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A Compensated Root Water Uptake Model for Crops under Stress from Water Availability

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1. INTRODUCTION

Combined effects of population growth, climate change and decline in soil fertility lead to increased stress on irrigation water for food production.

Selection of irrigation and drainage practices depends on
- ❑ Root water uptake of plants
- ❑ Ability of crops to respond to water stress

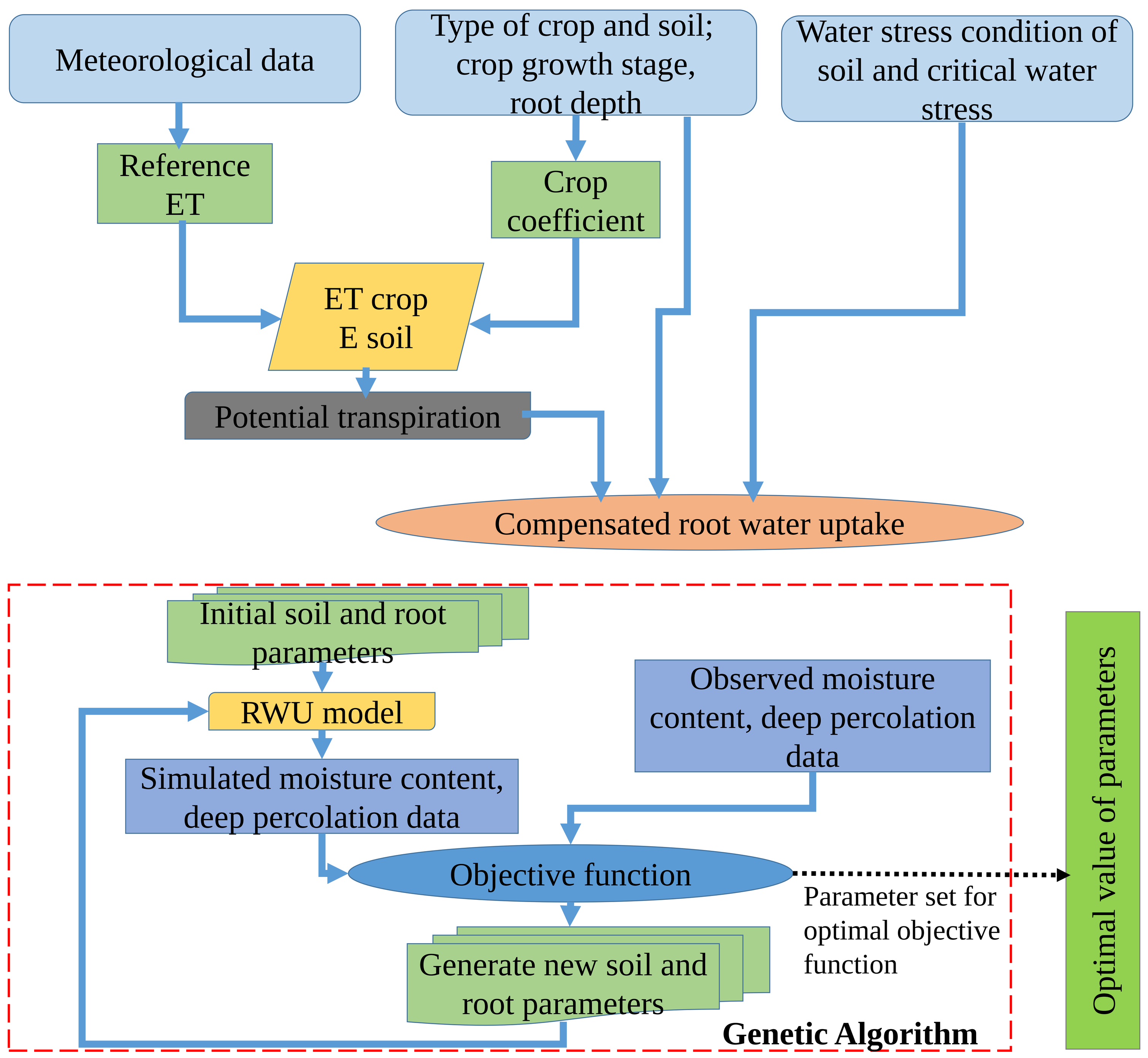
Knowledge of soil moisture patterns allows
- ❑ Efficient planning of irrigation scheduling
- ❑ Better crop yield forecasting

Root water uptake (RWU) controls plant evapotranspiration and water recharge to groundwater. Deficiency of water in the root zone results in reduced plant growth and affects crop yield. Thus, precise quantification of irrigation water requirements will help in achieving sustainable water management.

2. OBJECTIVE

- ❑ To develop a compensated non-linear RWU model using a sink term in Richards equation as proposed by Ojha and Rai (1996)
- ❑ To evaluate the performance of the compensated RWU model for different available moisture conditions
- ❑ To examine the identifiability of model parameters for different available soil moisture conditions

3. METHODOLOGY



4. COMPENSATED ROOT WATER UPTAKE MODEL

Governing Equation: $$\frac{\partial\theta(h)}{\partial t}=\frac{\partial}{\partial z}\left(K(h)\left(\frac{\partial h}{\partial z}+1\right)\right)-S(z,t)$$

Stress Index, $$\omega(t)=\int_0^{z_r}\alpha(h,z,t)*L(z,t)\,dz$$

Actual transpiration: $$T_{ac}(t)=\begin{cases}T_{pot}(t) & ;\omega(t)>\omega_c\\ \frac{\omega(t)}{\omega_c}T_{pot}(t) & ;\omega(t)\le\omega_c\end{cases}$$

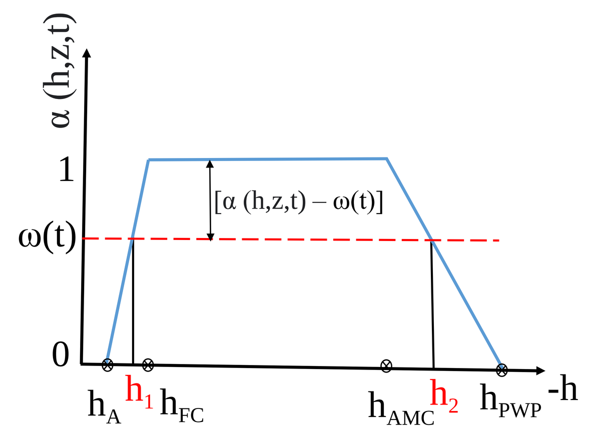


Fig 1: Stress response function variation

Model Parameters:
- ❑ ω_c: critical stress indicator for compensation
- ❑ β: non-linear coefficient which depends upon root pattern
- ❑ α_v, n_v: soil water retention parameters
- ❑ K_{sat}: saturated hydraulic conductivity

Actual compensated uptake:

$$S_{ac}(z,t)=\underbrace{\alpha(h,z,t)L(z,t)T_{pot}(t)}_{\text{uncompensated portion}}+\underbrace{a\left[\alpha(h,z,t)-\omega(t)\right]L(z,t)H\left[\alpha(h,z,t)-\omega(t)\right]}_{\text{compensated portion}}$$

5. FIELD EXPERIMENTS

Fig 2: Different growth stages of maize crop

$$\theta_{RAMC}=\theta_{FC}-DF(\theta_{FC}-\theta_{PWP})$$

Readily available moisture values at 7 different plots were maintained at different moisture contents. This is achieved by changing the depletion factor considered for each field.

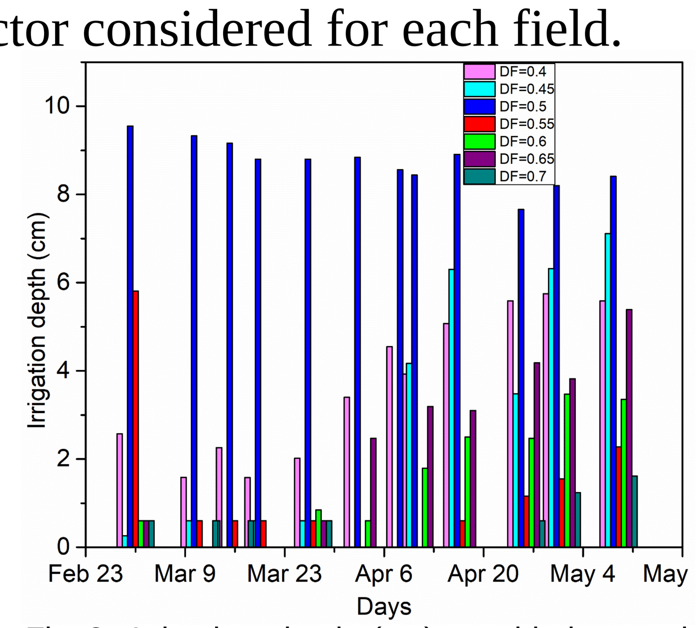


Fig 3: Irrigation depth (cm) provided to maintain different readily available moisture values

Table 1:Percentage particle content in the field soil

Particle on soil	% content
Clay	1.03
Silt	2.38
Very fine sand	6.23
Fine Sand	40.63
Medium Sand	30.5
Coarse Sand	5.25
Very Coarse Sand	3
Gravel	5.25
Soil Type	Loamy Sand

Sat. Hydraulic Conductivity= 0.60 cm/min (Guelph Permeameter)

Specific Gravity= 2.49
Bulk density= 1.575 g/cc
Dry density= 1.44 g/cc

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6. RESULTS

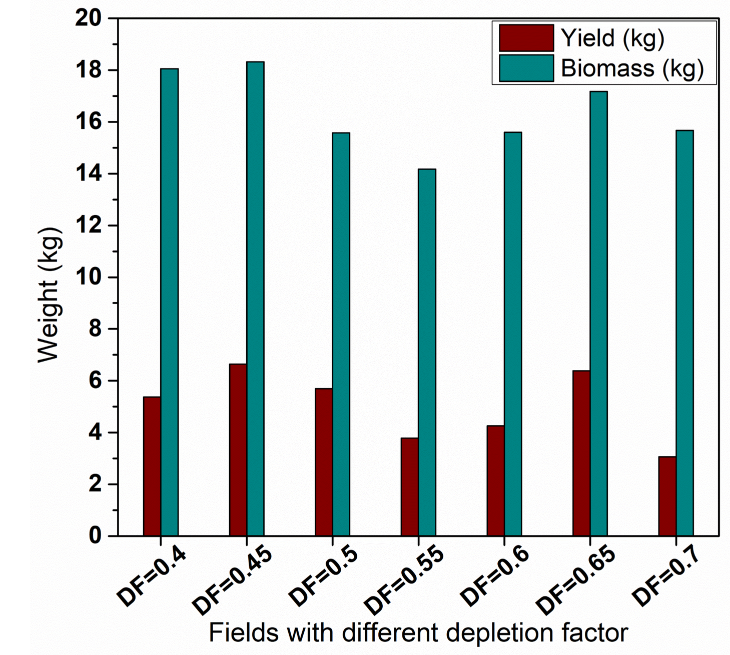

Fig 4: Observed Biomass and yield (in kg) at different fields

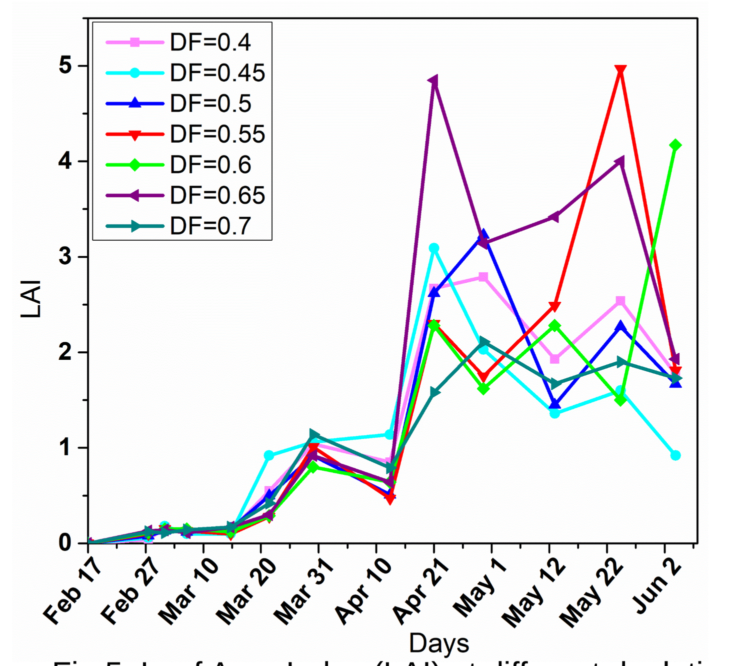

Fig 5: Leaf Area Index (LAI) at different depletion factors

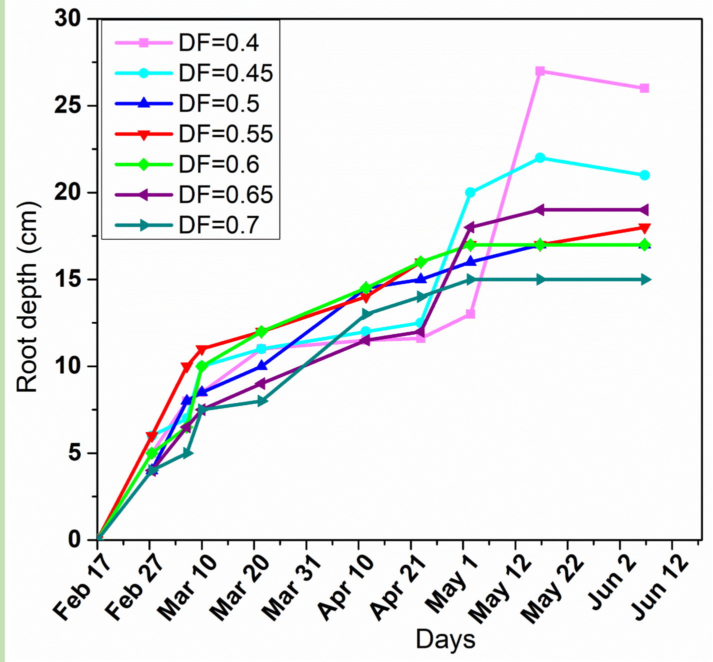

Fig 6: Root depth of maize crop observed at different depletion factors

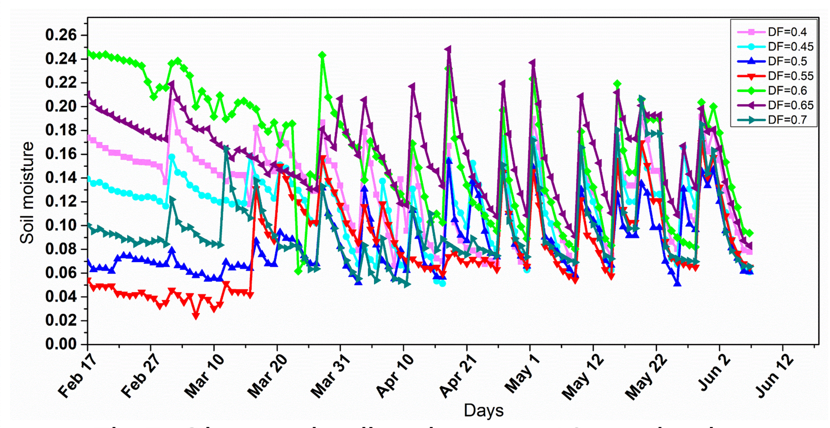

Fig 7: Observed soil moisture at 10 cm depth on different fields for the experiment with maize crop

Table 2: Measured and estimated values (from Genetic algorithm) of soil hydraulic and root water uptake parameters for the experiment with wheat crop on Sandy loam soil

Soil	seed value	True value					Estimated value					No. of generation
		ω_c	β	K_{sat}(cm/day)	α_v(1/m)	n_v	ω_c	β	K_{sat}(cm/day)	α_v(1/m)	n_v	
Sandy Loam	0.3	0.5	2	106	7.5	1.89	0.29	1.21	121	6.1	1.51	119
	0.5	0.5	2	106	7.5	1.89	0.35	2.95	119	5.88	1.45	91
	0.8	0.5	2	106	7.5	1.89	0.27	2.53	131	5.21	2.05	111

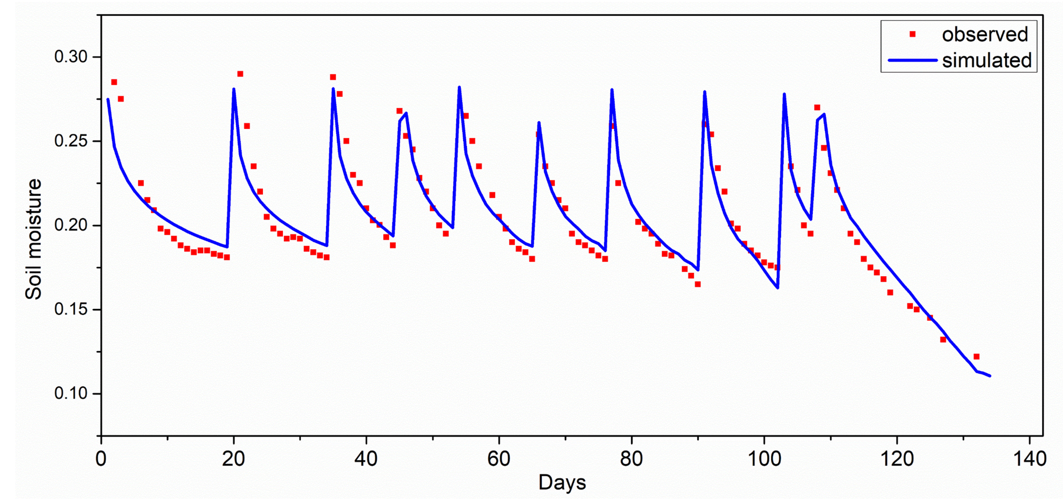

Fig 8:Observed and simulated soil moisture values at 20 cm depth (experiment with wheat crop)

7. CONCLUSION

- ❑ The developed model is able to simulate the actual soil moisture content at different depths
- ❑ The yield and biomass from fields at higher water stress (DF=0.6) is observed to be nearly same as that with lower stress (DF=0.4 or 0.45)
- ❑ Estimated model parameter values, in case of sandy loam soil, were not found to be in good agreement with the true values
- ❑ Simultaneous estimation of both RWU and soil hydraulic parameters in high conductivity soil is ineffective as the vertical flow overshadows the root water uptake