Irrigation atlas

Drip, Flood and Sprinkler Irrigation

Leaching practice for different cases of soil salinization

Irrigation atlas (leaching practice for different cases of soil salinization)

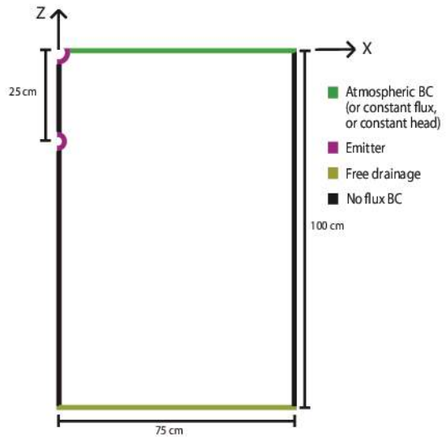


Fig. 1: The conceptual structure of the model

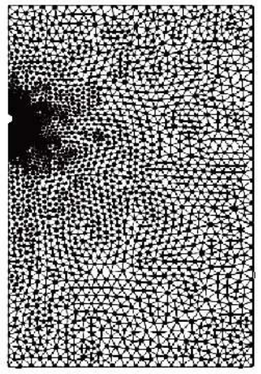


Fig. 2: The FE calculation mesh

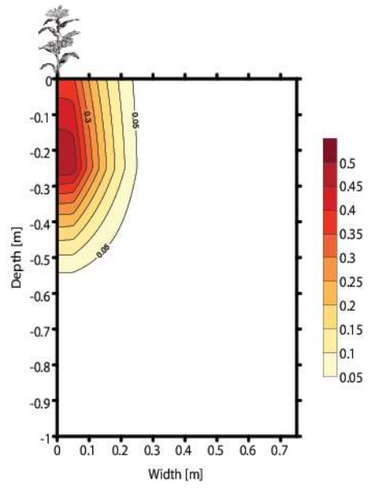


Fig. 3: Roots water uptake function

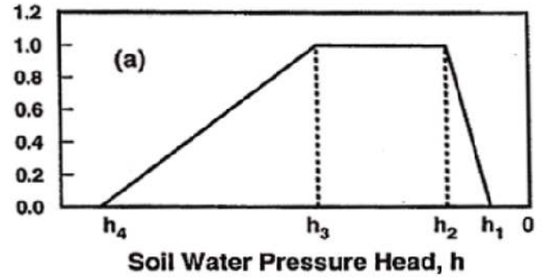


Fig. 4: Plant water stress response function by Feddes et al. (1978)

Conceptual structure. For the scenarios, a 2D (x , z) rectangular soil domain (75 cm x 100 cm) was generated (see Fig. 1). The irrigation techniques will be applied on this domain for the purpose of leaching.

Soil properties. The considered soils are: sand, loam, and silt, which havebeen taken from the provided soil catalog in HYDRUS . On the basis of the significant differences in the soil hydraulic properties of the selected soils, this selection covers a wide spectrum of hydraulic phenomena (see Tab. 1).

Roots water uptake. The maximum rooting depth is 60 cm and the maximum rooting radius is 30 cm. The uptake rate varies within this domain (see Fig. 3). The used Feddes' parameters, that describe the plant water stress response function for maize, were taken according to Wesseling (1991) (see Fig. 4).

Solute transport. Salinity was simulated here as a tracer with the same transport parameters for all cases which are:

Longitudinal dispersivity =2 cm, transverse dispersivity =0,2cm.
No diffusion and equilibrium transport was considered.

Used irrigation (leaching) methods. Freshwater was applied continuously to leach the salts out of the roots zone to reach a concentration of 3 dS/m or less using:

- **Surface (SI) or subsurface (SDI) drip irrigation.** A dripper as a point source for water was considered at different depths (z) for the SDI, and different distances from the plant (x) for the SI method. The dripper discharge is 2 l/h for both methods.
- **Sprinkler irrigation.** The sprinkler irrigation was considered as a uniform constant flux at the upper boundary of the domain. The flux varies according to the soil type and does not exceed the saturated hyd-aulic conductivity of the corresponding soil: Q(sand)=1 cm/h, Q(Loam)=0.9 cm/h, Q(silt)= 0.25 cm/h.
- **Flood irrigation.** The flood irrigation was considered as a constant head (H= 5 cm) at the upper boundary of the domain.

- The leaching was finished when no effective improvement of the impact of the leaching was observed.

Initial conditions. The initial conditions were created with pre-simulations to get different salinity distributions (see next page). Salts were applied with the irrigation water (6 dS/m = 3,84 mg/cm^3). Regarding the salinity distribution there are three different initial conditions:

1- root zone salinity (RZS)
2- surface salinity (SS)
3- mix of both (RZS+SS)

For each of these different conditions, salt was introduced into the three different soil types so that all the soils contain the same salt mass but different salt concentrations, due to the differences in water content distributions of those soils. Tab. 2 shows the settings of the pre-simulations used for generating the different initial conditions.

Tab. 1: Van Genuchten model's parameters for sand, loam, silt

	θr [-]	θs [-]	α[1/cm]	n [-]	Ks[cm/h]	l [-]
Sand	0,045	0,43	0,145	2,68	29,7	0,5
Loam	0,078	0,43	0,036	1,56	1,04	0,5
Silt	0,034	0,46	0,016	1,37	0,25	0,5

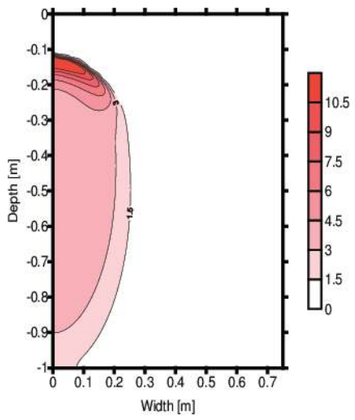
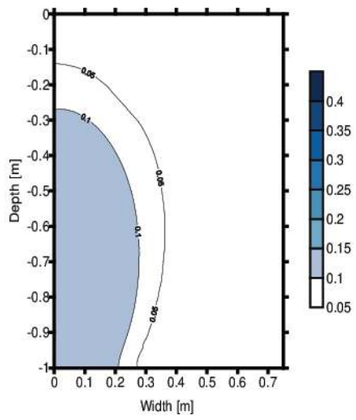
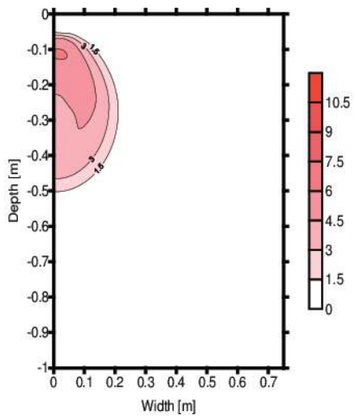
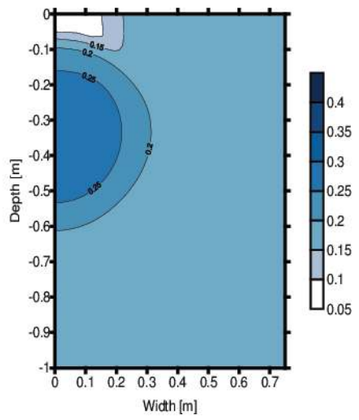
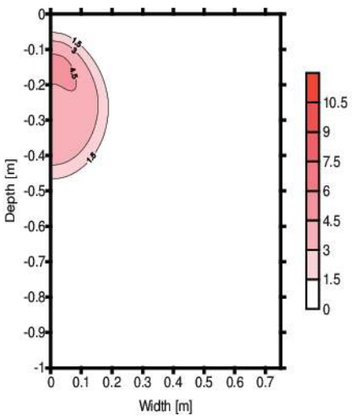
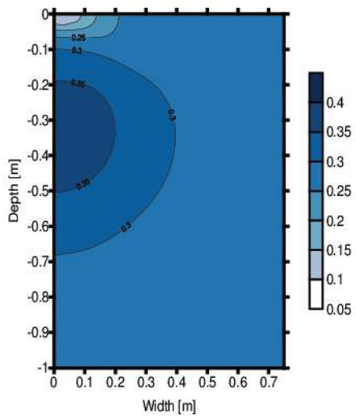
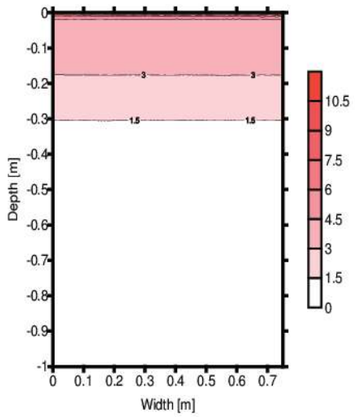
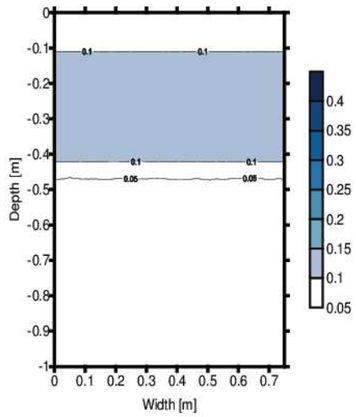
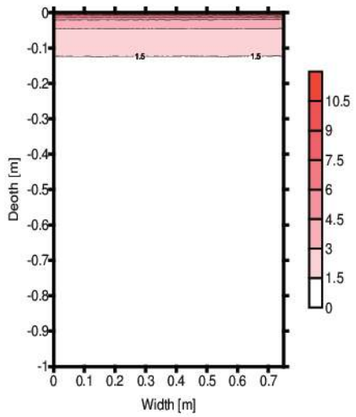
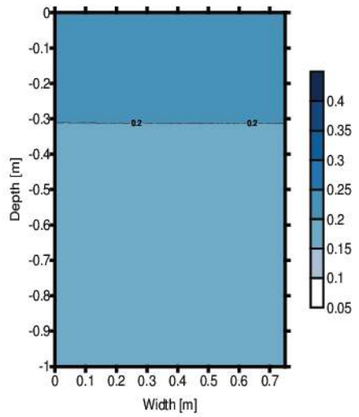
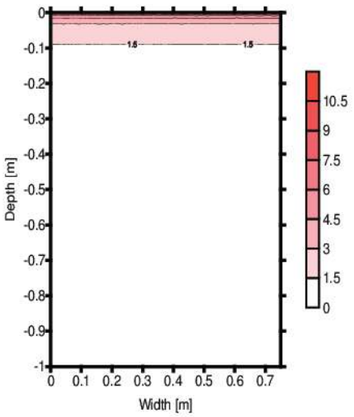
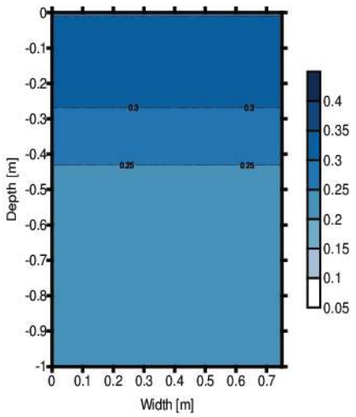
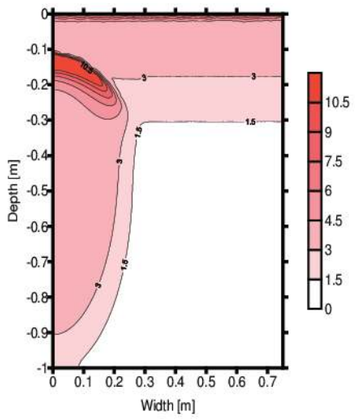
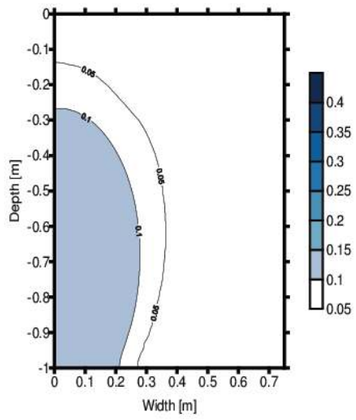
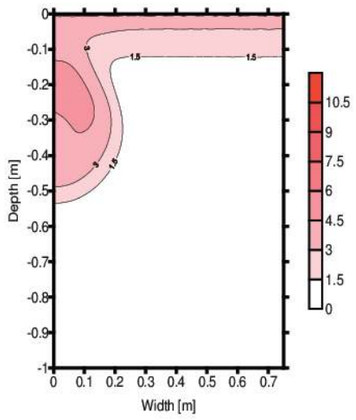
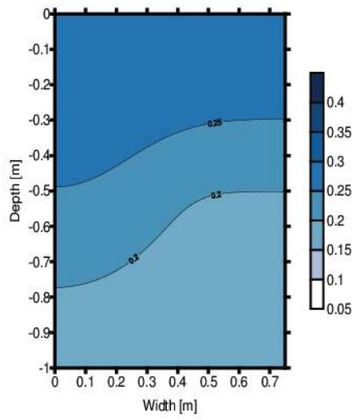
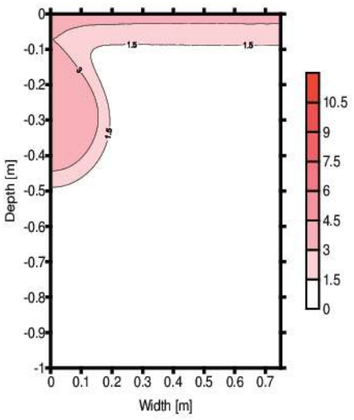
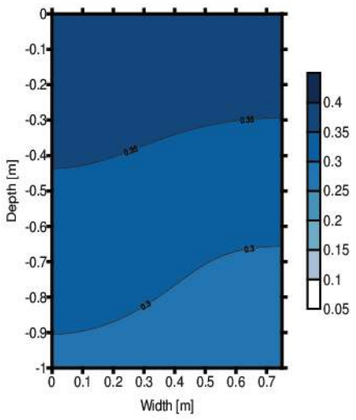
Tab. 2: Setups of the initial conditions pre-simulations

Type of Salinity	Root water uptake	Evaporation	Water application method, quantity and quality	Initial conditions
RZS	6 mm/d	no	Daily 7mm (with 6dS/m) during 5 hours from 25 cm deep dripper.The simulations ran for 96 hours	h = -200 cm C= 0 [mg/cm^3]
SS	no	1,2 mm/d	Saline water was applied at the soil surface for 20h without E, then E took place for different periods according to the soil type: 20h for sand, and 100 h for loam and silt	h = -400 cm C= 0 [mg/cm^3]
RZS+SS	no	1,2 mm/d	Water application as in SS	h & C results from RZS

Symbols and abbreviations

h : pressure head [cm]
C : salts concentration [mg/cm^3]
Q : constant flux boundary condition [cm/h]
H : constant pressure boundary condition [cm]
SI : surface drip irrigation
SDI : subsurface drip irrigation
RZS : root zone salinity
SS : surface salinity
T : minimum time for leaching
E : evaporation
θ : volumetric water content
● : emitter

Initial conditions (concentration and water content)

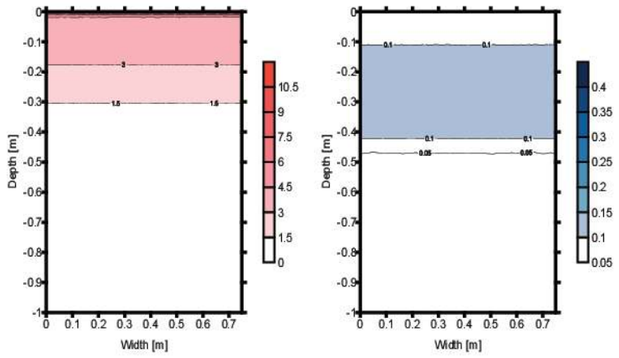
	Sand		Loam		Silt	
	C [mg/cm^3]	θ [-]	C [mg/cm^3]	θ [-]	C [mg/cm^3]	θ [-]
Root zone salinity						
Surface salinity						
Mixed salinity						

Sand

Surface salinity, sandy soil

	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 1 cm/h
Water content [-]	T=180 h	T=250 h	T = 220 h	T = 220 h	T = 2 h	T = 30 h
Concentration [mg/cm^3]						

Initial conditions: salts are located near the soil surface

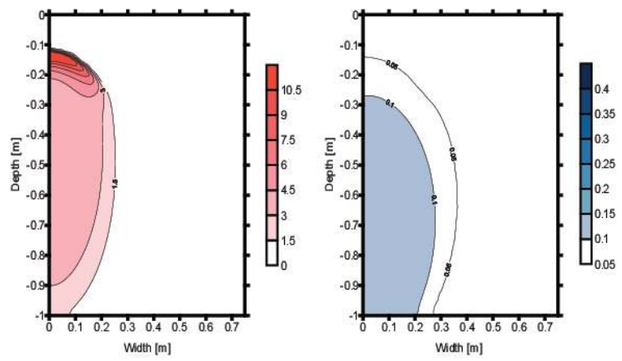


combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	240 mm	332,5 mm	285,6 mm	292,5 mm	661,3 mm	300 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	56,4 mm	74,9 mm	49 mm	43,5 mm	354,4 mm	160 mm
Percolation	183,6 mm	257,6 mm	236,6 mm	249 mm	306,9 mm	140 mm
Relative leached salts	21,5 %	55,5 %	9 %	7,1 %	99 %	93,7 %

Root zone salinity, sandy soil

	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 1 cm/h
Water content [-]	T= 75 h	T= 300 h	T = 120 h	T = 200 h	T = 2 h	T = 30 h
Concentration [mg/cm^3]						

Initial conditions: salts are located within the root zone

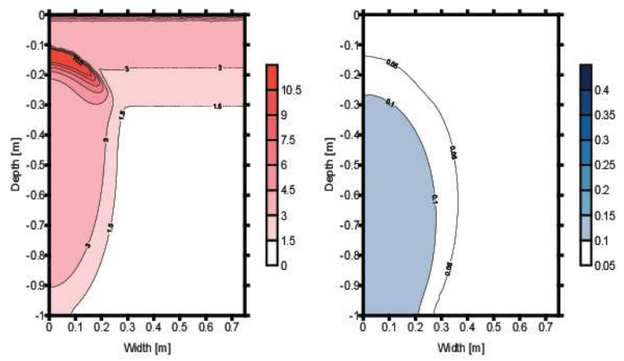


combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	100 mm	399 mm	155 mm	266 mm	662,7 mm	300 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	42,5 mm	79,5 mm	39 mm	35,5 mm	306,8 mm	164 mm
Percolation	57,5 mm	319,5 mm	116 mm	230,5 mm	355,9 mm	136 mm
Relative leached salts	76,8 %	88,6 %	79,8 %	77,5 %	100 %	80 %

Mixed salinity, sandy soil

	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 1 cm/h
Water content [-]	T=180 h	T=300 h	T = 120 h	T = 220 h	T = 2 h	T = 33 h
Concentration [mg/cm^3]						

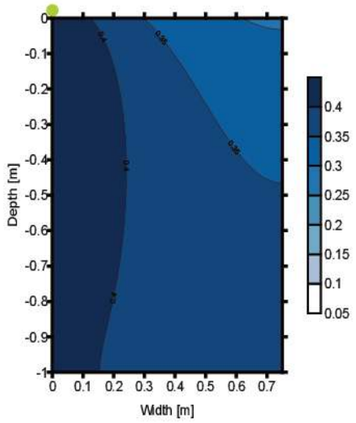
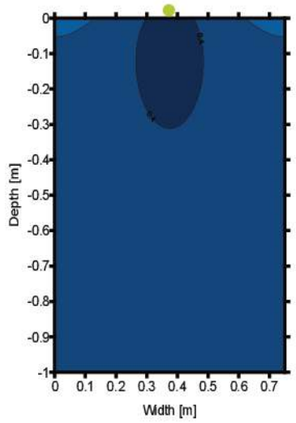
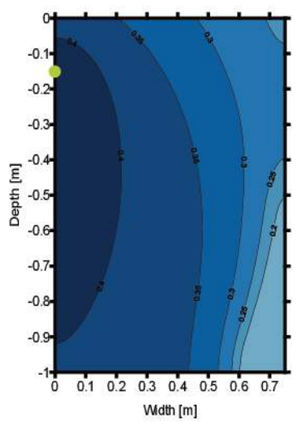
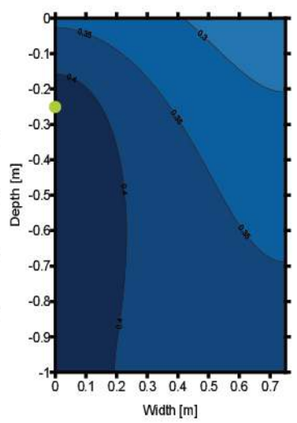
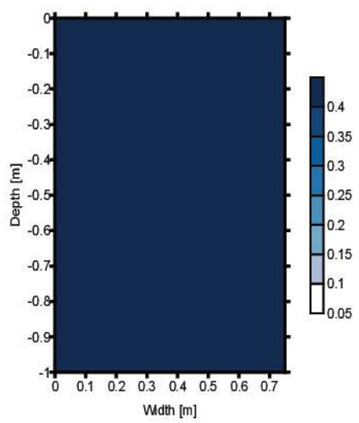
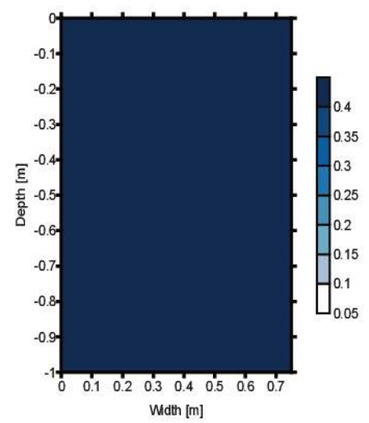
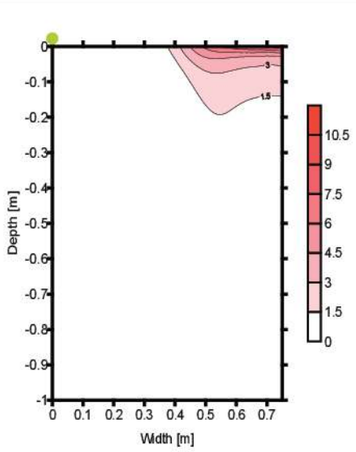
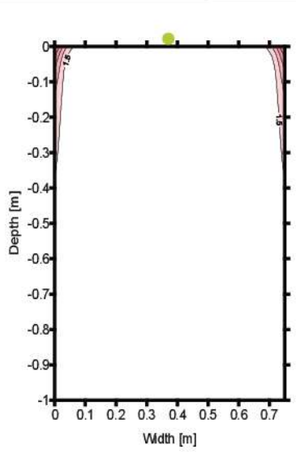
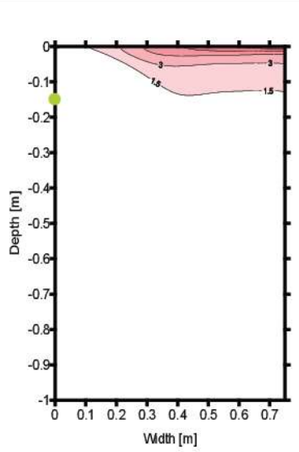
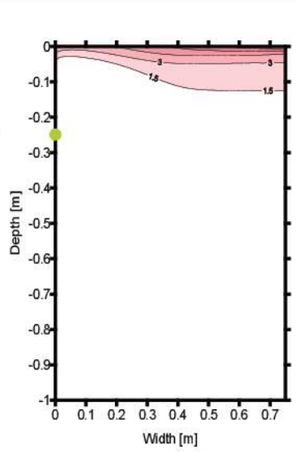
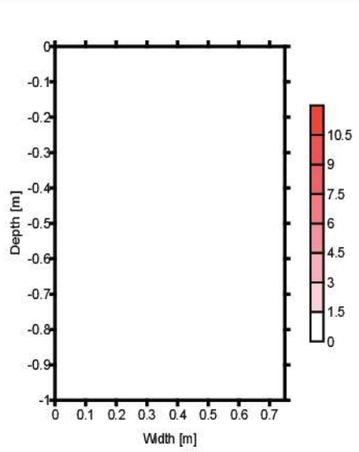
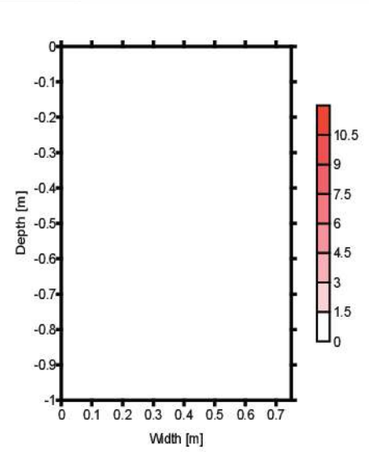
Initial conditions: salts are located near the soil surface & root zone



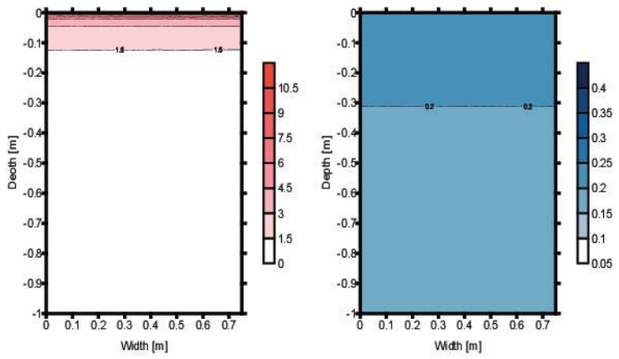
combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	240 mm	398,5 mm	155,7 mm	292,5 mm	662,1 mm	330 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	50,3 mm	79 mm	40 mm	35,8 mm	358,4 mm	164 mm
Percolation	189,7 mm	319,5 mm	115,7 mm	256,7 mm	303,7 mm	166 mm
Relative leached salts	65,5 %	74,5 %	55,1 %	53,9 %	100 %	98,5 %

Loam

Surface salinity, loamy soil

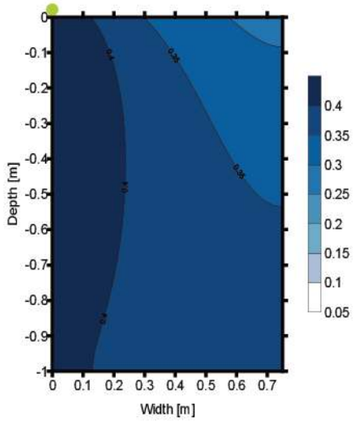
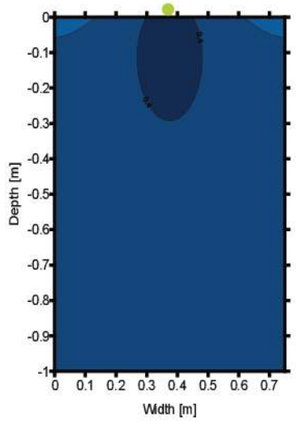
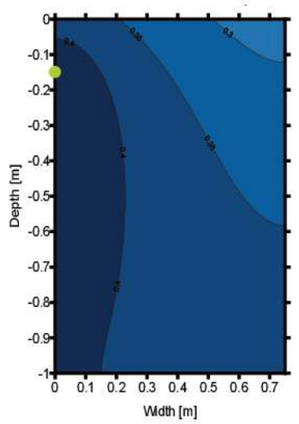
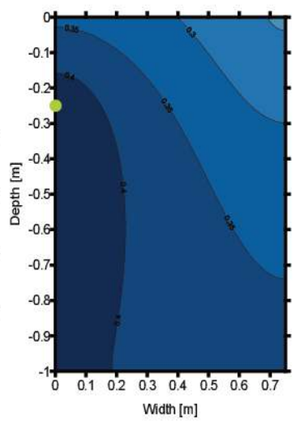
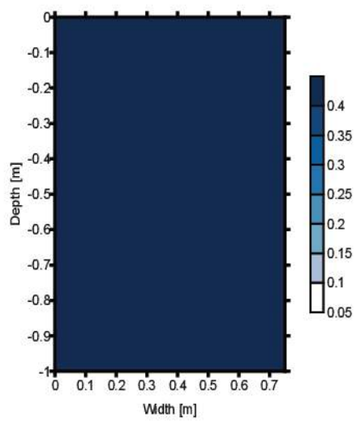
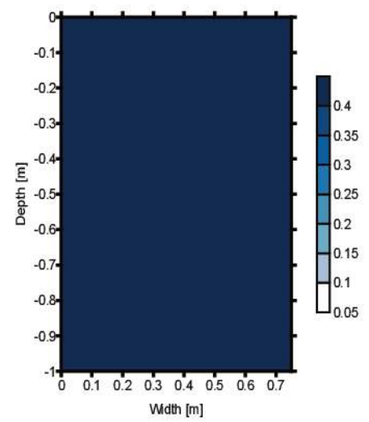
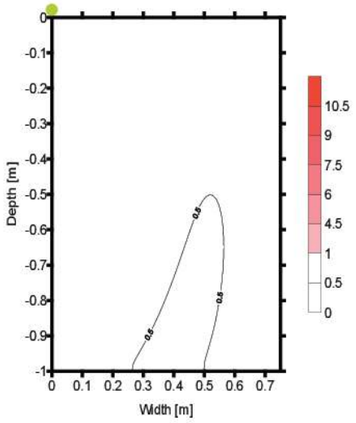
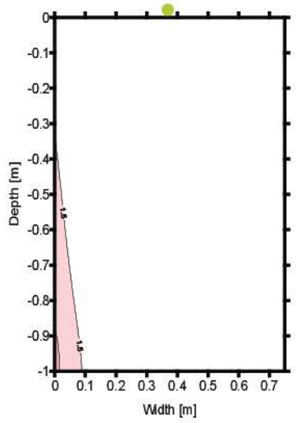
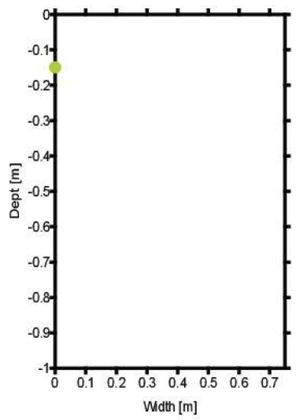
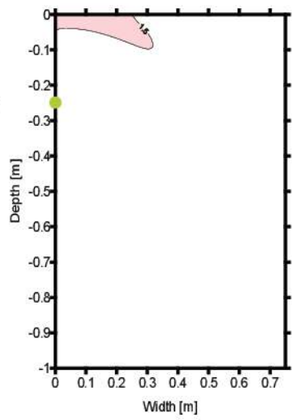
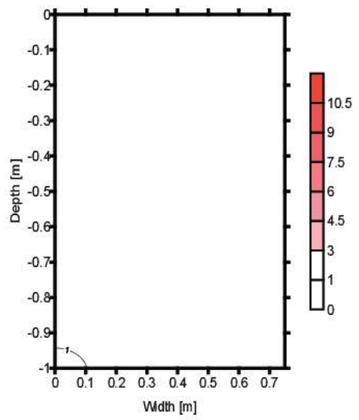
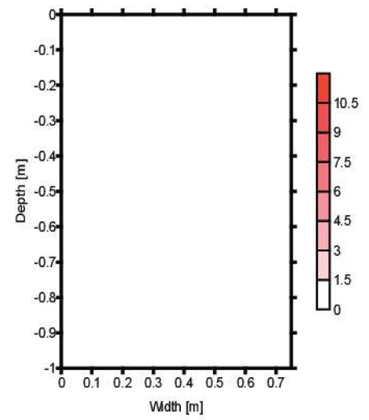
	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 0.9 cm/h
	T= 240 h	T= 400 h	T = 145 h	T = 250 h	T = 40 h	T = 60 h
Water content [-]						
Concentration [mg/cm^3]						

Initial conditions: salts are located near the soil surface

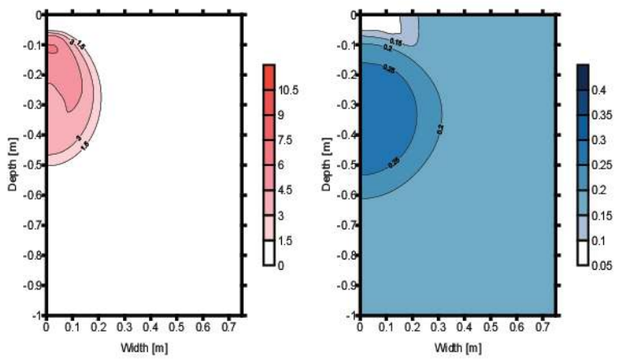


combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	319 mm	532 mm	188 mm	333 mm	461 mm	541 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	199 mm	209 mm	163 mm	186 mm	248 mm	251 mm
Percolation	120 mm	323 mm	25 mm	147 mm	213 mm	290 mm
Relative leached salts	3,6 %	38,4 %	0 %	1 %	71 %	90,5 %

Root zone salinity, loamy soil

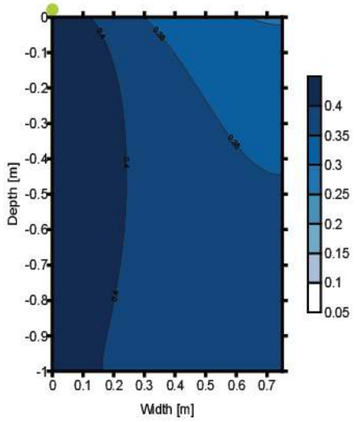
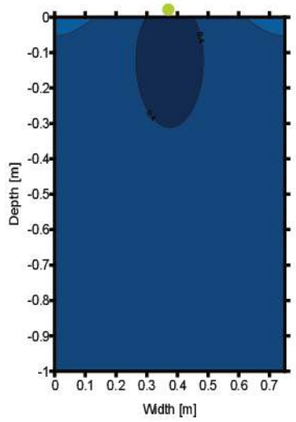
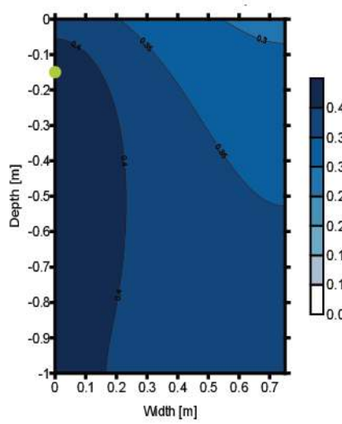
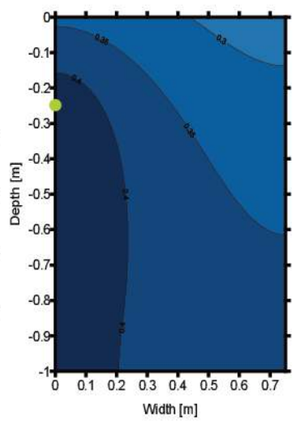
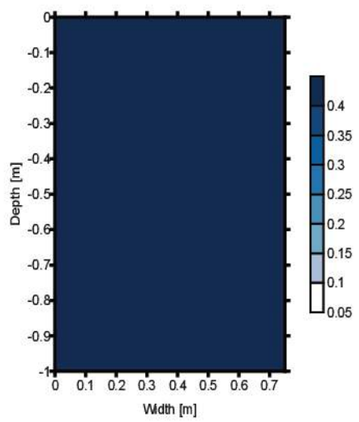
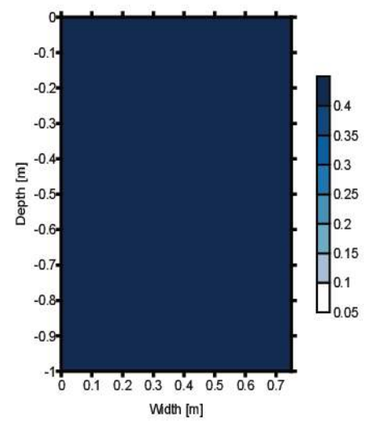
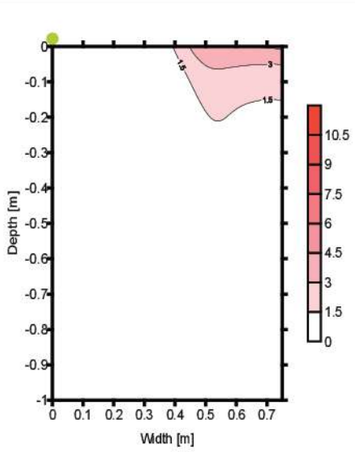
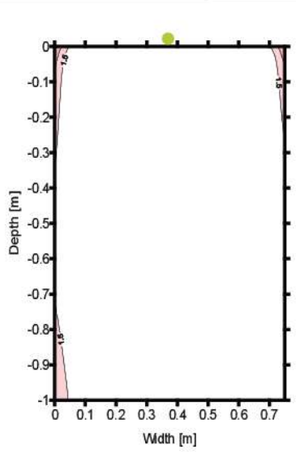
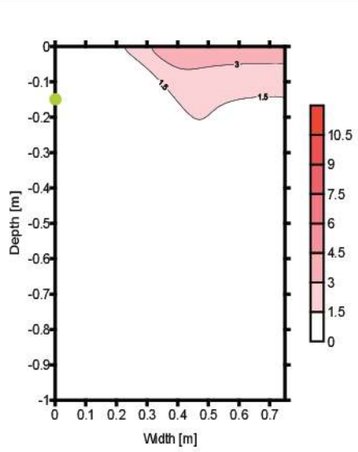
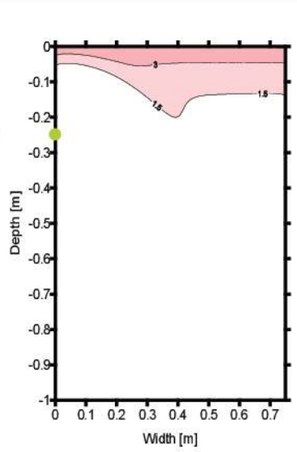
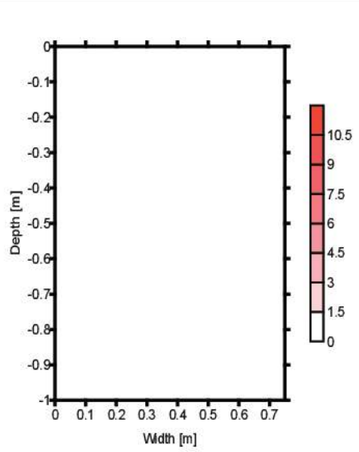
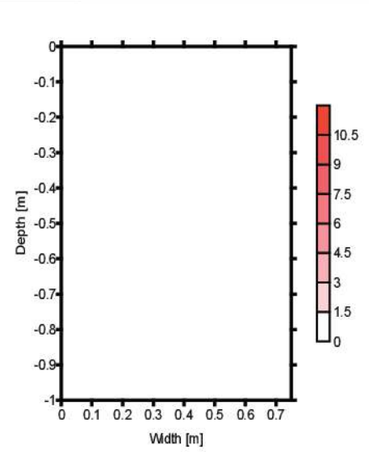
	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 0.9 cm/h
	T=210 h	T=300 h	T = 250 h	T = 230 h	T = 40 h	T = 50 h
Water content [-]						
Concentration [mg/cm^3]						

Initial conditions: salts are located within the root zone

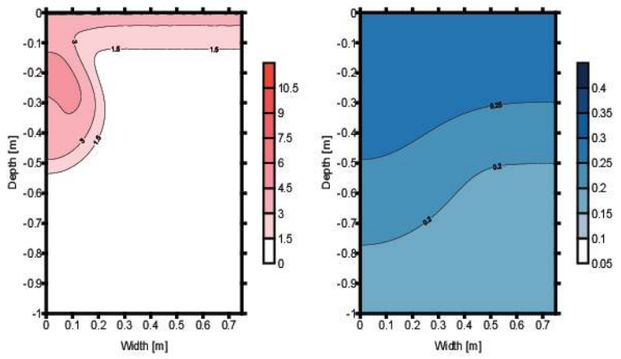


combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	279 mm	399 mm	325 mm	306 mm	461 mm	447 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	177 mm	193 mm	174 mm	164 mm	229 mm	233 mm
Percolation	102 mm	206 mm	151 mm	142 mm	232 mm	214 mm
Relative leached salts	52,8 %	46 %	44,7 %	26,9 %	83 %	77 %

Mixed salinity, loamy soil

	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 0.9 cm/h
	T=240 h	T=400 h	T = 250 h	T = 250 h	T = 46 h	T = 60 h
Water content [-]						
Concentration [mg/cm^3]						

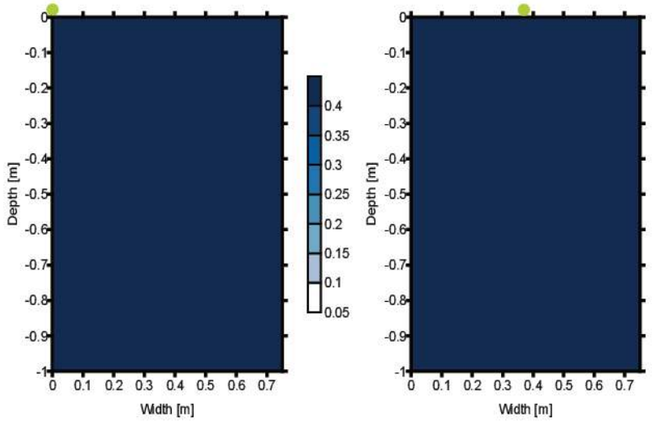
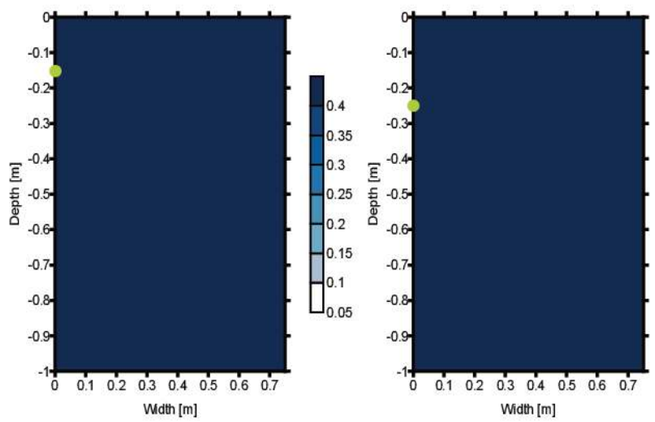
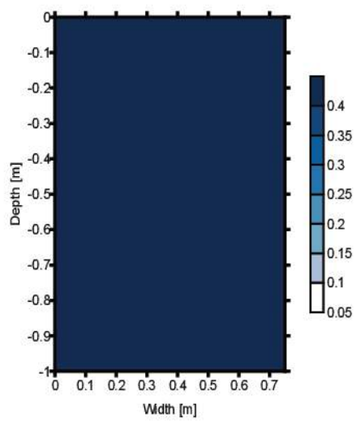
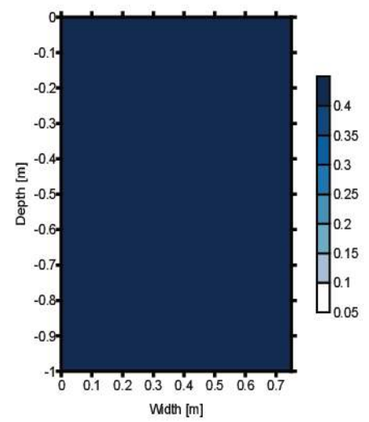
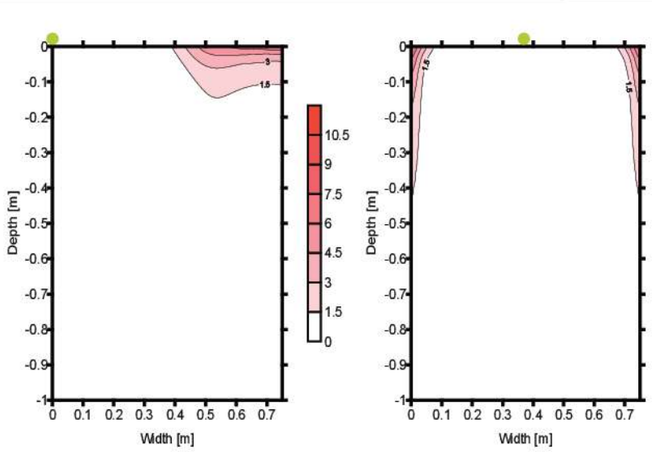
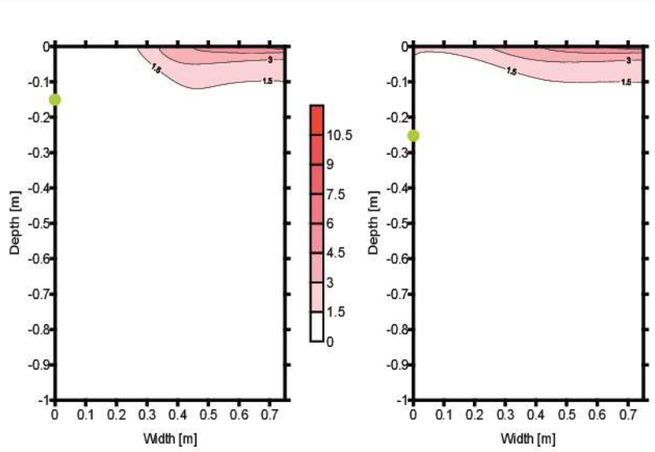
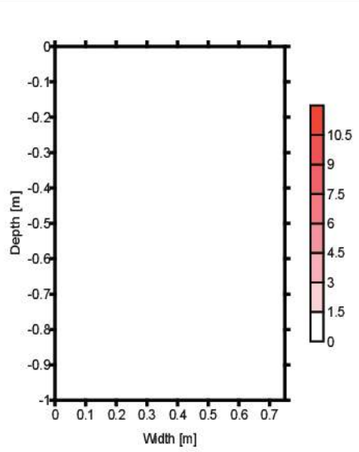
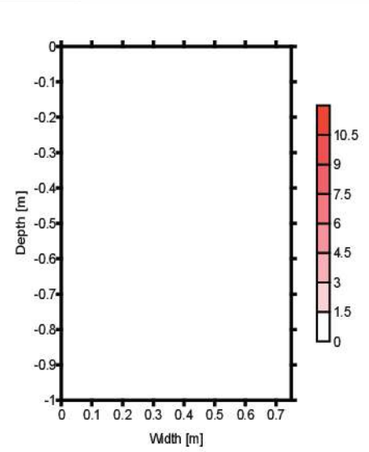
Initial conditions: salts are located near the soil surface & root zone



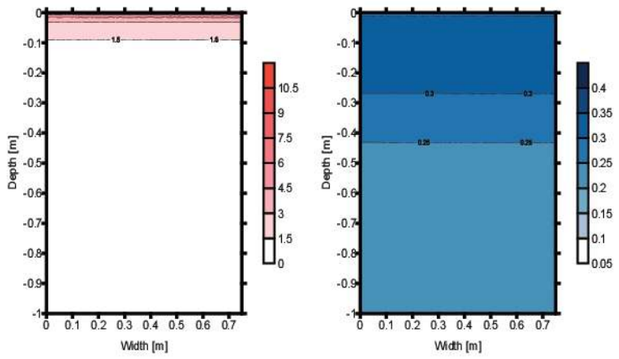
combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	319 mm	532 mm	325 mm	333 mm	513 mm	540 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	153 mm	163 mm	148 mm	142 mm	202 mm	204 mm
Percolation	166 mm	369 mm	177 mm	191 mm	311 mm	336 mm
Relative leached salts	40,5 %	68 %	30,5 %	19,7 %	91 %	94,1 %

Silt

Surface salinity, silty soil

	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 0.25 cm/h
	T= 250 h	T= 400h	T = 230 h	T = 350 h	T = 240 h	T = 240 h
Water content [-]						
Concentration [mg/cm^3]						

Initial conditions: salts are located near the soil surface

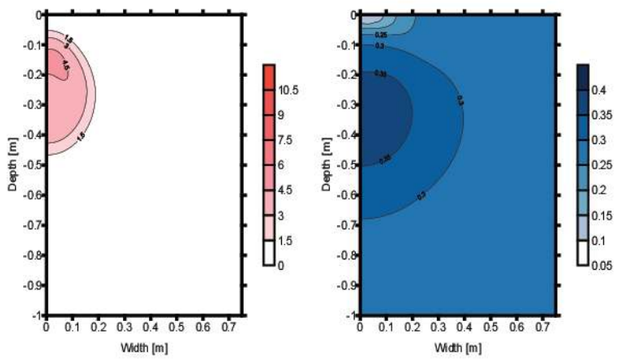


combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	332 mm	532 mm	299 mm	465,5 mm	631 mm	600 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	186 mm	191 mm	185 mm	183,5 mm	190,4 mm	194 mm
Percolation	146 mm	341 mm	114 mm	282 mm	440,6 mm	406 mm
Relative leached salts	2,6 %	13 %	0,5 %	1 %	96,4 %	90,2 %

Root zone salinity, silty soil

	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 0.25 cm/h
Water content [-]	T= 300 h	T= 400 h	T = 300 h	T = 300 h	T = 200 h	T = 200 h
Concentration [mg/cm^3]						

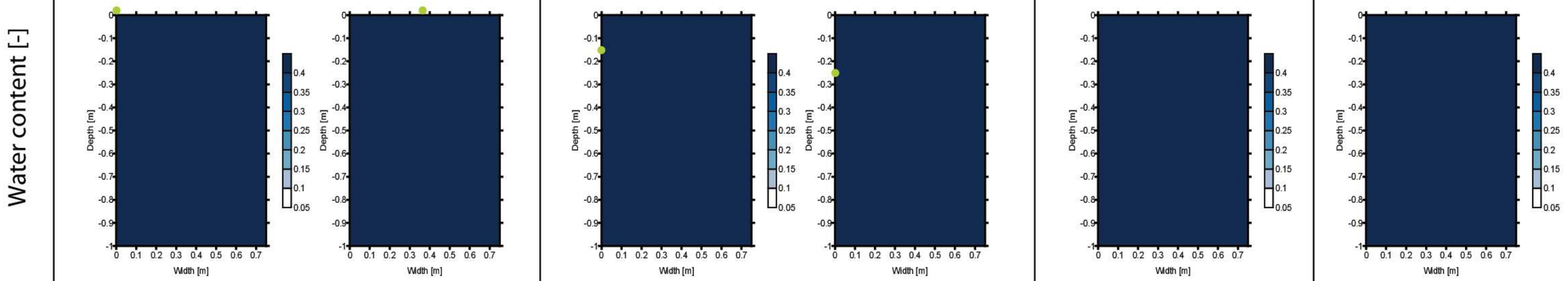
Initial conditions: salts are located within the root zone



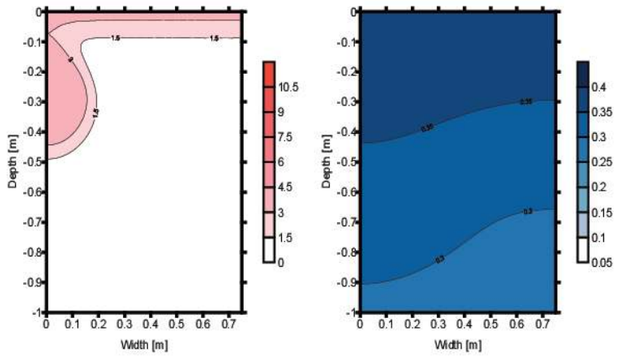
combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	399 mm	532 mm	390 mm	397 mm	533 mm	500 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	151 mm	156 mm	150 mm	148 mm	156 mm	157 mm
Percolation	248 mm	376 mm	240 mm	249 mm	377 mm	343 mm
Relative leached salts	78,5 %	57,7 0%	52,4 %	31 %	93,4 %	88,6 %

Mixed salinity, silty soil

	Surface drip irrigation (SI)		Subsurface drip irrigation (SDI)		Flooding	Sprinkler
	x = 0 cm	x =37,5 cm	z = -15 cm	z = -25 cm	H = 5 cm	Q = 0.25 cm/h
Water content [-]	T= 300 h	T= 400 h	T = 300 h	T = 350 h	T = 240 h	T = 240 h
Concentration [mg/cm^3]						



Initial conditions: salts are located near the soil surface & root zone



combination	SI-0cm	SI-37,5cm	SDI-15cm	SDI-25cm	Flooding	Sprinkler
Irrigation	399 mm	532 mm	390 mm	465,5 mm	622,4 mm	600 mm
Evaporation	-	-	-	-	-	-
Transpiration	-	-	-	-	-	-
Soil water change	124 mm	129 mm	127 mm	121 mm	129,7 mm	192 mm
Percolation	275 mm	403 mm	263 mm	344,5 mm	492,7 mm	408 mm
Relative leached salts	48,7 %	45 %	35,7 %	25,1 %	97,5 %	86,6 %