Fitting a numerical model for the analysis of the wet bulb dimensions by drip irrigation

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INTRODUCTION

Drip Irrigation. Efficient system and sustainable management of water resource only if:

- Soil-water-plant relationship
- Hydraulics of the system
- Materials and setup

High level of management in 3 aspects

Soil-water-plant relationship

- Irrigation frequency and flow
- Weather (Evapotranspiration)
- Hydraulic properties of soil
- Structure and texture

- Data generation
- Prediction tools

WET BULB DYNAMICS

INTRODUCCION

Factors affecting the efficiency of drip irrigation in Uruguay

Limited access to information

Designs based on foreign experiences, hardly applicable to local soils and crops.

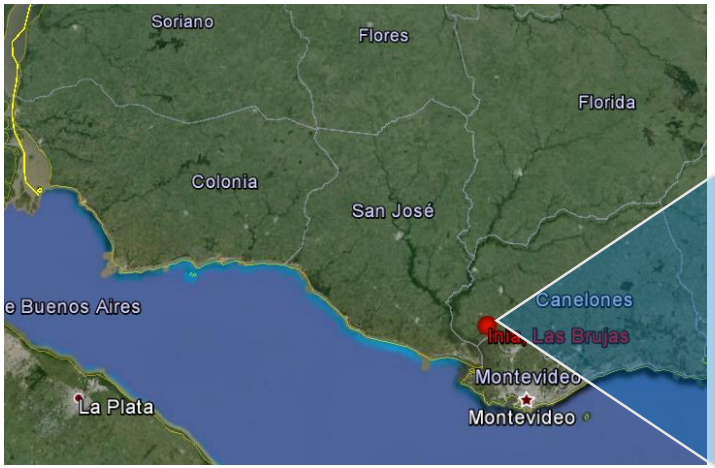
Percolation water and soil structure phenomena, not reaching bulb overlapping

Tools for predicting characteristics of the wet bulb and its dynamics.

Numerical modeling tools for prediction

Experimental data generation

METHODOLOGY – Experimental Field



Lat: 34º 39’50.17”S
Long: 56º 19’43.23”O
Elevation: 45 m
Soils:

Horizon	Depth(cm)	Sand (%)	Silt (%)	Clay (%)	Texture
A	0-25	13	64	23	Silty loam
B	25-65	8	33	59	Silty clay loam
C	65- +	7	36	57	Silty clay loam

Activity period: December 20th, 2013 - June 4th, 2014.

METHODOLOGY – Experimental Field

1- Controlled conditions:
Boundary conditions, drainage, pluviometry.

2- Instrumental

- **Lysimeter (radius=0,6m; height=1,2m),**
- **8 Digital Tensiometers STW-6 and 6 analog tensiometers, placed at different radius and depths**
- **Data Logger: Delta-T Devices Ltd.**
- **Irrigation equipment: ½ inch HDPE pipes, pumping pressure of 10 m. Self-compensating drippers of 2 L/h**

METHODOLOGY – Experimental Field

- **Neutron sonde, CPN 503, (Campell Pacific Nuclear corp, CA, USA).**

3-Measured Parameters:

- ***Matricial head (hPa)*: every hour**

- ***Drainage volume (L)*: At the end of every treatment**

- ***Agroclimatics variables:* Weather Station (DAVIS LB – Vantage). Real time data for evapotranspiration. (Penman- Monteith , FAO 56 for 1 hour)**

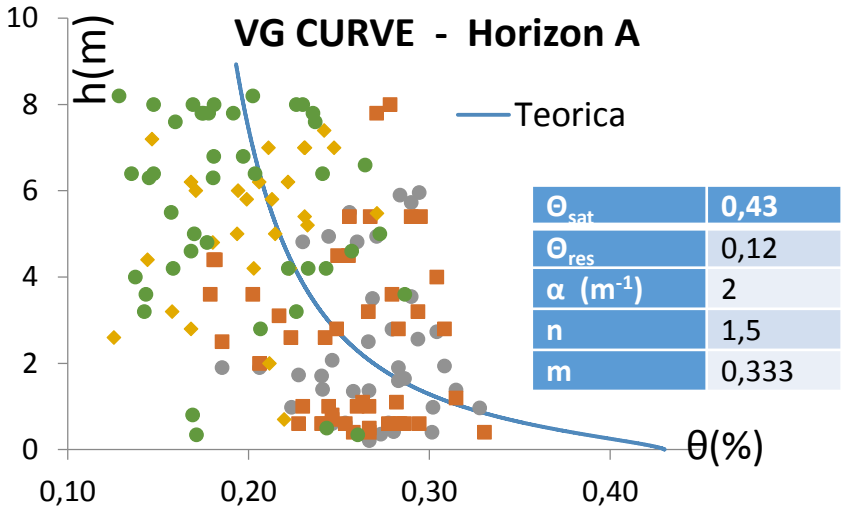
- **Water *Content* (θ): 3 times a day, (Abril 1st 2014 – May 19st de 2014)**

- ***Irrigation treatment*: 2L1h, 2L2h, Lp1h/4L1h, 4L2h, 4Lp1h/ 8L1h, 8L2h, 8Lp1h**

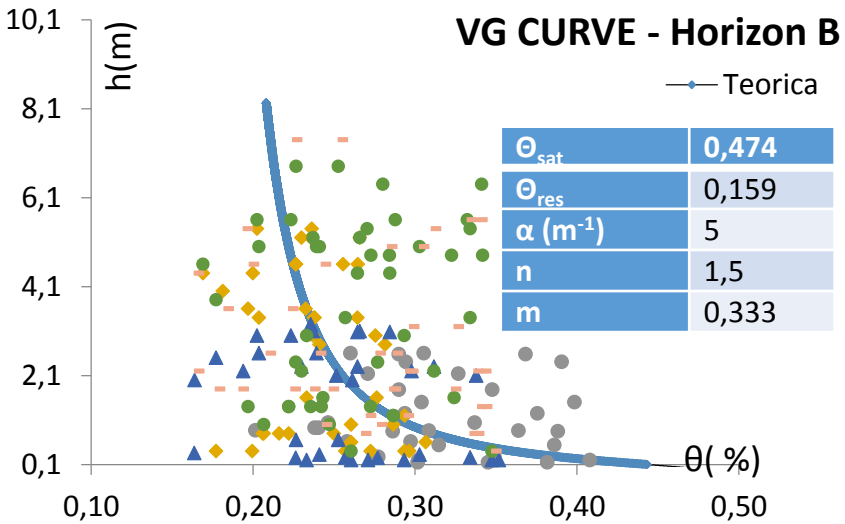
METHODOLOGY - Characteristics Curves

Van Genuchten Model

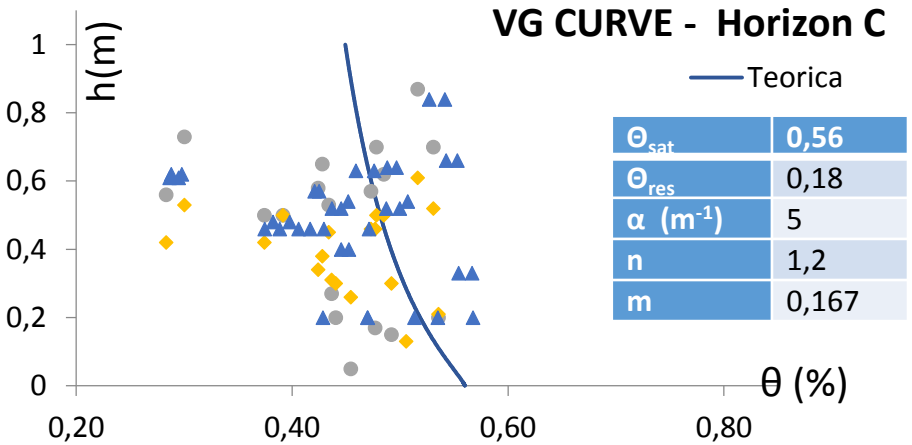
$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{(1+(\alpha h)^n)^m} \qquad h < 0$$



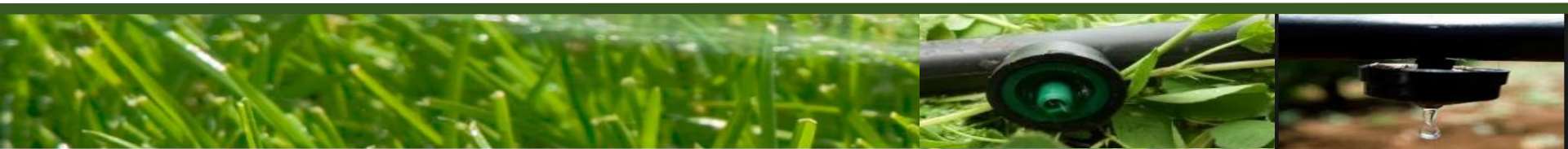
Θ_{sat}	0,43
Θ_{res}	0,12
α (m^{-1})	2
n	1,5
m	0,333



Θ_{sat}	0,474
Θ_{res}	0,159
α (m^{-1})	5
n	1,5
m	0,333

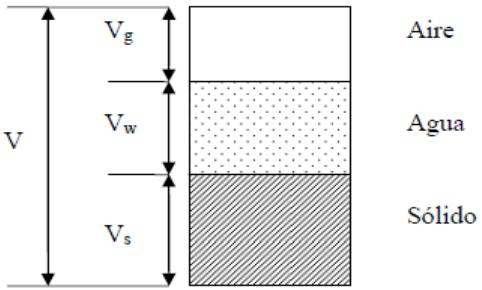


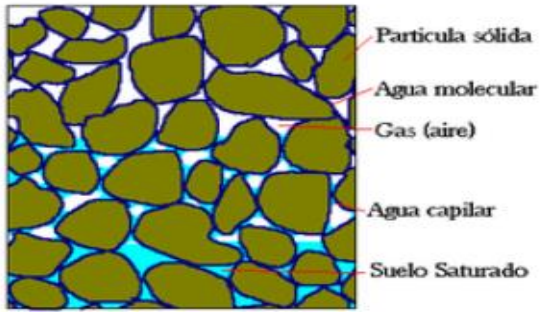
Θ_{sat}	0,56
Θ_{res}	0,18
α (m^{-1})	5
n	1,2
m	0,167



METHODOLOGY- The Physical model

CONCEPTUAL SCHEME





Phase Model from an elementary volume of unsaturated soil

$$\frac{\partial \theta}{\partial t} = \nabla \bullet \left(K(h) \nabla (H) \right) - S$$

Conceptual Scheme simplifications

- **Homogeneous Horizons ➡ Axysimetry (y - axis) ➡ 3D problem**
- **Not considered thermodinamic and soil mechanical processes**
- **Not considered hysteresis processes**

METHODOLOGY- Numerical model (Code Bright)

1- UPC, Barcelona, Spain, 1994- *Resolve* thermo-hidro-mechanics (THM), 2D and 3D problems, saturated and no saturated media, transient flow. Finit elements for the numerical scheme for space discretization and finit difference for time discretization . Fortran Cod.

2- Richards Equation for water balance.

$$\frac{\partial \theta}{\partial t} = \nabla \bullet \left(K(h) \nabla (H) \right) - S$$

3-Constitutive laws :

- ***Retention Curve: Van Genuchten model***

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \left(1 + \left(\frac{P_g - P_l}{P} \right)^{\frac{1}{1-\lambda}} \right)^{\lambda}$$

Pg=0, P=1/α (m); Pl=h(Mpa), λ=m

- ***Intrinsic permeability: Kozeny´s model :***

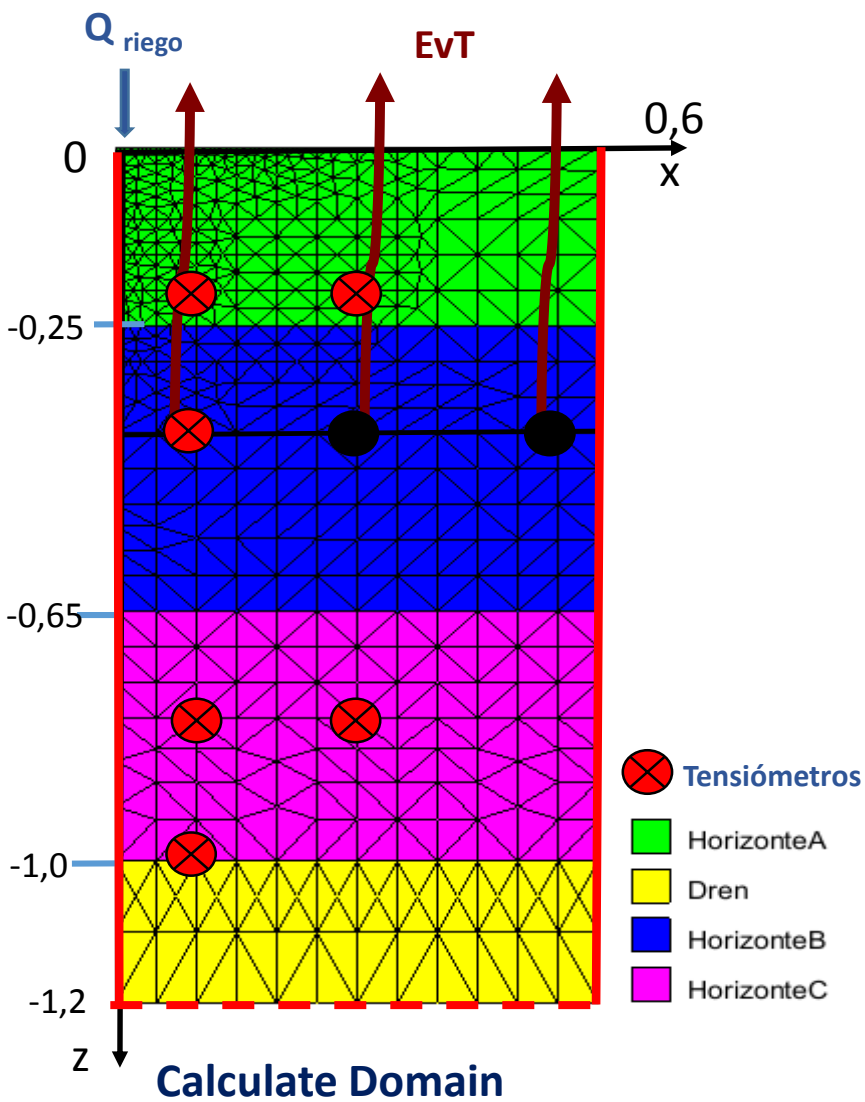
$$k = k_o \frac{\phi^3 (1-\phi_o)^2}{(1-\phi_o)^2 \phi_0{}^3}$$

ϕ_o : reference porosity; k_o: intrinsec permeability for ϕ_o

- ***Relative permeabilty: Van Genuchten model:***

$$K_r = \sqrt{S_e} \left[1 - (1 - S_e{}^{1/\lambda})^{\lambda} \right]^2$$

METHODOLOGY- Numerical model (Code Bright)



➢ Flow conditions

- **EvT:** Evapotranspiration root zone: 40cm. Reference Crop: Alfalfa
- **Q_{riego}:** One central dripper

➢ Boundaries Conditions

Seepage: drenaje only in saturation state
h>= 0hPa (saturación)

No-flow condition: lateral boundaries

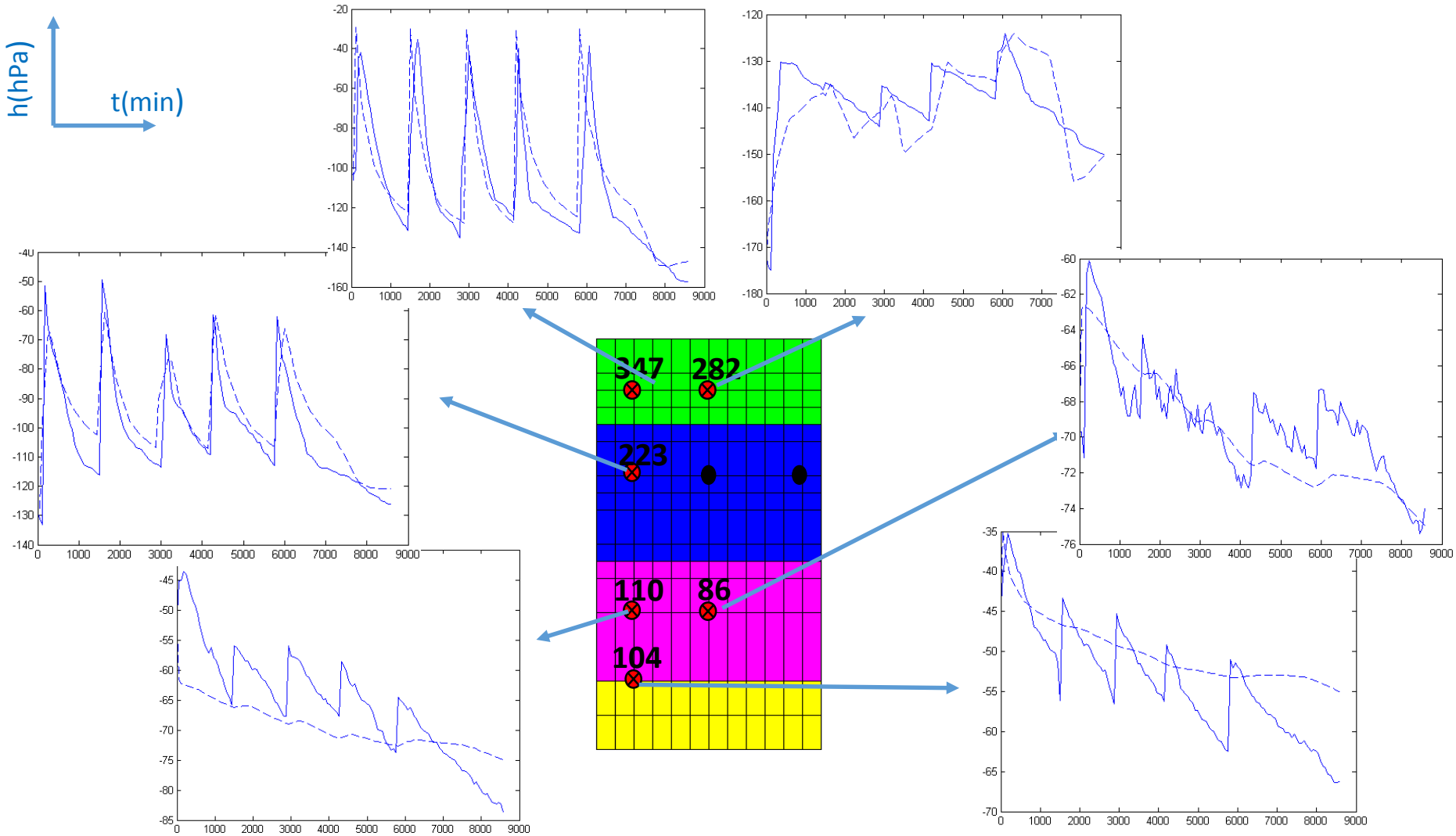
➢ Initial Condicitions

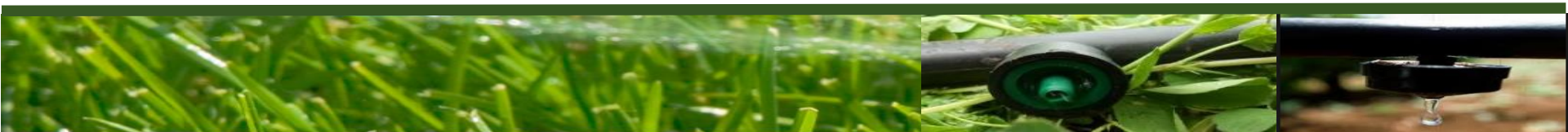
Initial pressure head was set for each influence área for the tensiometer and for each irrigation treatment.

➢ Calibration Parameters

- Intrinsic Permeability, **(kx, ky=kz)**
- VG- Curves Parameters **(α, m)**
- Relative Permeability **(λ)**

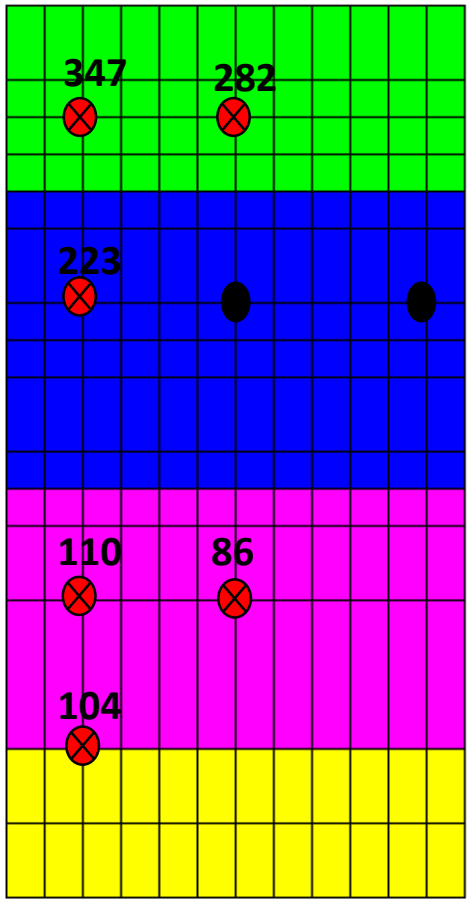
RESULTS AND ANALYSIS- Calibration T 4L1h





RESULTS AND ANALYSIS- Calibration

	ERM (%)					
Treatment	347	283	223	110	104	86
2L1h	ND	36,4	31,9	2,6	ND	16,5
2L2h	13,1	ND	31,7	5,6	ND	3,1
2Lp1h	15,3	12,8	7,4	70,8	22,18	62,3
4L1h	14,2	3,8	8	9,6	7,3	2,4
4L2h	8,4	4,7	8,7	1,2	2,6	2,3
4Lp1h	9,03	6,2	4,4	5,6	ND	4,5
8L1h	18,9	15,3	21,5	41,2	9,7	29,6
8L2h	10,6	10,7	12,6	2,5	3,8	31,3
8Lp1h	5,7	2,2	9	3,6	1,02	24,4



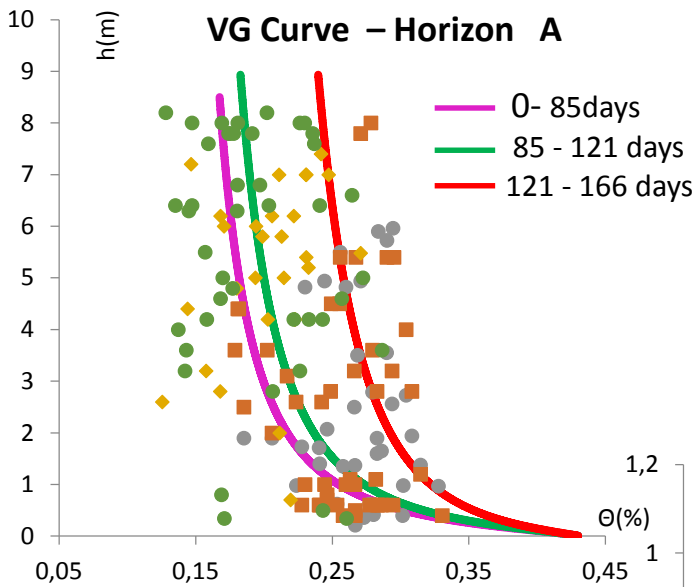
ERM < 30% => acceptable

ND= No Data

● ***out of service tensiometer.***

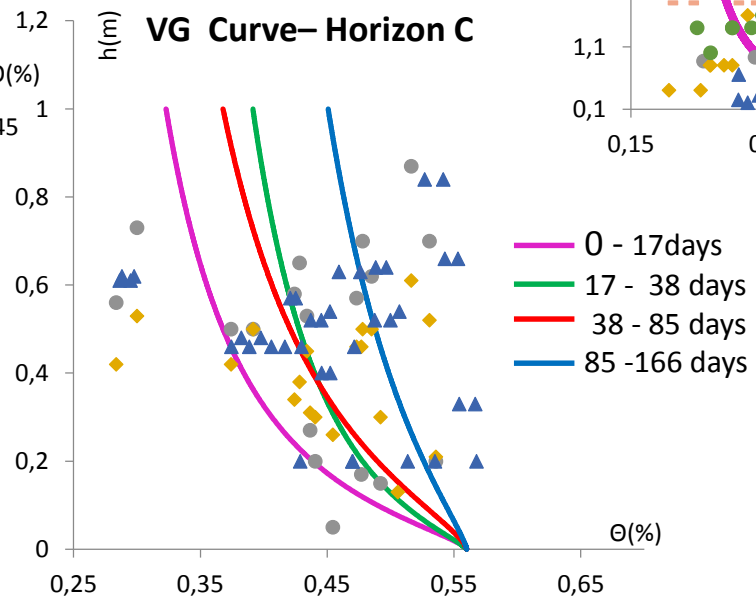
⊗ ***operating tensiometer.***

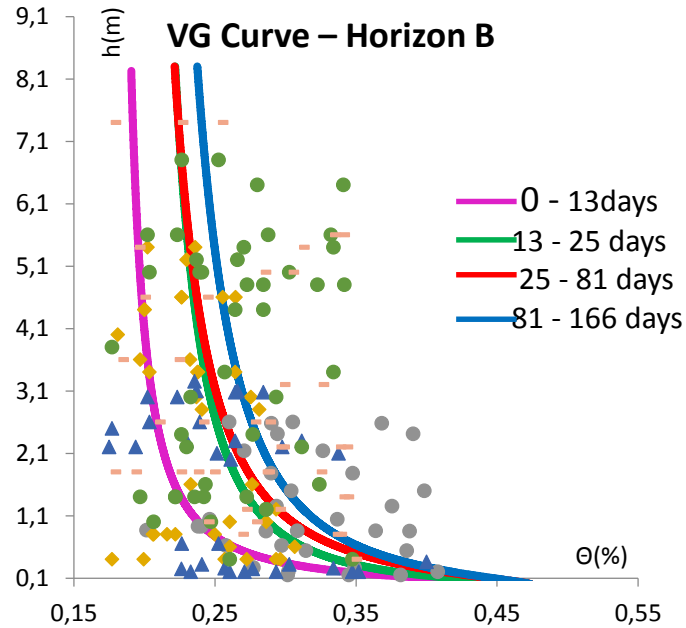
RESULTS AND ANALYSIS – Retention Curve



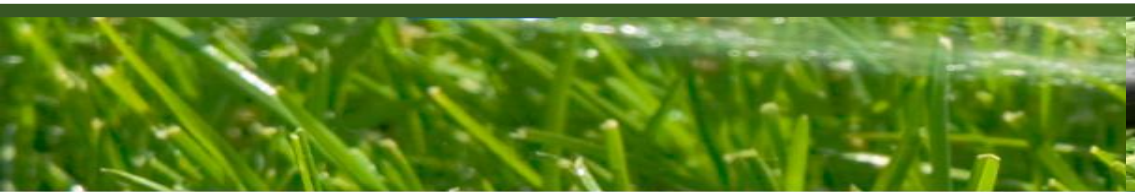
α(m-1)	5	5	5
m	0,33	0,3	0,2
λ	0,3	0,3	0,3

α(m-1)	10	10	5	3,3
m	0,3	0,2	0,3	0,2
λ	0,3	0,1	0,4	0,4

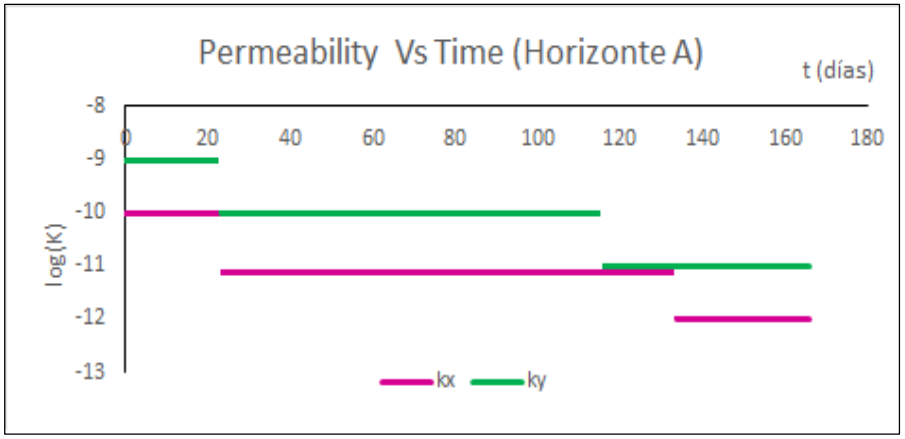


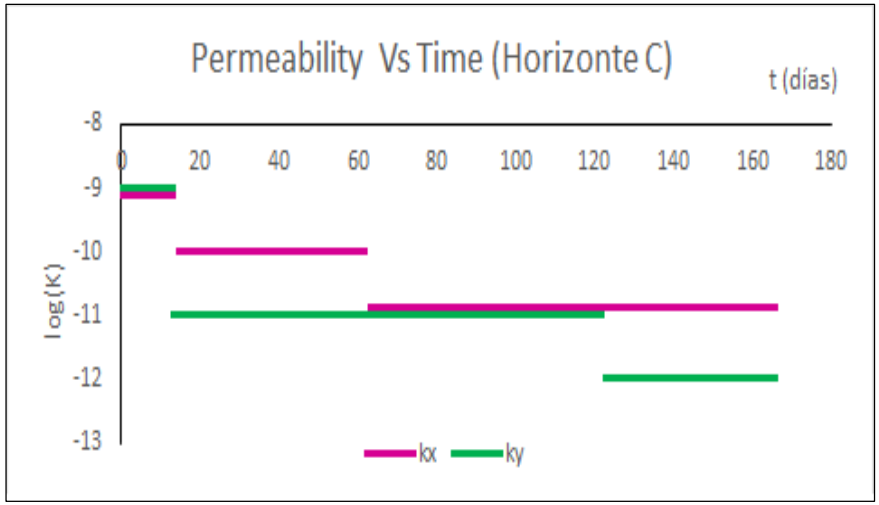


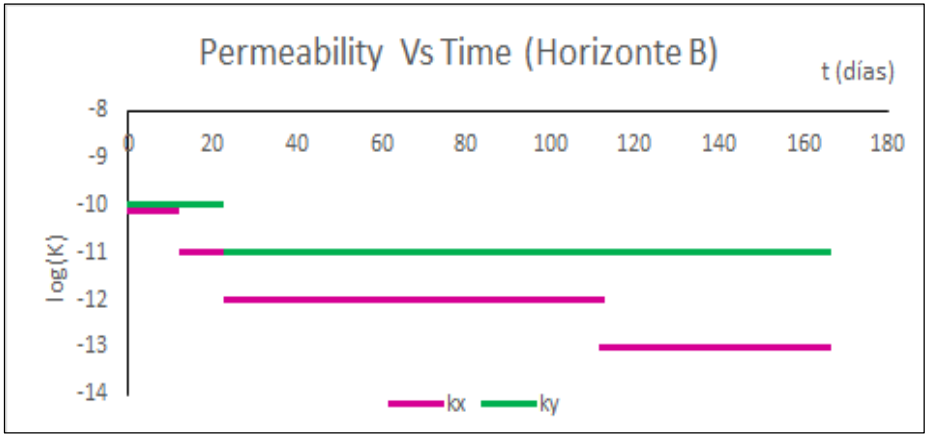
α(m-1)	10	5	5	5
m	0,4	0,3	0,33	0,3
λ	0,3	0,3	0,3	0,3



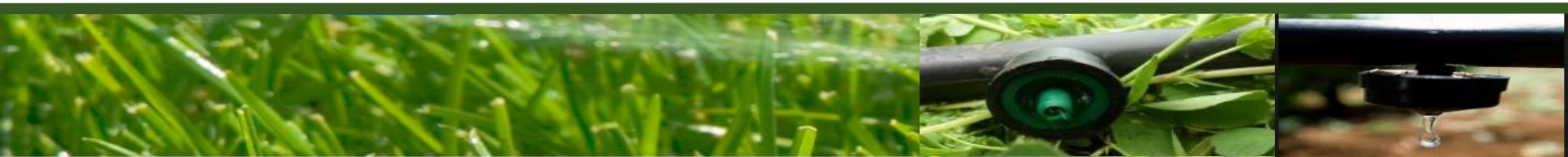
RESULTS AND ANALYSIS – Intrinsec Permeability







Intrinsec Permeability		
	Calibrated	Theorical
HA	$1e^{-9}$– $1e^{-12}$	$1e^{-13}$ --- $1e^{-15}$
HB	$1e^{-10}$- $1e^{-13}$	
HC	$1e^{-9}$ – $1e^{-12}$	



RESULTS AND ANALYSIS – Wet bulb estimation

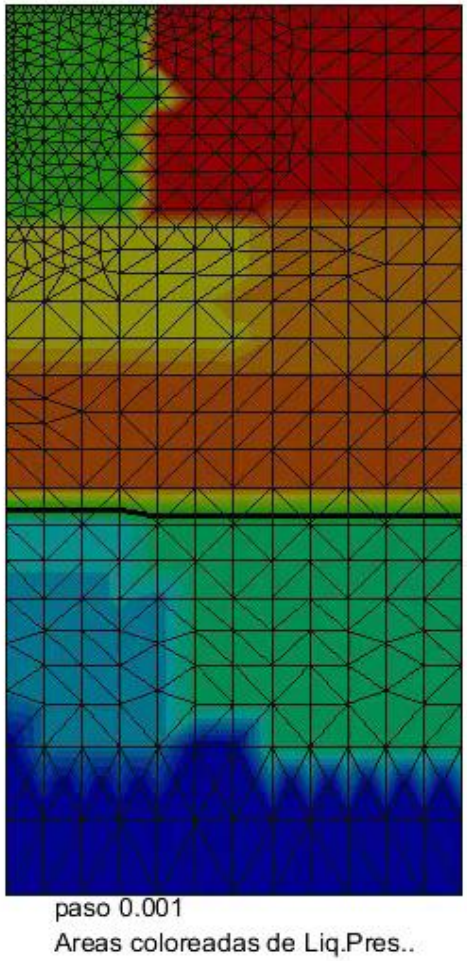
Tratamiento	1ª Aplicación			Fin período de riego			N° de aplicaciones
	R_{max} (cm)	h_{Rmax} (cm)	h_{max} (cm)	R_{max} (cm)	h_{Rmax} (cm)	h_{max} (cm)	
2L1h	7	5	25	8	5	25	3 d
2L2h	10	25	30	12	25	35	3 d
2Lp1h	10	10	31	14	30	43	6/3d
4L1h	17	0-25	50	17	30	50	2d
4L2h	20	22	52	20	22	52	1d
4Lp1h	17	0	18	18	0	21	2/ 1d
8L1h	21	27	55	17	30	50	2d
8L2h	35	15	57	35	15	57	1d
8Lp1h	23	25	37	27	25	51	2/1d

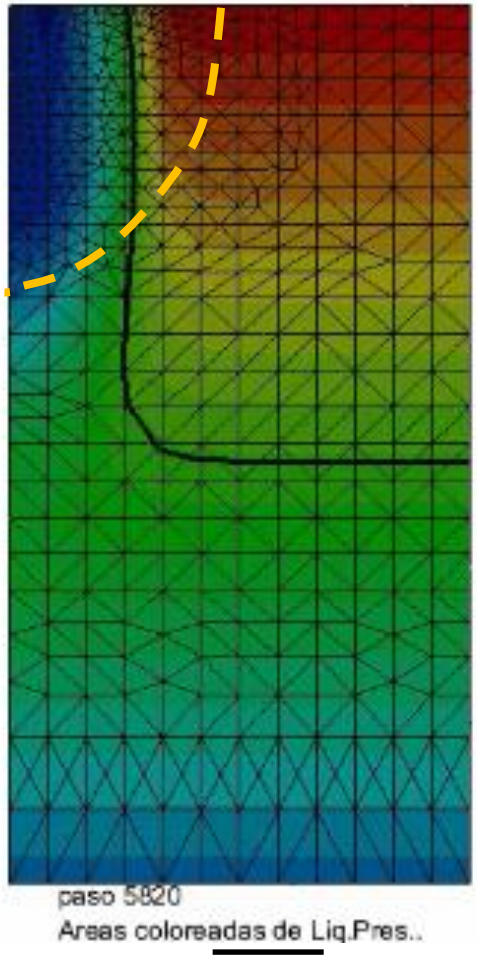
Karmelli et al, 1985 and Quezada el al, 2005

For Silty loam and silty clay loam soils with irrigation flows **4L/h y 8L/h**

r(cm)= 30 – 40
h(cm) < = 40

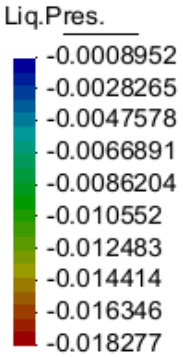
RESULTS AND ANALYSIS – Wet Bulb estimate





Bulbo Teórico

Curva h=100hPa



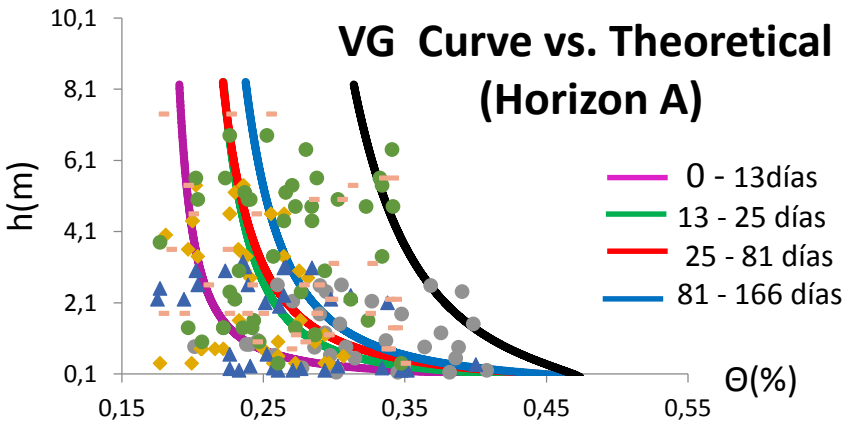
CONCLUSIONS

- Calibrated model for the analysis of wet bulb dimensions for typical soils of the center-south of the country (silty loam and silty clay loam).

- Lowers radius and more depths than the obtained by the literature for clay soils (Bresler, 1977; Keller y Bliesner, 1990; Pizarro, 1990; Zazueta, 1992)

- Calibration parameters shows a evolution to more water retention capacity of soil, but in all cases below than the theoretical values

- Improve microscale phenomena (thermodynamics, hysteresis, soil mechanicals)



α(m^{-1})	10	5	5	5	1,4
m	0,4	0,3	0,33	0,3	0,24
λ	0,3	0,3	0,3	0,3	0,3