Irrigation Water Management using Weather and Extended Range Services

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Introduction
Irrigation Water Management with Weather Forecasts

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

Optimization Model
Objective: Minimize Water use
Decision Variable: Irrigation Water Application

Farm Scale Hydrologic Model

Constraint:
P(Root Zone Soil Moisture <= Water Stress Threshold)=\alpha (say 0.95)

1000 Rainfall Scenarios given Forecasts
Real-time Soil Moisture

Optimized Irrigation Water to be applied

Study Area
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 ($ET_{\text{max}}$)
Length of growing season ($T_{\text{seas}}$)
Minimum probability with which the crop will not undergo water stress ($\alpha$)
Water Conservation and Change in $R_Y$ in Different Cases
Extended Range

Decision Variable (Irrigation Water) Search Space

Search based Optimization

Limited Ensemble

Weather Generator: Hidden Markov Model

Large Ensemble Given Forecasts/ Predictions

Forecasts

Days

Farm-scale Ecohydrological Model with Monte Carlo Simulations

Forecasts

Days

Checking Probabilistic Constraints

Optimal Irrigation Water Management Plan for 3 Weeks
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.
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 (1 week - 3 weeks)

Farm Scale
Small Farm with Sensor Crop A
Small Farm with no Sensor Crop A
Small Farm with no Sensor Crop B
Local Scale Rainfall Using AI/ML
Optimization Model: Minimize Water Use No loss in yield (with certain Probability)
Farm Scale Eco-hydrological Model

Taluka Scale
Small Farm with Sensor Crop B
Small Farm with no Sensor Crop C
Sensor Data: Soil Moisture
Crowdsourced Data (qualitative)

District Scale
Crop Identification Using AI/ML
Soil Moisture from Satellites with coarse footprint

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

Merged Soil Moisture at Local Scale with AI/ML
Taluka Level Optimum Irrigation Water Requirement at Weather/Extended Range Scale
Optimum Water Use
Thank you
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