HYDRUS-1D Modeling of an Irrigated Agricultural Plot with Application to Aquifer Recharge Estimation

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HYDROGEOLOGY GROUP

INTRODUCTION

- Estimating aquifer recharge
  - determining water resource availability
  - assessing aquifer vulnerability to pollutants
- Arid and semi-arid regions → recharge estimation can be difficult (predominately focused recharge)
- Recharge is additionally complicated by irrigation
  - may remove water from focused recharge sources
  - creating new sources of diffuse recharge

(Scanlon *et al.* 2002)

- In irrigated regions, accurate knowledge of recharge, evaporation, and transpiration is especially important for the sustainable management of scarce water resources.

(Garatuza-Payan *et al.* 1998)

INTRODUCTION (2)

- Estimate groundwater recharge

↓ The methodologies can be grouped

- Surface-water
- Unsaturated zone
- Saturated zone

→

- Physical techniques
- Tracers techniques
- Numerical modeling approaches

The best choice → Depends
- Spatial and temporal scales
- Intended application

(Scanlon *et al.* 2002)

- Objective → to estimate the contribution of irrigation to aquifer recharge with a modeling approach based on *HYDRUS-1D* (Šimůnek *et al.* 2005) simulations of root-zone water dynamics. We only present preliminary results demonstrating the modeling approach and the calibration of the model to experimental data.

STUDY LOCATION: Campo de Cartagena

- Campo de Cartagena
  - Surface 1440 km^2
  - Average annual rainfall 300 mm
  - Mean annual temperature 18ºC
  - ET_p = 800-1200 mm y^{-1} (Sánchez *et al.* 1989)

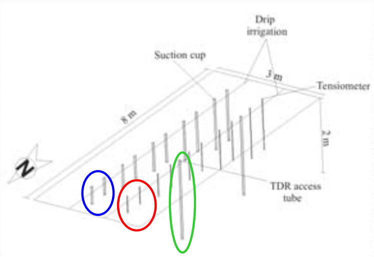
- Primary land use is agriculture →
  - Row crops (principally lettuce and melon) 128.1 km^2
  - Perennial vegetables (principally artichoke) 34.1 km^2
  - Fruit trees (principally citrus) 136.8 km^2

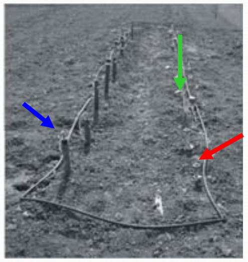
Drip irrigation is used widely in the region due to the scarcity of water resources and the need for water conservation.

FIELD SITE AND EXPERIMENT

Experimental plot at the Tomas Ferro Agricultural Science Center (Technical University of Cartagena)

Agricultural practices was managed according to standard in Campo de Cartagena, including cultivating crops (melon and lettuce) and drip irrigation (Ø 16 mm; emmiters spacing 30 cm; 4 L h^{-1})





Tensiometers (Soilmoisture Equipment Corp, Goleta, CA, USA)

TRIME-FM TDR access (Imko,Germany)

Meteorological data from the Servicio de Información Agraria de Murcia (http://siam.imida.es)

HYDRUS-1D Modeling

Simulation → **root zone water dynamics** → ***HYDRUS-1D* (Šimůnek et al. 2005)**

Included →
- **Irrigation**
- **Evaporation**
- **Root water uptake process**

Input
Sand, silt and clay contents
Bulk density

→ ***ROSSETA* (pedotransfer function)** →

Output
θ_r, θ_s, α, n, and K_s

↓ **Refinements**

Model fitting
(subset of the measured θ and h data)

HYDRUS-1D Modeling (2)

Implementing the atmospheric boundary condition →

daily
- **irrigation**
- **precipitation**
- **potential evaporation**
- **transpiration**

- **Reference evapotranspiration, $ET_0(t)$** → **Penman - Monteith method**
- **Potential evapotranspiration, $ET_p(t)$** → $ET_p(t) = K_c(t) \cdot ET_0(t)$ **(Allen *et al.* 1998)**
- **Potential evaporation, $E_p(t)$** → $E_p(t) = ET_p(t) \cdot e^{-\beta \cdot LAI(t)}$ **(Kroes and Van Dam, 2003)**

β : radiation extinction coefficient (≈ 0.4) $LAI(t)$: leaf area index

- **Potential transpiration, $T_p(t)$**

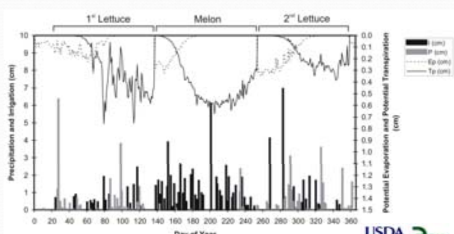
↓

$$T_p(t) = ET_p(t) - E_p(t)$$

- **Root water uptake reduction**

↓

Feddes *et al.* (1978) model
(database *HYDRUS-1D*)



RESULTS

The most intensive data collection → **cultivation of melon, 5/17/2007 to 9/10/2007 (Day Of Year 137-253)**

- **The root zone θ and h data from this period**
- **The inverse parameter optimization routines (*HYDRUS-1D*)**

→ **Test and adjust the calibration of the soil hydraulic property model**

Several possible parameterizations were considered →
- **number of soil layers**
- **number of hydraulic parameters**

The best parameterization →
- **four soil layers**
- **α and n, fitted for each layer**

The best correlation between measured and simulated θ and h values
$R^2 = 0.90$

Depth cm	Textural fractions (%)			Bulk density g·cm^{-3}	θ_r cm cm^{-3}	θ_s cm cm^{-3}	α (Fit) cm^{-1}	n (Fit) -	K_s cm d^{-1}
	Sand	Silt	Clay						
0-30	18.7	76.0	3.5	1.45	0.04	0.38	0.078	1.16	46.4
30-60	13.8	80.2	6.0	1.52	0.05	0.38	0.046	1.23	29.9
60-90	19.5	77.2	3.3	1.58	0.04	0.35	0.014	1.27	30.1
90-150	10.8	82.0	6.6	1.70	0.04	0.36	0.020	1.46	13.2

RESULTS (2)

Cultivation of melon, 5/17/2007 to 9/10/2007 (Day Of Year 137-253)

The best correlation between measured and simulated θ and h values
$R^2 = 0.90$

Final soil parameterization

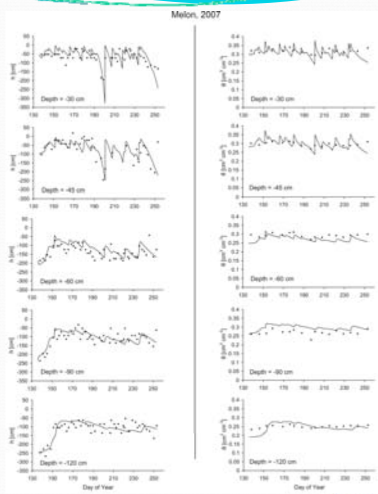
Predict (*HYDRUS-1D*)

Root zone soil moisture dynamics for other crops

Correlation between measured and simulated θ and h values

1st Lettuce → $R^2 = 0.82$
2/7/2007 to 5/16/2007 (DOY 38-136)

2nd Lettuce → $R^2 = 0.82$
9/25/2007 to12/24/2007 (DOY 268-358)



CONCLUSIONS

- Good agreement was obtained between the calibrated *HYDRUS* simulation model and the root zone measurements.
- Calibrated model → it will be possible to compute for various cropping and irrigation scenarios the fraction of irrigation water that passes below the root zone and contributes to aquifer recharge.
- Combining data of land use and cropping patterns for the Campo de Cartagena, it will be possible to estimate the amount of recharge associated with irrigated agriculture.
- Spanish Geological Survey (IGME, 1994) → (using a different methodology estimated) total recharge to the top unconfined aquifer 69 $hm^3\ y^{-1}$
  - 46 $hm^3\ y^{-1}$ natural recharge
  - 23 $hm^3\ y^{-1}$ irrigation return

Our preliminary calculations → slightly larger value for recharge due to irrigation

This aspect of our work will be the subject of a future publication

THANK YOU