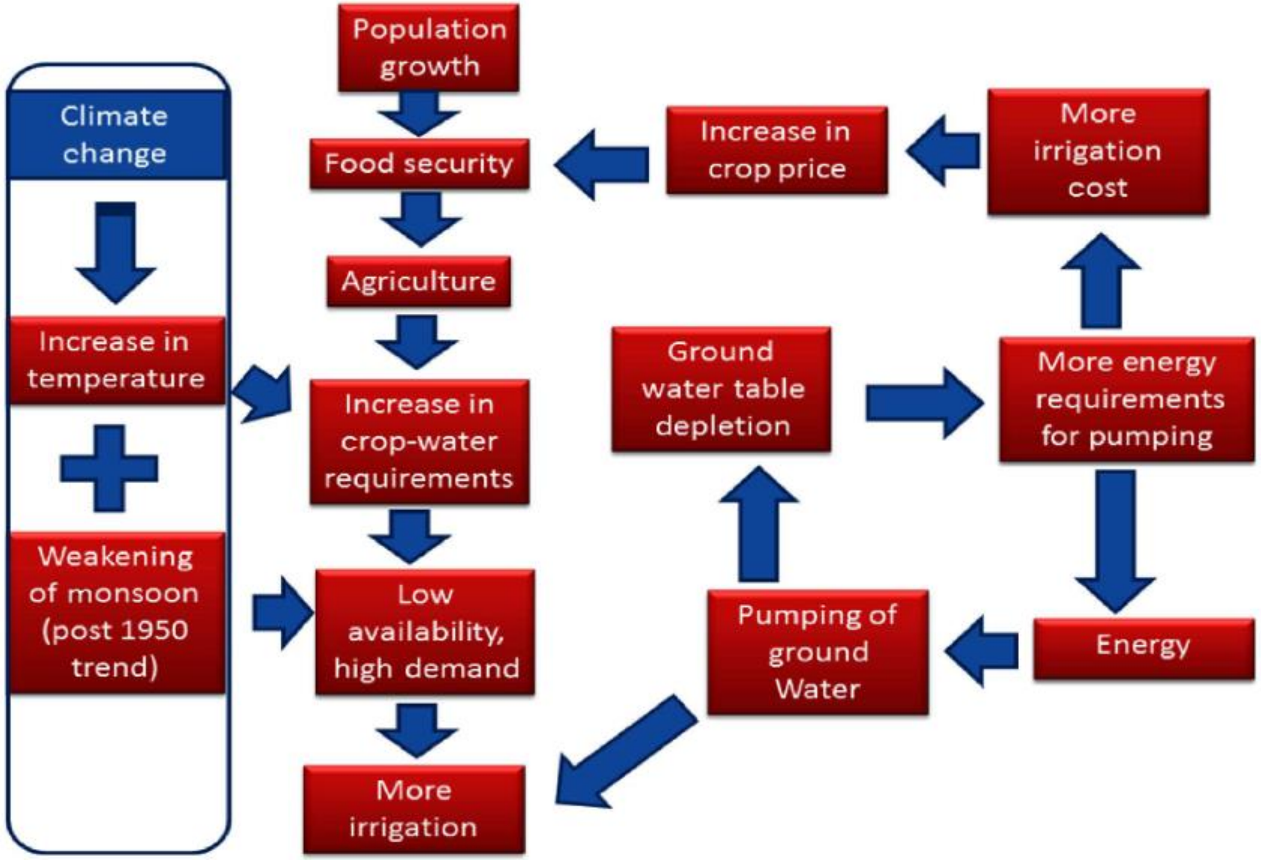
Irrigation Water Management using Weather and Extended Range Services

Adrija Roy, Parag Narvekar, Raghu Murtugudde and Subimal Ghosh

Indian Institute of Technology Bombay

Mumbai, India

Introduction



Irrigation Water Management with Weather Forecasts

Weather Forecasts → Rainfall Distribution

1000 Rainfall Scenarios given Forecasts

Real-time Soil Moisture

Optimization Model
Objective: Minimize Water use

Decision Variable: Irrigation Water Application

Farm Scale Hydrologic Model

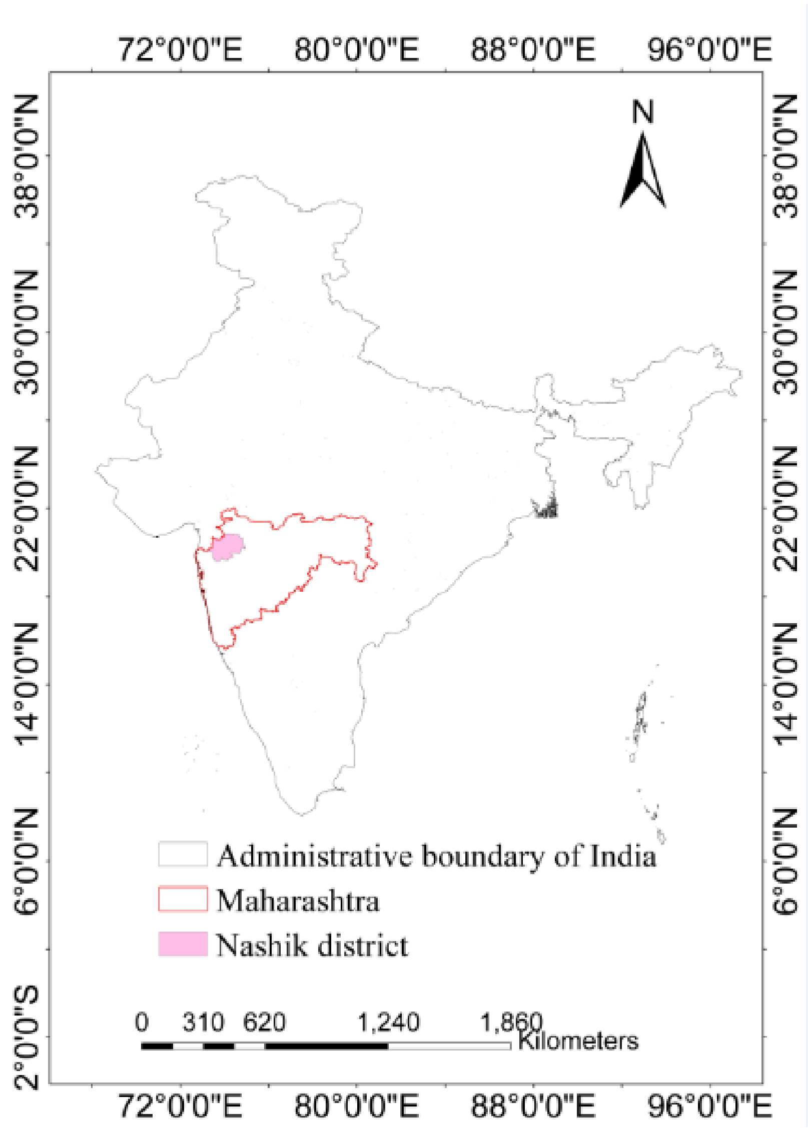
Constraint:
P(Root Zone Soil Mositure <= Water Stress Threshold)=α (say 0.95)

Optimized Irrigation Water to be applied

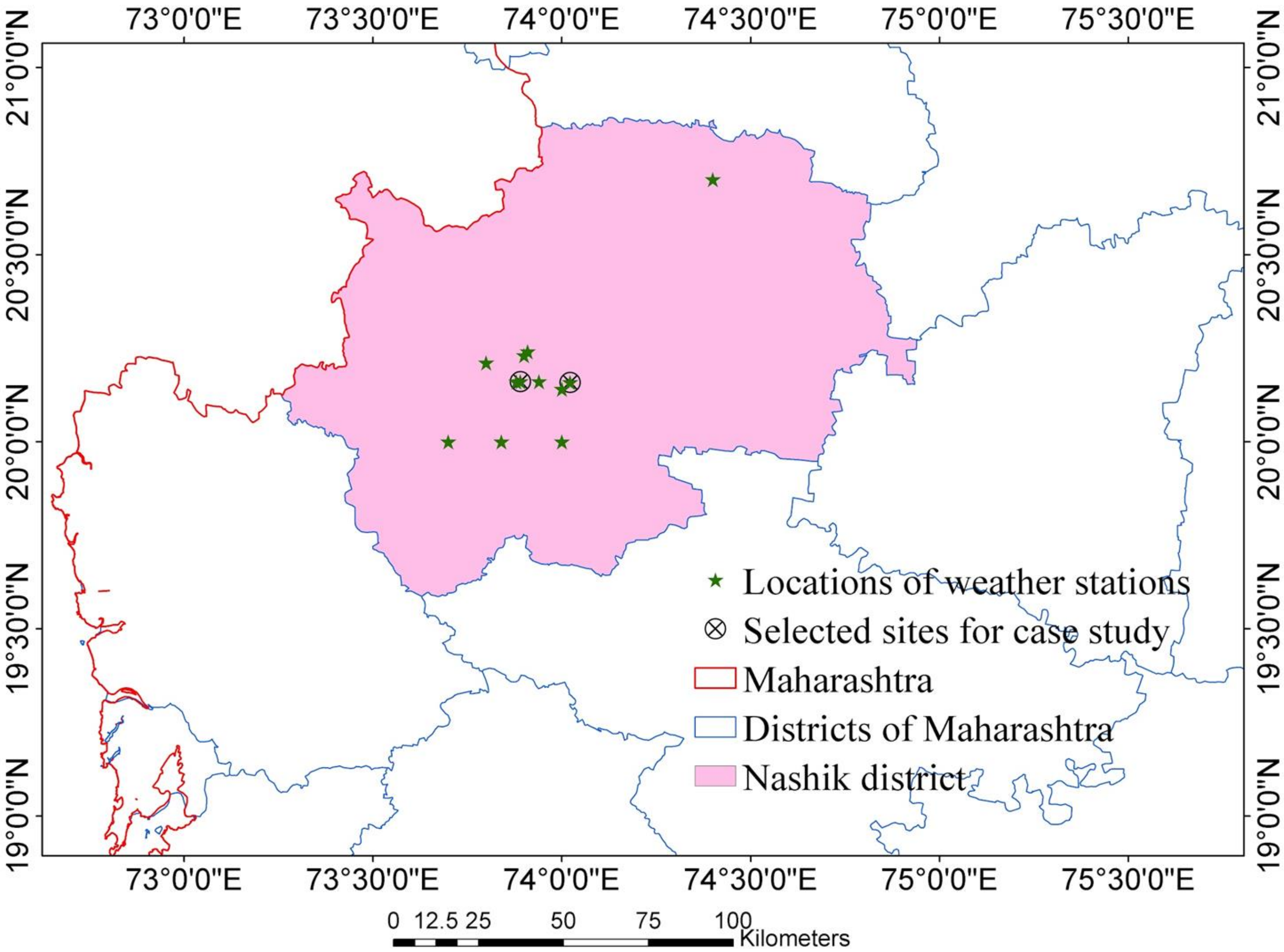
Roy et al. (2019) Patent filed
Roy et al. (2021) , WRR

Photo (field) Credits: http://news.mit.edu/2017/design-cuts-costs-energy-drip-irrigation-0420 and https://researchmatters.in/news/better-soil-moisture-sensors-using-graphene-oxide

Study Area

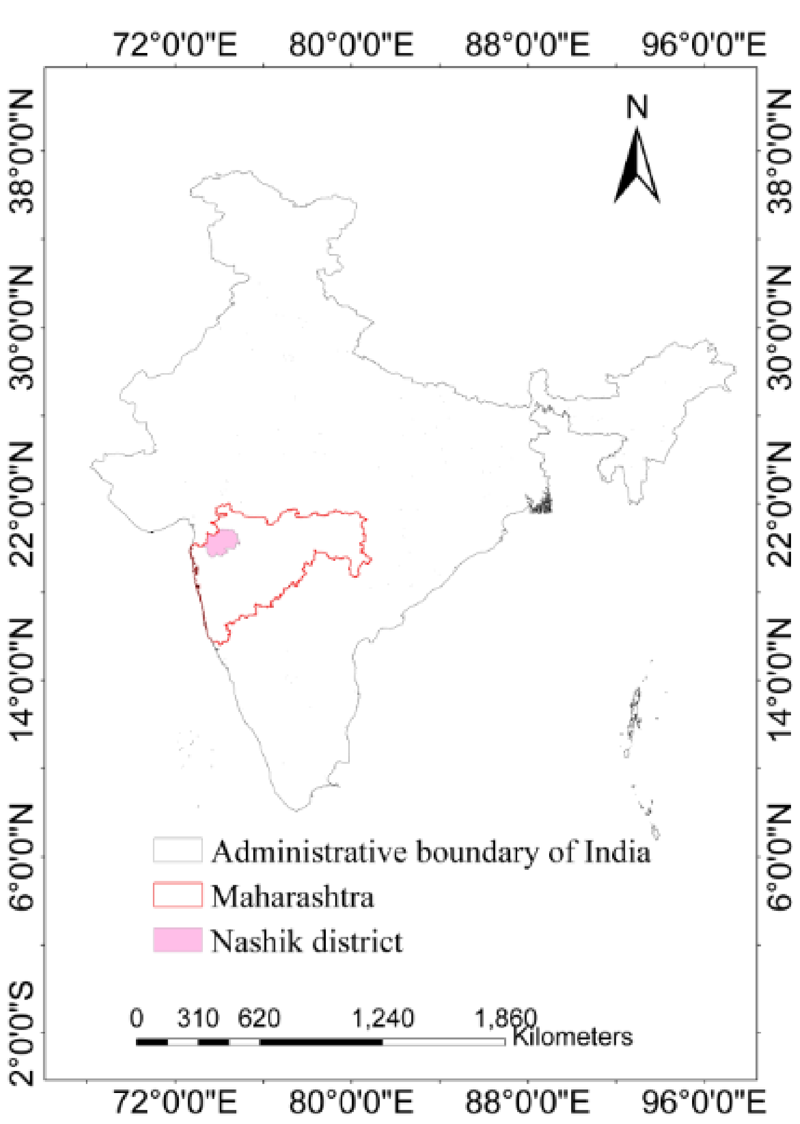


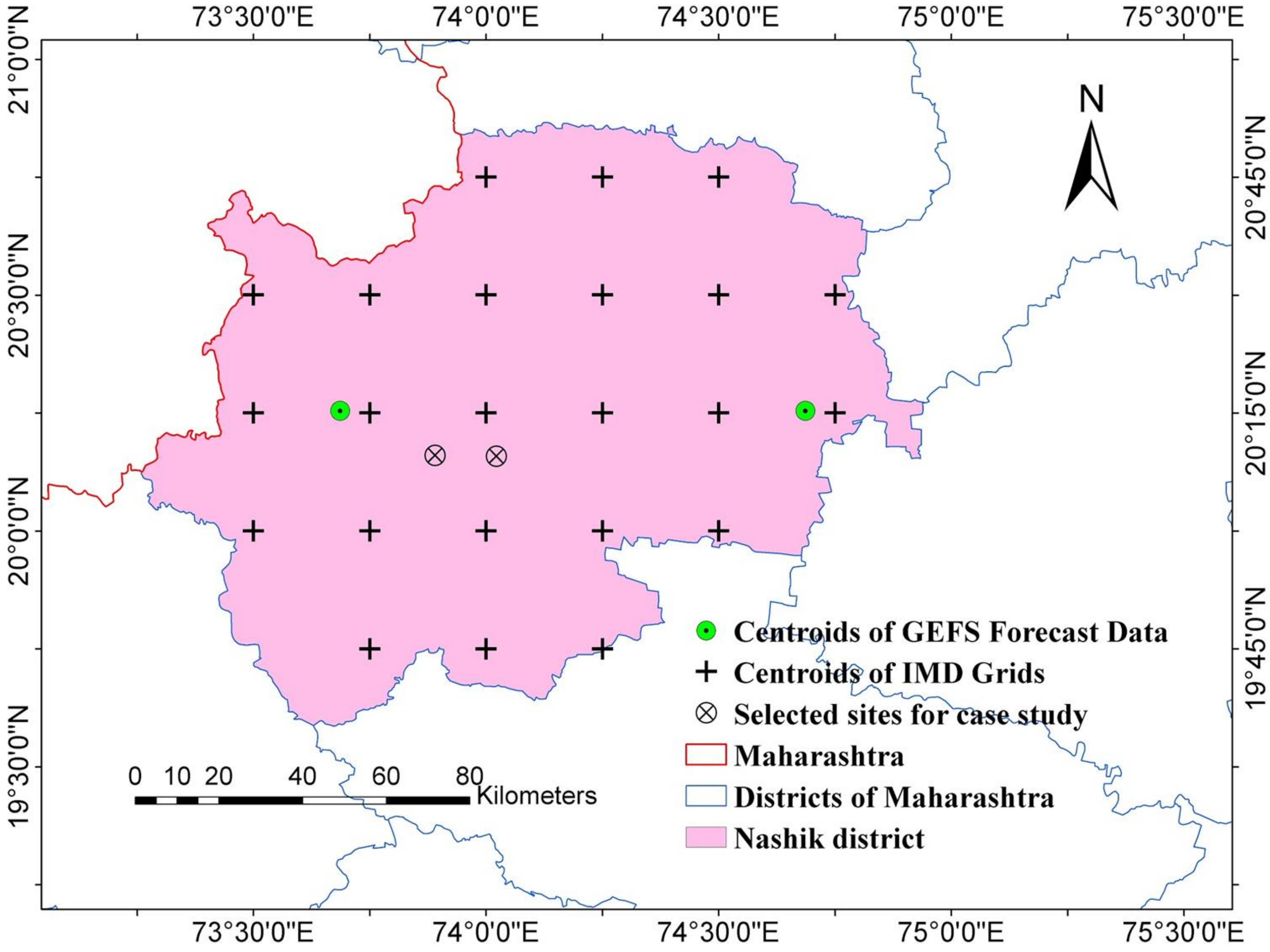
72°0'0"E
80°0'0"E
88°0'0"E
96°0'0"E
38°0'0"N
30°0'0"N
22°0'0"N
14°0'0"N
6°0'0"N
2°0'0"S
N
Administrative boundary of India
Maharashtra
Nashik district
0 310 620 1,240 1,860
Kilometers



73°0'0"E
73°30'0"E
74°0'0"E
74°30'0"E
75°0'0"E
75°30'0"E
21°0'0"N
20°30'0"N
20°0'0"N
19°30'0"N
19°0'0"N
Locations of weather stations
Selected sites for case study
Maharashtra
Districts of Maharashtra
Nashik district
0 12.5 25 50 75 100
Kilometers

Study Area


72°0'0"E
80°0'0"E
88°0'0"E
96°0'0"E
38°0'0"N
30°0'0"N
22°0'0"N
14°0'0"N
6°0'0"N
2°0'0"S
N
Administrative boundary of India
Maharashtra
Nashik district
0 310 620 1,240 1,860
Kilometers


73°30'0"E
74°0'0"E
74°30'0"E
75°0'0"E
75°30'0"E
21°0'0"N
20°45'0"N
20°30'0"N
20°15'0"N
20°0'0"N
19°45'0"N
19°30'0"N
N
Centroids of GEFS Forecast Data
Centroids of IMD Grids
Selected sites for case study
Maharashtra
Districts of Maharashtra
Nashik district
0 10 20 40 60 80
Kilometers

Analytical Solution of Soil Moisture Dynamics

Modelling Soil Moisture and Irrigation Amount:

The basic soil moisture balance equation $nZ_r \frac{ds_t}{dt} = R_t + I_t - ET(s_t) - LQ(s_t)$

Mainly two source-sink components: rainfall and combined loss (ET, runoff and leakage)

Rate of rainfall is described as a probabilistic component (R_t)

ET, runoff and leakage rate → calculated as a function of present soil moisture amount and soil hydraulic properties

$ET(s_t)$: the rate of evapotranspiration loss as a function of soil moisture at time t

$LQ(s_t)$: the rate of loss due to runoff and leakage as a function of soil moisture at time t

I_t : the irrigation rate, which is our main deliverable

Parameters of the Model:

s^* or Point of incipient stomatal closure, when plant transpiration is reduced.

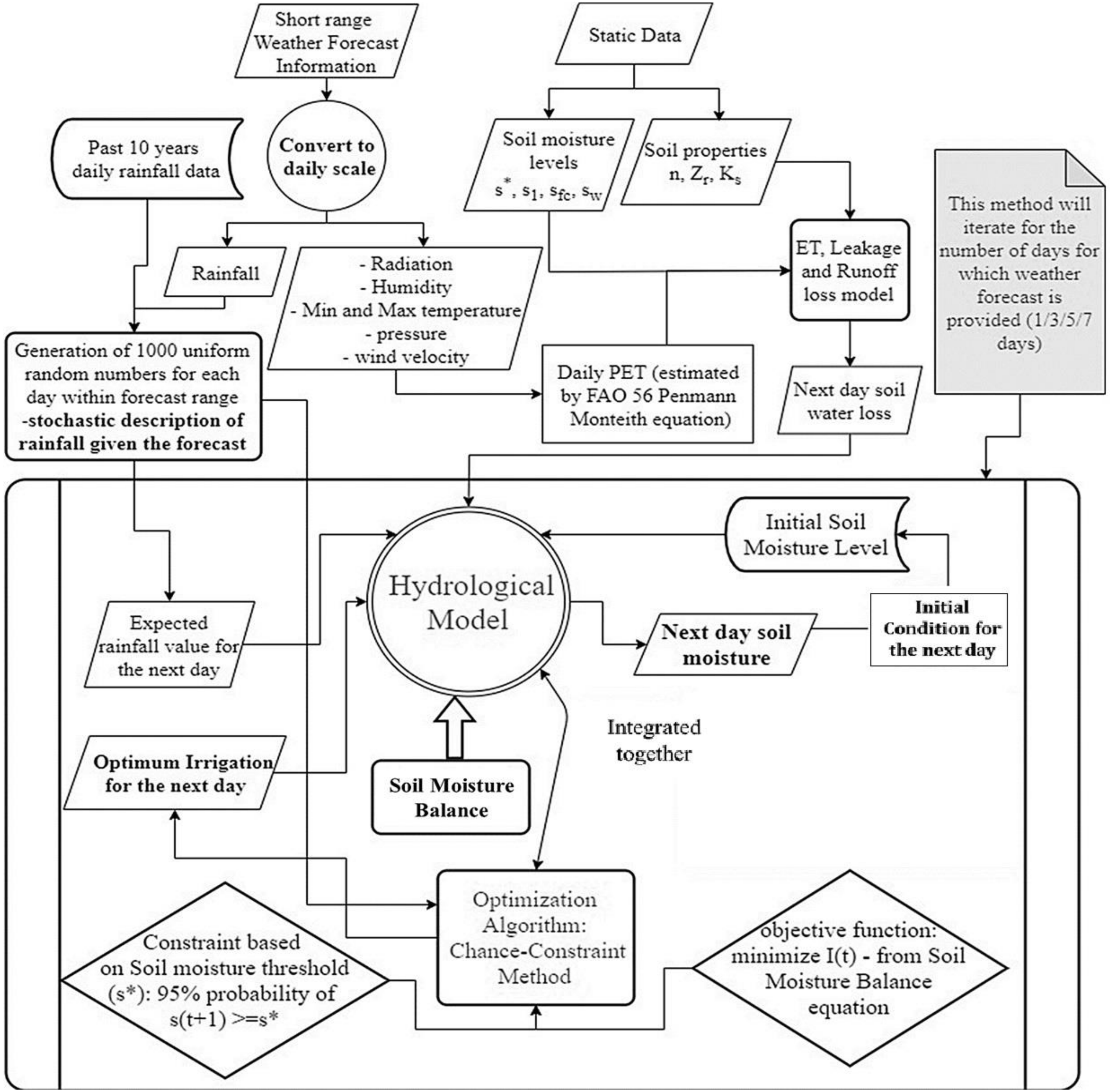
Soil moisture at:-

Field capacity (s_{fc})
Wilting point (s_w)
Hygroscopic point (s_{fc})

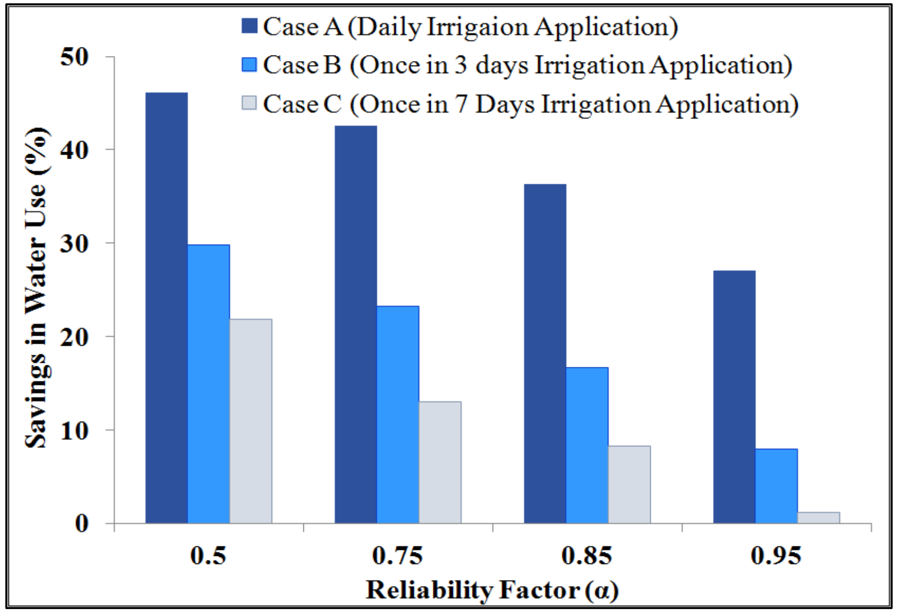
Soil porosity (n)
Soil rooting depth (Z_r)
Maximum Evapotranspiration rate (ET_{max})

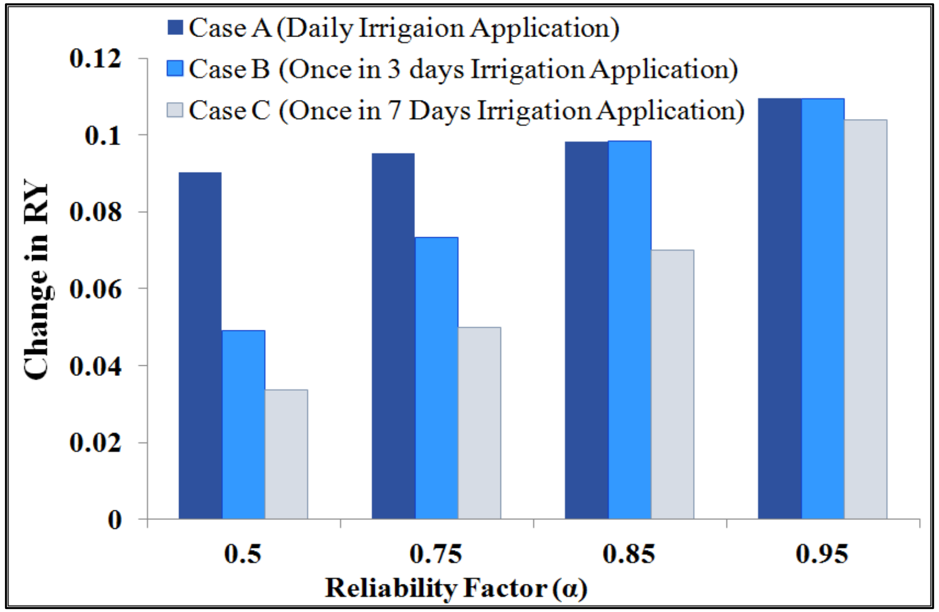
Length of growing season (T_{seas})

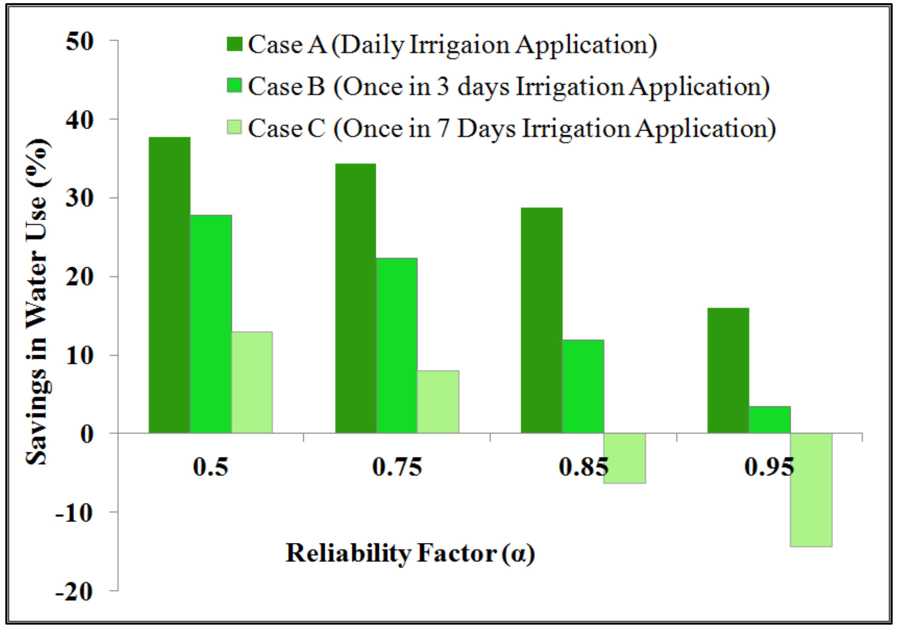
Minimum probability with which the crop will not undergo water stress (α)

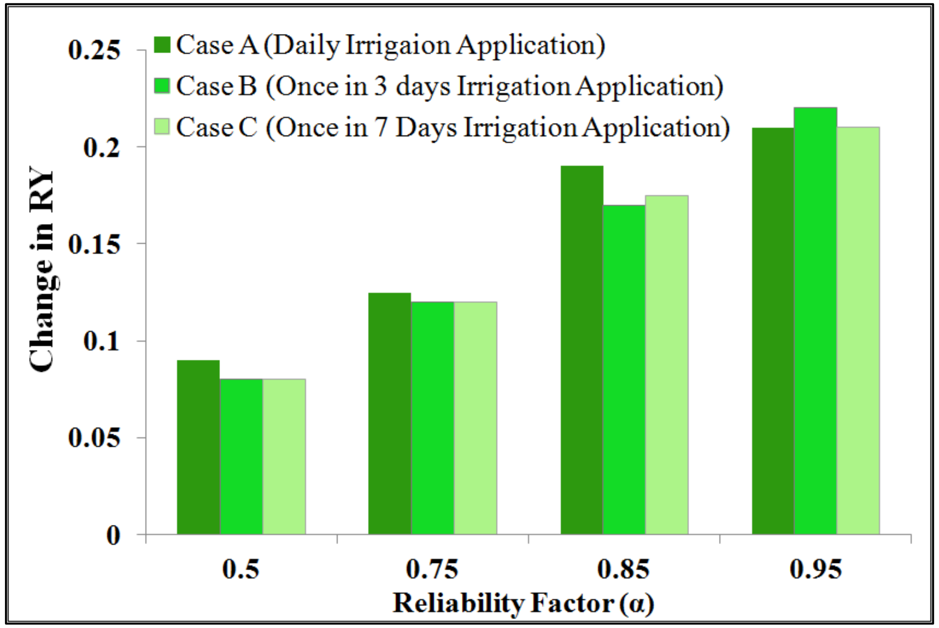


Water Conservation and Change in RY in Different Cases

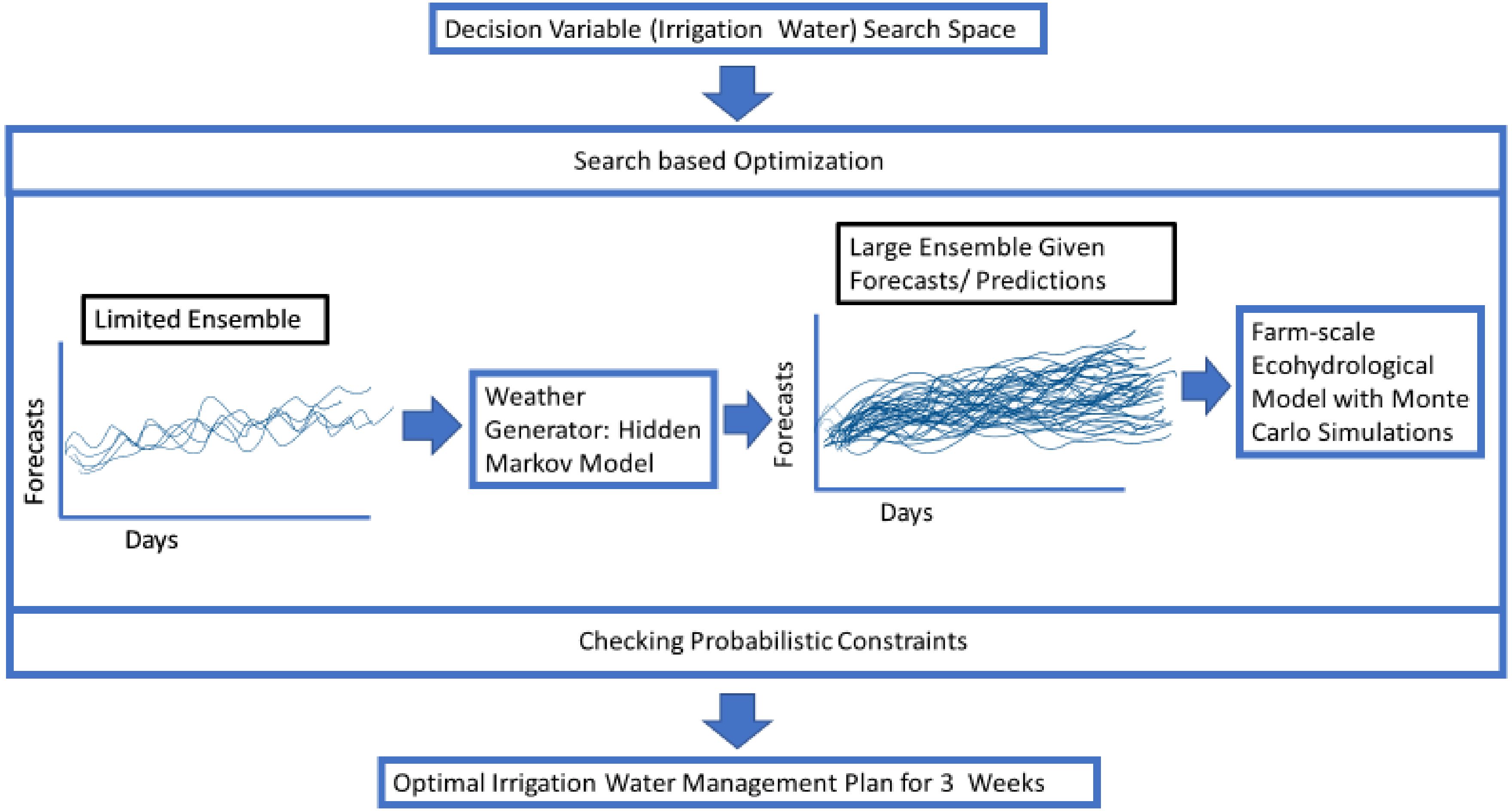






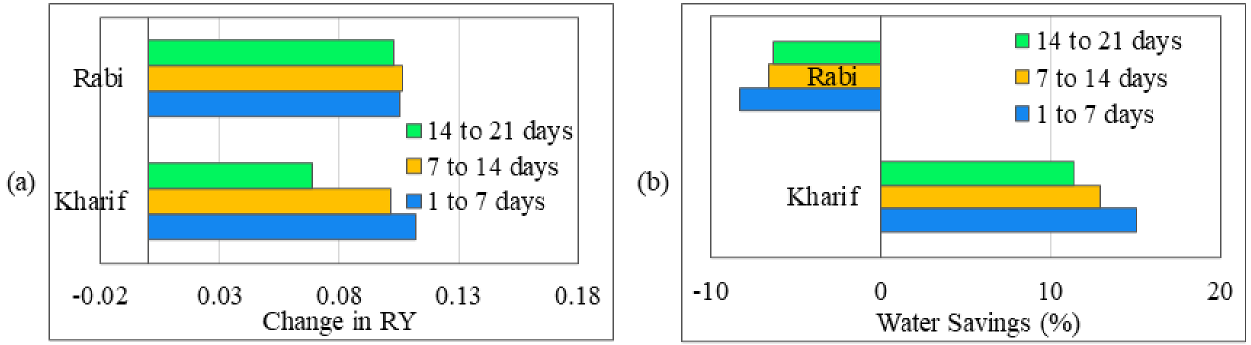


Extended Range

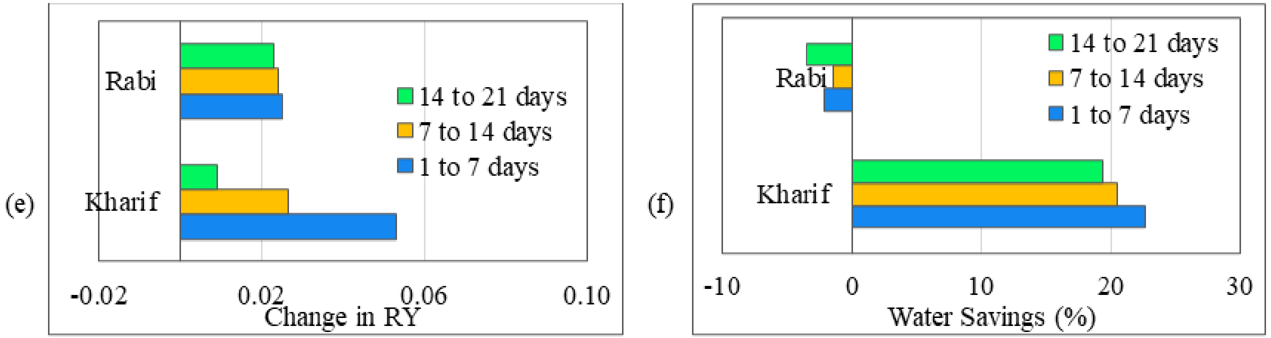


Water Savings and Maintaining RY   Site 1

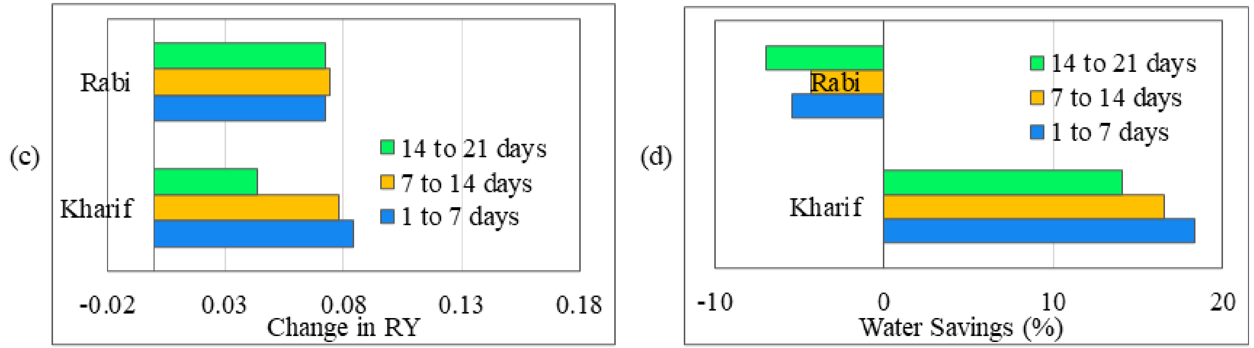
α = 0.95



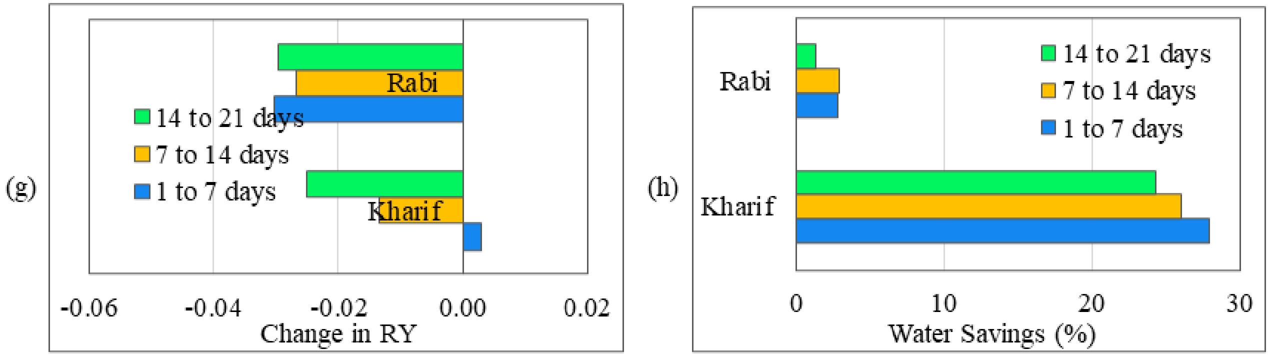
α = 0.75



α = 0.85

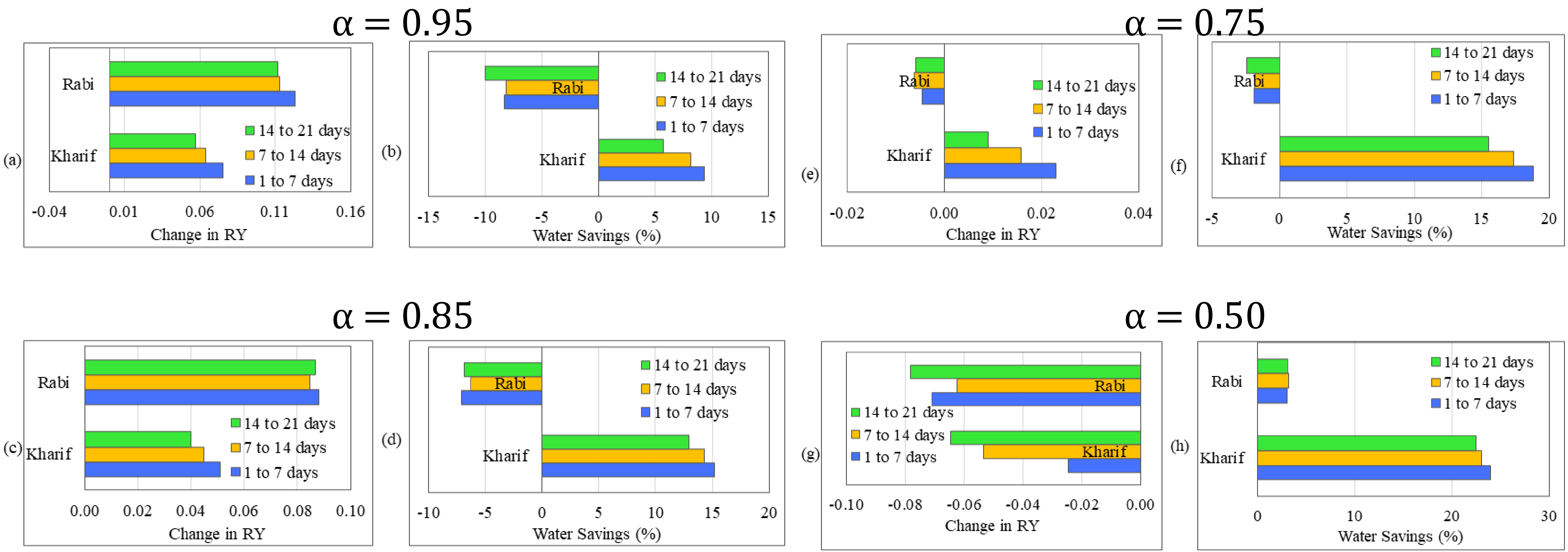


α = 0.50



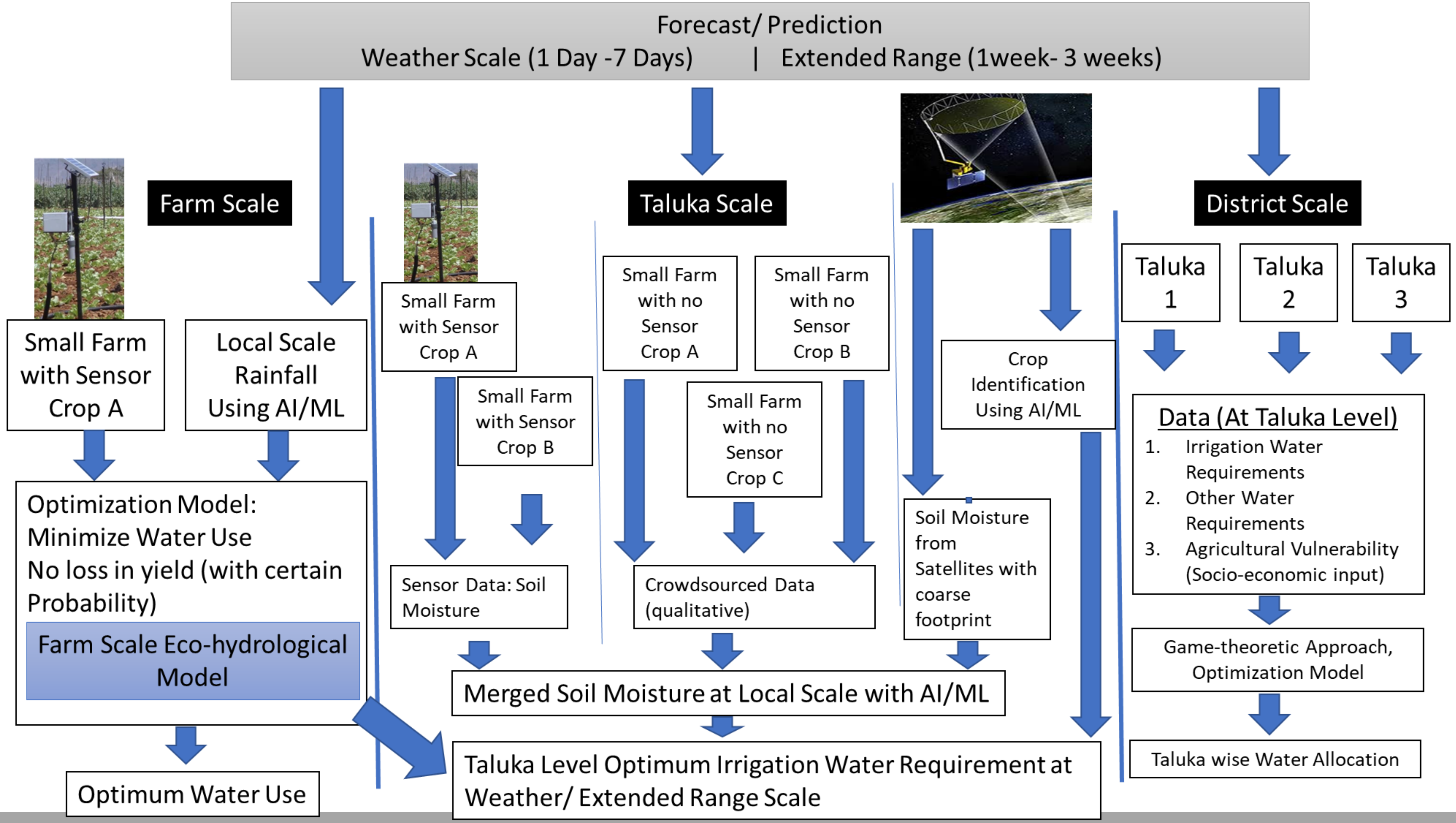
Changes in RY (a, c, e and g) and savings in irrigation water use (b, d, f and h) w.r.t. the farmer's method of irrigation scheduling, using the proposed framework with extended range forecast for (t+1)th to (t+7)th day, (t+8)th to (t+14)th day and (t+15)th to (t+21)th day

Water Savings and Maintaining RY Site 2



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

Next Step


Forecast/ Prediction
Weather Scale (1 Day -7 Days) | Extended Range (1week- 3 weeks)
Farm Scale
Small Farm with Sensor Crop A
Local Scale Rainfall Using AI/ML
Optimization Model:
Minimize Water Use
No loss in yield (with certain Probability)
Farm Scale Eco-hydrological Model
Optimum Water Use
Small Farm with Sensor Crop A
Small Farm with Sensor Crop B
Sensor Data: Soil Moisture
Taluka Scale
Small Farm with no Sensor Crop A
Small Farm with no Sensor Crop B
Small Farm with no Sensor Crop C
Crowdsourced Data (qualitative)
Soil Moisture from Satellites with coarse footprint
Crop Identification Using AI/ML
Merged Soil Moisture at Local Scale with AI/ML
Taluka Level Optimum Irrigation Water Requirement at Weather/ Extended Range Scale
District Scale
Taluka 1
Taluka 2
Taluka 3
Data (At Taluka Level)
1. Irrigation Water Requirements
2. Other Water Requirements
3. Agricultural Vulnerability (Socio-economic input)
Game-theoretic Approach, Optimization Model
Taluka wise Water Allocation

Thank you

Contact: Subimal@civil.iitb.ac.in