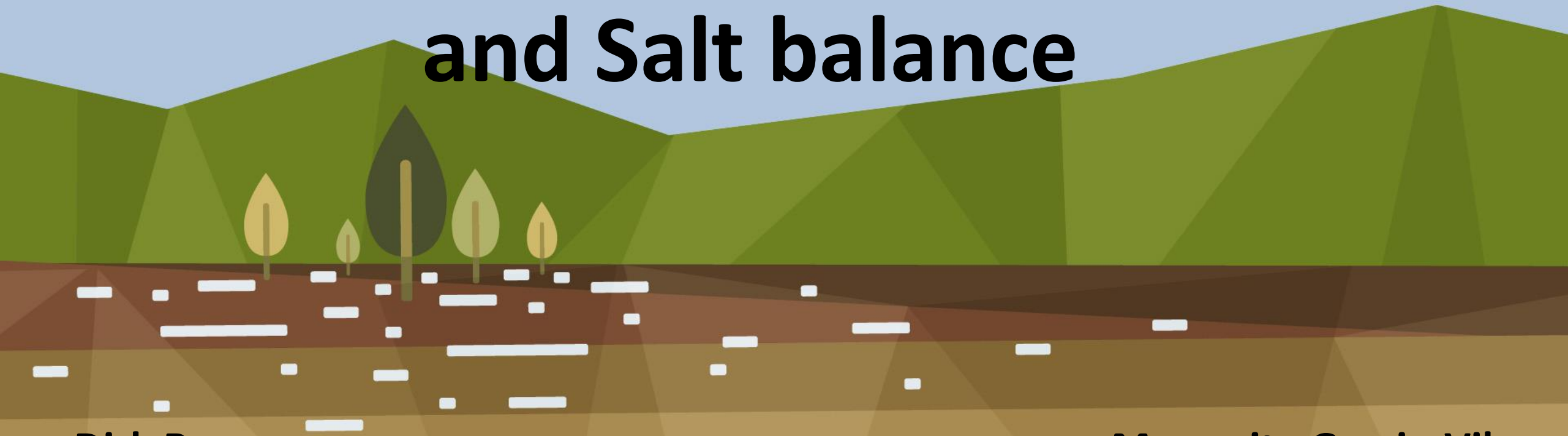
Food and Agriculture Organization of the United Nations

International Network of Salt-Affected Soils

Simulation of soil water and Salt balance



Dirk Raes
KU Leuven (Belgium)

Margarita Garcia-Vila
IAS, CSIC (Spain)

GSP Webinars

Modelling plant growth with AquaCrop, 26 November 2024

GLOBAL SOIL PARTNERSHIP

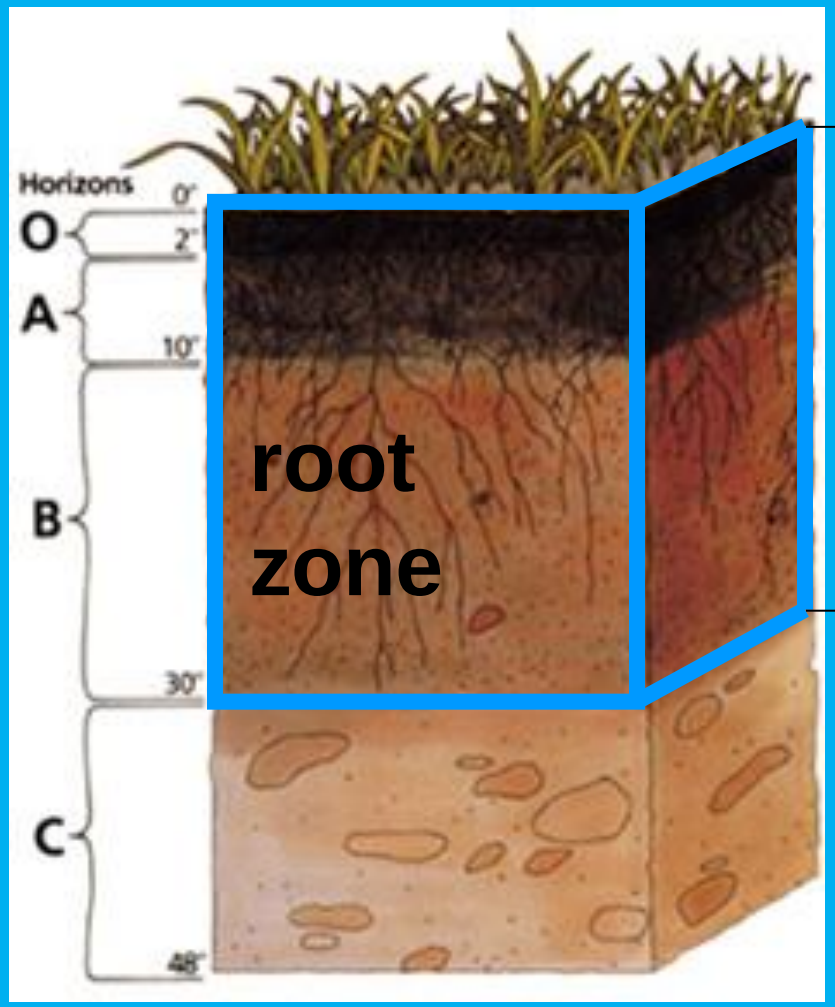
1. AquaCrop model overview

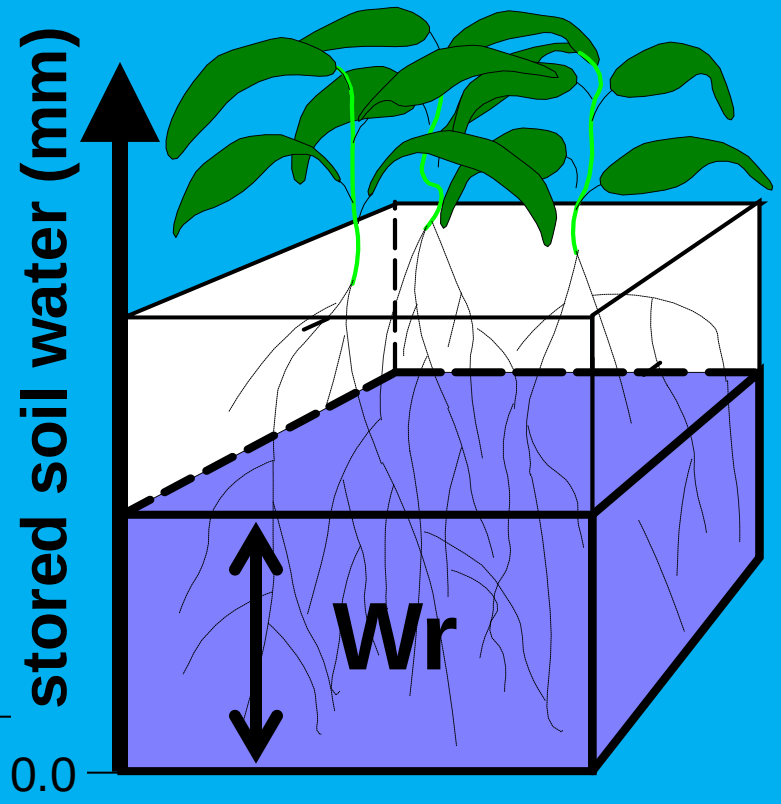
2. Simulation of soil Water and Salt balance

3. Crop production and irrigation management under saline conditions

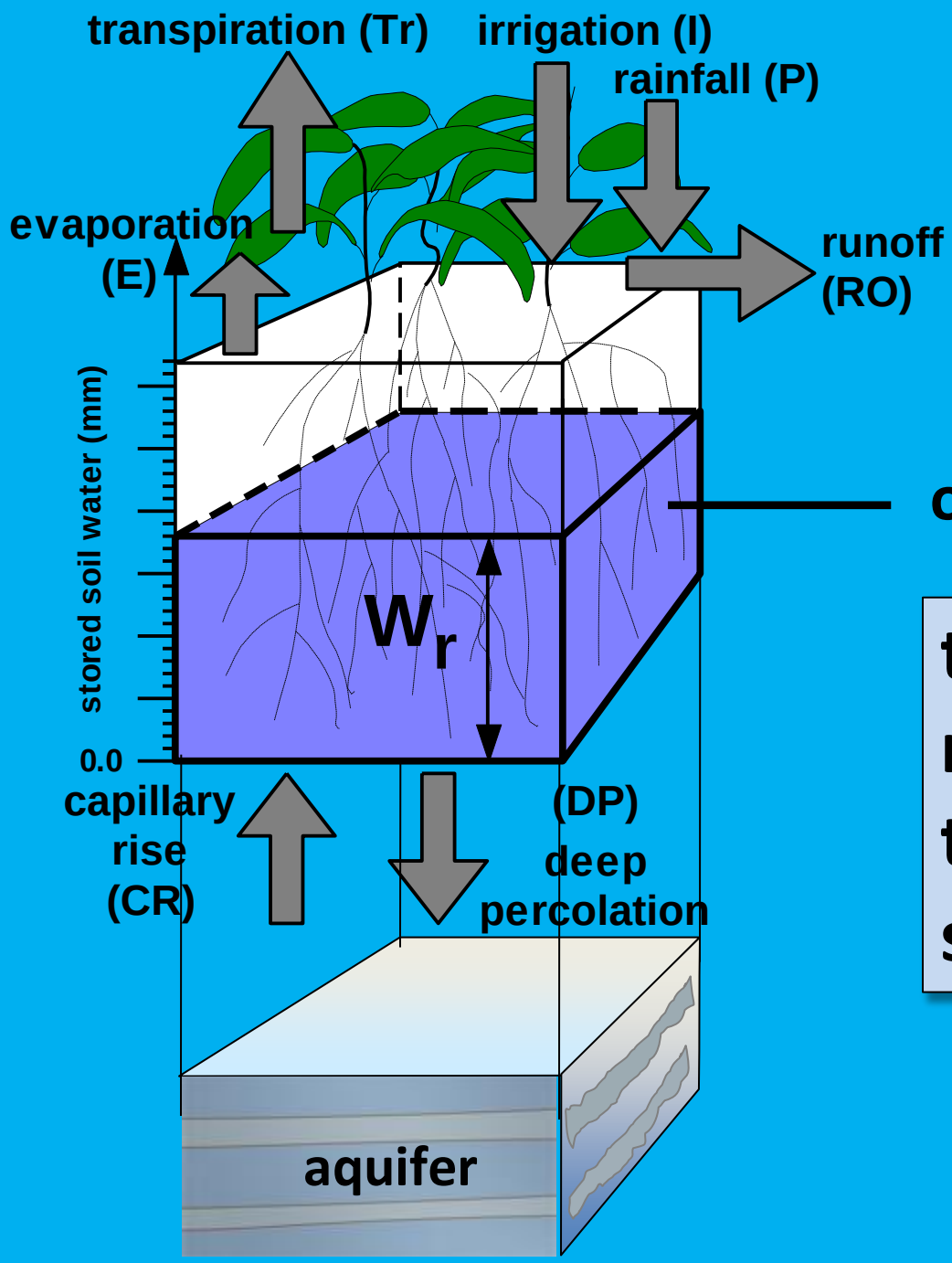
Simulation of the soil water and salt balance

1. Soil water balance
2. Salt balance
3. Evaluation of the salt balance





root zone as
a reservoir



soil water balance

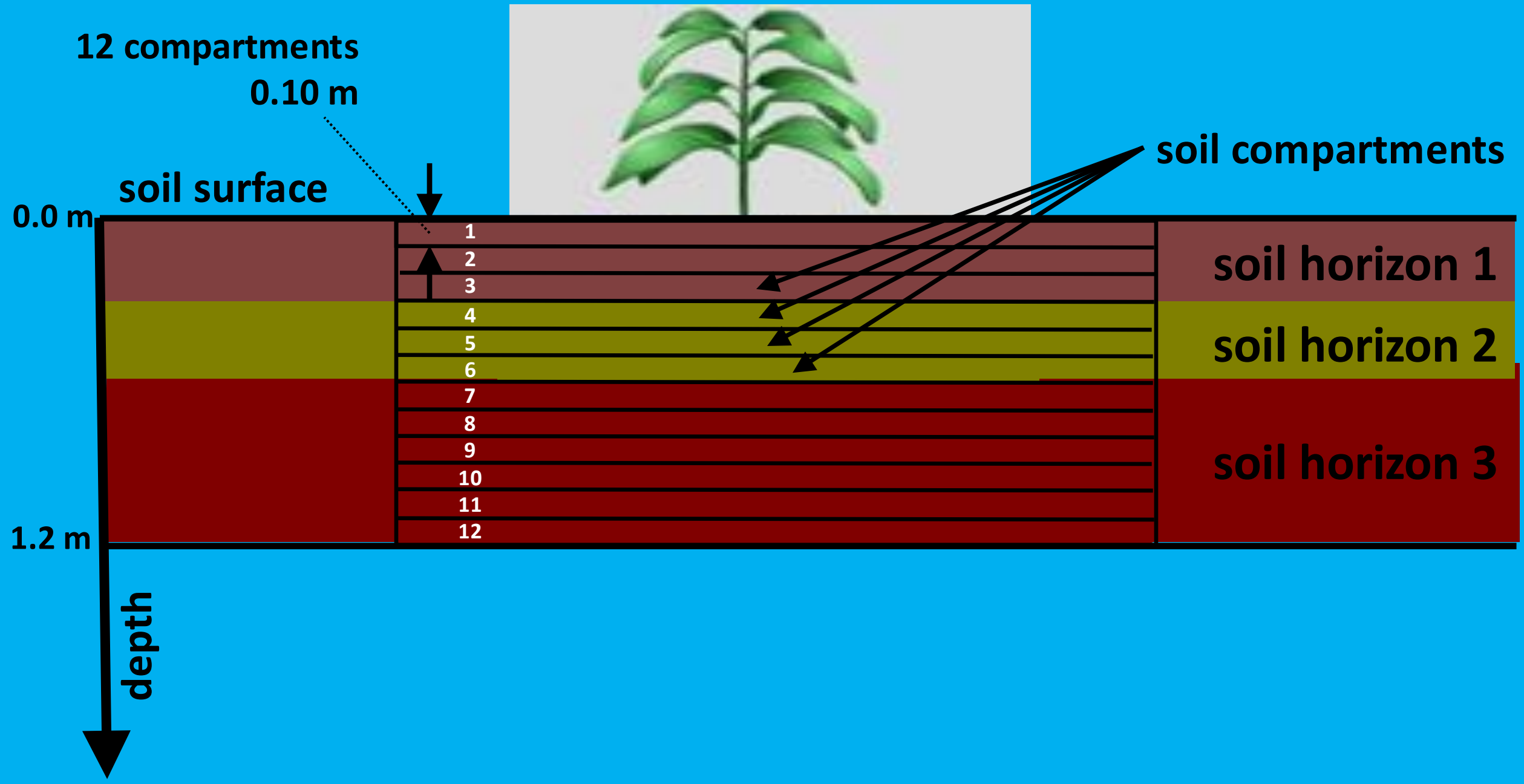
The change of water stored in the root zone (Wr) is monitored by keeping track of the incoming and outgoing water fluxes.

(daily time step)

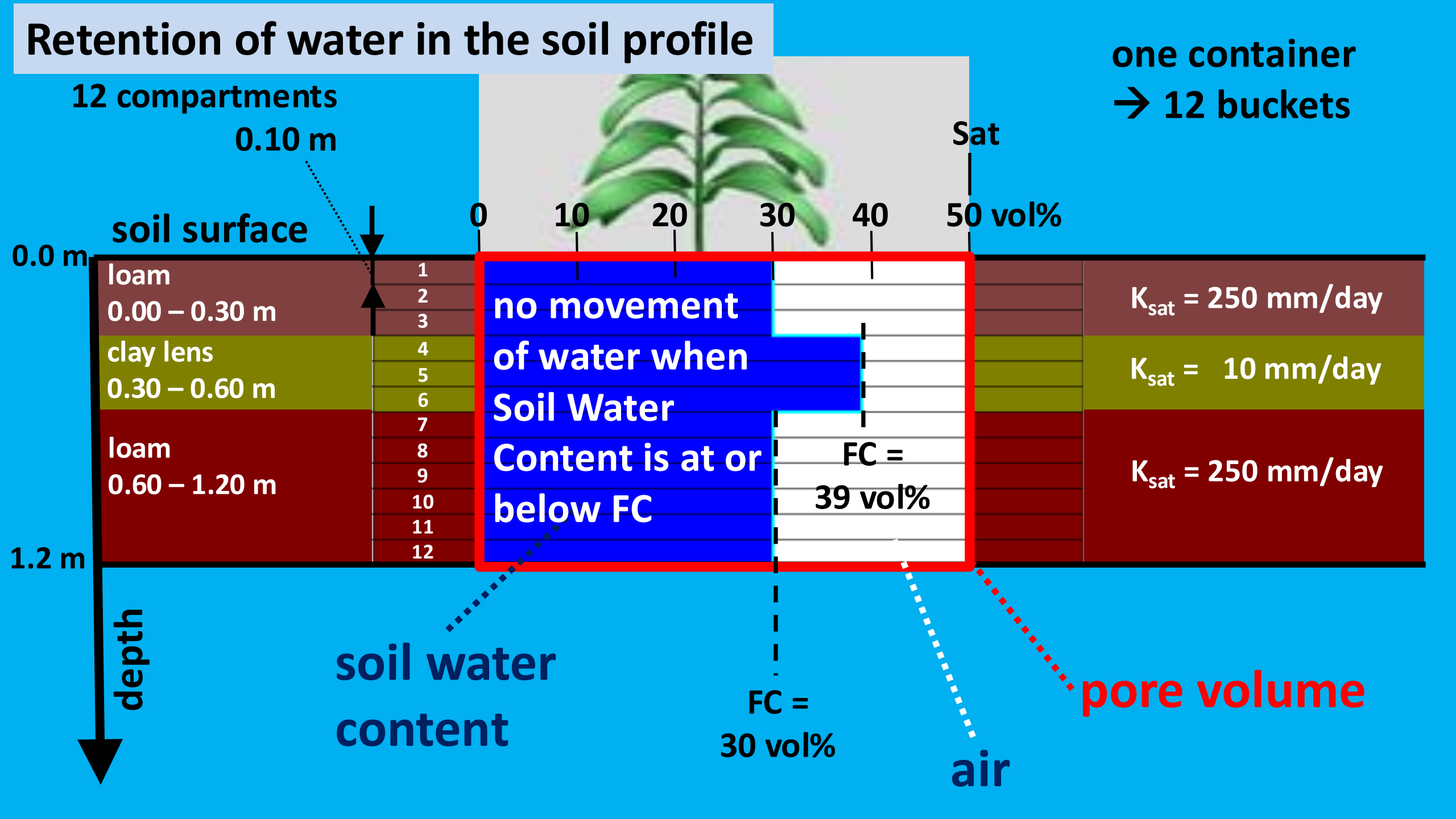
one container (simplified presentation)

to describe accurately the retention, movement and uptake of water in the soil profile, AquaCrop divides the soil profile into small compartments

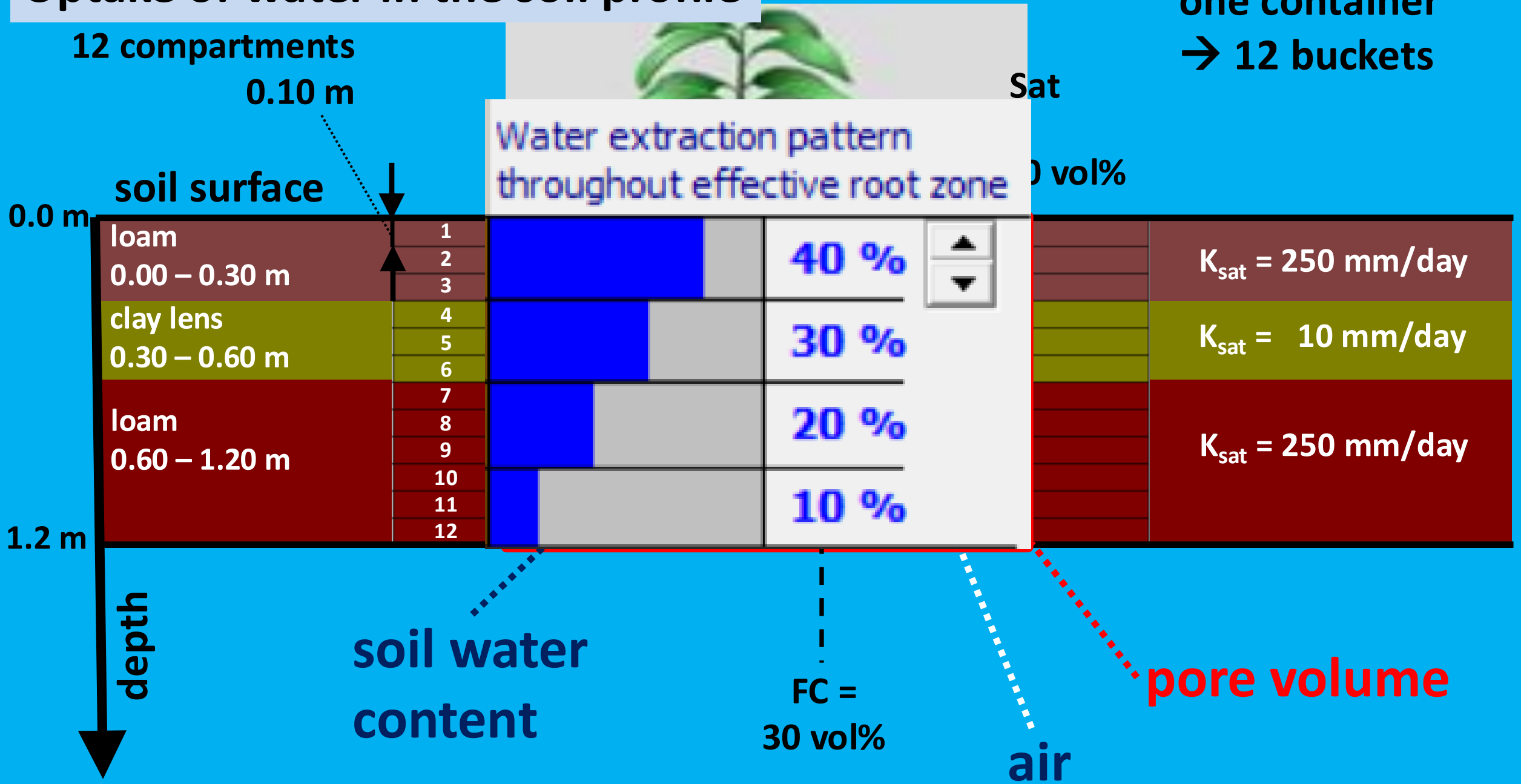

soil surface
0.0 m
root
zone
1.2 m
depth


12 compartments
0.10 m
soil surface
soil compartments
0.0 m
1.2 m
depth
1
2
3
4
5
6
7
8
9
10
11
12
soil horizon 1
soil horizon 2
soil horizon 3

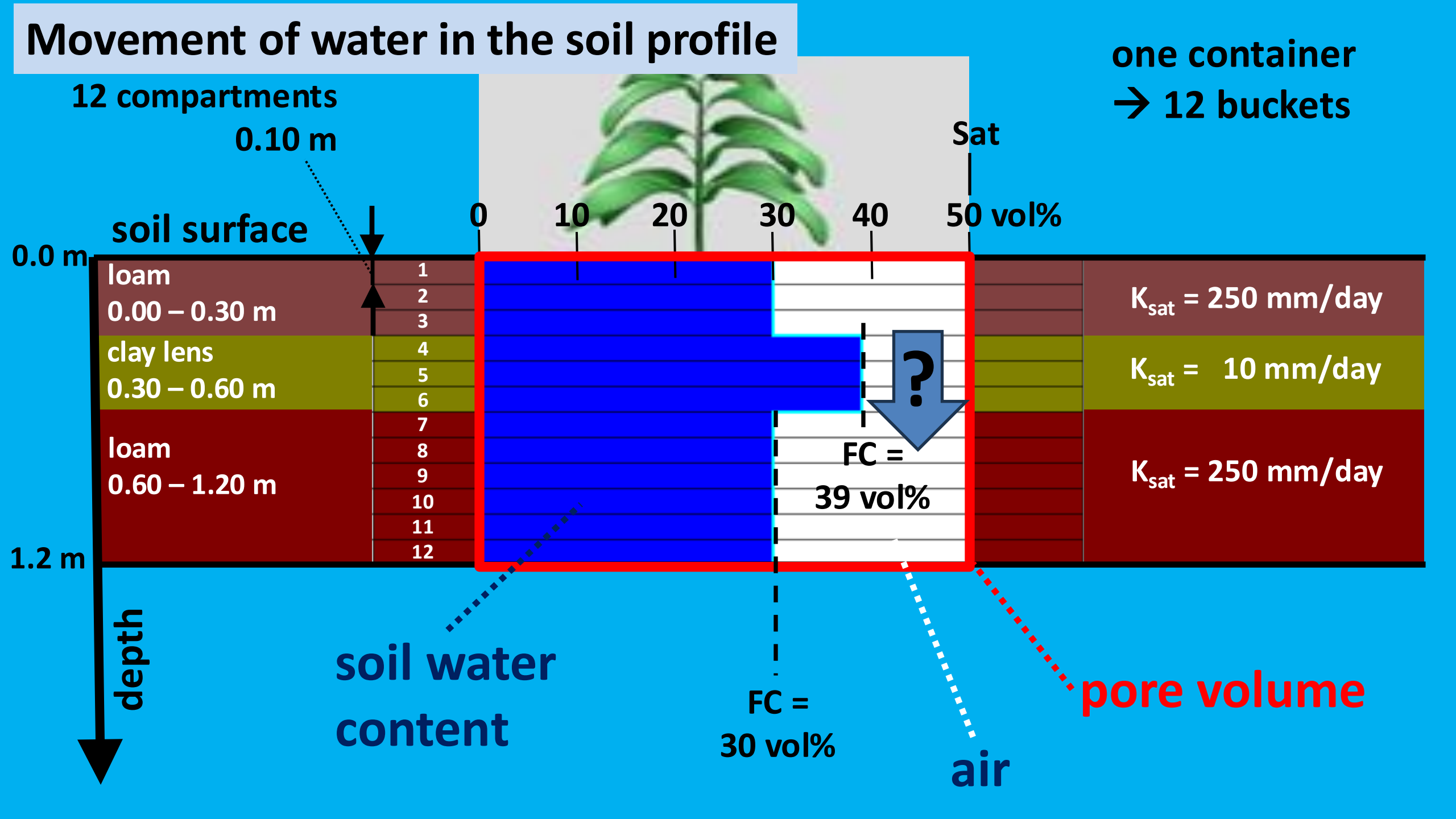
Retention of water in the soil profile



Uptake of water in the soil profile



Movement of water in the soil profile

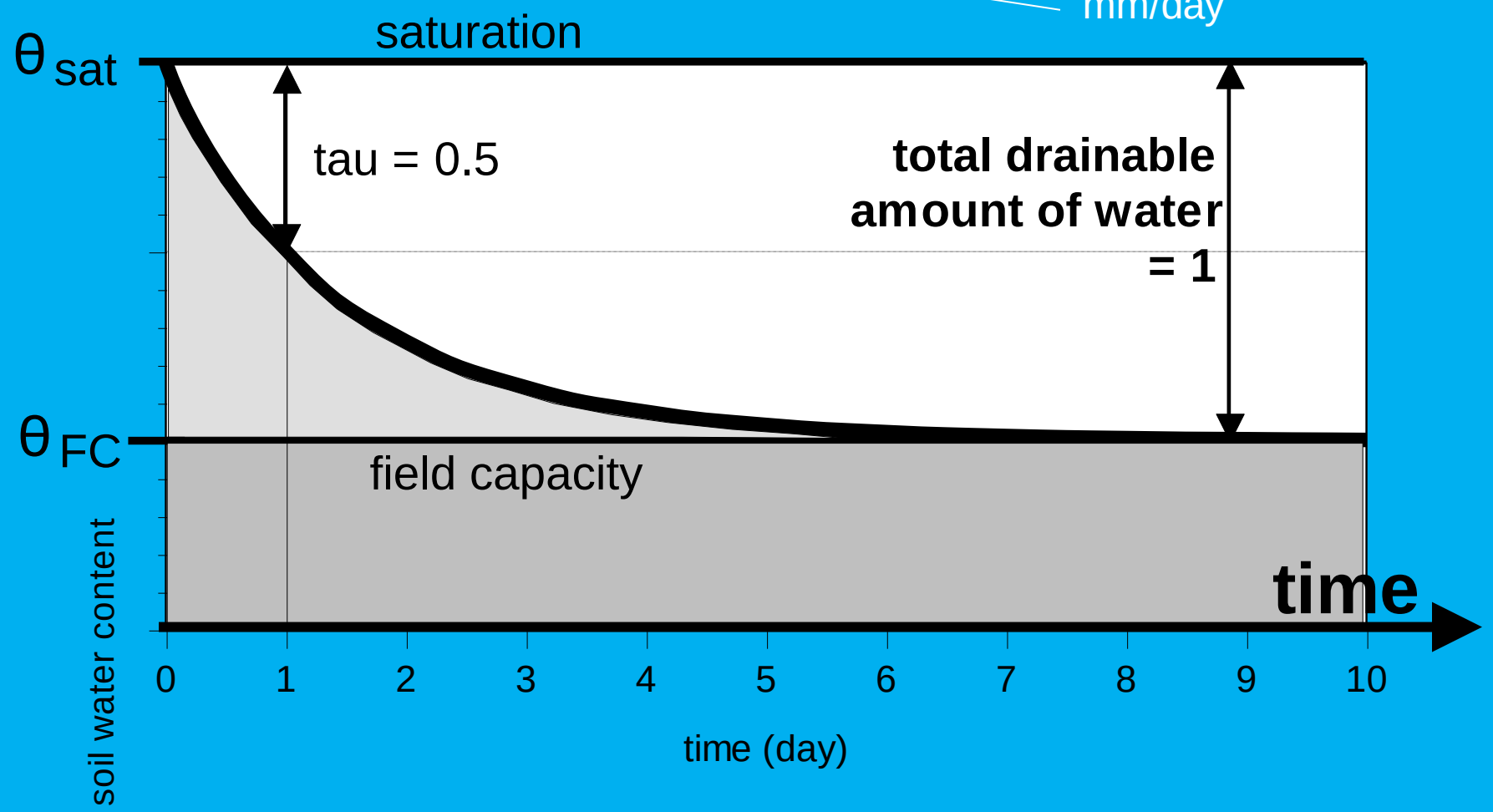


Movement of water in the soil profile

the drainage characteristic (tau)

$$0 \leq \tau = 0.0866\ Ksat^{0.35} \leq 1$$

mm/day



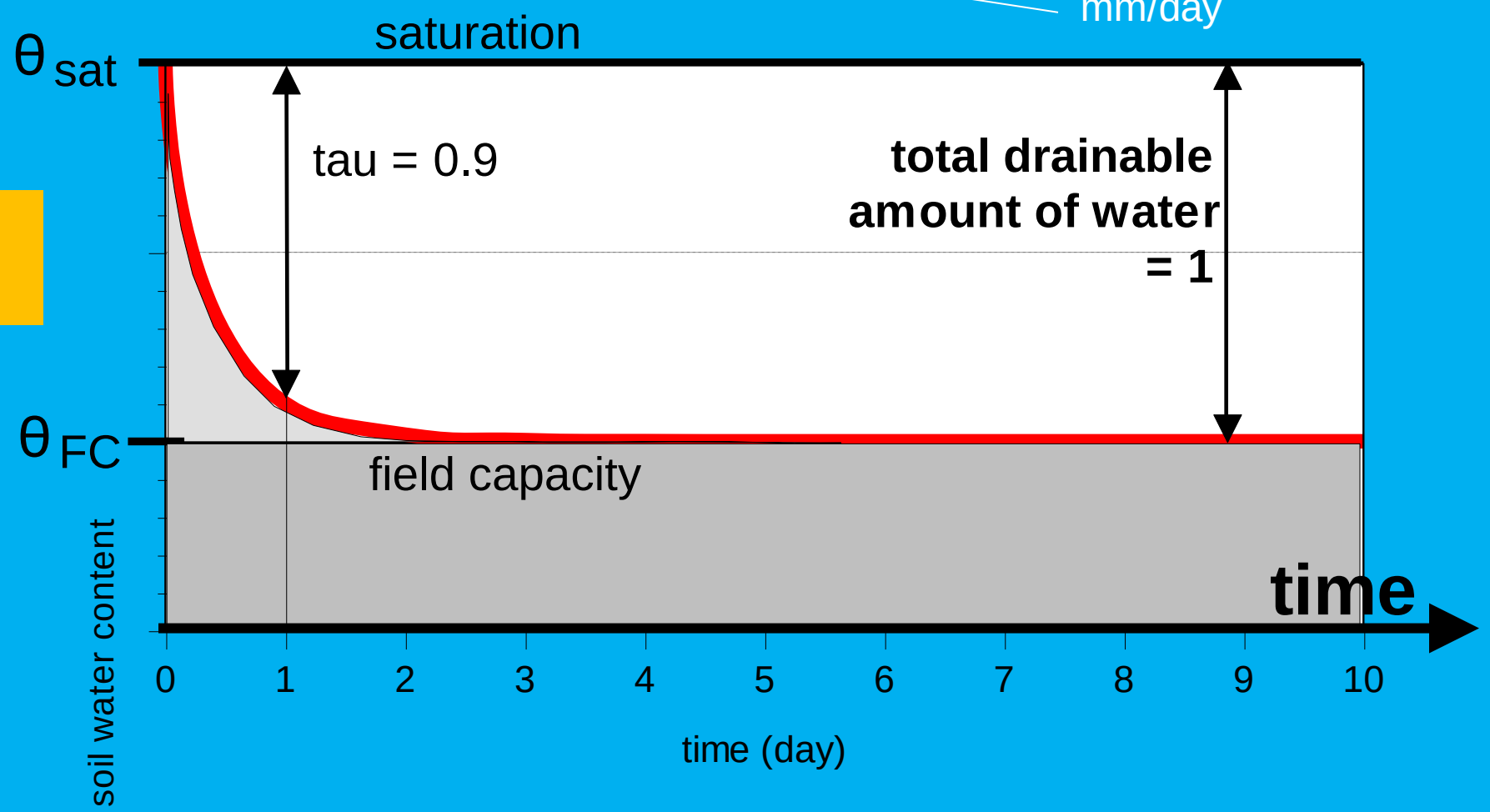
Movement of water in the soil profile

the drainage characteristic (tau)

$$0 \leq \tau = 0.0866\ Ksat^{0.35} \leq 1$$

mm/day

sand



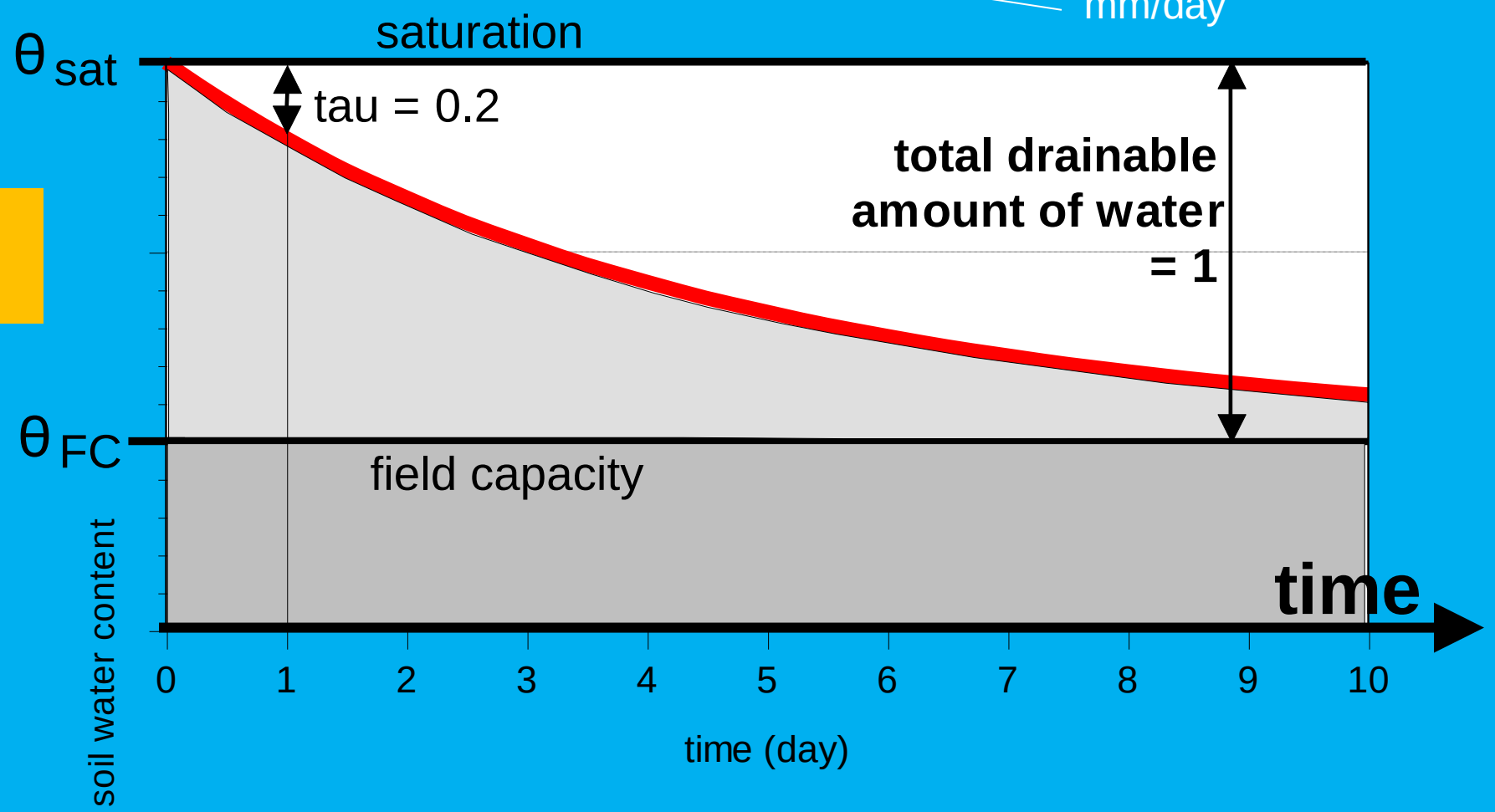
Movement of water in the soil profile

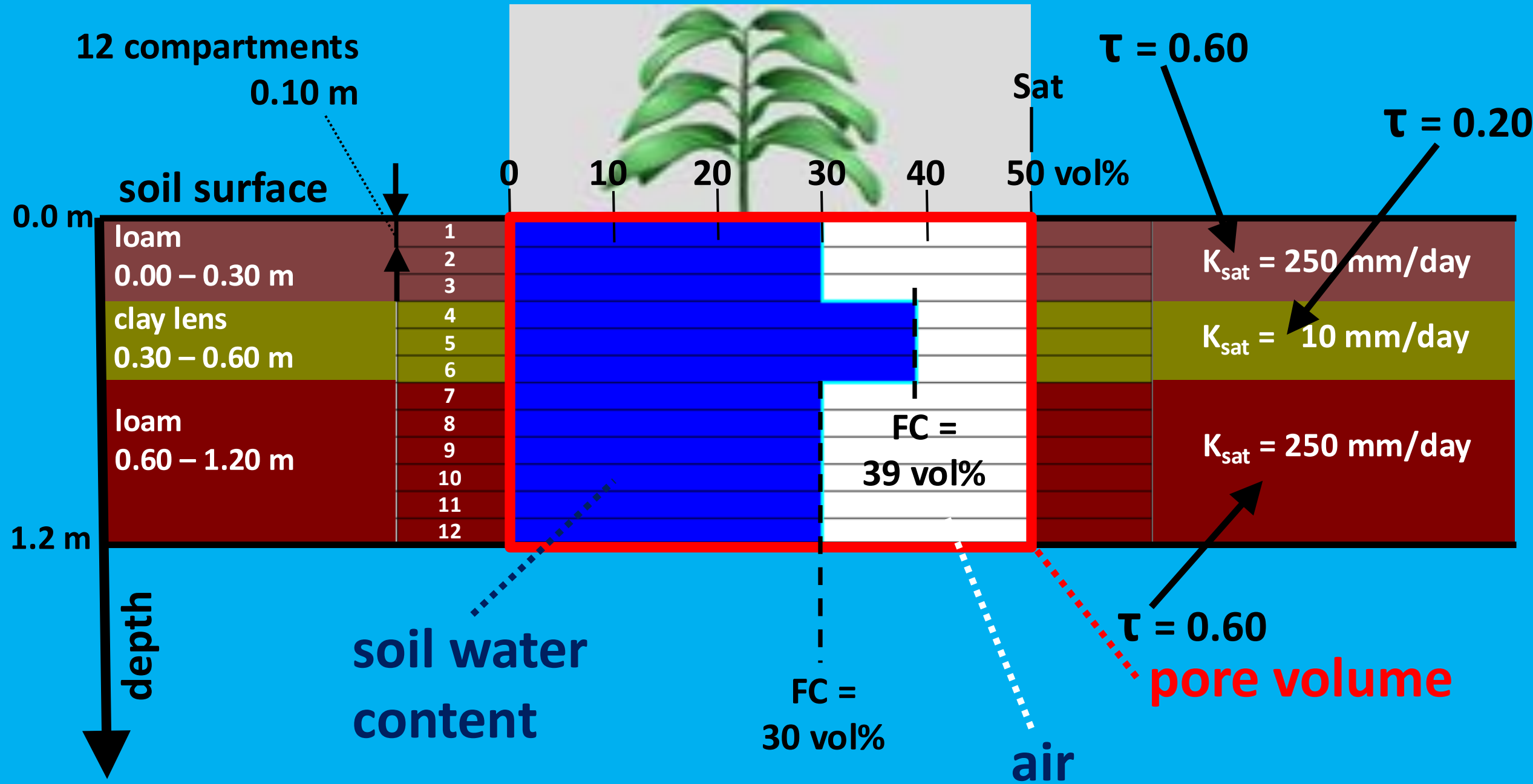
the drainage characteristic (tau)

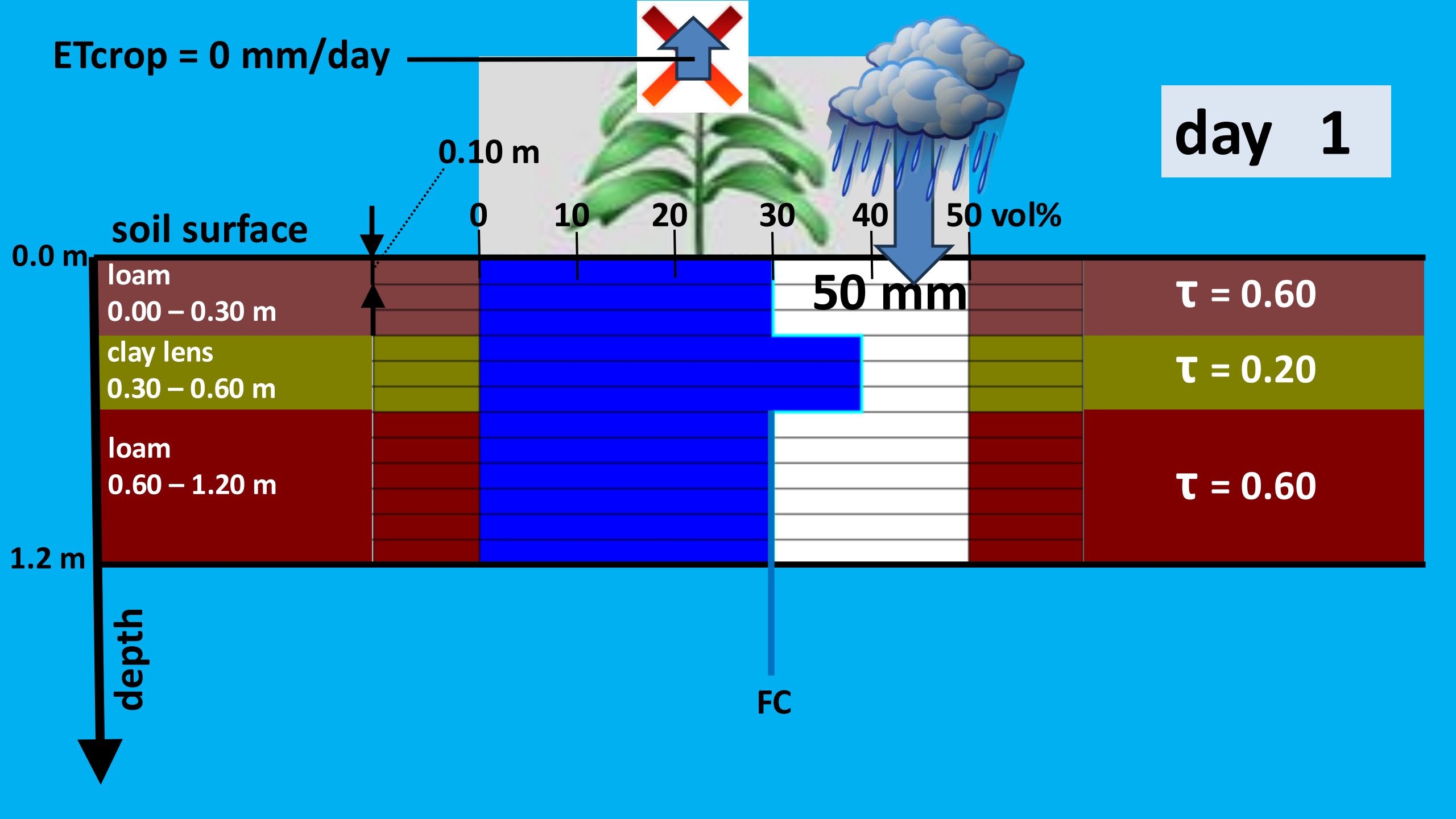
$$0 \leq \tau = 0.0866\ Ksat^{0.35} \leq 1$$

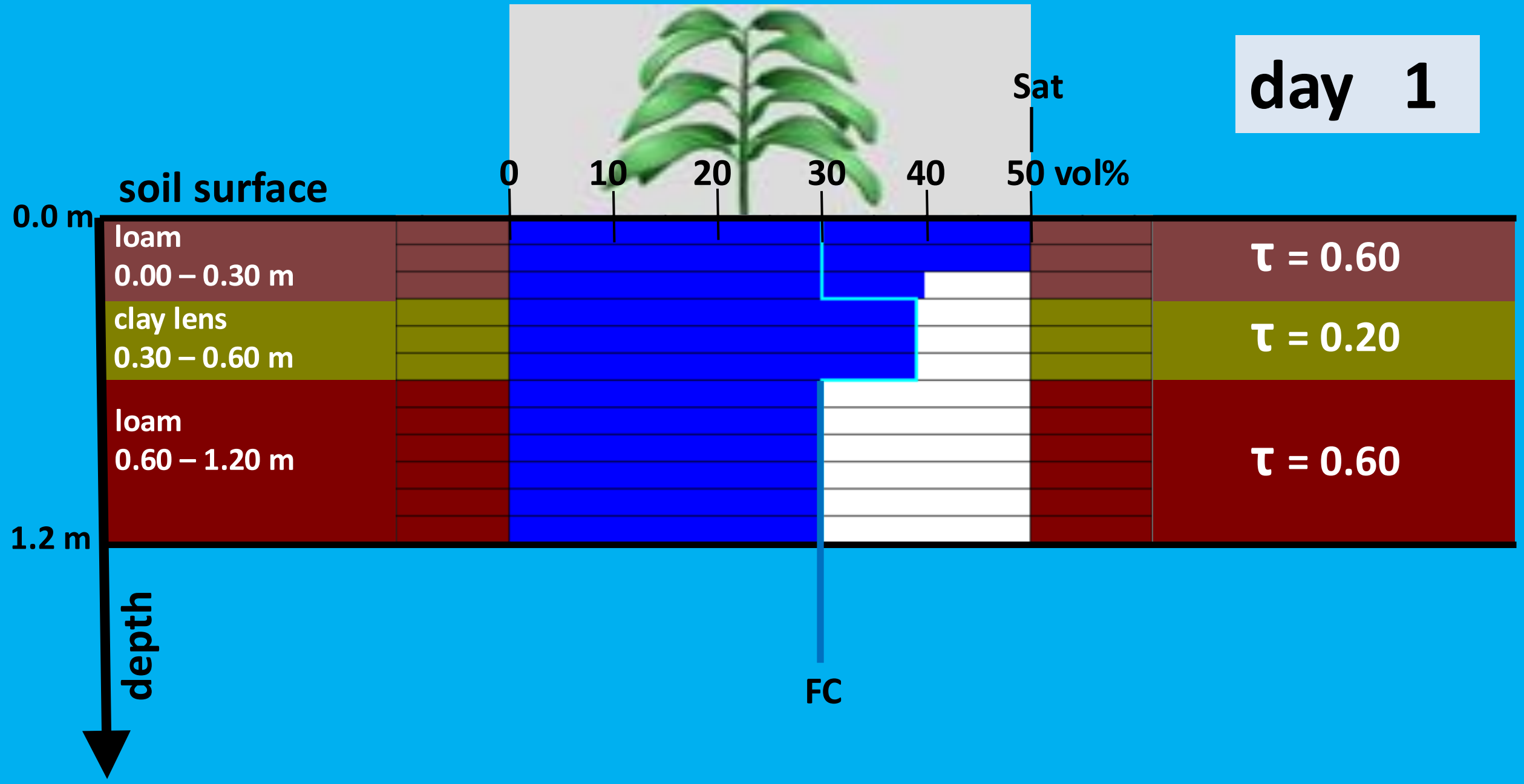
mm/day

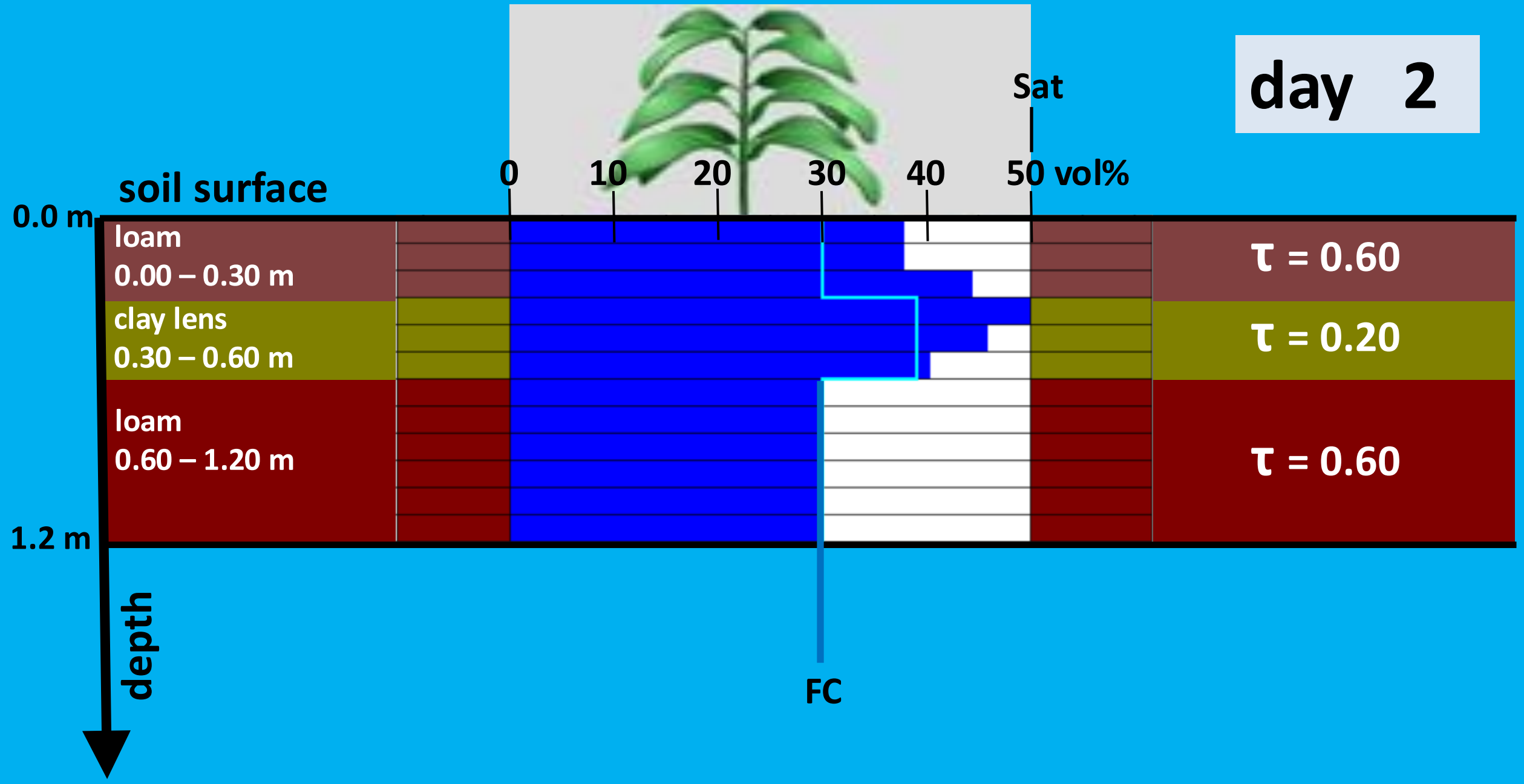
clay

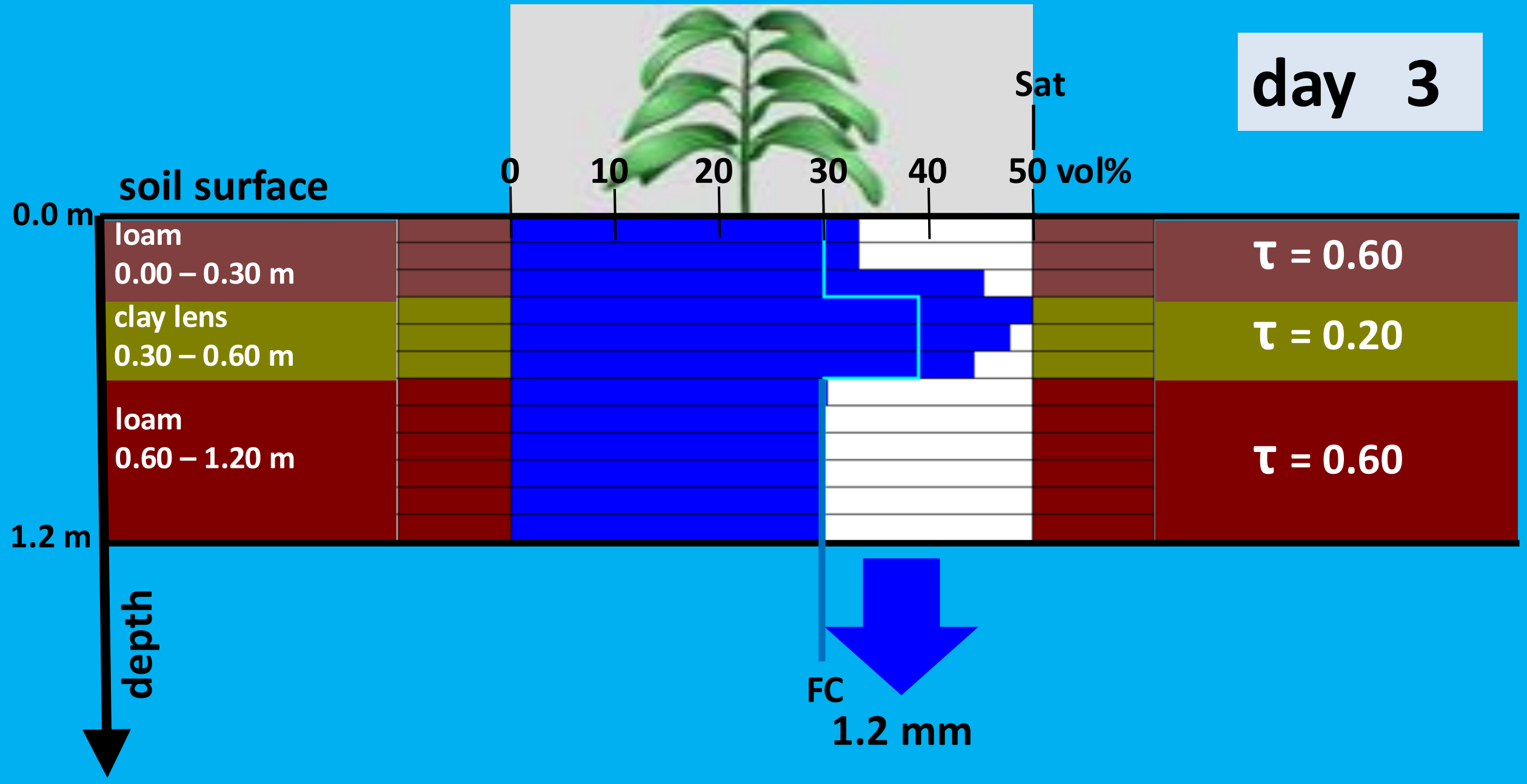


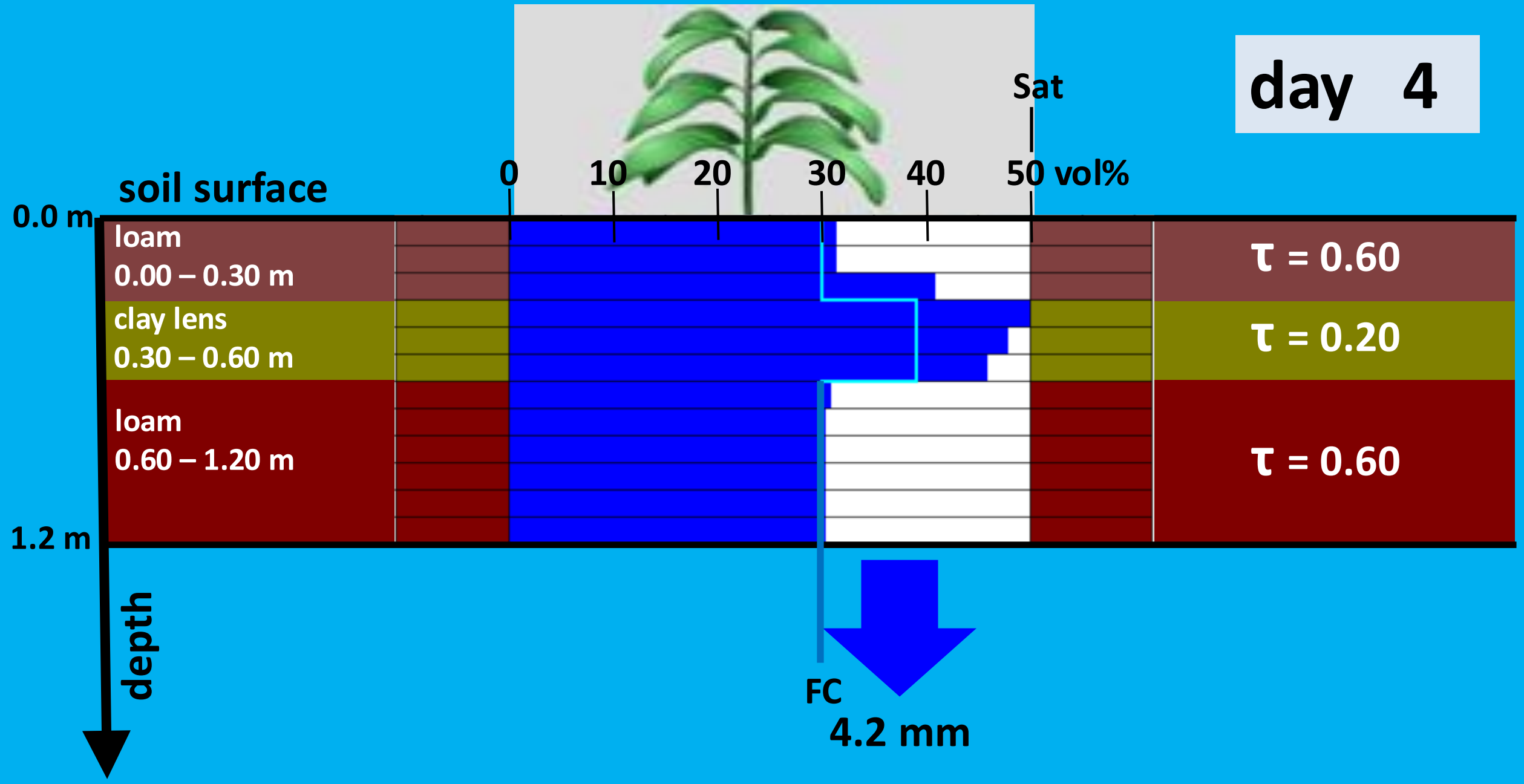

12 compartments
0.10 m
soil surface
0.0 m
1.2 m
depth
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
1
2
3
4
5
6
7
8
9
10
11
12
0
10
20
30
40
Sat
50 vol%
FC =
39 vol%
τ = 0.60
τ = 0.20
τ = 0.60
K_{sat} = 250 mm/day
K_{sat} = 10 mm/day
K_{sat} = 250 mm/day
soil water content
FC =
30 vol%
air
pore volume

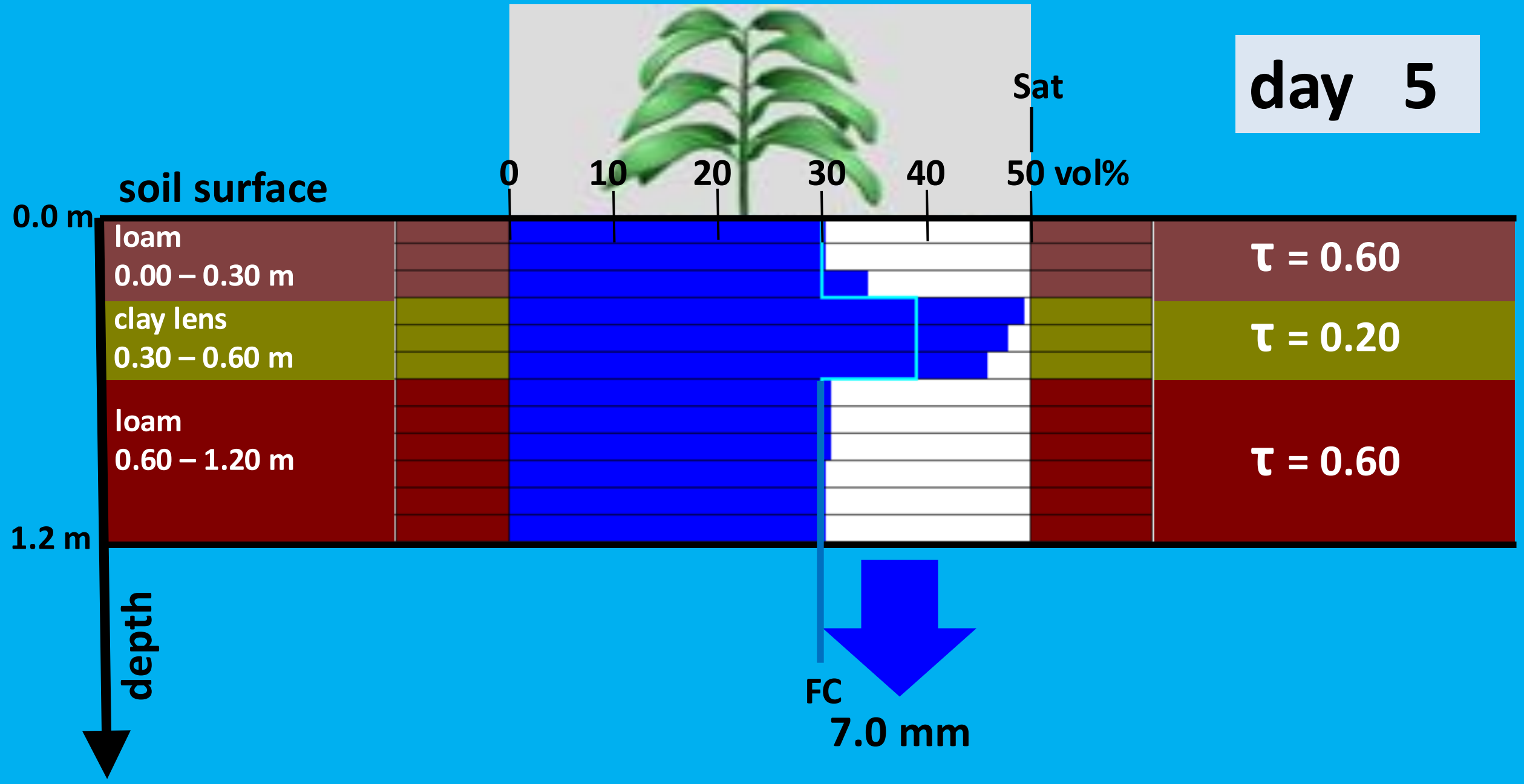

ETcrop = 0 mm/day
day 1
0.10 m
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
50 mm
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC

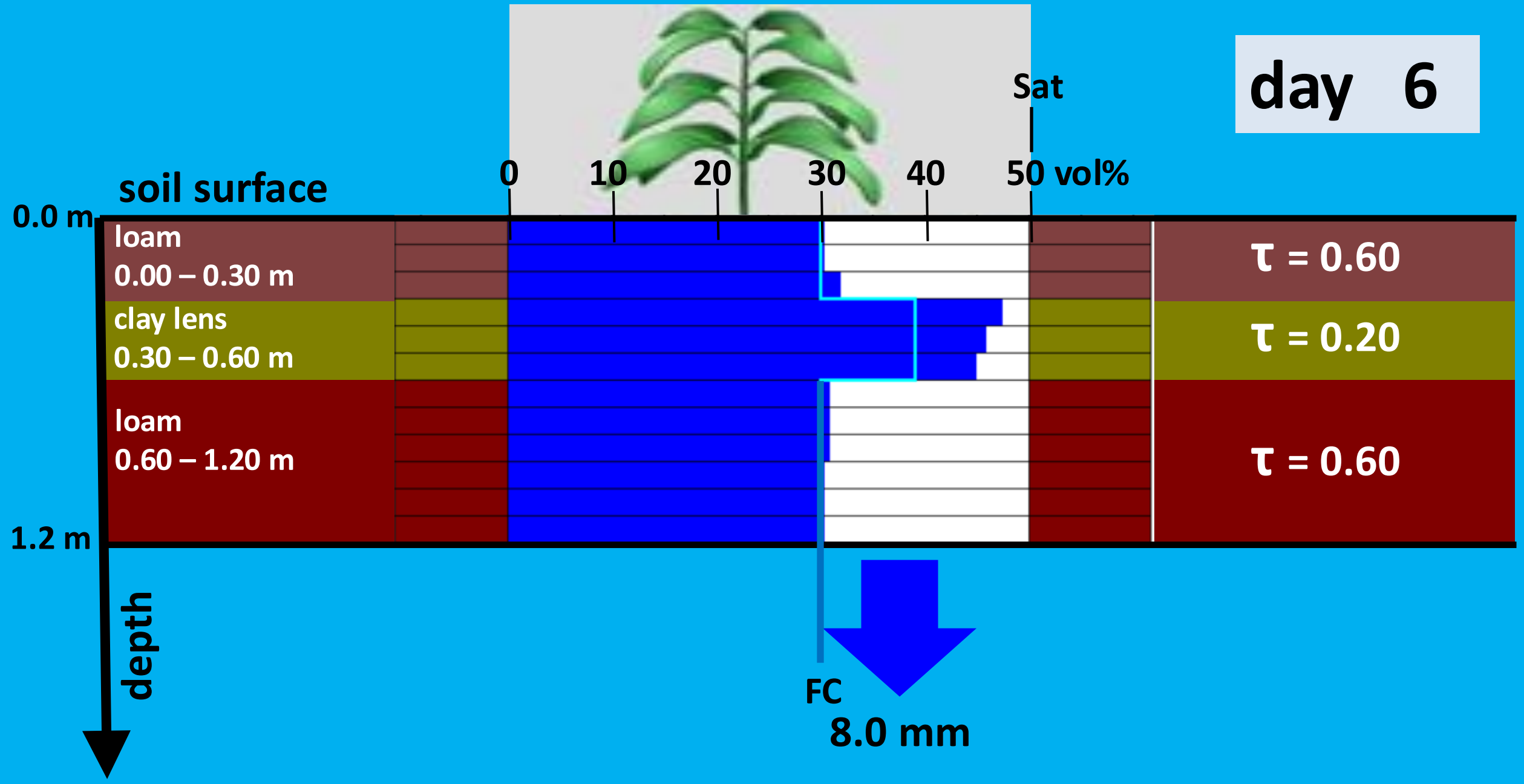

day 1
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC

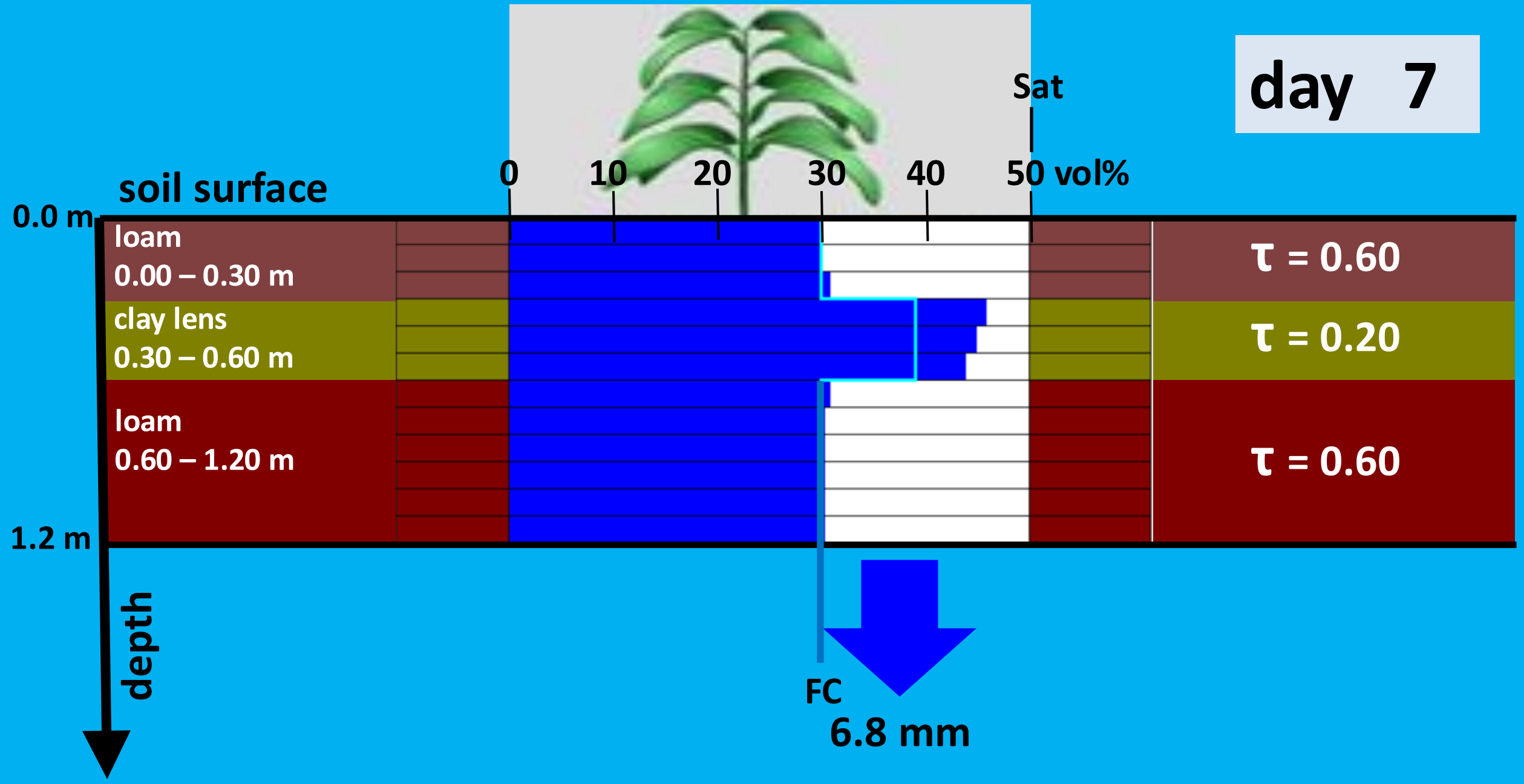

day 2
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC

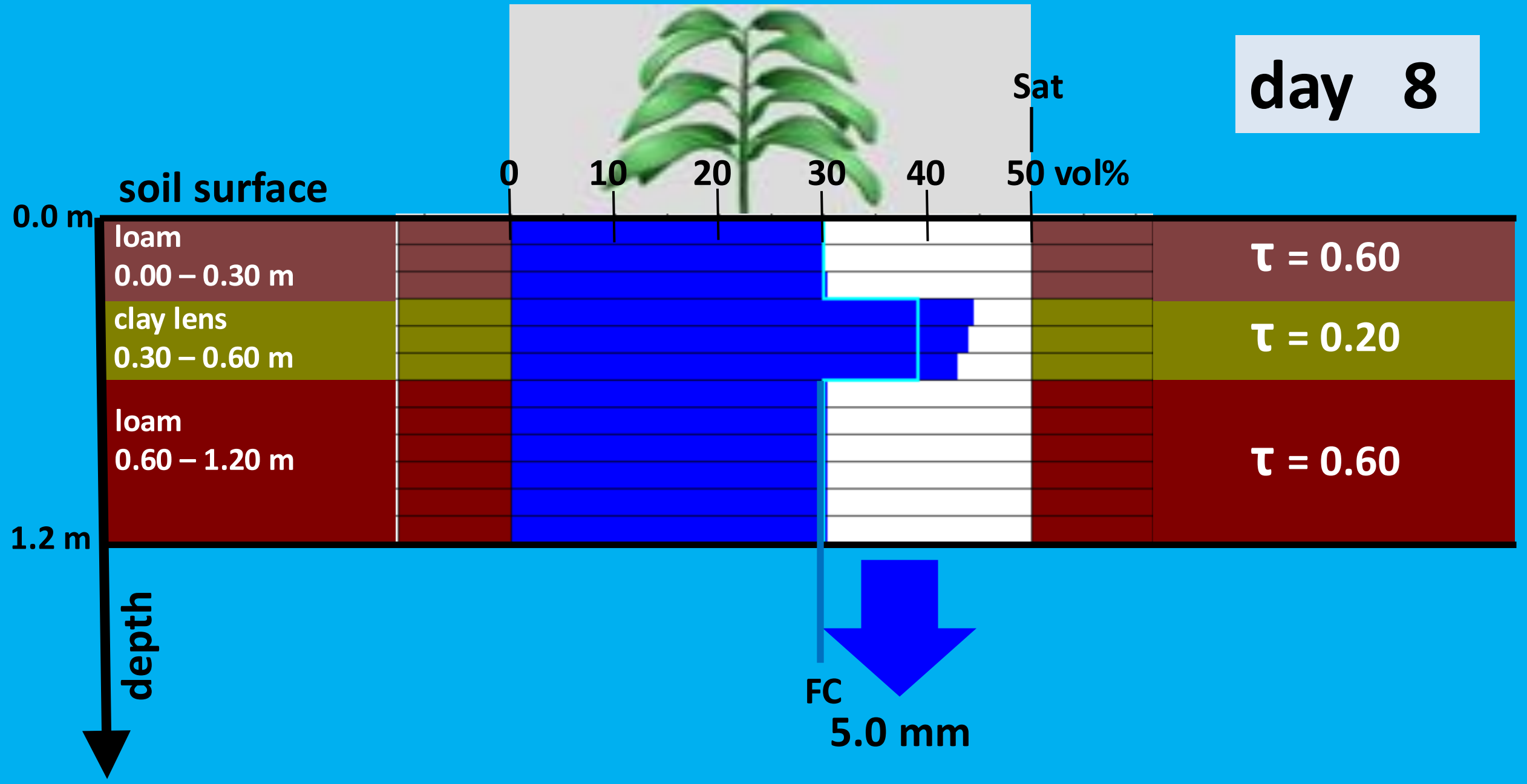

day 3
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC
1.2 mm

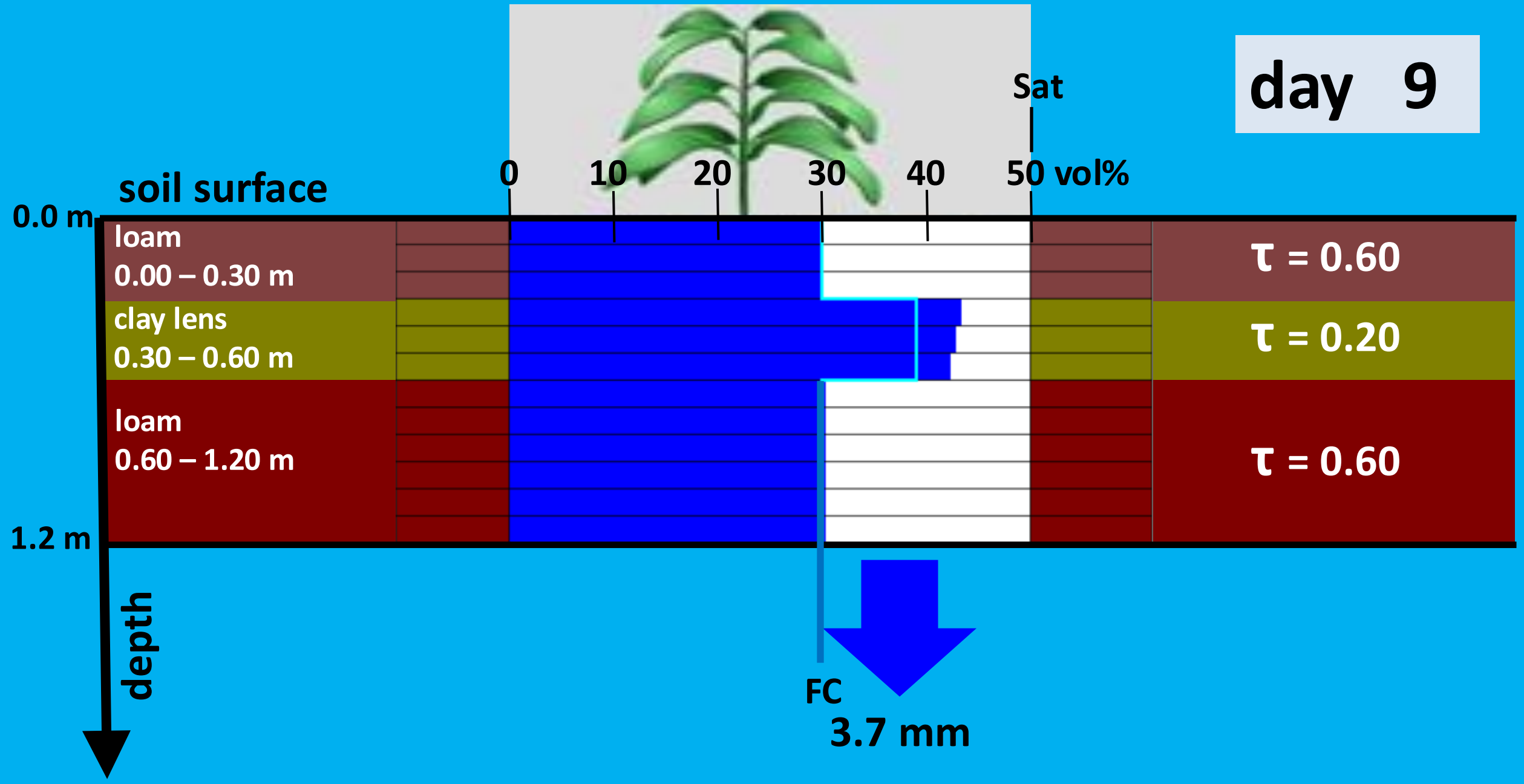

day 4
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC
4.2 mm

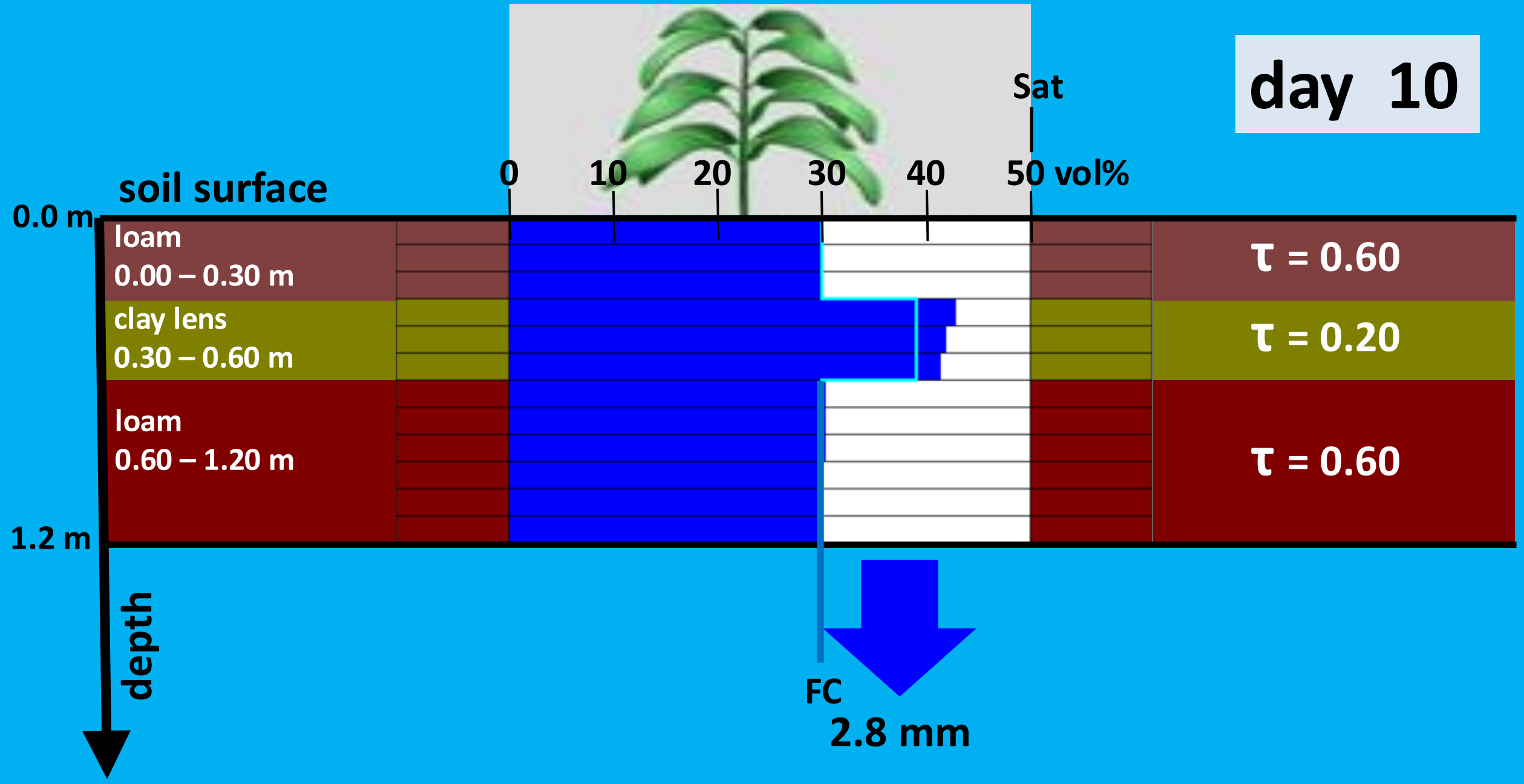

day 5
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC
7.0 mm

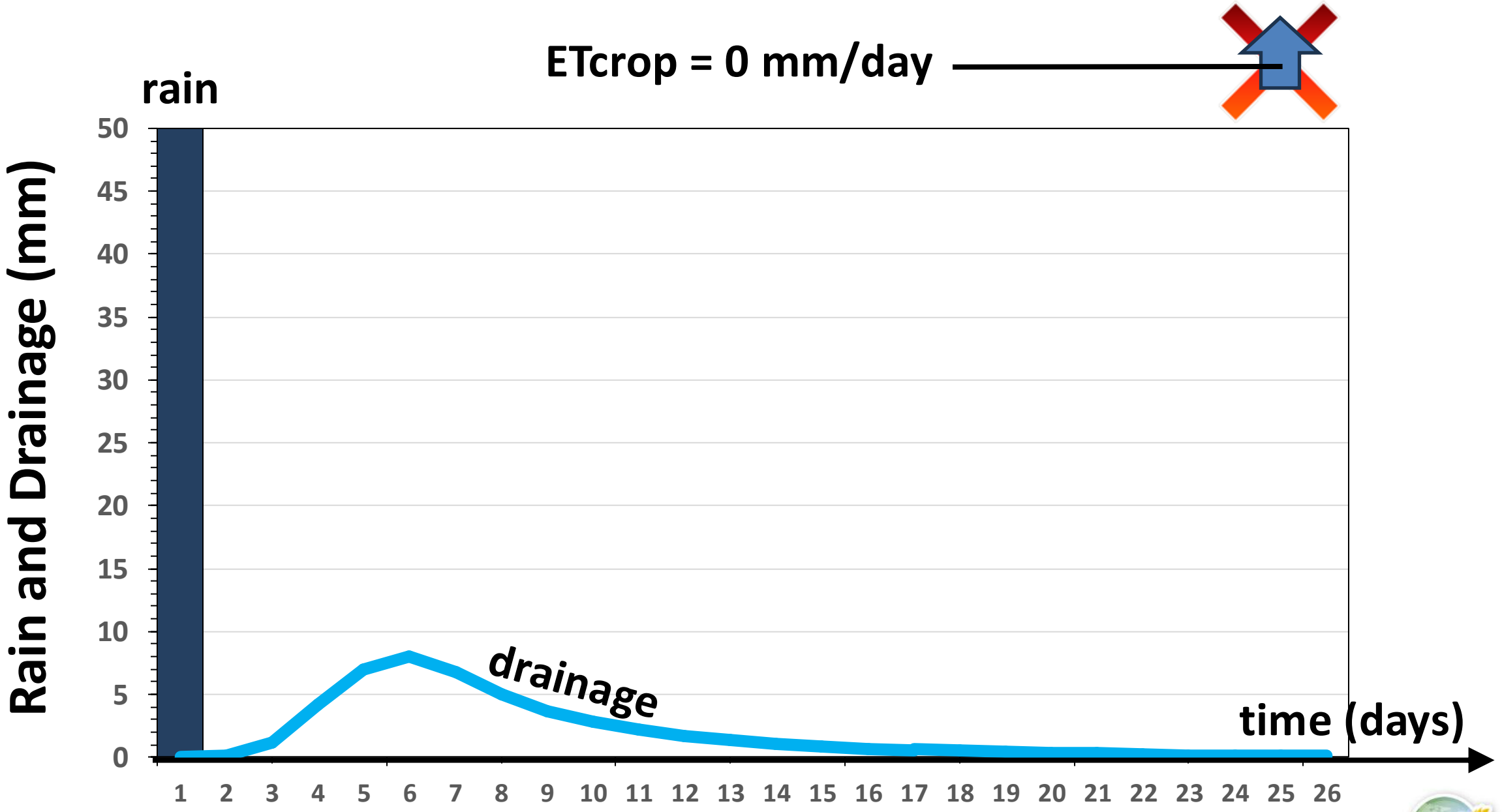

day 6
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC
8.0 mm


day 7
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC
6.8 mm


day 8
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC
5.0 mm


day 9
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC
3.7 mm


day 10
Sat
0
10
20
30
40
50 vol%
soil surface
0.0 m
loam
0.00 – 0.30 m
clay lens
0.30 – 0.60 m
loam
0.60 – 1.20 m
τ = 0.60
τ = 0.20
τ = 0.60
1.2 m
depth
FC
2.8 mm


ETcrop = 0 mm/day
rain
Rain and Drainage (mm)
50
45
40
35
30
25
20
15
10
5
0
drainage
time (days)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

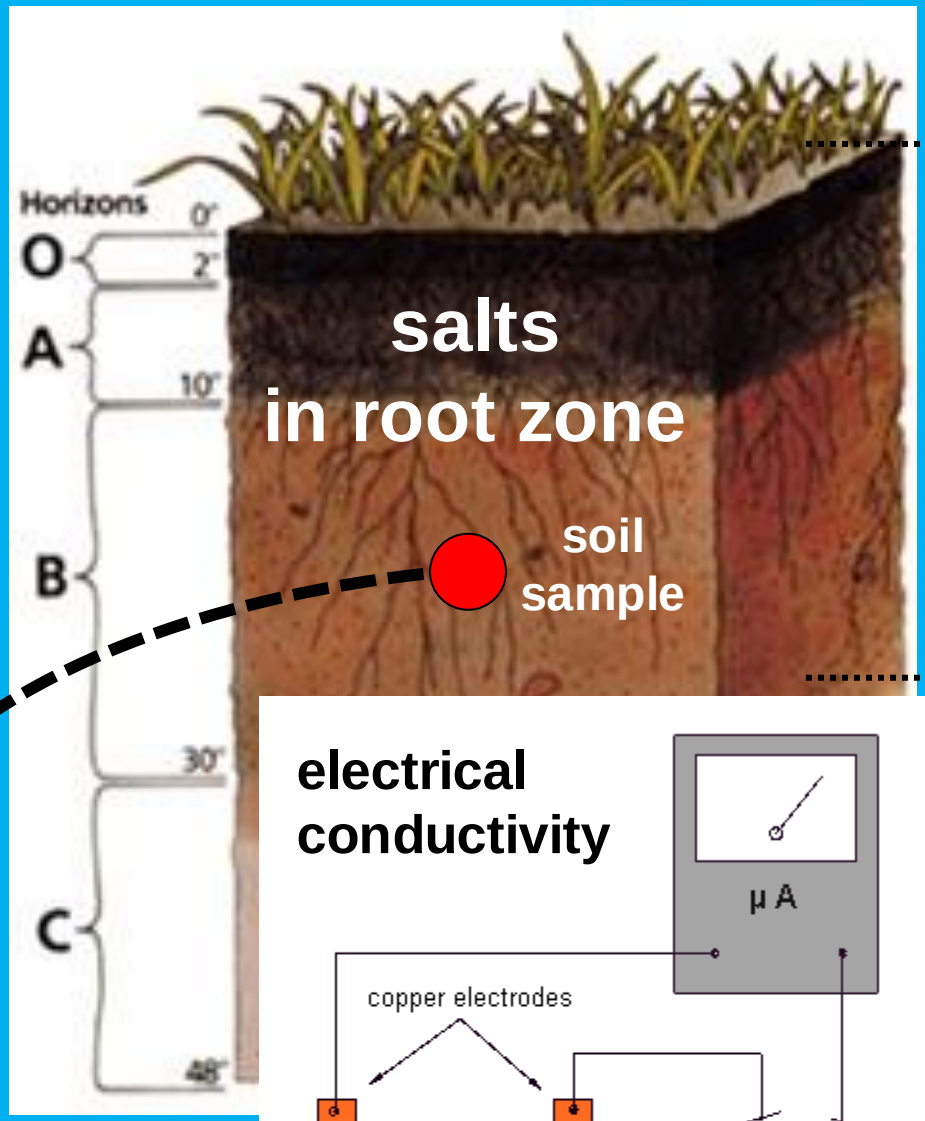
Simulation of the soil water and salt balance

1. Soil water balance
2. **Salt balance**
3. Evaluation of the salt balance

Indicator for salinity stress

ECe

add deionized water until a saturation paste is achieved



rooting depth

indicator for soil salinity stress

EC_e [dS/m]

electrical conductivity of saturation soil-paste extract

Salt accumulation and removal

Salt balance

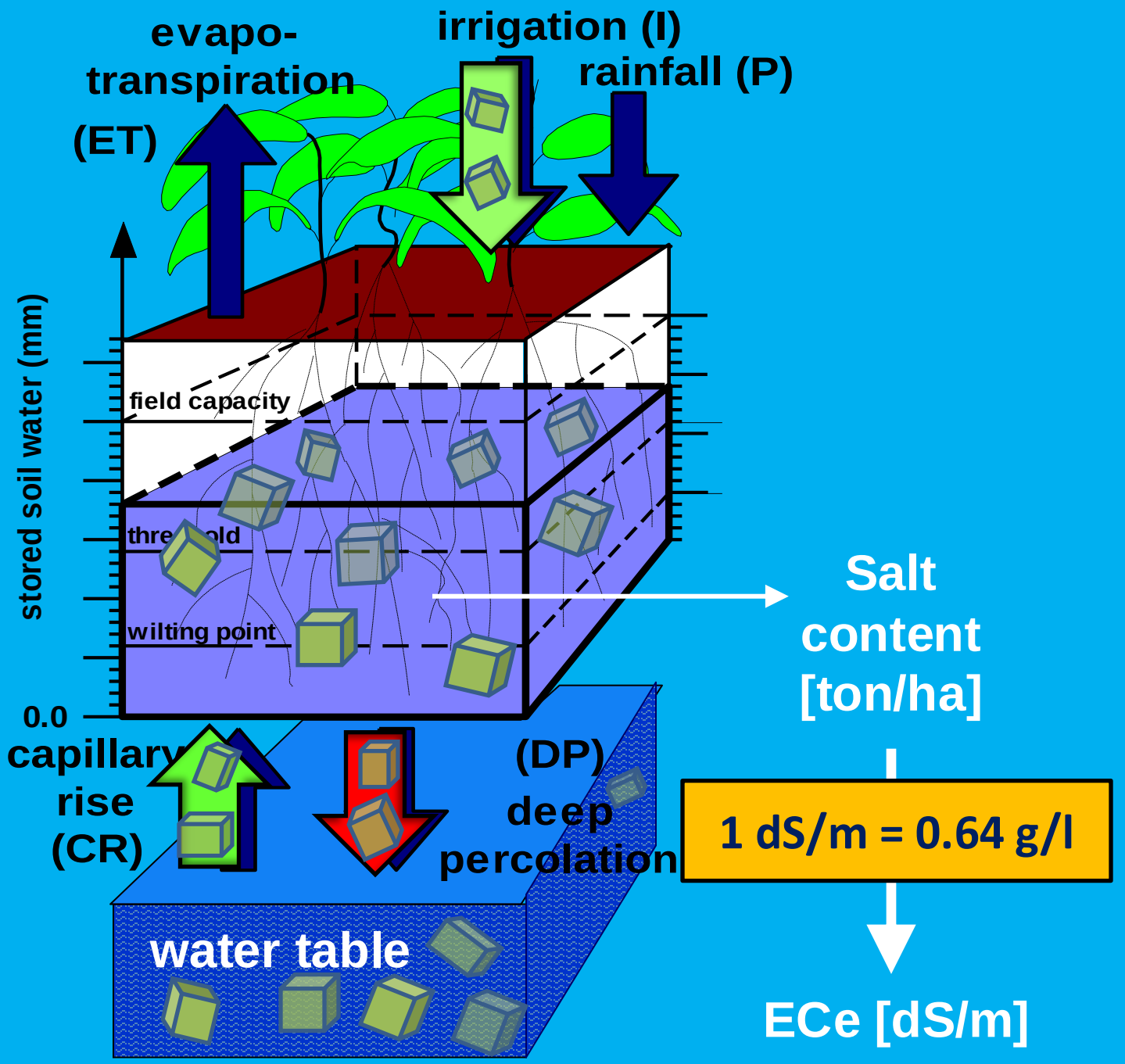
input

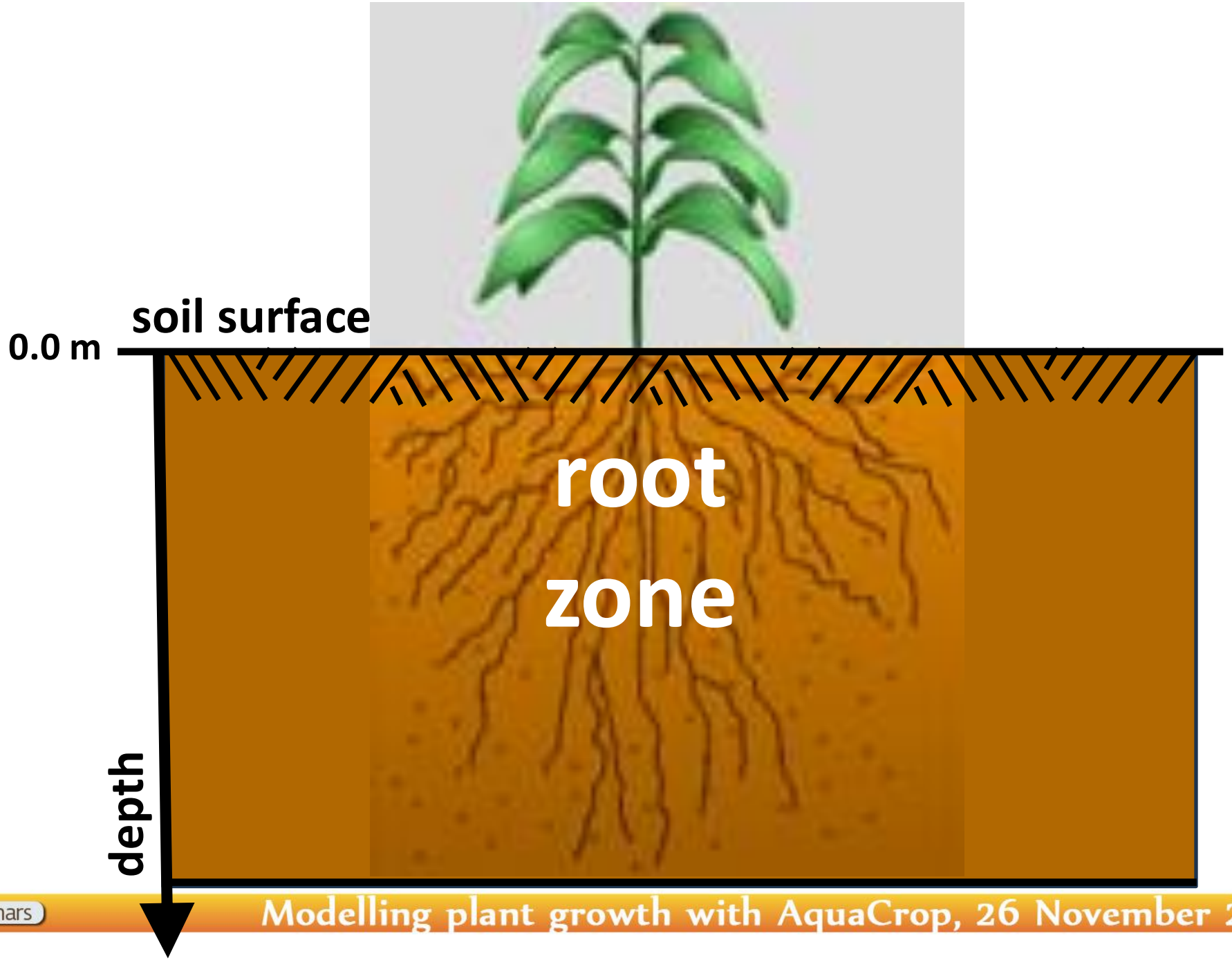
- Irrigation water
- Capillary rise from saline groundwater table

removal

- Leaching (deep percolation)

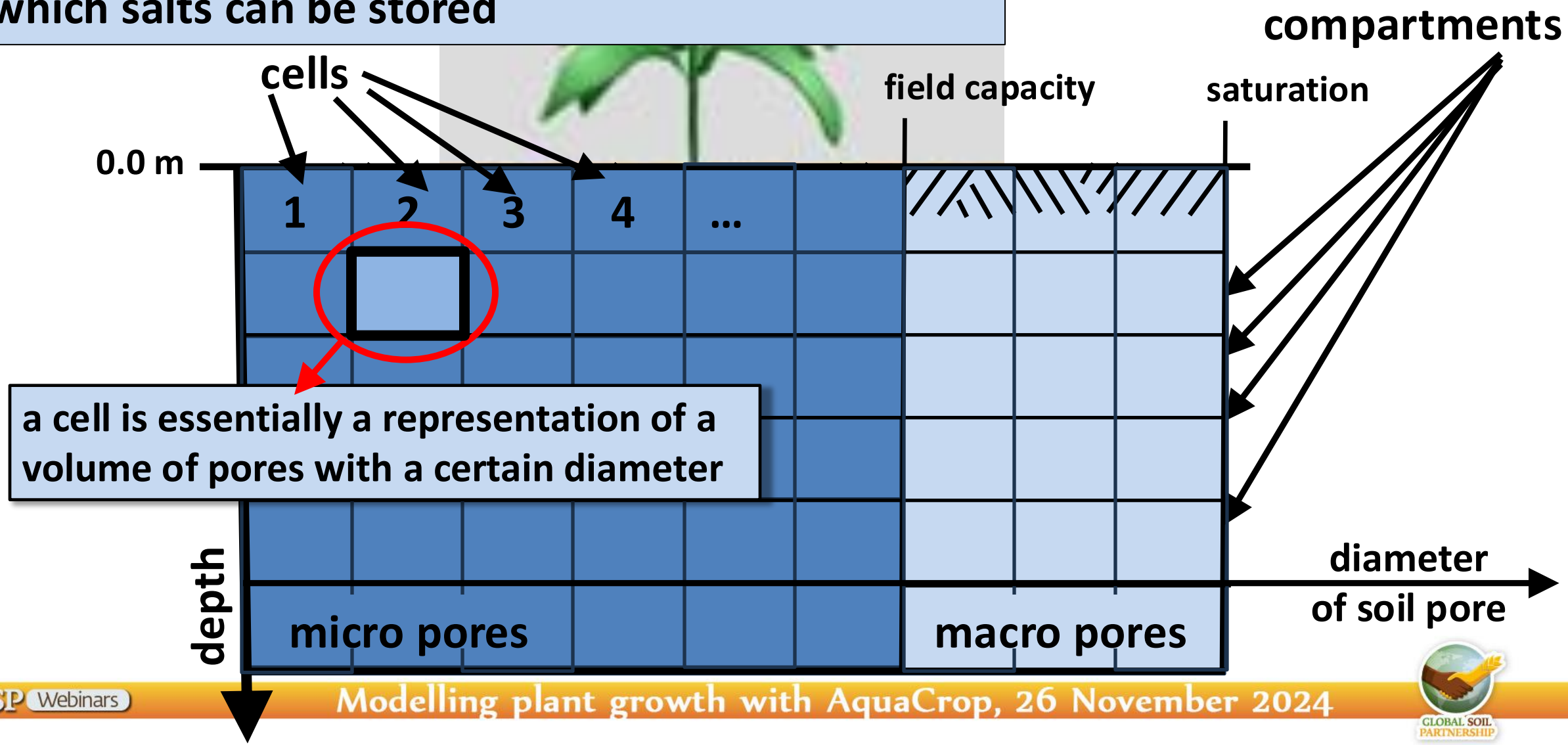
excess rainfall
excess irrigation




soil surface
0.0 m
root
zone
depth

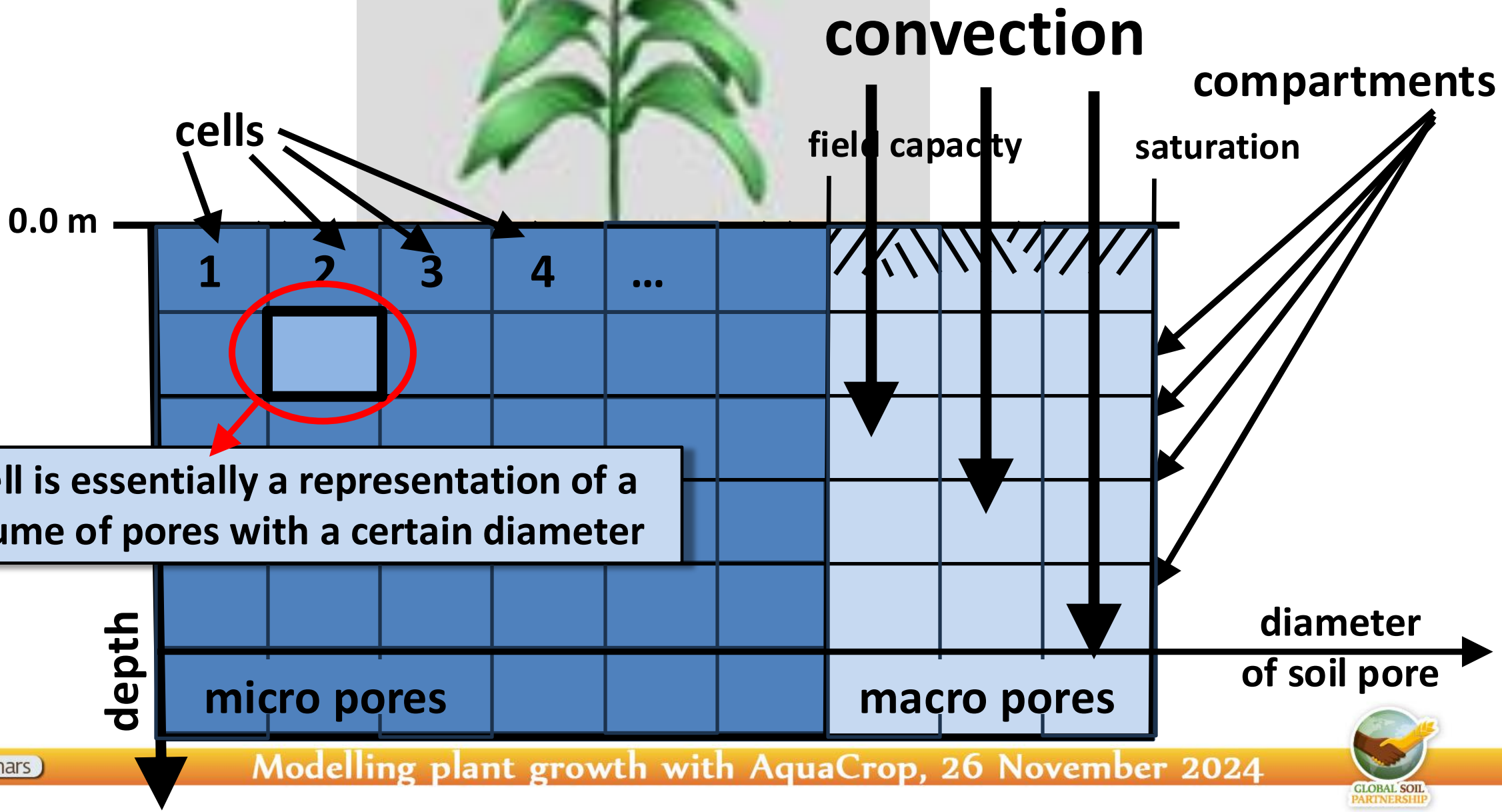
to simulate the convection and diffusion of salts, a soil compartment is divided into a number of cells in which salts can be stored

to simulate the convection and diffusion of salts, a soil compartment is divided into a number of cells in which salts can be stored



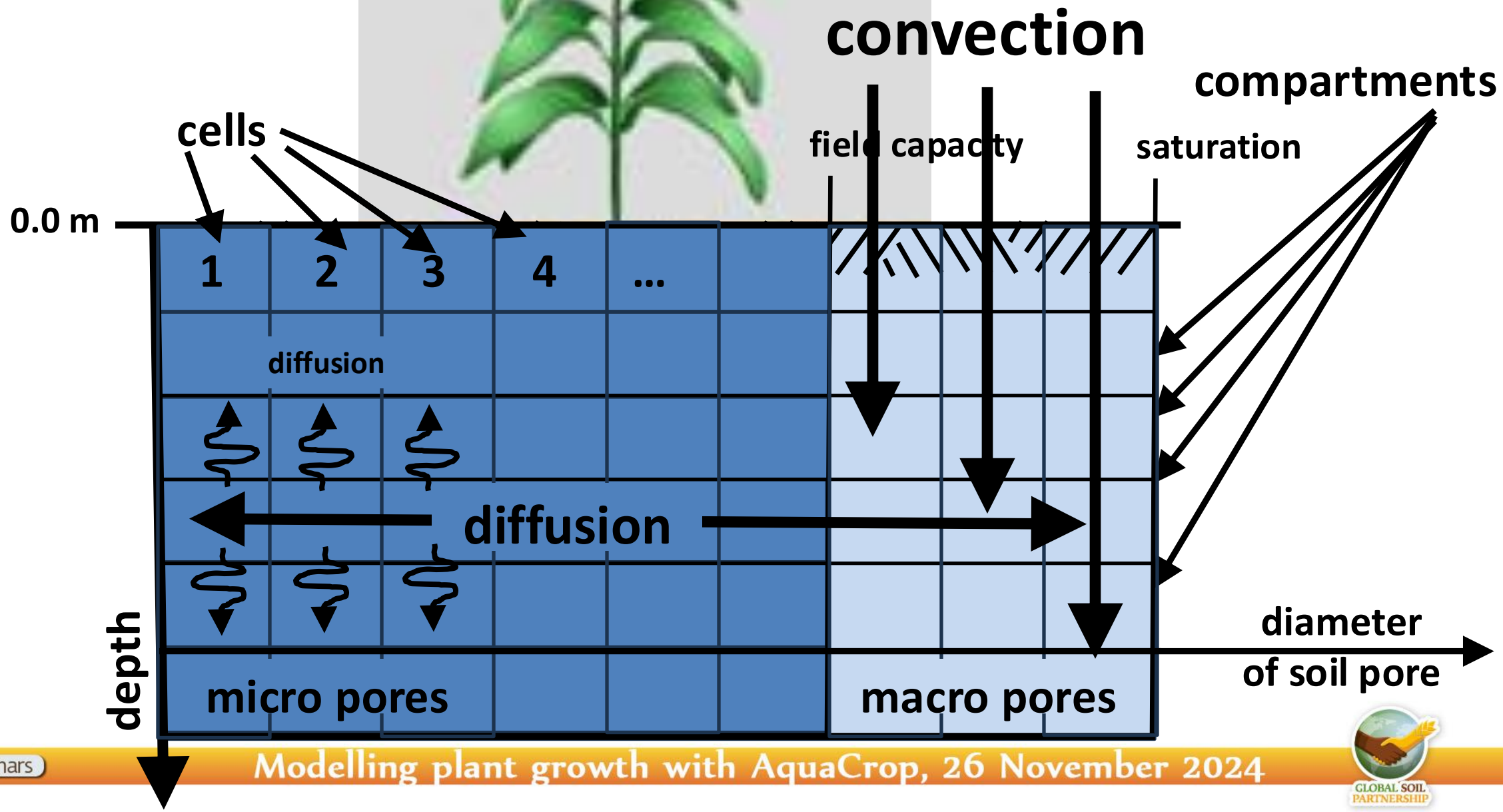
convection and diffusion of salts

the solute transport in the macro pores bypass the soil matrix

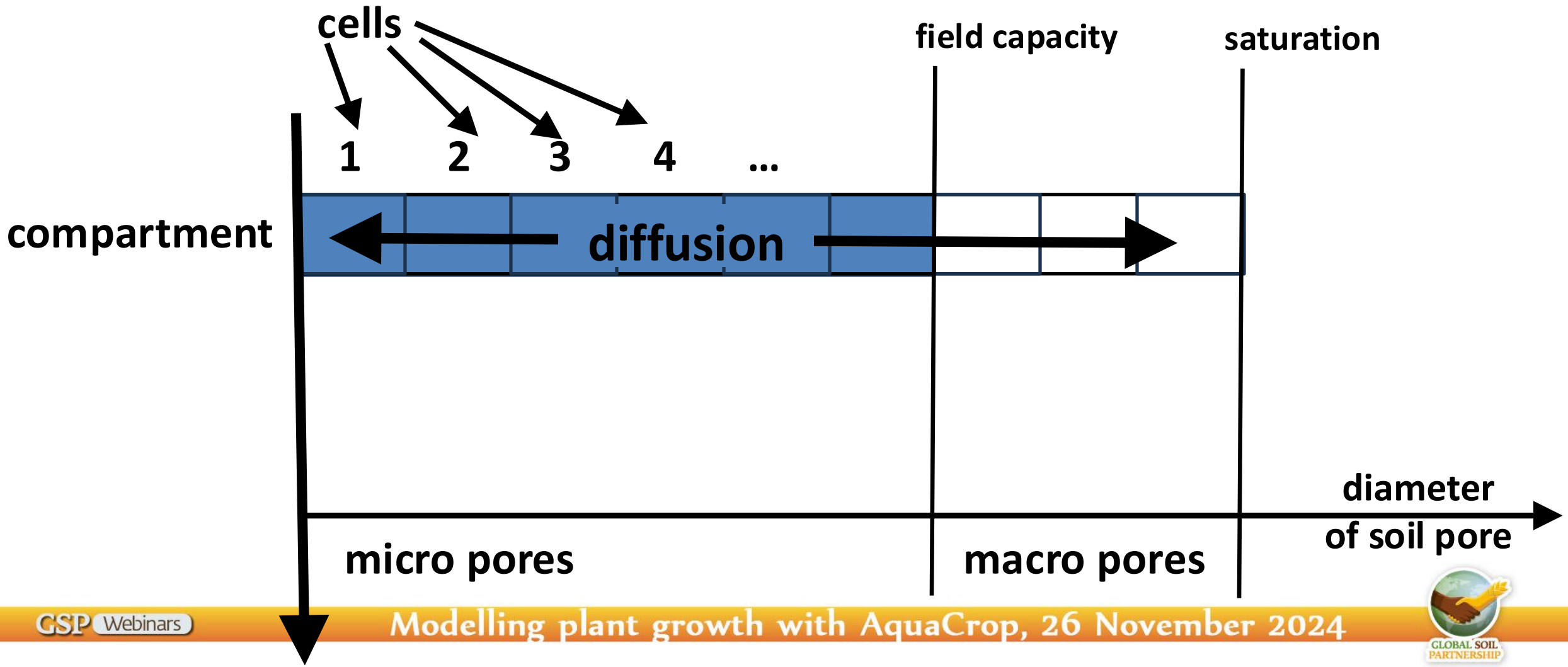


convection and diffusion of salts

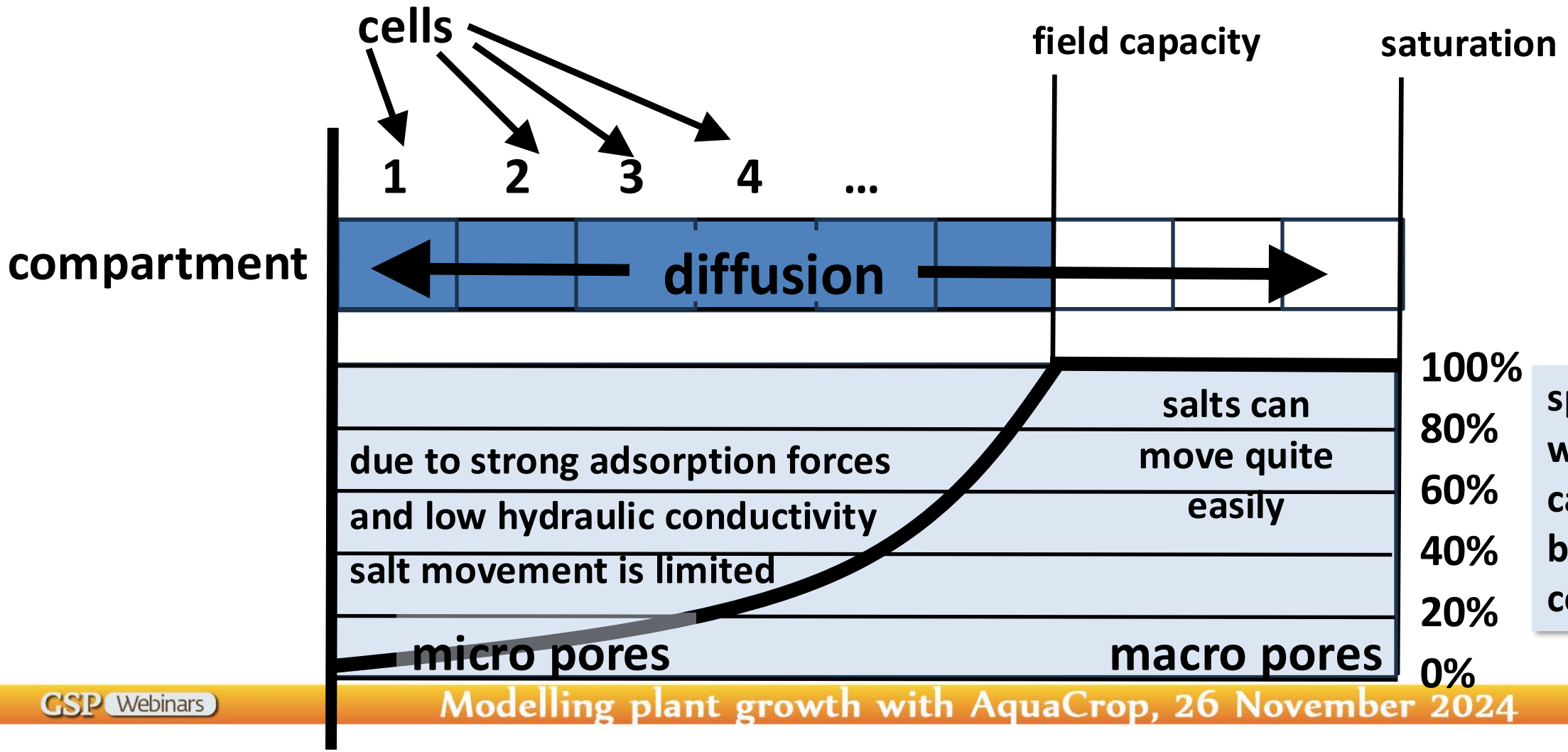
the solute transport in the macro pores bypass the soil matrix



the driving force for the diffusion process
is the salt concentration gradient that exists between
the water solution in the adjacent pores



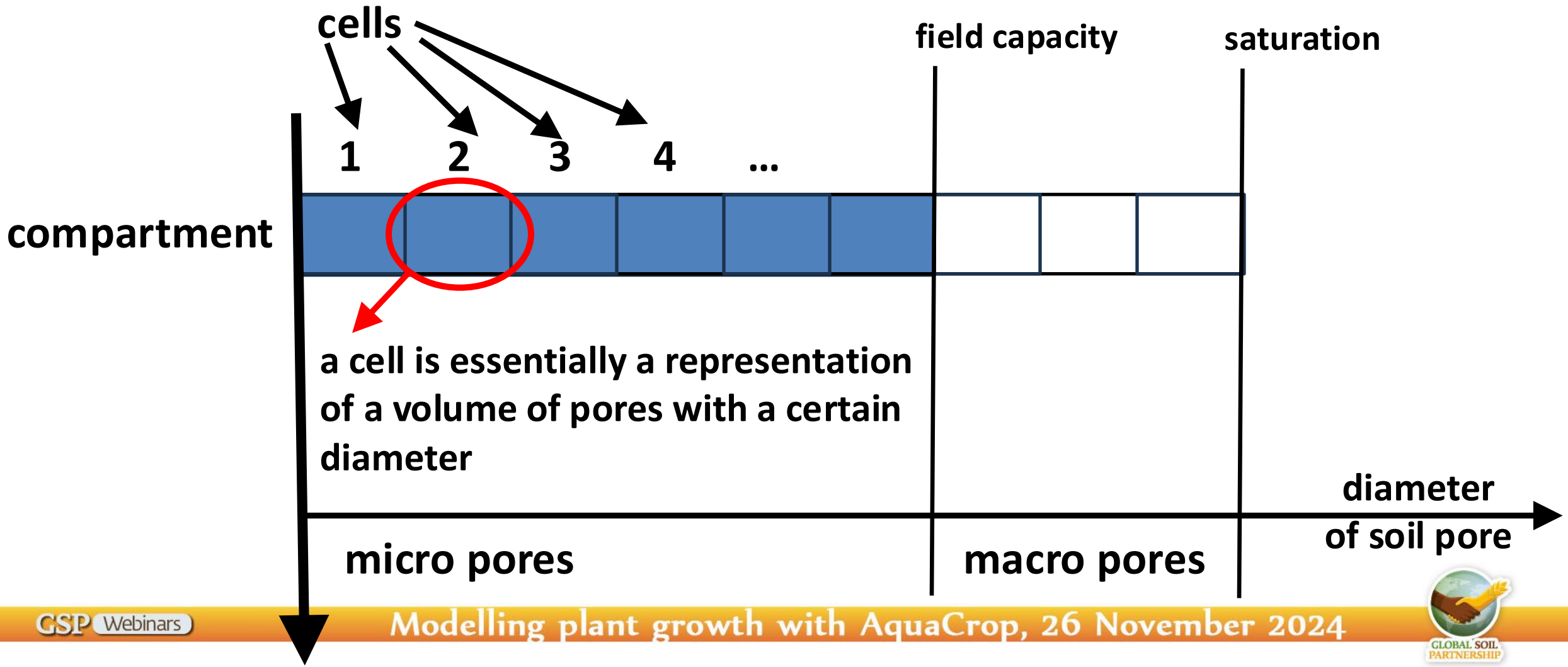
the driving force for the diffusion process is the salt concentration gradient that exists between the water solution in the adjacent pores

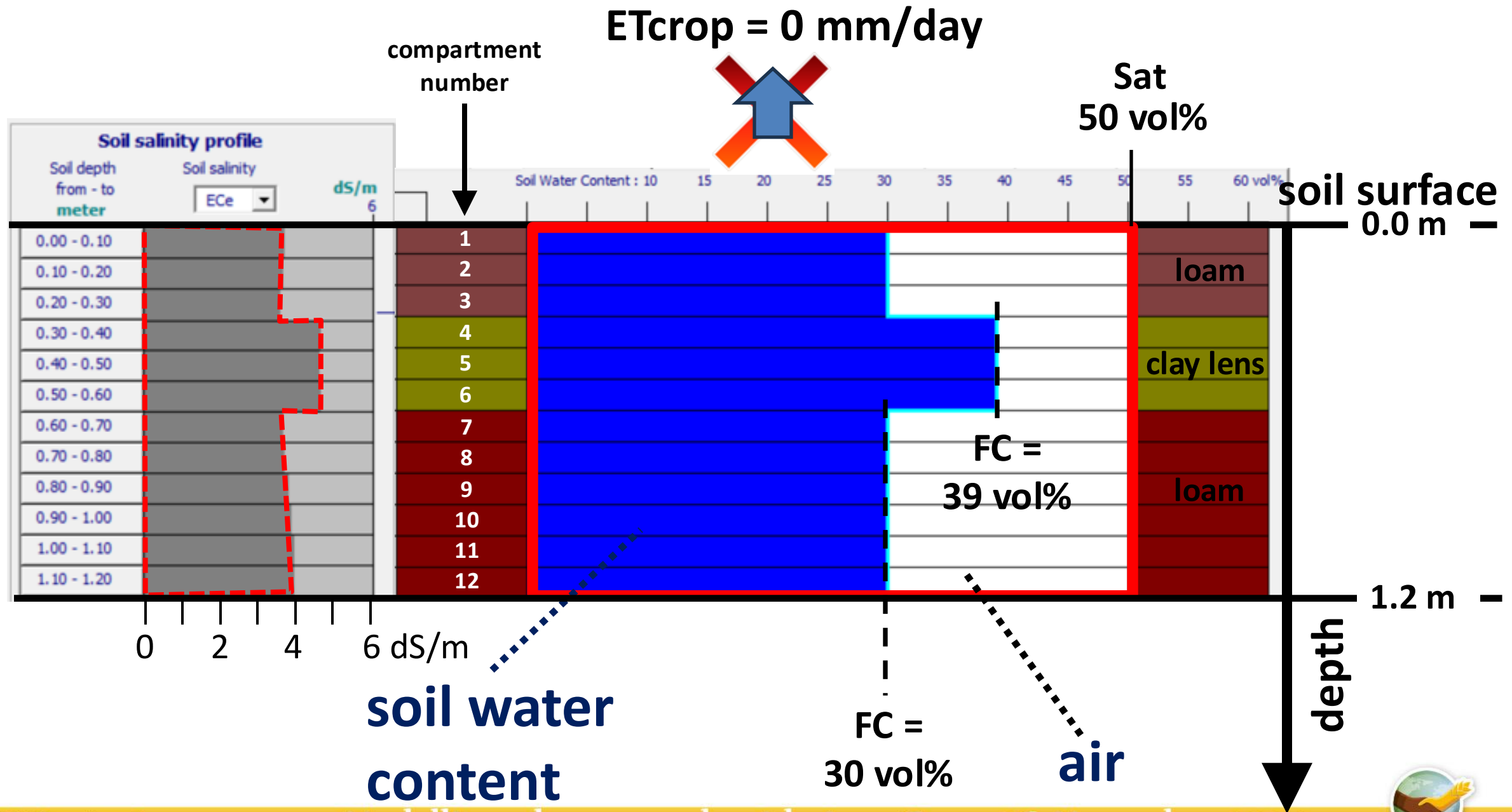


speed with which salts can move between cells

The number of cells depends on the soil type.

Since salts are strongly attached to the clay particles
a clayey horizon will contain more cells than a sandy horizon




ETcrop = 0 mm/day
compartment number
Sat
50 vol%
soil surface
0.0 m
Soil salinity profile
Soil depth from - to meter
Soil salinity
ECe
dS/m
Soil Water Content : 10 15 20 25 30 35 40 45 50 55 60 vol%
0.00 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 0.60
0.60 - 0.70
0.70 - 0.80
0.80 - 0.90
0.90 - 1.00
1.00 - 1.10
1.10 - 1.20
1 2 3 4 5 6 7 8 9 10 11 12
loam
clay lens
loam
FC =
39 vol%
0 2 4 6 dS/m
soil water content
FC =
30 vol%
air
1.2 m
depth

salt:
Σ(IN) = 0.640 ton/ha

compartment number

50 mm
EC_w = 2 dS/m

soil surface
0.0 m

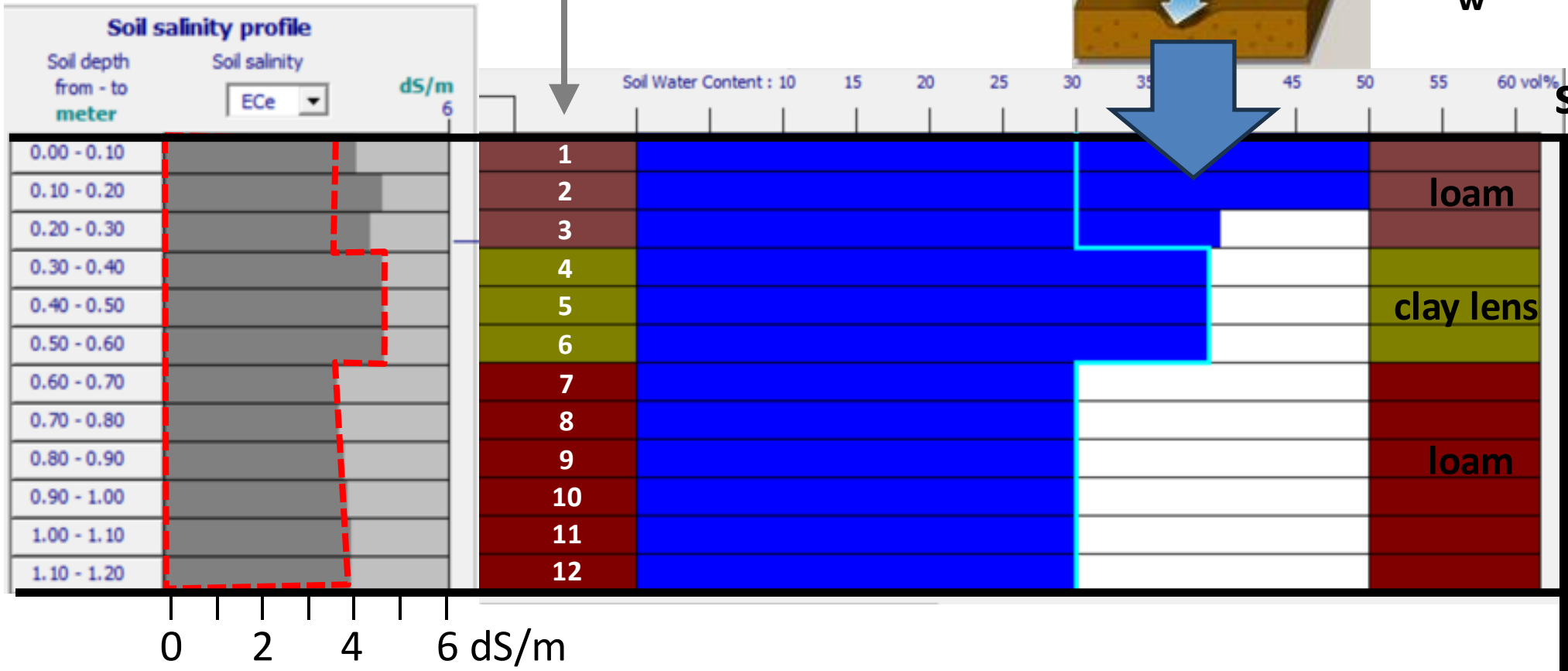
1.2 m

depth

loam

clay lens

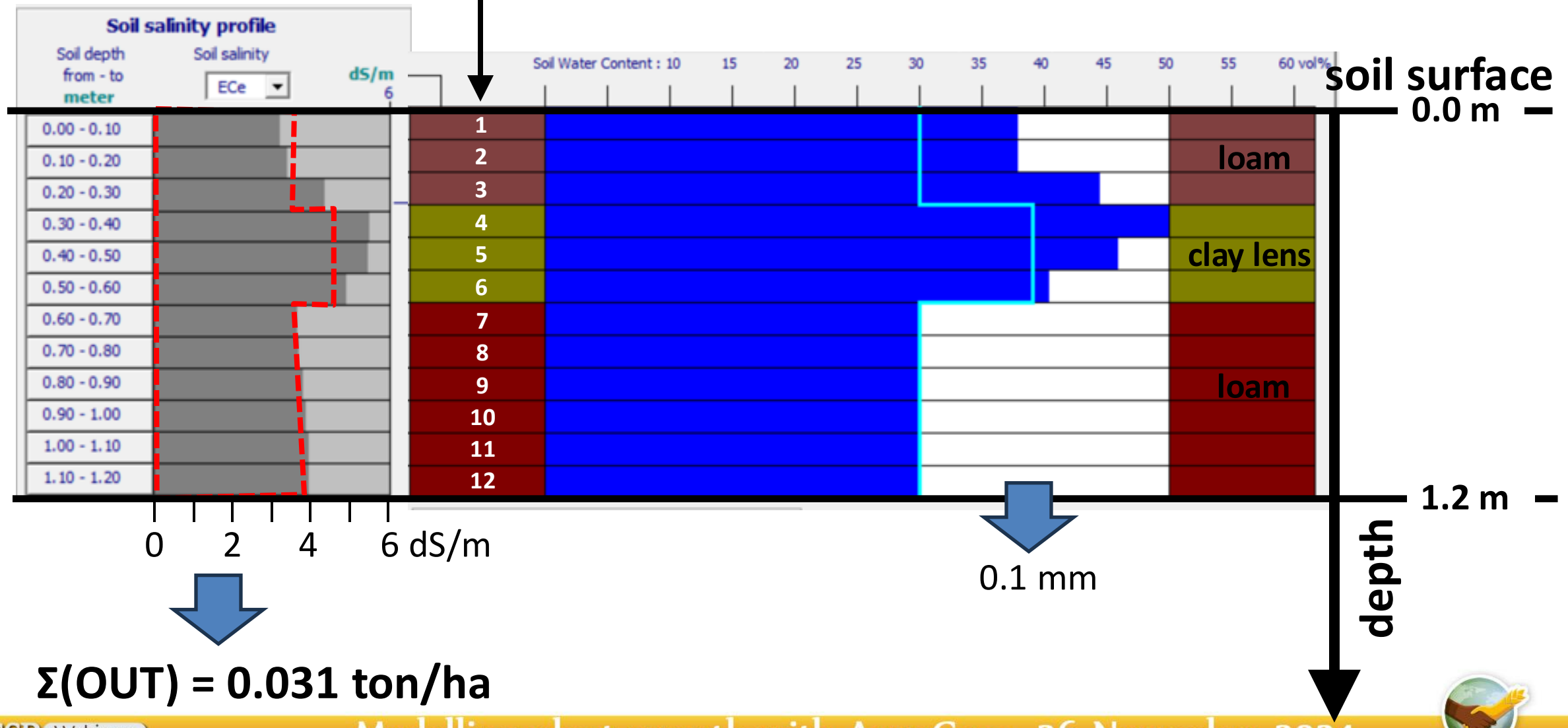
loam



salt:
Σ(IN) = 0.640 ton/ha

compartment number

day 2

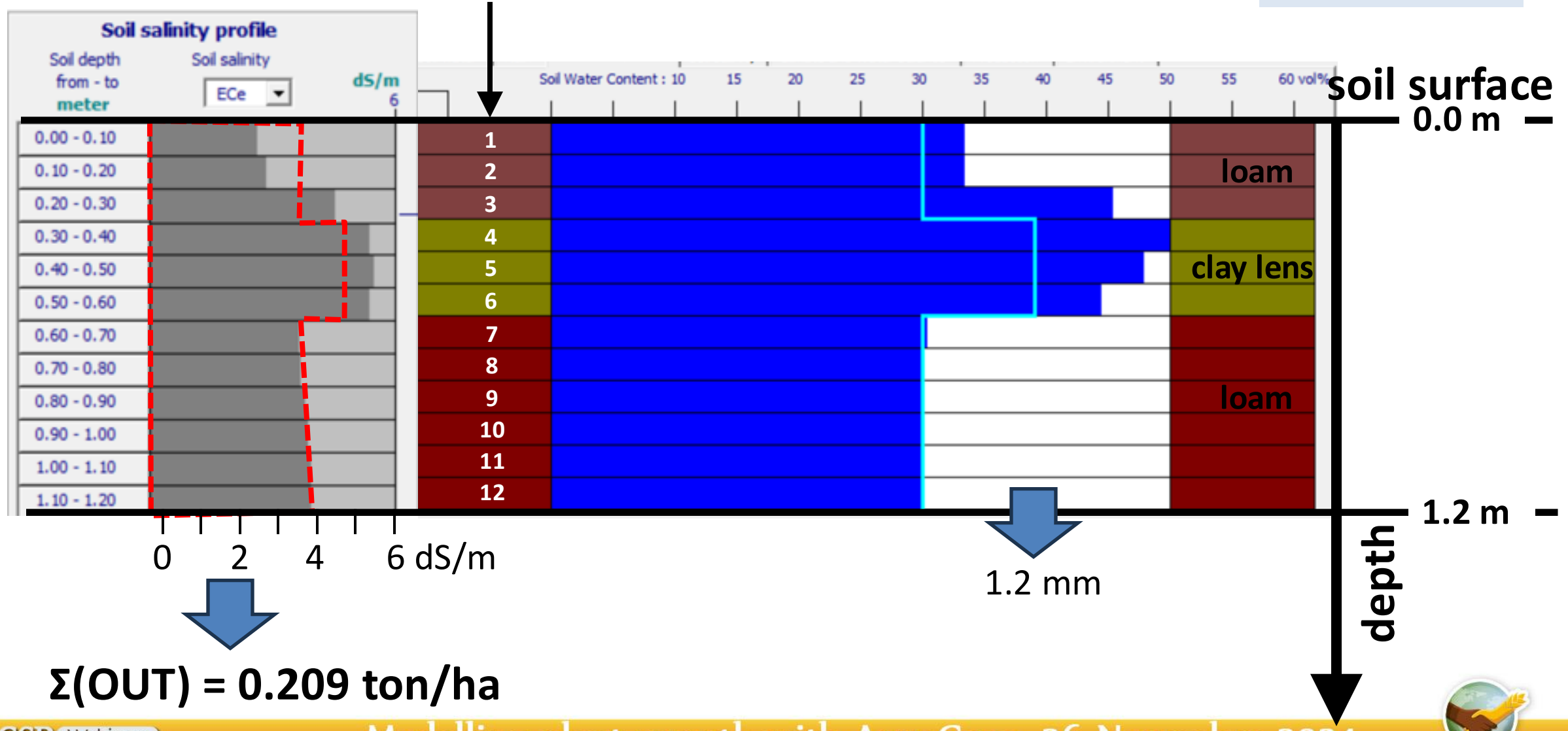


Σ(OUT) = 0.031 ton/ha

salt:
Σ(IN) = 0.640 ton/ha

compartment number

day 3

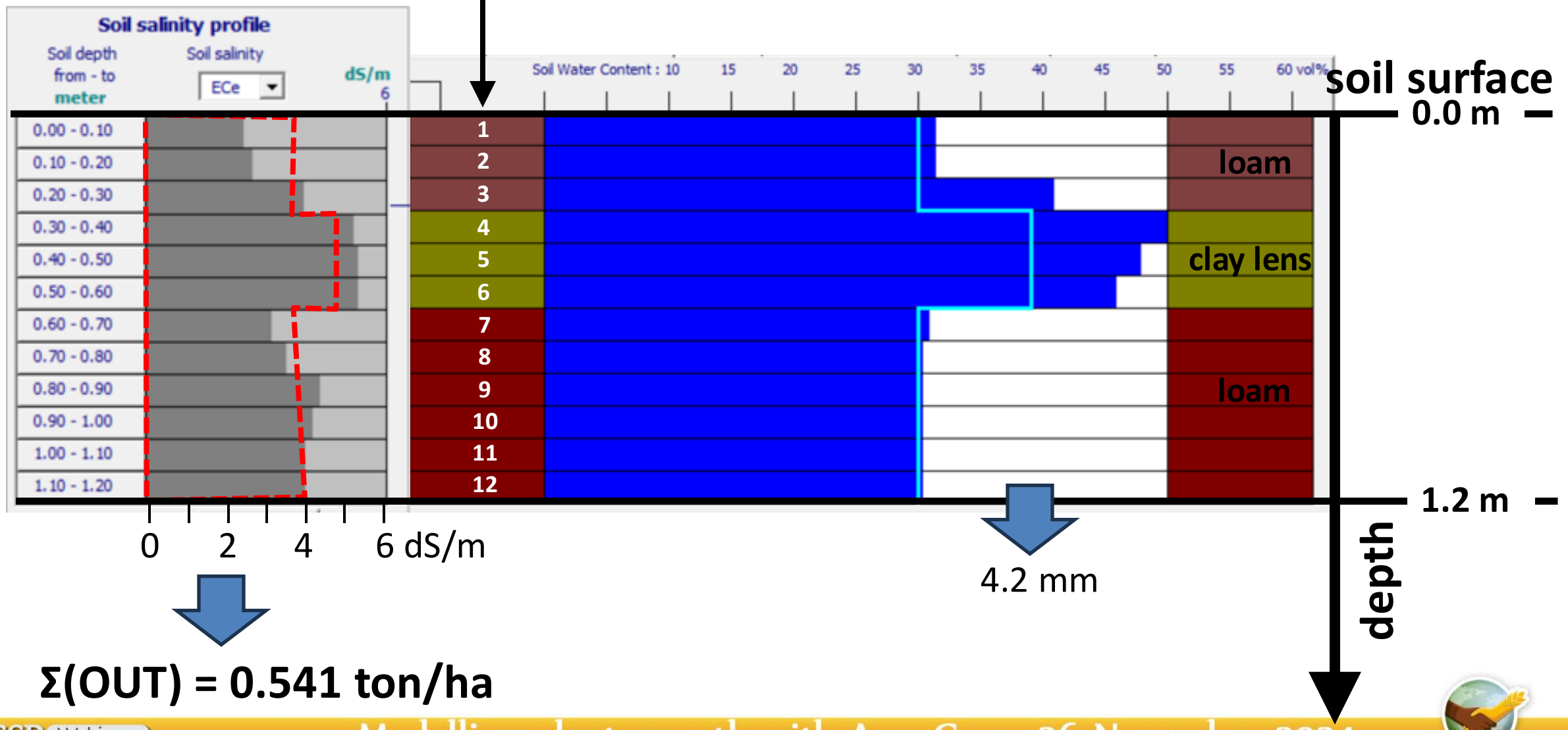


Σ(OUT) = 0.209 ton/ha

salt:
Σ(IN) = 0.640 ton/ha

compartment number

day 4

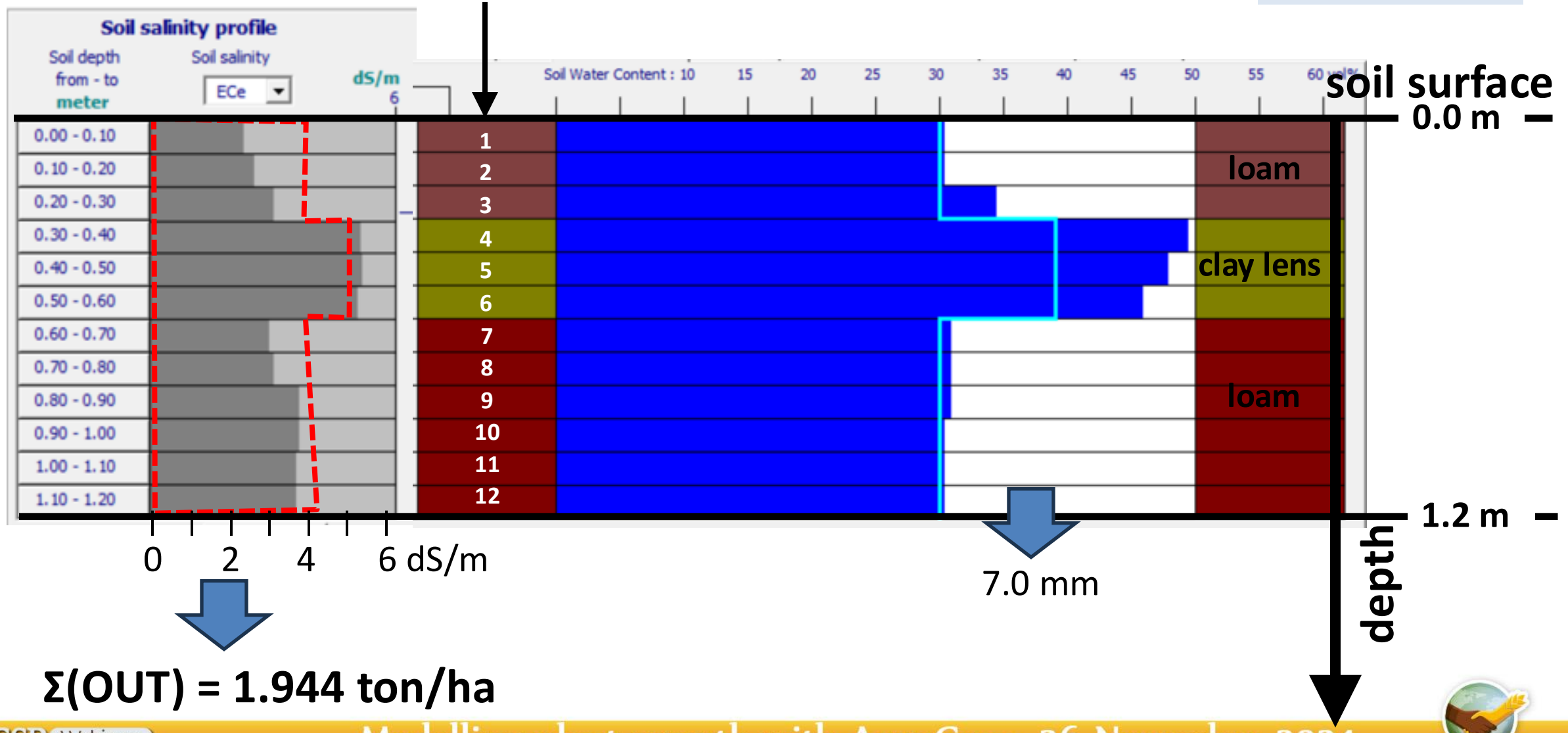


Σ(OUT) = 0.541 ton/ha

salt:
Σ(IN) = 0.640 ton/ha

compartment number

day 5

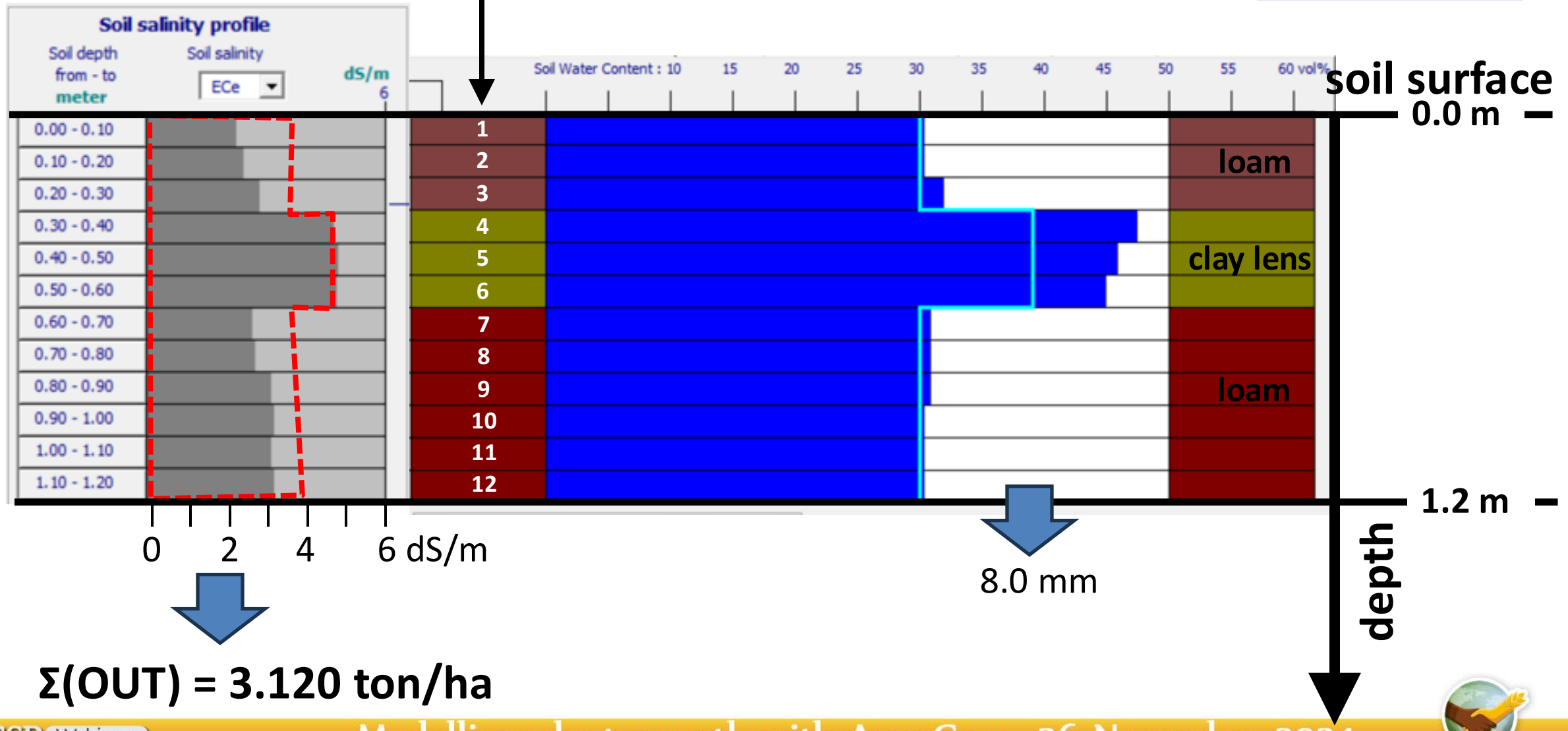


Σ(OUT) = 1.944 ton/ha

salt:
Σ(IN) = 0.640 ton/ha

compartment number

day 6

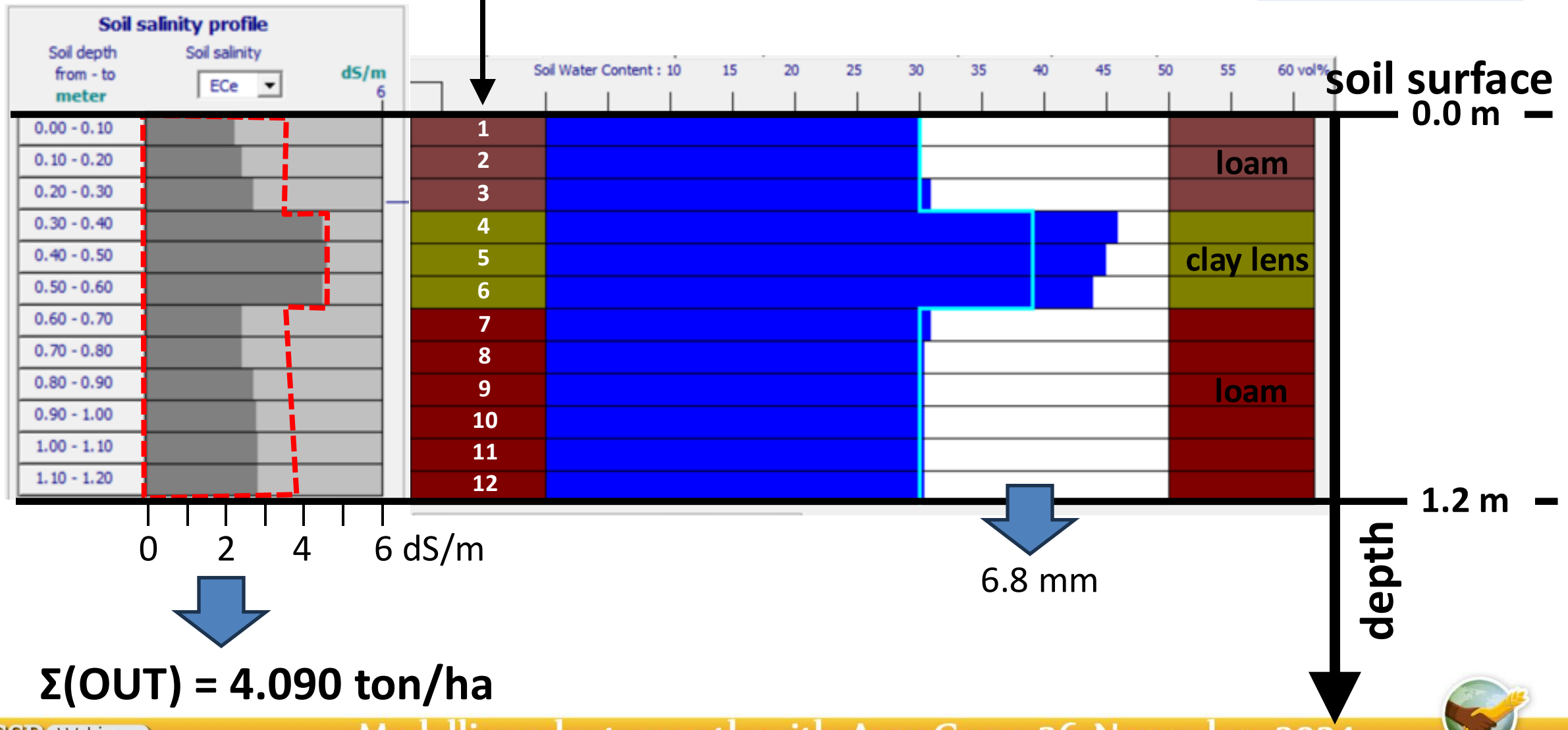


Σ(OUT) = 3.120 ton/ha

salt:
Σ(IN) = 0.640 ton/ha

compartment number

day 7

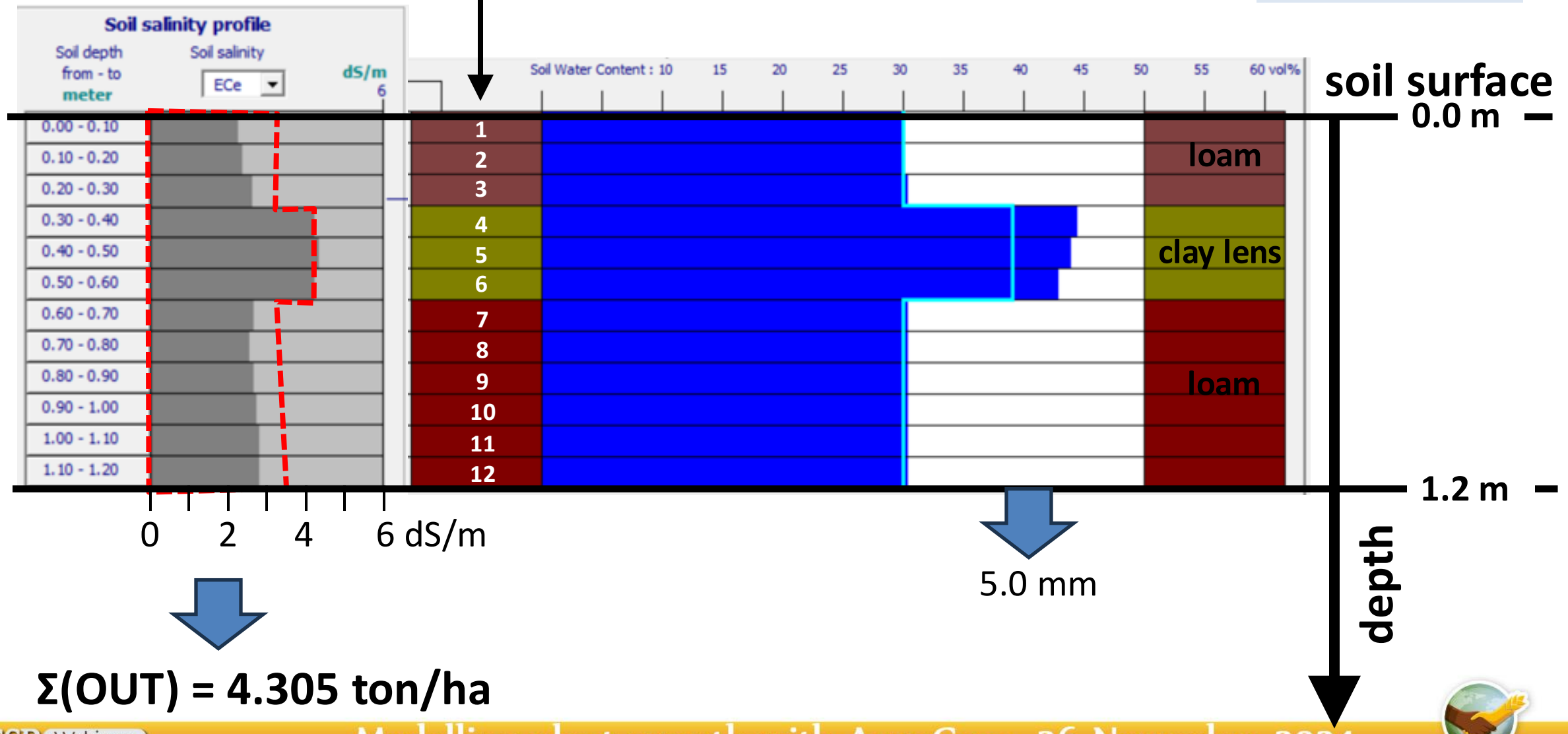


Σ(OUT) = 4.090 ton/ha

salt:
Σ(IN) = 0.640 ton/ha

compartment number

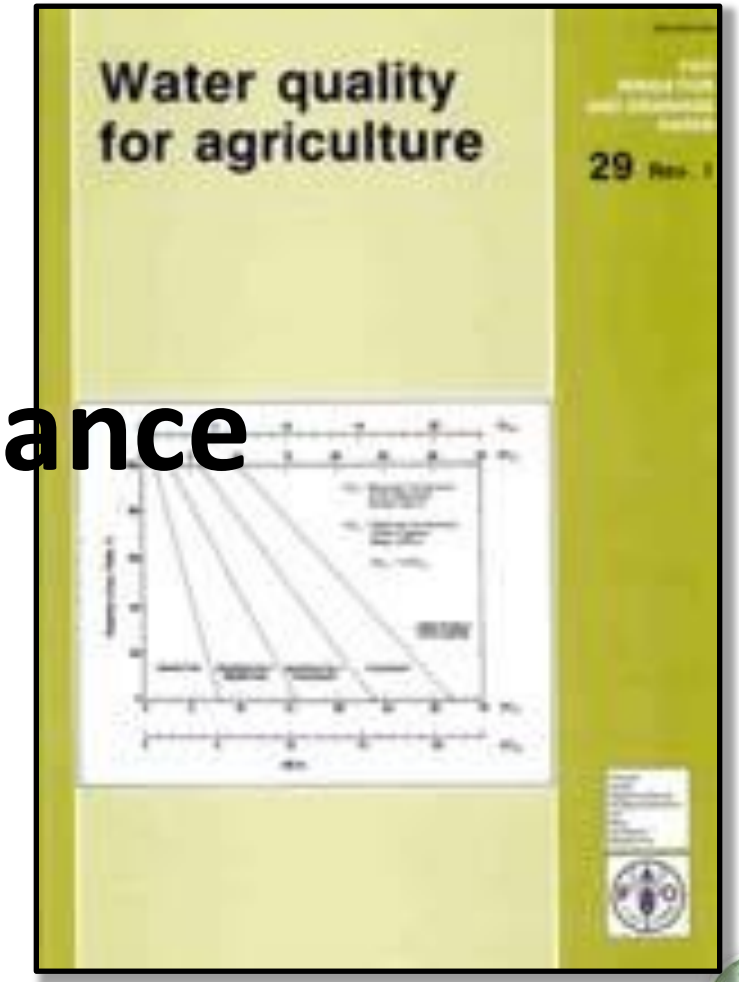
day 8



Σ(OUT) = 4.305 ton/ha

Simulation of the soil water and salt balance

1. Soil water balance
2. Salt balance
3. **Evaluation of the salt balance**

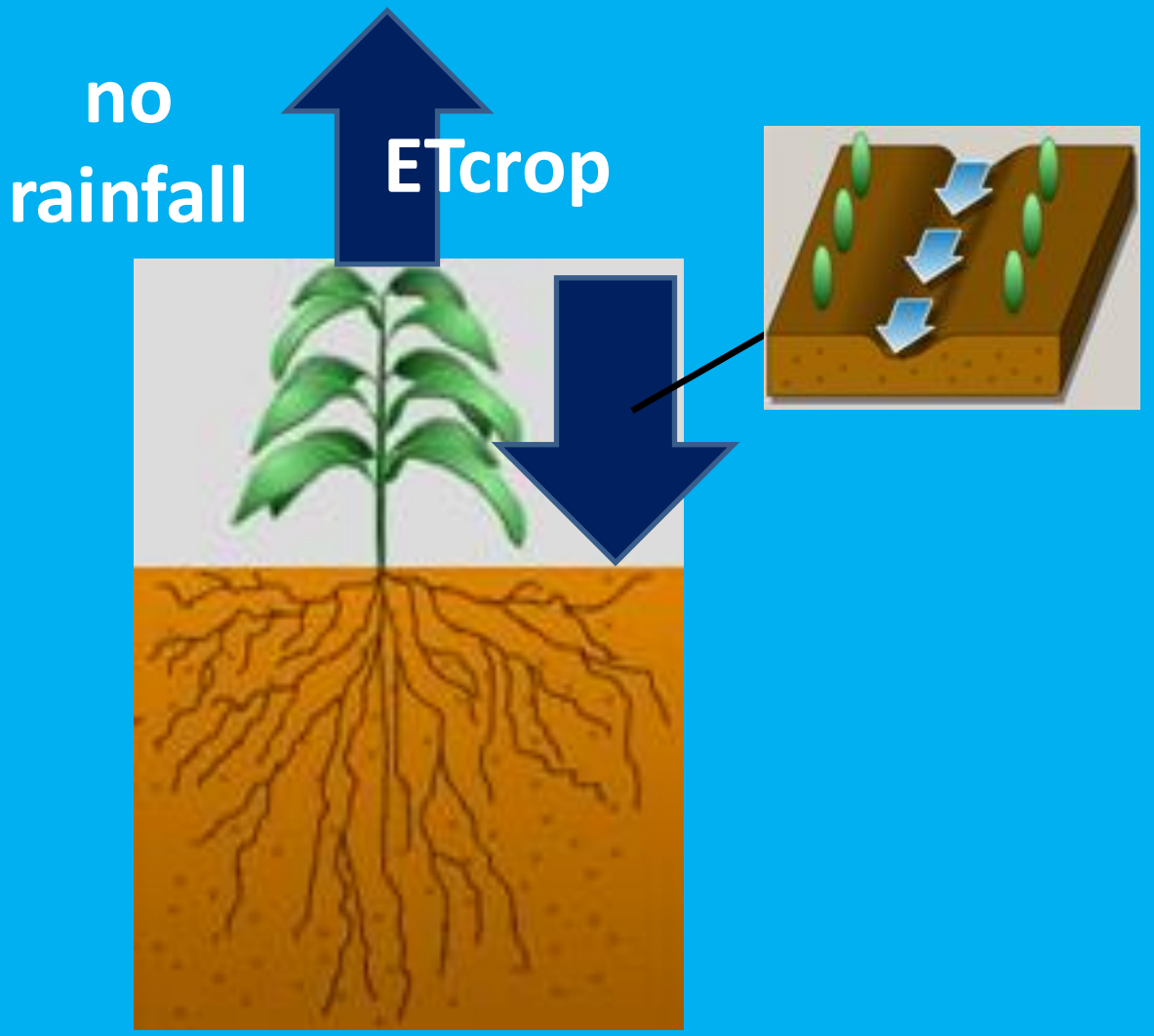


Ayers and Westcot. 1985.

Water quality for agriculture.

FAO Irrigation and Drainage Paper N° 29

Theoretical calculation of ECe



Assumptions

Theoretical calculation of ECe

ECw

1 dS/m
2 dS/m
3 dS/m
.. dS/m

no rainfall

ETcrop

+ 10%
+ 20%
+ 30%
+ ….

irrigation = ETcrop + extra

Assumptions

ECe ?

40%
30%
20%
10%

Water extraction in root zone

Leaching fraction

Deep percolation = extra

Soil texture: sandy loam to clay loam

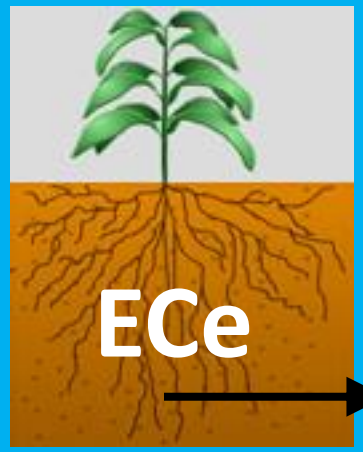


Fig. 2

EFFECT OF SALINITY OF IRRIGATION WATER (EC_w) ON SOIL SALINITY (EC_e) OF THE ROOT-ZONE UNDER VARYING WATER MANAGEMENT

ECe: Soil salinity in root zone (dS/m)

6
5
4
3
2
1
0.5

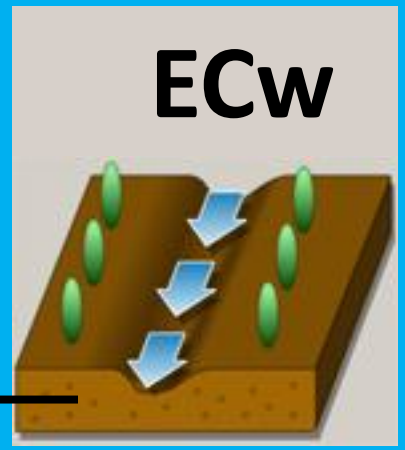
LF = 5%
LF = 10%
corresponds to GUIDELINE assumptions
LF = 20%
LF = 40%
LF = 80%

Assumed water use pattern
40 %
30 %
20%
10
root-zone

0
1.0
2.0
3.0
4.0

ECw: Quality of irrigation water (dS/m)

Soil texture: sandy loam to clay loam



Ayers and Westcot. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper N° 29

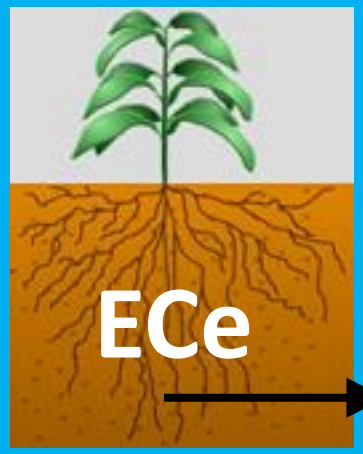


Fig. 2

EFFECT OF SALINITY OF IRRIGATION WATER (EC_w) ON SOIL SALINITY (EC_e) OF THE ROOT-ZONE UNDER VARYING WATER MANAGEMENT

ECe: Soil salinity in root zone (dS/m)

LF = 5%

LF = 10%

LF = 20%

LF = 40%

LF = 80%

corresponds to GUIDELINE assumptions

for various LF: leaching fraction

Assumed water use pattern

40 %

30 %

20%

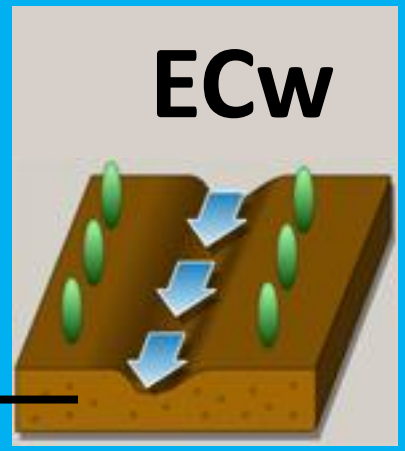
10

root-zone

0 1.0 2.0 3.0 4.0

ECw: Quality of irrigation water (dS/m)

Soil texture: sandy loam to clay loam



Ayers and Westcot. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper N° 29

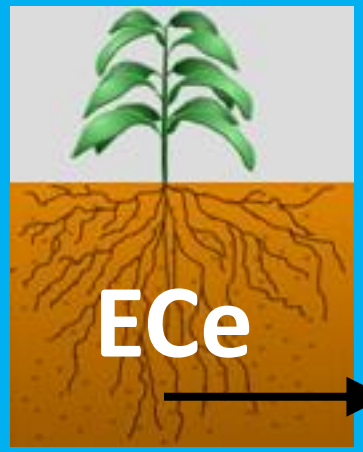


Fig. 2

ECe: Soil salinity in root zone (dS/m)

6
5
4
3
2
1
0.5

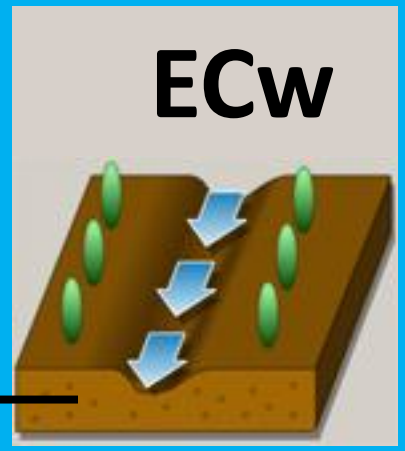
LF = 20%

0
1.0
2.0
3.0
4.0

ECw: Quality of irrigation water (dS/m)

AQUACROP

Loam
Sandy loam
Sand
Silty clay loam



Soil texture:
sandy loam
to clay loam

Ayers and Westcot. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper N° 29

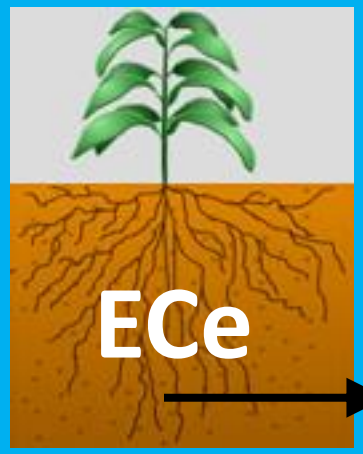


Fig. 2

ECe: Soil salinity in root zone (dS/m)

6
5
4
3
2
1
0.5

LF = 20%

0
1.0
2.0
3.0
4.0

ECw: Quality of irrigation water (dS/m)

Salt balance

AQUACROP

Loam
Sandy loam
Sand
Silty clay loam

ECw

Soil texture:
sandy loam
to clay loam

Ayers and Westcot. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper N° 29

References

FAO AquaCrop website

https://www.fao.org/aquacrop/en/

Food and Agriculture Organization of the United Nations

AquaCrop

Overview | Software | Applications | Workshops | Resources | News

- Tutorials
- Training handbooks
- Reference manuals
- Publications
- Videos

Reference manuals

- Reference manual for AquaCrop version 7.1 – Chap
- Reference manual for AquaCrop version 7.1 – Chapter 2
- Reference manual for AquaCrop version 7.1 – Chapter 3
- Reference manual for AquaCrop version 7.1 – Chapter 4
- Reference manual for AquaCrop version 7.1 – Chapter 5
- Reference manual for AquaCrop version 7.1 – Annexes

Food and Agriculture Organization of the United Nations

International Network of Salt-Affected Soils

Modelling plant growth with AquaCrop, 26 November 2024

GLOBAL SOIL PARTNERSHIP