The SALTMED model as an integrated management tool for water, crops, soil, salinity and N-fertilizers

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International Network of Salt-Affected Soils

UK Centre for Ecology & Hydrology

The webinar organizers

International Network of Salt-Affected Soils

GLOBAL SOIL PARTNERSHIP

Food and Agriculture Organization of the United Nations

1. SALTMED Processes and Equations

Field scale SALTMED Model: Integrated water, crops, N-Fertilizers and field Management

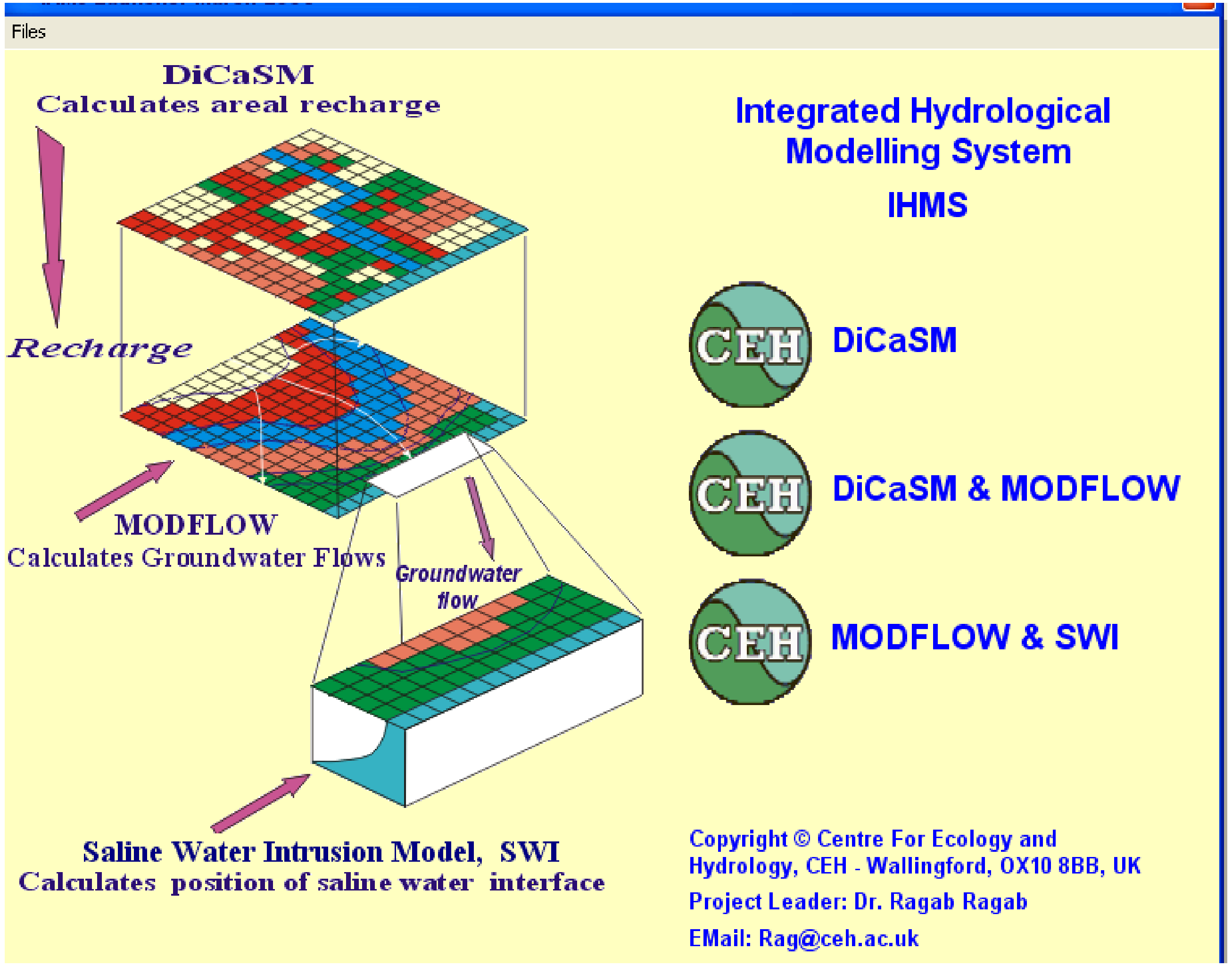
SALTMED
SAFIR,
SWUP-MED,
Water4Crops,–
4 EU Funded Projects

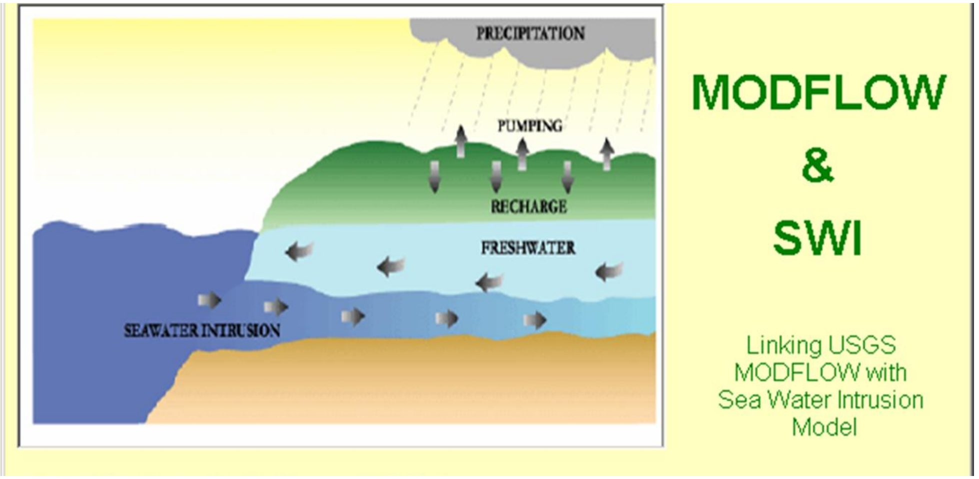
Free download at: http://icid-ciid.org/inner_page/41

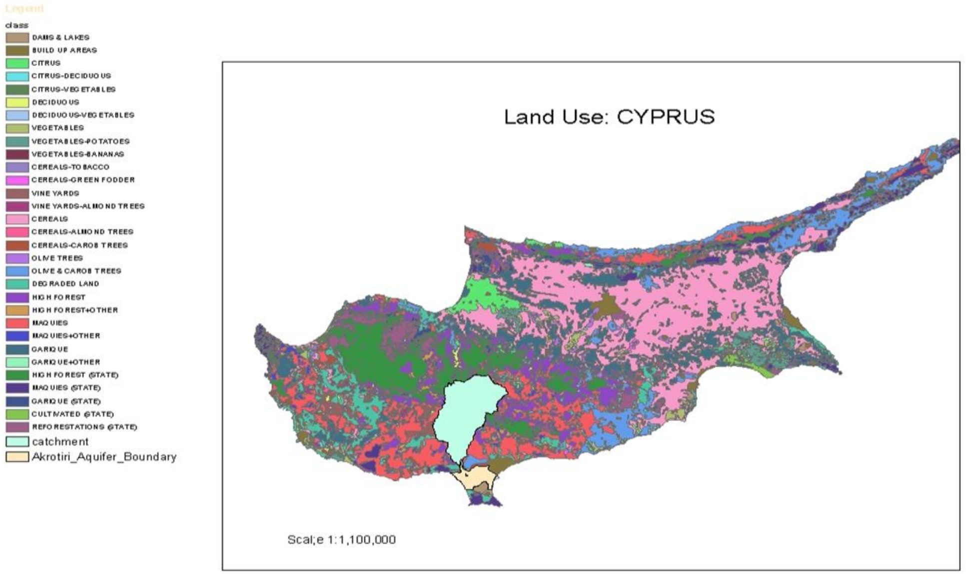
Ragab. 2020. https://onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1531-0361.saltmed-publications

The Catchment Scale model: The Integrated Hydrological Modelling System, IHMS: downloadable at: https://drive.google.com/open?id=1OuEIYkE9sr_XU25eJbuCOclR0Gi9ma-N

Also, from ICID web site: https://icid-ciid.org/inner_page/41







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SALTMED Model Development Publications

1. Ragab R. 2002. A Holistic Generic Integrated Approach for Irrigation, Crop and Field Management: The SALTMED Model. J. of Environmental Modelling & Software. 17(4): 345-361.

2. Ragab R. 2015. Integrated Management Tool for Water, Crop, Soil and N- Fertilizers: The SALTMED Model. J. Irrigation and Drainage. 64(1): 1–12.

3. Ragab Ragab. 2023. Use of Models as Management Tools, SALTMED Model as a Tool for Water, Crop, Field, and N-Fertilizers Management. Part VI in Redouane Choukr-Allah and Ragab Ragab (Eds) Biosaline Agriculture as a Climate Change Adaptation for Food Security. Springer. ISBN 978-3-031-24278-6 ISBN 978-3-031-24279-3 (eBook), https://doi.org/10.1007/978-3-031-24279-3 (pp325- 376)

4. Ragab R. (Editor), 2005. Advances in integrated management of fresh and saline water for sustainable crop production: Modelling and practical solutions. International Journal of Agricultural Water Management (Special Issue).78 (1-2): 1-164. Elsevier, Amsterdam. The Netherlands

5. Ragab, Ragab, (Editor). 2010 SAFIR-Safe and high quality food production using low quality waters and improved irrigation systems management. Amsterdam, The Netherlands, Elsevier, 106pp. (Agricultural Water Management, 98 (3).

6. Ragab. R. 2020. A special issue combines 17 research papers on SALTMED model. "SALTMED Publications in Irrigation and Drainage. Virtual Issues First published: 20 May 2020 Last updated: 20 May 2020. Wiley on line Library". https://onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1531-0361.saltmed-publications

SALTMED MODEL

Freely downloaded at:

The ICID web site :

https://www.icid.org/wg_crop.html

(EU funded) & the basis of the SALTMED model can be found at:

Special Issu : J. Agric. Water Management,volume 78 (1-2), September, 2005, (Guest Editor, Ragab Ragab)

The Results of SAFIR project (EU funded) can be found at:

Special Issu : J. Agric. Water Management,volume 98 (3), December, 2010, (Guest Editor, Ragab Ragab)

The results of SWUP-MED project (EU funded) can be found at:

Journal of Irrigation and Drainage, 2015.*Volume 64 (1) and the following issues.*

"SALTMED Publications in Irrigation and Drainage. Virtual Issues ***First published: 20 May 2020 Last updated: 20 May 2020. Wiley on line Library".***
https://onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1531-0361.saltmed-publications

SALTMED Online Course (freely available)

The latest version is the 2019 version and compatible for windows 7 and above, available at.

https://drive.google.com/file/d/1GHoL0daZYPRb4zn2H4M_oPl_3vlOUKpg/view

and from ICID web site at : https://icid-ciid.org/inner_page/41

The file size is 398MB

Online Course freely available at YouTube: Produced by Engineering & Consulting S.T.E.P GmbH, Aachen, Germany: https://stepconsulting.de/en/

follow the different parts of the model installation, description and application as well as the trouble shooting :

How to install the model, go to:

https://www.youtube.com/watch?v=Rt-V87jlg3w

The whole course is available at:

https://www.youtube.com/watch?v=JRMeUFzuBYU

Trouble shooting: Problems and solutions& FAQ:

https://www.youtube.com/watch?v=8NnpllMtSuE&list=PLZYmrBXSZmBk4w_eIIDbYegjaluPaisp-

Rational

SALTMED model was originally developed for SALTMED EU funded project to study the impact of using saline water on field crops of the Mediterranean region and assess the short and long-term impact of using saline water on the environment.

SALTMED model Development & Applications

- **The model has been developed and applied within four EU funded projects: SALTMED, SAFIR , SWUP-MED and Water4Crops.**

- **The model has successfully been tested against field experiments conducted in Egypt, Syria, Turkey, Morocco, Spain, Portugal, Greece, Denmark, UK, Syria, France, Serbia, Greece, Portugal, China, Kazakhstan, Nigeria, Iran, Brazil, USA France, Saudi Arabia, Bahrain, and Italy.**
- **The model has also been used to predict the impact of seawater rise and inundation on soil and vegetation of 7 lowland coastal sites in the UK using the climate change prediction up to 2099 (DEFRA funded).**

- **The model is suitable for academic researchers, for professionals and for practitioners.**

Benefit of using SALTMED model

1. Helps to predict the impact of climate change (rainfall, temperature, CO_2 , seawater intrusion , seawater inundation /tsunami) on soil, vegetation and food security.

2. Improves water use efficiency: reduce water use in agriculture and increase productivity to meet population needs, more crop per drop.

3. Helps to select the best strategies to irrigate using less water and save more. Example: irrigating half of the root zone in alternating system (Partial Root Drying Method, PRD). This method saves up to 40% of water.

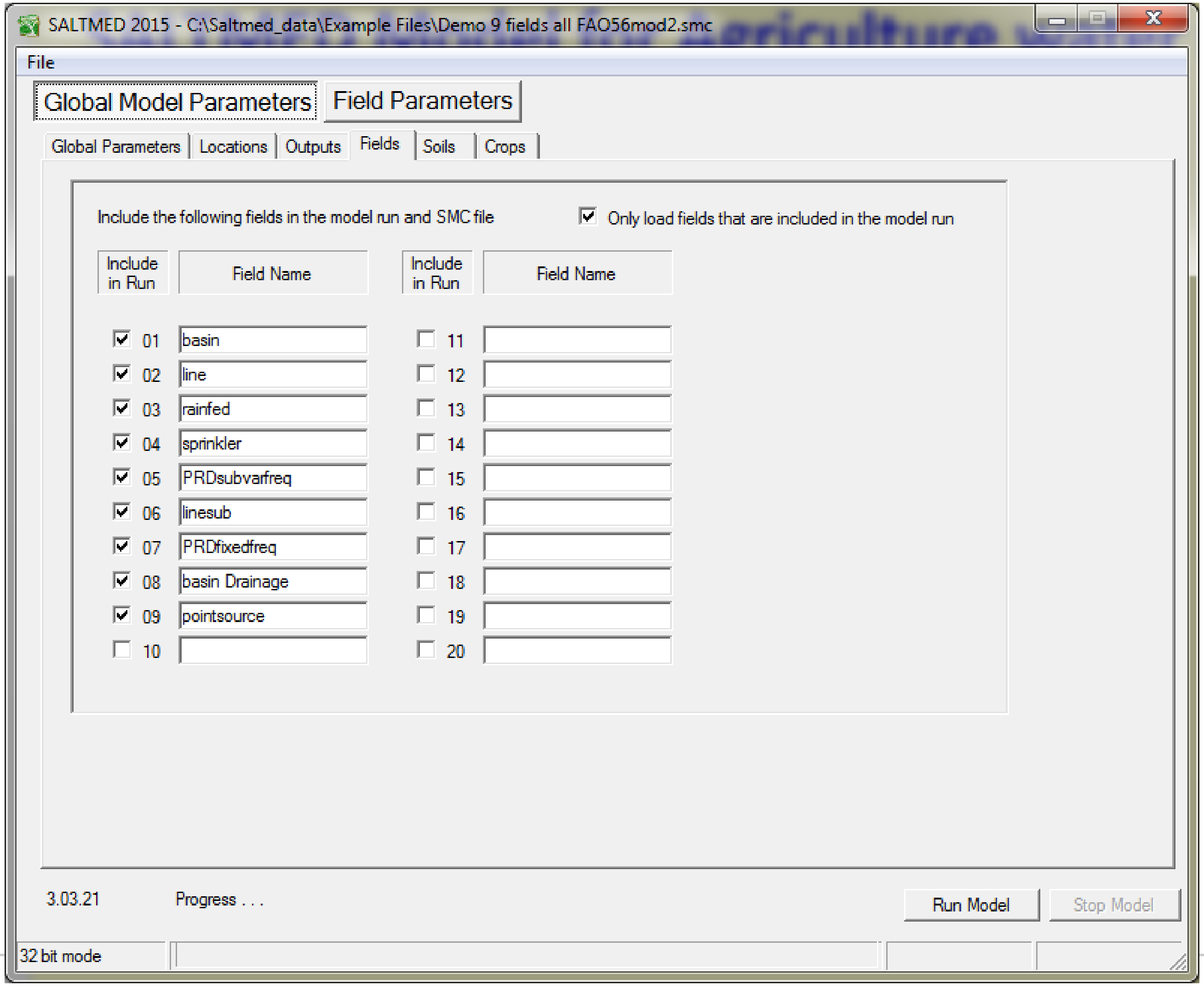
4. Guide users to select the most suitable crop , irrigation system and irrigation strategies when using poor quality water (saline water, brackish groundwater, agriculture drainage water and treated wastewater).

5. Predict the impact of using poor quality water on the environment and guide the user to the best strategies to minimize the negative impact , less water pollution and improve biodiversity.

SALTMED Model Main Components

1. Evapotranspiration using different methods
2. Plant water uptake accounting for salinity and water stress
3. Water and solute transport under different irrigation systems
4. Soil Nitrogen cycle including Soil Temperature dynamics
5. Leaching of salinity and nitrogen fertilizers
6. Drainage flow and Groundwater level dynamics
7. Crop yield – Biomass, water use efficiency and productivity
8. Crop rotations of different crops
9. Simultaneous runs of up to 20 multiple fields or treatments
10. The model has Crop and soil databases & example files
11. The model can run with "what if" climate change scenarios
12. The model calculates the crop growth based on Degree Days and calendar dates
13. Water balance, salt balance and nitrogen balance

SALTMED Simultaneous runs of 20 multiple fields or treatments



SALTMED Processes and Equations

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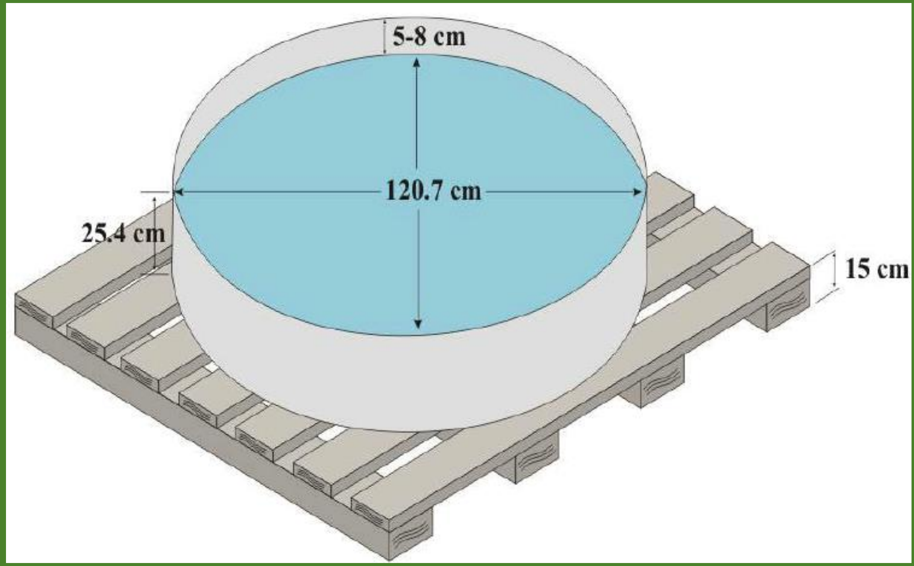
Evapotranspiration calculation options

1. Reference Evapotranspiration ETo is calculated from Class A pan measurements.

2. ETo Calculated from FAO (1998) Modified Penman-Monteith Equation.

3. ETo Calculated from the Original Penman-Monteith Equation with options for canopy resistance input from:
   3.1 Equations based on environmental parameters
   3.2 Abscisic acid (ABA) plant hormone & Leaf water potential measurements.
   3.3 Canopy resistance field Measurements
   3.4 Given seasonal average value

Evaporation - Class A Pan



Evapotranspiration

In presence of stomata / canopy surface resistance data, one could use the widely used equation Penman-Monteith (1965) in the following form:

where r_s and r_a are the bulk surface and aerodynamic resistances ($s\ m^{-1}$).

$$\lambda E_p = \frac{\Delta R_n + \rho C_p \frac{(e_s - e)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

where ET_o is the reference evapotranspiration, (mm day^{-1}), R_n is the net radiation, (MJ m^{-2} day^{-1}), G is the soil heat flux density, (MJ m^{-2} day^{-1}), T is the mean daily air temperature at 2 m height, (^oC), Δ is the slope of the saturated vapour pressure curve, (kPa $^oC^{-1}$), γ is the psychrometric constant, 66 Pa $^oC^{-1}$, e_s is the saturated vapour pressure at air temperature (kPa), e_a is the prevailing vapour pressure (kPa), and U_2 is the wind speed at 2 m height (m s^{-1}). The calculated ET_o here is for short well-watered green grass. In this formula, a hypothetical reference crop with an assumed height of 0.12 m, a fixed surface resistance of 70 s m^{-1} and an albedo of 0.23 were considered.

Calculating the stomata Conductance Based on Jarvis (1967) and Körner (1994): regression Equation

$$gs = gsmax * f(VPD) * f(T) * F(SW) * f(PAR)$$

gs is the stomata conductance, and gsmax is the maximum stomata conductance

f (VPD) is the relative effect of the VPD on stomata conductance

f(T) is the relative effect of the Temperature on stomata conductance

f (SW) is the relative effect of the soil water content on stomata conductance

f(PAR) is the relative effect of the radiation on stomata conductance

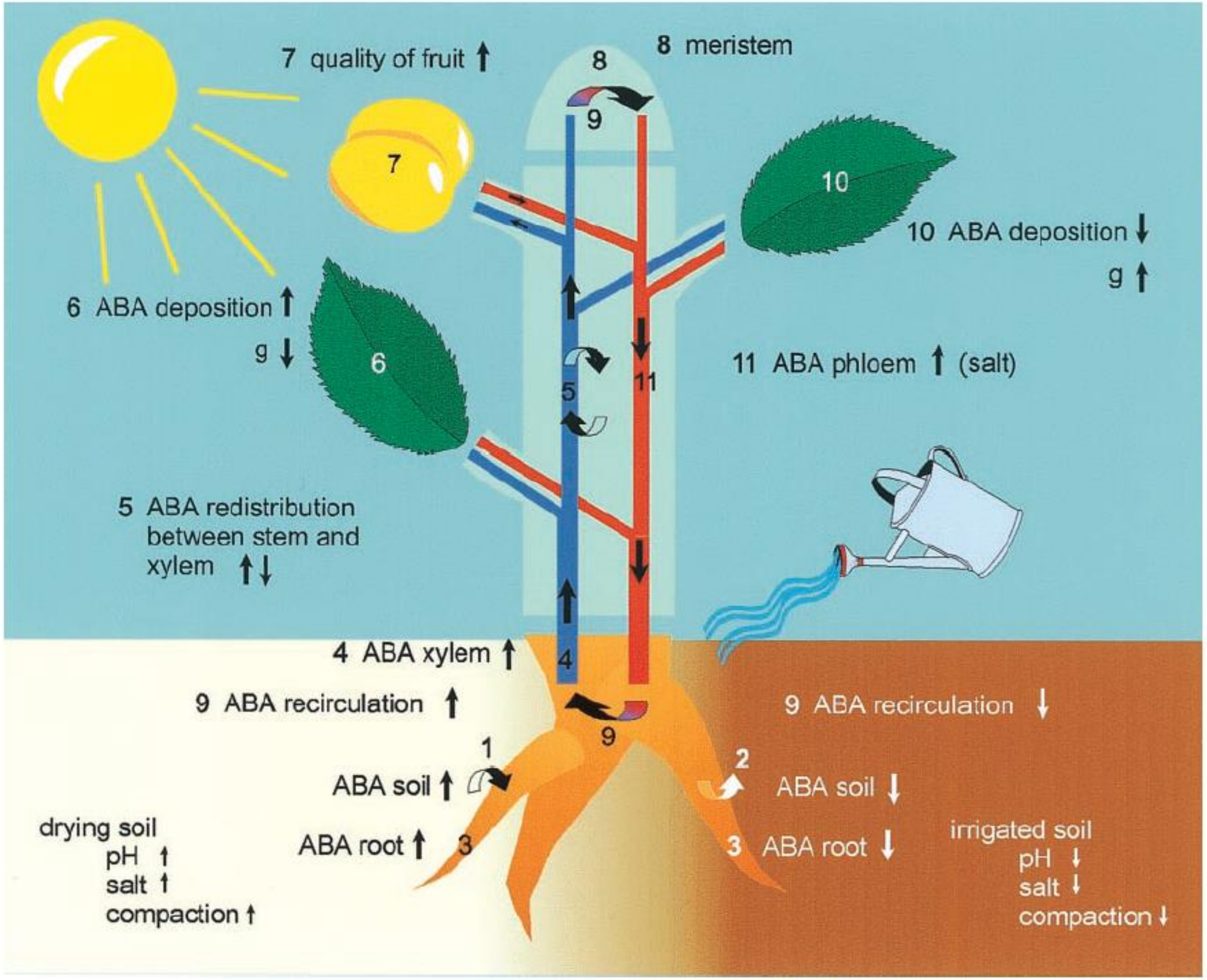


Fig. 1. The numbering of the model plant indicates several factors that influence the formation and intensity of the ABA long-distance signal. On the left hand side of the plant water shortage is demonstrated, the right hand side depicts a sufficient water supply.

Sauter *et al*. 2001

The Stomata Conductance using the ABA

Tardieu, F, Zhang, J. and Gowing, D. J. G. 1993. Stomatal control by both [ABA] in the xylem sap and leaf water status: a test of a model for droughted or ABA-fed field-grown maize. Plant, Cell and environment .16:413-420.

$$gs = gs\ minimum + \alpha * Exp\ (ABA * \beta * Exp\ (\sigma * \Psi l))$$

gs = Stomata conductance, mole/m^2/sec

gs minimum = mimimum Stomata conductance (*mole/m^2/sec*)

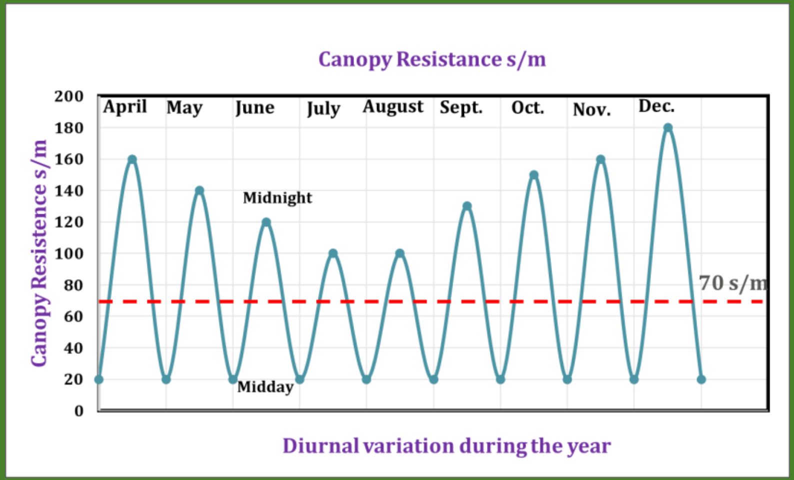
ABA = Absecic Acid concentration, daily values, (*mmole/m^3*)

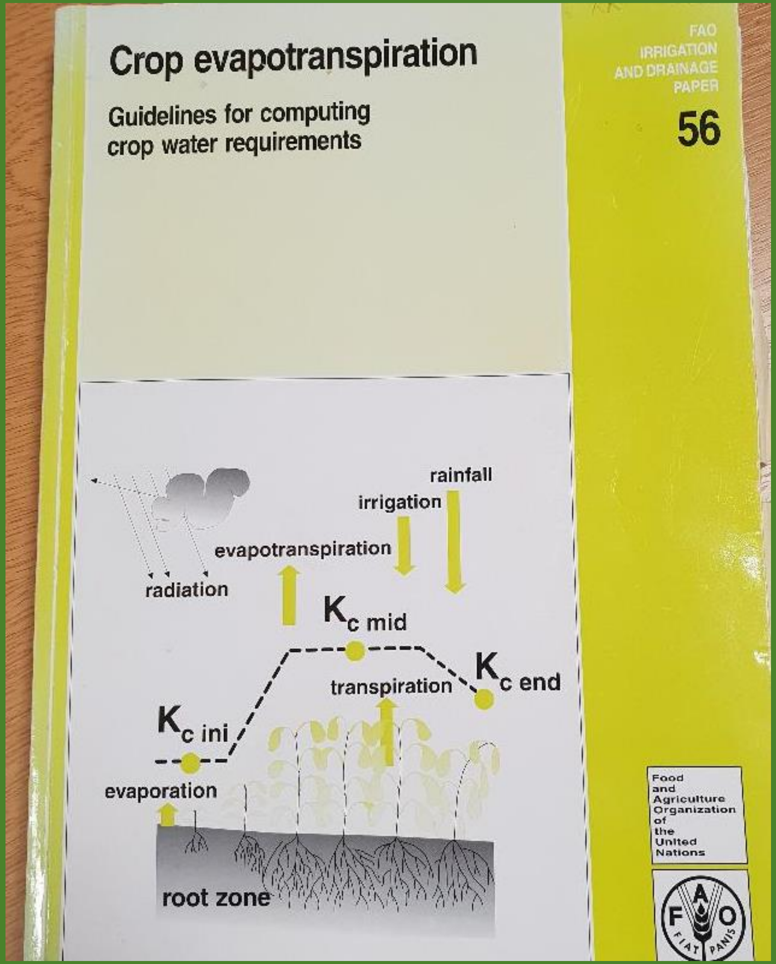
Ψl = Leaf water potential in M pa, daily values, *(-1.3 Mpa)*

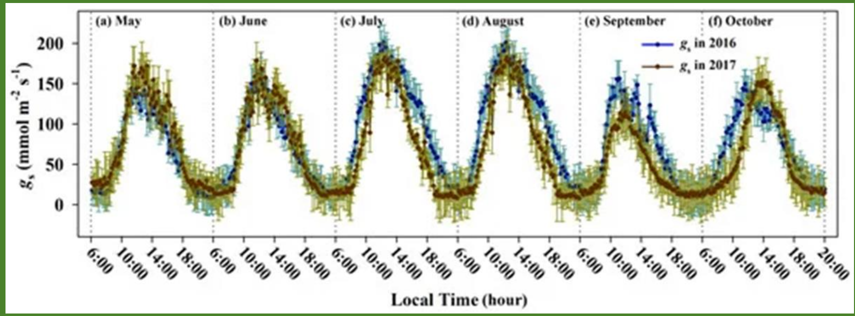
FAO Modified Penman-Monteith Equation

FAO – ICID cooperation

rs = 70s/m







Evapotranspiration

Penman - Monteith, FAO-56 (1998)Version

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 U_2)}$$

$$ET_c = ET_o (K_{cb} + K_e)$$

Water uptake in presence of salts

The water uptake function accounts for water stress & osmotic stress according to Cardon and Letey (1992), which determines the water uptake S (d^{-1})

$$S(z,t) = \left[\frac{S_{max}(t)}{1 + \left(\frac{a(t)h + \pi}{\pi_{50}(t)} \right)^{3}} \right] \lambda(z,t)$$

$$S_{max}(t) = ET_o(t) * K_{cb}(t)$$

$\lambda(z) = 5/3L$ for $z \leq 0.2L$

$= 25/12L * (1 - z/L)$ for $0.2L < z \leq L$

$= 0.0$ for $z > L$

where L is the maximum rooting depth

Water uptake in presence of salts

where S_{max} (t) is the maximum potential root water uptake at the time *t*,

z is the vertical depth taken positive downwards,

$\lambda(z,t)$ is the depth-and time-dependent fraction of total root mass,

h is the matrix pressure head,

π is the osmotic pressure head,

π_{50} (t) is the time-dependent value of the osmotic pressure at which $S_{max}(t)$ is reduced by 50%,

a(t) is a weighing coefficient accounts for the differential response of a crop to matrix and solute pressure. $a(t) = \pi_{50}(t)/h_{50}(t)$

where $h_{50}(t)$ is the matrix pressure at which $S_{max}(t)$ is reduced by 50%.

Crop Yield – crude estimation from relative Yield

$$RY = \frac{\sum S(t)}{\sum S_{max}(t)}$$

$$AY = RY * Y_{max}$$

Crop Growth, Biomass & yield production

Eckersten, H and Jansson, P,.- E. 1991. Modelling water flow, nitrogen uptake and production for wheat. Fertilizer Research 27: 313-329.

Increase in Biomass Δ q, g/m2/day = Net Assimilation "NA"

Net Assimilation, "NA" = Assimilation "A "– Respiration losses "R"

Assimilation rate, "A" per unit of area = E* I* f(Temp)* f(T)*f(Leaf-N) g/m^2/day

Crop Growth and Biomass production

The assimilation rate A per unit area =

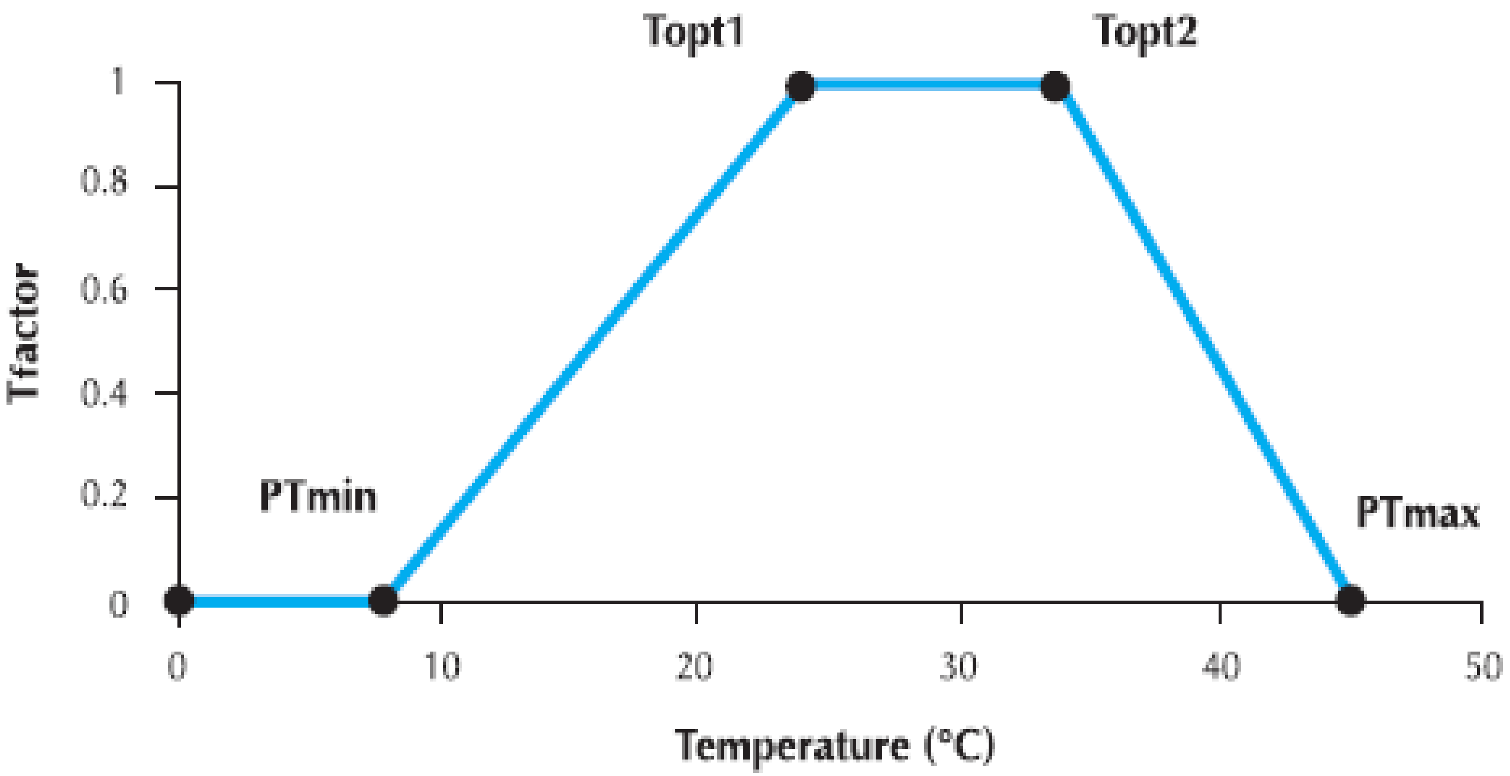
$$E^* \, I^* \, f(Temp)^* \, f(T)^* f(Leaf\text{-}N)$$

E* I* [stress factors related to temperature Temp, transpiration,T & leaf nitrogen content, Leaf-N]:

E = is the Photosynthesis Efficiency, g dry matter / MJ

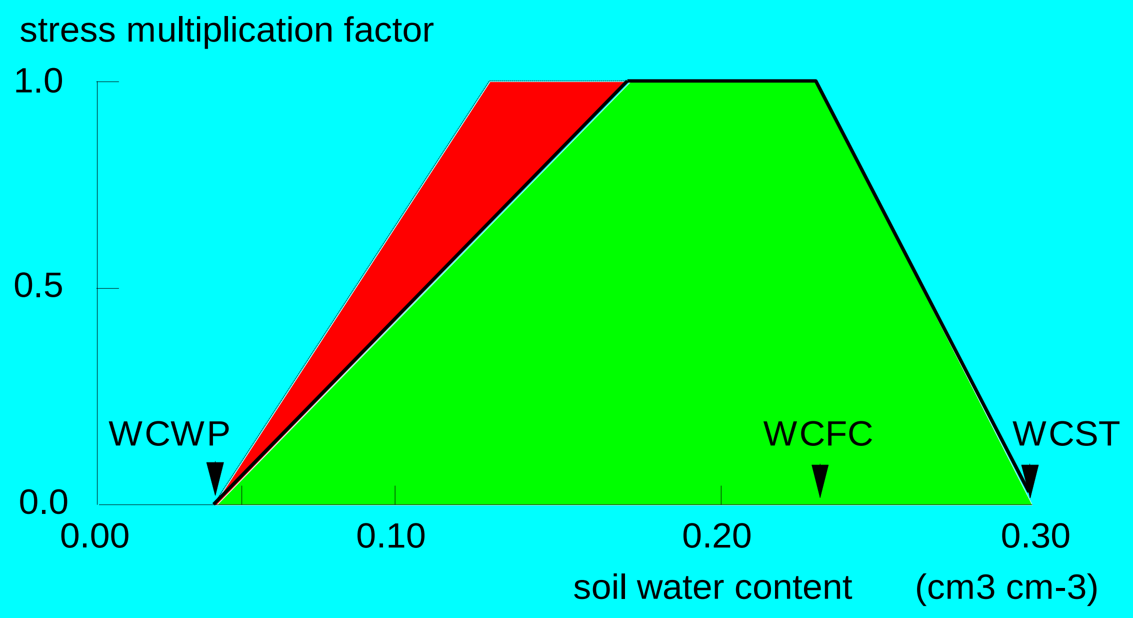
I : The radiation input: = Rs (1- e^{-k^*LAI}), Rs is global Radiation, MJ/m^2/day, k is extinction and LAI is the leaf area Index (m^2/m^2).

Effect of Temperature on Crop Growth



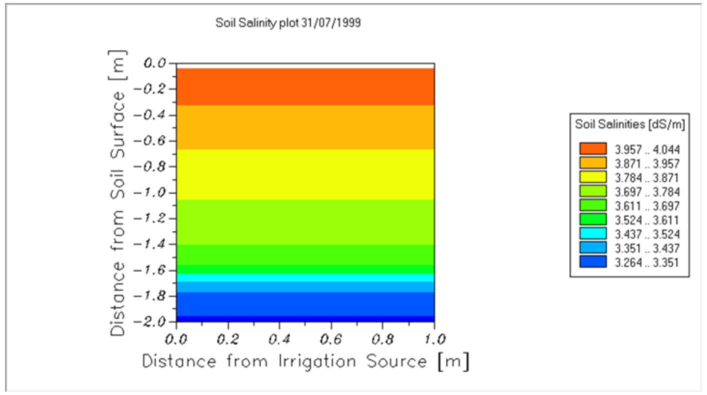
Note: PTmin and PTmax are the minimum and maximum temperatures for photosynthesis. Topt1 and Topt2 are the lower and higher extremes of the optimum temperature range.

The Transpiration stress factor, T, based on soil water content

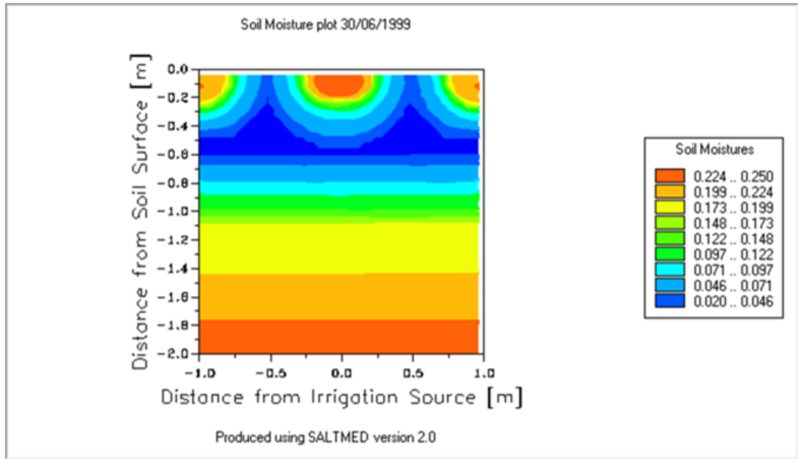


The relation between the soil water content and the stress multiplication factor on the rate of water uptake. (After Penning De Vries et al., 1989).

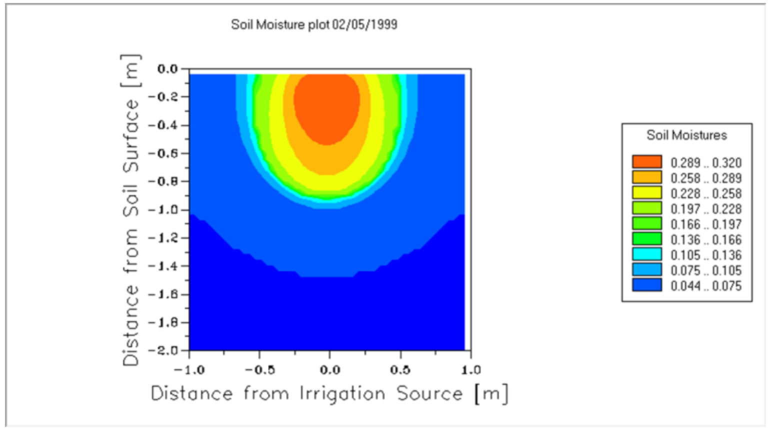
1-Dimensional Water and solute transport (basin, sprinkler, Centre Pivot irrigation systems)



2-Dimensional Water and solute transport (Trickle/Furrow irrigation systems)



Cylindrical /Spherical 3-Dimensional Water and solute transport (drip widely spaced drippers with no overlapping wetting fronts.



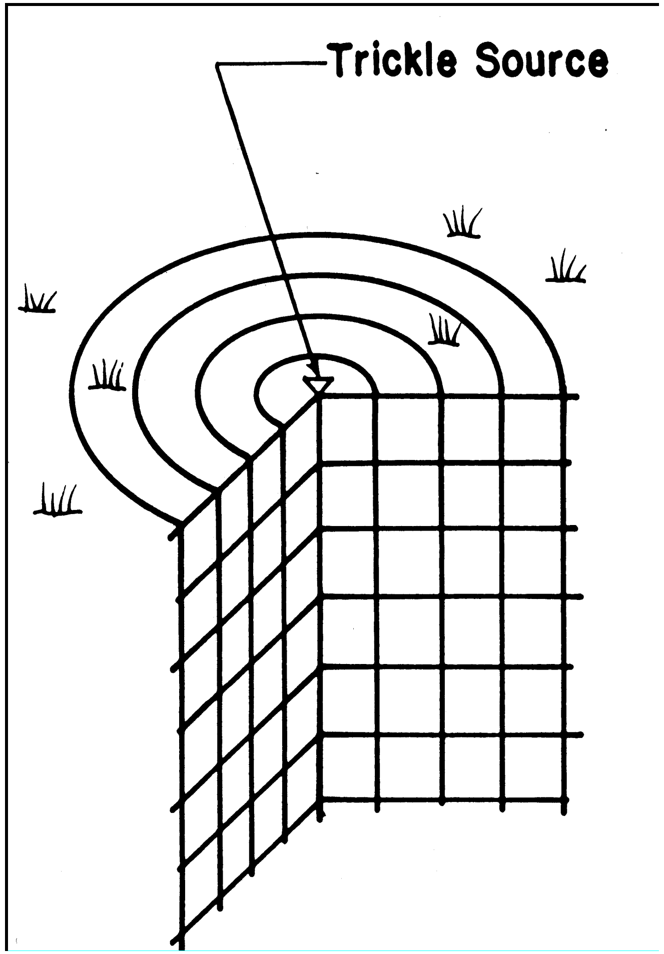
Water and solute transport under irrigation systems

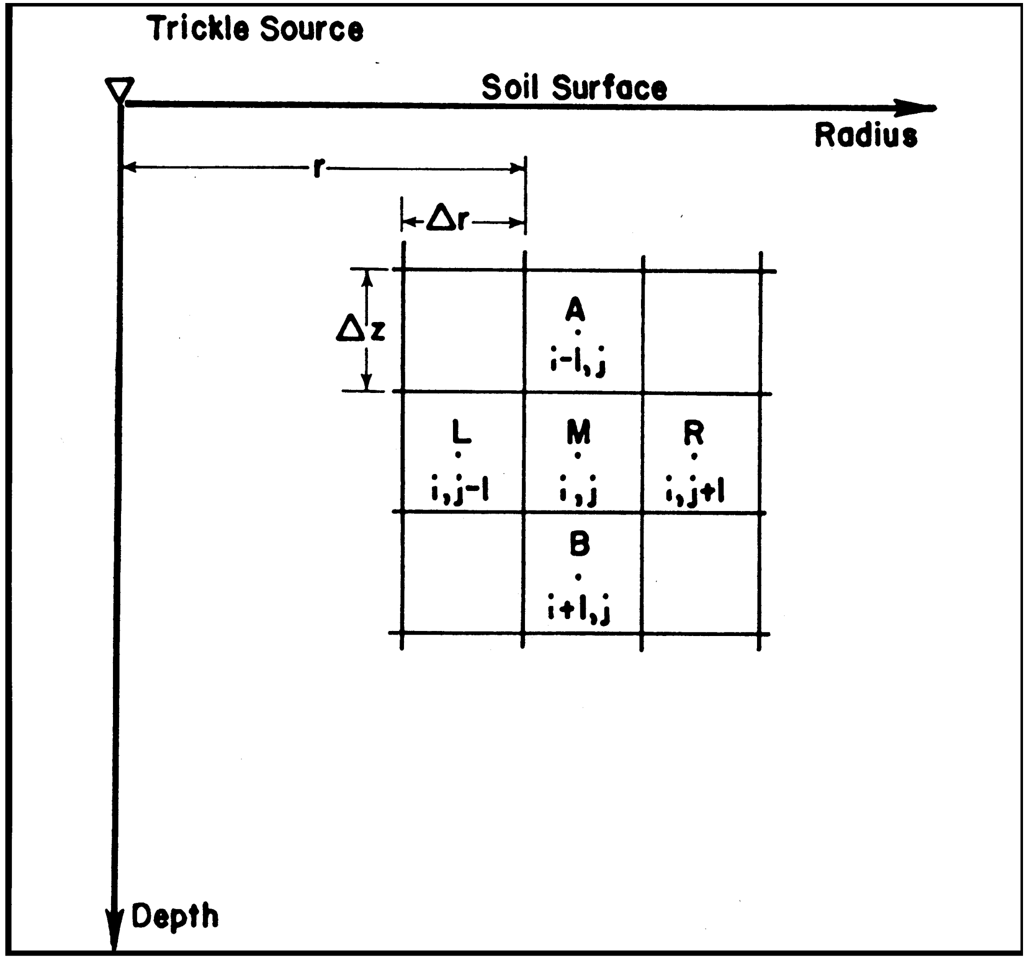
In Rain fed, basin and Sprinkler irrigation, water and solute transport can be described by One-Dimensional water and solute transport equation.

In Furrow & trickle line source water & solute transport can be described as two-dim. "plane flow" using Cartesian co-ordinates x and z.

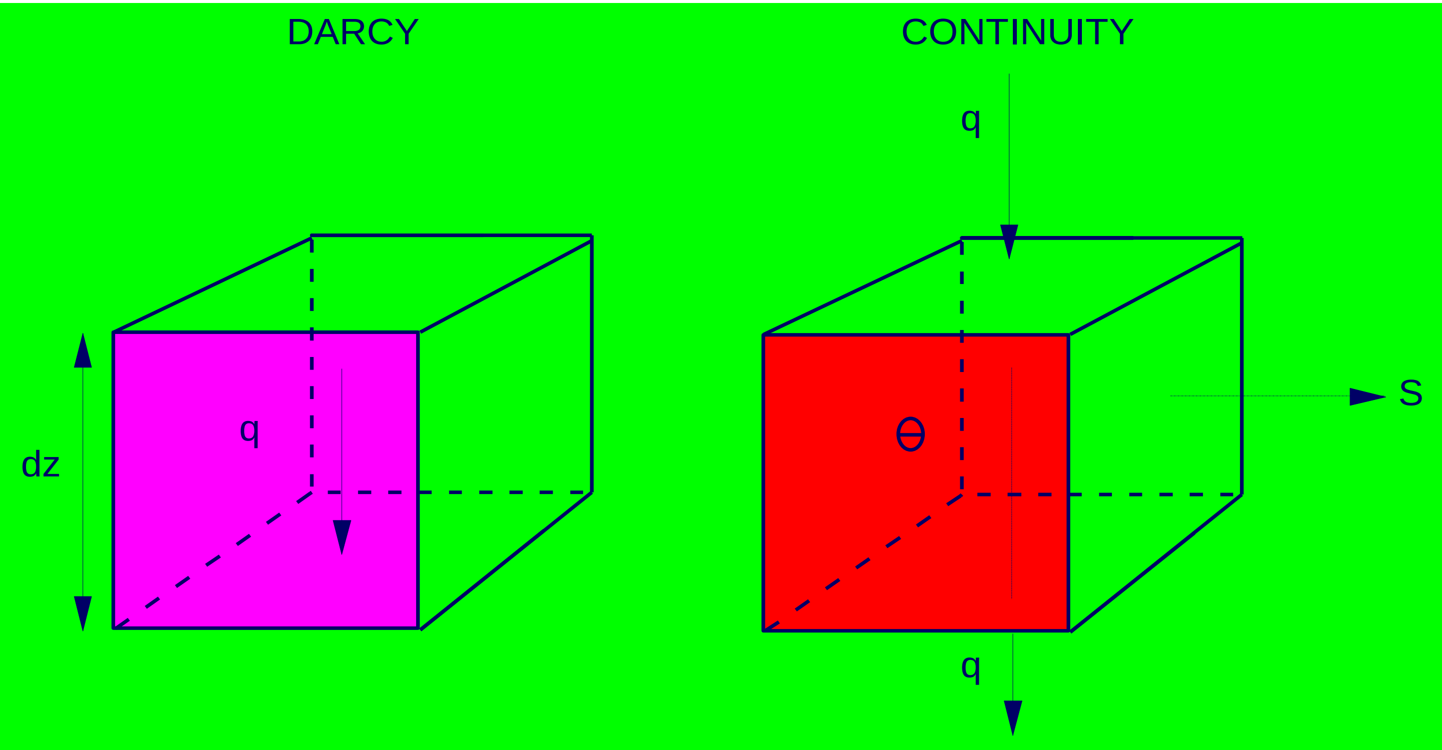
In trickle point source water & solute can be described as 3-dim. and can be viewed as "cylindrical flow" using cylindrical co-ordinates r and z.

2-Dimensional Water and solute transport (Trickle/Furrow irrigation systems)





Water and solute flow Equations



$$q = -k \frac{\delta H}{\delta z}$$

$$\frac{\delta \Theta}{\delta t} = - \frac{\delta q}{\delta z} - S$$

Schematic representation of the principle of the flow equations in presence of plant roots.

Water and solute flow

The vertical transient-state flow water in a stable and uniform segment of the root zone can be described by a Richard's type equation as:

$$\frac{\partial \theta}{\partial t} = -\frac{\partial}{\partial z}\left[K(\theta)\frac{\partial(\psi + z)}{\partial z}\right] - S_w$$

Water and solute one-dimensional flow

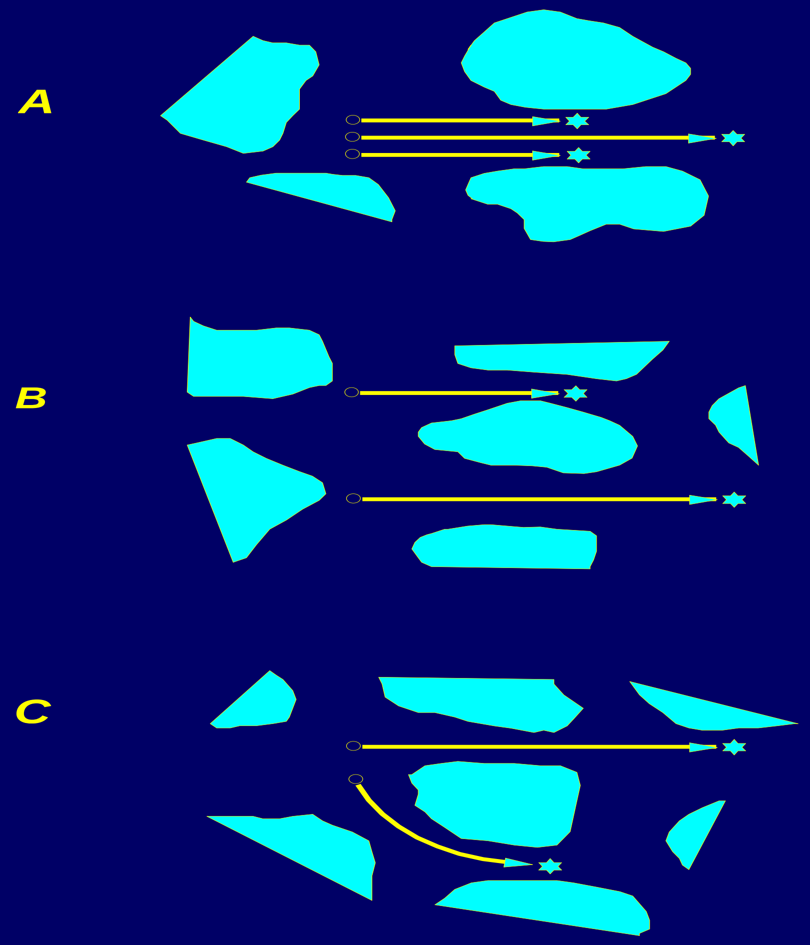
Solute flow by convection can be formulated (Hillel, 1977) as:

$$J_c = qc = v\theta c$$

where Jc is the solute flux density; q is the water flux density of the water; c the concentration of solute in the flowing water and v is the average velocity of the flow. The rate of a diffusion of a solute (Jd) in bulk water at rest is related (by Fick's law) to the concentration gradient as:

$$J_d = D_o\,(\delta c / \delta x)$$

Mechanical dispersion, A: effect of pore walls, B: effect of pore diameter, C: effect of tortuosity (De Smedt, 1979).



Water and solute flow

The convection flux generally causes hydrodynamic dispersion too, an effect that depends on the microscopic non-uniformity of flow velocity in the various pores. Thus a sharp boundary between two miscible solutions becomes increasingly diffuse about the mean position of the front. For such a case, the hydrodynamic dispersion coefficient has been found by Bresler (1975) to depend linearly on the average flow velocity V, as follows:

$$D_h = \alpha v$$

where α is an empirical coefficient. By the combination of the diffusion, the dispersion and the convection the overall flux of solute can be obtained as:

$$J = -(D_h + D_s)(\delta c / \delta x) + v\theta c$$

Overall solute flux = diffusion+ the dispersion+ the convection flux of solute

D_s is the solute diffusion in soil which decreases due to the fact that the liquid phase occupies only a fraction of soil volume, and also due to the tortuous nature of the path. It can, therefore, be expressed according to the following equation where D_0 is the diffusion coefficient as:

$$D_s = D_0 \theta \xi$$

where ξ is the tortuosity, it is an empirical factor smaller than unity, which can be expected to decrease with decreasing θ as:

$$\xi = \theta^{7/3} / \theta_s^2$$

Water and solute one-dimensional flow

If one takes the continuity equation into consideration, one-dimensional transient movement of a non-interacting solute in soil can be expressed as:

$$\frac{\partial(\theta c)}{\partial t} = \frac{\partial}{\partial z}\left(D_a \frac{\partial c}{\partial z}\right) - \frac{\partial(qc)}{\partial z} - S_s$$

in which c is the concentration of the solute in the soil solution, q is the convective flux of the solution, Da is a combined diffusion and dispersion coefficient, and Ss is a sink term for the solute representing root adsorption/uptake. The salt concentration, "c" in the righthand side of the equation means mg/litre soil solution while salt content "(θc)" at the lefthand side of the equation means mg/litre bulk soil. The model output results are given as "C" mg/l soil solution.

Water transport under Trickle/Furrow irrigation systems. 2-dimensional flow

For a stable, isotropic and homogeneous porous, the two-dim. flow of water in the soil can be described as:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[K(\theta)\frac{\partial \psi}{\partial x}\right] + \frac{\partial}{\partial z}\left[K(\theta)\frac{\partial (\psi + z)}{\partial z}\right] - S_w$$

Water and solute transport under Trickle/Furrow irrigation systems.
2-dimensional flow

$$\frac{\partial(C\theta)}{\partial t}=\frac{\partial}{\partial x}\left(D_{xx}\frac{\partial C}{\partial x}+D_{xz}\frac{\partial C}{\partial z}-q_{x}C\right)+\frac{\partial}{\partial z}\left(D_{zz}\frac{\partial C}{\partial z}+D_{zx}\frac{\partial C}{\partial x}-q_{z}C\right)-S_{s}$$

Trickle point source

Trickle point source is described by cylindrical flow equations obtained by replacing x by the radius "r" and rearranging Equations as given by Bresler (1975) and Fletcher Armstrong and Wilson (1983).

Water and solute 2-dimensional transport

The hydrodynamic dispersion coefficient (D_h) for 2-Dim solute flow, D_{ij} can be defined as follows:

$$D_{ij} = \lambda_T \, |V| \, \delta_{ij} + (\lambda_L - \lambda_T) V_i V_j / |V| + D_s(\theta)$$

where λ_L is the longitudinal dispersivity of the medium; λ_T is the transversal dispersivity of the medium; δ_{ij} is Kronecker delta; V_i is the i component of the average interstitial solution velocity $V = (V^2_x + V^2_z)^{1/2}$ and Ds (θ) is the soil diffusion coefficient:

$$D_s = D_0 \theta \xi$$

where ξ is the tortuosity, it is an empirical factor smaller than unity, which can be expected to decrease with decreasing θ as:

$$\xi = \theta^{7/3} / \theta_s^2$$

Soil Moisture and Salt content as output

The soil Moisture content, θ

The salt concentration, C (mg/litre soil solution)

The salt content $C*\theta$, (mg/litre bulk soil)

Relative salt concentration, C – Cirr /Cini

Soil hydraulic properties in SALTMED

Either given as input text files (Hydraulic conductivity vs Soil moisture and water potential vs soil moisture) or calculated according to van Genuchten (1980) as:

$$\theta(h) = \theta_r + [(\theta_s - \theta_r) / (1+|\alpha h|^n)^m]$$

$$K(h) = K_s K_r(h) = K_s Se^{1/2} [1- (1- Se^{1/m})^m]^2$$

These equations were used after being re-arranged to obtain the soil water potential and hydraulic conductivity as functions of effective saturation as:

$$S_e = (\theta - \theta_r) / (\theta_s - \theta_r)$$

$$h(S_e) = [(S_e^{-1/m} - 1)^{1/n}] / \alpha$$

$$K(S_e) = K_s Se^{\lambda} [1-(1- S_e^{1/m})^m]^2$$

$n=\lambda+1$

$m=\lambda/(\lambda+1) = m=\lambda/n$

$\alpha = (1/hb)$

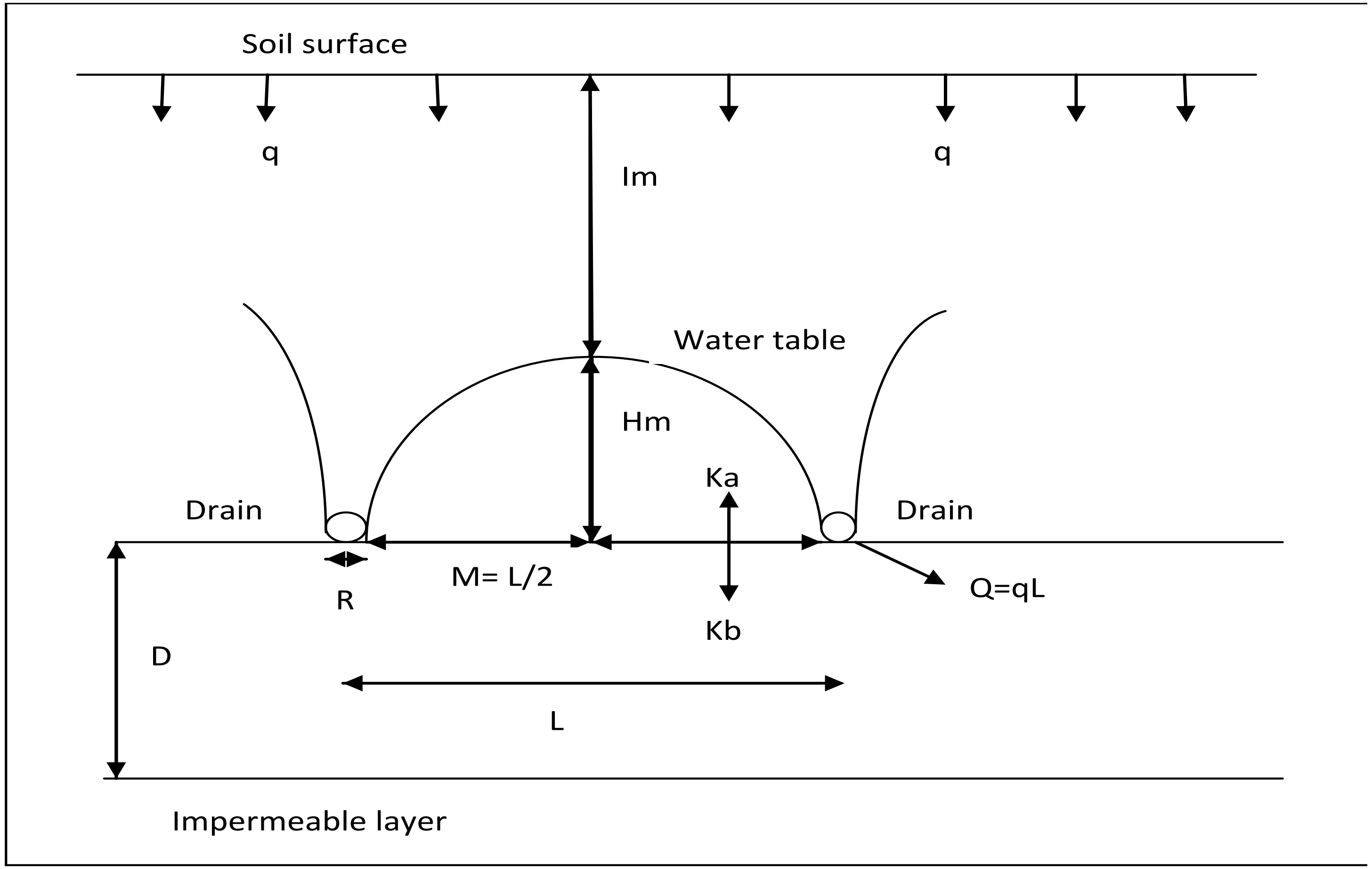
Where θ_r and θ_s denote the residual and the saturated moisture contents, respectively; K_s and K_r are saturated and relative hydraulic conductivity respectively, α and n are shape parameters, $m = 1 - 1/n$ S_e is effective saturation or normalized volumetric soil water content. α, n and λ are empirical parameters.

Salinity Leaching Requirements

$$LR = \frac{C_i}{C_d}$$

Where Ci is irrigation water Concentration & Cd is drainage water concentration or mean salinity concentration of the root zone.

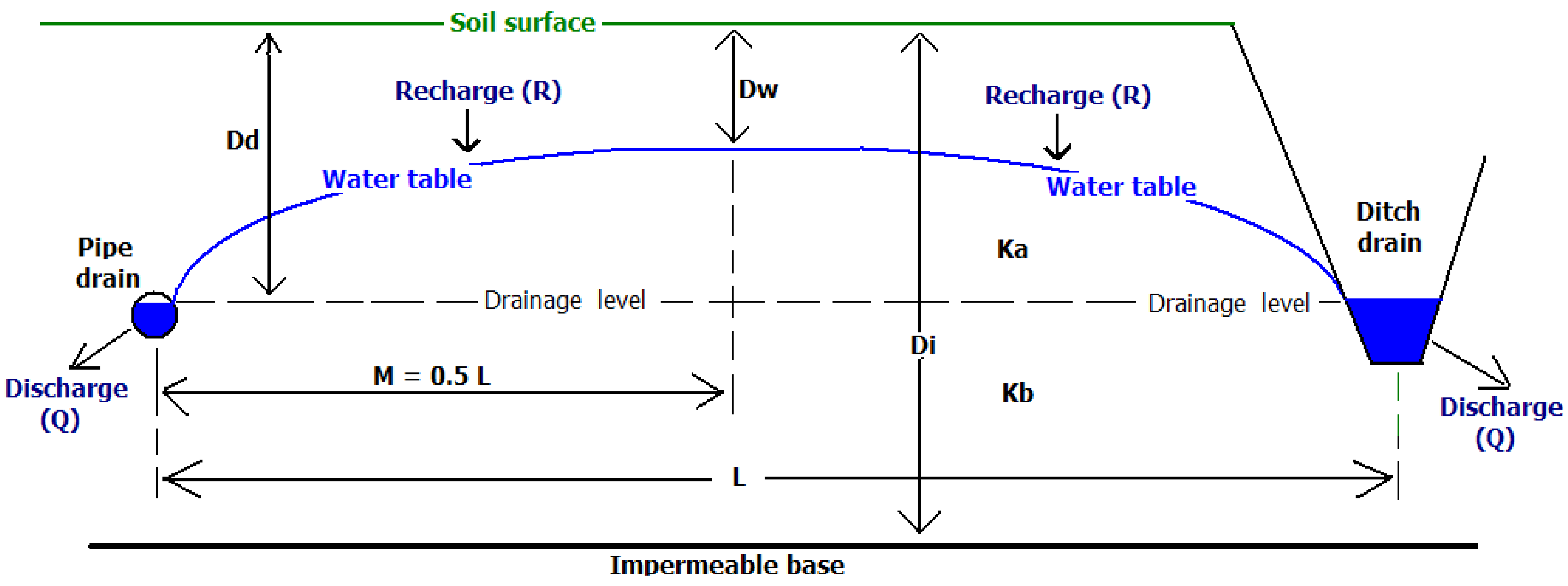
Sub surface drainage: Open and pipe drains



qL = (8Hm / L)(Kb x De + Ka x Ha)

Hooghoudt's equation was presented by Wesseling (1973).

Open and tiled Drainage System



Geometry subsurface drainage system by pipes or ditches

D = depth K = hydraulic conductivity L = Drain spacing

$$qL = (8Hm / L)(Kb \times De + Ka \times Ha)$$

Sub surface drainage

Hooghoudt's equation was presented by Wesseling (1973).

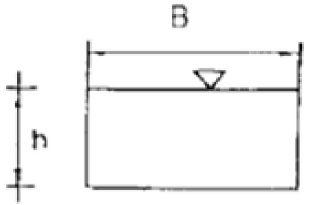
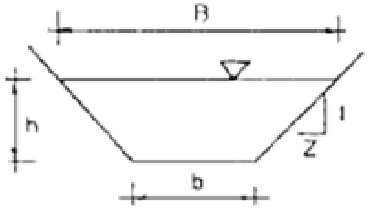
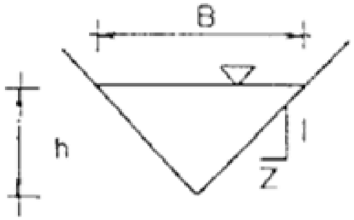
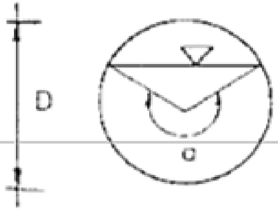
$$qL = (8Hm / L)(Kb \times De + Ka \times Ha) \qquad 1$$

where q is the steady recharge of water percolating to the water table equal to the drain discharge (m/day or m/hr), L is the drain spacing (m), Hm is the height of the water table midway between drains, taken with respect to the centre of the drain (m), Kb is the hydraulic conductivity of the soil below drain level (m/day or m/h), Ka is the hydraulic conductivity of the soil above drain level (m/day or m/h), De is Hooghoudt's equivalent depth to the impermeable layer below drain level, and Ha=Hm/2 is the average height of the water table above drain level.

Sub surface drainage

J. David Bankston[1], Jr. and Fred Eugene Baker[2]. 1995. Open Channel Flow in Aquaculture, Southern Regional Aquaculture Centre, SRAC Publication No. 374. March 1995.
[1]Louisiana Cooperative Extension Service and Sea Grant Program and [2]Louisiana Cooperative Extension Service, Louisiana State University Agricultural Centre.

Table 2. Channel section geometry and associated parameters.

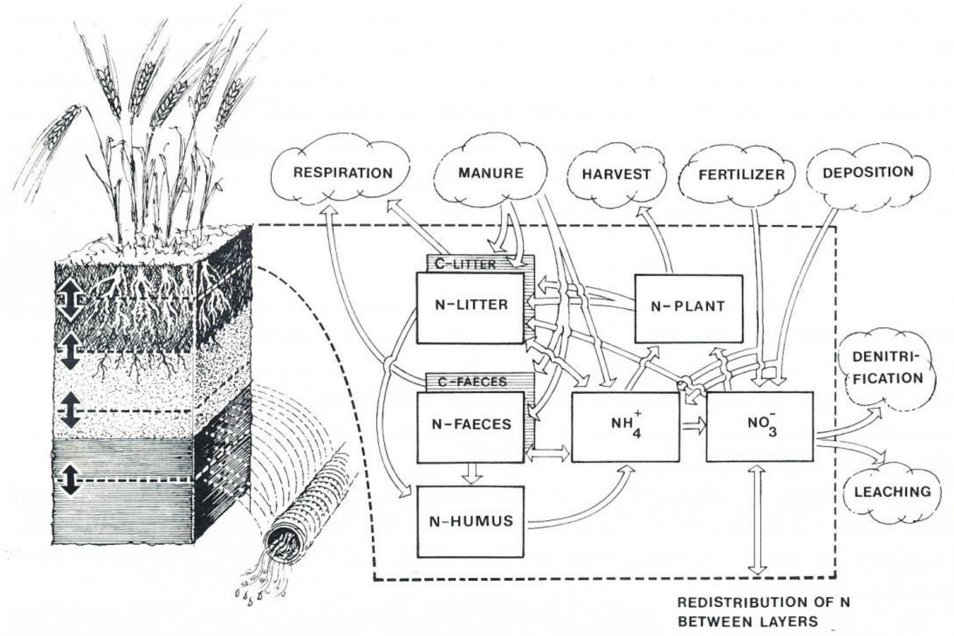
Section	Area A	Wetted perimeter P_w	Hydraulic radius $R = \frac{A}{P_w}$
	$B \times h$	$B + 2h$	$\frac{Bh}{B + 2h}$
	$(b + zh)h$	$b + 2h\sqrt{(1 + z^2)}$	$\frac{(b + zh)\,h}{b + 2h\sqrt{1 + z^2}}$
	zh^2	$2h\sqrt{1 + z^2}$	$\frac{zh}{2\sqrt{1 + z^2}}$
	$\frac{(\alpha - \sin\alpha)D^2}{8}$	$0.5\,\alpha D$	$0.25\left[\frac{1 - \sin\alpha}{\alpha}\right]D$

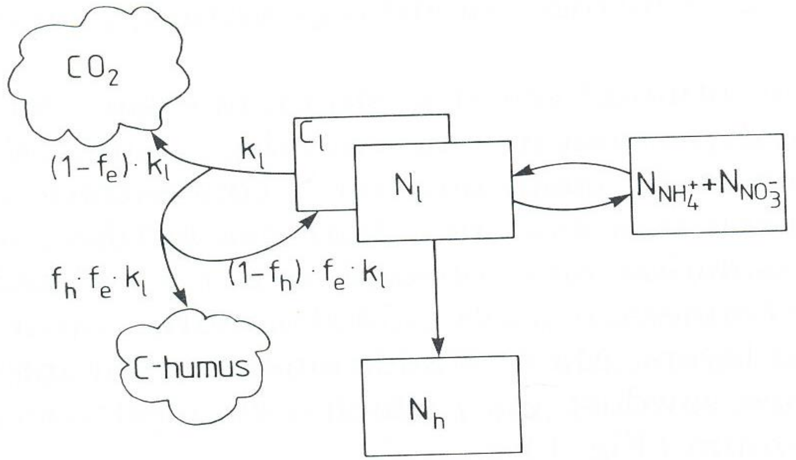
UK Centre for Ecology & Hydrology

Soil nitrogen cycle and processes according to Johnsson *et al.* (1987)

N- Processes include:

- Mineralization
- Immobilization
- Nitrification
- Denitrification
- Leaching
- Plant N Uptake





Mineralization of Humus

Mineralisation of humus, $N_h(z)$, is calculated as a first-order rate:

$$N_{h\rightarrow NH_4^+}(z) = k_h e_t(z) e_m(z) N_h(z)$$

where k_h is the specific mineralization constant and $e_t(z)$ and $e_m(z)$ are response functions for soil temperature and moisture, respectively.

$N_{h\rightarrow NH_4^+}(z)$ is in g nitrogen m^{-2} day^{-1}, kh is in day^{-1}, et and e_m are dimensionless, Nh(z) is in g nitrogen m^{-2}.

Mineralization rate= N amount in humus x mineralization rate X effect of temperature X effect of soil moisture

Mineralization of Litter

Decomposition of soil litter carbon, $C_l(z)$, is a function of a specific rate constant (k_l), temperature and moisture:

$$C_{l(d)}(z) = k_l e_t(z) e_m(z) C_l(z)$$

$C_{1(d)}(z)$ is expressed in g carbon m^{-2} day^{-1}; k_l in day^{-1}, e_t and e_m are dimensionless and $C_l(z)$ is in g carbon m^{-2}. The relative amounts of decomposition products formed:

$$C_{l\to CO_2}(z) = (1 - f_e) C_{l(d)}(z)$$

$$C_{l\to h}(z) = f_e f_h C_{l(d)}(z)$$

$$C_{l\to l}(z) = f_e (1 - f_h) C_{l(d)}(z)$$

Mineralization of Litter to NH4

Is governed by a synthesis efficiency constant (f_e) & a humification factor (f_h).

$C_{l \to CO_2}$, $C_{l \to h}$ and $C_{l \to l}$ are expressed in g carbon m^{-2} day^{-1}, $C_{l(d)}$ is in g carbon m^{-2}, f_e and f_h are dimensionless . Net mineralization or immobilisation of nitrogen in litter ($N_l(z)$) is then determined:

$$N_{l \to NH_4}(z) = \left[\frac{N_l(z)}{C_l(z)} - \frac{f_e}{r_o} \right] C_{l(d)}(z)$$

$N_{l \to NH_4}$ **is in g nitrogen m^{-2} day^{-1}, N_l is g nitrogen m^{-2}, C_l is g carbon m^{-2}, f_e and r_o (the C-N ratio of microorganisms and humified products) are dimensionless.**

Nitrification of NH4 to NO3

The transfer rate of ammonium to nitrate:

$$N_{NH_4 \rightarrow NO_3}(z) = k_n e_t(z) e_m(z) \left[N_{NH_4}(z) - \frac{N_{NO_3}(z)}{\eta_q} \right]$$

depends on the potential rate (k_n) which is reduced as the nitrate-ammonium ratio (η_q) is approached.

$N_{NH_4 \rightarrow NO_3}$ **is expressed in g nitrogen m^{-2} day^{-1},**

N_{NH_4} and N_{NO_3} **are in g nitrogen m^{-2}, k_n is in day^{-1}, and η_q, e_t and e_m are dimensionless.**

Denitrification of No3 to N2 and N2O

$$N_{NO_3\rightarrow}(z) = k_d(z)e_{md}(z)e_t(z)\left[\frac{[N_{NO_3}(z)]}{[N_{NO_3}(z)] + c_s}\right]$$

$N_{NO_3\rightarrow}$(z) and k_d(z) are expressed in g nitrogen m^{-2} d^{-1},

$N_{NO_3}(z)$ is in g nitrogen m^{-2}, C_s is in mg l^{-1}, e_t and e_{md} are dimensionless.

The effect of nitrate concentration is controlled by the half saturation-constant, Cs (i.e. the concentration where the rate is 50% of the maximum, if all other conditions are optimal.

Plant Nitrogen Uptake

A logistic uptake curve (greenwood et al., 1974) is used to define the cumulative potential N demand during the growing season:

$$\int u(t)\,dt = \frac{u_a}{1 + \frac{u_a - u_b}{u_b} e^{-u_c t}}$$

where u_a is the potential annual N uptake, u_b and u_c are shape parameters and t is days after the start of the growing season, u_a is expressed in g nitrogen m^{-2} season^{-1}. Daily uptake of nitrate is then calculated from the relative root fraction in the layer ($f(z)$), the proportion of total mineral N as nitrate and the derivative of the growth curve (u). u is obtained on daily basis expressed as gram nitrogen m^{-2} day^{-1},

$N_{NO_3}(z)$ **and** $N_{NH_4}(z)$ **are in gram nitrogen m^{-2}.**

Plant Nitrogen uptake

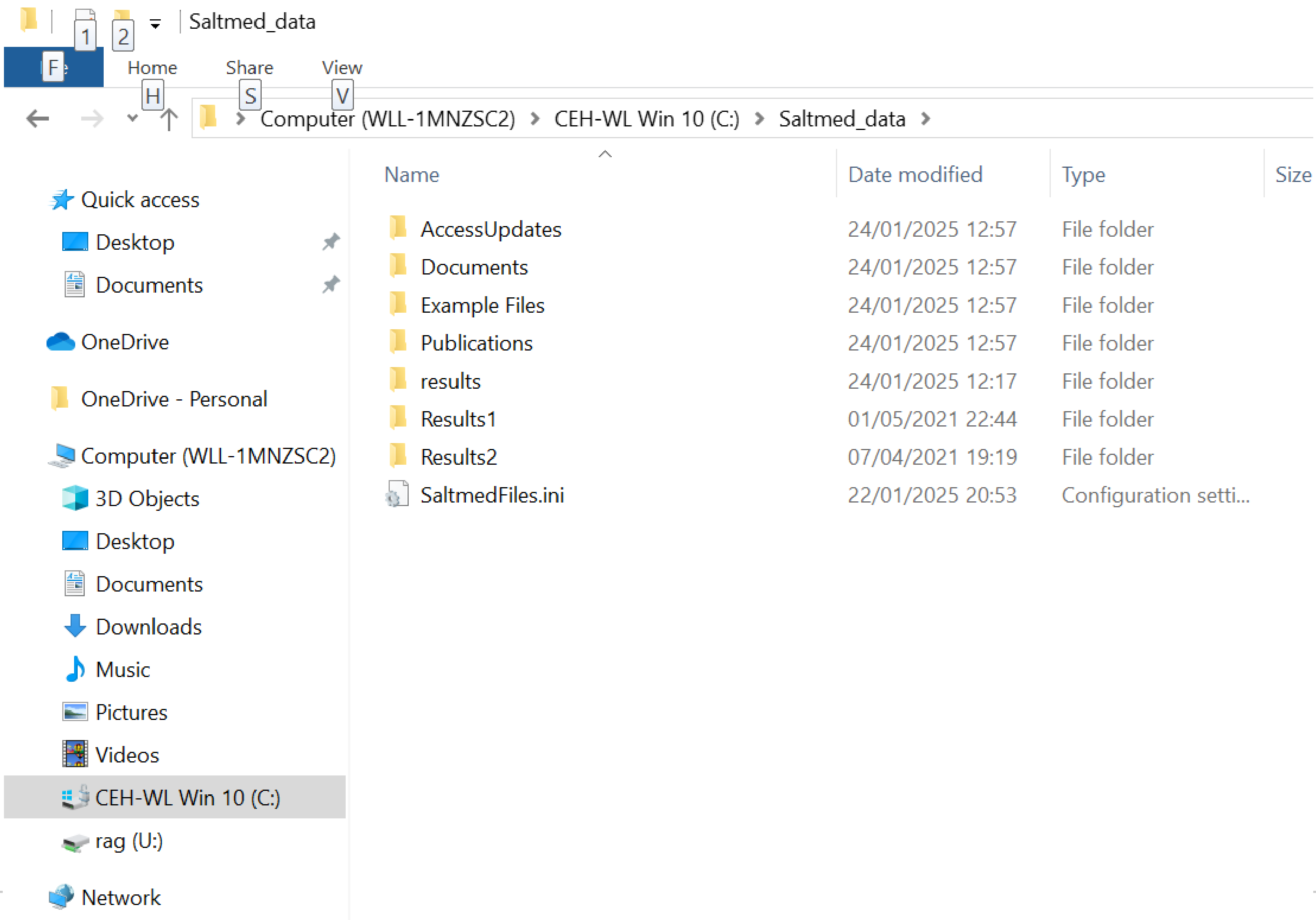
$$N_{NO_3\rightarrow}(z) = k_d(z)e_{md}(z)e_t(z)\left[\frac{[N_{NO_3}(z)]}{[N_{NO_3}(z)] + c_s}\right]$$

$N_{NO_3\rightarrow}$ **(z) and k_d(z) are expressed in g nitrogen m^{-2} d^{-1},**

$N_{NO_3}(z)$ **is in g nitrogen m^{-2}, C_s is in mg l^{-1}, e_t and e_{md} are dimensionless.**

$N_{NO_3\rightarrow p}(z) - MIN$ of $f_r(z)\frac{N_{NO_3}(z)}{N_{NO_3}(z) + N_{NH_4}(z)}u$ and $f_{ma}N_{NO_3}(z)$

SALTMED Model Folders



SALTMED Input

Input files of climate, irrigation , nitrogen, etc. are given as:
1. Excel files
2. Access database
3. Text files

Parameters Input

New Soil , crop, irrigation, etc. parameters are typed in and can be saved in database or /and as text file “smc” can be retrieved back.

SALTMED Results

Saved under “Results” folder as Excel.csv files or as Access database “Output.accdb“ if selected and text files or text files.

SALTMED Model Links

SALTMED 2019. The model is a free download from the following link:

The International Commission on Irrigation and Drainage, ICID web site: http://icid-ciid.org/inner_page/41

SALTMED online course on YouTube: https://www.youtube.com/watch?v=JRMeUFzuBYU

"SALTMED Publications in Irrigation and Drainage. Virtual Issues First published: 20 May 2020 Last updated: 20 May 2020. Wiley online Library". https://onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1531-0361.saltmed-publications

ICID Webinar on Use of saline water, 2020: http://icid-ciid.org/inner_page/131

How to install the model: https://www.youtube.com/watch?v=Rt-V87jlg3w

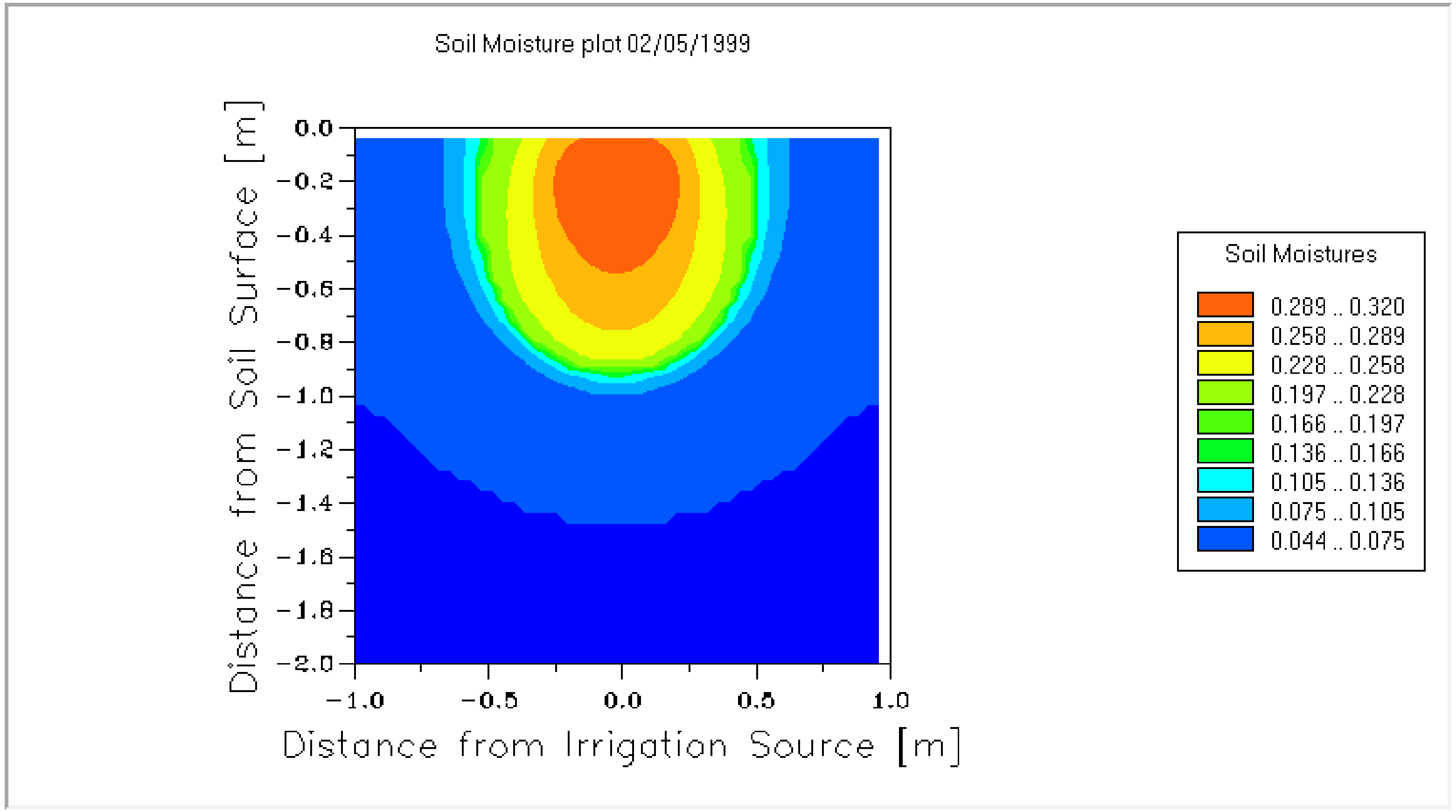
Frequently asked questions:
https://www.youtube.com/watch?v=vcOGQDjPQso&list=PLZYmrBXSZmBk4w_eIIDbYegjaluPaisp-&index=8

Troubleshooting: problems and solutions:

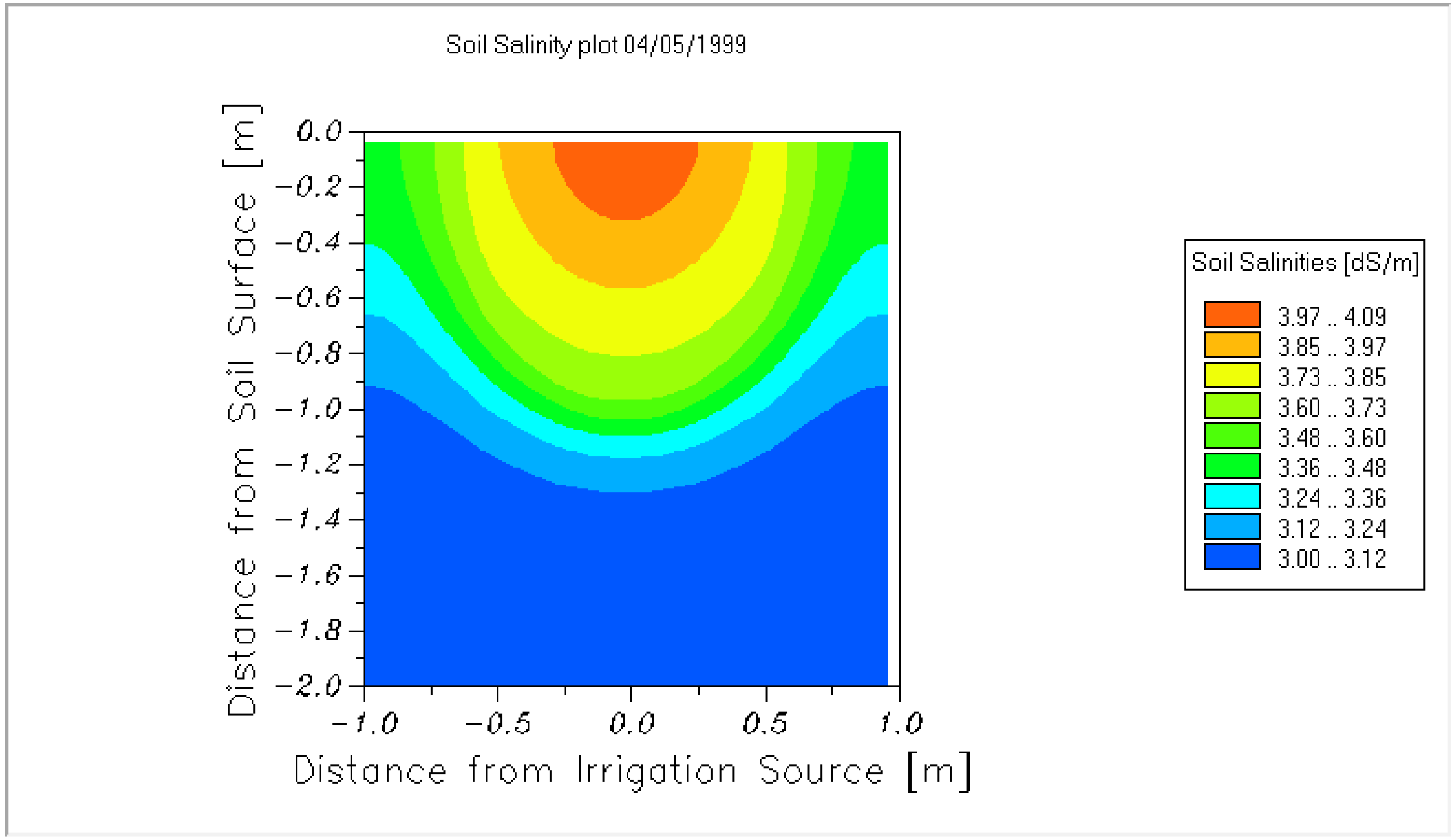
https://www.youtube.com/watch?v=8NnpllMtSuE&list=PLZYmrBXSZmBk4w_eIIDbYegjaluPaisp-
Individual Issues (8 Issues): Trouble shooting-Problems and solutions:
https://www.youtube.com/watch?v=8NnpllMtSuE
https://www.youtube.com/watch?v=3xvntZfomdA
https://www.youtube.com/watch?v=qVf_mB2Eh9k
https://www.youtube.com/watch?v=CSdl6w3oE4Y
https://www.youtube.com/watch?v=s9js_Bmgg6k
https://www.youtube.com/watch?v=RVe4_Z742gI
https://www.youtube.com/watch?v=Q7DZvSLjYhM
https://www.youtube.com/watch?v=vcOGQDjPQso

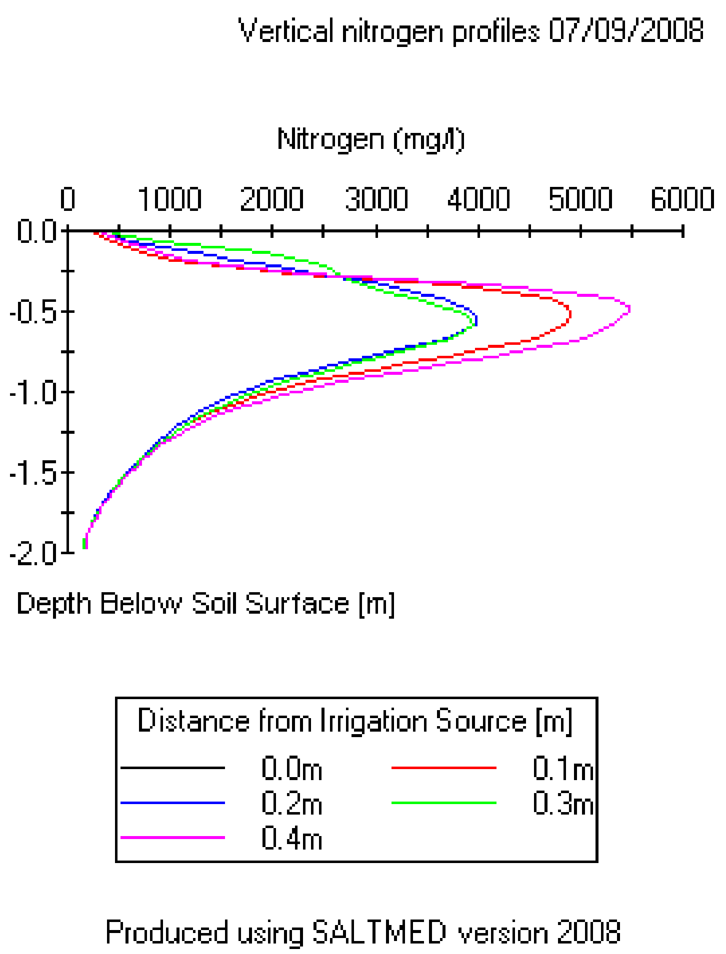
Real time on screen graphic output during the model run

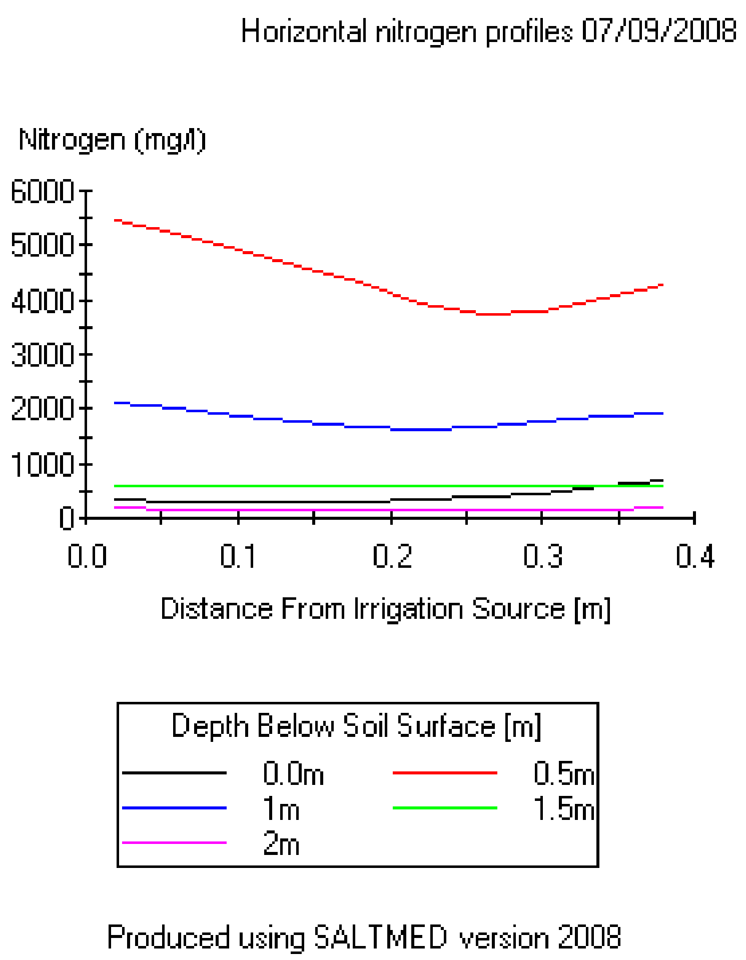
Evolution of soil moisture profile over time under trickle line source



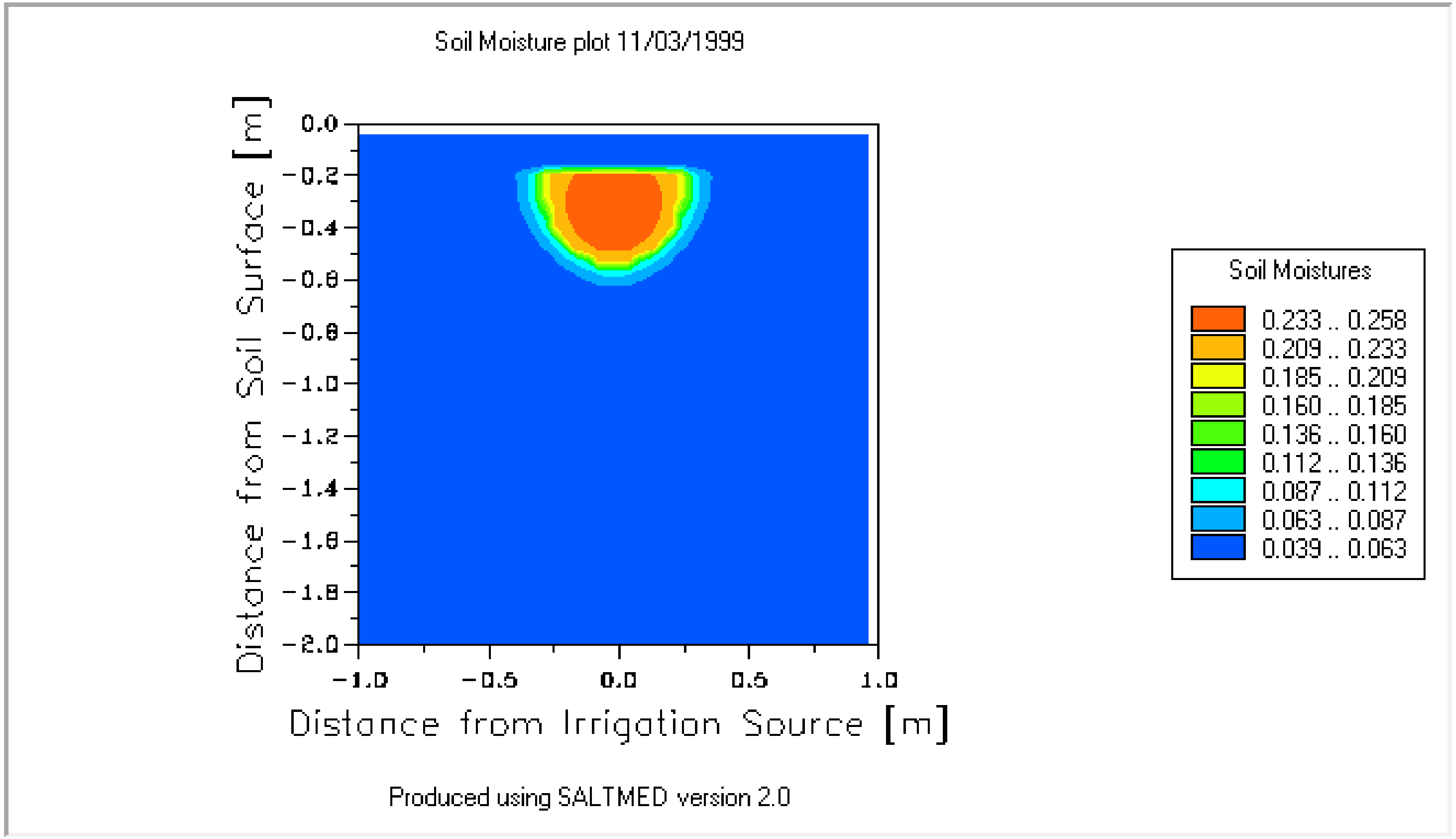
Evolution of soil salinity profile over time under trickle line source



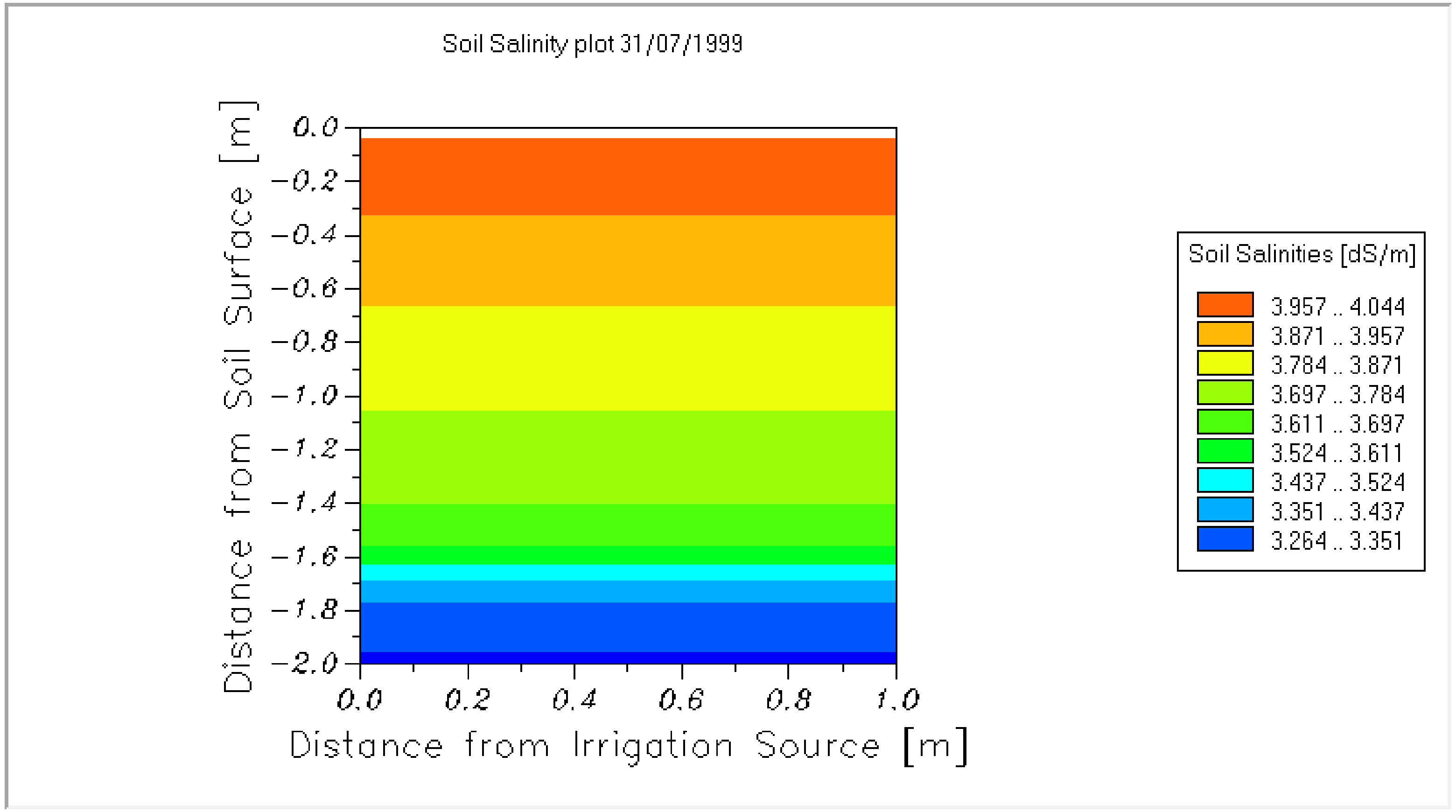

Vertical nitrogen profiles 07/09/2008
Nitrogen (mg/l)
0
1000
2000
3000
4000
5000
6000
0.0
-0.5
-1.0
-1.5
-2.0
Depth Below Soil Surface [m]
Distance from Irrigation Source [m]
0.0m
0.1m
0.2m
0.3m
0.4m
Produced using SALTMED version 2008


Horizontal nitrogen profiles 07/09/2008
Nitrogen (mg/l)
6000
5000
4000
3000
2000
1000
0
0.0
0.1
0.2
0.3
0.4
Distance From Irrigation Source [m]
Depth Below Soil Surface [m]
0.0m
0.5m
1m
1.5m
2m
Produced using SALTMED version 2008

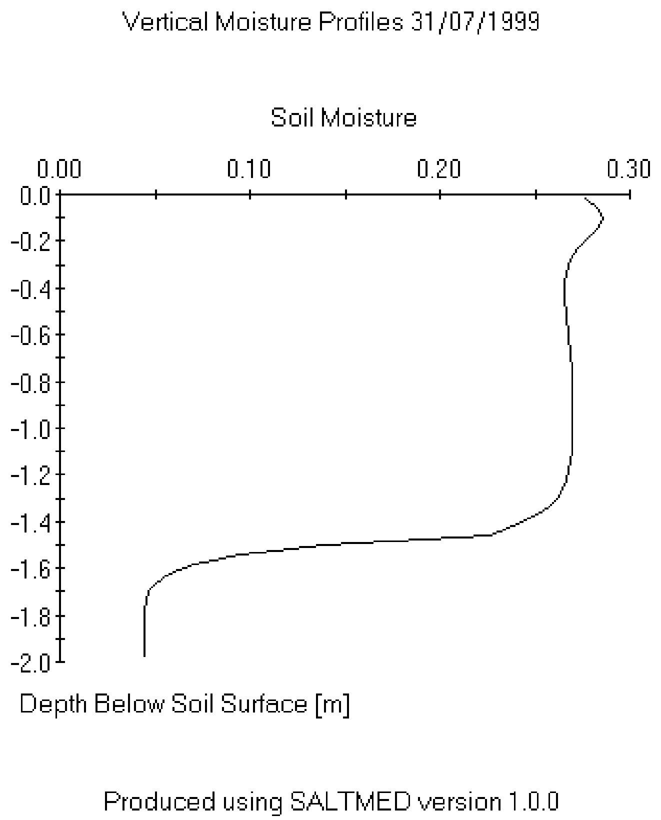
Evolution of soil moisture profile over time under sub-surface trickle line source

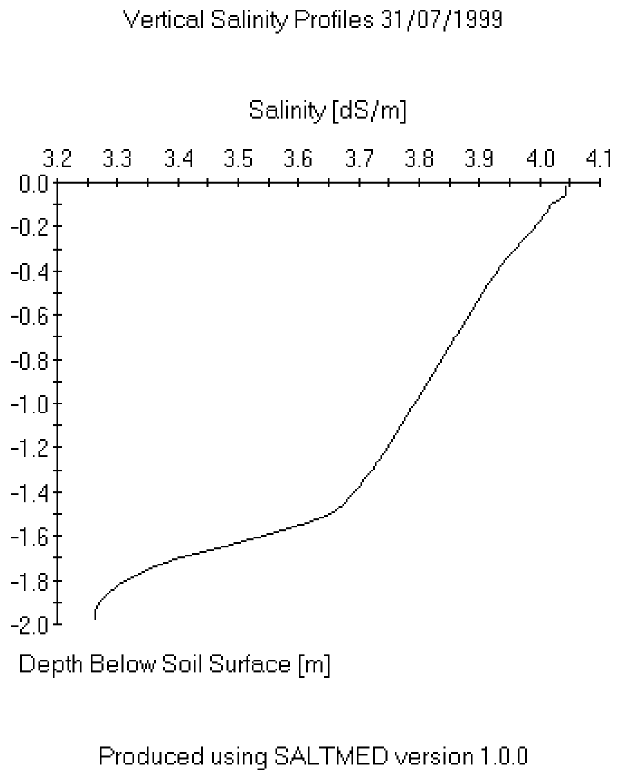


Salinity profile under basin irrigation

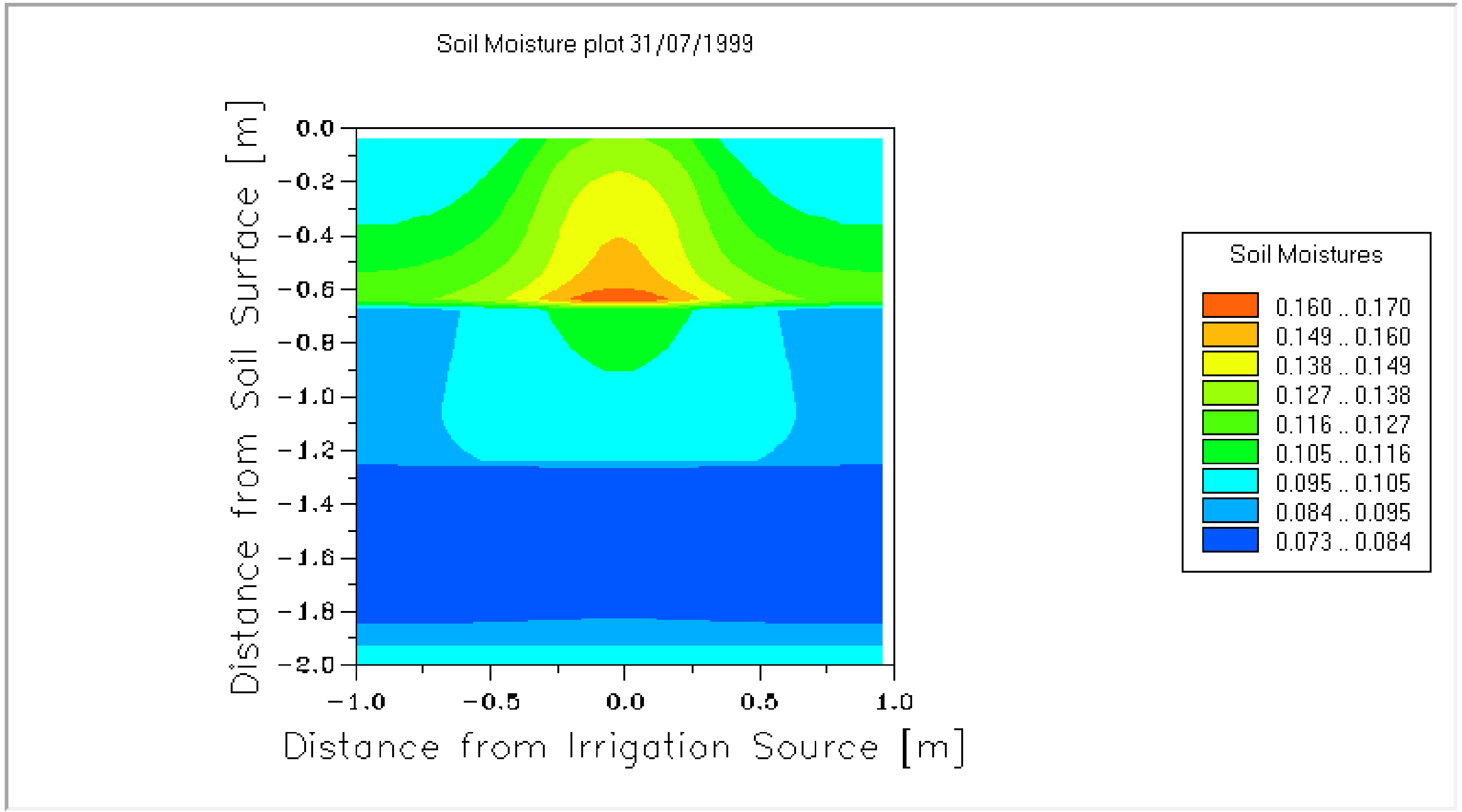


Soil moisture and salinity distribution under basin irrigation

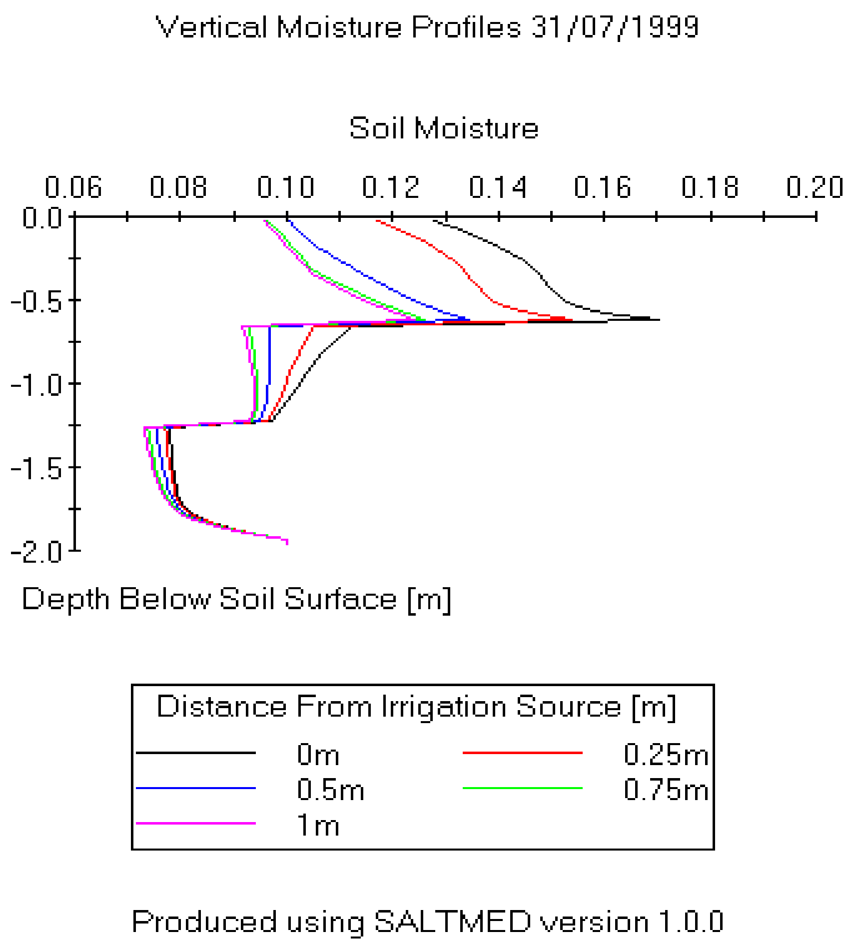




Evolution of soil moisture over time under trickle line source- 3 different soil layers



Soil moisture profile of multilayers



Partial Root Drying , PRD

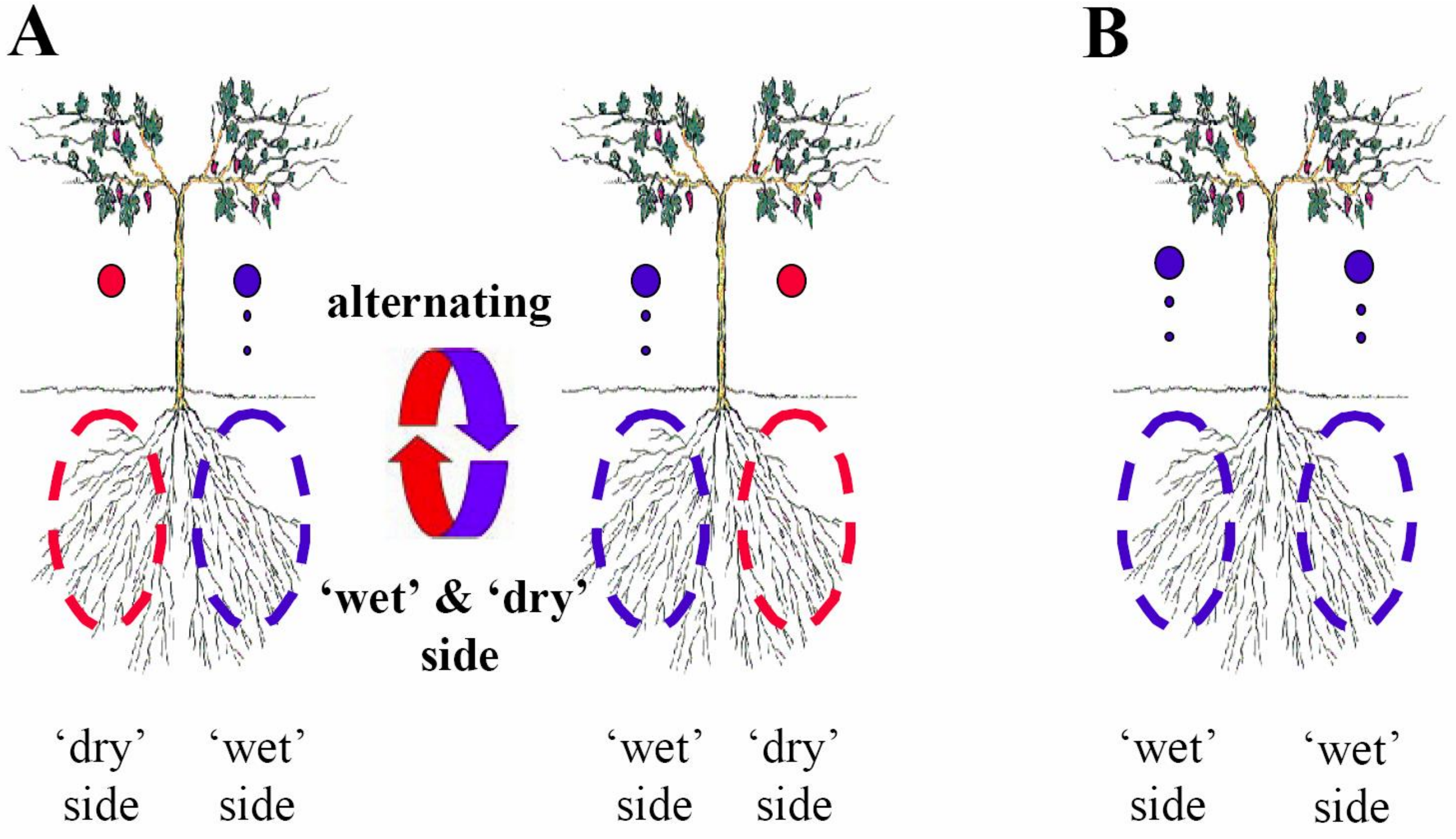
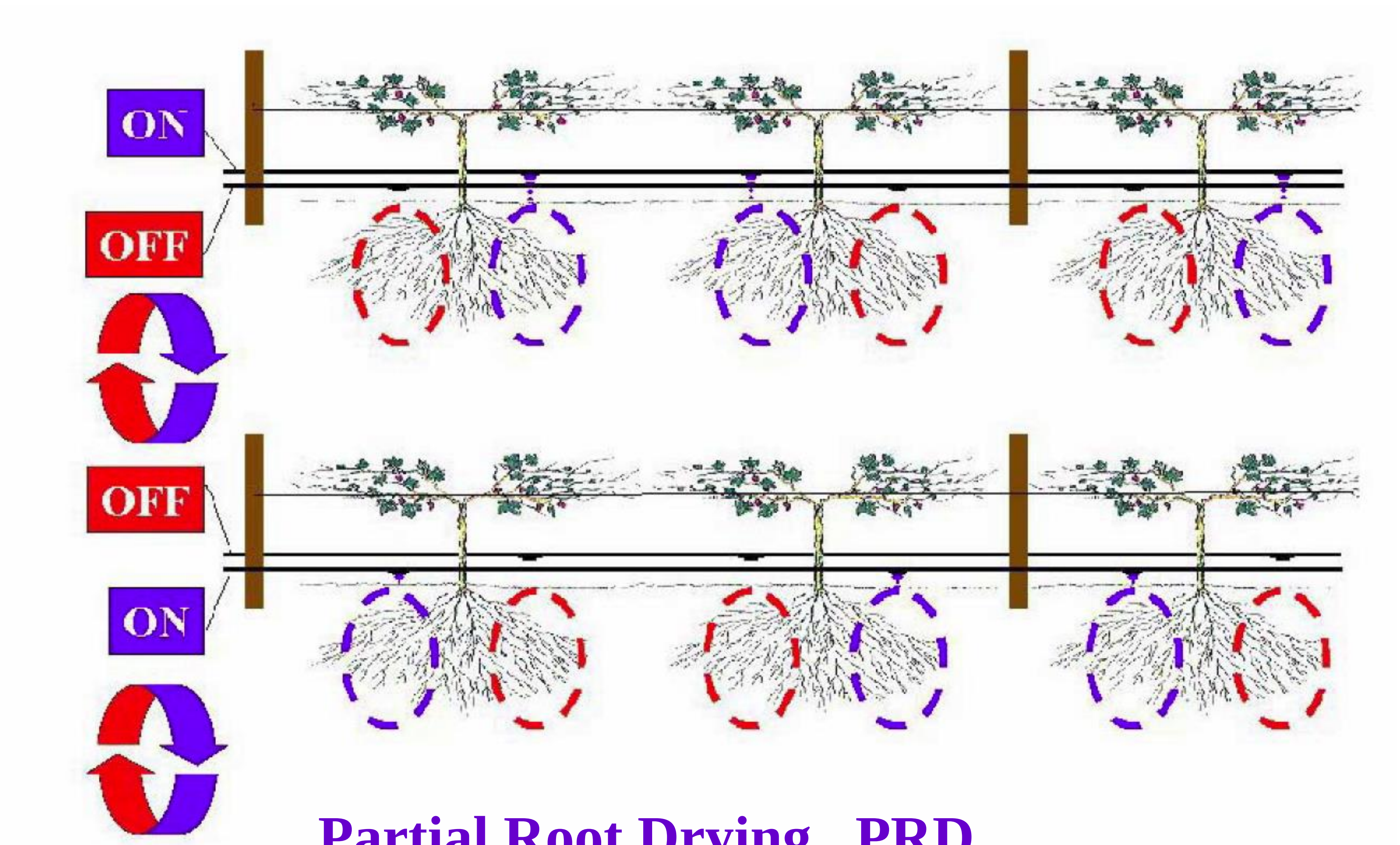
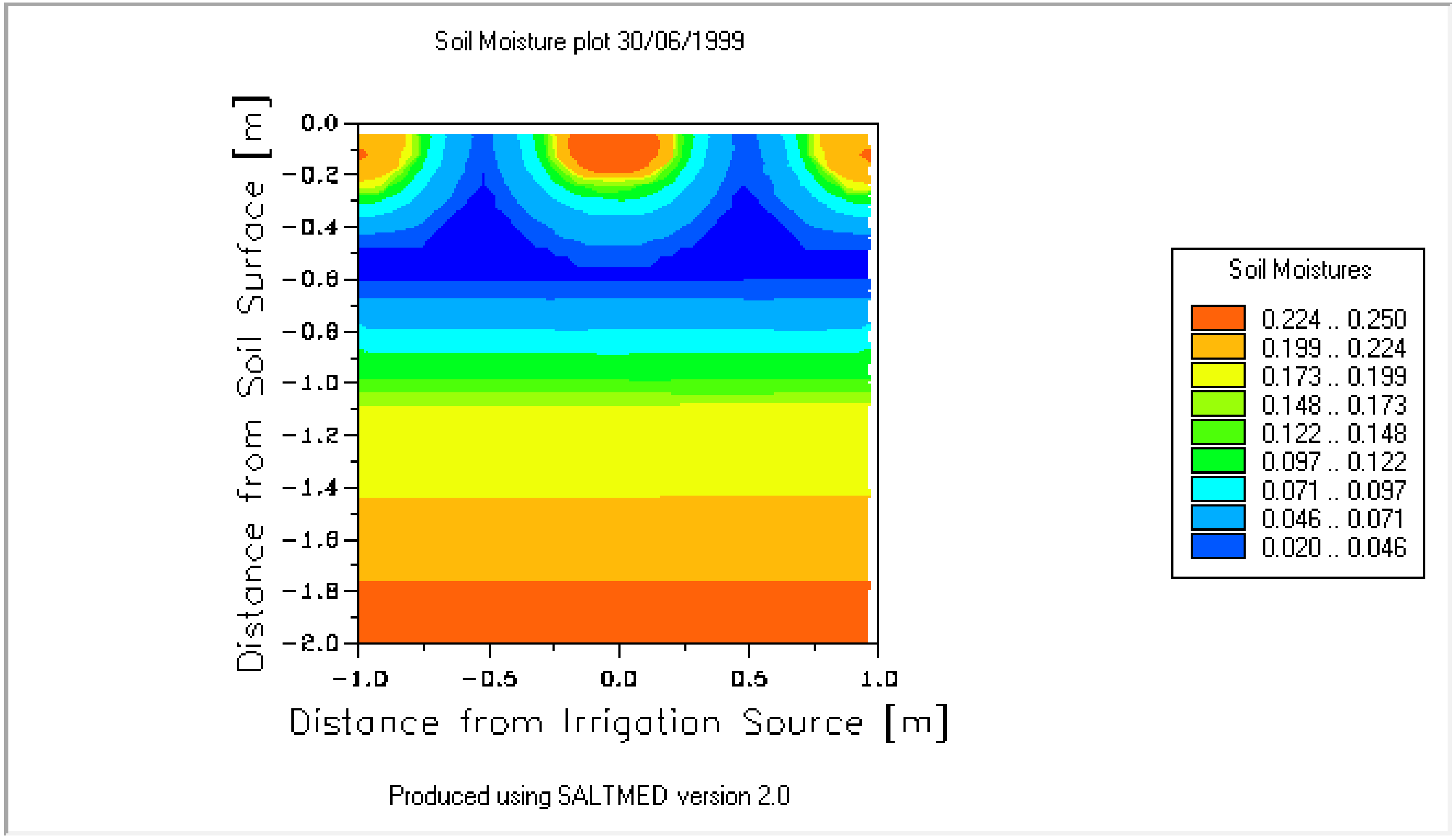
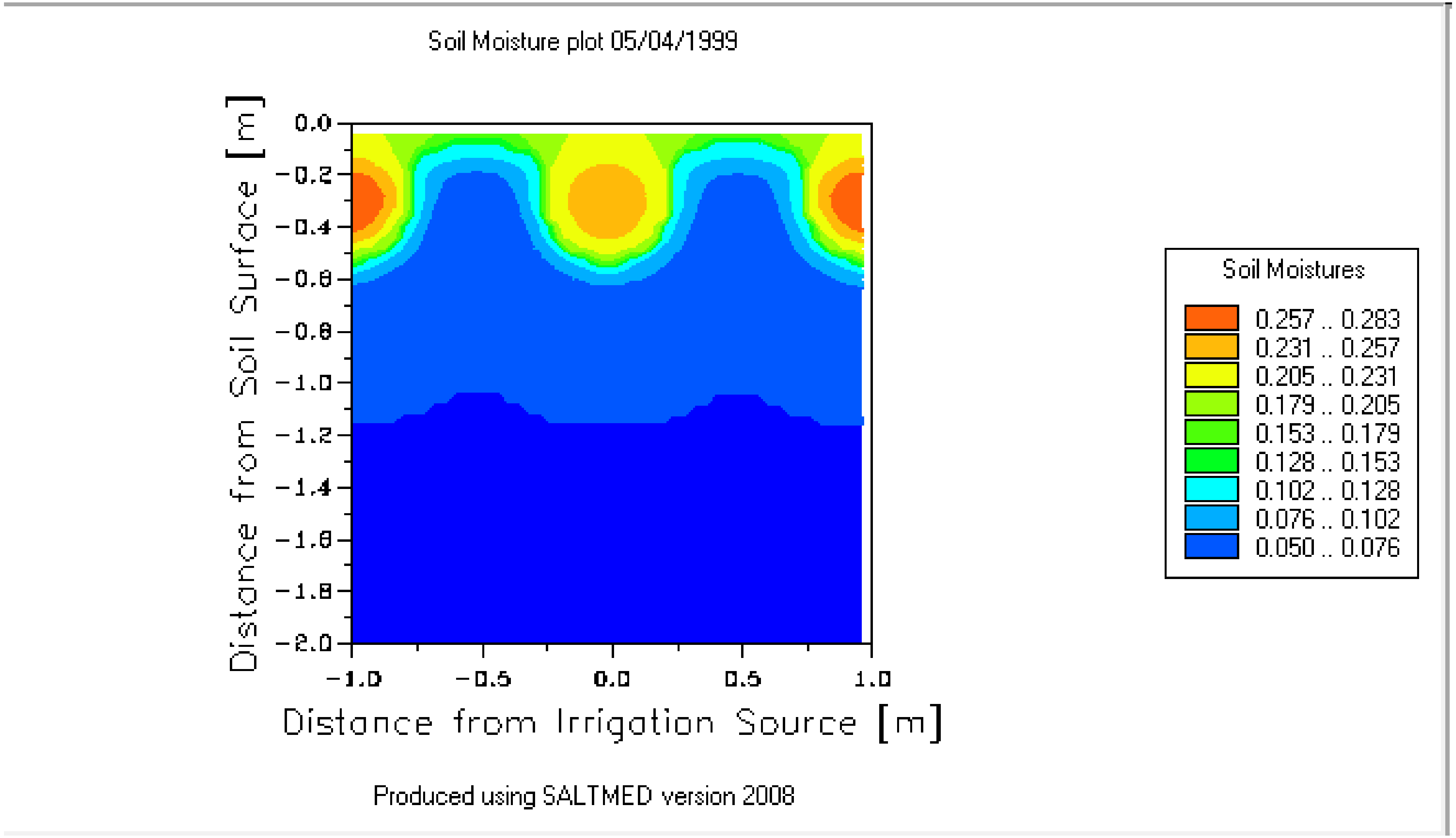


Figure 2.1 Implementation of PRD irrigation set up: A) PRD: at any time water was withheld from one side; B) control: vines received water on both sides.



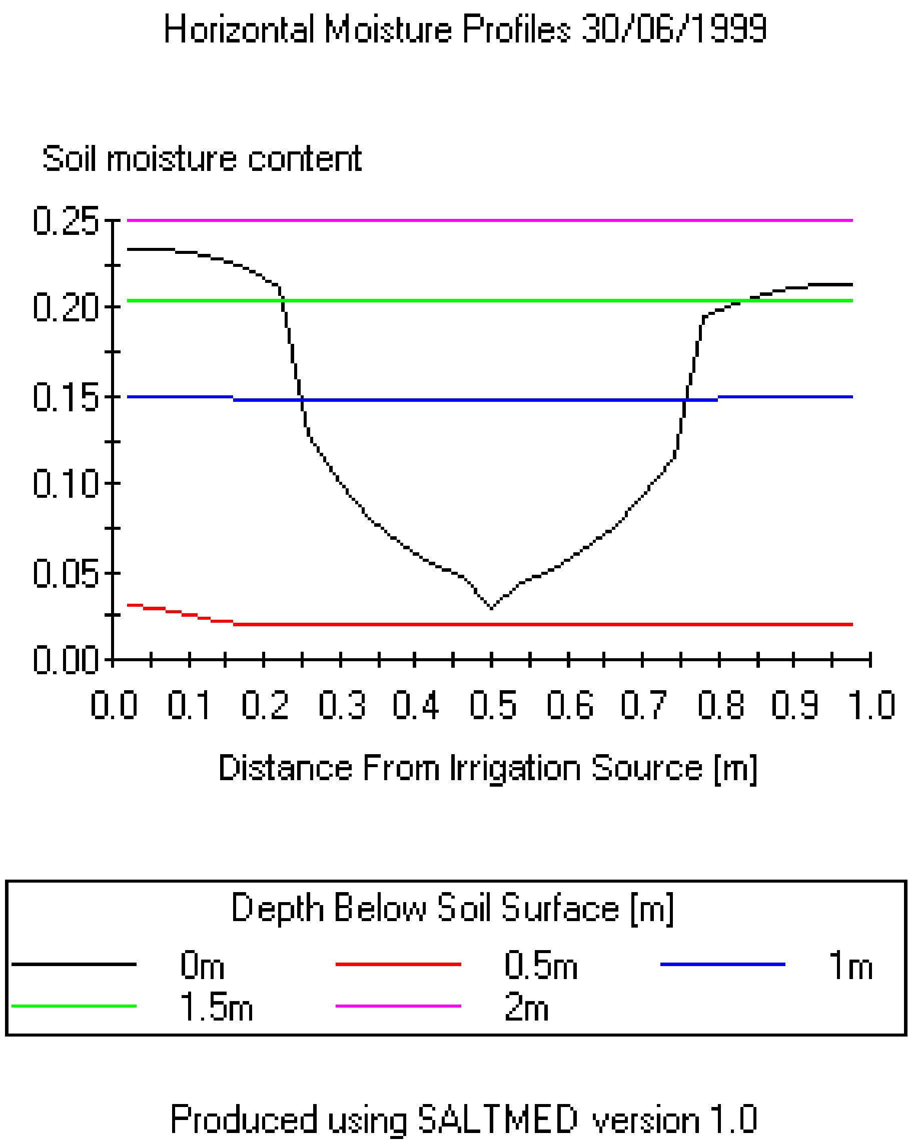
Partial Root Drying , PRD


Soil Moisture plot 30/06/1999
Distance from Soil Surface [m]
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
-1.0
-0.5
0.0
0.5
1.0
Distance from Irrigation Source [m]
Soil Moistures
0.224 .. 0.250
0.199 .. 0.224
0.173 .. 0.199
0.148 .. 0.173
0.122 .. 0.148
0.097 .. 0.122
0.071 .. 0.097
0.046 .. 0.071
0.020 .. 0.046
Produced using SALTMED version 2.0

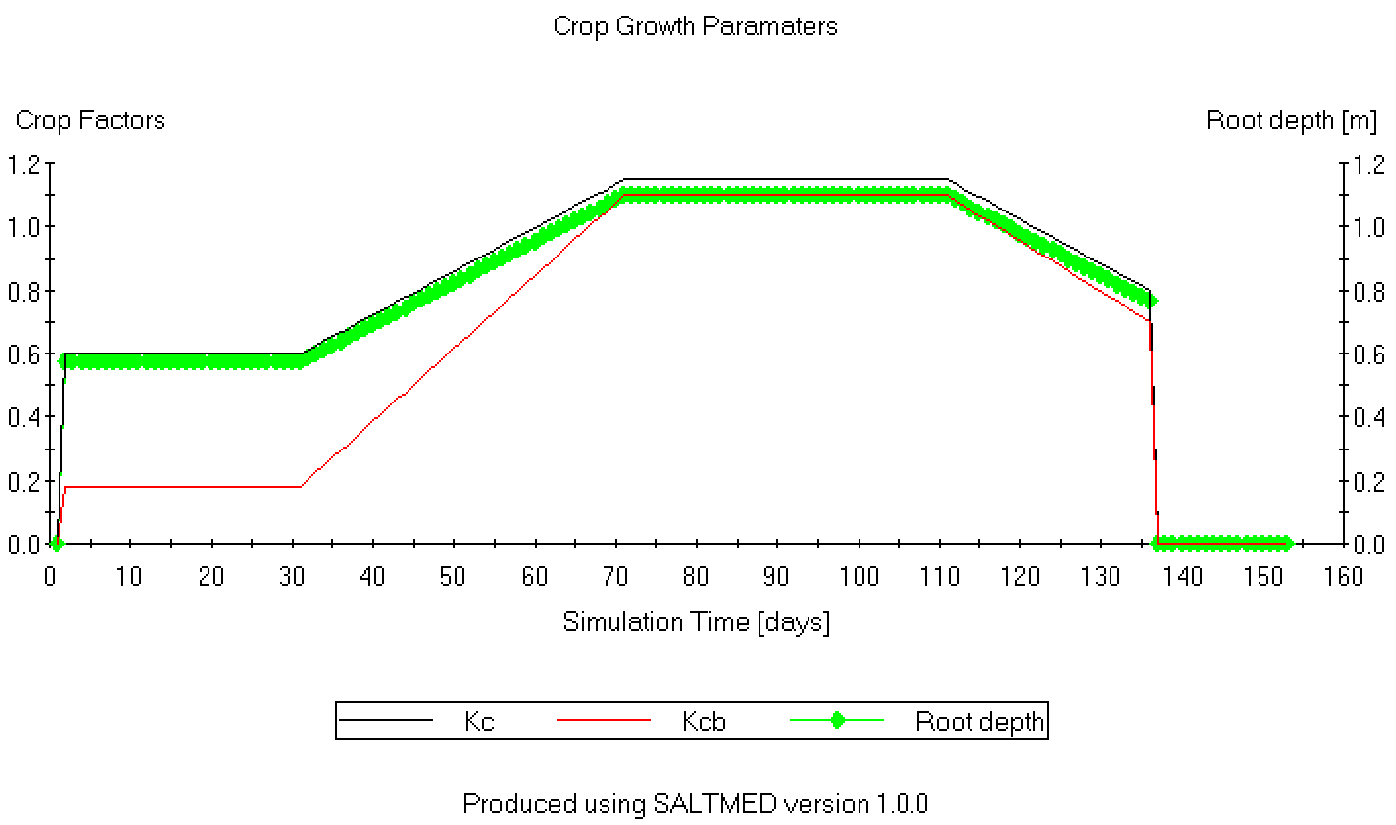


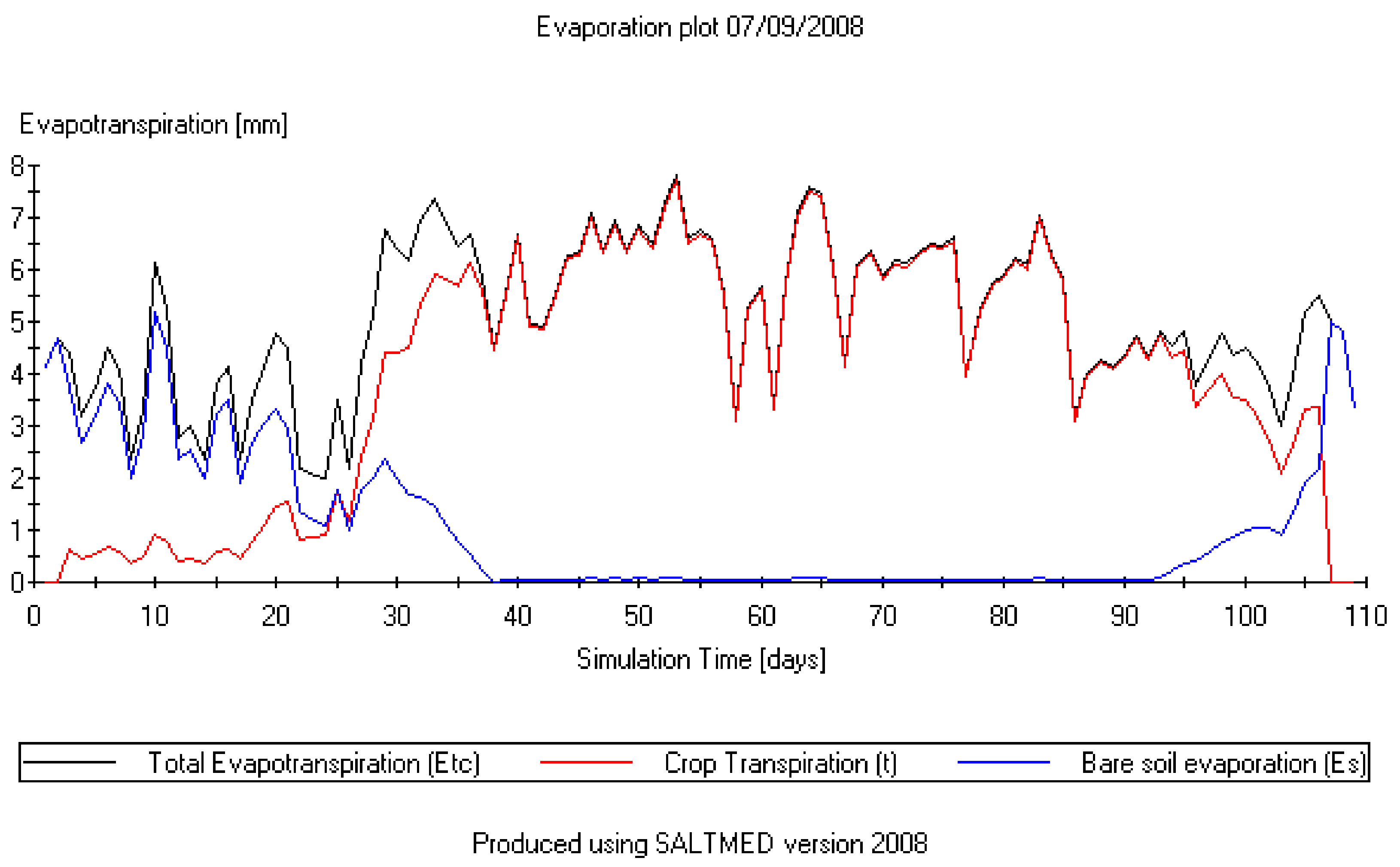
Soil Moisture plot 05/04/1999
Distance from Soil Surface [m]
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
-1.0
-0.5
0.0
0.5
1.0
Distance from Irrigation Source [m]
Soil Moistures
0.257 .. 0.283
0.231 .. 0.257
0.205 .. 0.231
0.179 .. 0.205
0.153 .. 0.179
0.128 .. 0.153
0.102 .. 0.128
0.076 .. 0.102
0.050 .. 0.076
Produced using SALTMED version 2008

PRD- Soil moisture

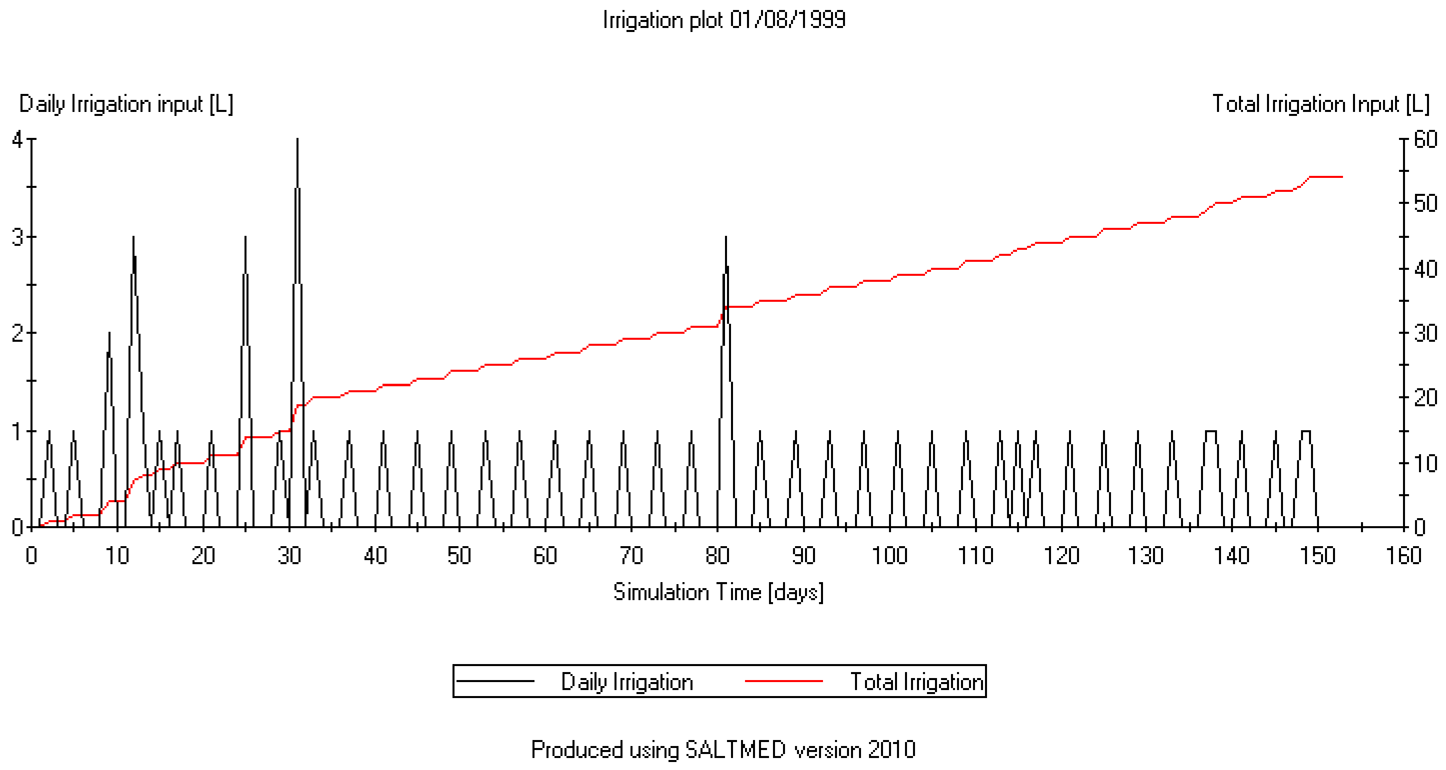


Evolution of crop parameters Kc, Kcb and root depth over time

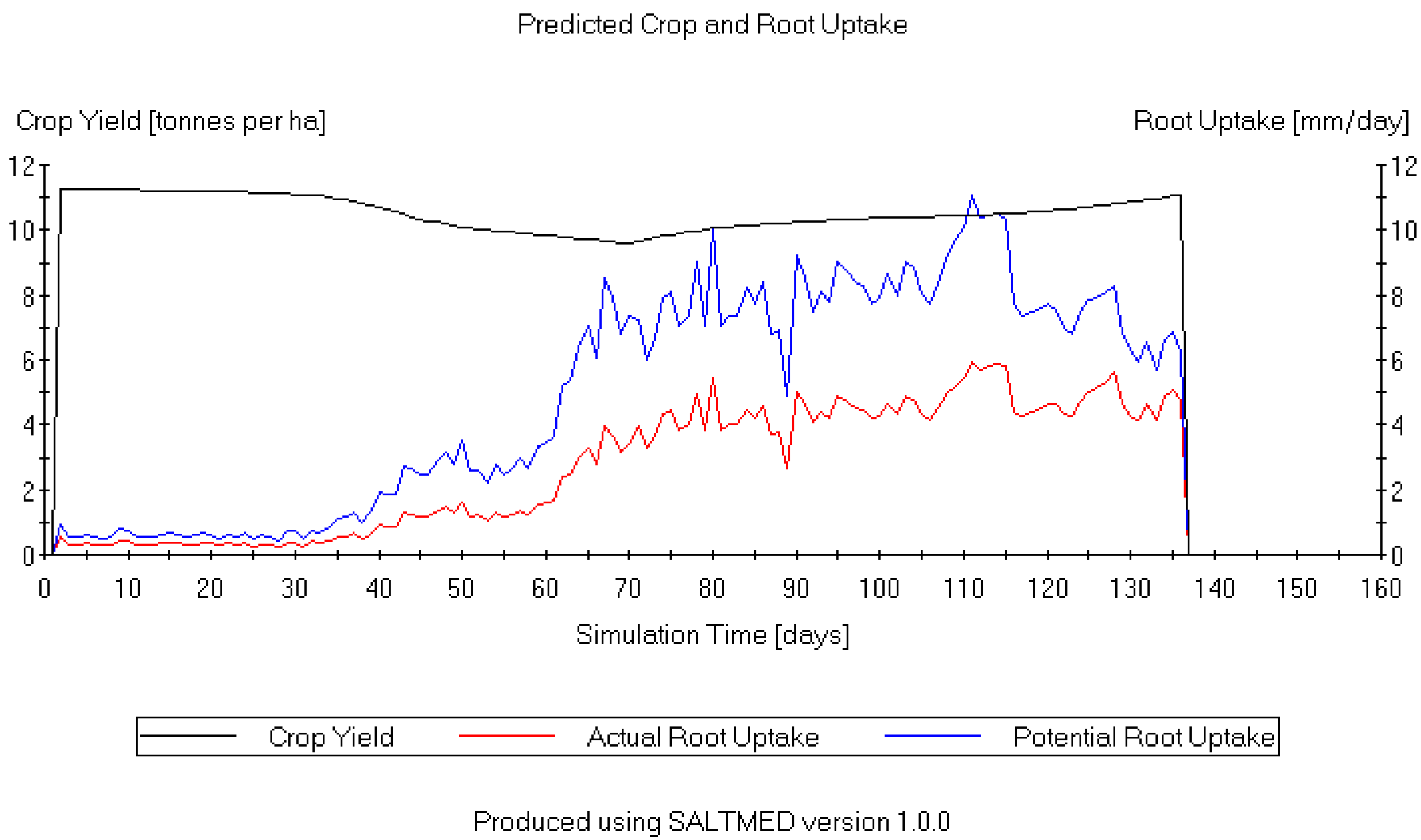


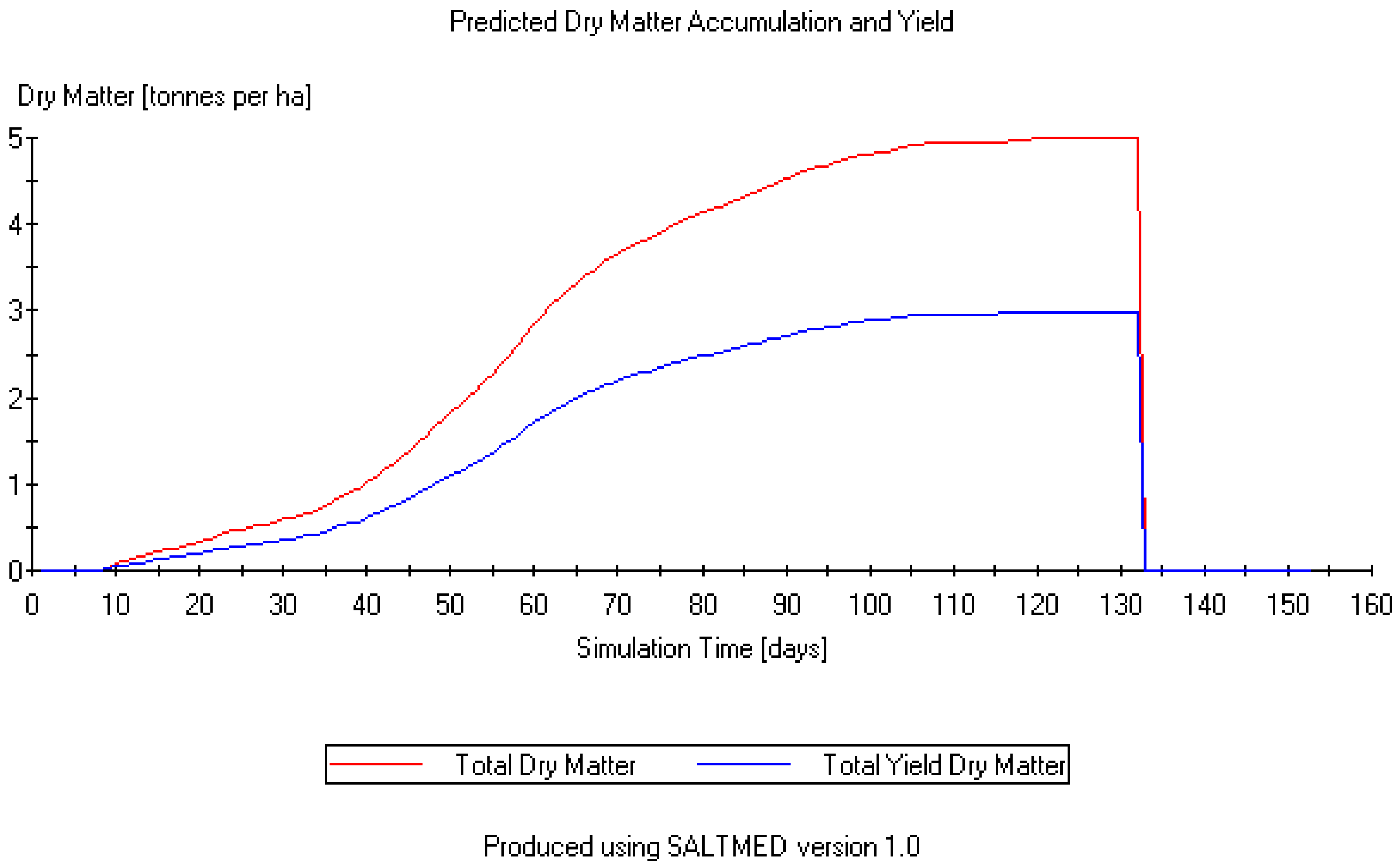

Evaporation plot 07/09/2008
Evapotranspiration [mm]
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
110
Simulation Time [days]
Total Evapotranspiration (Etc)
Crop Transpiration (t)
Bare soil evaporation (Es)
Produced using SALTMED version 2008

Irrigation + rainfall

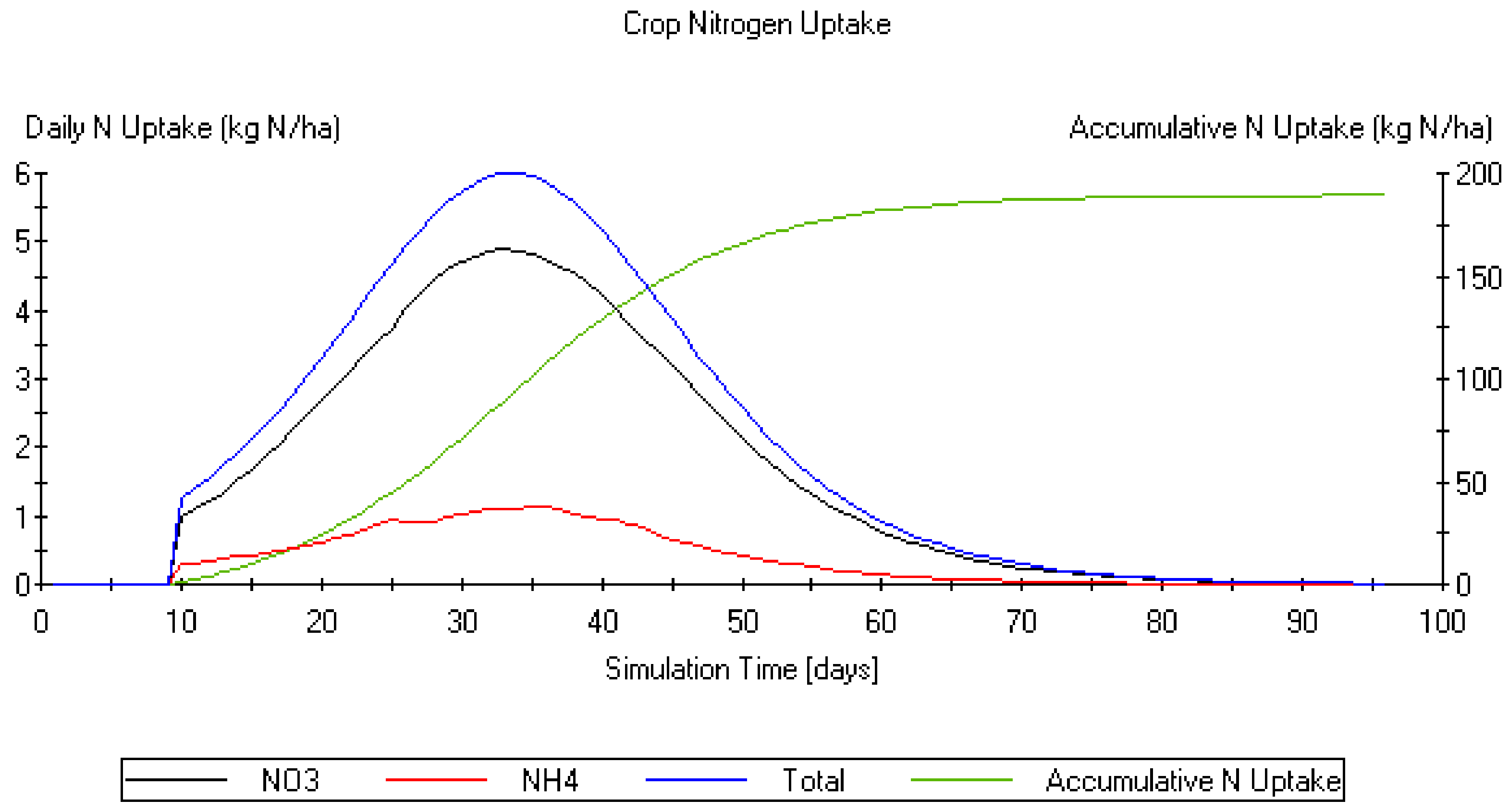


Crop potential and actual water uptake and yield

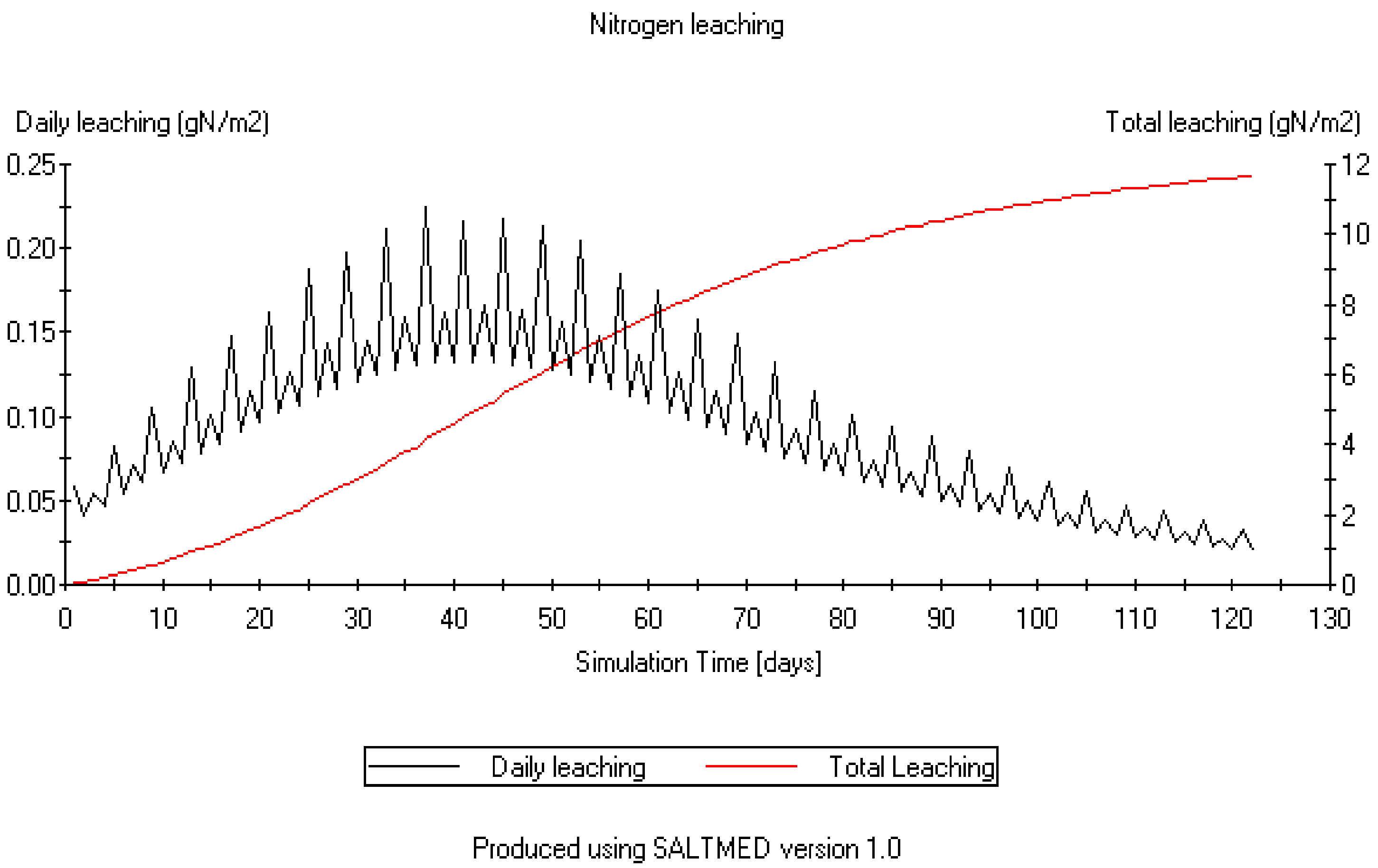




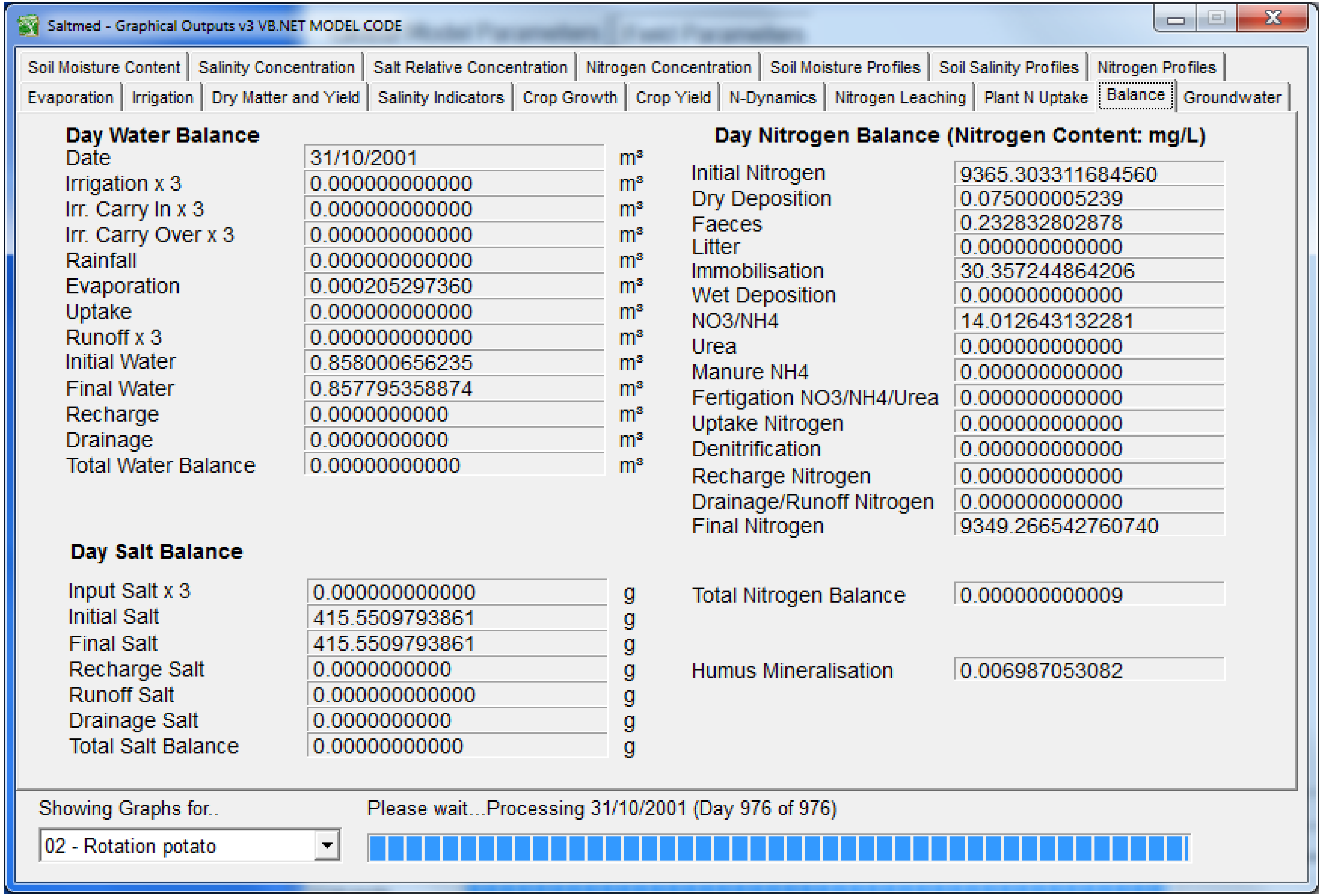
Predicted Dry Matter Accumulation and Yield
Dry Matter [tonnes per ha]
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Simulation Time [days]
Total Dry Matter
Total Yield Dry Matter
Produced using SALTMED version 1.0



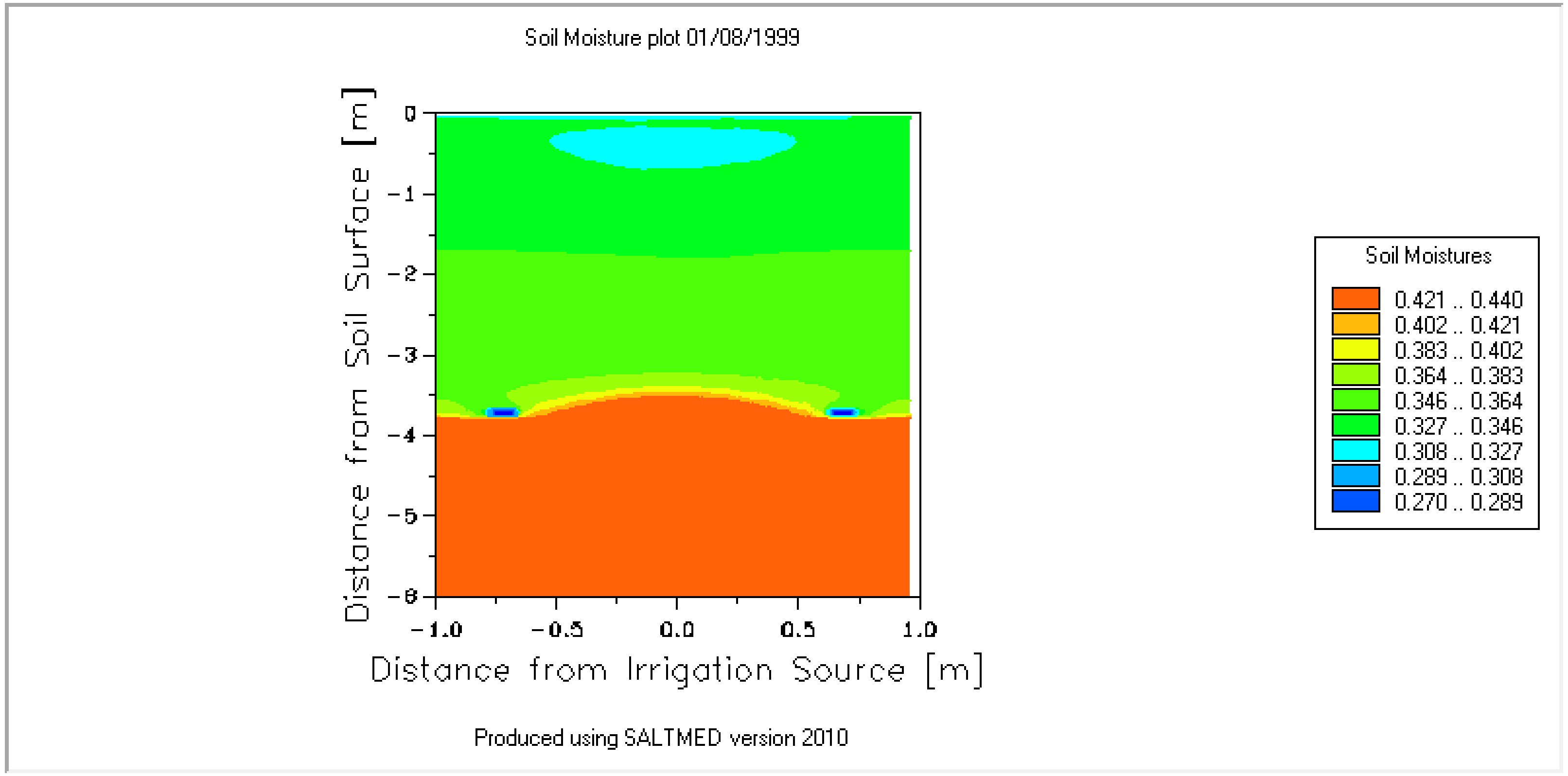
Produced using SALTMED version 1.0

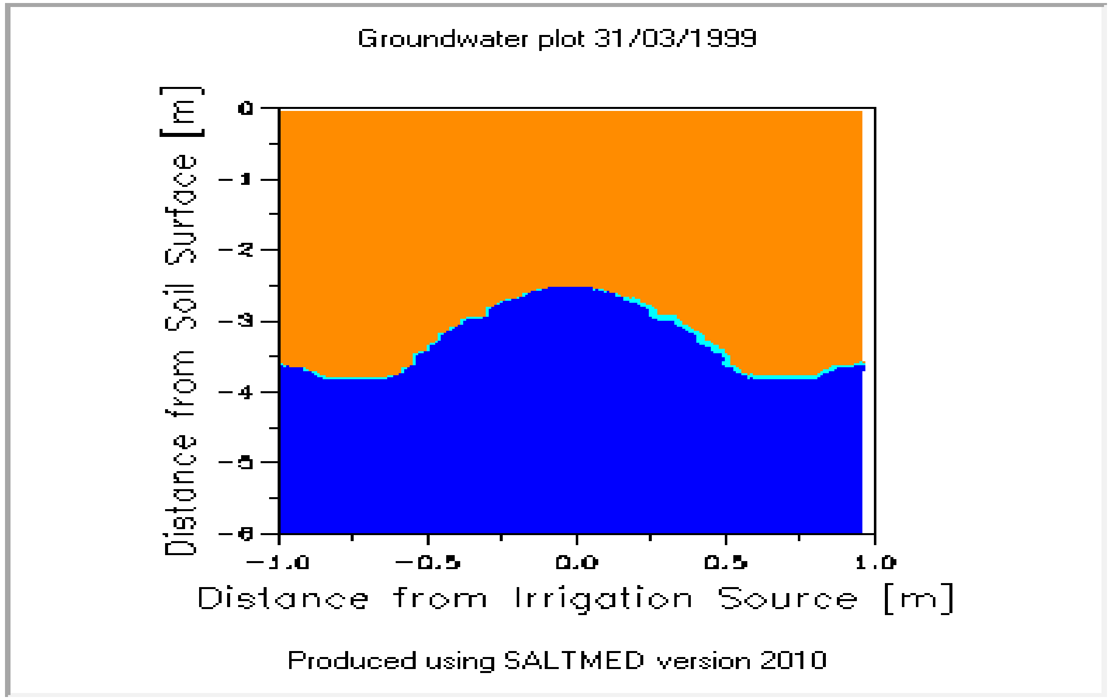


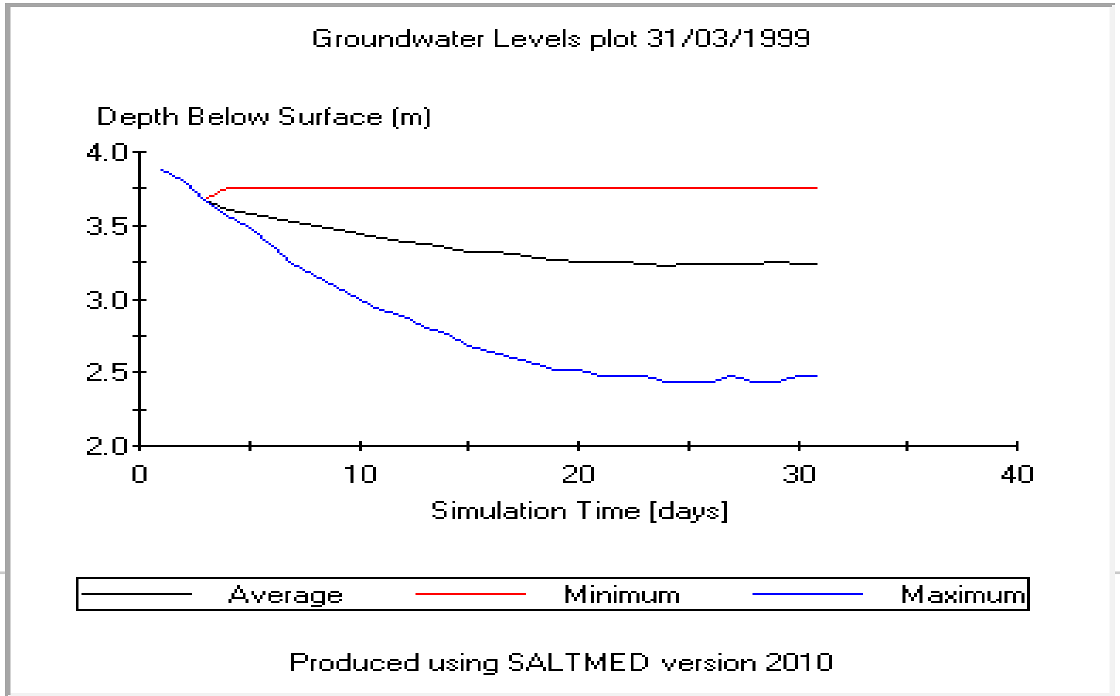
Nitrogen leaching
Daily leaching (gN/m2)
Total leaching (gN/m2)
0.25
0.20
0.15
0.10
0.05
0.00
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Simulation Time [days]
Daily leaching
Total Leaching
Produced using SALTMED version 1.0


Saltmed - Graphical Outputs v3 VB.NET MODEL CODE
Soil Moisture Content
Salinity Concentration
Salt Relative Concentration
Nitrogen Concentration
Soil Moisture Profiles
Soil Salinity Profiles
Nitrogen Profiles
Evaporation
Irrigation
Dry Matter and Yield
Salinity Indicators
Crop Growth
Crop Yield
N-Dynamics
Nitrogen Leaching
Plant N Uptake
Balance
Groundwater
Day Water Balance
Date 31/10/2001 m³
Irrigation x 3 0.000000000000 m³
Irr. Carry In x 3 0.000000000000 m³
Irr. Carry Over x 3 0.000000000000 m³
Rainfall 0.000000000000 m³
Evaporation 0.000205297360 m³
Uptake 0.000000000000 m³
Runoff x 3 0.000000000000 m³
Initial Water 0.858000656235 m³
Final Water 0.857795358874 m³
Recharge 0.0000000000 m³
Drainage 0.0000000000 m³
Total Water Balance 0.00000000000 m³
Day Salt Balance
Input Salt x 3 0.000000000000 g
Initial Salt 415.5509793861 g
Final Salt 415.5509793861 g
Recharge Salt 0.0000000000 g
Runoff Salt 0.000000000000 g
Drainage Salt 0.0000000000 g
Total Salt Balance 0.00000000000 g
Day Nitrogen Balance (Nitrogen Content: mg/L)
Initial Nitrogen 9365.303311684560
Dry Deposition 0.075000005239
Faeces 0.232832802878
Litter 0.000000000000
Immobilisation 30.357244864206
Wet Deposition 0.000000000000
NO3/NH4 14.012643132281
Urea 0.000000000000
Manure NH4 0.000000000000
Fertigation NO3/NH4/Urea 0.000000000000
Uptake Nitrogen 0.000000000000
Denitrification 0.000000000000
Recharge Nitrogen 0.000000000000
Drainage/Runoff Nitrogen 0.000000000000
Final Nitrogen 9349.266542760740
Total Nitrogen Balance 0.000000000009
Humus Mineralisation 0.006987053082
Showing Graphs for..
02 - Rotation potato
Please wait...Processing 31/10/2001 (Day 976 of 976)

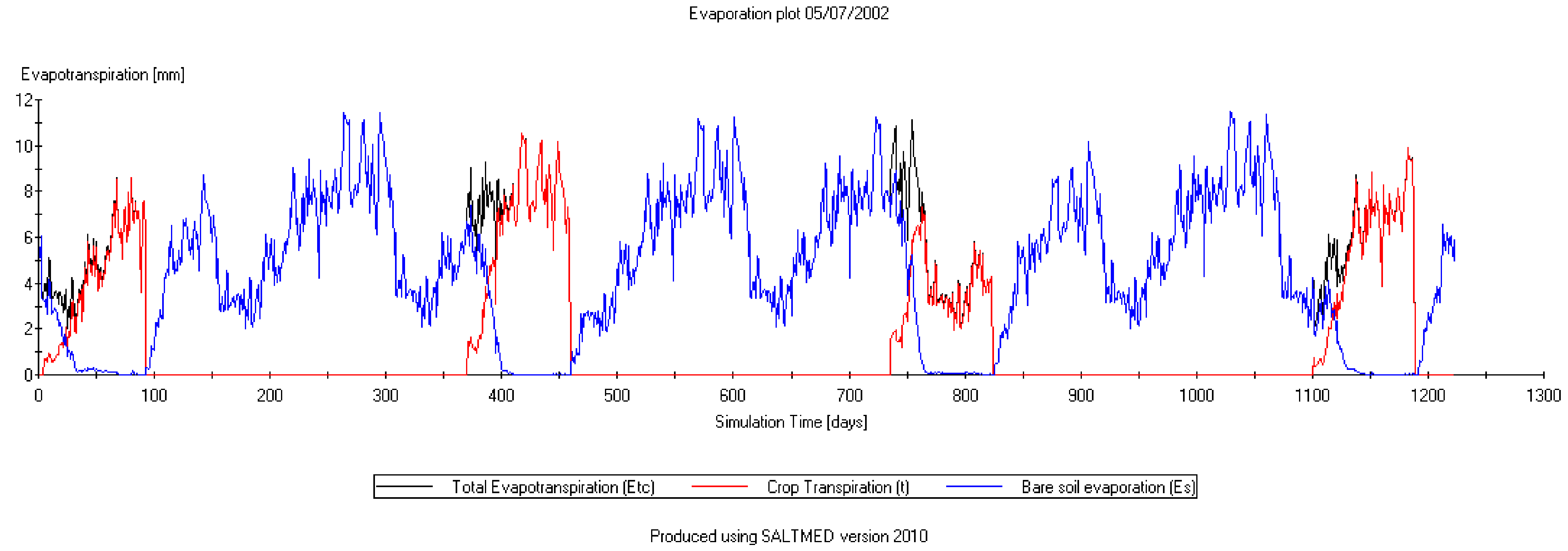
Presence of Drainage



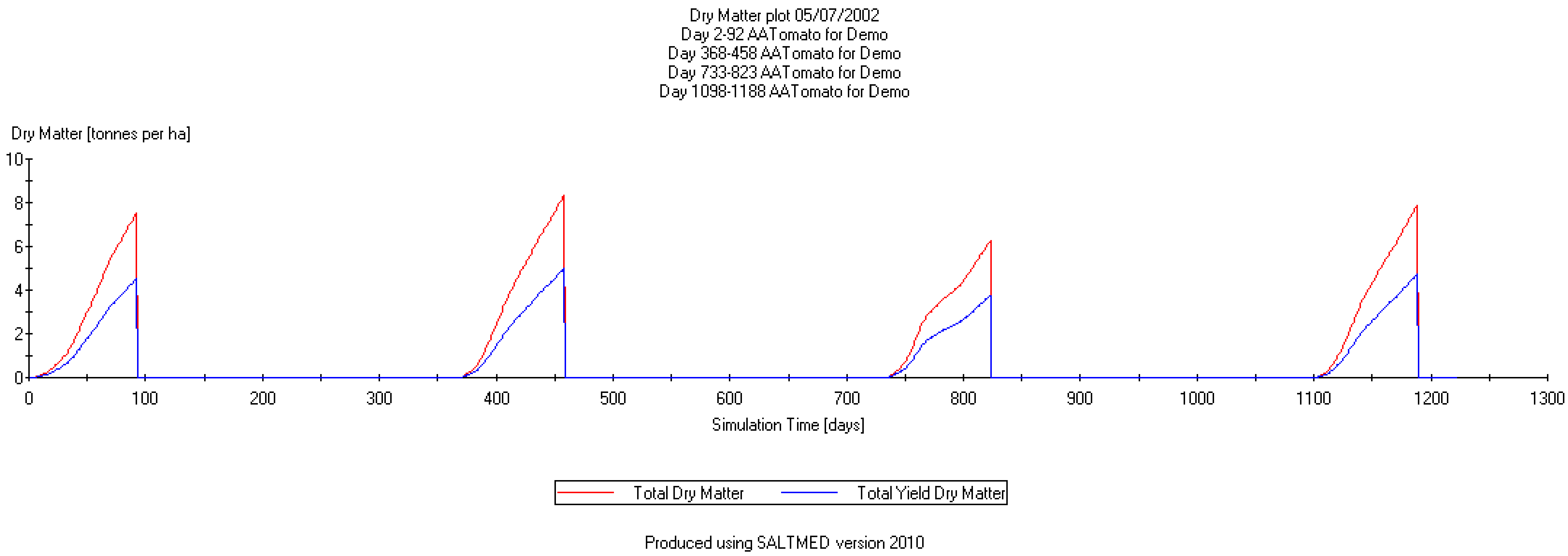

Groundwater plot 31/03/1999
Distance from Soil Surface [m]
0
-1
-2
-3
-4
-5
-6
-1.0
-0.5
0.0
0.5
1.0
Distance from Irrigation Source [m]
Produced using SALTMED version 2010


Groundwater Levels plot 31/03/1999
Depth Below Surface (m)
4.0
3.5
3.0
2.5
2.0
0
10
20
30
40
Simulation Time [days]
Average
Minimum
Maximum
Produced using SALTMED version 2010

Crop Rotation



Crop Rotation



UK Centre for Ecology & Hydrology

The goodness of fit expressions are:

the root mean square error (RMSE), coefficient of determination (R^2), and coefficient of residual mass (CRM).

The RMSE values show by how much the simulations under- or overestimate the measurements:

$$\mathrm{RMSE} = \sqrt{\frac{\sum (yo - ys)^2}{N}} \qquad (1)$$

where

ys = predicted value
yo = observed value
N = total number of observations

The R^2 statistics demonstrate the ratio between the scatter of simulated values to the average value of measurements:

$$R^2 = \left\{ \frac{1}{N} \frac{\sum (yo - \bar{yo})(\bar{ys} - \bar{yo})}{\sigma yo - \sigma ys} \right\} \qquad (2)$$

where

$\bar{yo}$ = averaged observed value
$\bar{ys}$ = averaged simulated value

σyo = observed data standard deviation
σys = simulated data standard deviation

The coefficient of residual mass (CRM) is defined by

$$\mathrm{CRM} = \frac{\left(\sum yo - \sum ys\right)}{\sum yo}$$

The CRM is a measure of the tendency of the model to over- or underestimate the measurements. Positive values for CRM indicate that the model underestimates the measurements and negative values for CRM indicate a tendency to overestimate. For a perfect fit between observed and simulated data, values of RMSE, CRM and R_2 should equal 0.0, 0.0, and 1.0, respectively.

Non- conventional way to use the models

Using the model to predict missing parameters and difficult-to-measure parameters (i.e. Pi 50, Kcb , Kc, Photosynthesis efficiency, LAI, soil hydraulic properties and crop characteristics, etc.).

Using the model to predict Climate change impact (CO_2, Radiation, rainfall, temperature, individually or collectively) on yield, sowing and harvest dates length of season, Crop water requirement and impact of seawater inundations/ Tsunami on the environment.

Using the model for experimental design such as the best crop rotation (e.g. shallow rooted followed by deep rooted crops), tillage level, mulching, fertilizer and irrigation scheduling, mixed waters versus cyclic fresh /saline water.

Using the model to investigate the root system geometry, selecting suitable variety for regions or suitable under future climate change.

Using the model to design a program for data collection.


Thank You!