Physical properties of soils

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Physical properties of soils

Color
Texture
Structure
Bulk density
Density
Pore space volume
Water regulation

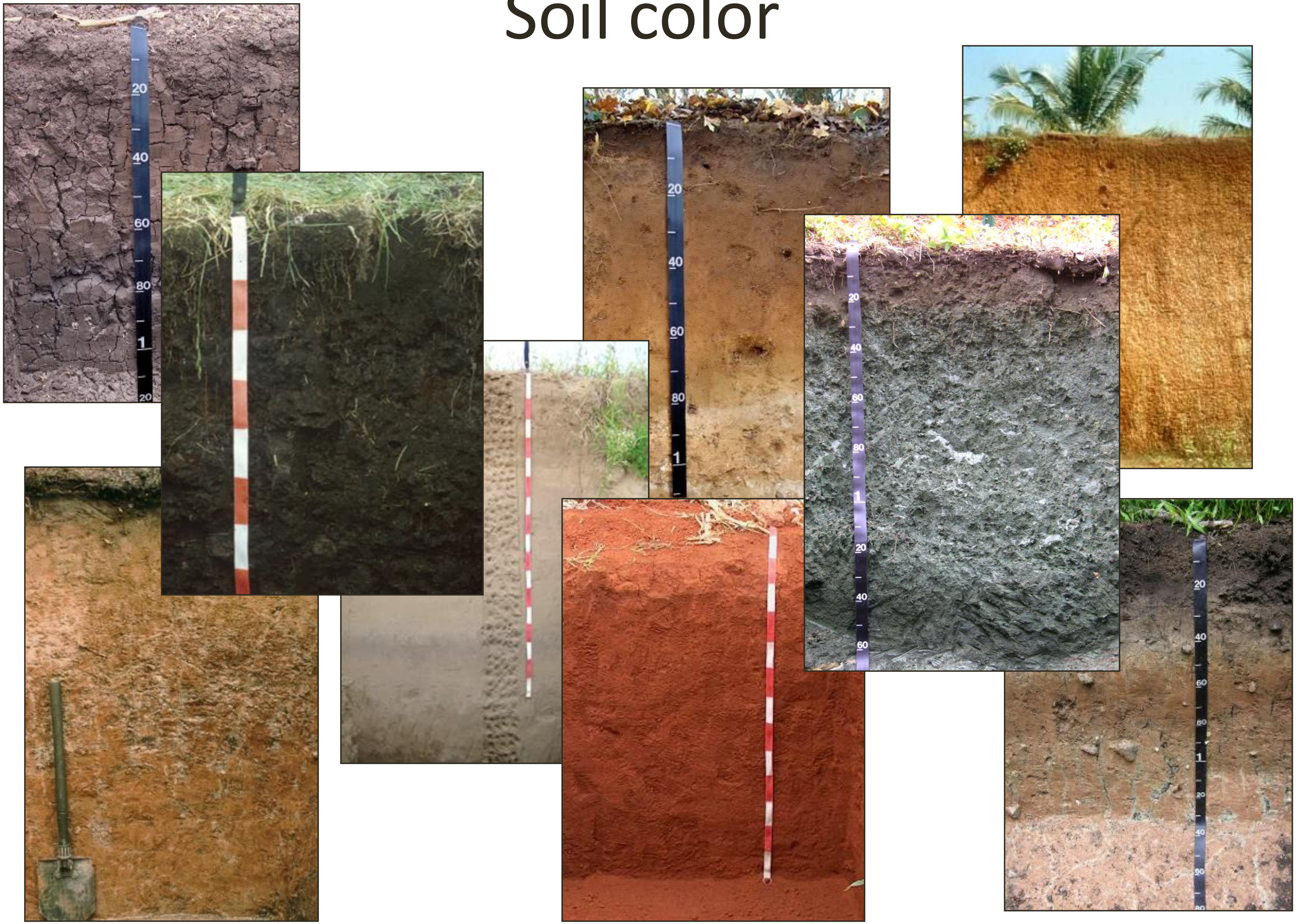
Why is color important?

- Relationship with organic matter content
- Relationship with moisture content
- Relationship with mineralogical composition
- Soil profile horizonation
- Important role in soil classification
- Indicator of soil moisture regime

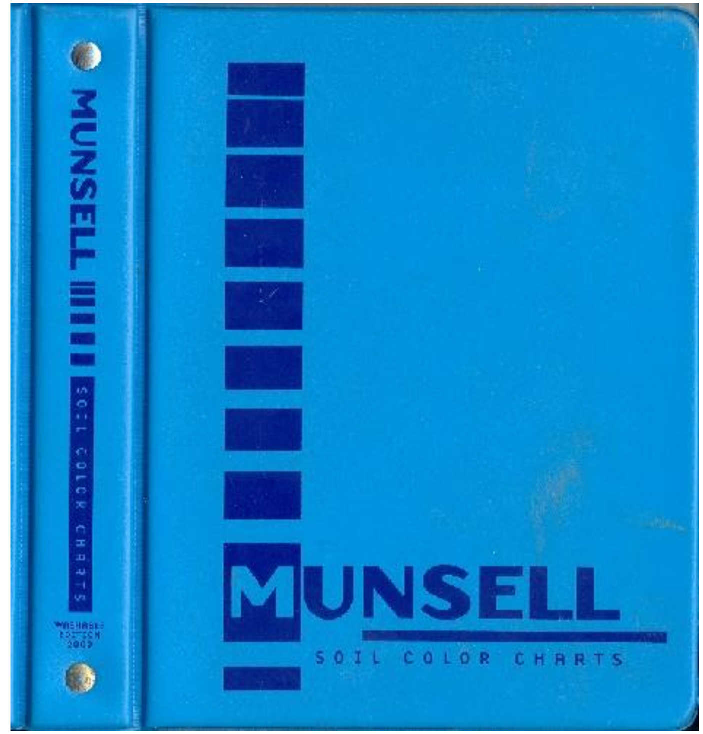


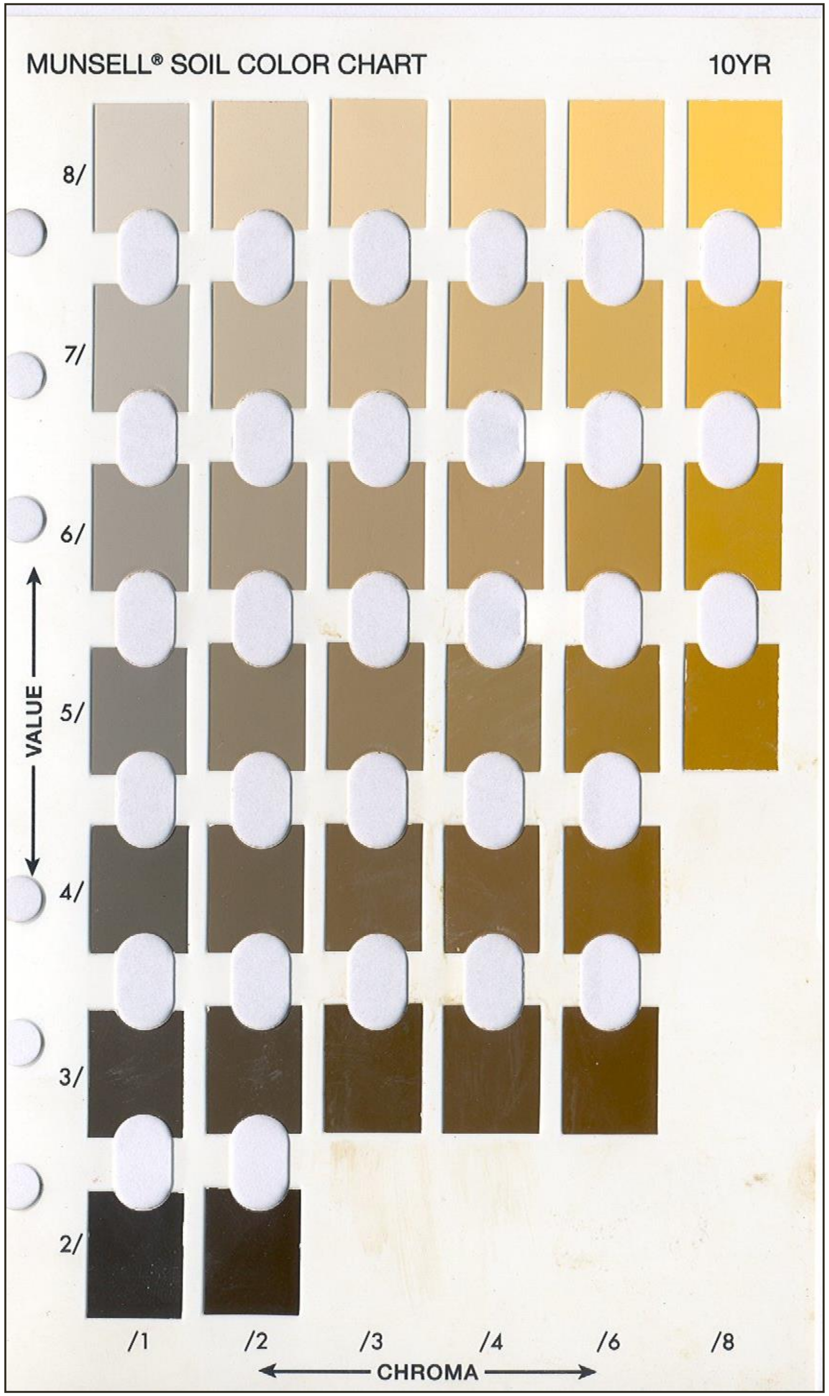


Soil color



MUNSELL
Color chart





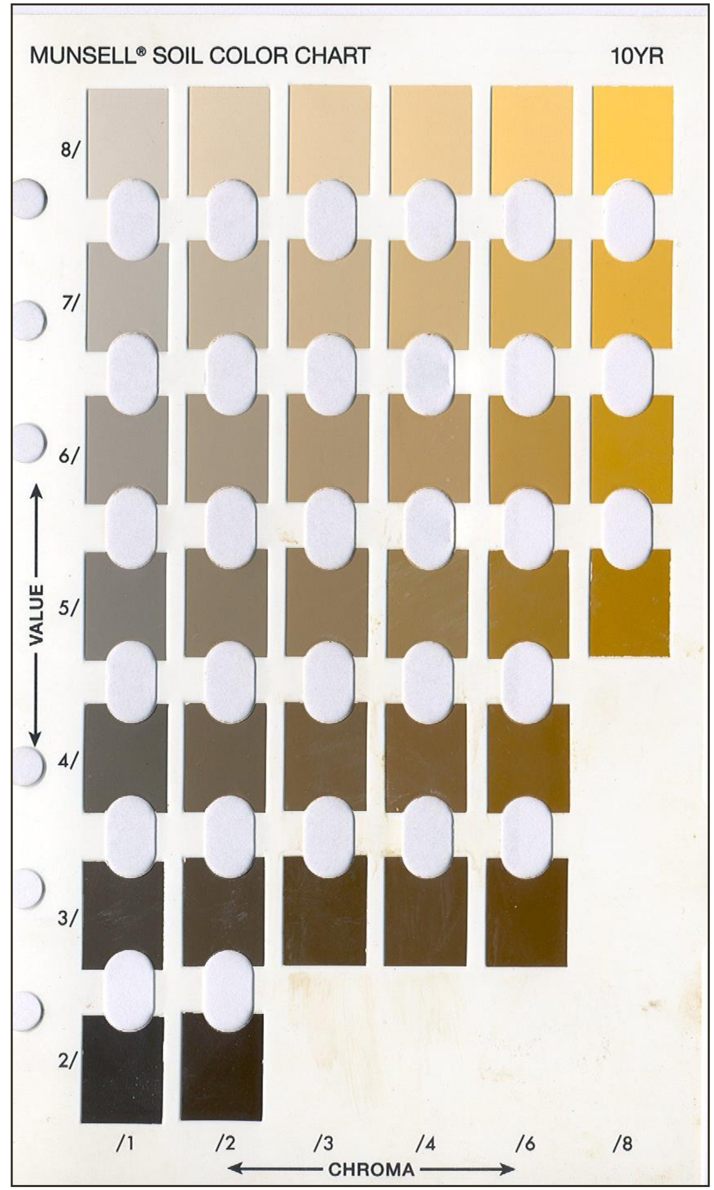
HUE

the dominant spectral color (red, yellow, blue, green)

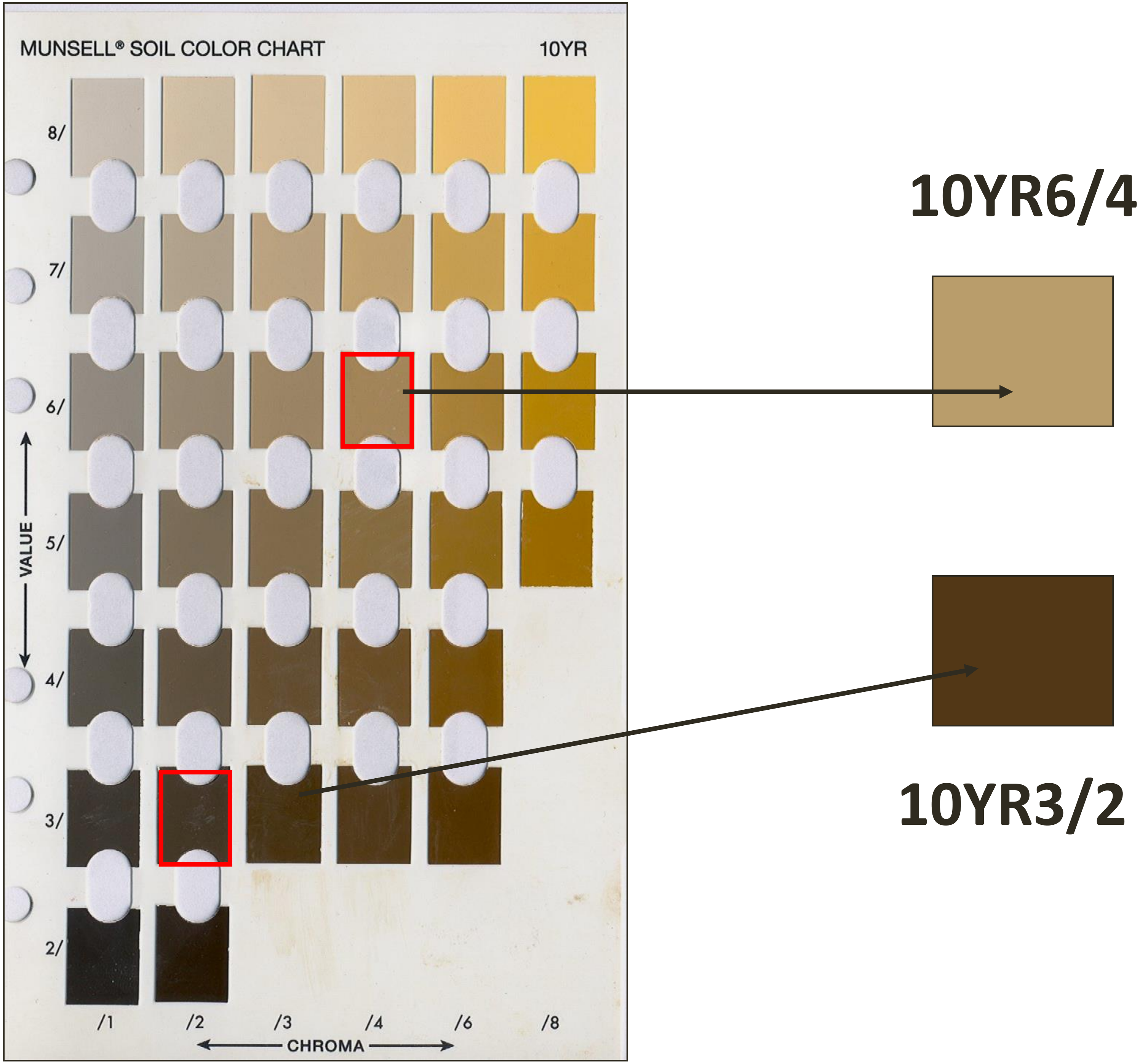
Y= yellow

R= red

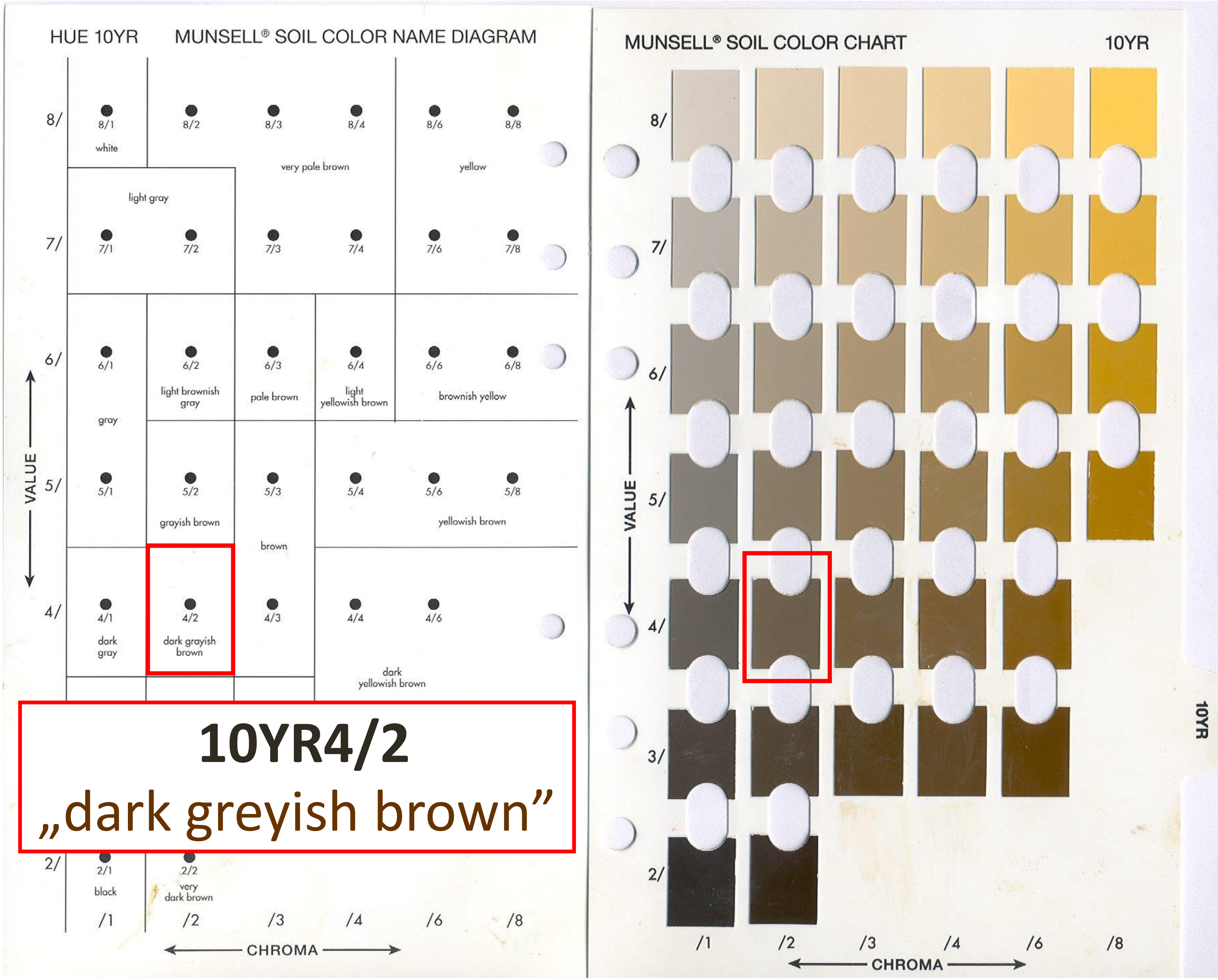
VALUE: Relative blackness or whiteness;
the amount of reflected light



CHROMA: Intensity of color (saturation)



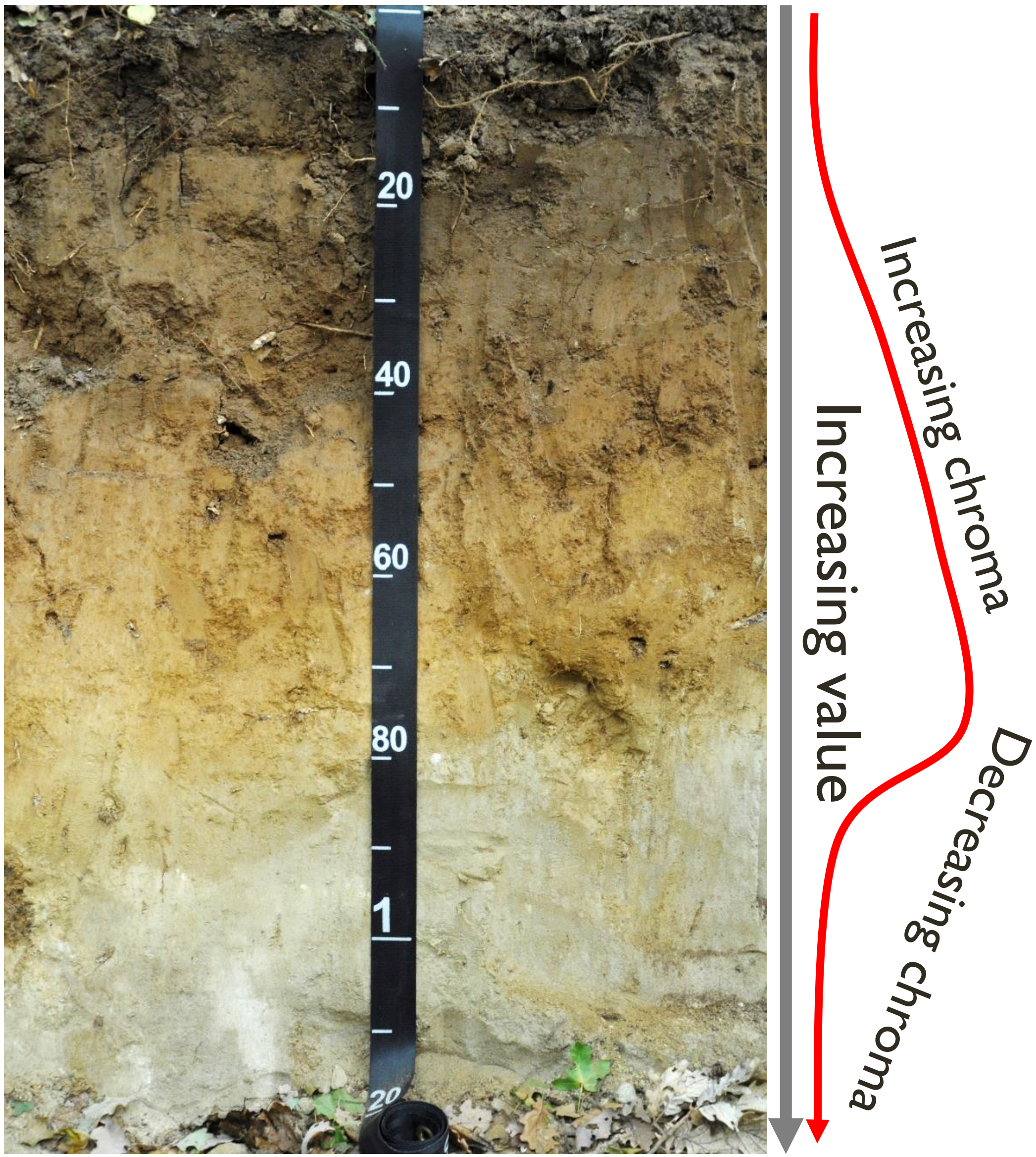
MUNSELL® SOIL COLOR CHART
10YR
8/
7/
6/
5/
4/
3/
2/
VALUE
/1
/2
/3
/4
/6
/8
CHROMA
10YR6/4
10YR3/2

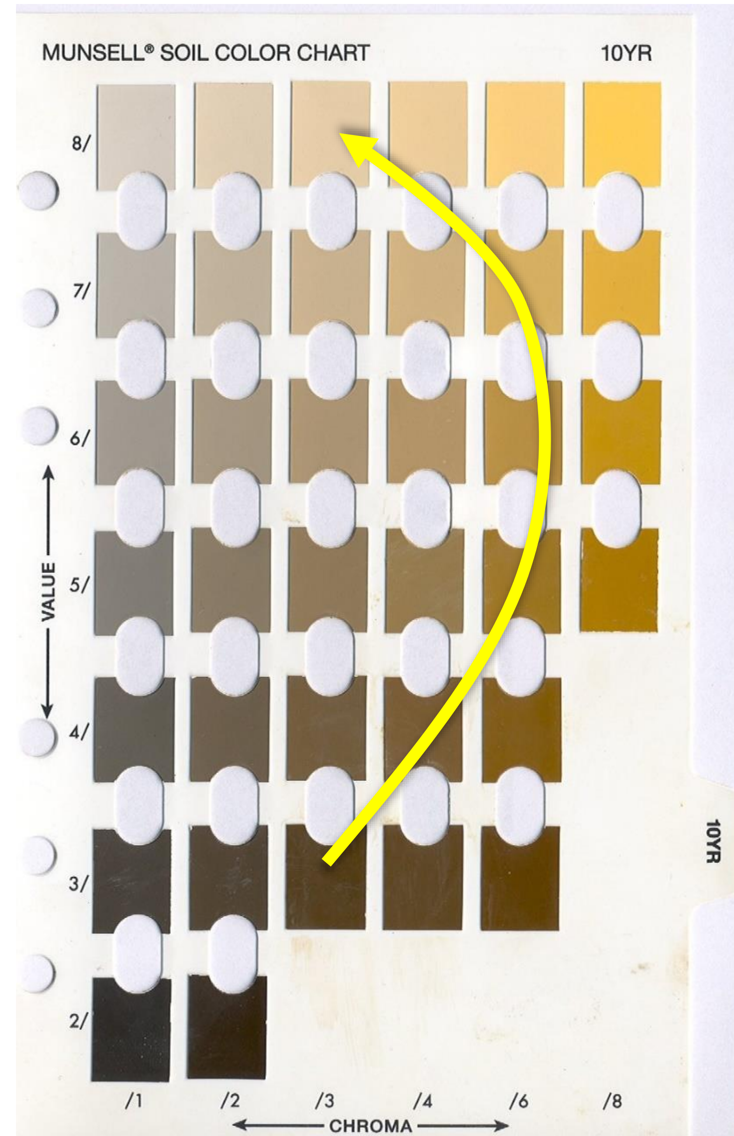


10YR4/2

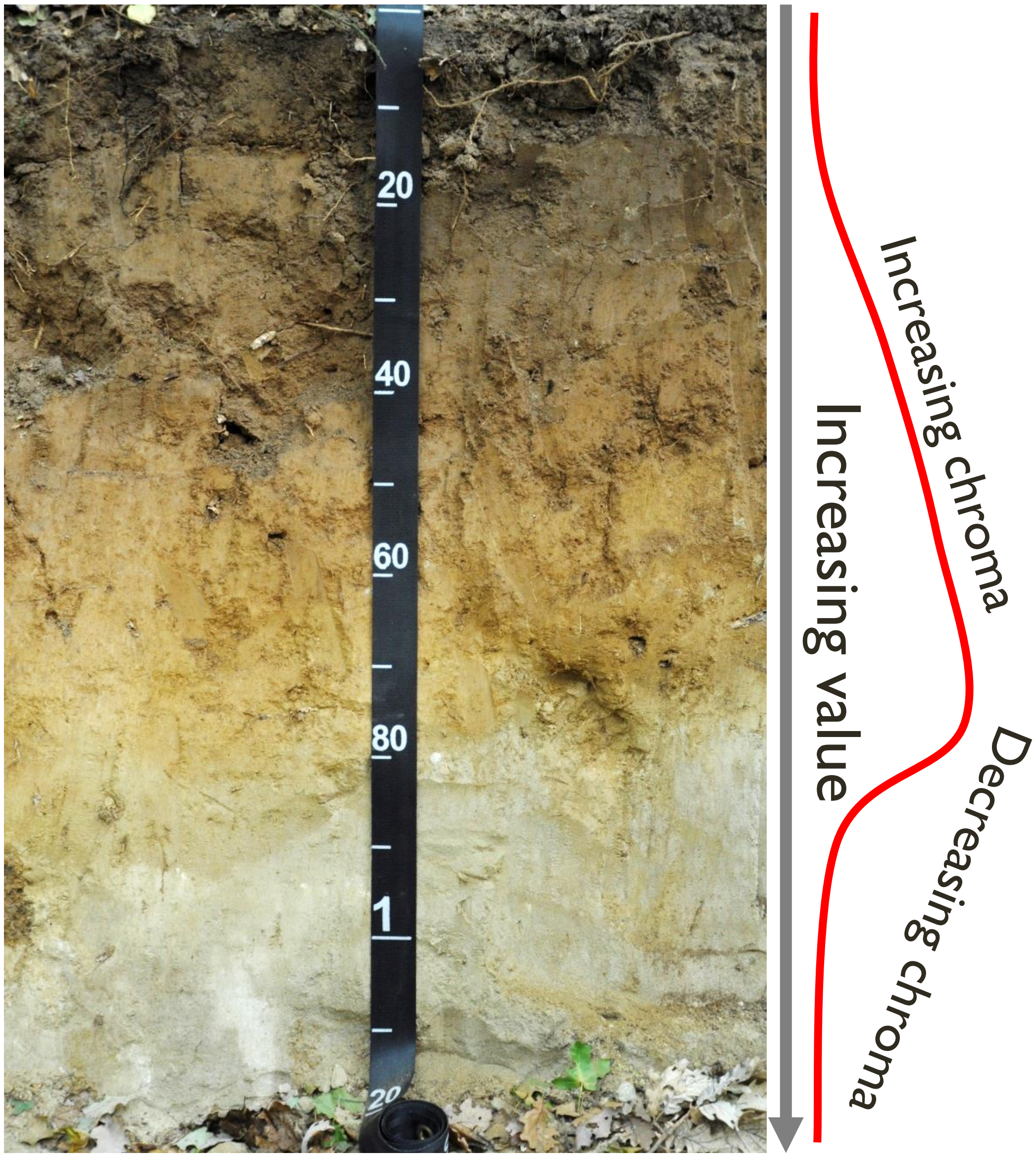
„dark greyish brown”

Importance of soil colour





Importance of soil colour



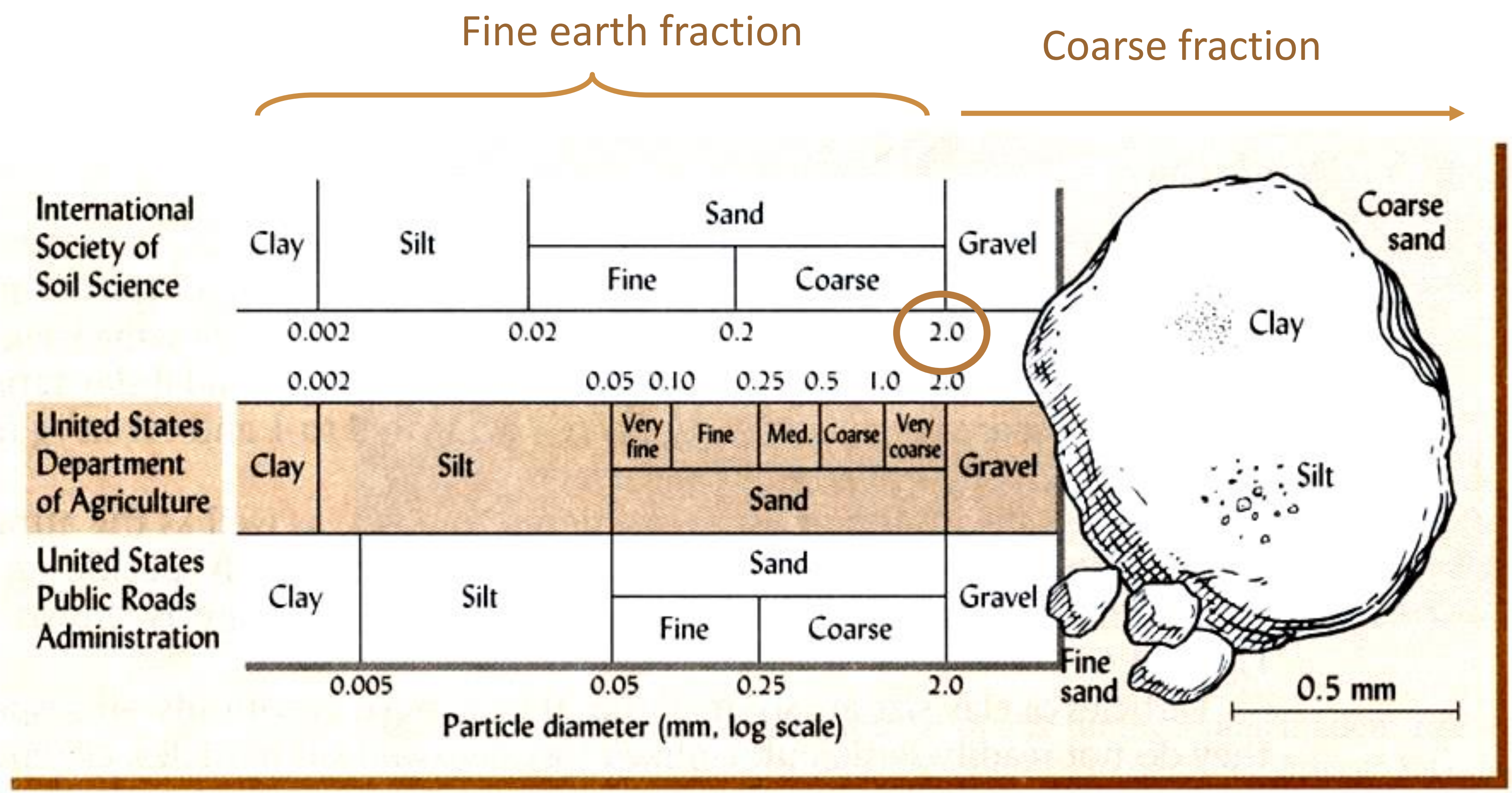
Increasing value
Related to decrease in organic matter content

Increasing chroma
Related to weathering and material transport (eg. Clay migration) in the soil

Importance of soil colour

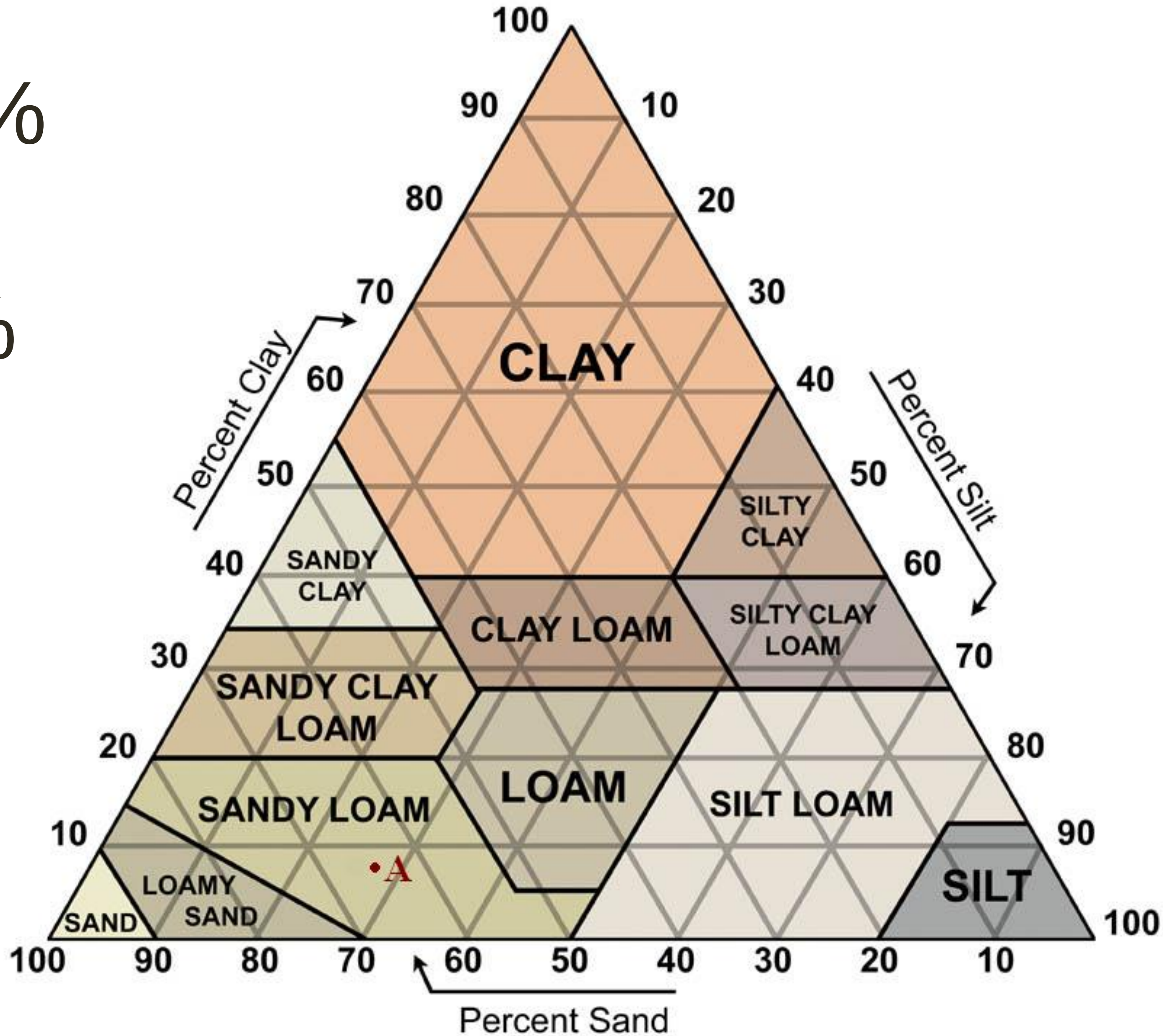
- Indicator of soil drainage and degree of soil aeration
- Soil colour is influenced by the oxidation state of iron and manganese
- No mottles – well aeration, well-drained soil
- Red, yellow/grey, blue mottling – poorly drained, waterlogging
- Excess water triggers chemical and biochemical processes that produce toxins damaging the root system.
- This reduces the ability of plants to take up nutrients

Particle size

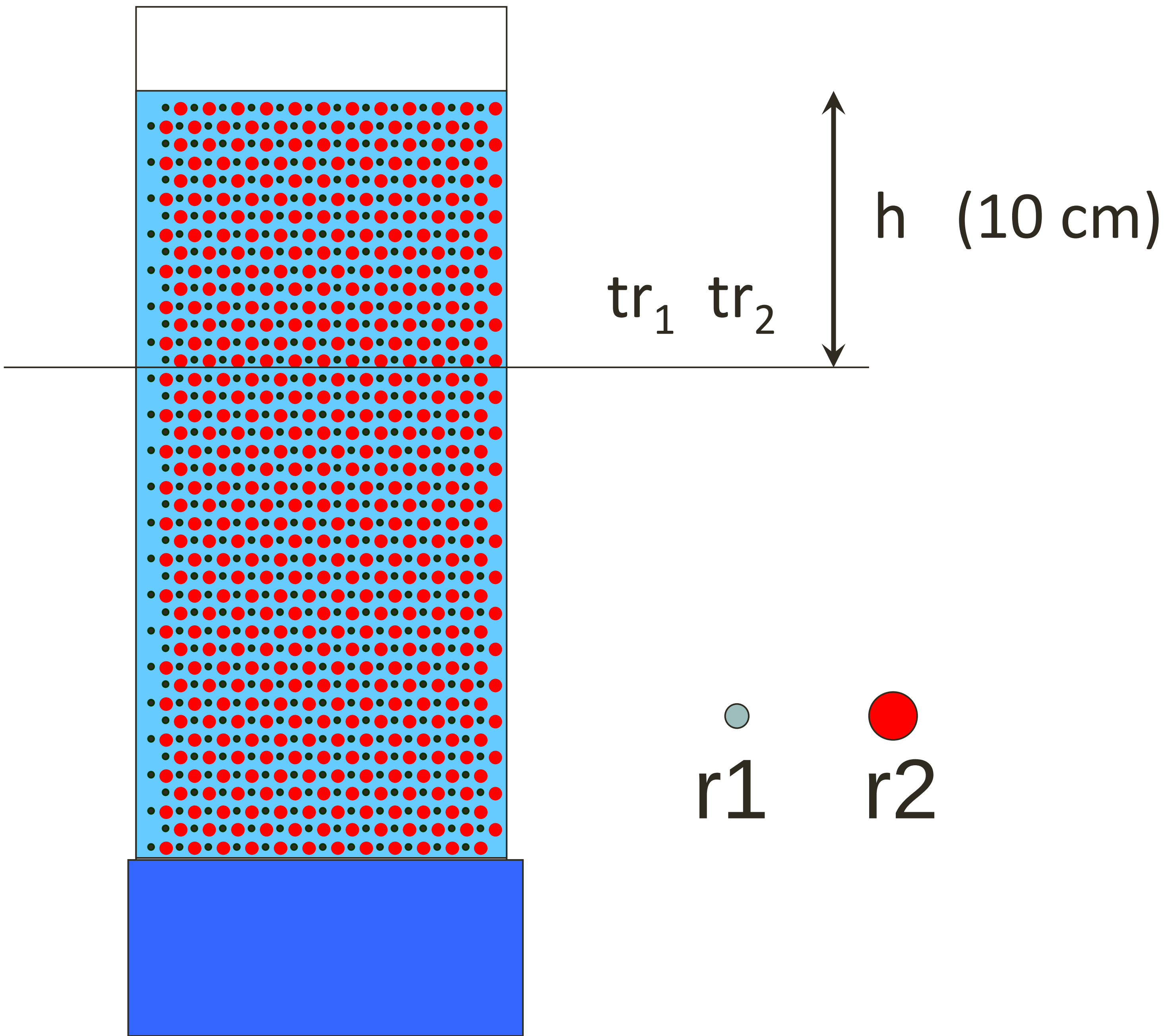


A TEXTÚRA HÁROMSZÖG DIAGRAM

Sand 45 %
Silt 40 %
Clay 15 %



Texture determination in lab



h (10 cm)
tr_1 tr_2
r1
r2

A TEXTÚRA HÁROMSZÖG DIAGRAM

Sand 45 %

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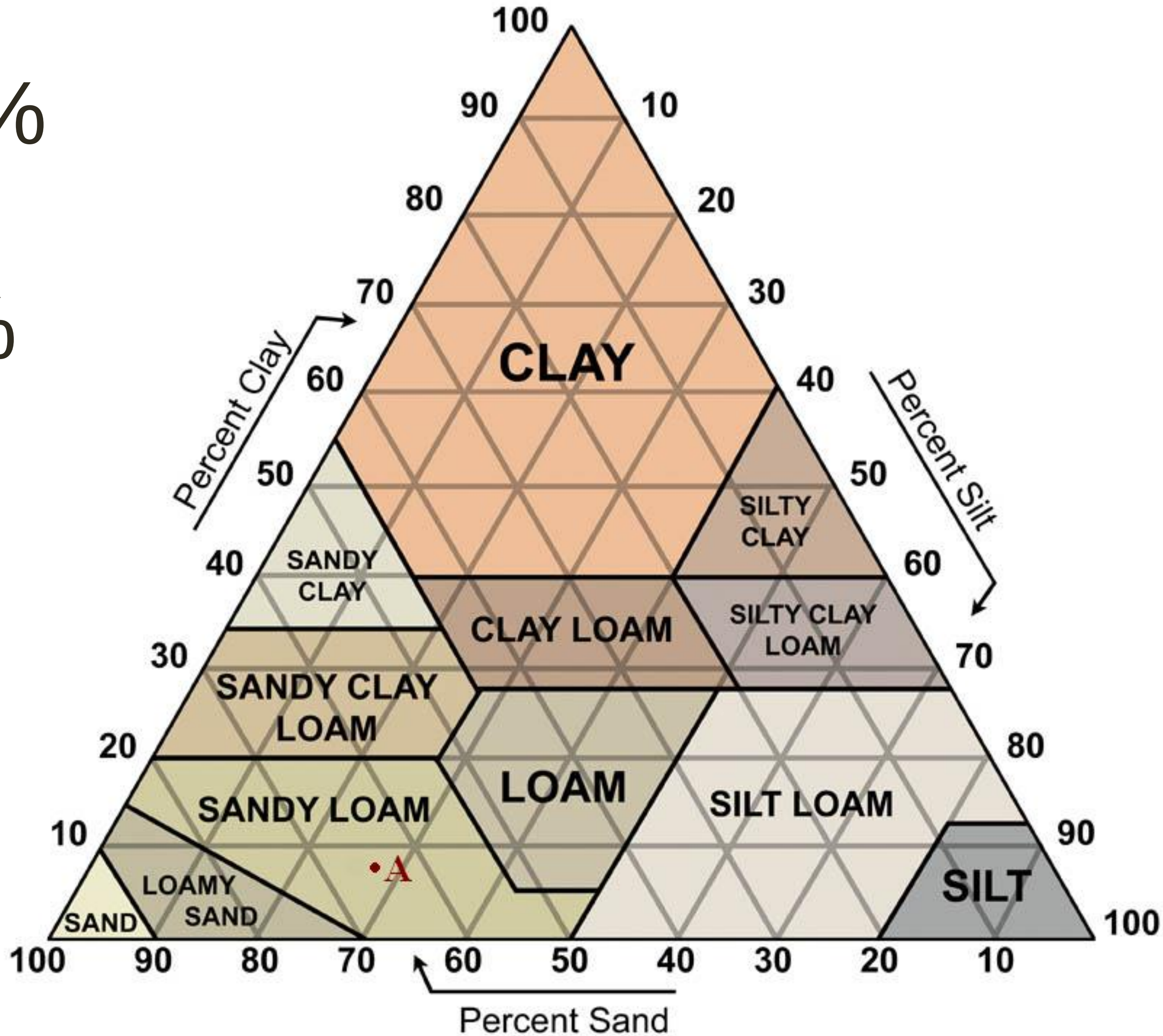
Clay 15 %



Texture

Field determination: finger testing

Based on stickiness, consistence

Sand

- Coarse
- Non formable
- Sratchy noise

Loam

- Formable but breakd
- In wet state like dough
- In dry state like flour

Clay

- Sticky
- Formable
- Shiny surface

Importance of soil texture

Defines the size of mineral particles

Refers to the relative proportion of the various particle-size groups in the soil (large-sand, medium-silt, small-clay)

Influences

- Water retention and availability
  - Finer texture (higher clay content) retains more water than coarse texture
  - Loam, clay loam texture has the highest available water content
- Soil structure
  - Finer texture helps the development of a strong structure
- Aeration and drainage
  - Finer-textured soils are less aerated and might be less drained
- Soil workability and trafficability
  - High clay content soils are harder to work with
- Supply and retention of nutrients
  - Finer-textured soils have more nutrient-holding capacity

IV. Bulk density

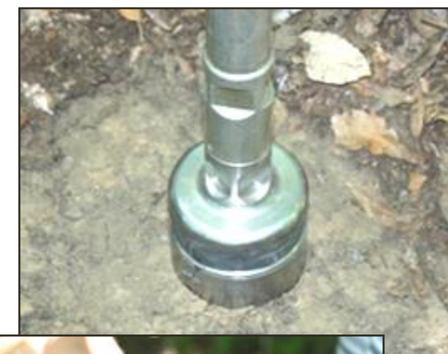
Bulk density (Db)
The dry mass of soil per unit of total volume, including pore space.
Usually expressed in **g/cm³**.

Why it matters
Bulk density reflects how compact or loose the soil is. It influences porosity, root penetration, water movement, and aeration.

Measurement
Bulk density must be measured on an **undisturbed soil sample** because the natural structure and pore space have to be preserved.

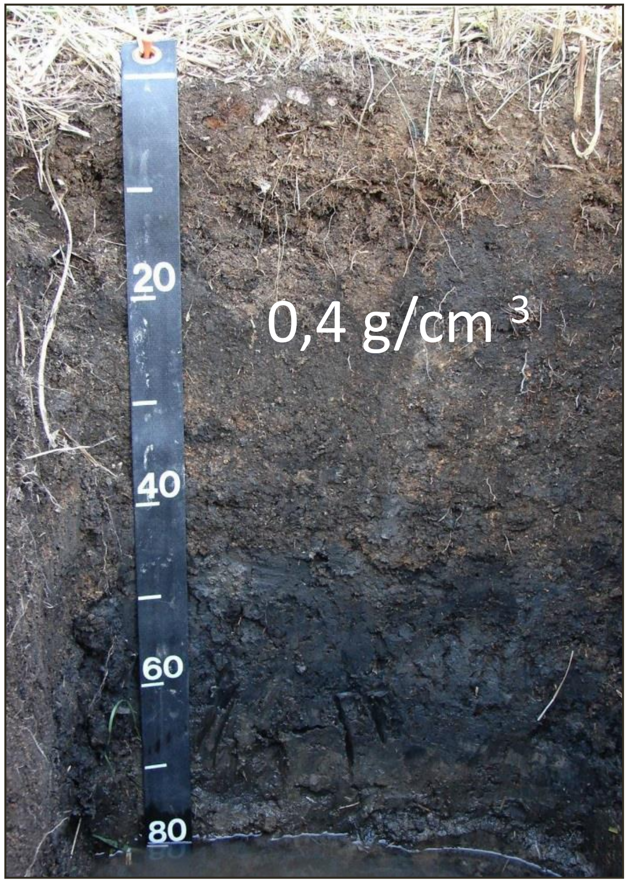
Typical values
For most mineral soils, representative values are about **1.1–1.6 g/cm³**.

Interpretation
Higher bulk density usually indicates more compact soil and less pore space.
Lower bulk density usually indicates looser soil, more pore space, or higher organic matter content.

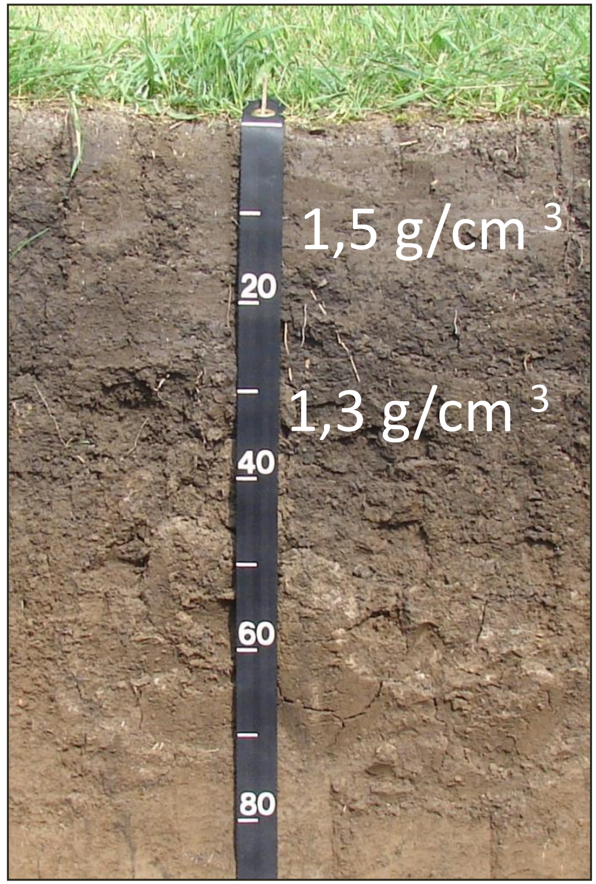


Taking undisturbed samples

Organic soil

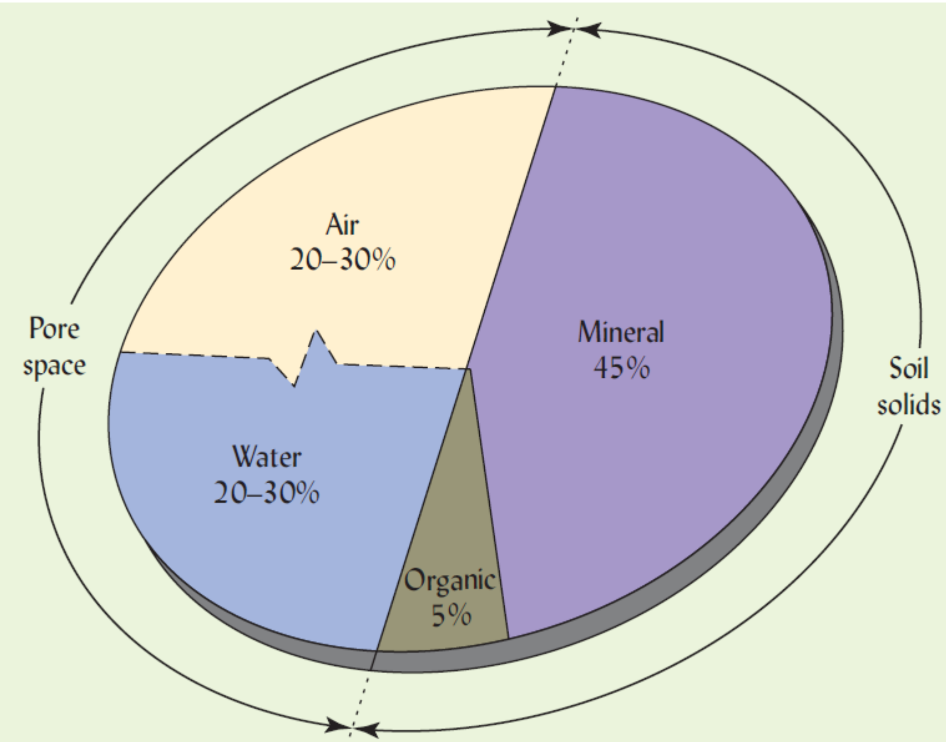


Compacted chernozem soil



Soil with clay illuviaton

IV. Soil porosity



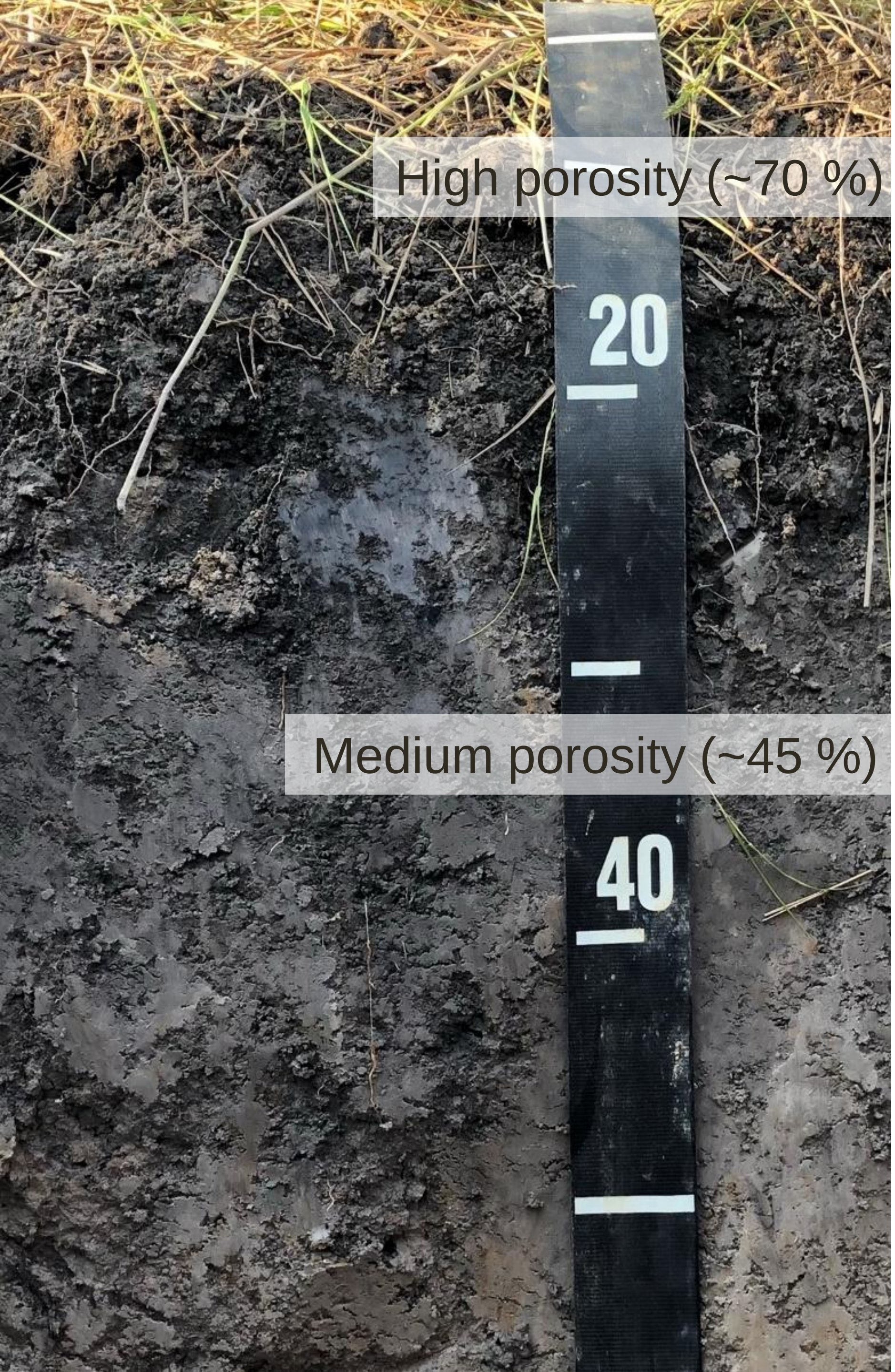
Large pores – air regulation
Medium pores – moisture regulation
Small pores – microorganisms

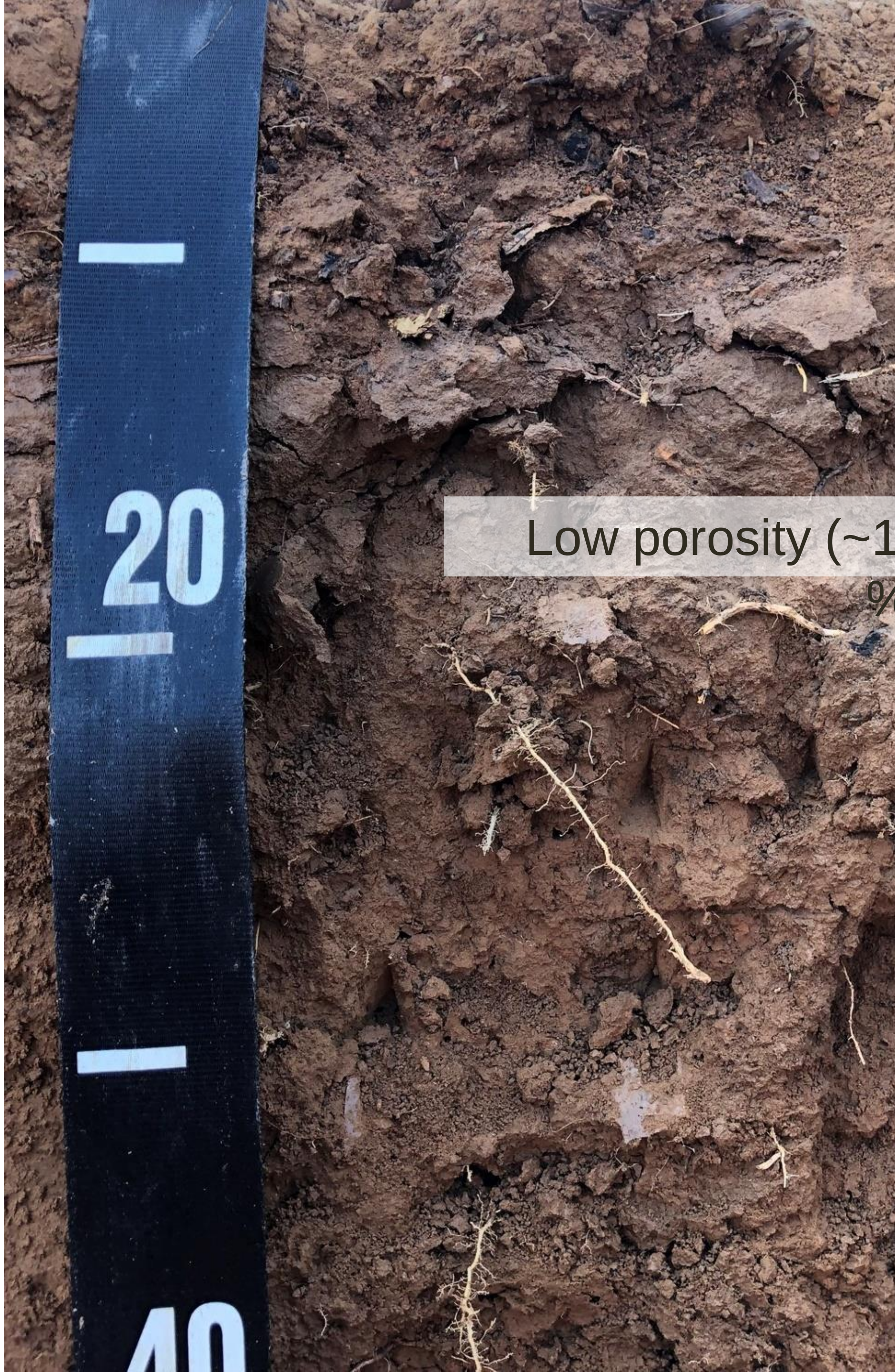
Volume occupied by pores (not solid space in the soil)

Regulates the movement of air and water

Good structure – high porosity between and within aggregates

Poor structure – low porosity


High porosity (~70 %)
20
Medium porosity (~45 %)
40


20
Low porosity (~1
%

Importance of porosity

Good soils have high porosity between and within aggregates

Low porosity → low aeration → build up CO_2, CH_4, sulphide gases → reduces the ability of plants to take up water and nutrients (N, P, K, S)

Plants utilize S and N in oxygenated sulphate (SO_4^{2-}), nitrate (NO_3^-) and ammonium (NH_4^+) forms → well-aerated soils are required for uptake and utilization

Biodiversity is also the highest in well-aerated soils

Roots are not able to penetrate and grow through firm, tight, compacted soils → restricting the plant to utilize the nutrients and water

Good porosity → better drainage → less likely is that the soil pores will be water filled (oxygen poor, reducing conditions)

Structure of the soil

The arrangement and organization of primary and secondary particles in a soil mass is known as soil structure.

Binding forces
Binding agents

→

Structure formation
Aggreagates

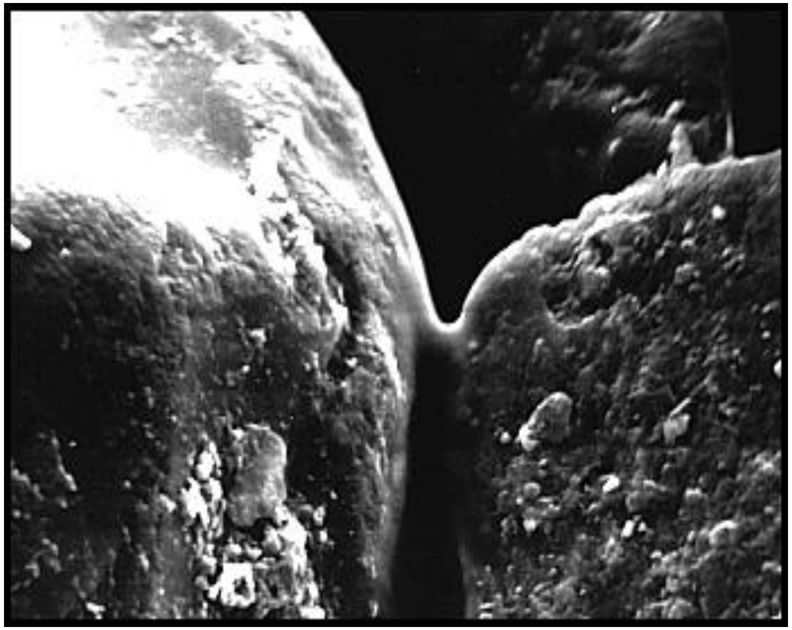
The morphology, type and stability of aggregation is characteristic to the soil forming processes

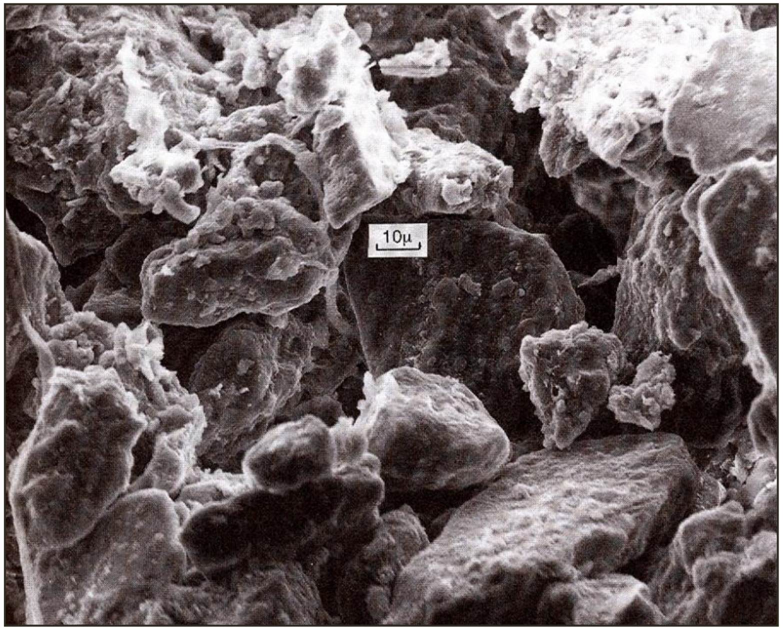



Soil structure

Soils structure is a non-stable soil property

Importance: it determines a mechanical properties; air, water, nutrient management; adsorption processes





Particles larger than 0,002 mm are the „skeleton" of the strucure

Particles smaller than 0,002 mm are the binding agents

Most important binding agents:

Calcium-carbonate, clay minerals, oxides, organisms and their products

Soil structure

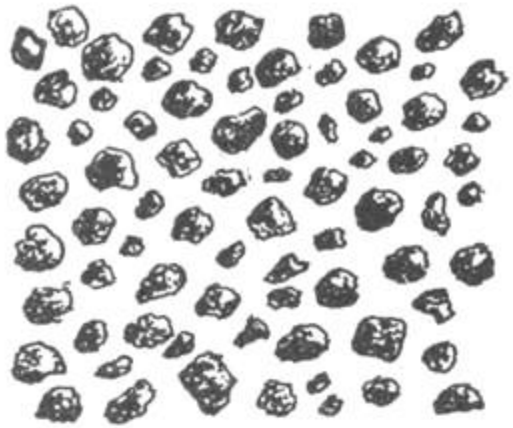
Structureless soil

Identification of aggregates is not possible

- Presence of individual particles
- Compacted or cemented soil

Soils with structure

By expressing gentle pressure on the soil, it breaks apart to similar aggregates

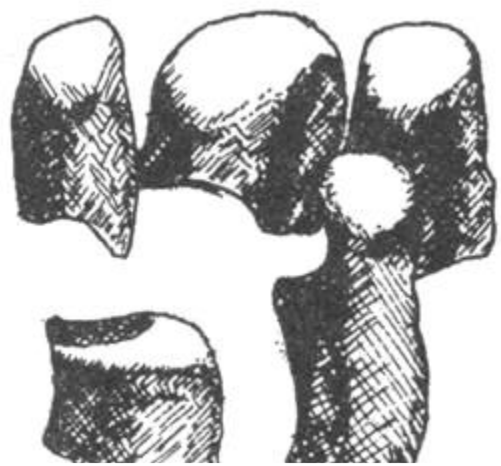


granular

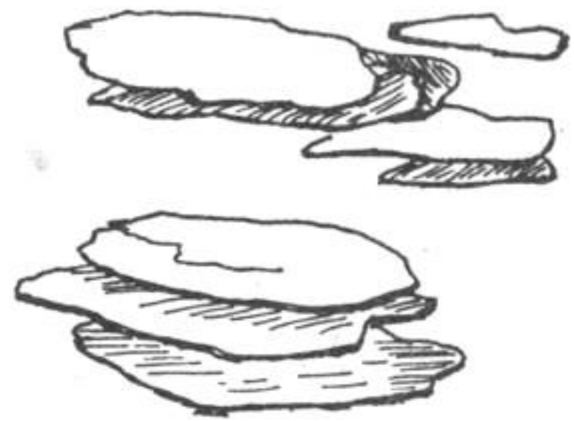
angular blocky

subangular blocky

prismatic



columnar



platy

granular

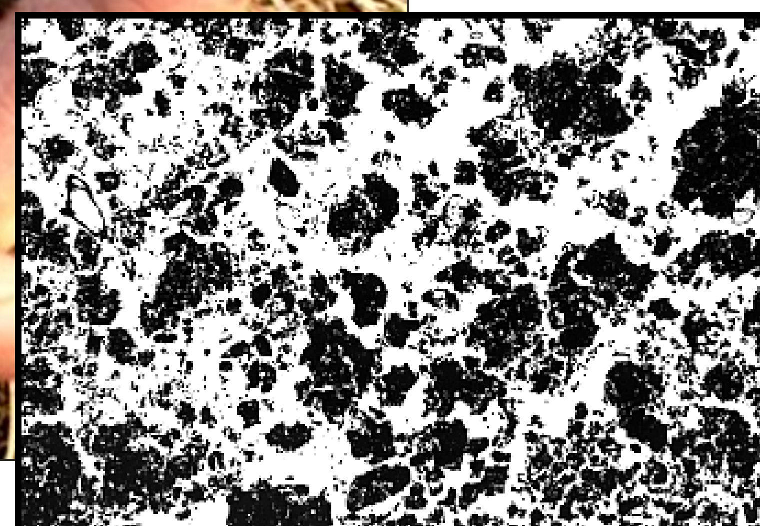
angular blocky

subangular blocky

prismatic

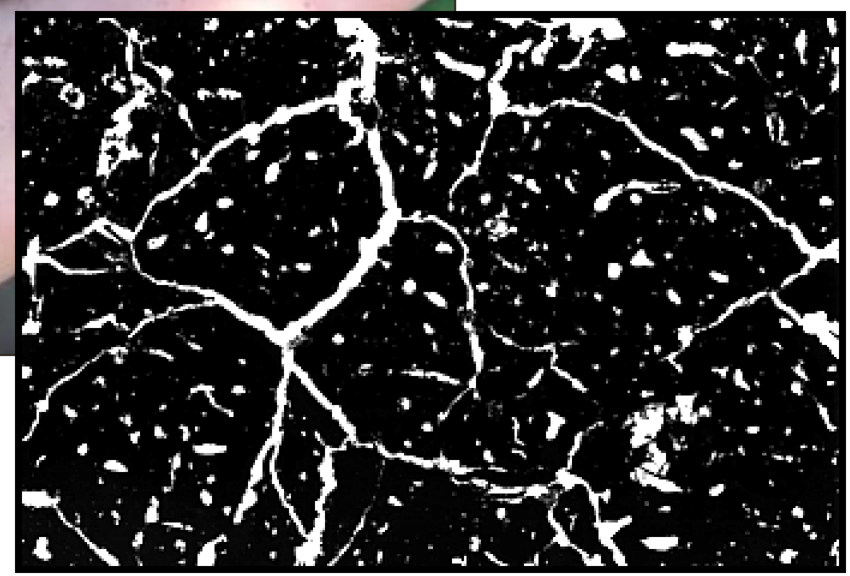
columnar

platy

granular

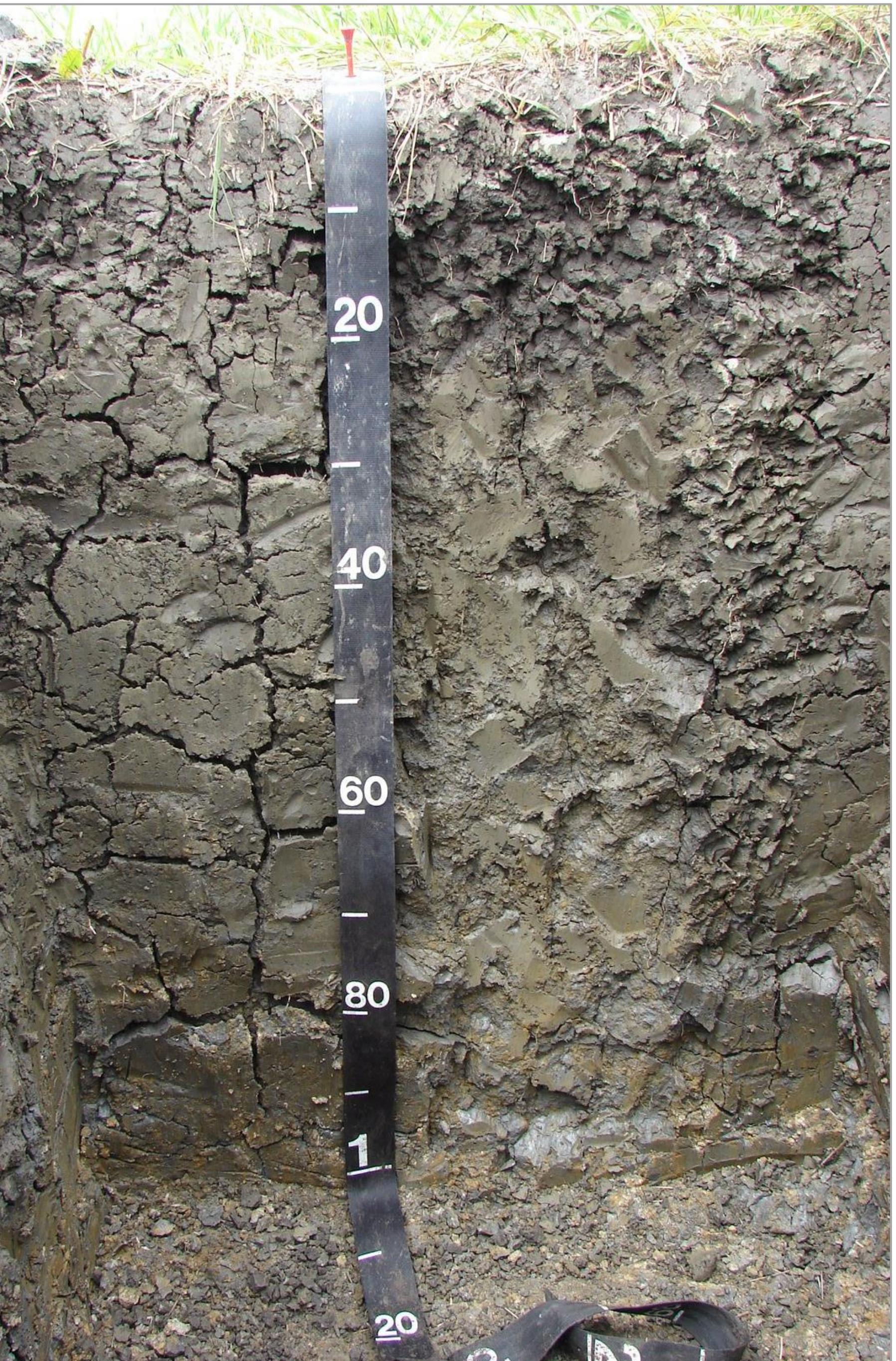

Humus-rich
surface
horizons



Angular blocky


Surface horizons of clay rich soils

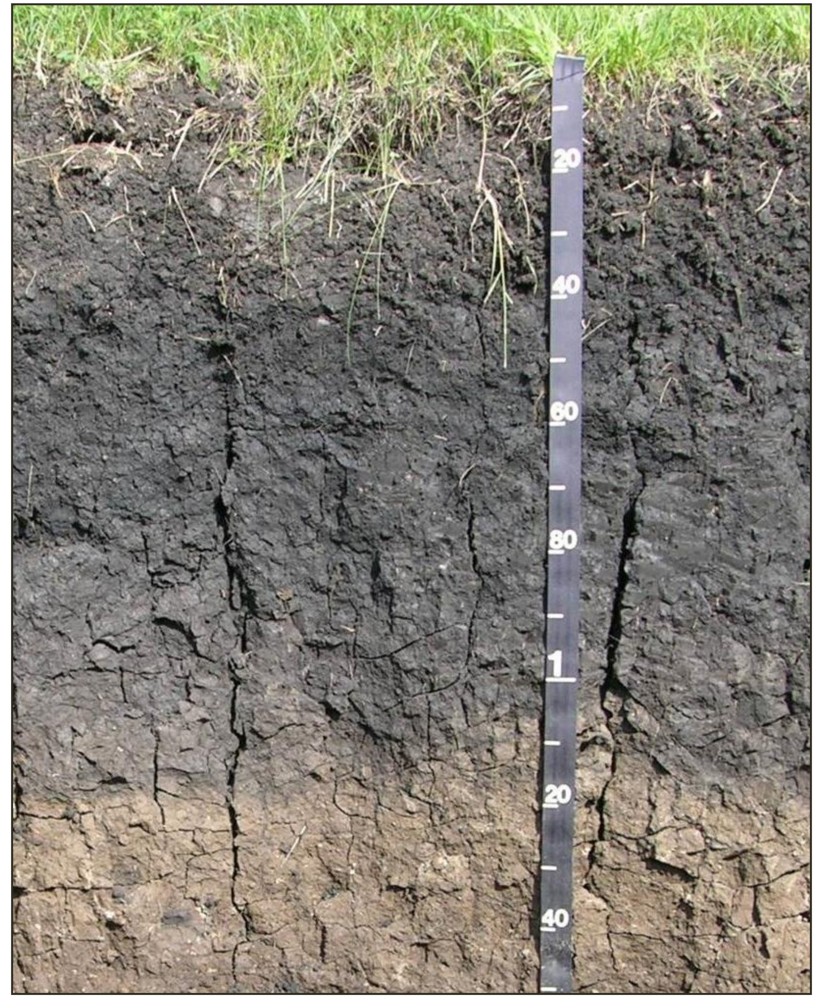
Subangular blocky



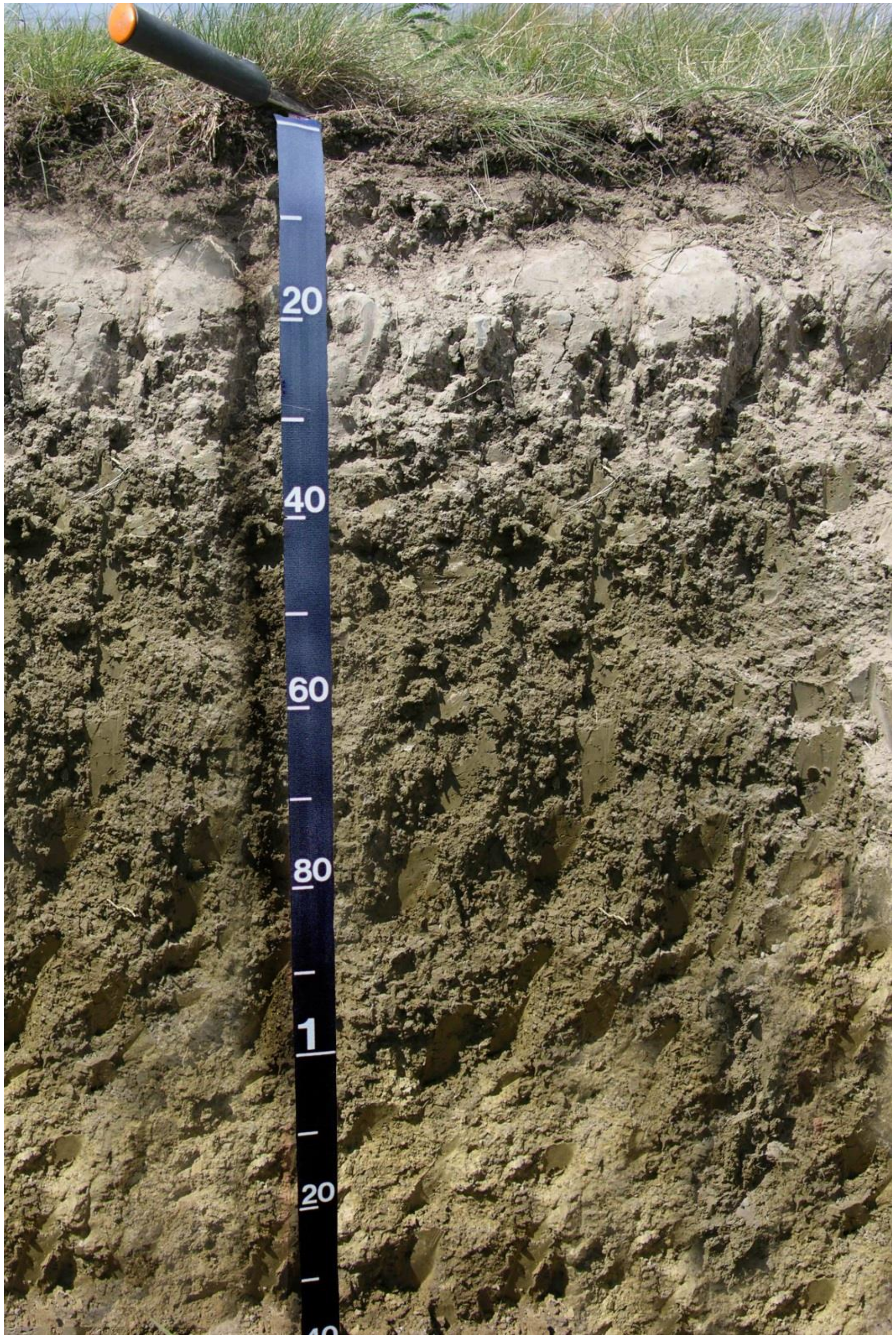
Surface and subsurface horizons of high clay content soils

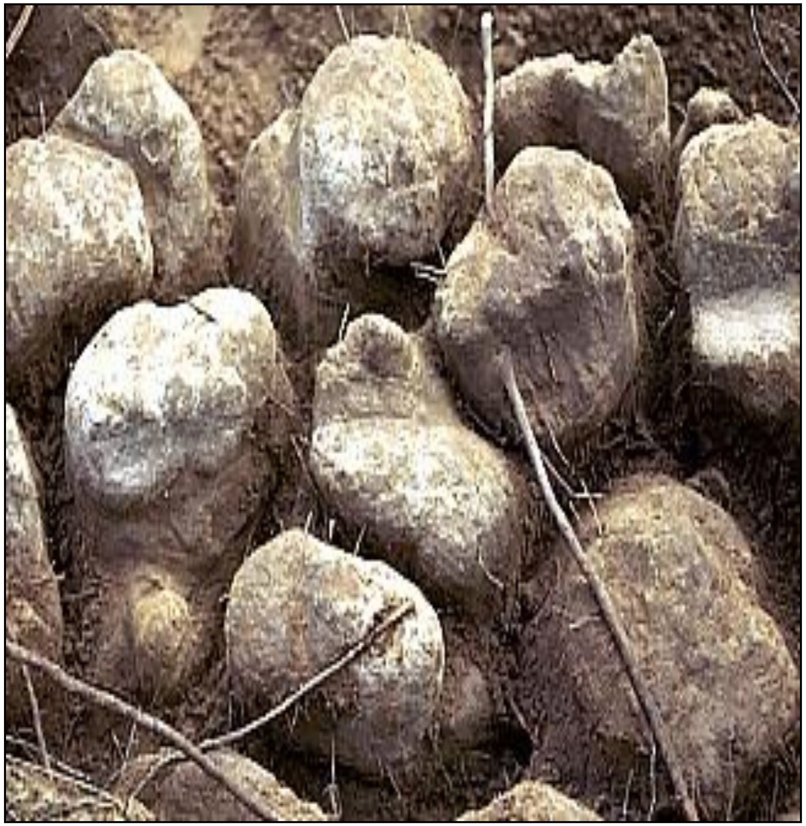
prismatic

Bt horizons of soils with clay illuviation



Cracked horizons of shrink-swell soils

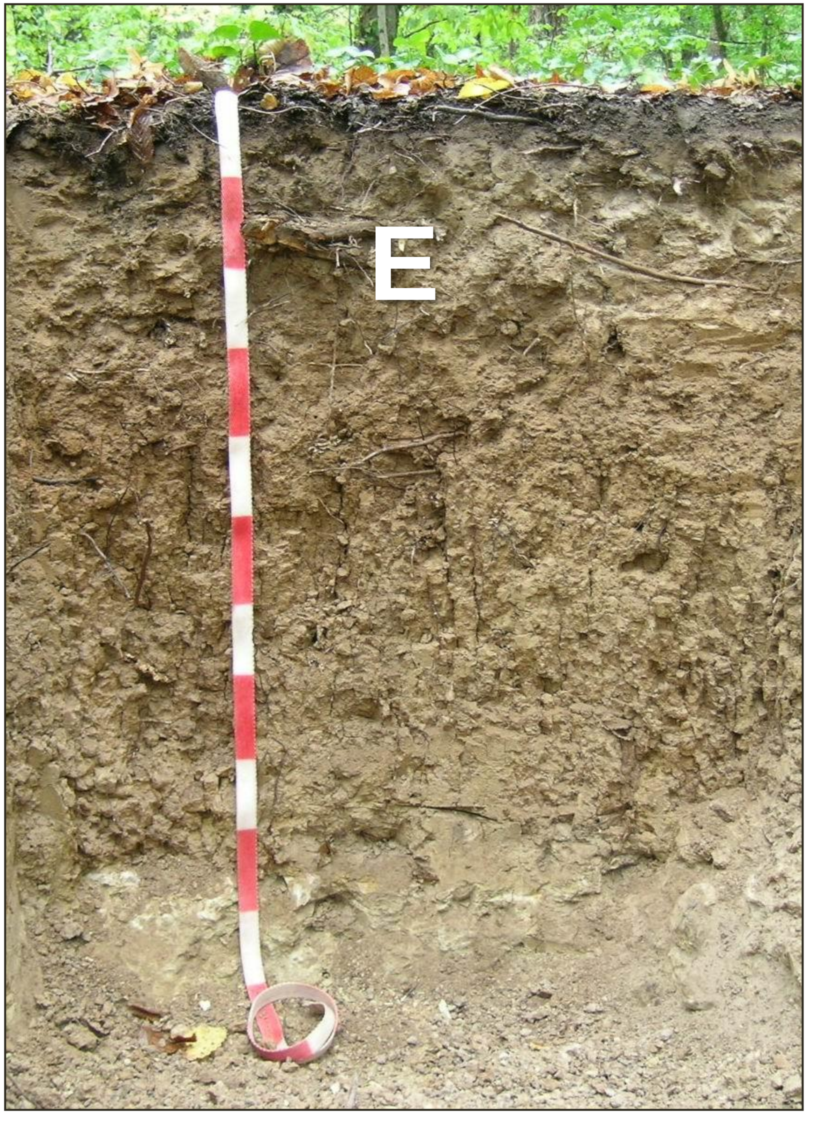




columnar

Btn horizons of salt affected soils

platy



E horizons
Compacted horizons

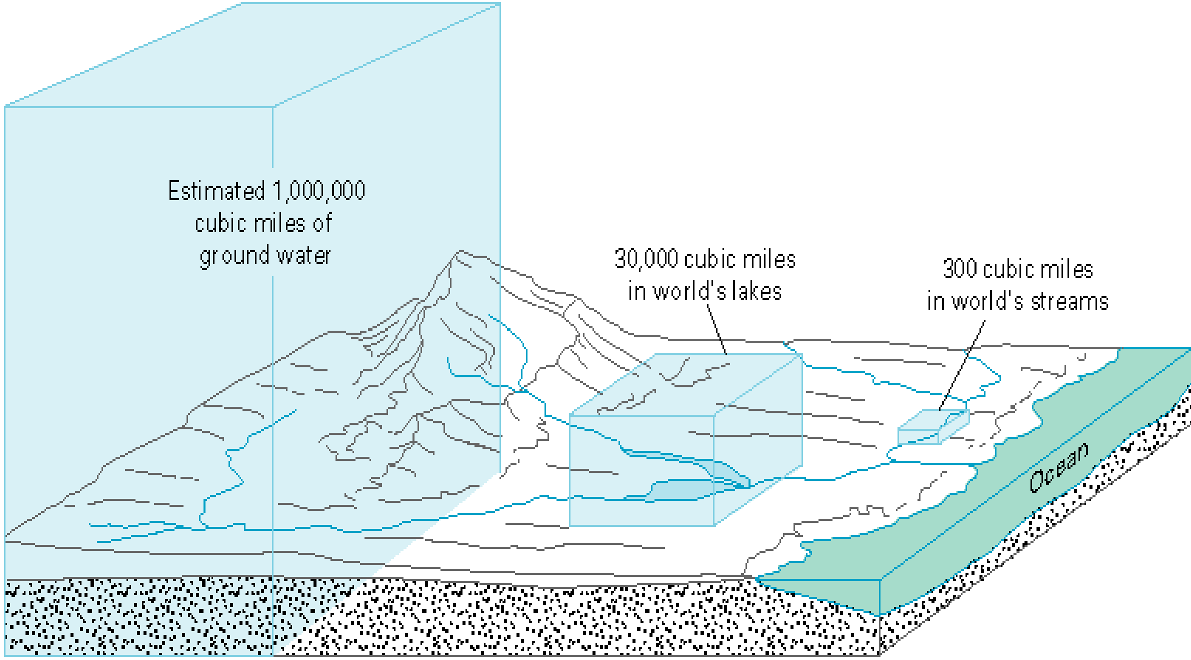
What is the favorable soil structure for the topsoil?

If the <u>topsoil</u>

- Is dominated by friable, fine aggregates that are subrounded and often porous – Favourable

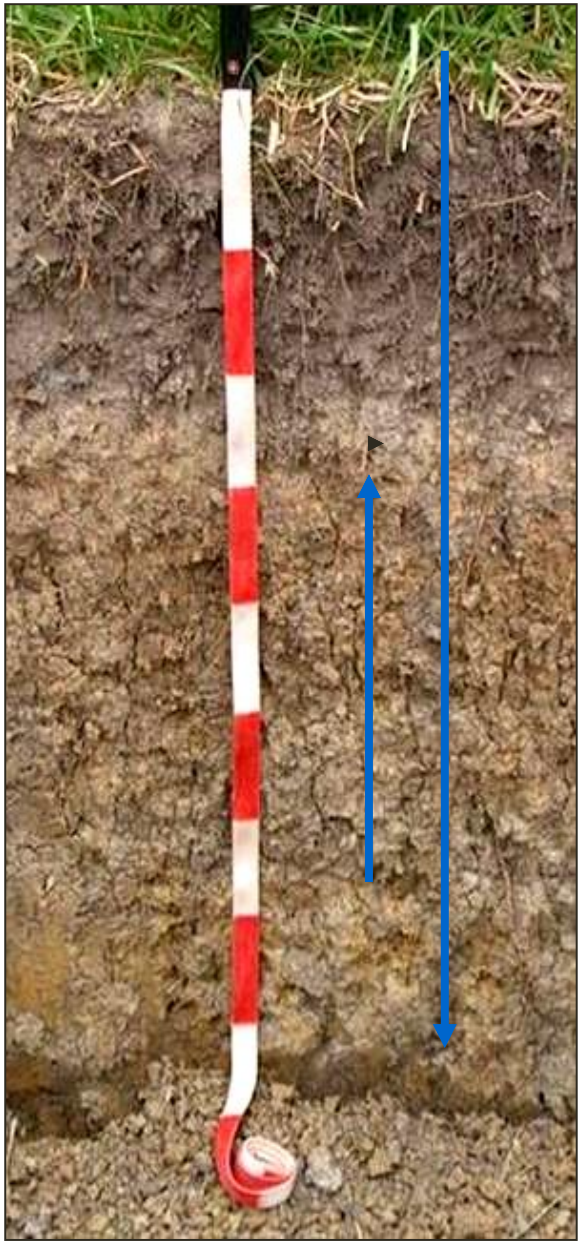
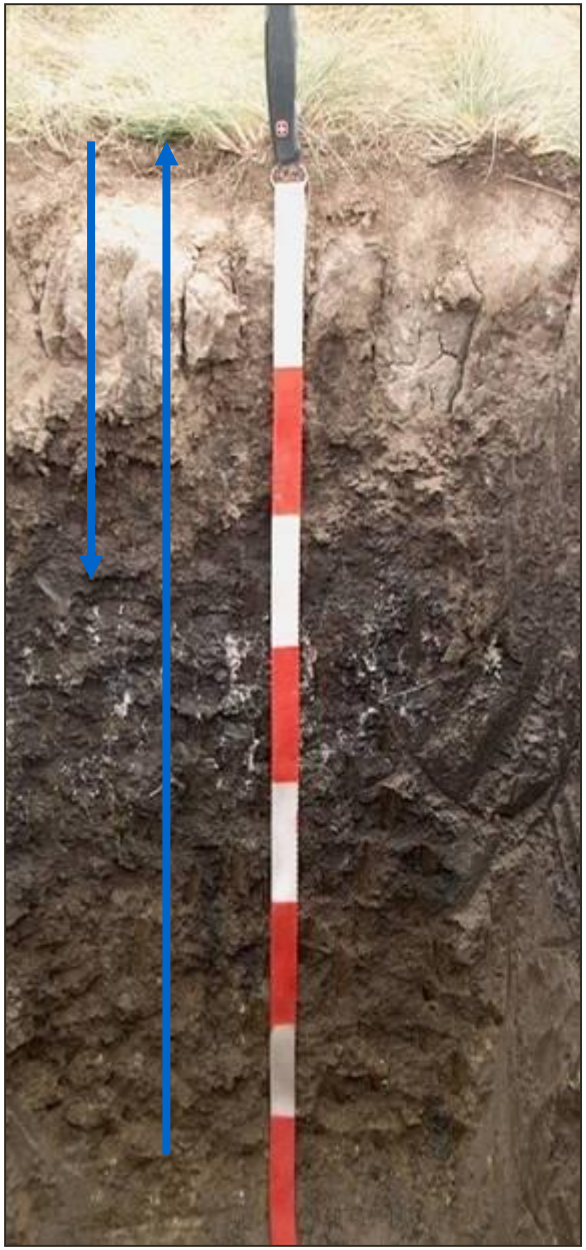
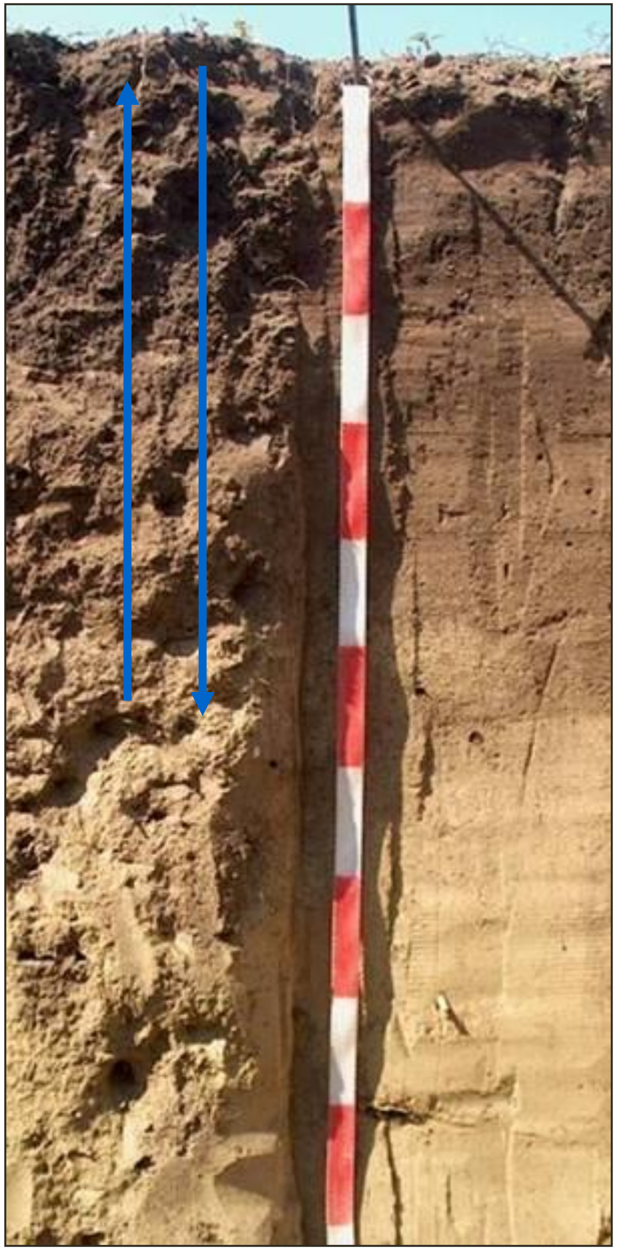
- Is dominated by aggregates that are firm, subangular, angular shaped with few or no pores – Moderately favourable
- Is dominated by coarse aggregates that are firm, angular, subangular, with few or no pores – Not favourable

Soil water

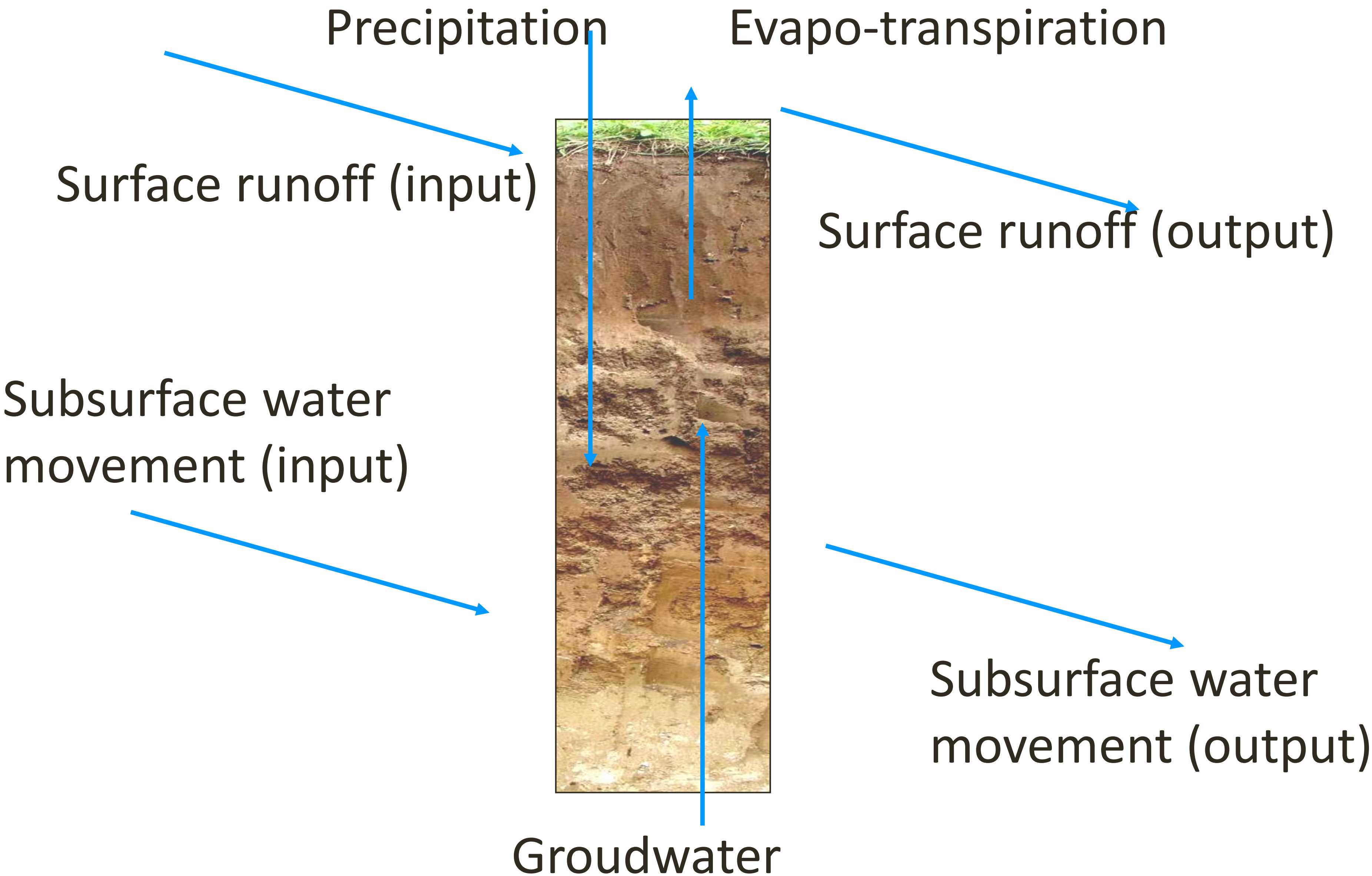


71 % Oceans
97,41 % of total water - salty

- Ice: 2 %
- Hardly accessible subsurface waters: 0,7 %
- Easily accesible waters: <0,05 %
  - lakes: 60 %
  - soil water: 33 %
  - atmosphere: 6 %
  - rivers: 1 %

Water inputs and outputs in the soil



Determination of soil moisture content

- Gravimetric method
  - Based on the weight difference between the moist and dried soil sample
- Tensiometric method
  - Determines the moisture retaining capacity of the soils solid phaes
- Electrical resistance based method
  - Electrical conductivity is proportional to soil moisture (except in case of having high salt content)
- Neutron scattering methos
  - H ions in the water reduce the speed of neutrons provided by a radiation source

Water retention capacity of the soil

The amount of water which can be received/retained by the soil in different circumstances

Maximum retention capacity (1): amount of water in a saturated soil

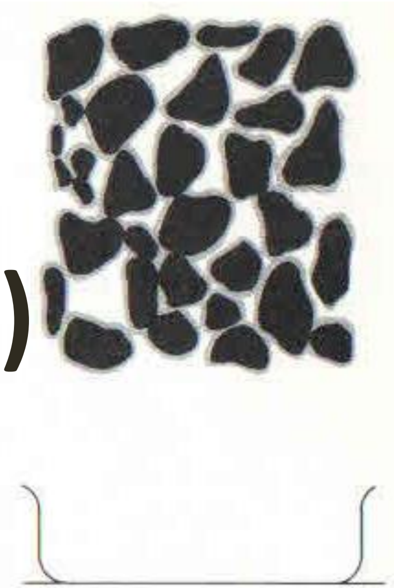
Field capacity (2): the amount of water which can be retained by soil against the gravity

Wilting point (3): the amount of water which is bound strong enough by the soil. Plant cannot uptake the water, they die.

(1)

(2)

(3)



Potential of the water in the soil

What kind of forces determine the movement/retention of the water in the soil

$$\Psi_T = \Psi_M + \Psi_P + \Psi_Z + \Psi_S$$

Ψ_T = Overall potential of the water in the soil

Ψ_M = Matrix potential

Ψ_P = Hydraulic (pressure) potential

Ψ_G = Gravitational potential

Ψ_S = Solute potential

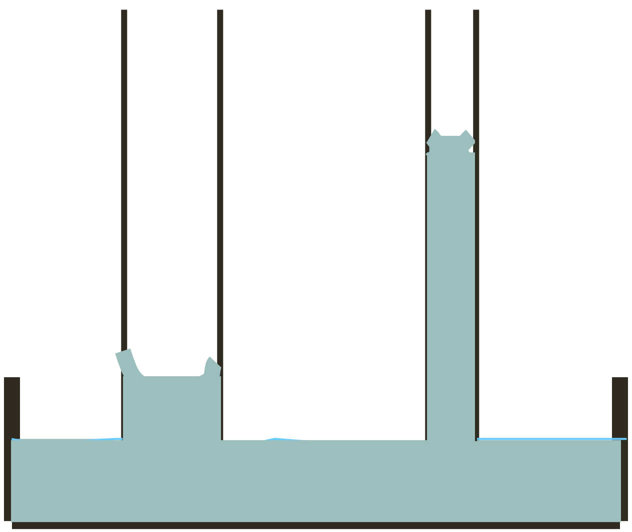
In laboratory we measure the matrix potential:

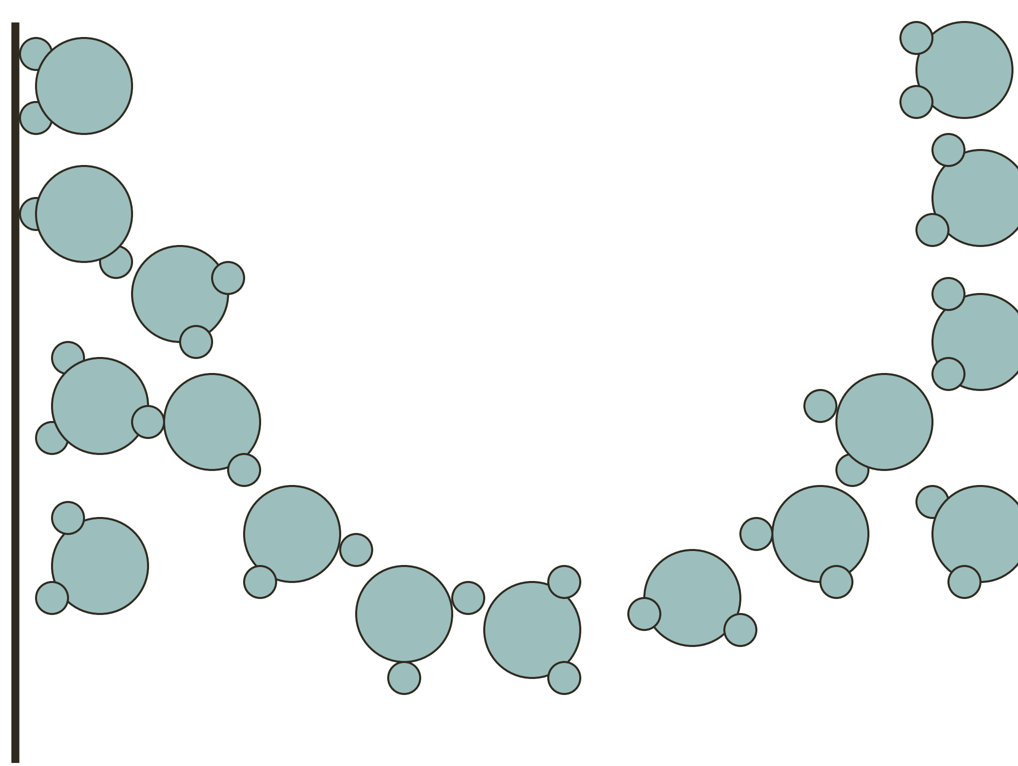
water retention of the soils – pF curves

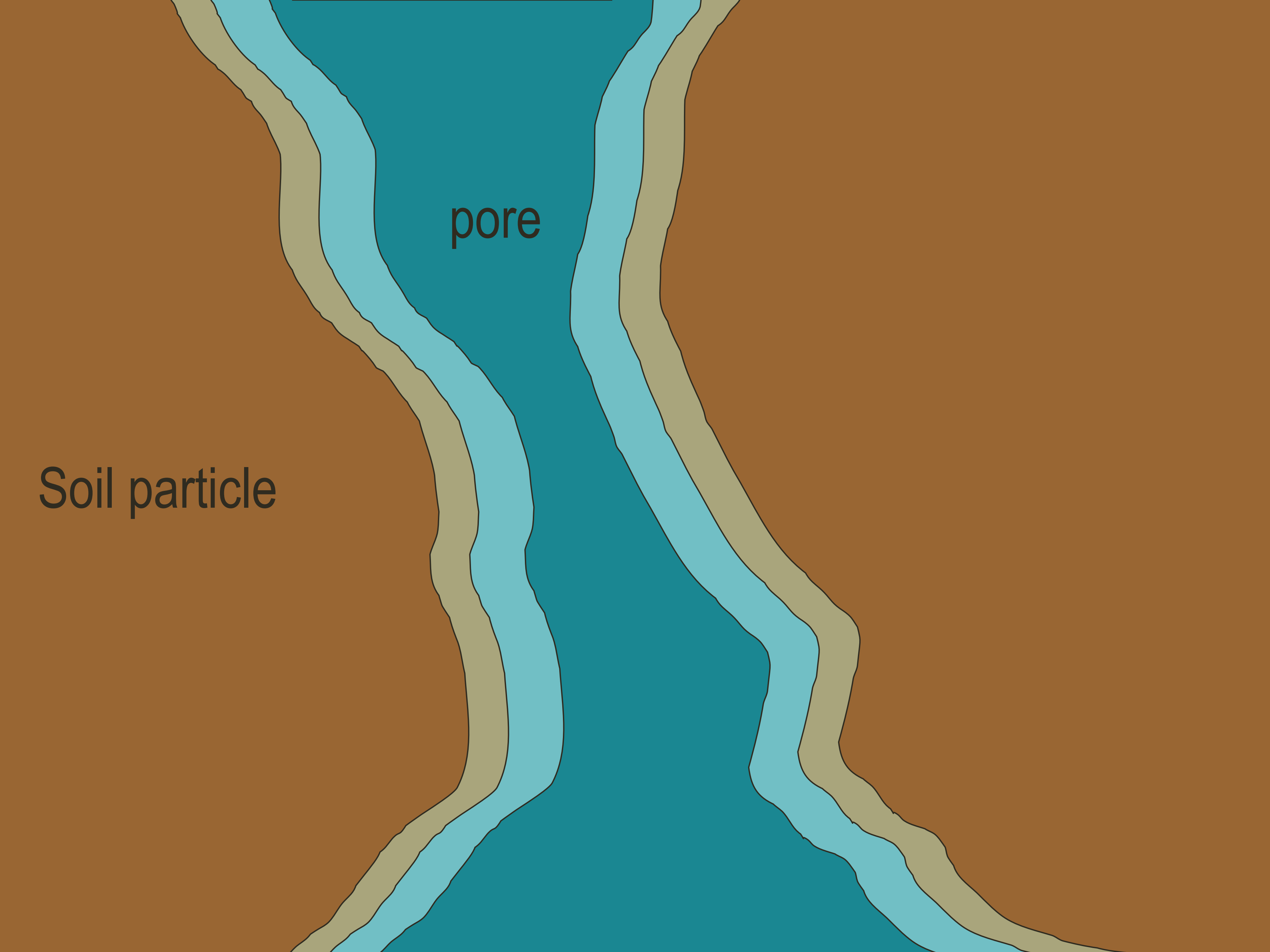
Forces that determine the matrix potential

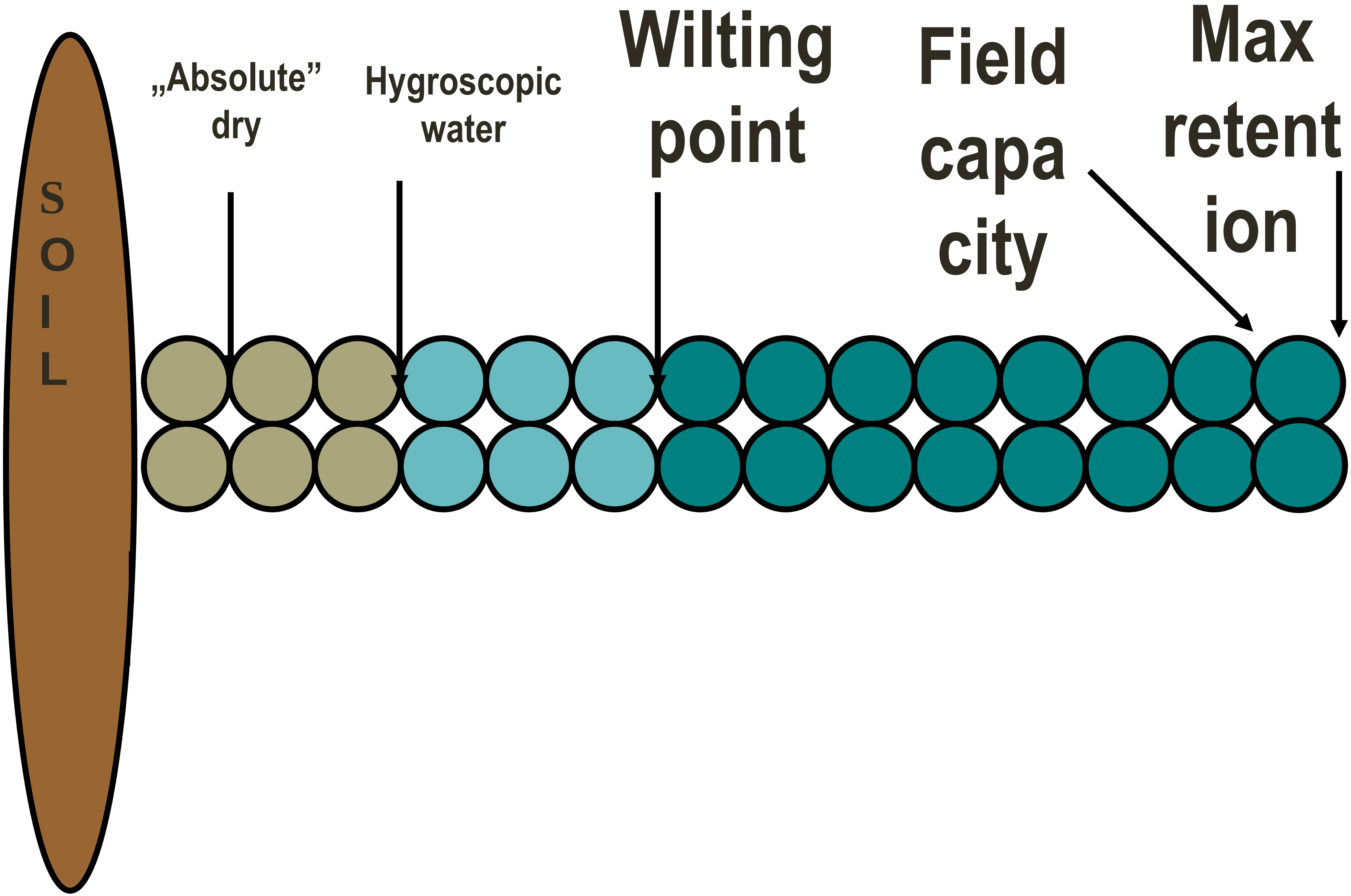
Adhesion: responsible for the cohesion of a material in a solid state(eg. Soil particles) and a material in another state (eg, water)

Cohesion: Responsible for the within-particle cohesion (e.g., water molecules)

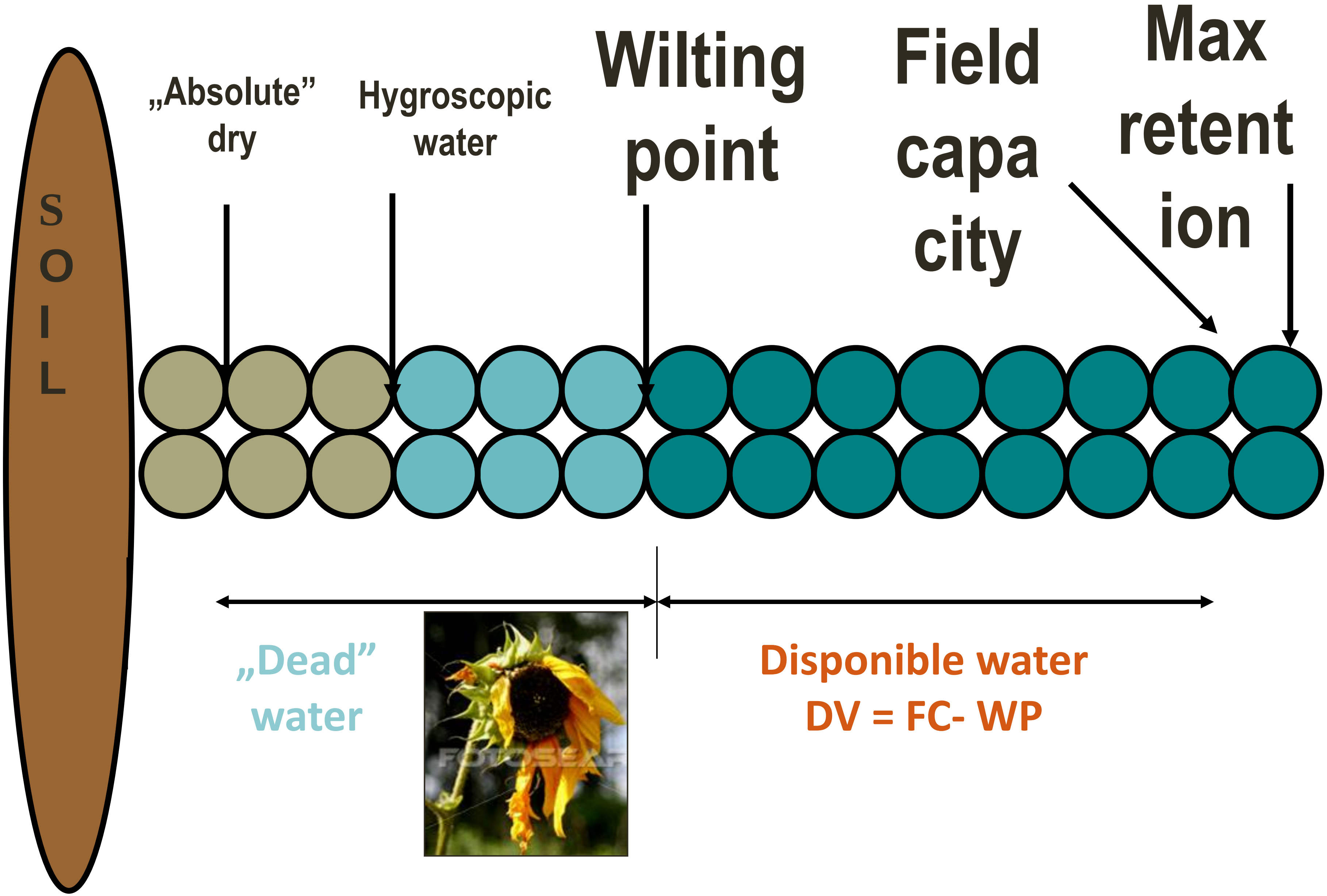





pore
Soil particle



S O I L
„Absolute" dry
Hygroscopic water
Wilting point
Field capa city
Max retent ion



SOIL
„Absolute” dry
Hygroscopic water
Wilting point
Field capa city
Max retent ion
„Dead” water
Disponible water
DV = FC- WP

pF

- How much „suction" is needed to fight the matrix potential
- pF = „suction" expressed by the base ten logarithm of a pressure of a water column (cm)

0 cm (1 cm) water column = pF 0 (saturated state)

10 cm water column = pF 1

100 cm water column = pF 2

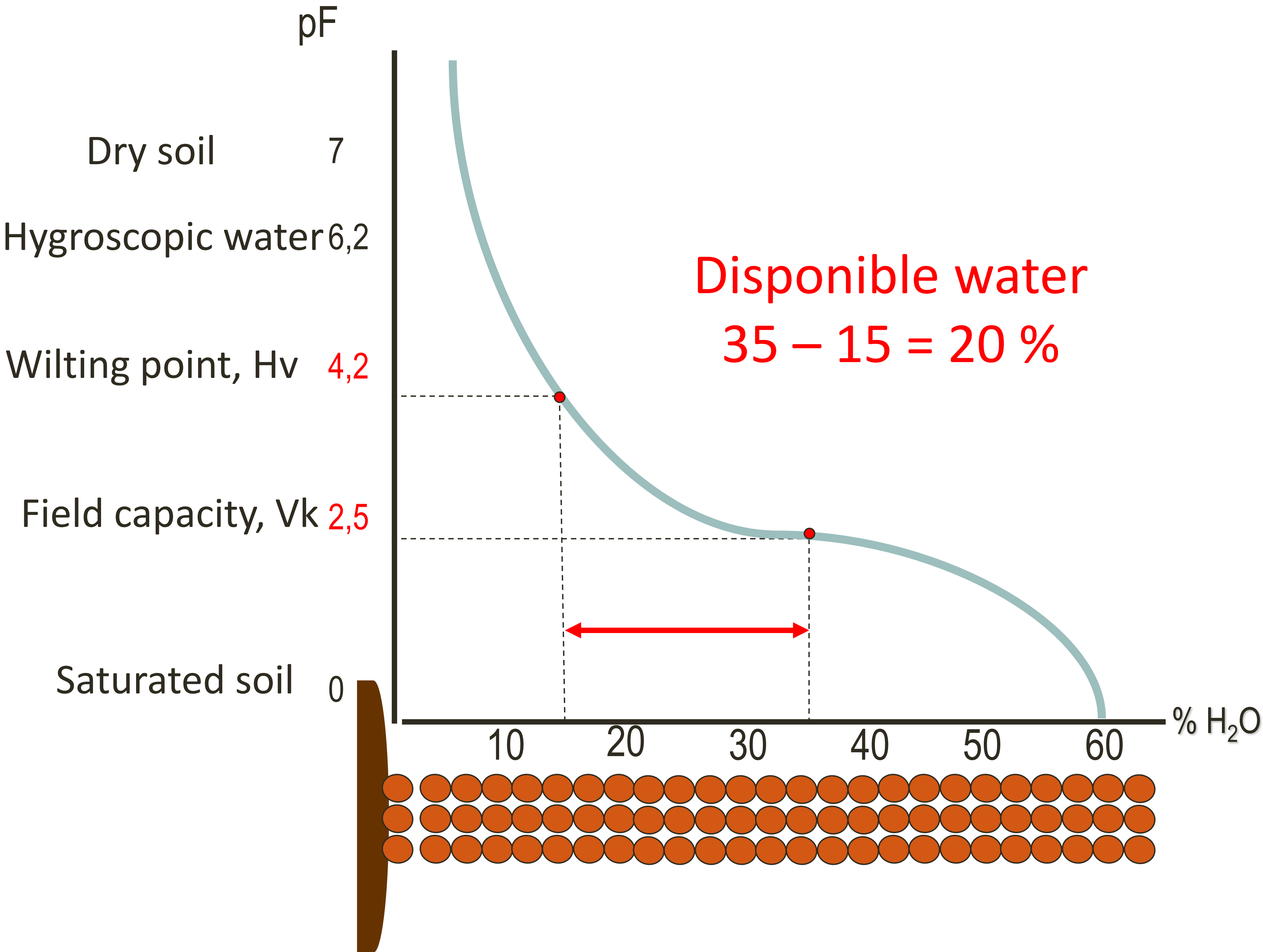
1000 cm water column = pF 3   (1 bár ~ 1 atm)

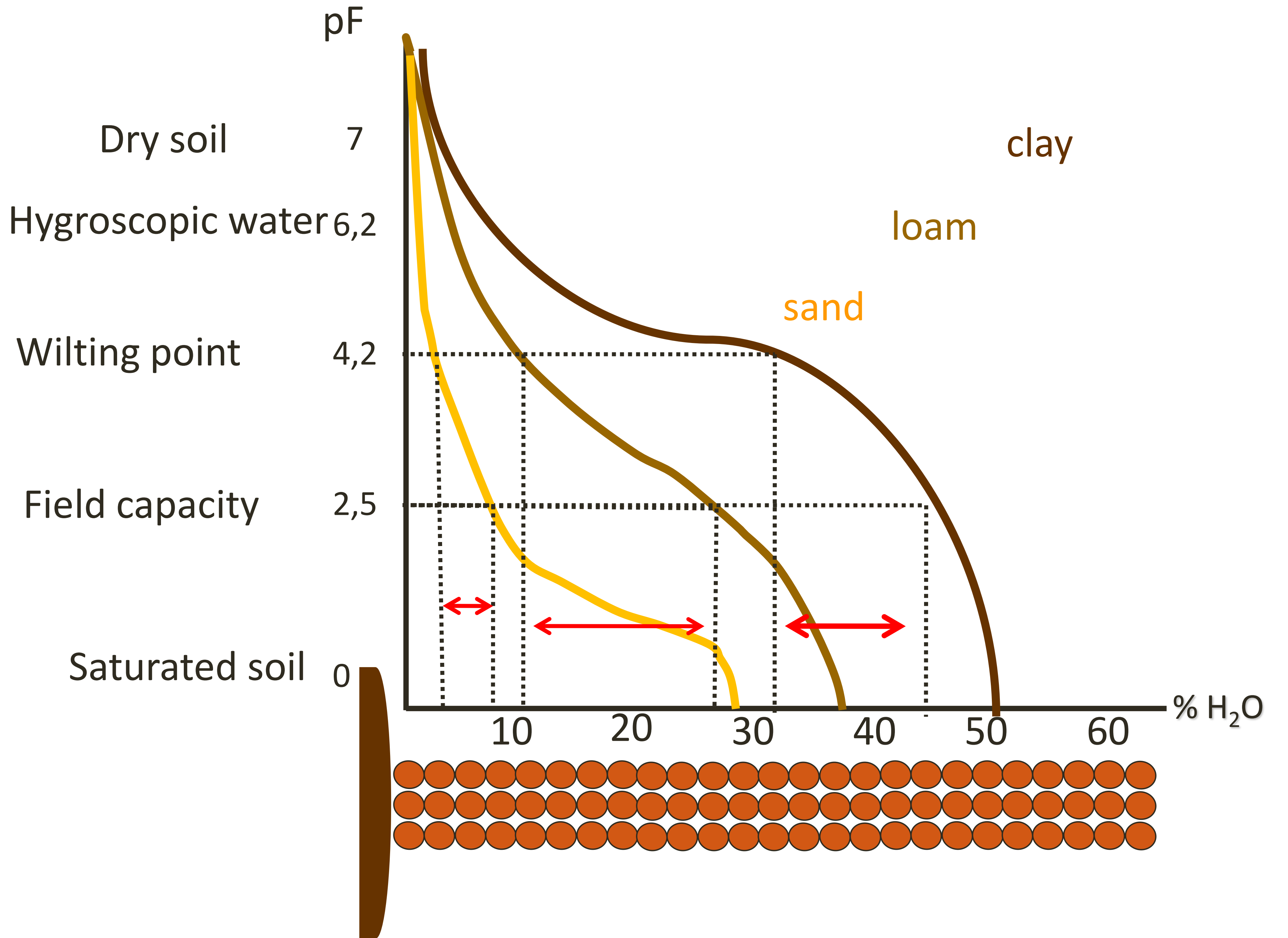
10000 cm water column = pF 4

100000 cm water column = pF 5

1000000 cm water column = pF 6

10000000 cm water column **= pF 7 („absolute" dry soil)**


pF
Dry soil
7
Hygroscopic water
6,2
Wilting point, Hv
4,2
Field capacity, Vk
2,5
Saturated soil
0
Disponible water
35 – 15 = 20 %
% H_2O
10
20
30
40
50
60


pF
Dry soil
7
Hygroscopic water
6,2
Wilting point
4,2
Field capacity
2,5
Saturated soil
0
clay
loam
sand
10
20
30
40
50
60
% H_2O

Practical Applications of the pF Curve

1. **Characterizing soil moisture energy status**
   Describes how strongly water is held in the soil (e.g., wilting point, available water).
2. **General assessment of soil physical and water retention properties**
   Helps determine how the soil absorbs, stores, and releases water.
3. **Characterization of soil pore system**
   The shape of the curve reveals information about pore size distribution.
4. **Monitoring changes in soil structure and water management properties**
   Detects changes due to compaction, tillage, degradation, or improvement.
5. **Planning irrigation timing and frequency, and determining optimal water amounts**
   Supports precise irrigation scheduling based on plant-available water.
6. **Drainage system planning**
   Assists in designing systems that remove excess water effectively.
7. **Further calculations and evaluations of soil water management properties**
   Inputs for hydrological modeling, soil classification, and land evaluation.