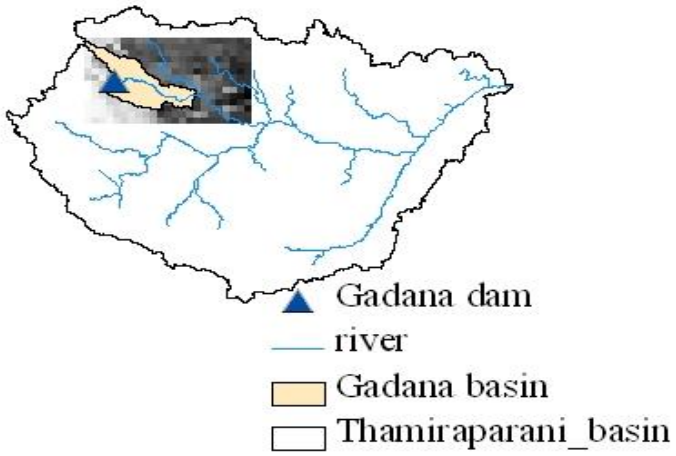


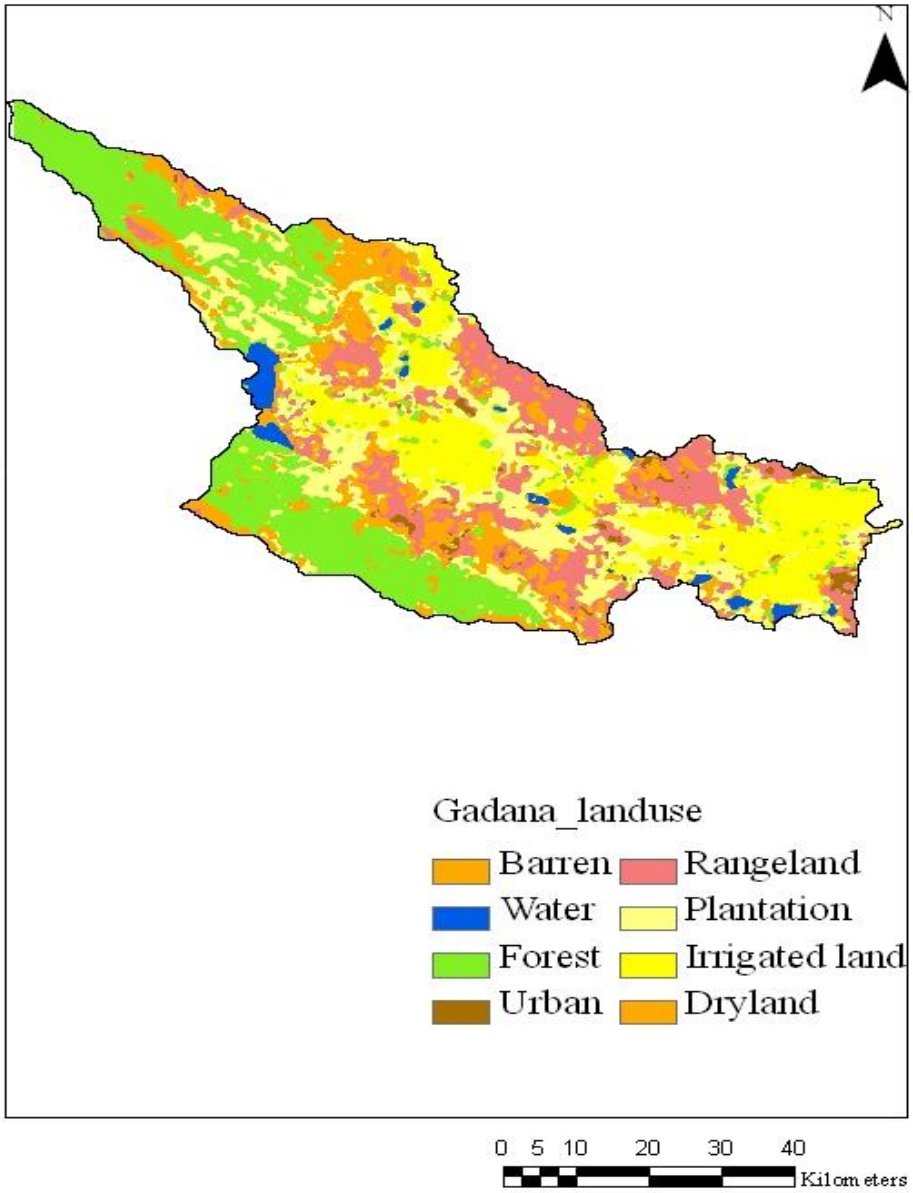
Crop		Root zone depth (RZD)[1] (m)	Allowable soil moisture depletion (P)[2]
a. Small vegetables			
Broccoli		0.4-0.6	0.45
Brussels sprouts		0.4-0.6	0.45
Cabbages		0.5-0.8	0.45
Carrots		0.5-1.0	0.35
Cauliflowers		0.4-0.7	0.45
Celery		0.3-0.5	0.20
Garlic		0.3-0.5	0.30
Lettuce		0.3-0.5	0.30
Onions	– dry	0.3-0.6	0.30
	– green	0.3-0.6	0.35
	– seed	0.3-0.6	0.35
Spinach		0.3-0.5	0.20
Radishes		0.3-0.5	0.30
b. Vegetables – Solanum Family (*Solanacea*)			
Eggplant		0.7-1.2	0.45
Sweet peppers (bell)		0.5-1.0	0.30
Tomatoes		0.7-1.5	0.40
c. Vegetables – Cucumber Family (*Cucurbitaceae*)			
Cantaloupes		0.9-1.5	0.45
Cucumbers	– fresh market	0.7-1.2	0.50
	– machine harvest	0.7-1.2	0.50
Pumpkin, winter squash		1.0-1.5	0.35
Squash, zucchini		0.6-1.0	0.50
Sweet melon		0.8-1.5	0.40
Watermelon		0.8-1.5	0.40
d. Roots and tubers			
Beet, table		0.6-1.0	0.50
Cassava	– year 1	0.5-0.8	0.35
	– year 2	0.7-1.0	0.40
Parsnips		0.5-1.0	0.40
Potatoes		0.4-0.6	0.35
Sweet potatoes		1.0-1.5	0.65
Turnips (and Rutabaga)		0.5-1.0	0.50
Sugar beet		0.7-1.2	0.553

Source: FAO irrigation manual

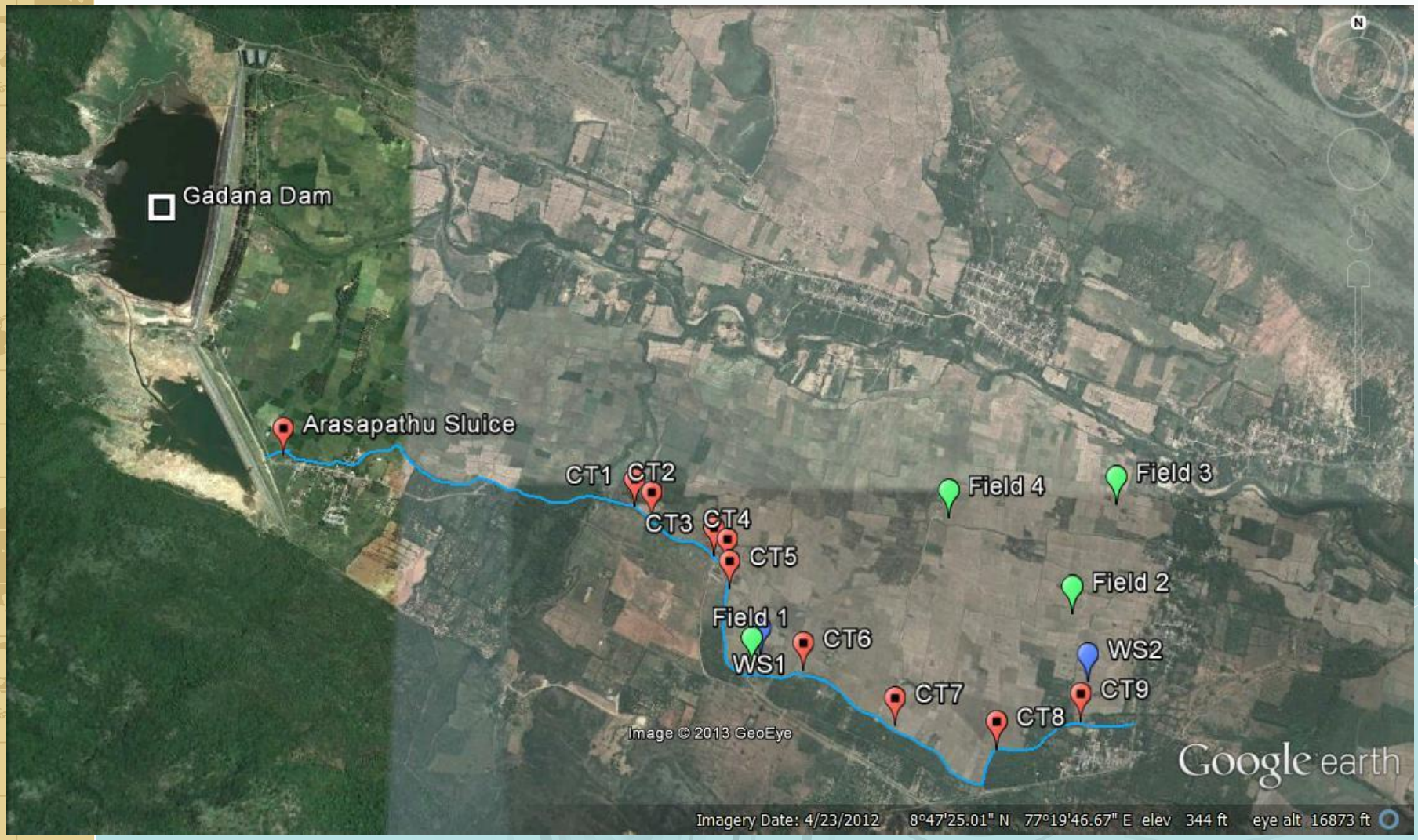
Study Area


India
Thamiraparani basin
Tamilnadu

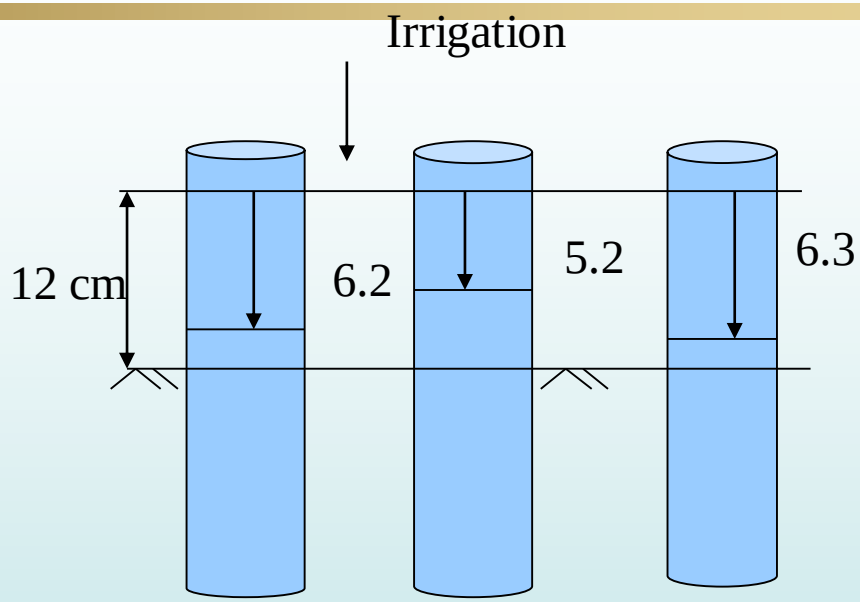

Gadana dam
river
Gadana basin
Thamiraparani_basin


N
Gadana_landuse
Barren
Rangeland
Water
Plantation
Forest
Irrigated land
Urban
Dryland
0 5 10 20 30 40
Kilometers

Field Instrumentation



Record daily measurements in the field water tube and percolation tube in order to estimate the field water balance based evapotranspiration.

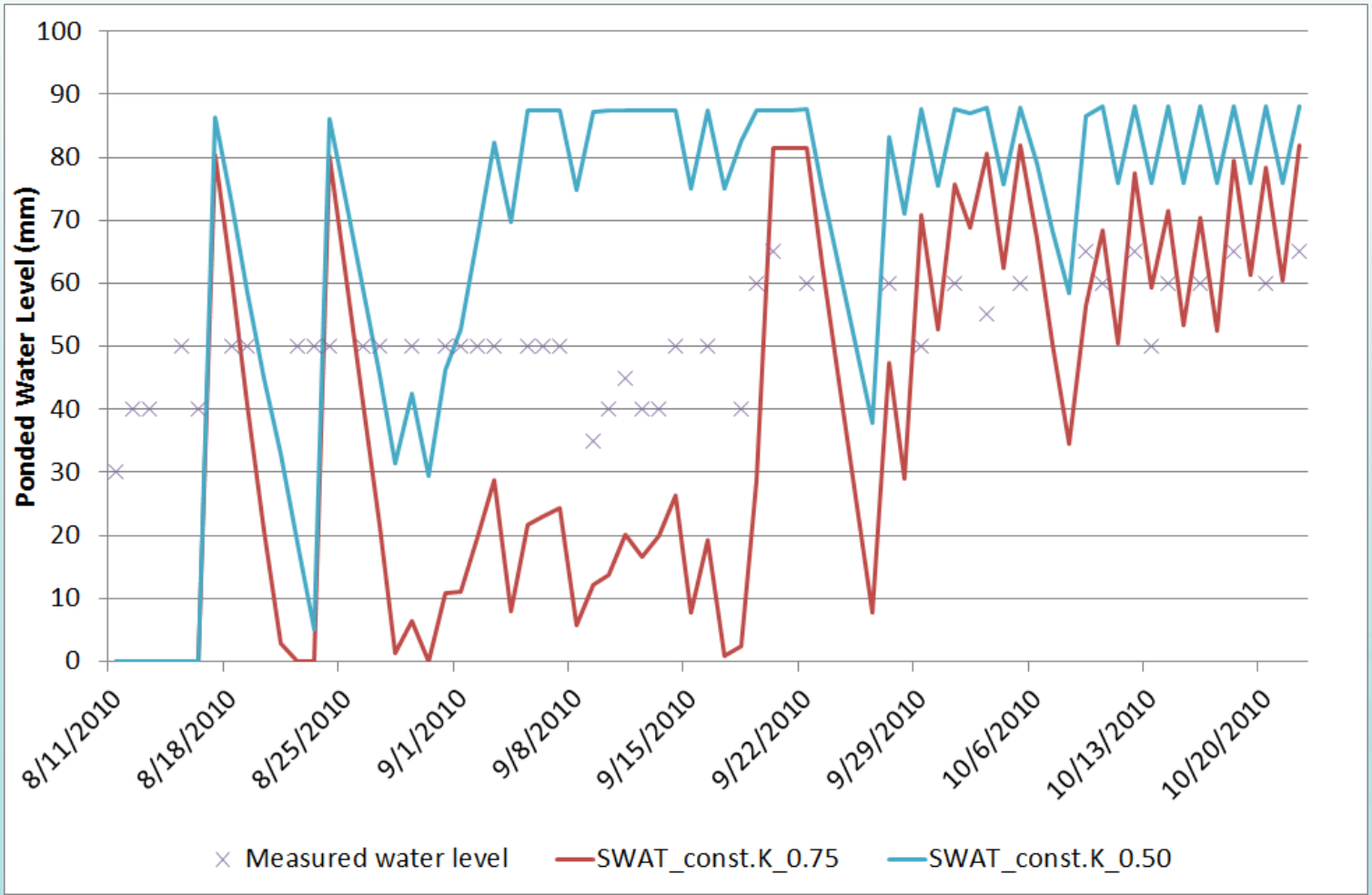


Field water tube

RESULTS AND DISCUSSION

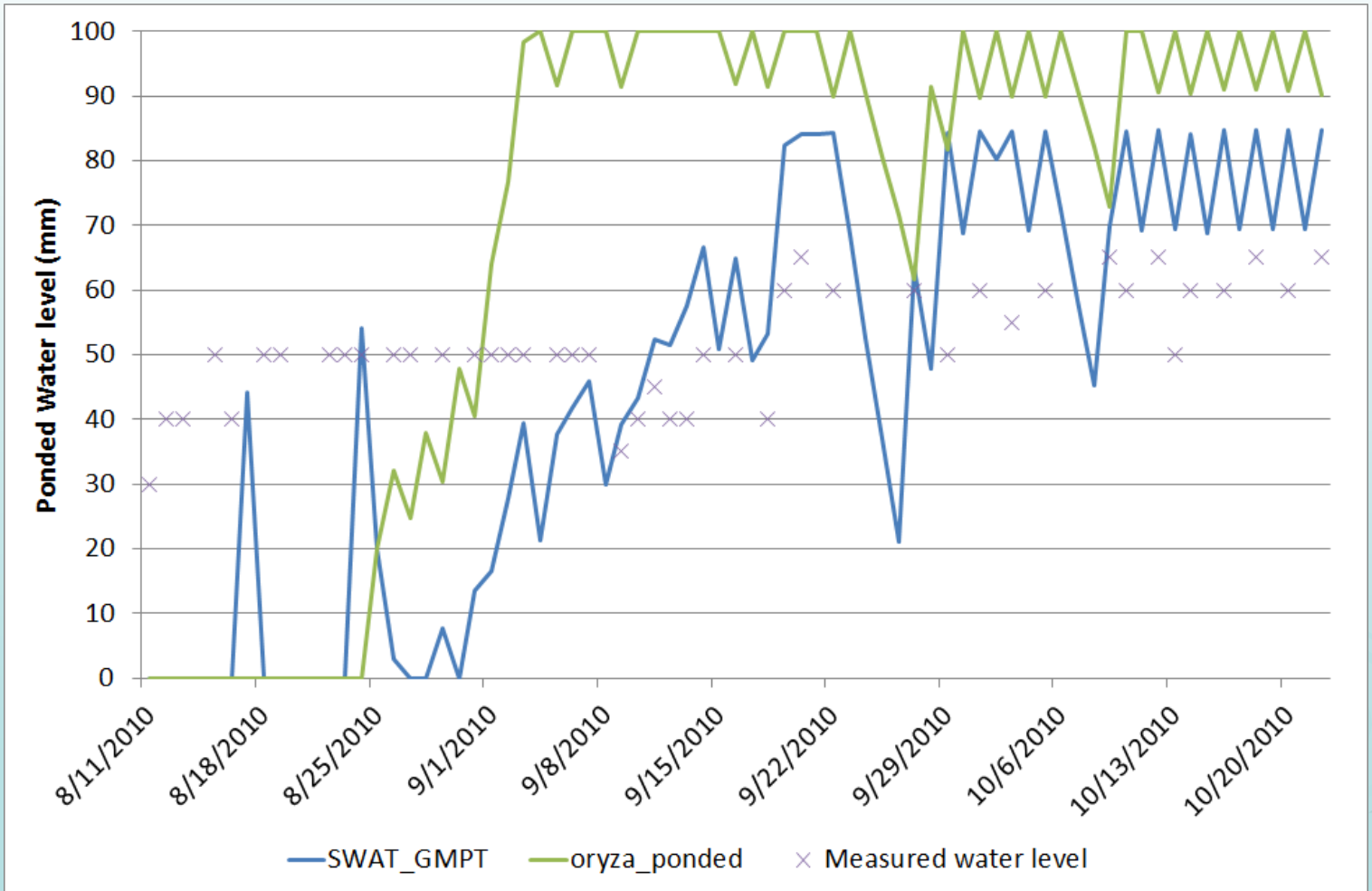
Ponded water level

- Constant infiltration rate

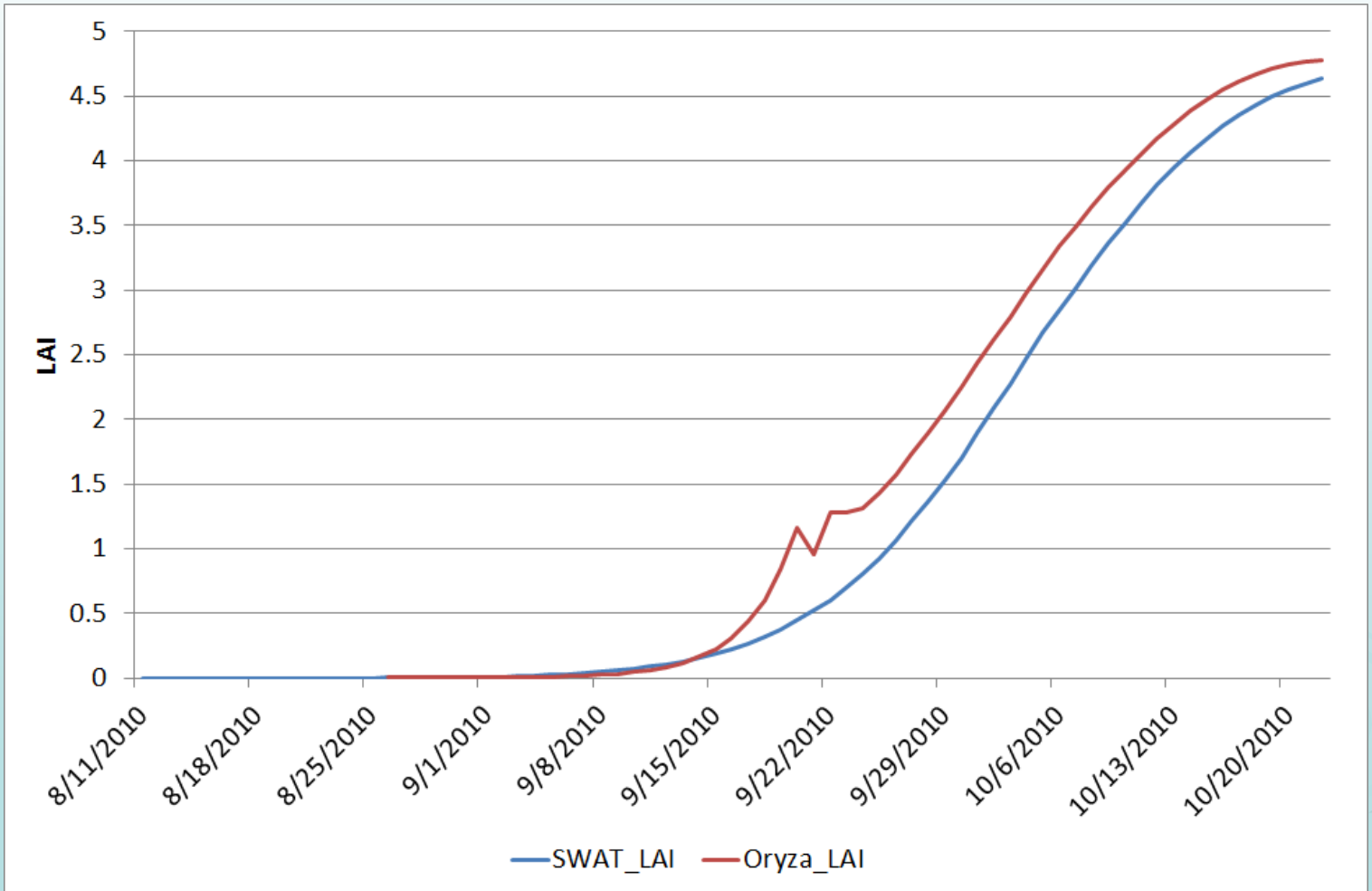


Ponded Water level

- Two layer Green & Ampt model

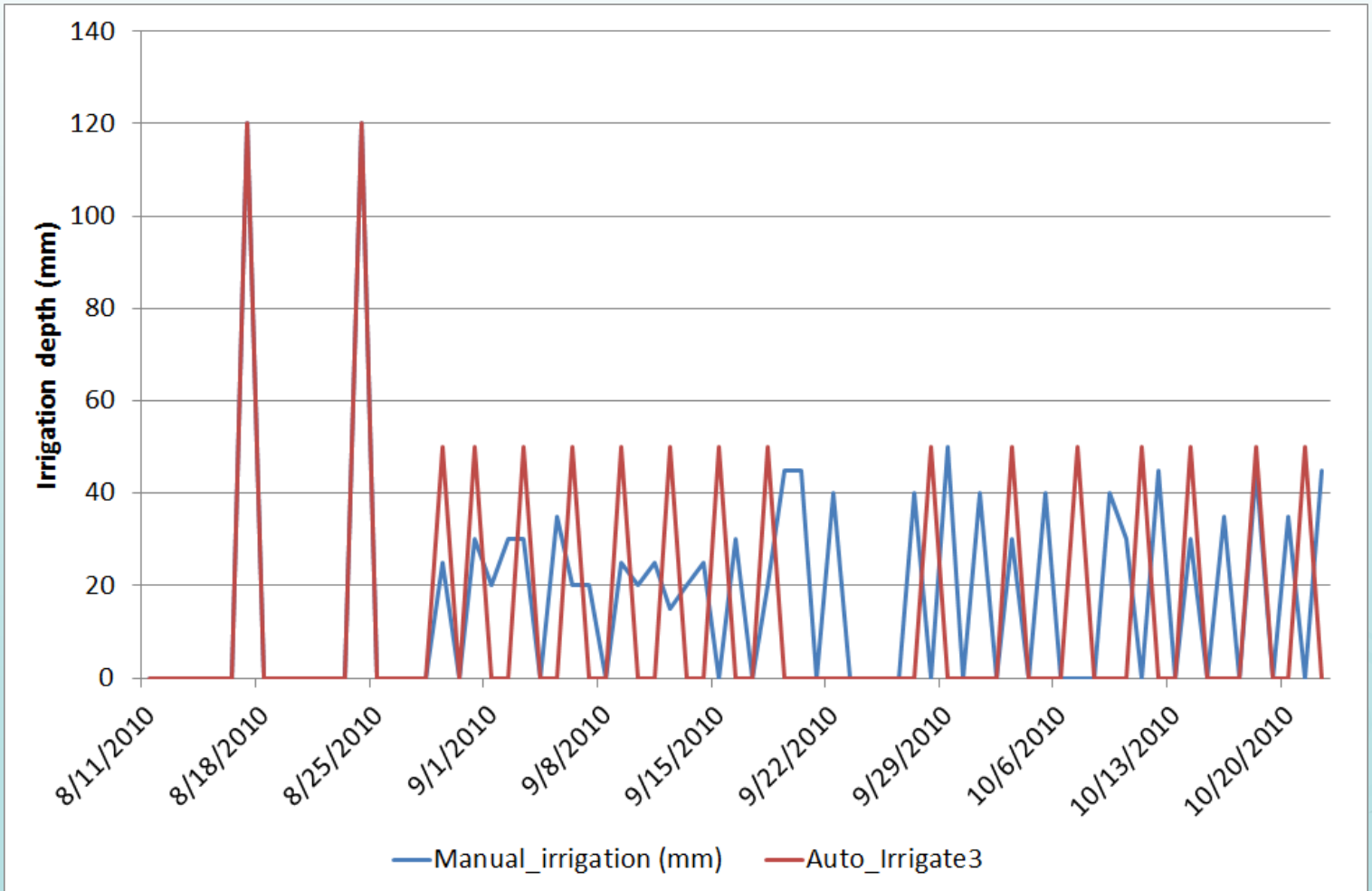


Leaf Area Index



Auto Irrigation

- Based on ponded water level



Other Modifications

- Irrigation from farm ponds
  - There are lot of small tanks (not big enough to be reservoirs) from which significant amount of irrigation takes place in India and other countries
- Simulation of conjunctive water use is possible
  - (Auto) Irrigation from a mix of surface and ground water sources

Future Plans

- Testing with many more field data
  - India and other countries
  - Verification with other models ORYZA, AQUACROP, DSSAT
- Turning-ON and OFF auto irrigation for different phases of crop growth
  - Based on ponded water level for some growth stages & soil water stress for other stages
    - Irrigation BMP (SRI, AWD etc.,)
- Integration of the modifications to the current code and the modular code