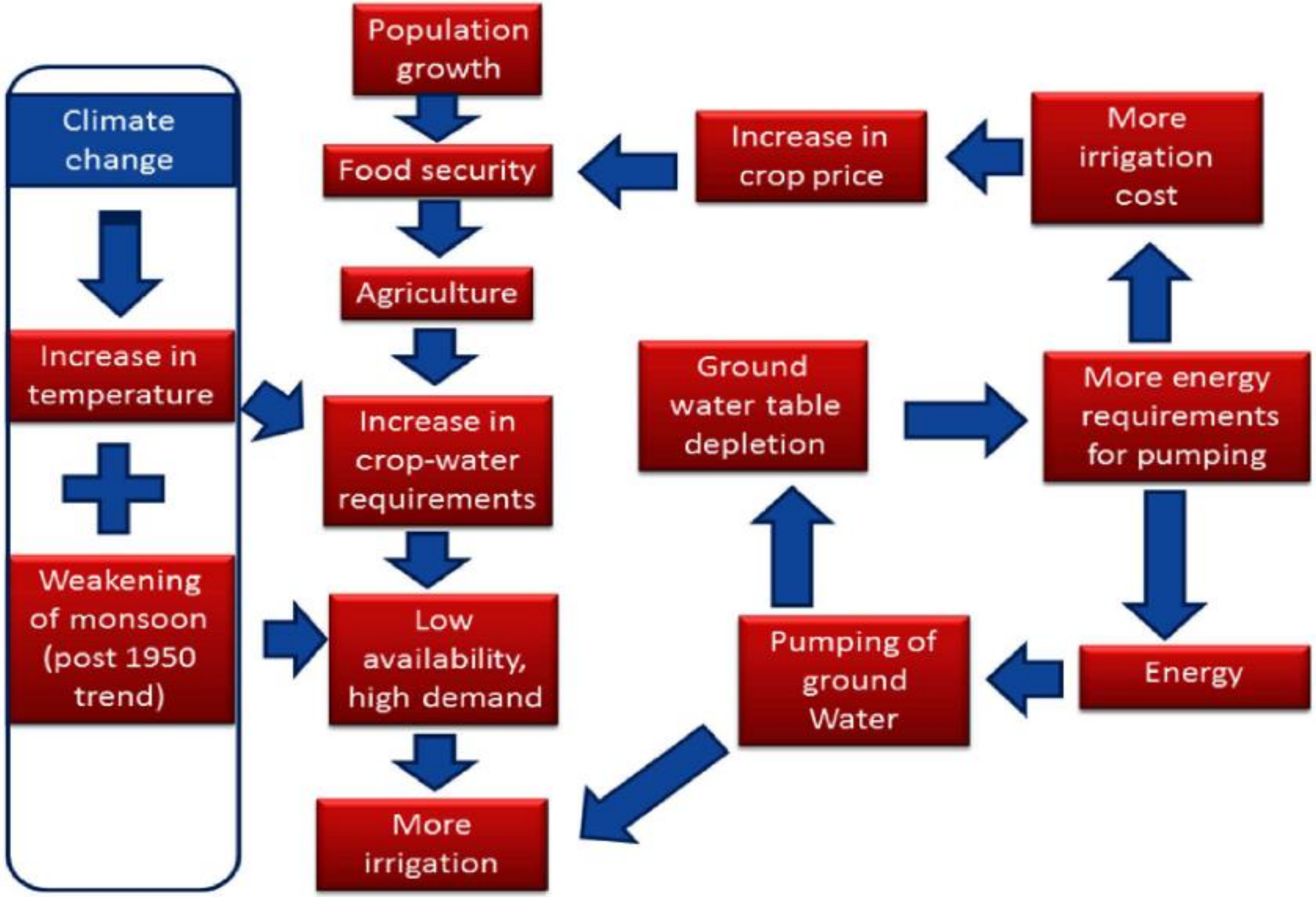
Climate Change and Adaptation: Sustainable Water Management

Subimal Ghosh

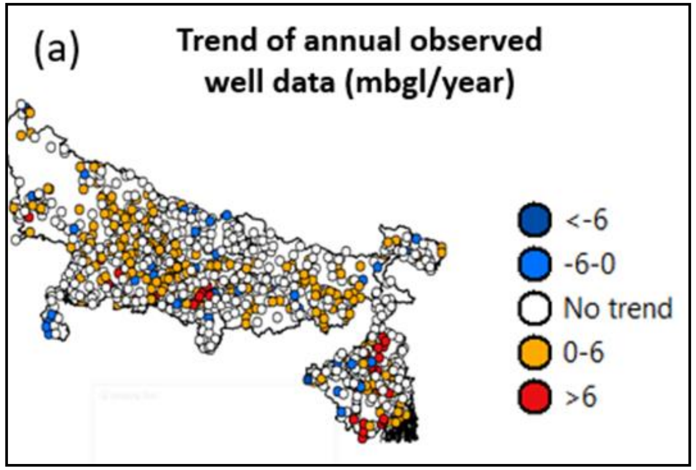
Interdisciplinary Program in Climate Studies

IIT Bombay

Food-Energy-Water in a Changing Scenario



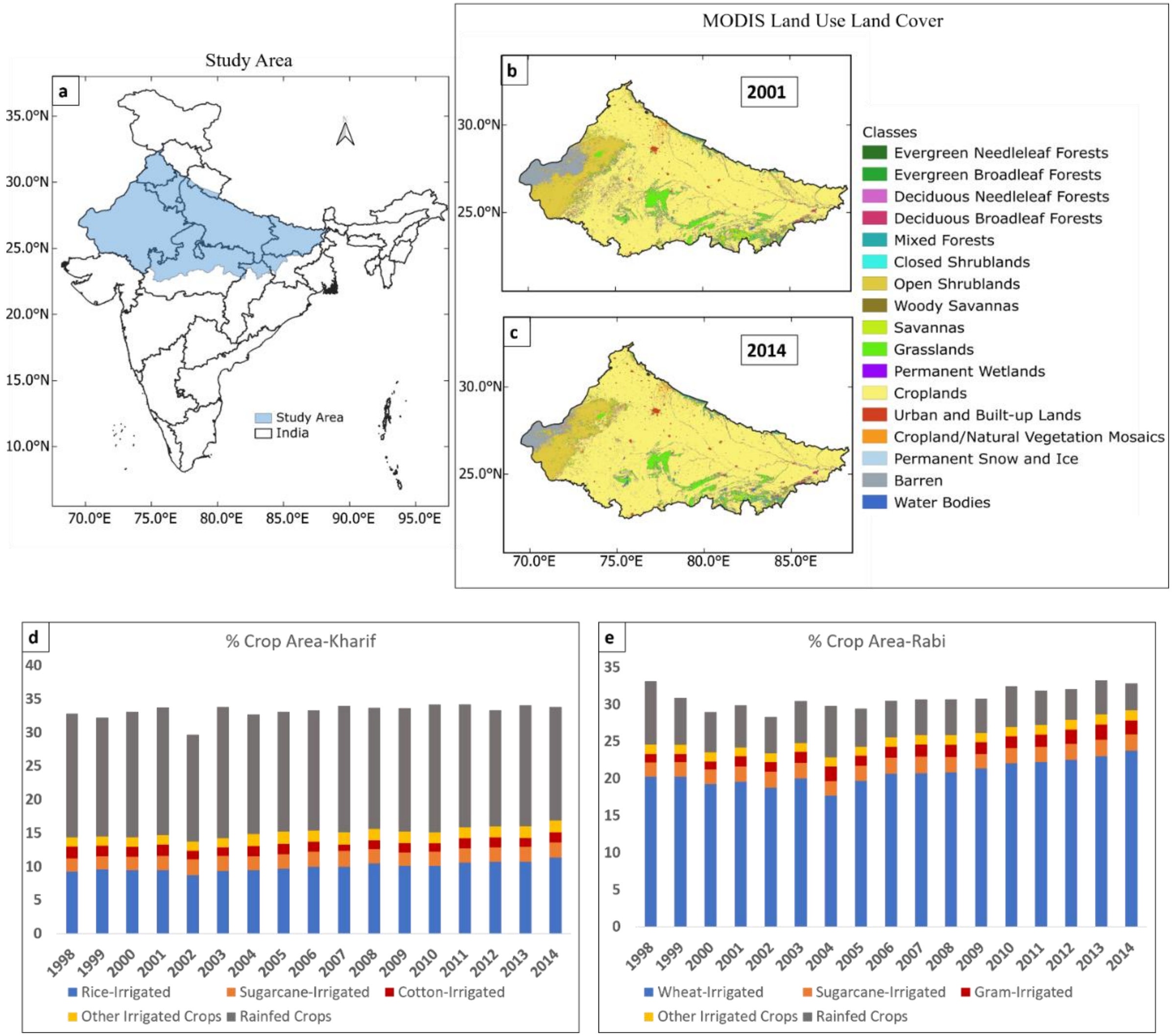
Increasing groundwater depth in Gangetic Basin



Solutions

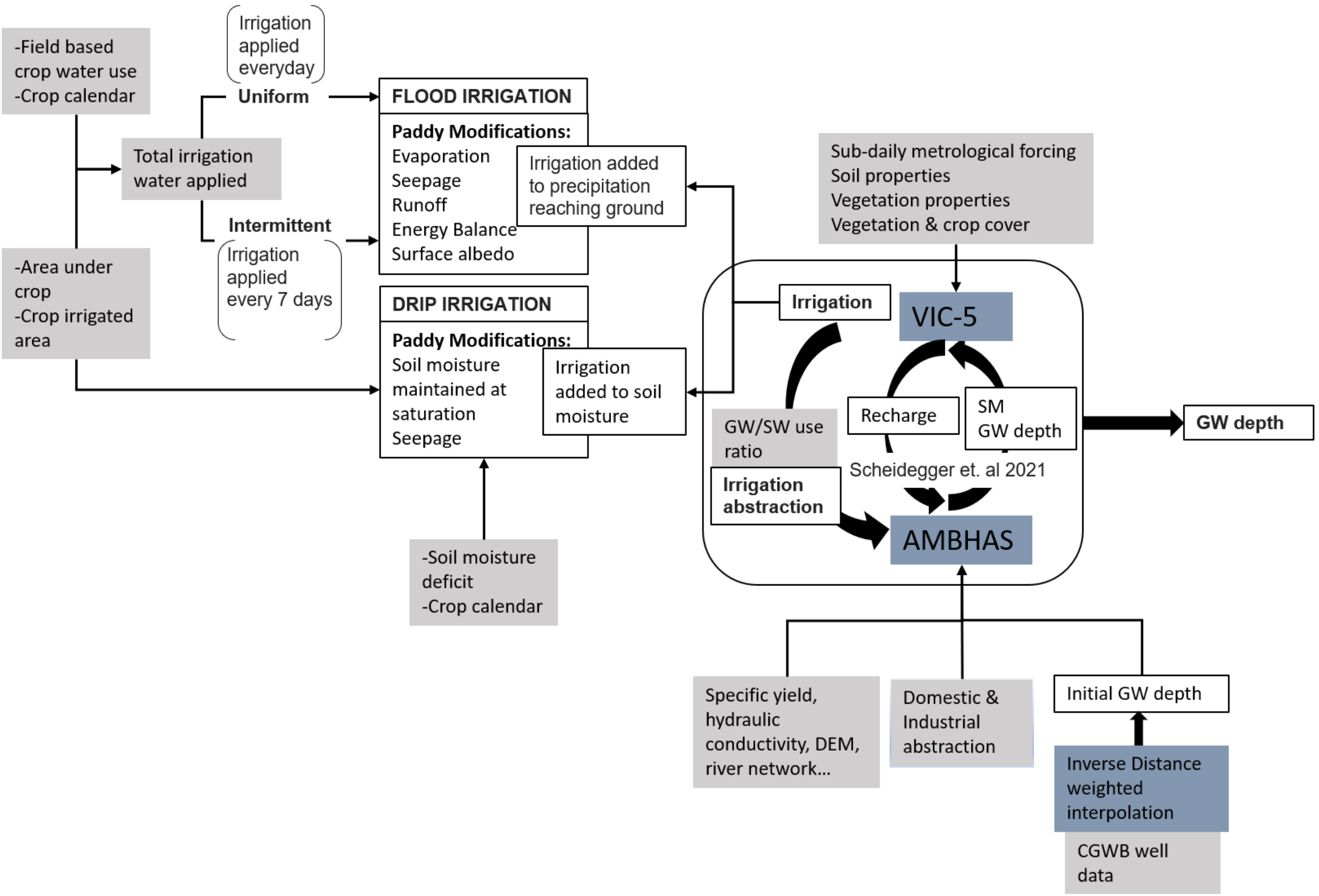
- More crop per drop or More nutrition per drop
    - Switching flood to drip irrigation
    - Improved irrigation water management
    - Participatory framework targeting the most vulnerable farmers

Major Crop Practice in India



- Irrigation affects water and energy cycle
- Land surface modelling must include irrigation
- Existing coupled models- demand driven irrigation with generic crop
- India-uncontrolled irrigation
- Paddy primary crop-submerged crop-water and energy balance mechanisms different

VIC-AMBHAS-IRR model



Forward-difference two-dimensional, one-layer groundwater model with governing equation:

$$\frac{\partial}{\partial x}\left(T\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T\frac{\partial h}{\partial y}\right)=S_y\frac{\partial h}{\partial t}-q_r+q_p+q_b$$

Where: h=hydraulic head, T = aquifer transmissivity, S =aquifer storage coefficient, q_r =groundwater recharge, q_p =groundwater pumping, q_b =baseflow to rivers

- **aquifer is isotropic**, can be heterogeneous
- T recalculated at each time-step as the saturated aquifer thickness varies, according to:

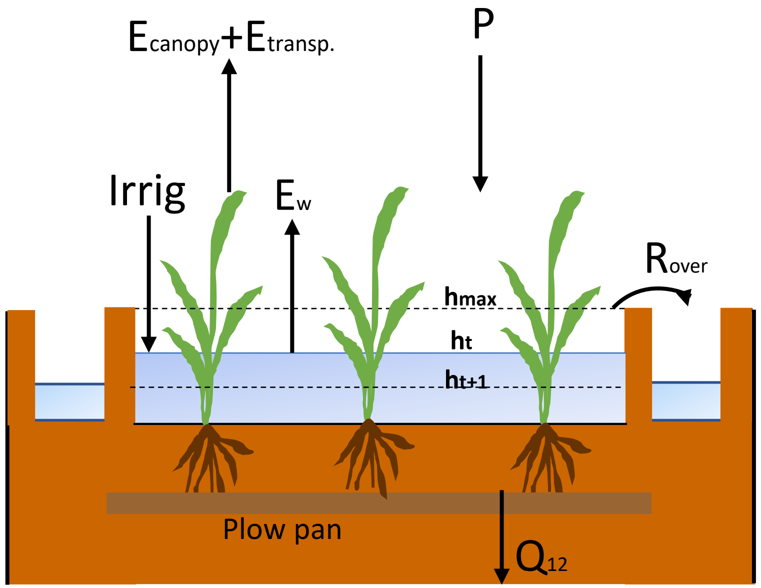
$$T = K\ (h - z_{base})$$

where K=hydraulic conductivity, and z_{base}= elevation of the base of the aquifer

Joseph et al. (2022), ERL (revision)

Paddy Formulation

Concept from SWAT (Xie and Cui, 2011),MATCRO rice (Masutomi et al., 2016), Devanand et al. 2019



Energy Balance:

1) $R_n = H + LE + G + S_{tw}$

Where : $S_{tw} = c_{pw}\rho_w d_w \frac{\partial T_s}{\partial t}$

S_{tw}=heat flux stored in surface water,

c_{pw}=specific heat of water, ρ_w=density of water,

d_w=depth of water, T_s=surface temperature

2) Surface albedo: soil albedo replaced with albedo of water

Water Balance:

1) **Evaporation-**soil evaporation replaced with open water evaporation

$$E = E_{canopy} + E_{transpiration} + E_w$$

2) Seepage-

$$Q_{12} = 0.1\% \; of \; Q_{12,max}$$

Q_{12} is the seepage from layer1 to layer2

Field tilling creates low permeability layer beneath the field, which cannot infiltrate at the maximum capacity

3) Overbund flow-

$$R_{over} = (h_t - h_{max})/\Delta t \qquad , h_t > h_{max}$$
$$R_{over} = 0 \qquad , h_t \le h_{max}$$

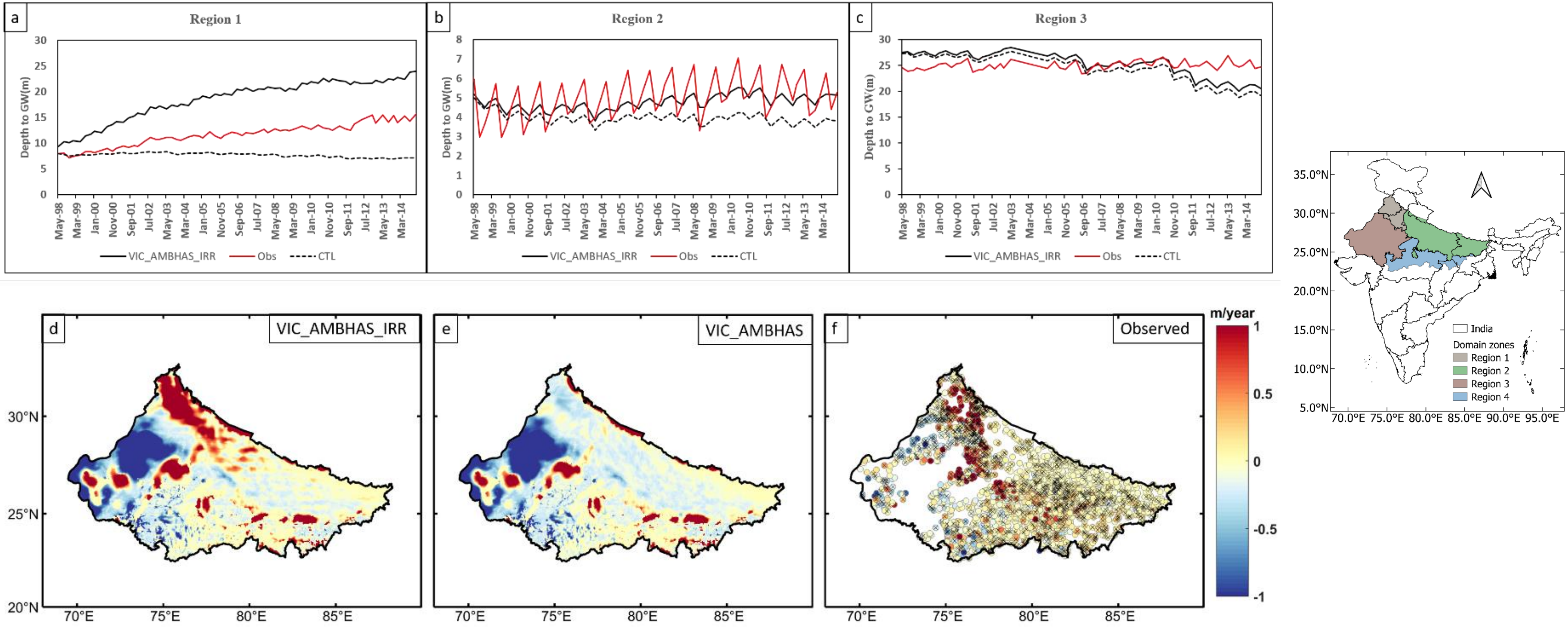
h_{max} is considered to be 300mm (Mishra et al. 2007)

4) Ponded depth-

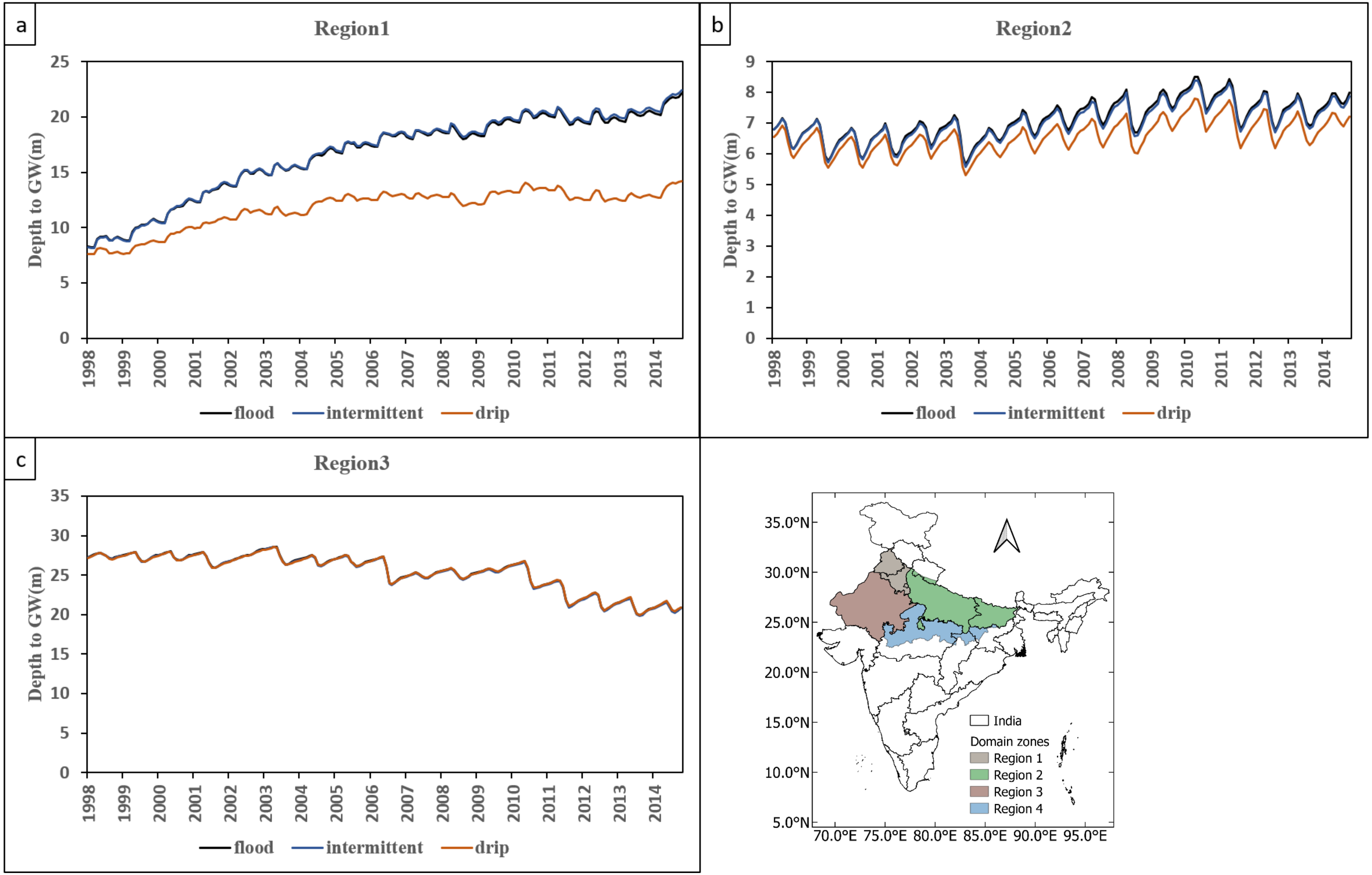
$h_t$is the ponded depth at time step t

$$\Delta h_w = (P + irrig - E_w - \text{infilt}).\Delta t$$
$$h_{t+1} = h_t + \Delta h_w \qquad ,\text{if } h_{t+1} < 0 \text{ set } h_{t+1} = 0$$

Model Performances

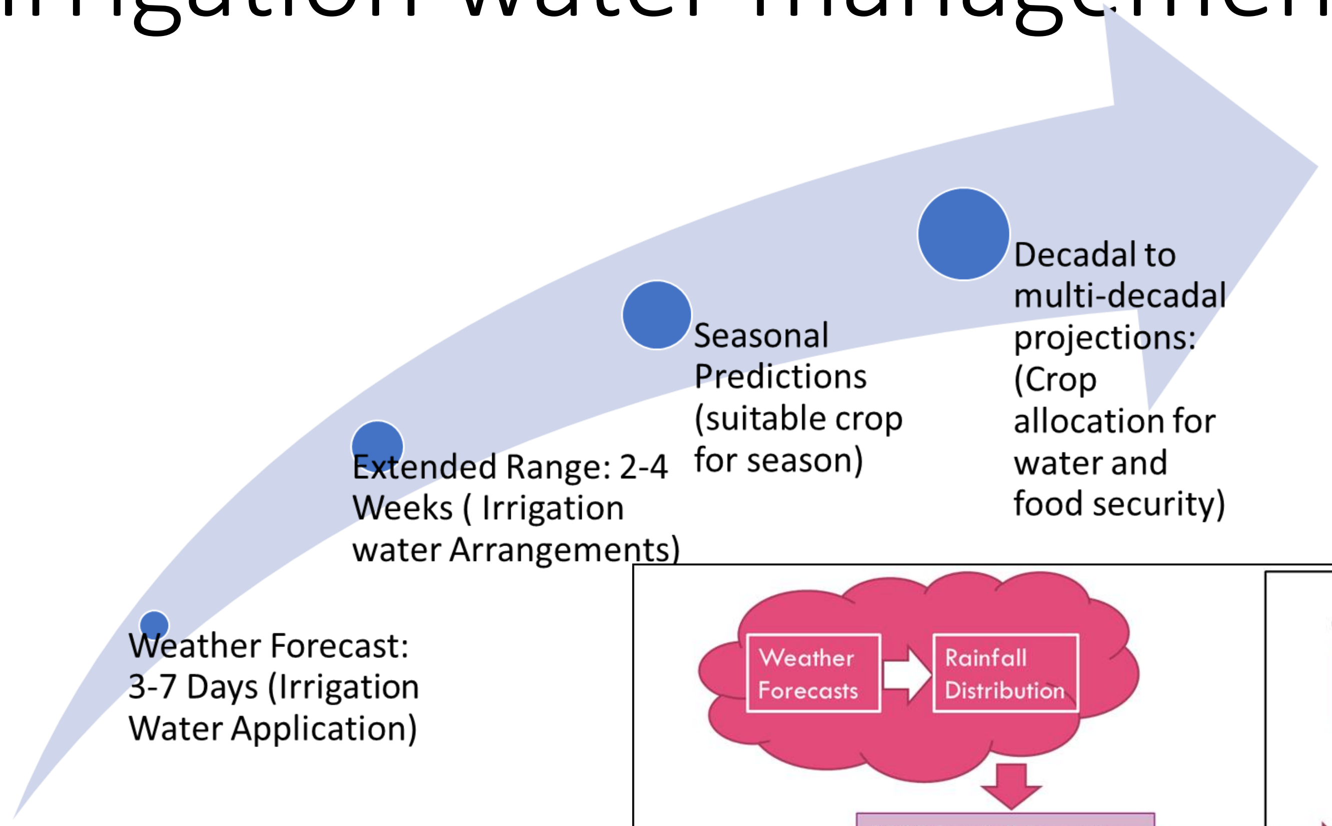


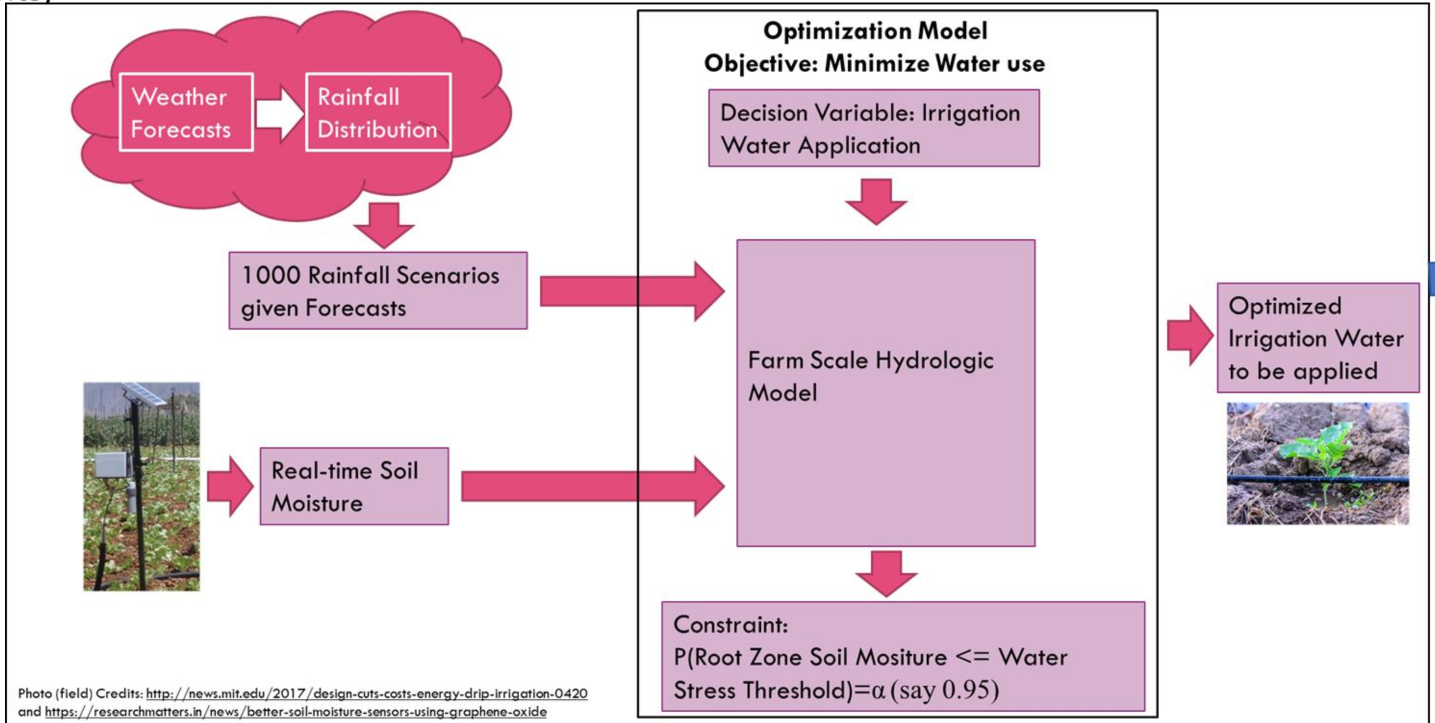
Evaluation of Model Performance



Depth to GW simulated from flood, intermittent and drip irrigation

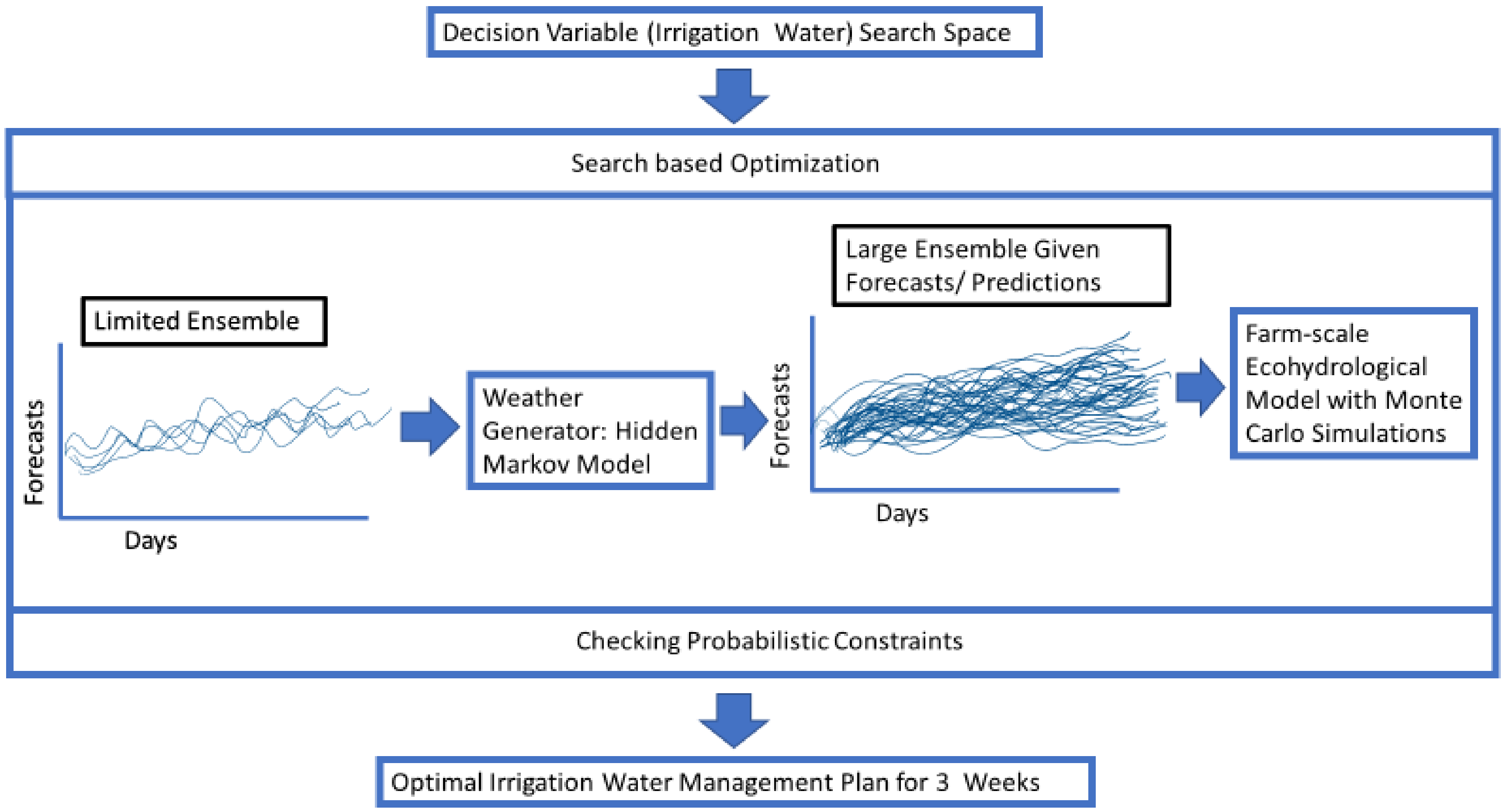
Irrigation water management



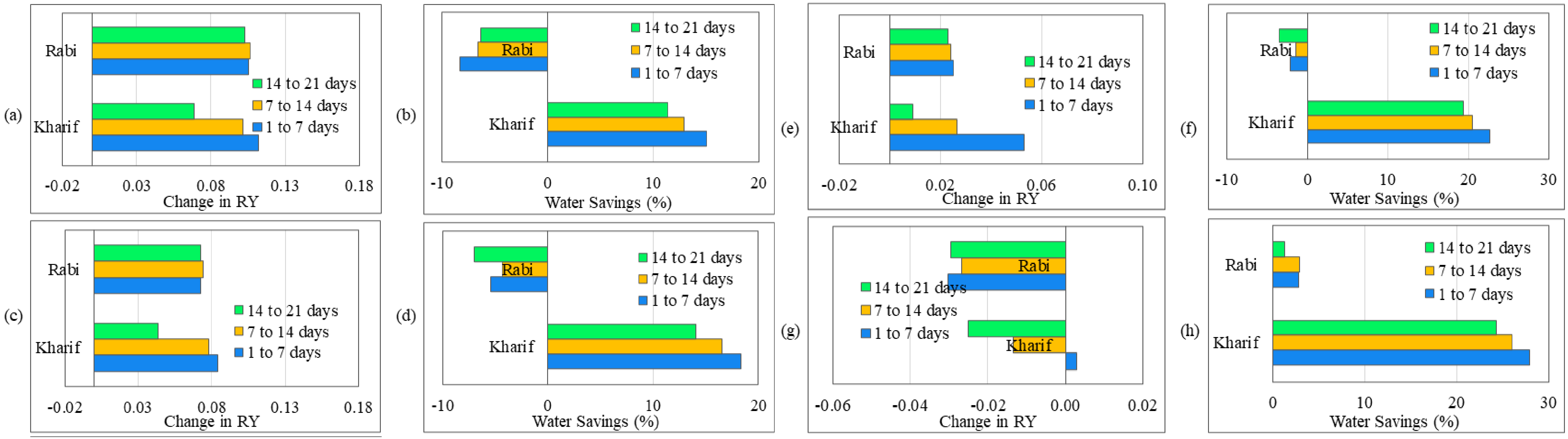


Saves 10-30% water with no loss in the yield
Patent filed; Roy et al. (2021), WRR

Extending with ERPAS



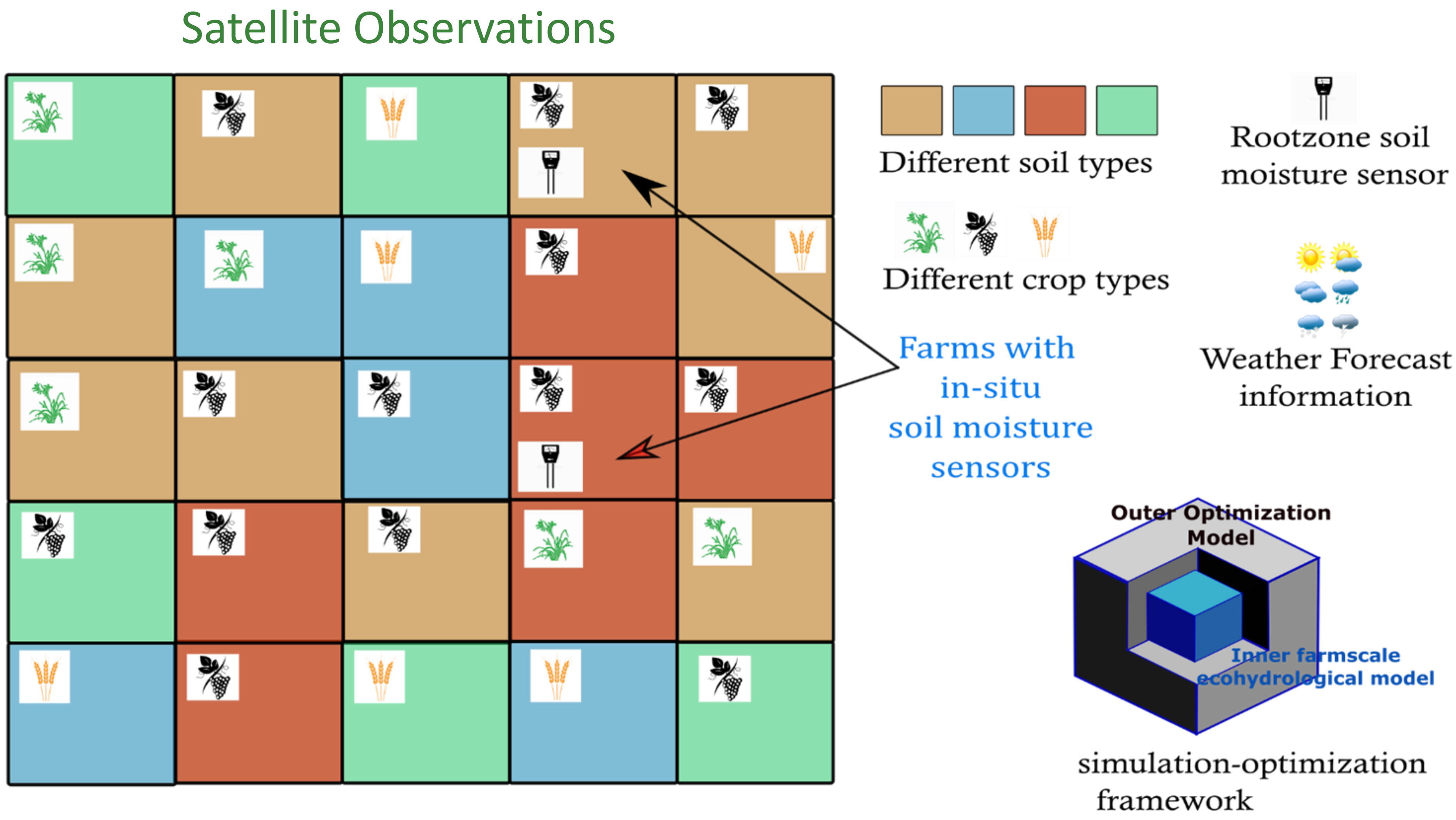
Water Savings and Maintaining RY Site 1



Changes in RY (a, c, e and g) and savings in irrigation water use (b, d, f and h) w.r.t. the farmer's method of irrigation scheduling, using the proposed framework with extended range forecast for $(t+1)^{th}$ to $(t+7)^{th}$ day, $(t+8)^{th}$ to $(t+14)^{th}$ day and $(t+15)^{th}$ to $(t+21)^{th}$ day
reliability factor value (α): 0.95 in (a) and (b), 0.85 in (c) and (d), 0.75 in (e) and (f), 0.5 in (g) and (h).

Roy et al. (2022), Climate Services

Upscaling over a large region

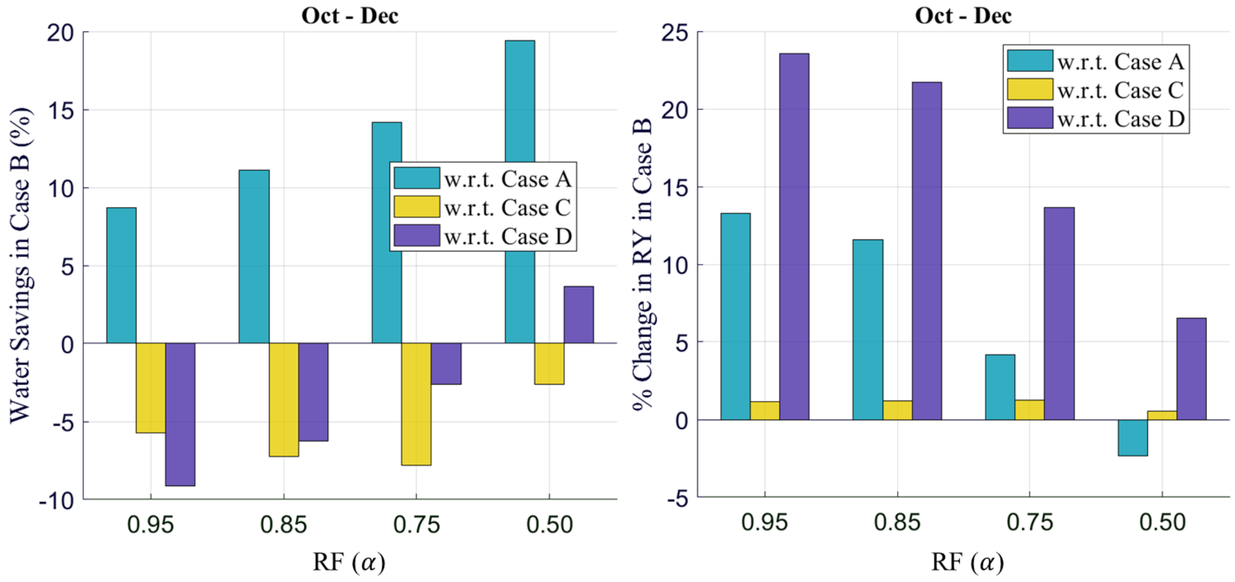


Soil Moisture Prediction at Sites

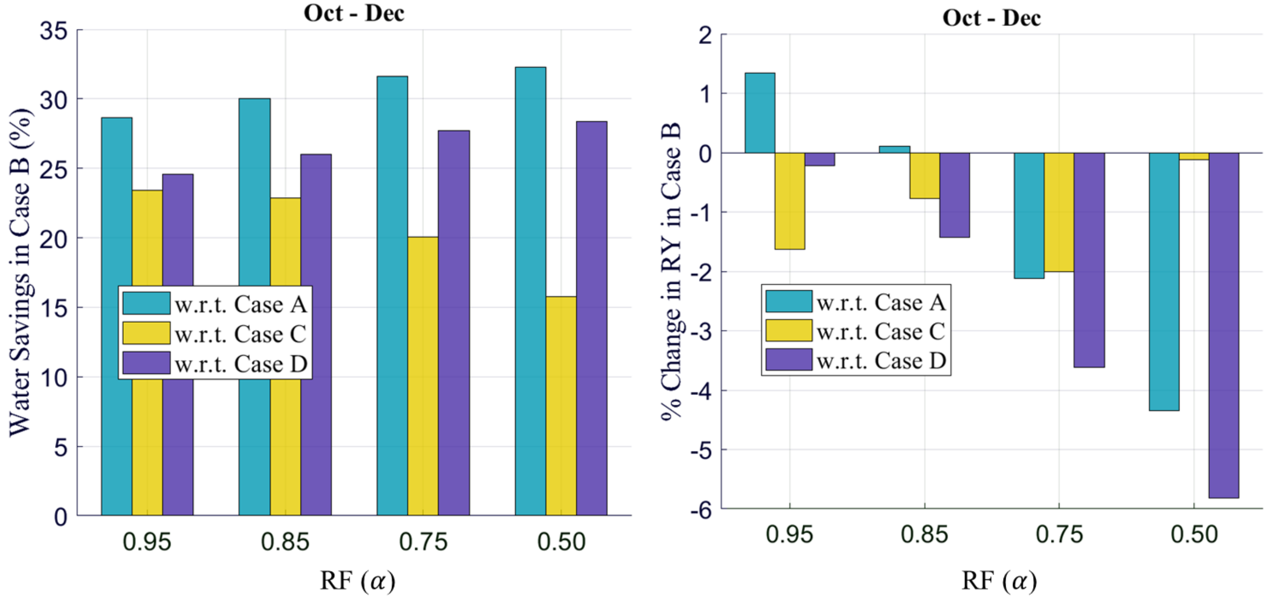
- Site 1 and Site 2 (S1 and S2) – considered as "base sites". Sites with similar soil types were taken as "test sites" → Site No. 6, 11, 14, 21 (S1*) and Site No. 15 (S2*)
- All these predictors: (**LST, EVI, NDVI, Temperature, Precipitation,** Background **RZSM data** scaled **from RS observed SSM products**) are extracted for the test sites
- Long Short-Term Memory model (LSTM) – predict the RZSM with these predictors
- Observed datasets for soil moisture is used to train the model

Station No.	s_w	s_h	s_{fc}	s^*	n	Z_r	K_s	β	SWR	Soil Type	%Clay
Site 1	0.3	0.24	0.75	0.45	0.28	450	400	18	164	**Clay Loam**	35
Site 2	0.25	0.20	0.65	0.35	0.56	400	800	11	152	**Sandy loam**	30
6	0.28	0.195	0.65	0.5	0.36	400	400	16	150	**Clay Loam**	30
11	0.28	0.195	0.65	0.5	0.36	400	400	16	162	**Clay Loam**	40
14	0.28	0.195	0.78	0.5	0.3	400	600	18	157	**Clay**	55
15	0.3	0.21	0.68	0.4	0.45	400	750	12	154	**Sandy Clay Loam**	30
21	0.28	0.195	0.78	0.5	0.3	400	600	18	156	**Clay Loam**	30

Water Savings and Change in Yield



S6



S15

Thank You