# PLANT – SOIL – WATER

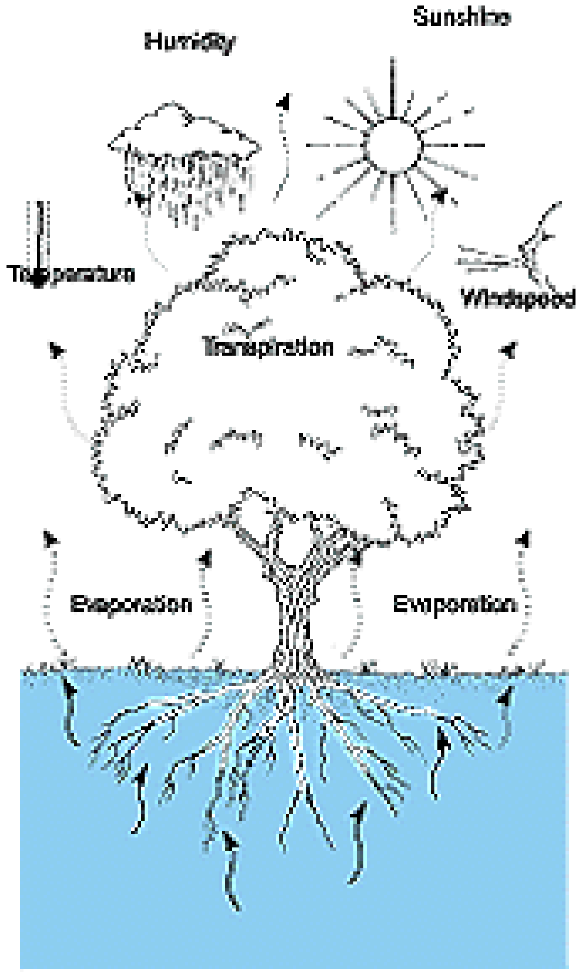
# WATER MANAGEMENT

# The role of water for plants
## general life conditions

- cellular component: 80-85% of protoplasm;
- solvent and carrier material when nutrient uptake;
- it is of basical importance for thermoregulation of plants, due to its high specific heat (evaporation needs high energy);
- a raw material for photosynthesis;
- a reaction medium for biochemical processes;
- it maintains turgor pressure;

# Water budget of the plant

- water uptake – root hairs;
- delivery of water – water potential;
- water release – transpiration;
- rainfall – irrigation;

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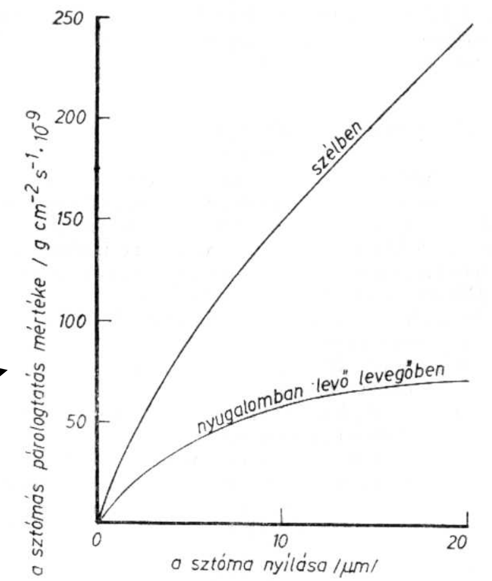
# Water release – transpiration – environment

- water;
- solar radiation;
- temperature;
- air humidity –

  see: water potential!
- wind;
- biological characteristics;

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# Classification of plants according to production areas

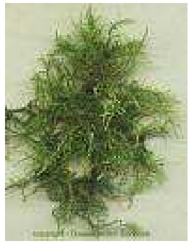
**regulator:**

- hydrofits;

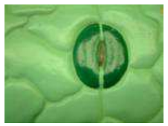
air hum.!

- hygrofits;

air humidity!



- mezofits – temperate belt;



- xerofits;

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# Xerofit plants

## dry production area - protection

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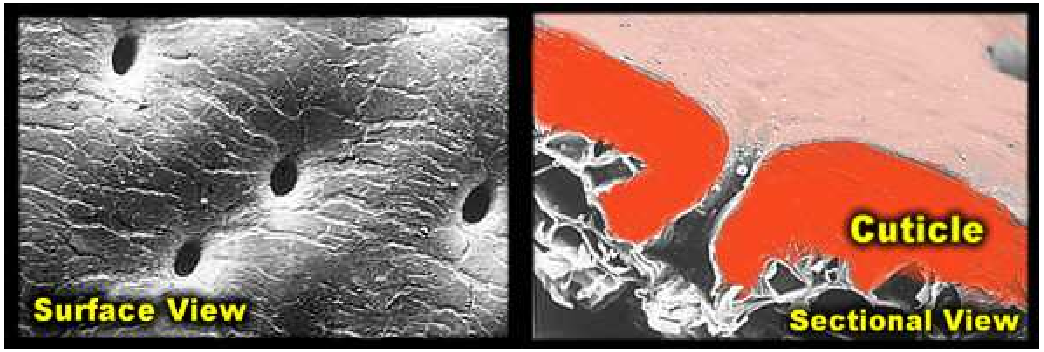
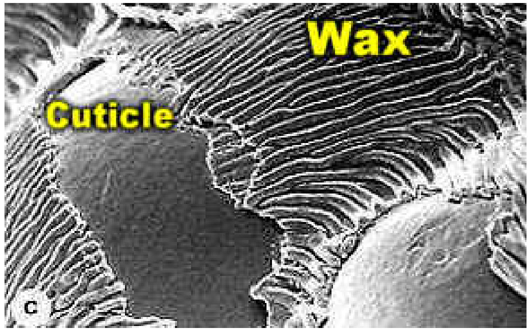
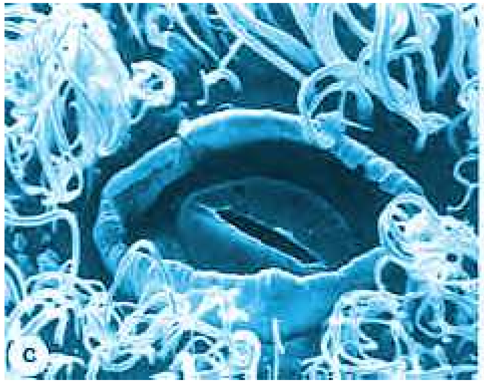



wax

# Evaporation

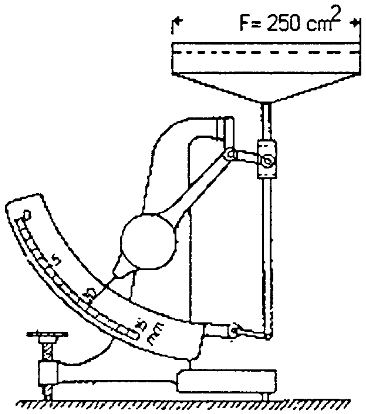
**Types of evaporation:**

- ***evaporation*:** evaporation of fre water surface; furthermore, evaporation of snow, ice and bare soil;
- ***transpiration*:** transpiration of plants;
- ***evapotranspiration*:** joint transpiration of plants and soil;

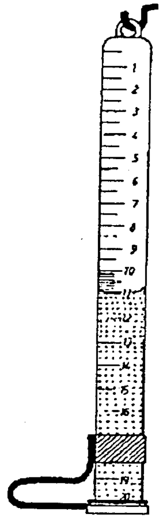
# Evaporation of water surfaces

- In case of evaporation of water surfaces, actual evaporation ($E_t$) corresponds to the potential evaporation ($E_{pot}$): $E_t = E_{pot}$;
- Evaporation of water surfaces are measured by **evaporation bath**.
- Determination of evaporation of water surfaces may happen:
  - directly, by measurements;
  - indirectly, by calculations (e.g. (Meyer's formula).

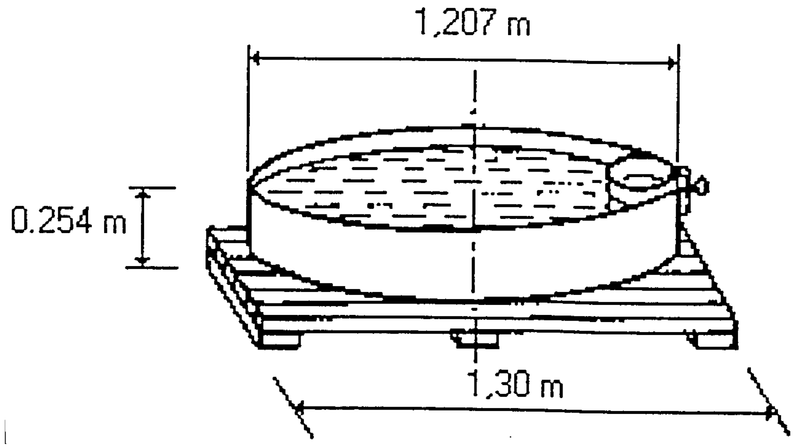
# Measurement of evaporation of water surfaces (evaporimeters)




Wild's instrument



Piche's instrument




„A" type evaporation bath

# Calculation of evaporation of water surfcaes

## Meyer's formula:

$$P = a \cdot \left[ E(t') - e \right] \cdot \left( 1 + b \cdot w \right)$$

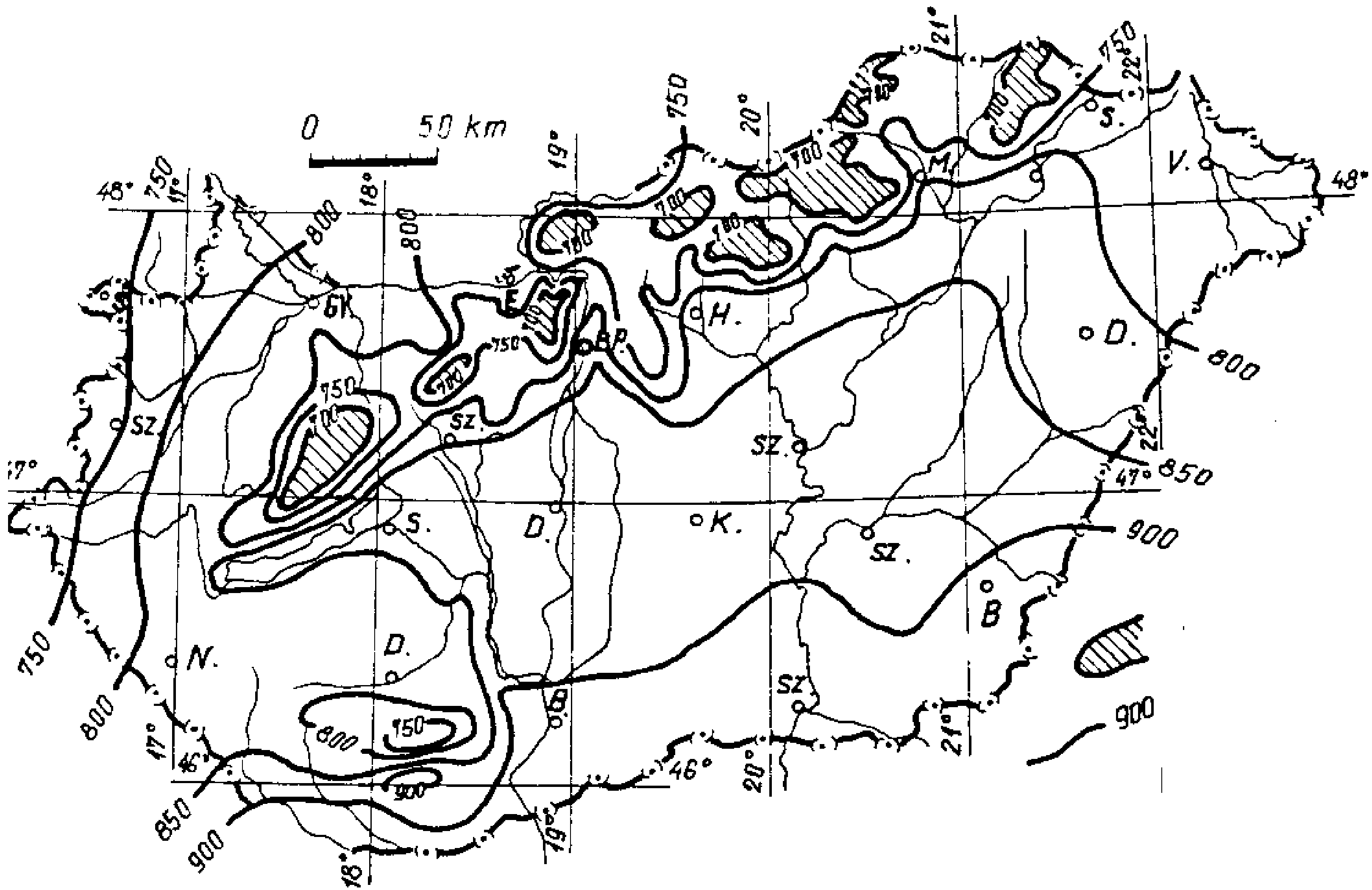
P = the sum of the monthly actual evaporation (mm/month);
E = water temperature - dependent saturation vapor presure of the air layer immediately above the water surface ($g/m^3$);
e = actual air humidity ($g/m^3$);
w = mean monthyl wind speed (m/s);
a, b = constants (their values under climatic and geographical conditions of Hungary are 11 and 0,2 , respectively);

## Aerodynamical method:

$$P = N \cdot \left[ E(t') - e \right] \cdot w$$

N = factor number depending on the given month

# Several-year averages of the evaporation of free water surface in Hungary



# Evaporation of soils

- Evaporation of soils is evaporation of water of soil-bound and free water in the soil.
- Evaporation of soils is less intense, than that of free water surfaces.
- Desiccation of soils decreases the intensity of the evaporation of soils.
- In bound soils – a significant portion of soil moisture is bound to the soil particles with great force. The intensity of evaporation and thus drying out of the soil are slower and less consistent than in loose sandy soils.
- During cultivation, the near-surface dusty layer acts as an insulator and prevents the soils from drying out (the significance of stubble).
- In hollow, cracked soils, due to the improved air exchange, the intensity of the evaporation is greater.

Evaporation of a soil

# Evapotranspiration 1

## Evaporation of the soil and plant

Transpiration can be featured by the following metrics:

- ***transpiration coefficient:*** *is the water amount, which is necessary for producing* 1 kg dry matter (litre/kg);
- ***intensity of the transpiration:*** *is the water amount, which evaporated from unit leaf surface during unit time* ($g/m^2/day$);
- ***productivity of the transpiration:*** *is the amount of dry material that is produced when* 1 kg water evaporated (g/kg);

# Transpiration

- **transpiration:** evaporation of individual plants;
- The plant is able to control the size of stoma $\Rightarrow$ transpiration is not only physical but physiological process, as well. This is why we speak about evaporation.
- The opening and closing of stomata are regulated by the turgidity.

# Evapotranspiration 2

Types of evapotranspiration that are characteristic for the soil – plant system:

- potencial evapotranspiratino and
- actual evapotranspiration

*Potential evapotranspiration is the* maximum evaporation, when

- the amount of the radiation energy provided by the solar energy is used entirely to the evaporation;

There are several methods to calculate potential evapotransiration. Three of them are highlighted here: (1) Thornthwaite's method, **(2) Antal's method,** (3) radiation method;

# Antal's method (1968)

- Weather

(potential evapotranspiration)

$$PET = 0,9(E - e)^{0,7}(1 + \alpha t)^{4,8}$$

E–e: daily mean value of the vapour pressure deficit (mb);

t: daily mean temperature (°C);

$\alpha$ = 1/273 thermal expansion coefficient of the air;

**Makra, L.,** Kiss, Á., Palotás, J., 1985: The Spatial and Temporal Variability of Drought in the Southern Part of the Great Hungarian Plain. *Acta Climatologica Universitatis Szegediensis*, 18-20(1-4), 65-85.

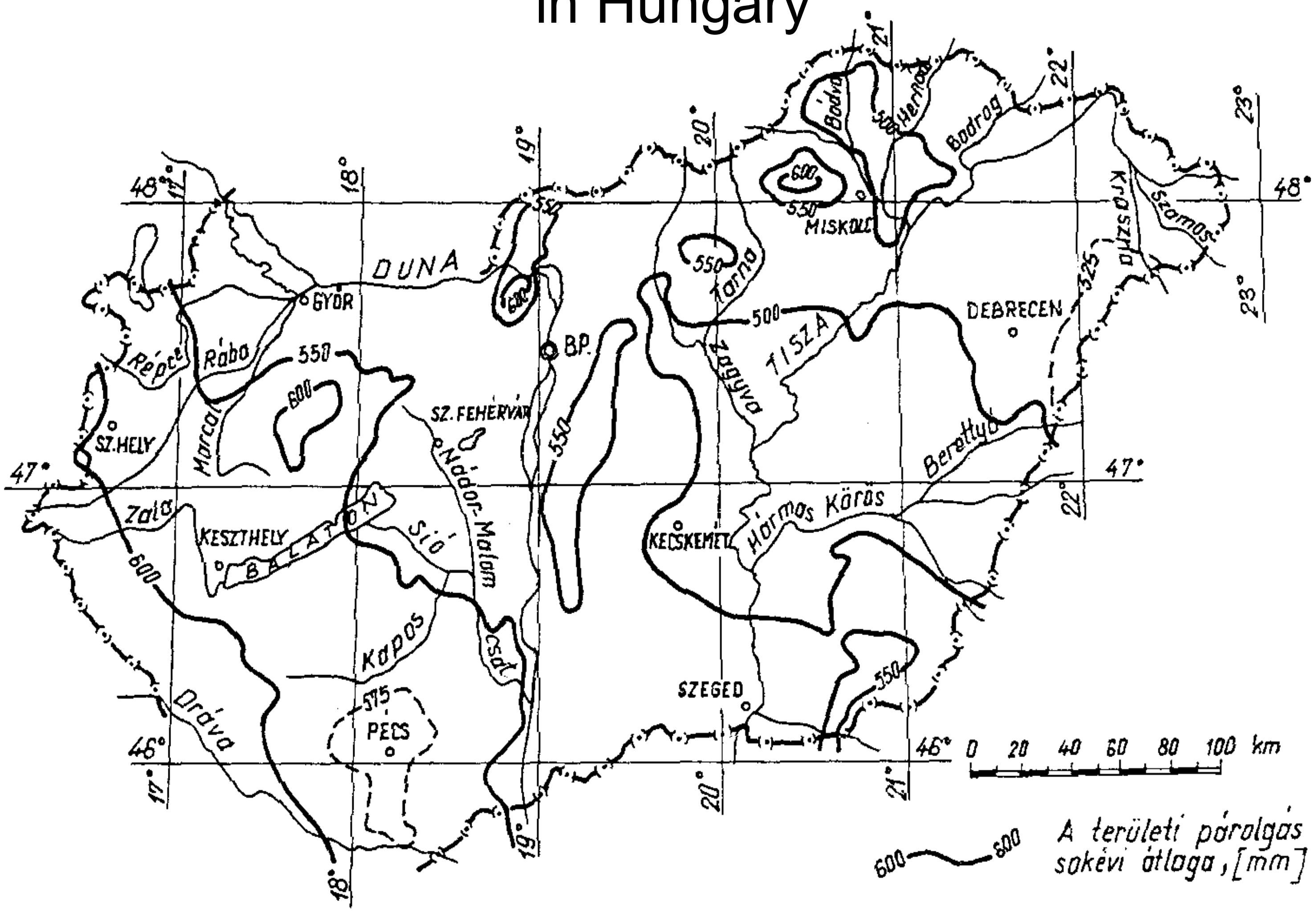
Abonyiné Palotás, J., **Makra, L.,** Kiss, Á., 1985: Aszály a dél-alföldi megyékben. (Drought in the counties of Southern Hungary.) *Gazdálkodás*, 29(5), 41-46. (in Hungarian)

**Makra, L.,** Kiss, Á., Abonyiné Palotás, J., 1985: Aszály a Dél-Alföldön és néhány fontos növény terméseredményei. (Drought in the southern part of Alföld (Great Plain) and the crop yield of some important plants.) *Légkör*, 30(2), 25-29. (in Hungarian)

**Makra, L.,** Kiss, Á., Abonyiné Palotás, J., 1986: Az aszály klimatológiai és talajvízháztartási összetevői a Dél-Alföldön. [Climatological and soil water balance components of drought in in the southern part of Alföld (Great Plain), with agricultural aspects.] *Alföldi Tanulmányok*, 10, 99-114. (in Hungarian)

# Actual evapotranspiration ($E_t$)

Several-year averages of the areal evapotranspiration in Hungary



# Calculation of the actual areal evapotranspiration ($E_t$)

***Turc's method*: it is assessed on the base of the annual precipitation total (C) and the annual mean temperature (T):

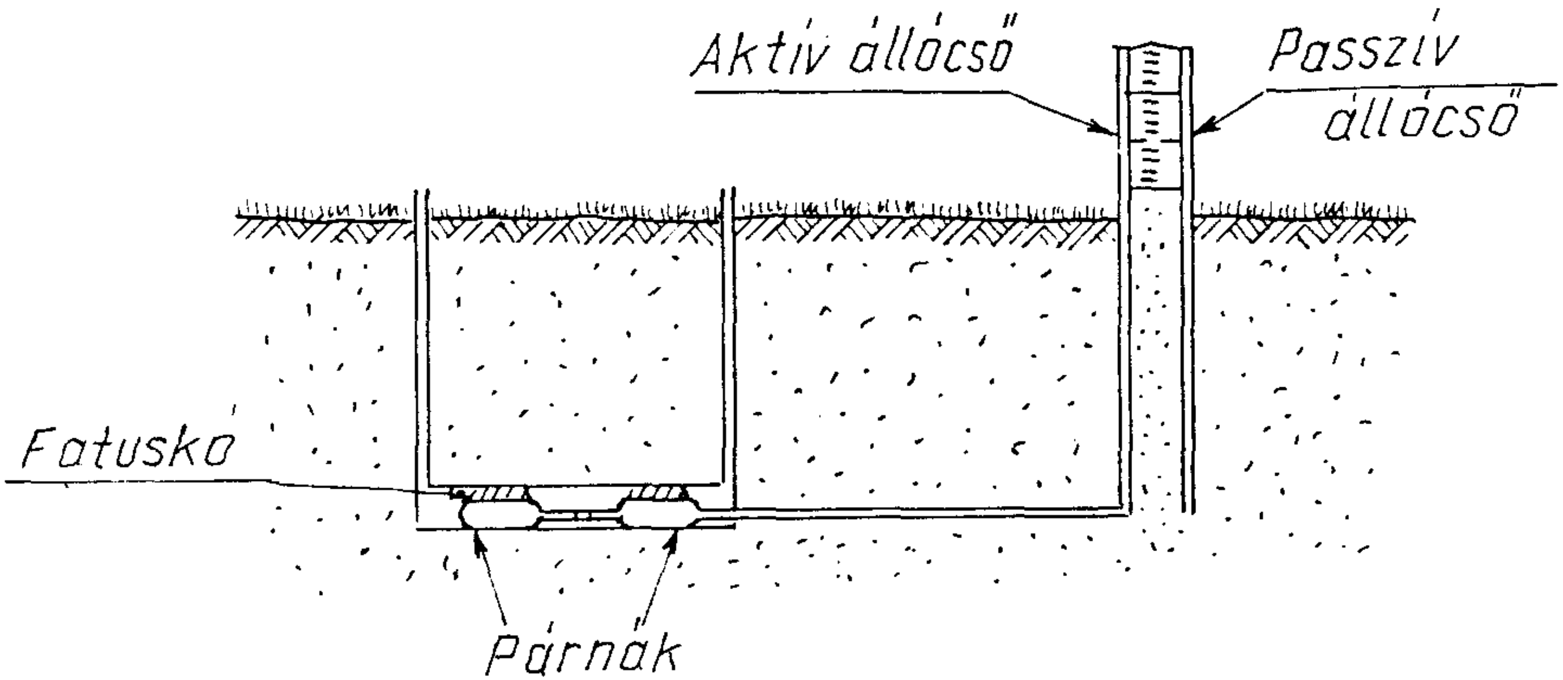
$$E_T = \frac{C}{\sqrt{0,9 + \frac{C^2}{L^2}}}$$

$$L = 300 + 25T + 0,05T^3$$

# Evapotranspiration 3

Calcualtions of the areal evapotranspiration:

by using lisimeter



# Evapotranspiration 4

## Evapotranspiration in Hungary

Annual values of potential evapotranspiration (PET) in Hungary are between 600 and 720 mm.

A major part of the annual amount of the potential evapotranspiration occurs in the summer half-year (550-600 mm)

# Evapotranspiration 5

For calculating actual evapotranspiration – besides actual evaporation - plant characteristics and soil moisture content (accessibility) should also be considered.

Evapotranspiration of water catchment areas can be calculated iniderctly, using land-water balance equation of the area:

$$C = P + F\ ^{*}$$

**where C = precipitation;**
**P = evapotranspiration;**
**F = runoff;**

***** The method can only be applied for several-year data sets and such natural catchment areas for which the topographical and geogaphical catchment areas coincide. Namely, in this case it can be assumed that the average amount of incoming waters is identical with the average amount of precipitation fallen to the catchment area. At the same time, the average amount of outgoing waters is identical with the sum of the average water discharge of the river leaving the area and the average evapotranspiration.

# Relationship between the heat- and water balance

**Aridity index**: H (dimensionless);

$P_p$ ($kg \cdot m^{-2}$): potential evapotranspiratioin;

S ($J \cdot m^{-2}$): radiation balance;

L ($m^2 \cdot s^{-2}$): evaporation heat;

$$H = \frac{P_p}{L} = \frac{E_s / L}{C} = \frac{E_s}{L\,C}$$

L: latent heat;
$E_s$: net radiation balance;
C: precipitation amount;

**Meaning:**

H › 1 **arid** (dry);

H ‹ 1 **humid** (wet) area;

Thne ratio of the annual sums of actual evapotranspiration and ($E_t$) and precipitation amount (C) is a function of H, namely

$$H = f\,(E_t, C)$$

The exact formula of the above relationship is as follows:

$$\frac{P}{C} = 1 - e^{-H}$$

From here the actual evapotranspiration:

$$P = C(1 - e^{-H})$$

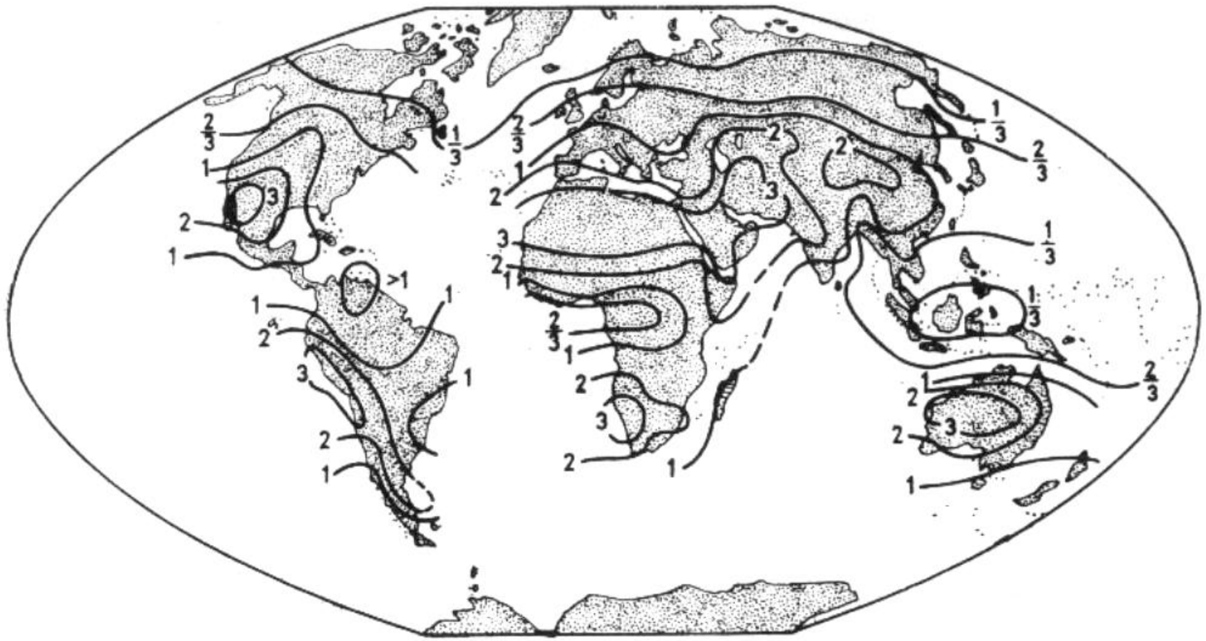
The runoff coefficient (F/C) can be calculated from the above equations. Since C=F+P, thus:

$$\frac{F}{C} = e^{-H}$$

The above formulae can be used when **when analyzing water balance of large regions**.

# The relationship of the aridity index with the plant geographical belts

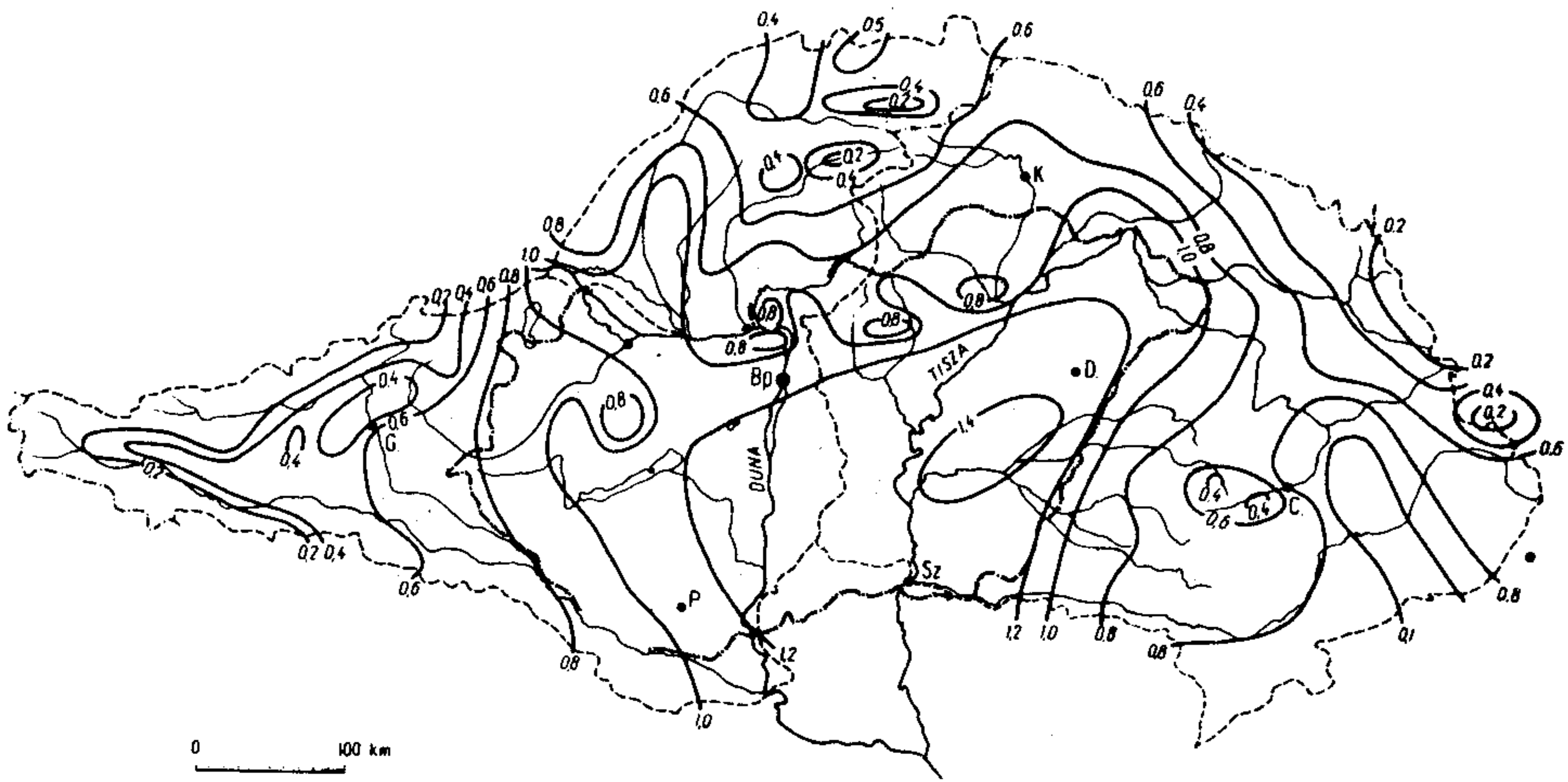
| $H$ | plant geographical belt |
|---|---|
| $< 1/3$ | tundra |
| $1/3 - 1$ | forest |
| $1 - 2$ | grassland (steppe, prairie |
| $2 - 3$ | semidesert |
| $> 3$ | desert |




Global distribution of the aridity index

# Evapotranspiration 6

Mean values of the aridity index, Carpathian-Basin



# Some values of the aridity index in Hungary

| | |
|---|---|
| • Szentgotthárd | 0,84 |
| • Zirc | 0,96 |
| • Pécs | 1,06 |
| • Homokszentgyörgy | 0,88 |
| • Mosonmagyaróvár | 1,18 |
| • Kecskemét | 1,49 |
| • Mezőhegyes | 1,19 |
| • Kékestető | 0,82 |
| • Nyíregyháza | 1,10 |

# Aridity index, Hungary

# WATER RESOURCES – WATER BALANCE

- Renewable resource – available in limited amount.
- Water resources of the Earth: about 2 billion $km^3$.
- 2/3 of the area of the Earth is covered by sea.
- 99% of the land water resource on the Earth is groundwater.
- Static water resources → slowly renewed
- Dynamic water resources → quickly renewed

# Water quality

**Parameters**

- oxygen budget
- minerals
- special

**Quality categories**

- excellent
- good
- moderately contaminated
- contaminated
- heavily contaminated

# Characteristics of the water

## Physical

- colour, odour
- state
- density
- melting point
- freezing point
- boiling point
- etc.

## Chemical

- composition
- pH
- conductivity
- solvent

## Biological

- 60-90%
- 2,5-6 l
- essential

# Runoff

Surface; Near surface; Underground;

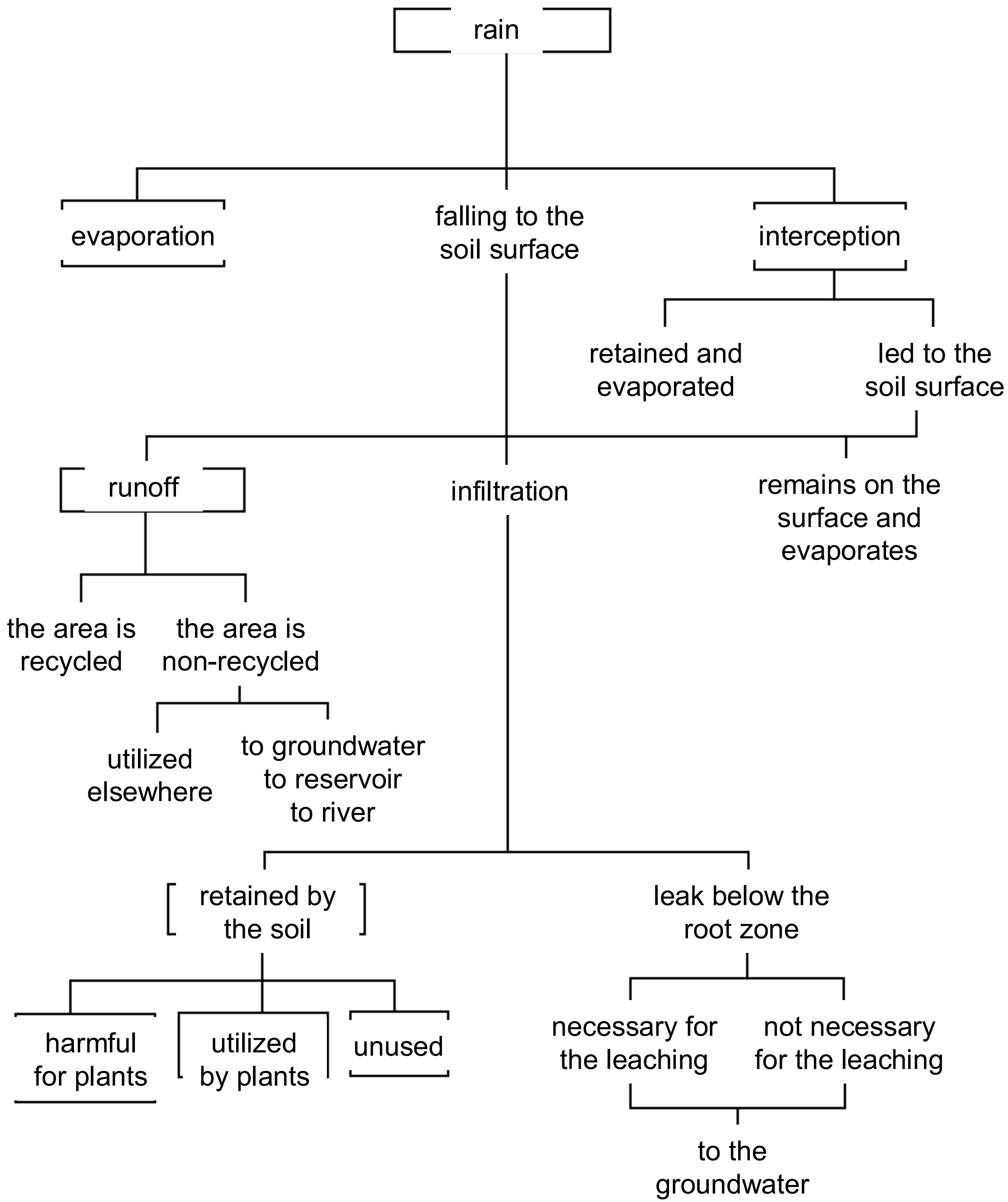
**It depends on the following factors:**

- water absorbing capacity of the soil;
- intensity of rainfall;
- the degree of inclination;
- the nature of the vegetation;
- temperature;

# Interception

**It is influenced by the following factors:**

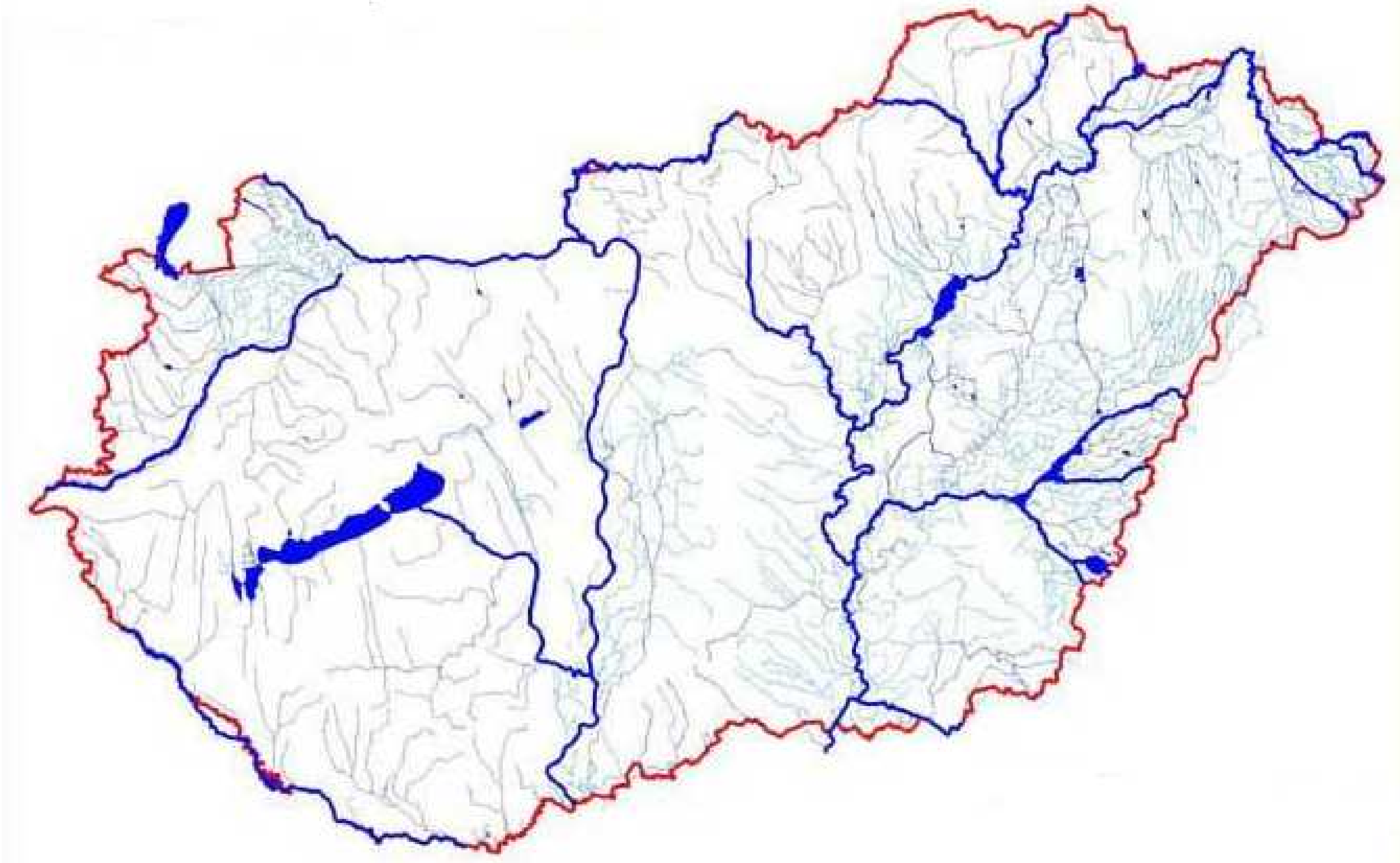
- species;
- plant coverage;
- phenophase;
- precipitation;
- wind;
- leaf temperature;
- LAI (leaf area index);


rain
evaporation
falling to the soil surface
interception
retained and evaporated
led to the soil surface
runoff
infiltration
remains on the surface and evaporates
the area is recycled
the area is non-recycled
utilized elsewhere
to groundwater
to reservoir
to river
retained by the soil
leak below the root zone
harmful for plants
utilized by plants
unused
necessary for the leaching
not necessary for the leaching
to the groundwater

# Surface waters

- Natural- or artificial waters;
- Still- or running waters;

# Surface waters of Hungary

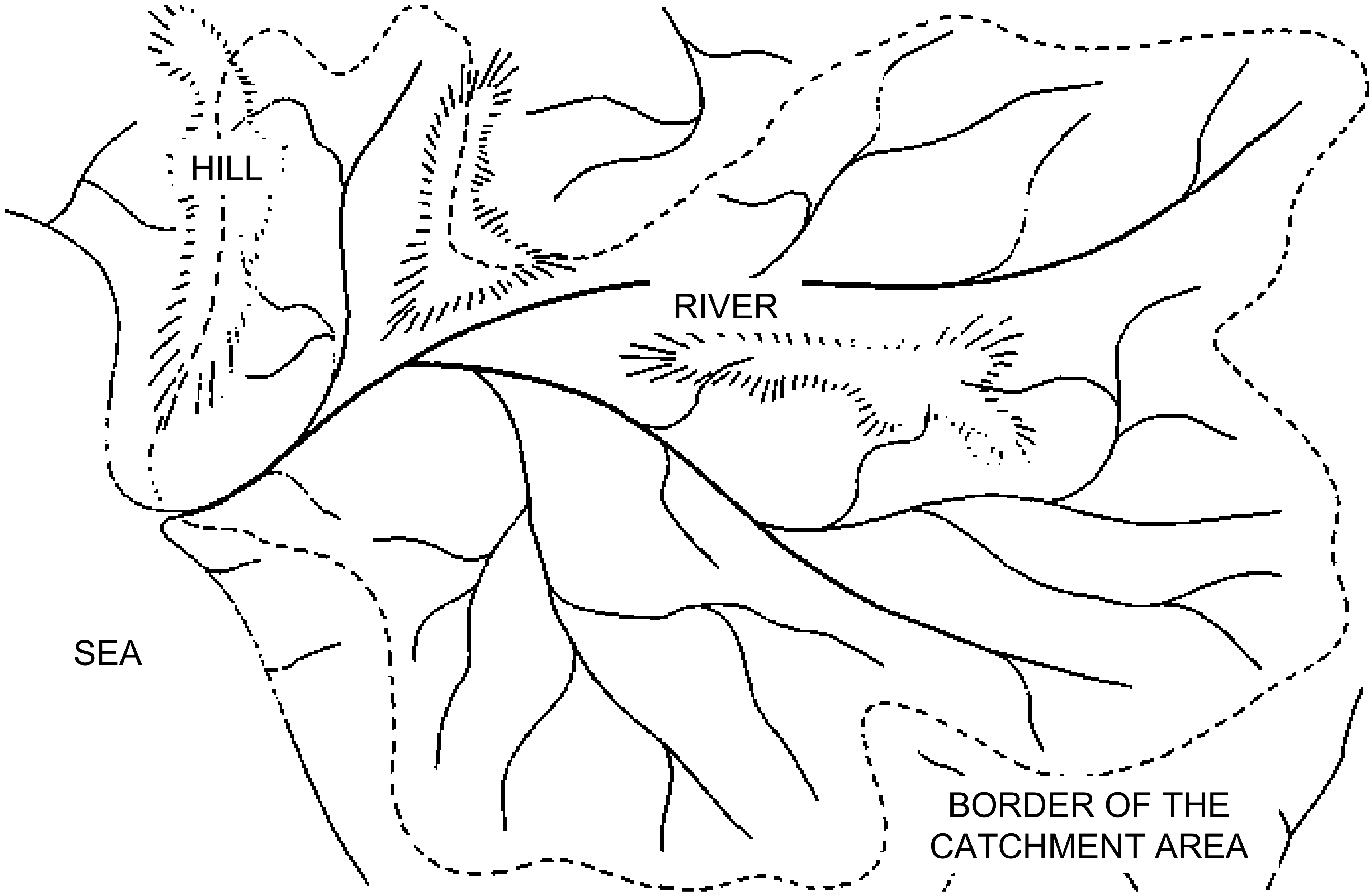


# Water flows

- Still: brooklet, creek, river, stream;
- Periodic: torrent (torda);

It is characterized by the size and length of the watercourse catchment area;

# Watercourse catchment area



# Still waters

- Origin: natural, artificial;
- Nutrient supply: eutrophic (nutrient-rich $\Rightarrow$ poor in species), oligotrophic (nutrient-poor $\Rightarrow$ species-rich) ;
- Water balance: with runoff, without runoff;
- Water supply: spring water, flow, end lake;
- Water temperature: cold, temperate, warm;

# Water balance of the soil

**Water capacity of the soil (VK):** means the maximum amount of water, whic is reatined / filled in by the soil under different circumstances. The amount of the water retained in the soil depends on the forces binding water to solid material.

***Maximum water capacity*:** means the water amount filling in the pores of the saturated soil completely;

***Minimum water capacity:*** it is determined so that the saturated soil is exposed to gravity, that is a part of the water is let to trickle out. What remains is the minimum water capacity.

***Field water capacity:*** means the water content of the soil wetted in the spring, which is characterized by greater than 10 μm pores filled in by air.

**Types of the water in the soil:**

- **bound water:** water is not available for plants. It may be chemically bound water (e.g. in minerals), or physically bound water (water that is strongly adherent to the surface, or loosely bound in the narrowest gaps in diameter less than 0.2 µm.

- **capillary water:** it is located in the capillaries in diameter 0.2-10 µm; permanently stored water available for plants, that solve  nutrients.

  - relying capillary water: it is supplied from groundwater;

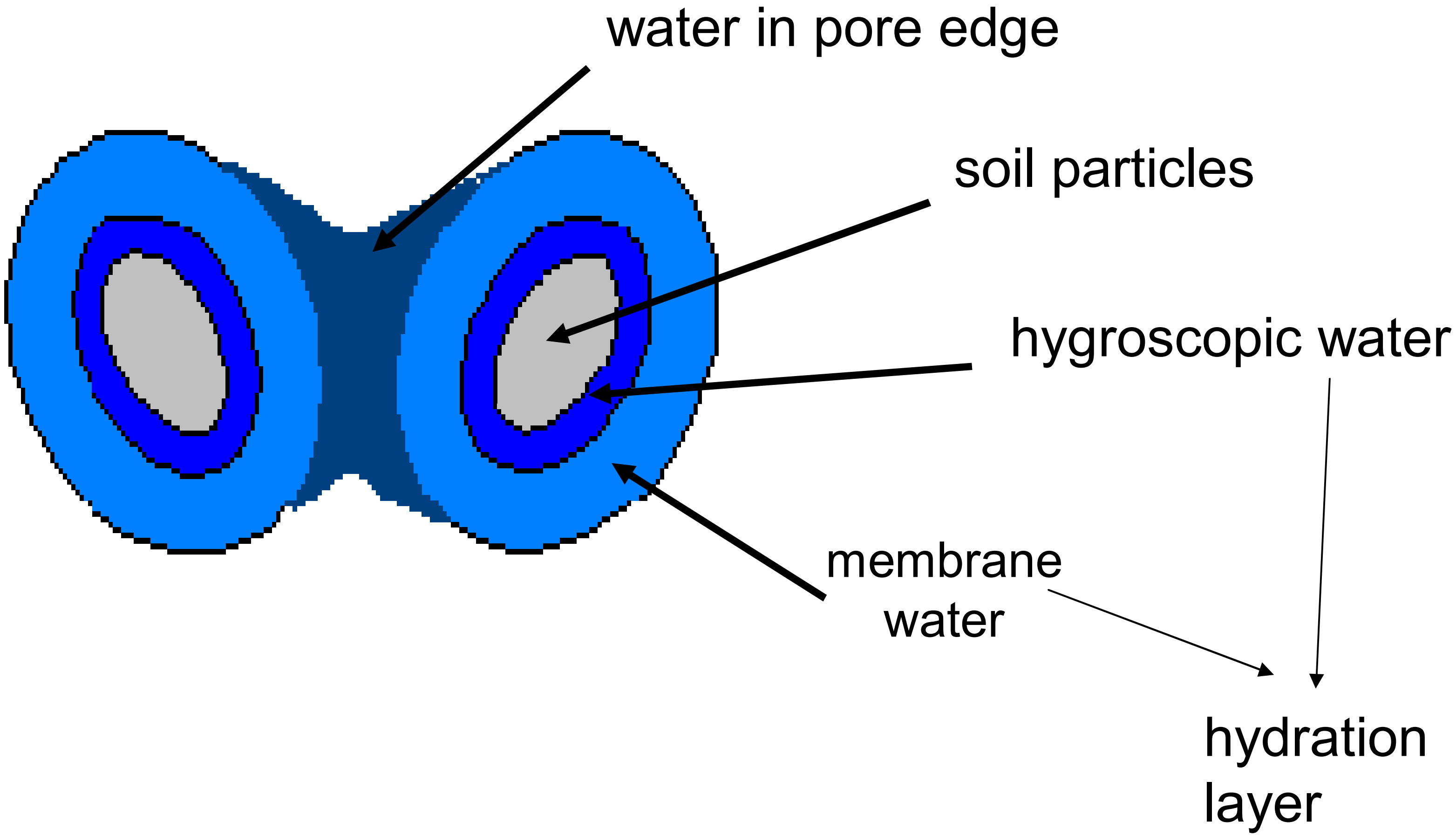
  - depending capillary water: it is supplied from infiltrated rain water;

  - isolated capillary water: temporary water content of the soil drying out;

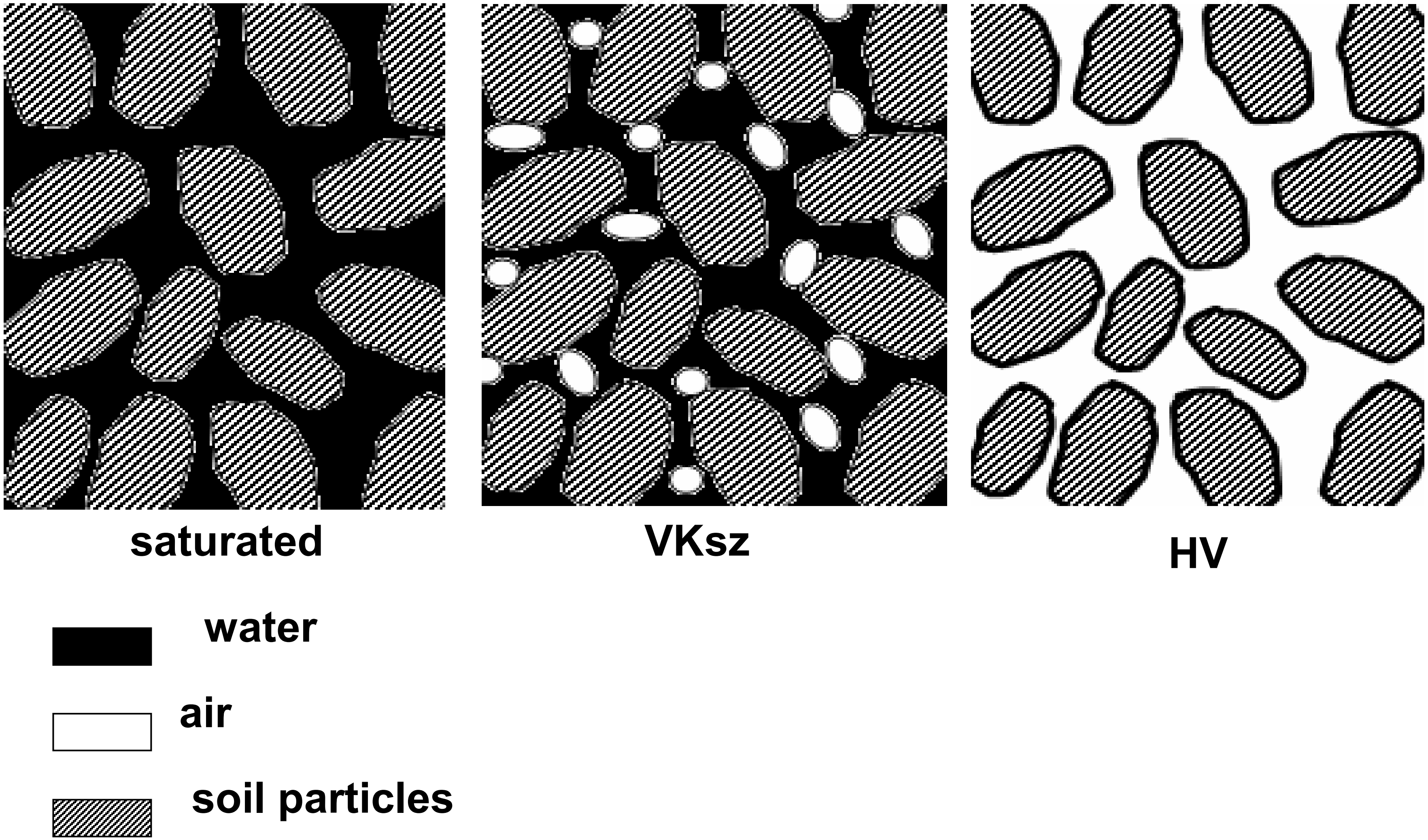
- **free water:** this fills in the larger pores after the saturation of the capillaries; it is not associated with the solid phase. Its feature is that, depending on the balance of the capillary forces and gravity, it migrates faster or slower towards the groundwater.

- **water vapour;**

# Bound water

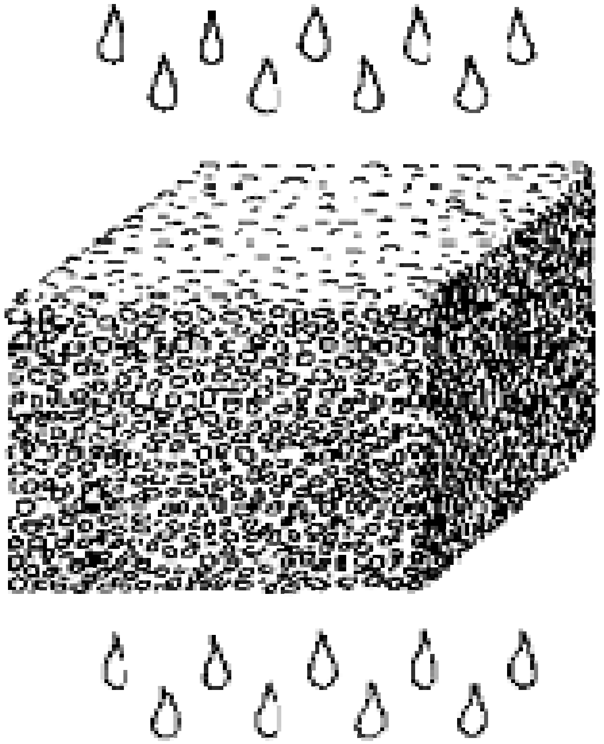

water in pore edge
soil particles
hygroscopic water
membrane water
hydration layer

# Pore volume and water capacity of the soil



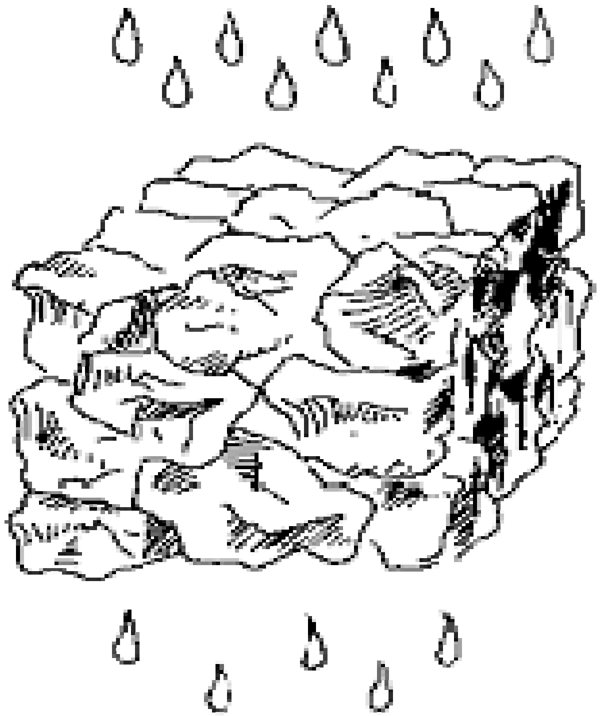
# The structure and water permeability of the soil

**crumbly**



**fast**

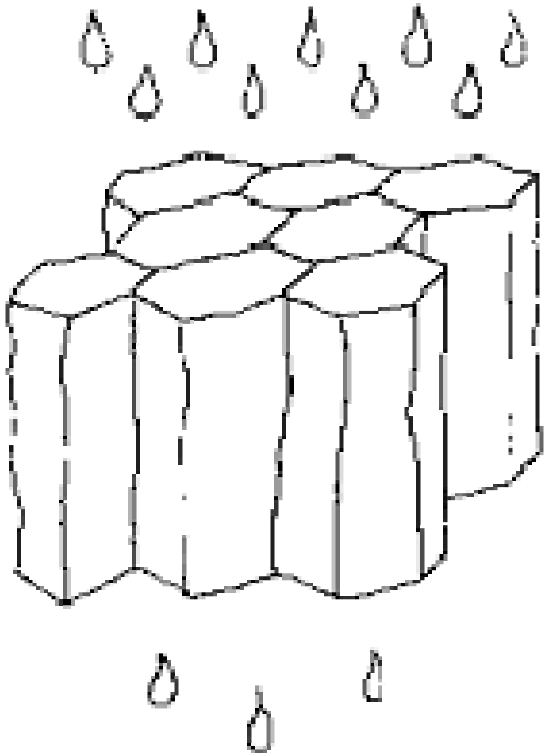
**rugged**

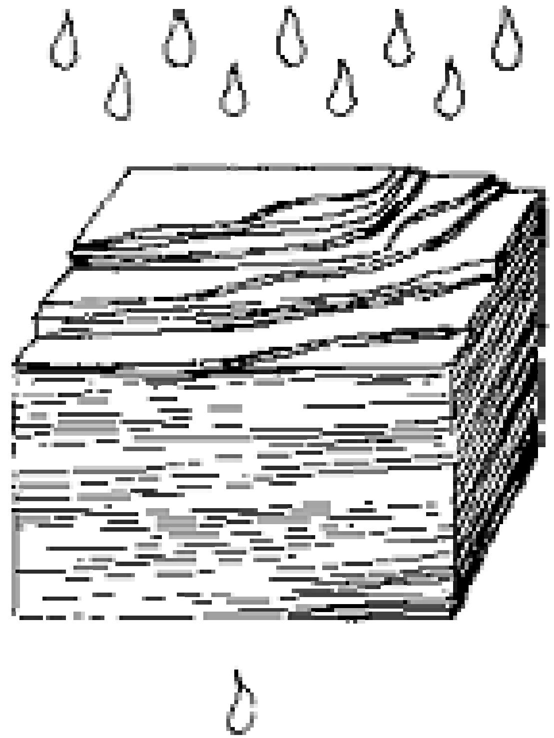


**moderate**

Source: FAO

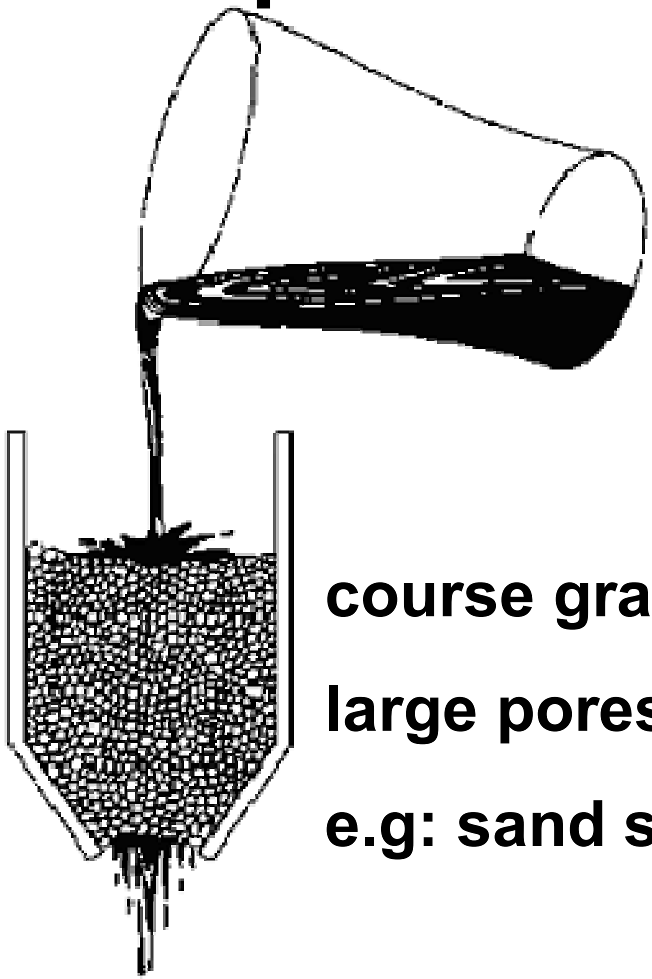
# The structure and water permeability of the soil




Forrás: FAO

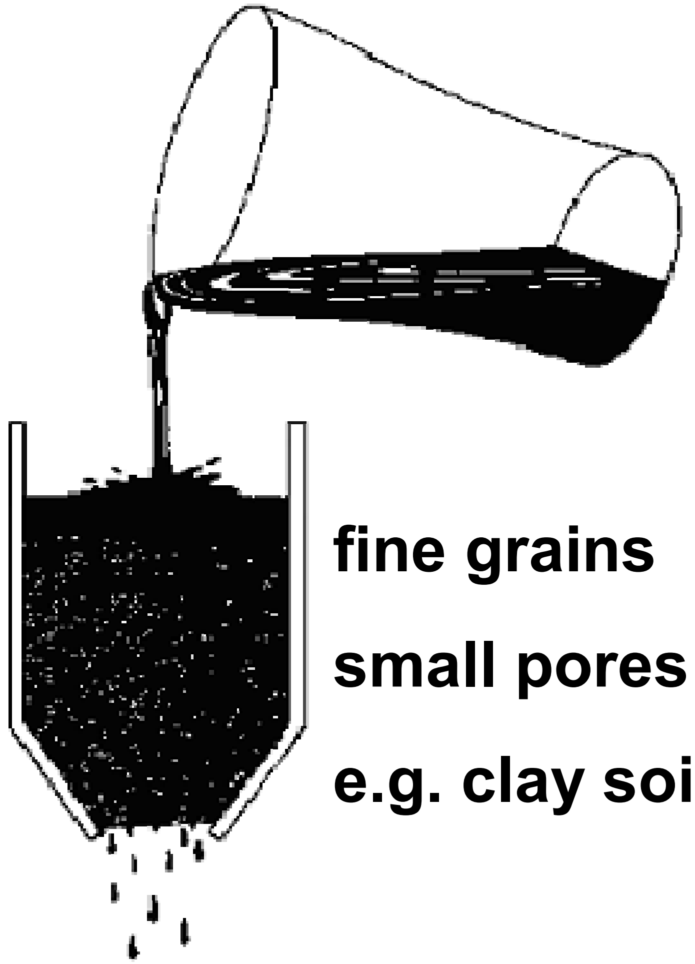
# The structure and water permeability of the soil



course grains

large pores

e.g: sand soil



fine grains

small pores

e.g. clay soils

Source: FAO

# Available (disponible) water (DV)

$$DV = VK - HV$$

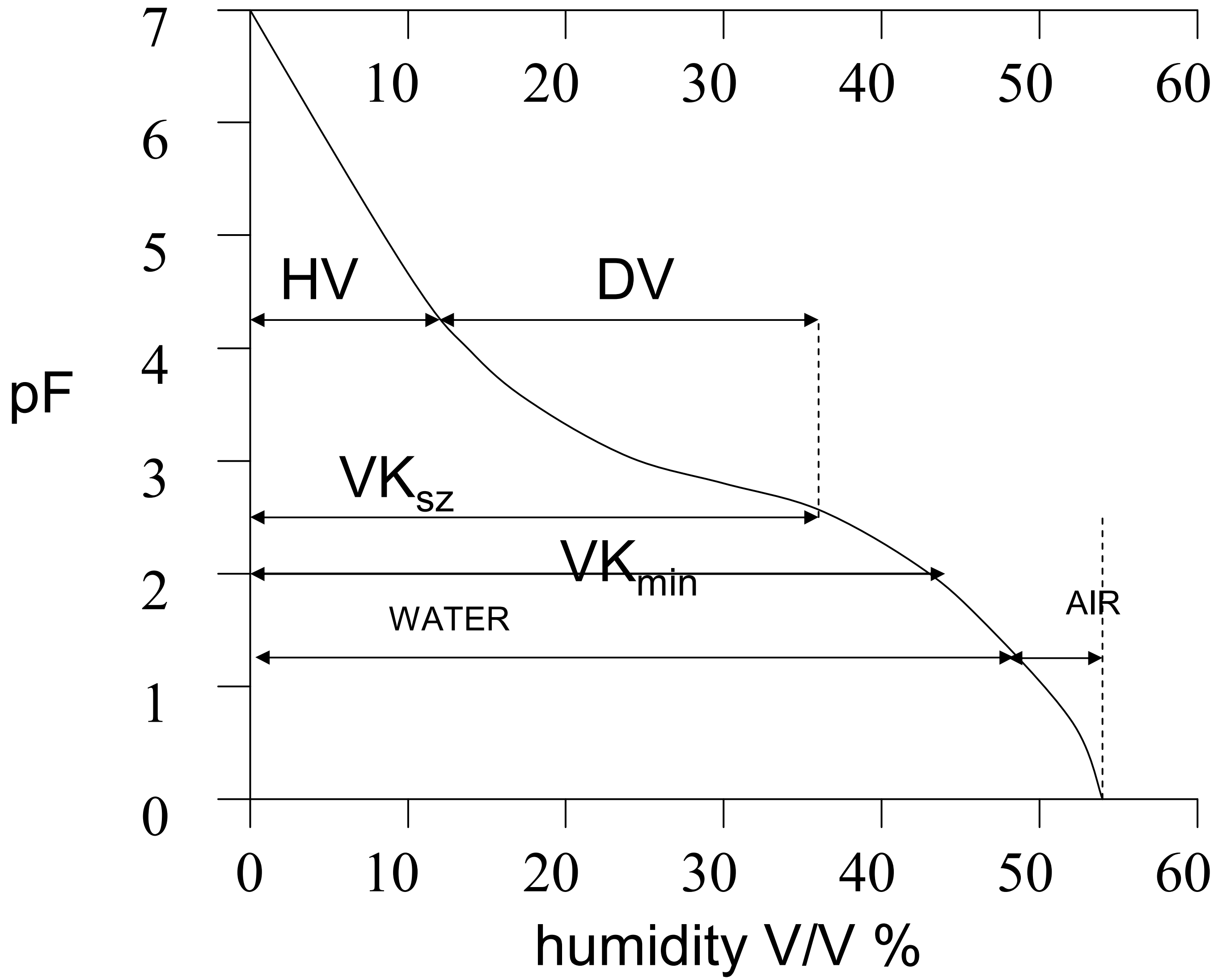
DV: disponible water (5-22 V/V%~40-150 mm/m)
VK: water capacity (15-45 V/V%)
HV: dead water (5-35 V/V%)

- Soil

(water supply capacity)

$$w = \frac{TV - HV}{VK - HV}$$

# pF-curve (water-holding capacity of the soil)



# Groundwater

- **According to pressure:** free surface, under pressure;
- **According to geometry:** water dome, floating, groundwater lake, groundwater stairs;
- **According to the hydrological regime:** oceanic, continental;
- **According to influences:** coming from rain or infiltration, medium-deep-, very deep-, normal depth types;

# Other groundwaters

- **Layer water:** rainwater getting into a water-bearing layer being between two impermeable layers;
- **Artesian water:** water accumulated below the surface being under pressure between impermeable layers;
- **Ásványvíz:** means such freshwater that comprises at least 500 mg/litre dissolved minerals;
- **Medicinal water:** those mineral waters and thermal waters that are of therapeutic effect due to their physical properties and/or chemical composition, and on the basis of their therapeutic effect and regulations of the country the nomination of medicinal water has been permitted;
- **Thermal water:** that layer water, temperature of which exceeds 30°C on the surface;
- **Karst water:** located between karstified rock layers;

# Factors affecting groundwater flow

## Natural factors

- water flows;
- lakes;
- forests;

## Artificial factors

- irrigation;
- swelling;
- underground drainage;

# EROSION

Harmful, destructive work of water:

Natural ⟷ Accelerated

Forms:

- surface (layer);
- In depth (linear);

# Surface (layer) erosion

**Little energy**

Forms:

- hidden: $VK_{max} \longrightarrow$ pulping;
- drop: crumb explosion;
- shroud: a few mm destruction;
- stemmed: until the cultivated layer, 30-70%;

# In depth (linear) erosion

**High energy**

Forms:

- fin;
- arch;
- hydraulic;

# The factors causing erosion

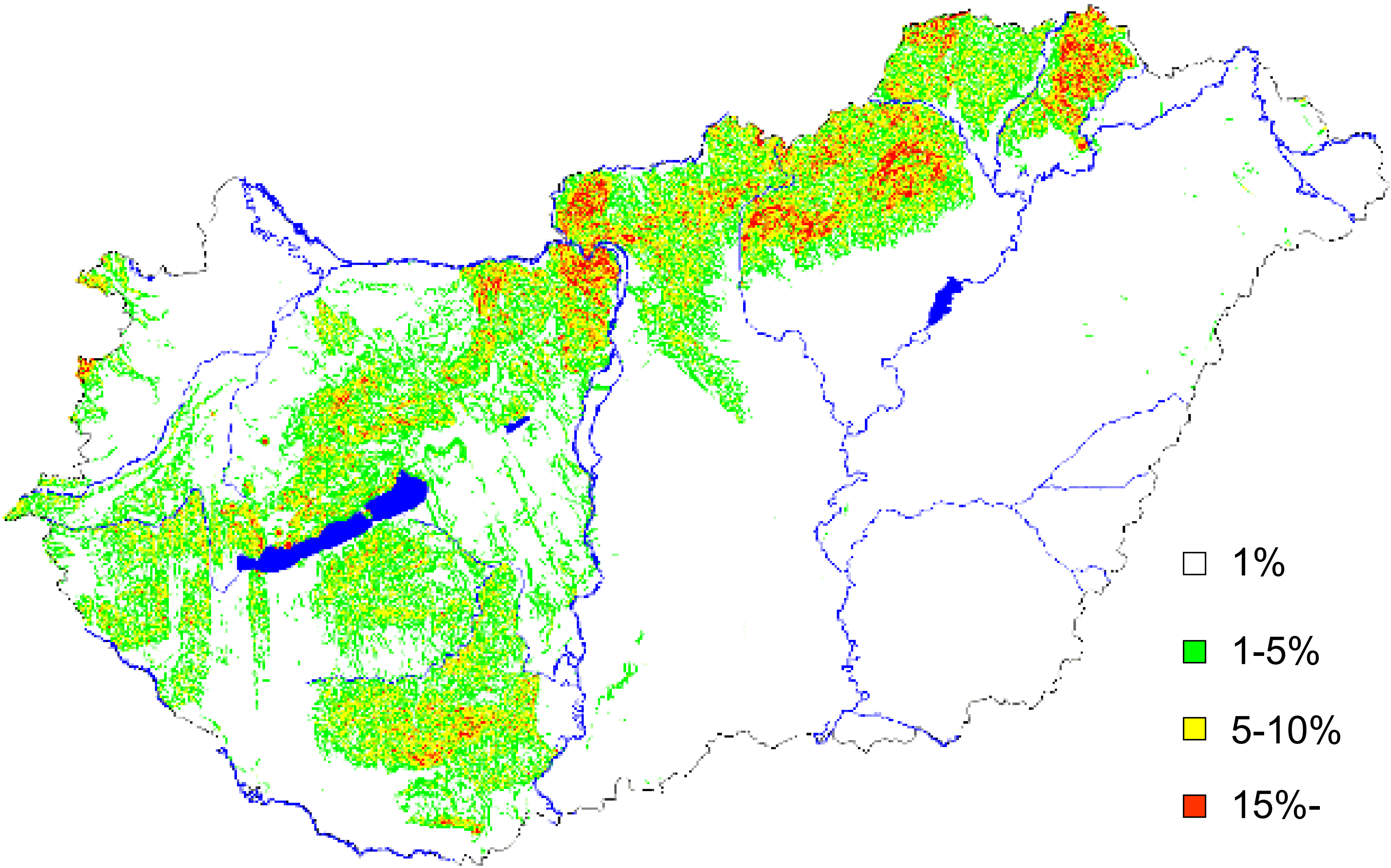
**Rainfall:**

- Volume, intensizty, duration, drop size, snow melt;

**Slope:**

- steepness, length, shape, position;

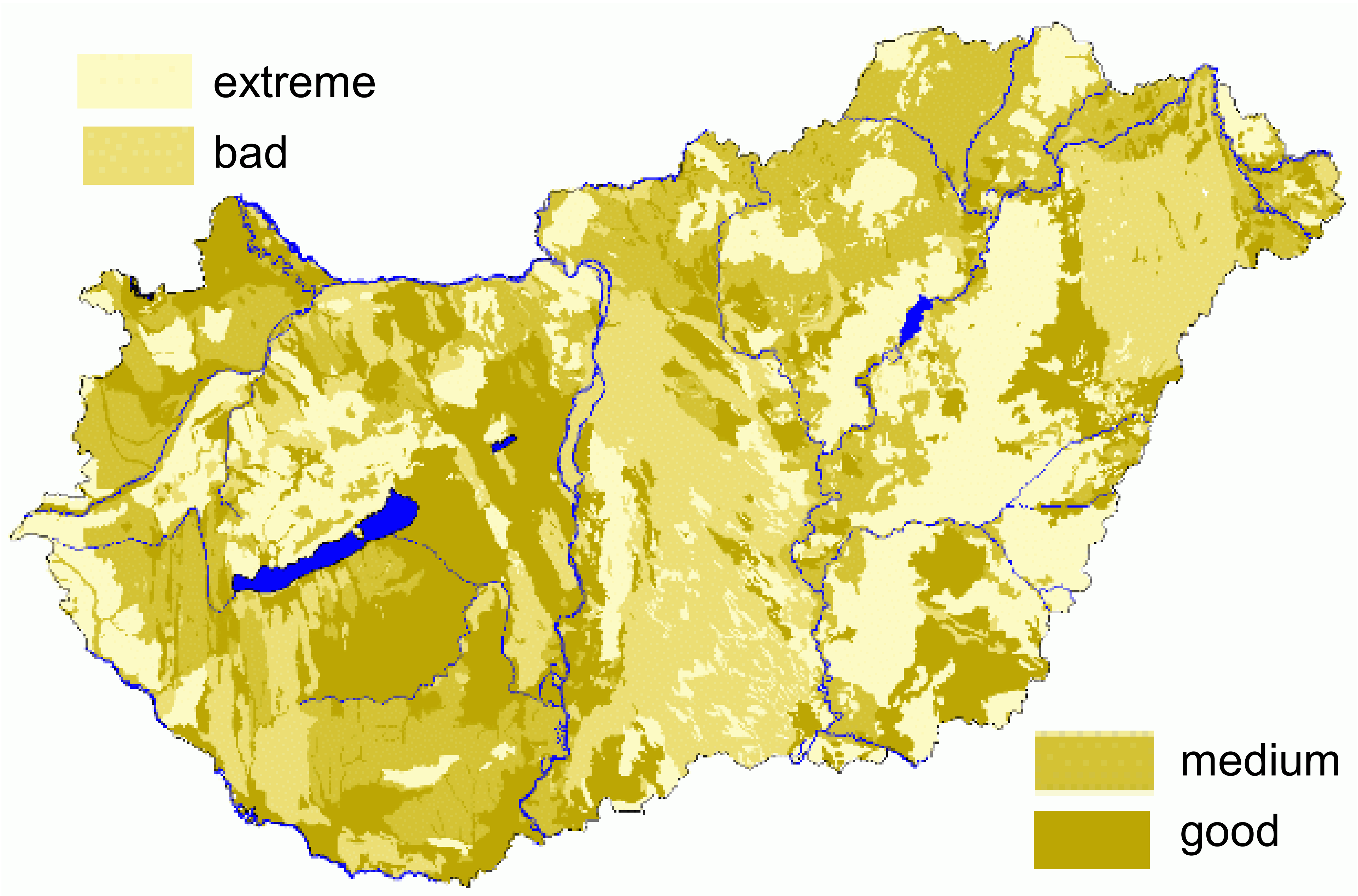
# Slope categories of Hungary



# Factors affecting erosion

- the moisture status of the soil;
- water management of the soil;
- structure of the soil;
- vegetation;
- character of cultivation;
- slope conditions;

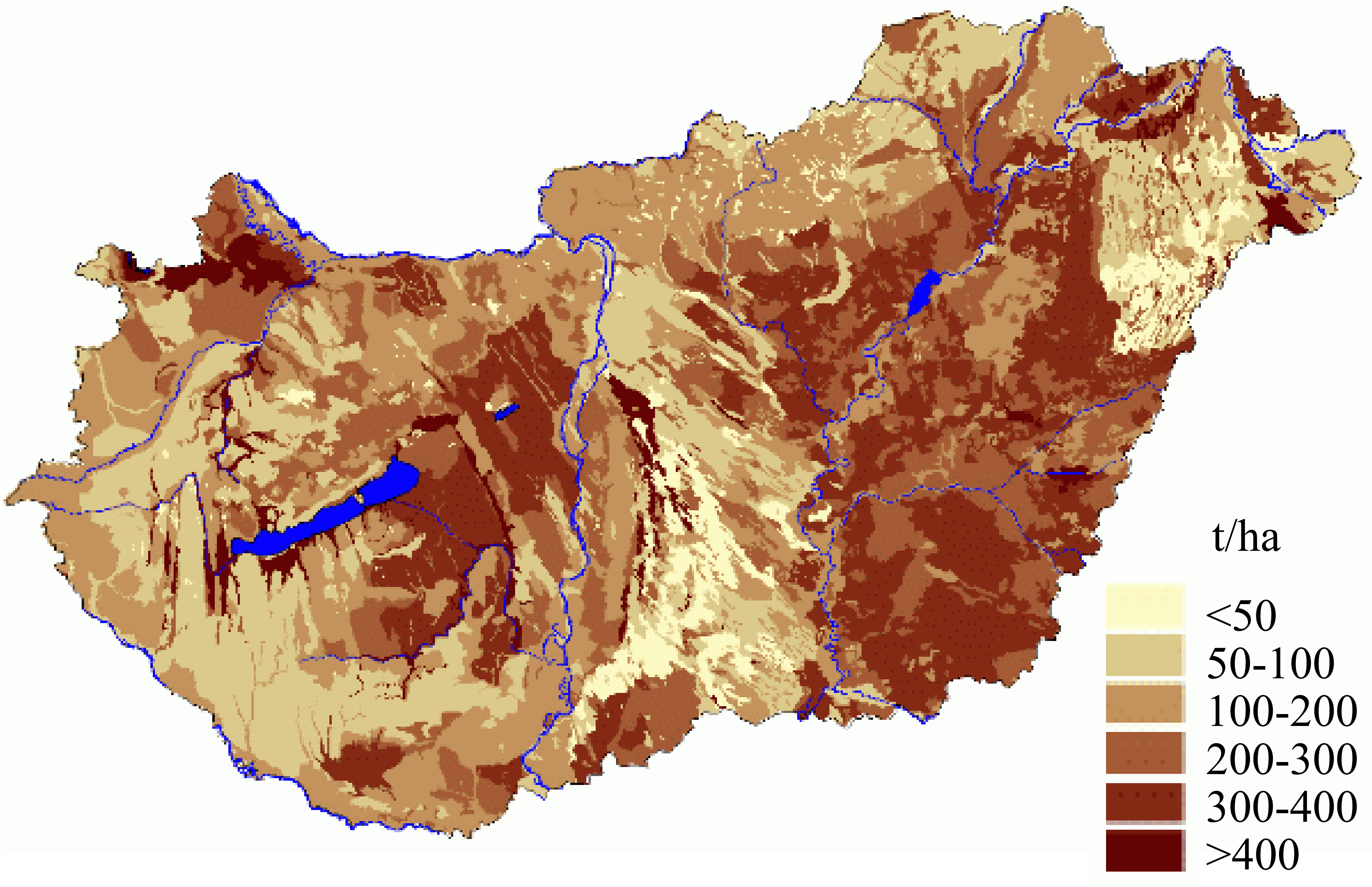
# Water management of the soils in Hungary



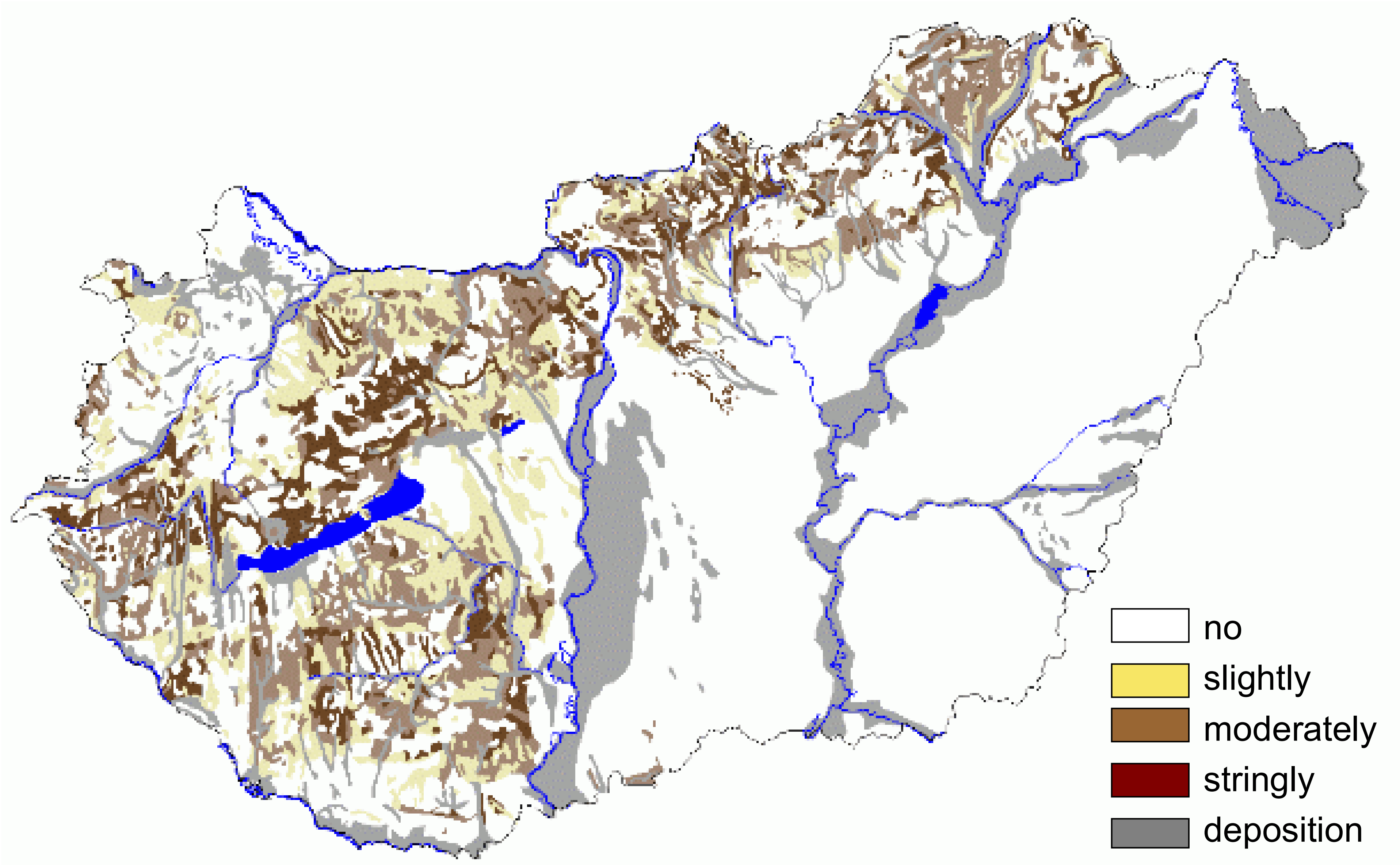
# Damages caused by erosion

- soil degradation;
- nutrient losses;
- water loss;
- yield loss (20-80%);

# Organic matter stock of the soil in Hungary



# Erosion rate of the soils in Hungary



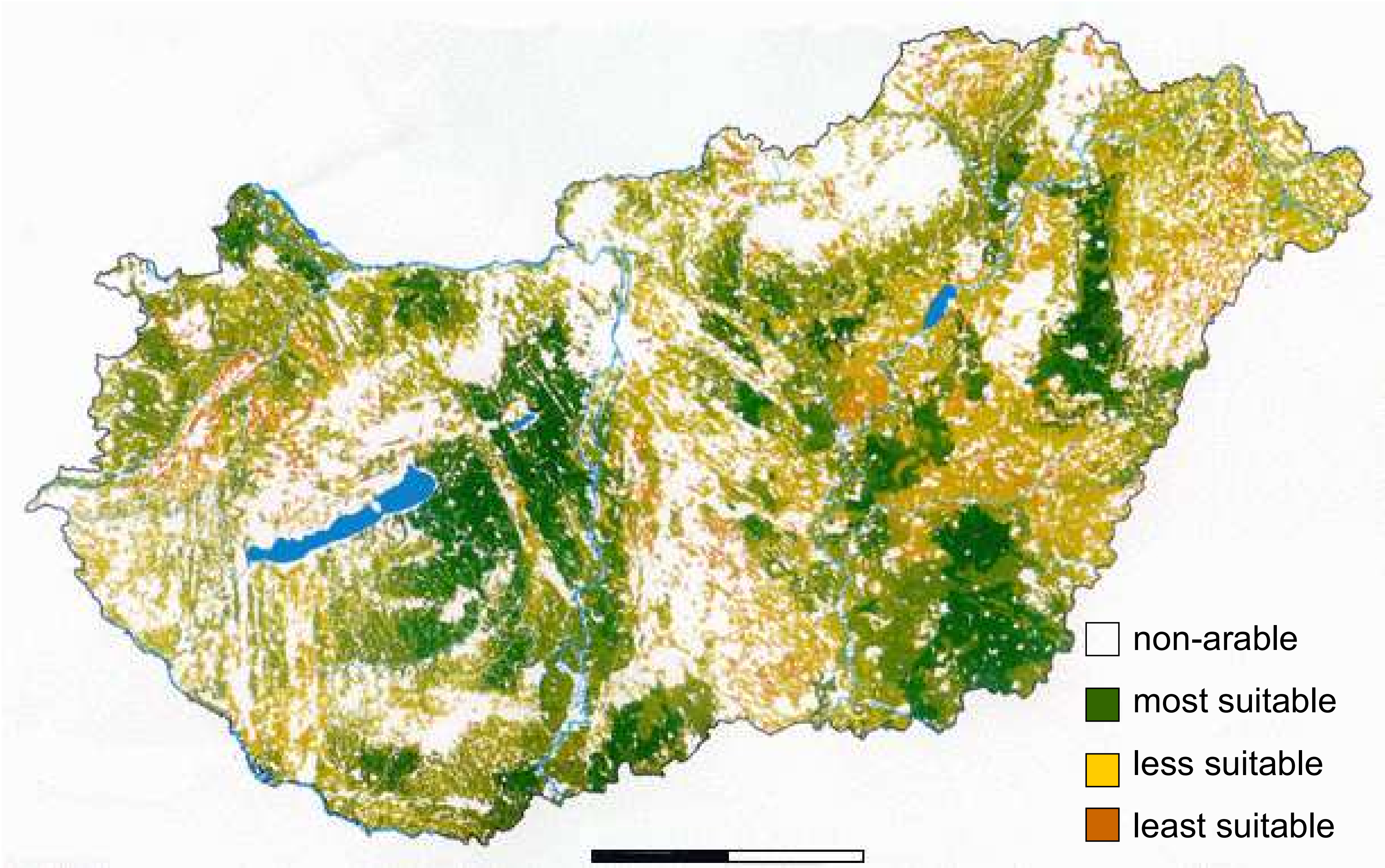
# Agrotechnical protection against erosion

- professional choice of cultivation type;
- establishment of large cultivation tables;
- Soil conservation cultivation methods;

# Selection of the cultivation type according to the degree of the slope

- arable land: 17%;
- grape-fruit: 17-30%;
- forest: 30% - ;

# Suitability for arable farming



# Establishment of large cultivation tables

Its length should be perpendicular to the slope!

Width : length = 1 : 4-10

# Cultivation technology 1

**Rules and ways of cultivation:**

- direction and depth of plowing;
- shooting? without shooting?
- minimum tillage, reduced tillage, conservation tillage (no till, ridge tillage, strip tillage), strip tillage, mulch tillage;
- tilth;

# Cultivation technology 2

**Fertilization:**

- depth of incorporation;
- heterogeneity;
- organic fertilizer;
- green manure;

# Cultivation technology 3

**Protective effect of the vegetation**

Stocking density, shading (LAI), growing period;

**good:** grassy clover, clover, mowed lawn, perennial legume forage crops;

**medium:** autumn cereals, rape, feed mixes, Sudan grass, maize silage, dense- and spring-sown crops;

**weak:** pea, bean, soy, vetch, tobacco. maize, potato, sunflower;

# Forest functions of protection against erosion

- reforestation, restoration;
- knitting ravine, establishment of forest belts storing water;
- establishment of soil-protecting bush bands and protective forest bands;

# Technical tasks of protection against erosion

- road network;
- castling;
- terrace;
- gullies bond;

# Road network

- interrupting slope;
- sketching;
- cross section;
- drainage;
- water quantity, speed, traffic;

# Castling

- Artificial corrugations in order to facilitate the infiltration and retain water rushing down;
- Forms:
  - horizontal trenches;
  - sloping trenches;
  - narrow-based;
  - broad-based;
  - cross-cultivation possibility;
  - impossible for cross-cultivation;

# Terraces

water retention

drainage

reducing the degree of the slope

# Lowland water management

Rain water retention and drainage of excess water;

**Reasons of harmful abundance of water:**

- Intense and a lot of rainfall;
- inlet;
- over-watering;

# Water-tolerant capacity of plants

- **Choking point!**
- Depends on:
  - species, variety;
  - phenophase;
  - plant height;
  - water cover;
  - air- and water temperature;

# Inland water

**Inland water:** precipitation on the exempt side + elevated groundwater saturates the soil and they shell cover the surface;

<u>Reasons:</u>

- a lot of rain, low temperatures;
- low evapotranspiration, inlets, soil conditions;
- topography, agrotechnics;
- fluctuations in groundwater level;

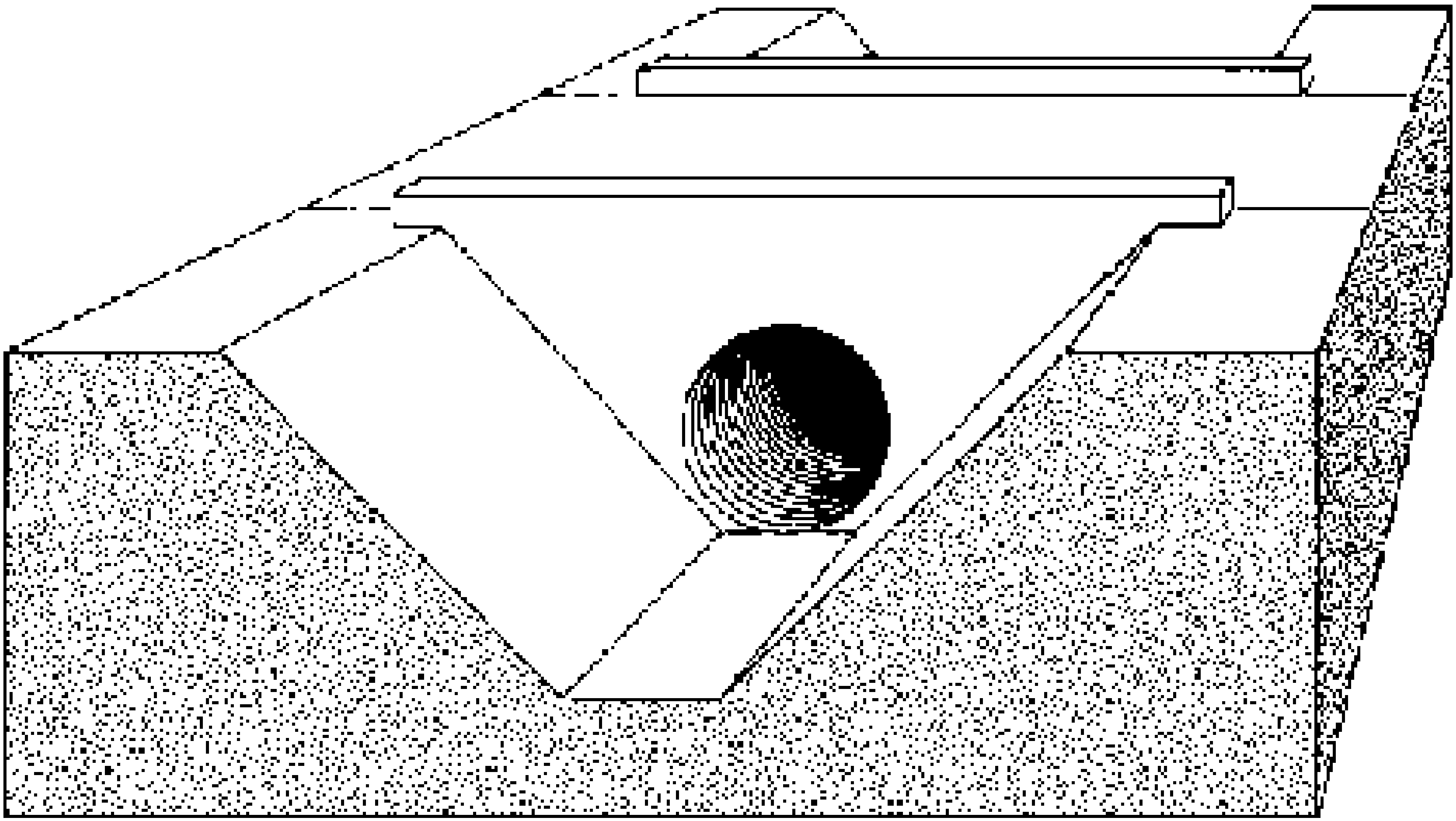
# Damages caused by inland water

- Destruction of the soil structure, cooling effect, nutrient leaching, secondary salinisation;
- Ground work can only be done in worse quality and not in the optimum time;
- Due to the unfavourable soil conditons, fuel consumption will inrease;
- Harvesting is more difficult, yield loss and quality deterioration will occur;

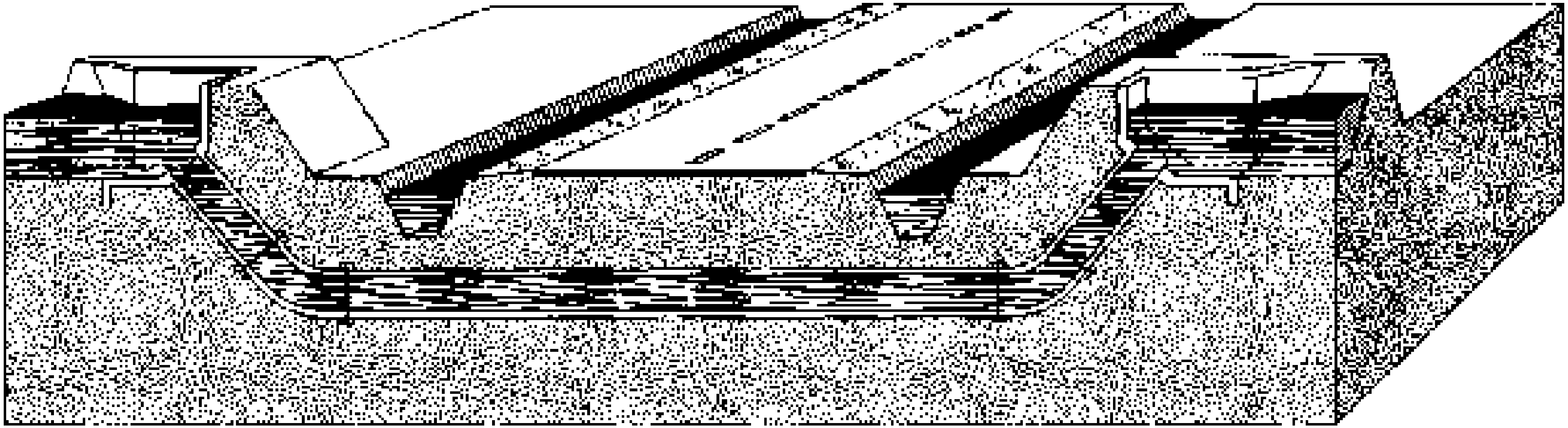
# Surface water management

- Dran channel, table channel, side channels, main channel, floodplain channel, belt channel, outland water channel;
- reservoir: natural, artificial;
- built object: crossing, controlling, fall focusing, machine-raised;

# Tube culvert

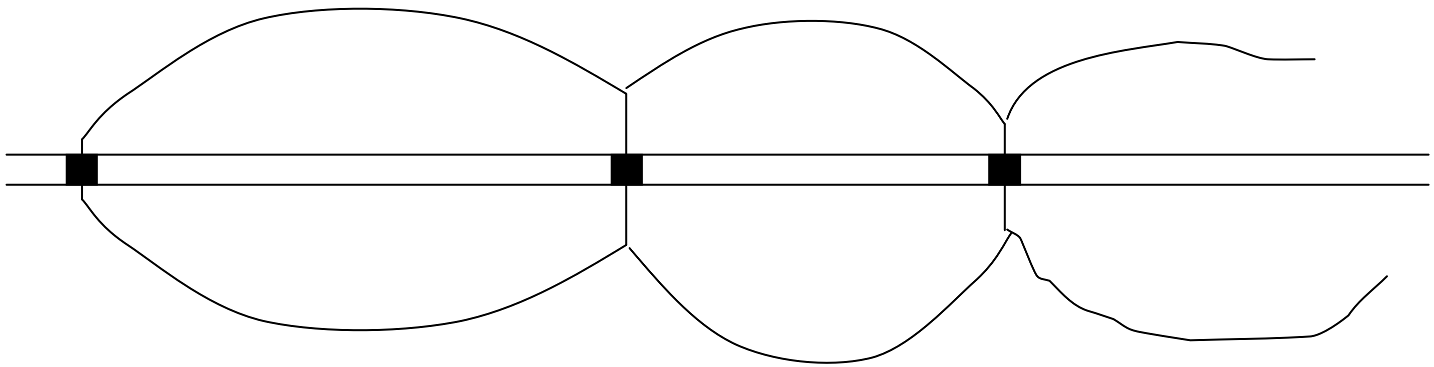


# Tunneling



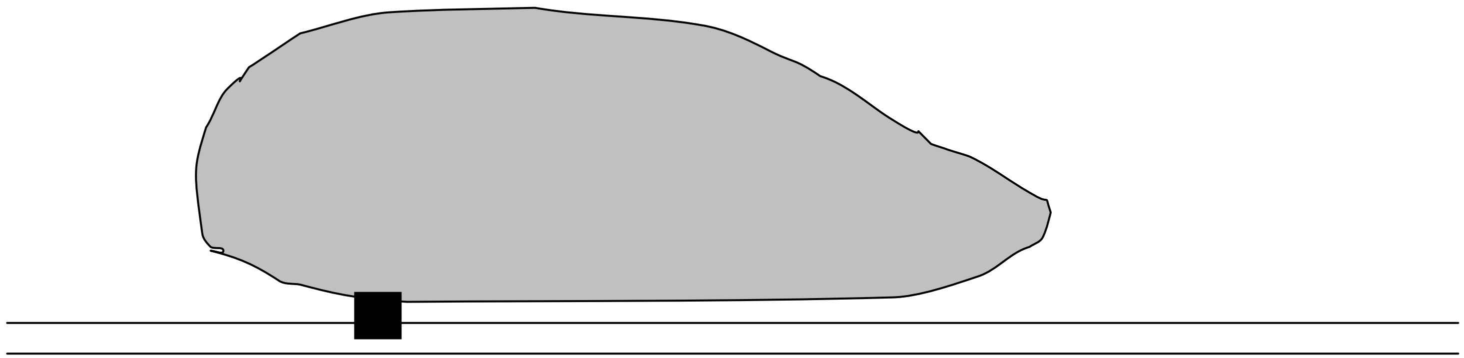
# Surface water management

Garland of reservoirs:



# Surface water management

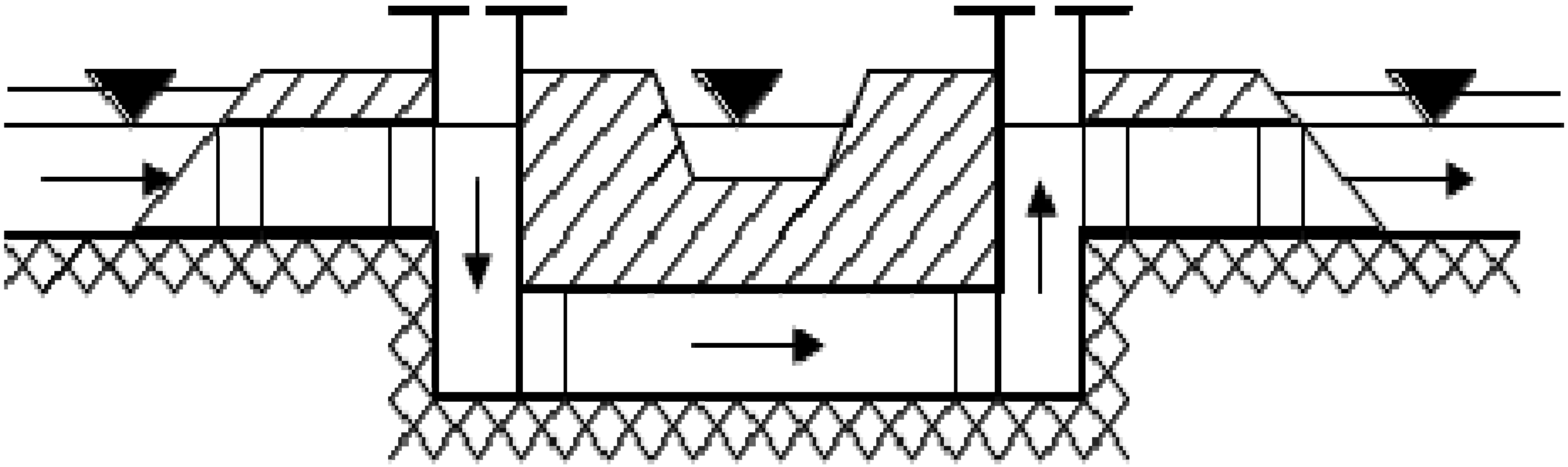
Side reservoir



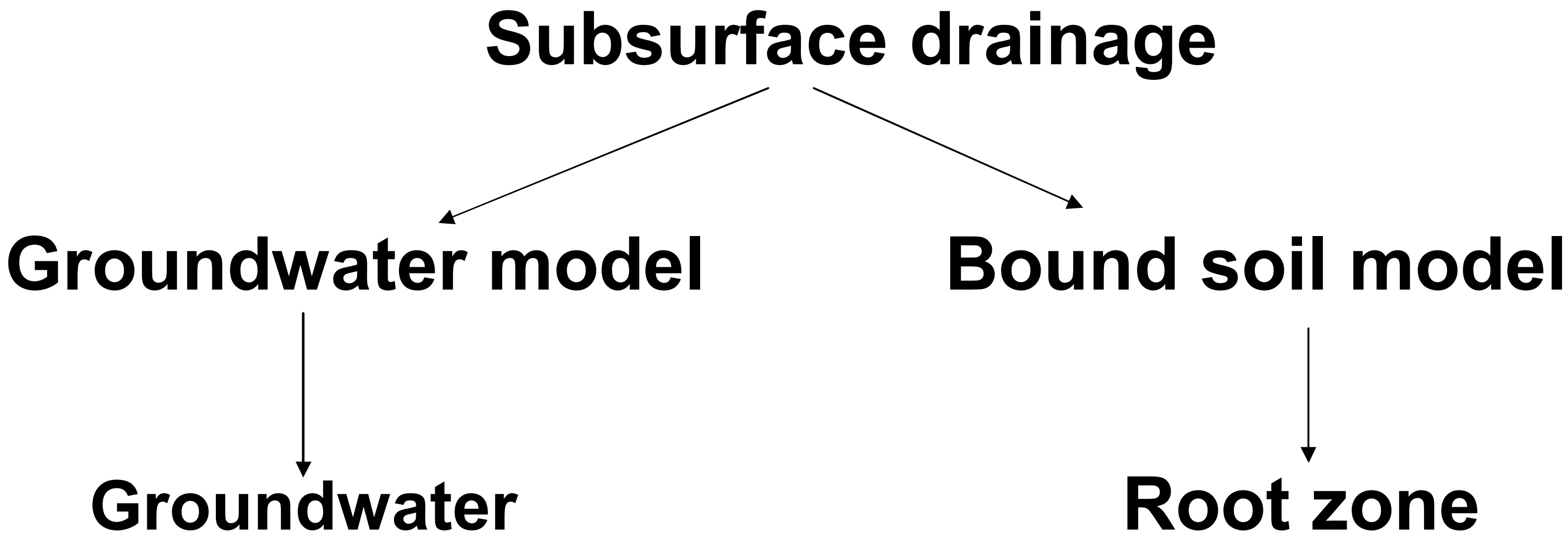
# Drainage and built objects of water level control

- **crossing structures:** culverts, tunneling, bridge;
- **controlling structures:** prohibitory, sluice, letting in;
- **fall-focusing structures:** bottom stair, chute;
- **sructures of machine-raising:** water management-, irrigation-, double acting-, estuarine-, intermediate pumping station, others (e.g. summer dam);

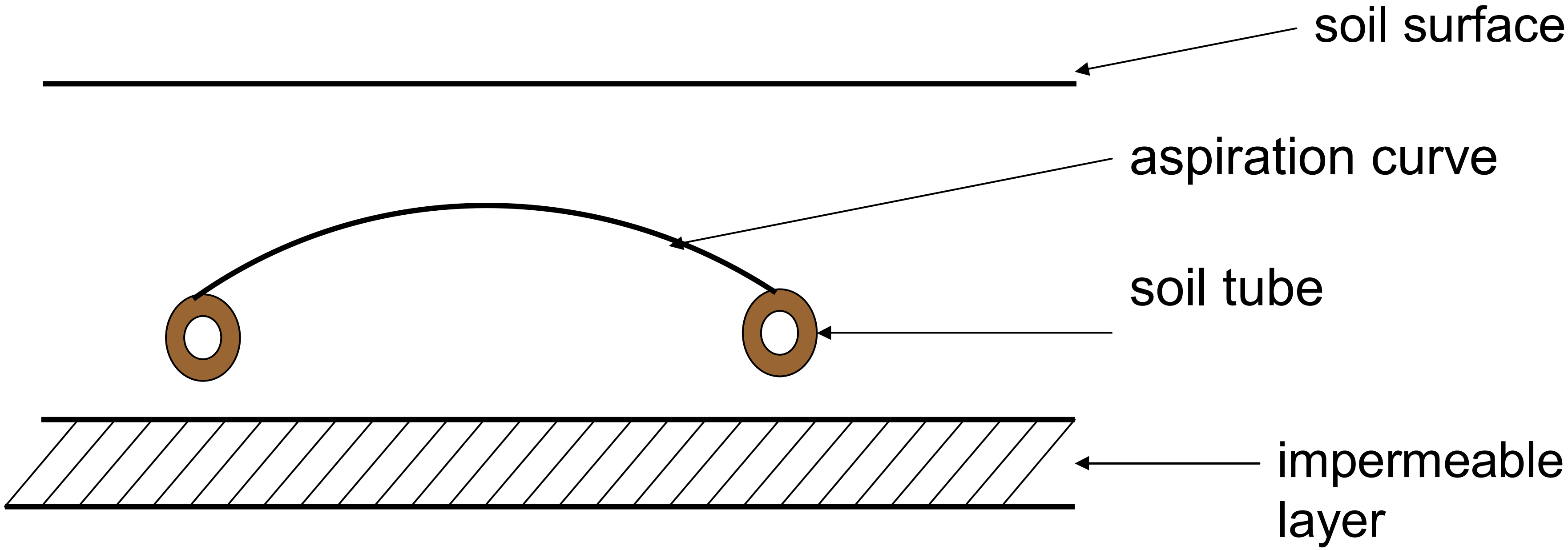
# Tunneling



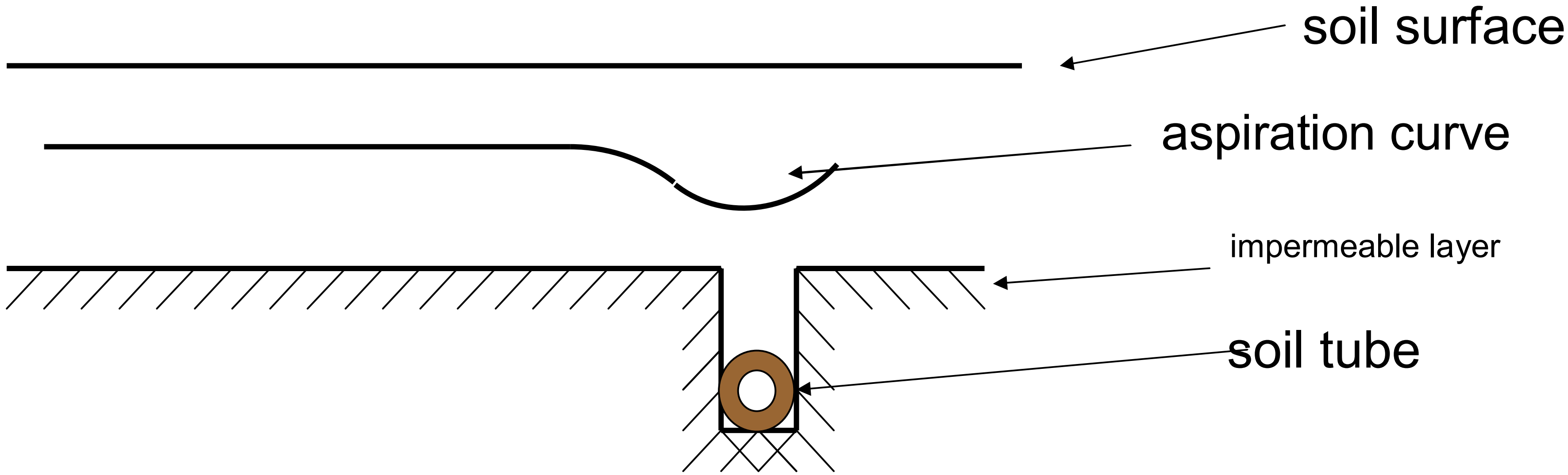
# Subsurface water management



# Groundwater model



# Bound soil model



# Pros and cons of underground drainage

## Pros

- water reception capacity and permeability of the soil will improve;
- soil works in optimal time and quality;
- nutrient intake of the roots will improve;
- soil salinity will reduce;
- microbal activity will intensify;

## Cons

- high investment costs;
- nutrient-leaching;
- skills and pumping stations;

# Material of the soil pipes

- formerly:burned clay;
- recently: flexible PE-, PP- and PVC pipes of corrugated skirt (circularly ribbed PVC pipes);
- size: d = 50, 65, 80, 100, 125, 160 and 200 mm. length: 45-200 m;
- other: sleeve, end cap, reducer, plug and outlet fittings;

# Soil pipe

Always look on the bright side of things!

**We finished for today, goodbye!**

ямарваа нэг зүйлийн гэгээлэг талыг нь үргэлж олж харцгаая

**өнөөдөртөө ингээд дуусгацгаая, баяртай**

让我们总是从光明的一面来看待事物吧！

今天的课程到此结束，谢谢！

دعونا ننظر دائما إلى الجانب المشرق من الأشياء!

**انتهينا لهذا اليوم، وداعا!**