# Rainwater harvesting and greywater recovery
## - Part 1 -

**Prof. Patrice CANNAVO**

AGROCAMPUS OUEST / Agreenium, France
Department of Physical Environment, Landscape Architecture
Environmental Physics and Horticulture research Laboratory

***Module 2: Resource use from a challenge perspective***
*Urban Agriculture for resource efficiency and waste management*

# Course outline

**1. Urban water hydrology**
- 1.1 Specificities of the urban context
- 1.2 Impacts of the vegetation on water regulation
- 1.3 Soil properties (reminder)

**2. Green roof potential for water runoff control**
- 2.1 Roles and constitution
- 2.2 Performance

**3. Greywater**
- 3.1 Origin, collection, treatment
- 3.2 Greywater reuse for irrigation

**4. Stormwater basin for road water runoff**
- 4.1 Operation
- 4.2 Infiltration performance and clogging process

**5. Self-assessment**

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## Urban water management

- Water network saturation
  - Intense rainfall = important water volume to collect = network saturation
  - Risk of flooding
  - Example of flooding in May 2012 in Nancy (NE of France); incident cost = 10 millions euros


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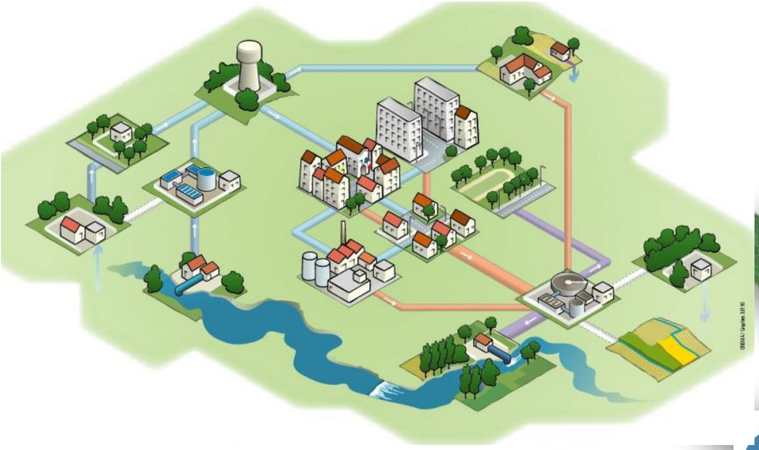
L'agglo de Nancy sous les eaux

## Urban water management

- Quality decrease
  - Runoff (roofs, gutters, tubes, pavements, sidewalks…) = increase in contaminants loads
  - Major treatments before reuse or water discharge

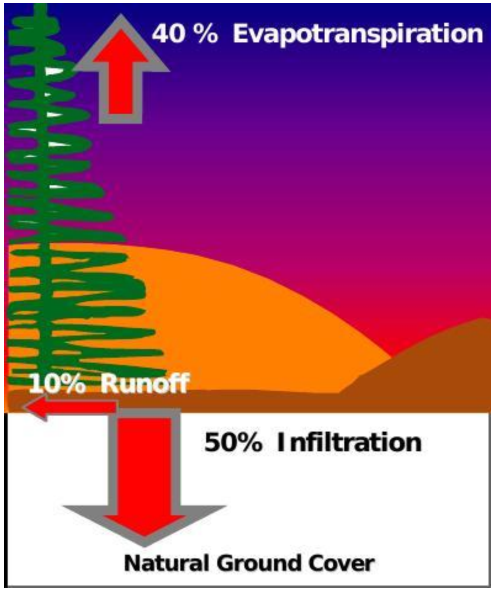
- Groundwater recharge
  - Aquifers recharge less natural
  - Direct discharge in water courses

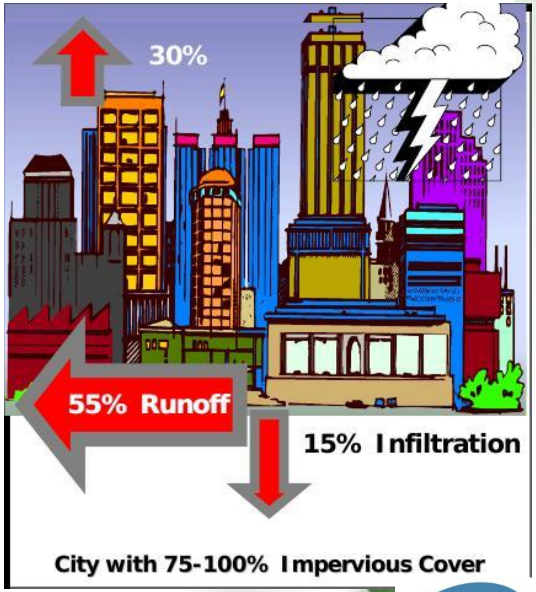


## Causes of urban rainwater management problems

- Loss/absence of plant cover (Dettwiller, 1978)
  - Summer rainfall of 5 mm
  - Rural environment = 4 mm of evapotranspiration within 24h
  - Urban environment = 0,5 mm of evapotranspiration within 24h

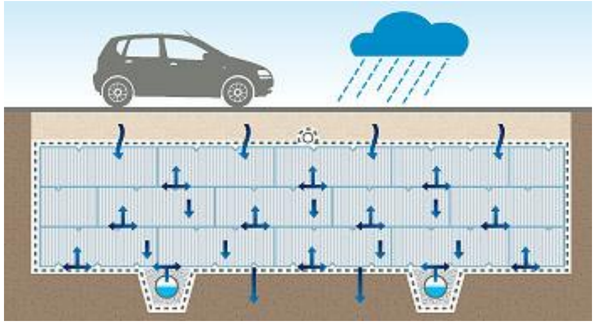
- Soil sealing
  - rainwater route modification, infiltration limitation

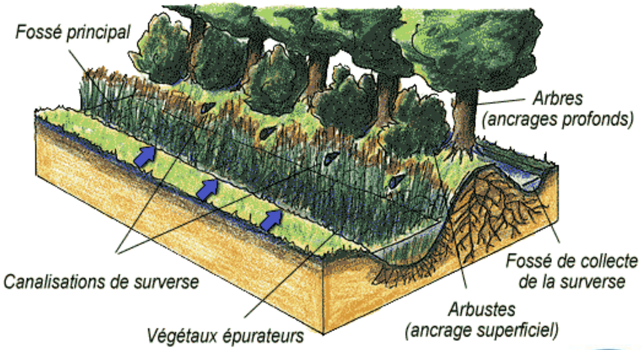


## Urban water management solutions

- Storage
  - Water captage : storm spillway, open-pit or burried storage basins, tank-structured pavements
- Infiltration
  - Porous pavements with innovative porous asphalt, disjoined pavements, infiltration sink, drainage swales





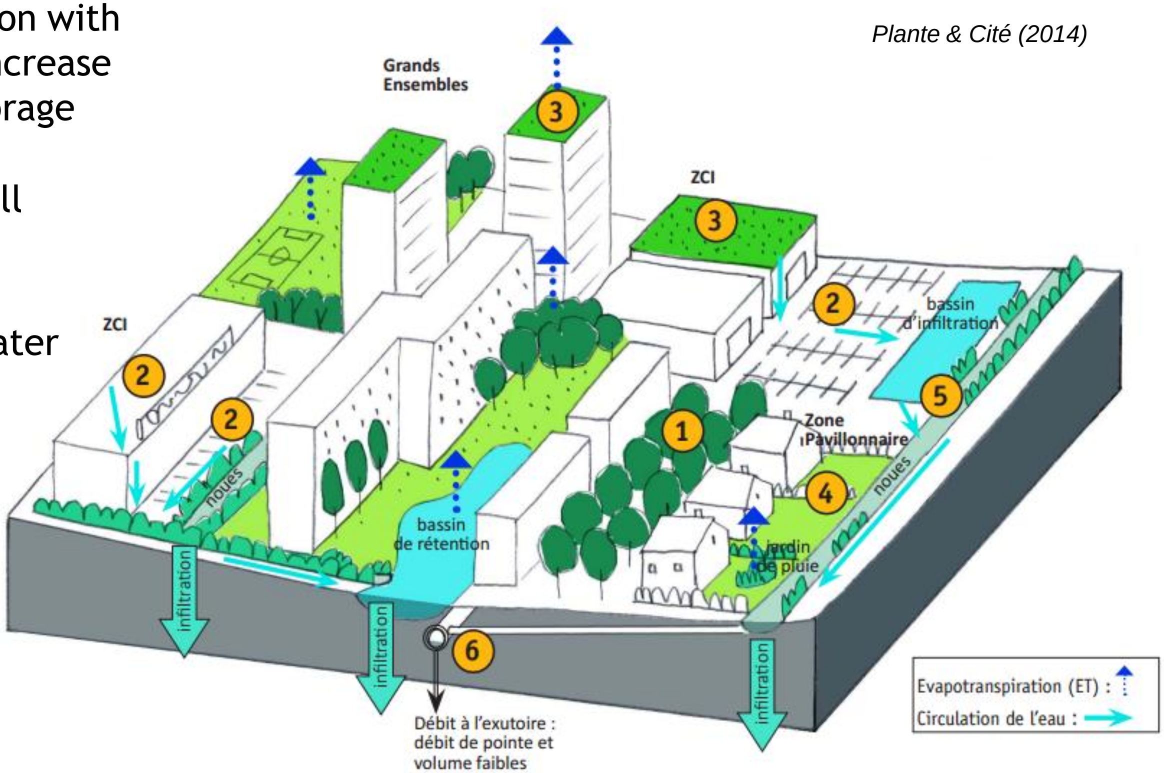
# 1. Urban water hydrology

> 1.2 Impacts of the vegetation on water regulation

## Greening strategies for a better water management at the neighborhood scale

1. Tree leaves reduce water runoff by rainfall interception
2. Impervious surfaces connection with drainage swales and basins increase infiltration and soil water storage
3. Green roofs temporarily store rainfall and favor evapotranspiration
4. Field water infiltration decreases water volume and reduces peak flow
5. Interconnexion possibility of the techniques
6. In case of exceptional rainfall events, public flood areas can temporarily store water in specific zones

*Plante & Cité (2014)*



# 1. Urban water hydrology

> 1.2 Impacts of the vegetation on water regulation

## Vegetation impact on water runoff *Plante & Cité (2014)*

Greening scenarios modelling in Nantes city (France)


Actual vegetation density | 75% uniform vegetation density decrease | 50% of roofs are green roofs

Runoff volume evolution

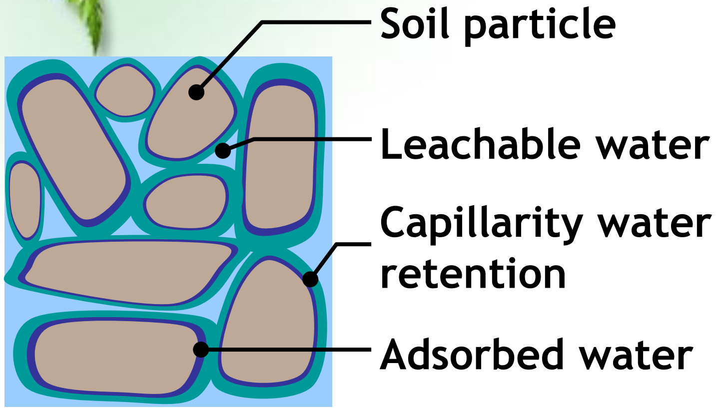

After roof greening | After a 75% vegetation density decrease

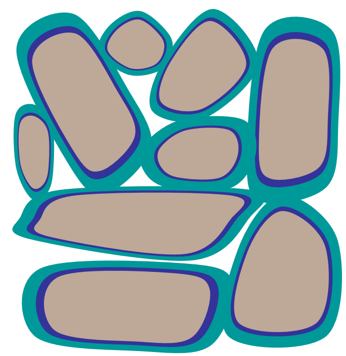
- Runoff increases when vegetation areas decrease, and decreases if green roofs exist.
- In highly dense infrastructure areas, green roofs are an efficient way to decrease runoff

# 1. Urban water hydrology

> 1.3 Soil properties (reminder)

## Physical soil properties: soil water retention / reservoir



**Saturation:**
All pores contain water

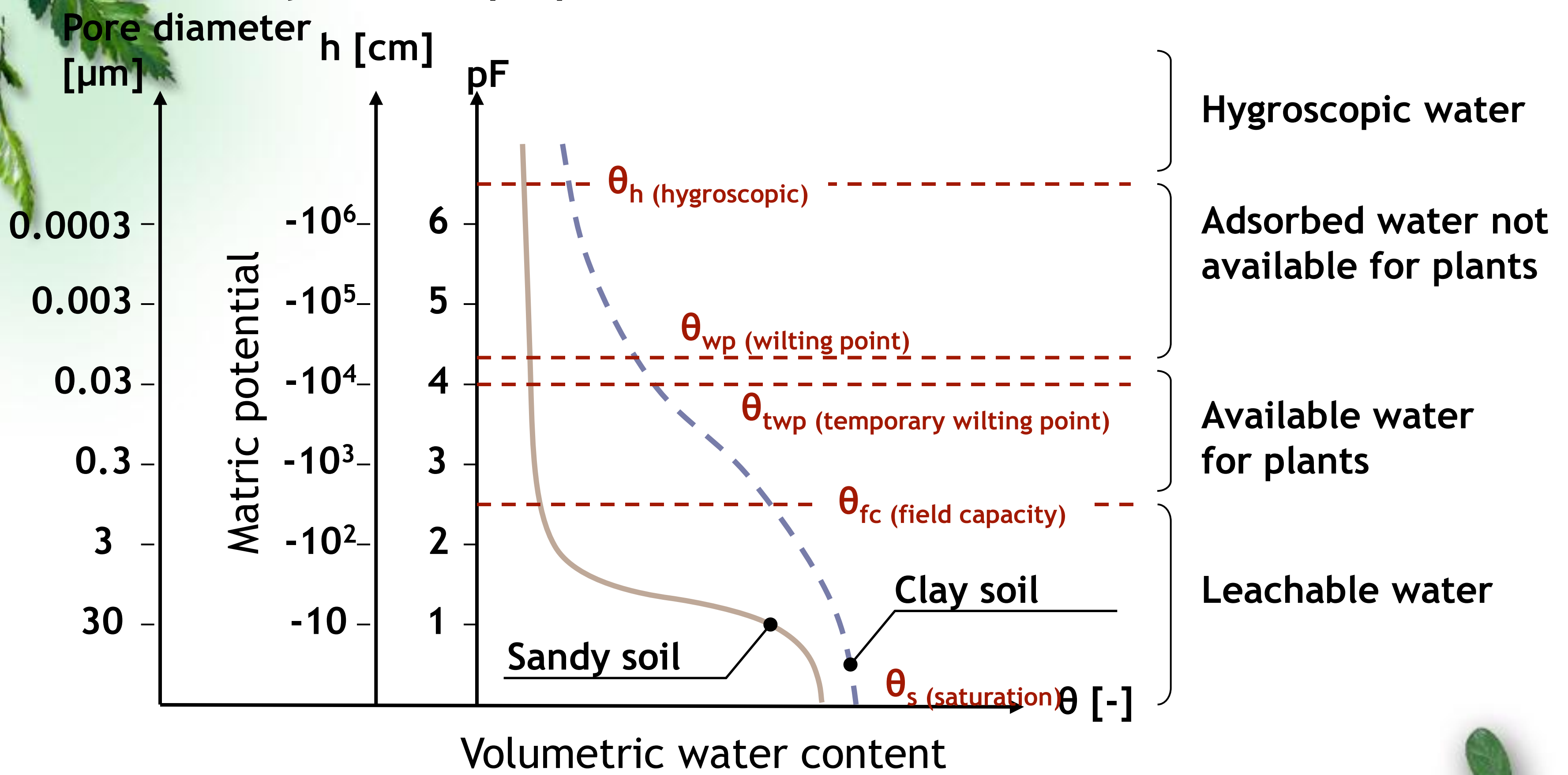
**Water-filled capacity:**
After natural drainage
Equivalent matric potential :
pF 2 – 2.5

**Permanent wilting-point:**
Equivalent matric potential :
pF 4.2
Beyond this, plants cannot absorb water and their development is limited

# 1. Urban water hydrology

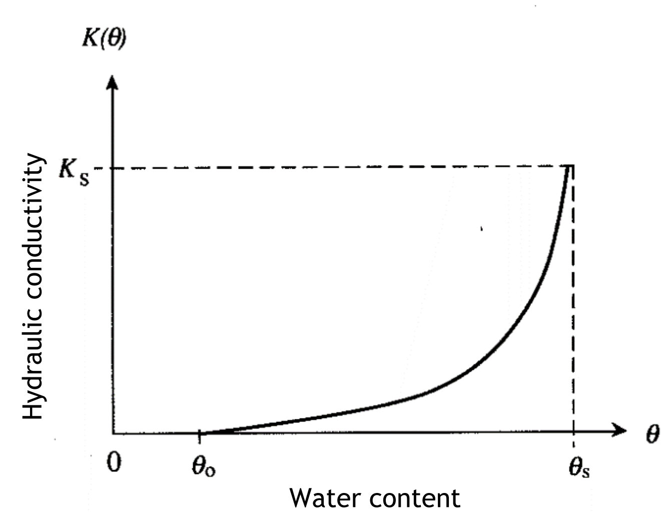


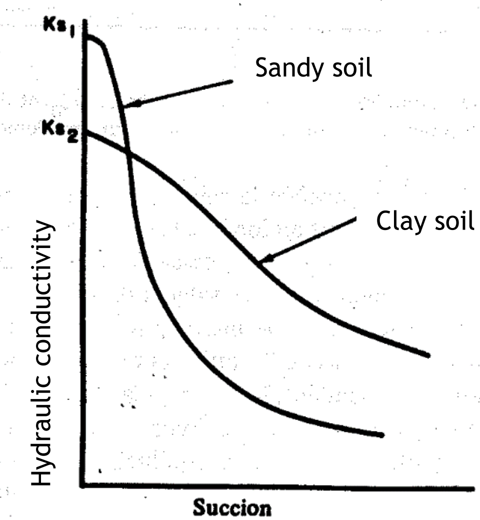
## Physical soil properties: soil water retention / reservoir




For a growing media (eg peat): field capacity = pF1, temporary wilting point = pF2, wilting point = pF3)

## Physical soil properties: soil hydraulic conductivity




The higher is the soil water content, the higher is the hydraulic conductivity

The highest hydraulic conductivity (Ks) is obtained at soil water saturation (θs)

Soil drying (ie succion increase) leads to a decrease in hydraulic conductivity

Hydraulic conductivity curve pattern depends on soil texture

Every soil is characterized by a soil hydraulic conductivity at saturation

## Physical soil properties: soil hydraulic conductivity

Values of soil hydraulic conductivity at saturation **After Calvet, 2003**

| Soil or aquifer | $K_{sat}$ $10^{-3}$ $m.s^{-1}$ |
|---|---|
| Coarse sand | 0.2 - 2 |
| Fine sand | 0.1 - 1 |
| Silt | $10^{-8}$ - $10^{-3}$ |
| Sandy clay | $10^{-4}$ - $10^{-3}$ |
| Clay sand | $10^{-6}$ - $10^{-4}$ |
| Clay | $10^{-10}$ - $10^{-6}$ |
| Loam | $10^{-5}$ - $10^{-3}$ |
| Compact limestone | $10^{-3}$ - $10^{-2}$ |
| Crack limestone | $10^{-2}$ - $10^{-1}$ |
| Karst | 0.1 - 10 |
| Chalk | $10^{-2}$ - $5.10^{-1}$ |

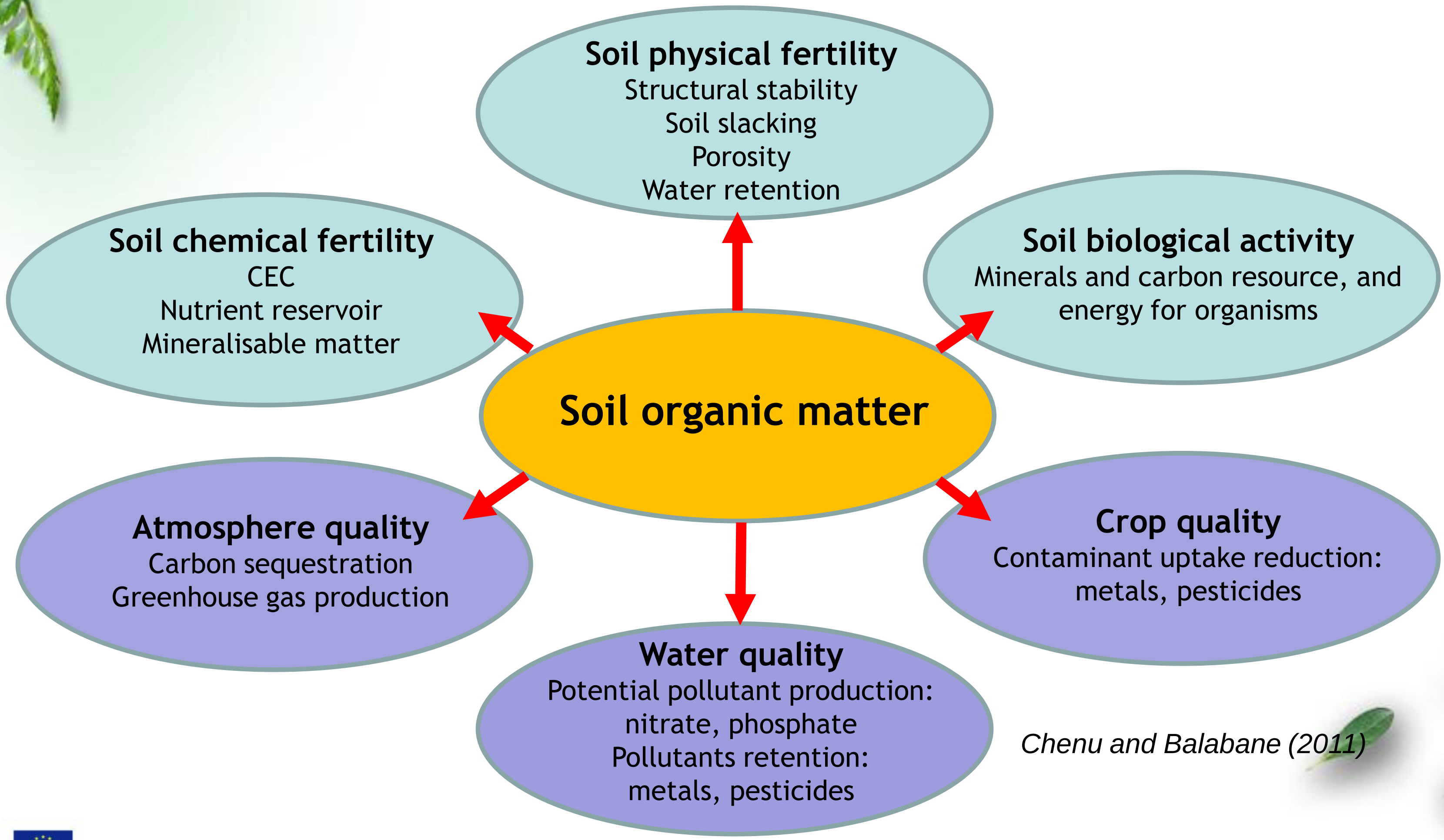
## Physical soil properties: soil hydraulic conductivity

Values of soil hydraulic conductivity at saturation

| $K_{sat}$ $ms^{-1}$ | $10^{-2}$ | $10^{-3}$ | $10^{-4}$ | $10^{-5}$ | $10^{-6}$ | $10^{-7}$ | $10^{-8}$ | $10^{-9}$ | $10^{-10}$ | $10^{-11}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Qualification | permeable | | semi-permeable | | | impervious | | | | |
| Granulometry | Gravel | Coarse to fine sand | | Very fine sand, coarse loam | | | Fine loam, clay | | | |
| Soils | Coarse texture | | Variable texture and clay texture and stable aggregates | | | Fine texture and bad structural stability | | | | |
| Consequences | Low water reservoir; difficulty of irrigation; groundwater contamination risk | | Medium – good drainage; no difficulty for crops; irrigation possible | | | Very bad drainage; crops limited to shallow root crops, streamwater contamination risk by runoff | | | | |

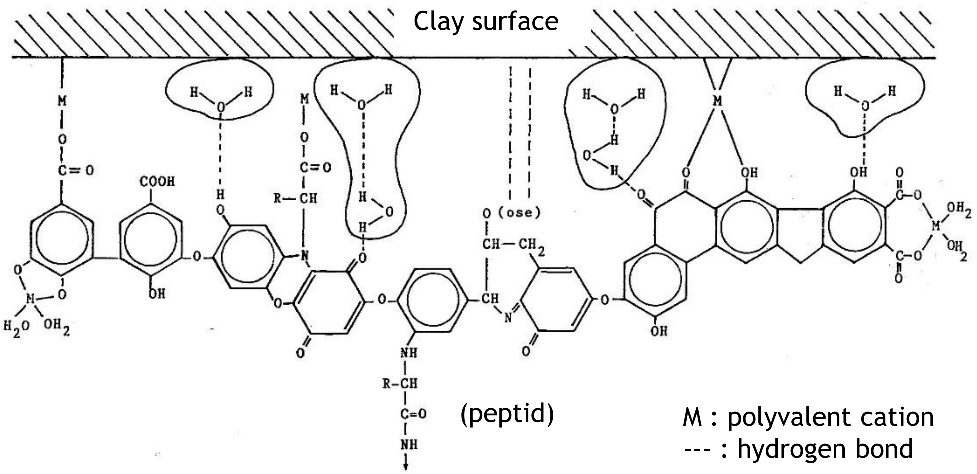
**After Calvet, 2003**

## Chemical soil properties: organic matter

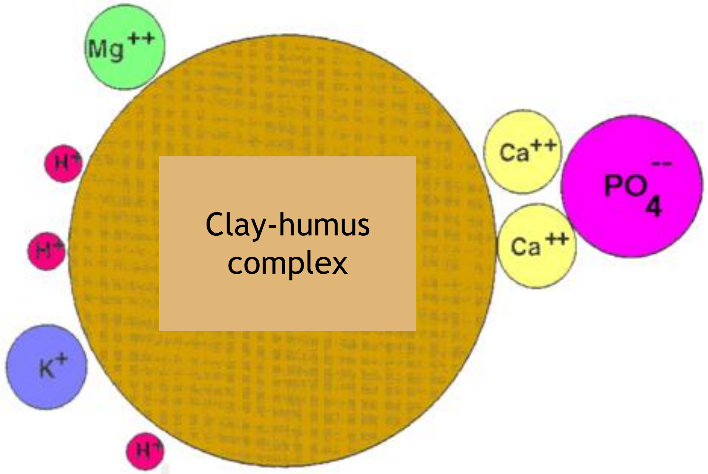



*Chenu and Balabane (2011)*

## Chemical soil properties: clay-humus complex and CEC




Clay-humus complex




Cation reservoir (CEC)

Clay and organic matter have a global negative electric charge
Their association is posible thanks to cationic bridges
=> **Clay-humus complex**
Some cationic bridges: polyvalent cations (Ca++, Mg++,…), $H_2O$, Fe and Al oxydes/hydroxydes, …

The clay-humus complex allows cation retention potentially exchangeable in water for plant nutrient uptake
=> **Cation Exchange Capacity (CEC)**

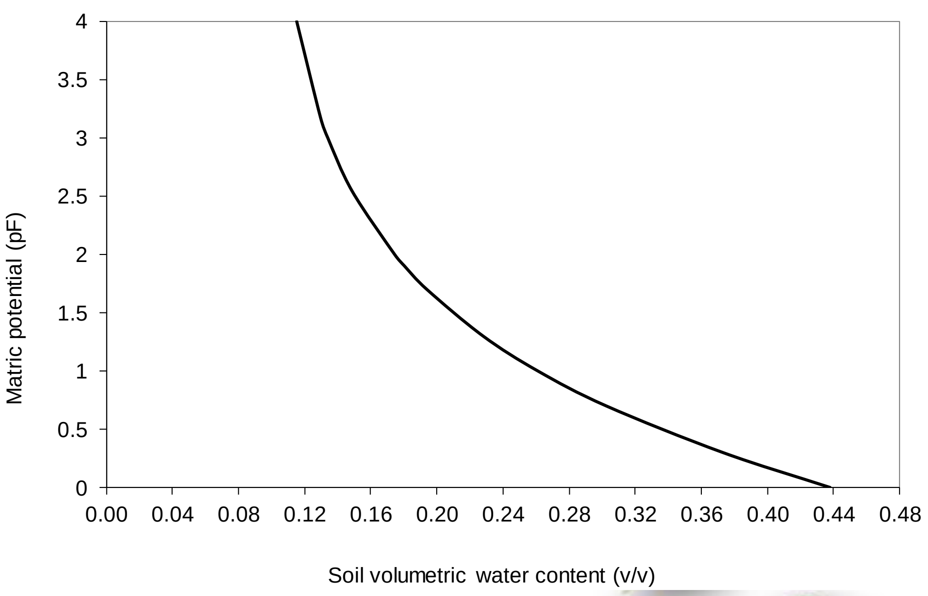
# 1. Urban water hydrology

## Exercise

A urban soil analisis is presented below:

-Soil texture: Clay 300 g/kg, loam 200 g/kg, sand 500 g/kg
-No coarse elements
-Organic matter content in layer 0-20 cm: 10 g/kg
-Hydraulic conductivity at saturation Ks: $10^{-7}$ m/s
-Soil bulk density: 1.7 $g/cm^3$

The soil water retention curve for the 0-50 cm layer is the following:




Questions:
1° Calculate the available soil water for plants in the 0-50 cm soil layer
2° Estimate its autonomy for plant water consumption, assuming a daily plant transpiration of 5 mm
3° Give explanations for the abnormal low Ks value

# 1. Urban water hydrology

## Solution

**Question 1**

The available soil water for plants (ASW) can be obtained from slide 11:
ASW = $(\theta_{pF2.5} - \theta_{pF4})$ * 1000 * z * F

Where: ASW is in mm of water (1 mm = 1 L/m$^2$), $\theta_{pF2.5}$ and $\theta_{pF4}$ are the soil volumetric water content at field capacity and temporary wilting point (m$^3$ water/ m$^3$ soil) respectively, z is the layer thickness (m) and F is the fine soil fraction (unit-less)(fine soil = soil particles size < 2 mm)

In the present case:
$\theta_{pF2.5}$ = 0.15, $\theta_{pF4}$ = 0.12, F=1 (no coarse elements), z= 0.5 m
Then, **ASW = (0.15-0.12)*1000*0.5*1 = 15 mm**

**Question 2**

From question 1, the soil water reservoir for plant consumption is 15 mm. If plants daily water uptake (transpiration) is of 5 mm, then the **soil autonomy corresponds to 15/5 = 3 days**, if there is no rainfall event during this period.

In the present case, the autonomy is relatively low. During the summer period, water supply by irrigation will be necessary to satisfy plant water requirements

# 1. Urban water hydrology

## Solution

**Question 3**

The soil hydraulic conductivity at saturation is of $10^{-7}$ m/s and corresponds to an semi-permeable/impervious soil (slide 14).
This soil is a sandy clay texture soil. The corresponding Ks value for a natural soil would be between $10^{-4}$ – $10^{-3}$ m/s, ie 1000 – 10000 times lower (slide 13).

Then, this urban is suffering from **a low infiltration capacity** that limits soil water recharge and favor water runoff.

Infiltration capacity depends directly on the **soil structure** (mineral and organic particles organization, forming soil aggregates). **Well-structured soils allow both water circulation in the macroporosity and water retention in the microporosity**.

Soil elements that favor soil aggregation are the **organic matter and clay**. If clay content is acceptable in the present case, the **organic matter content is very low** (acceptable value of 30-40 g/kg). Thus aggregation capacity is not optimal and soil structure resistance against rainfall and human traffic is poor. **Organic matter amendments (compost) should be preconized**.

Another important factor is **the soil bulk density, that is high in the present case**. It is generally considered that root growth is possible when the soil bulk density is lower than 1.6 g/cm$^3$. **This soil suffers from compaction** maybe due to human or vehicles traffic. It should be unpacked to favor both water infiltration and root growth.

# Thank you for your attention !