Water Cycle in Forest Ecosystem

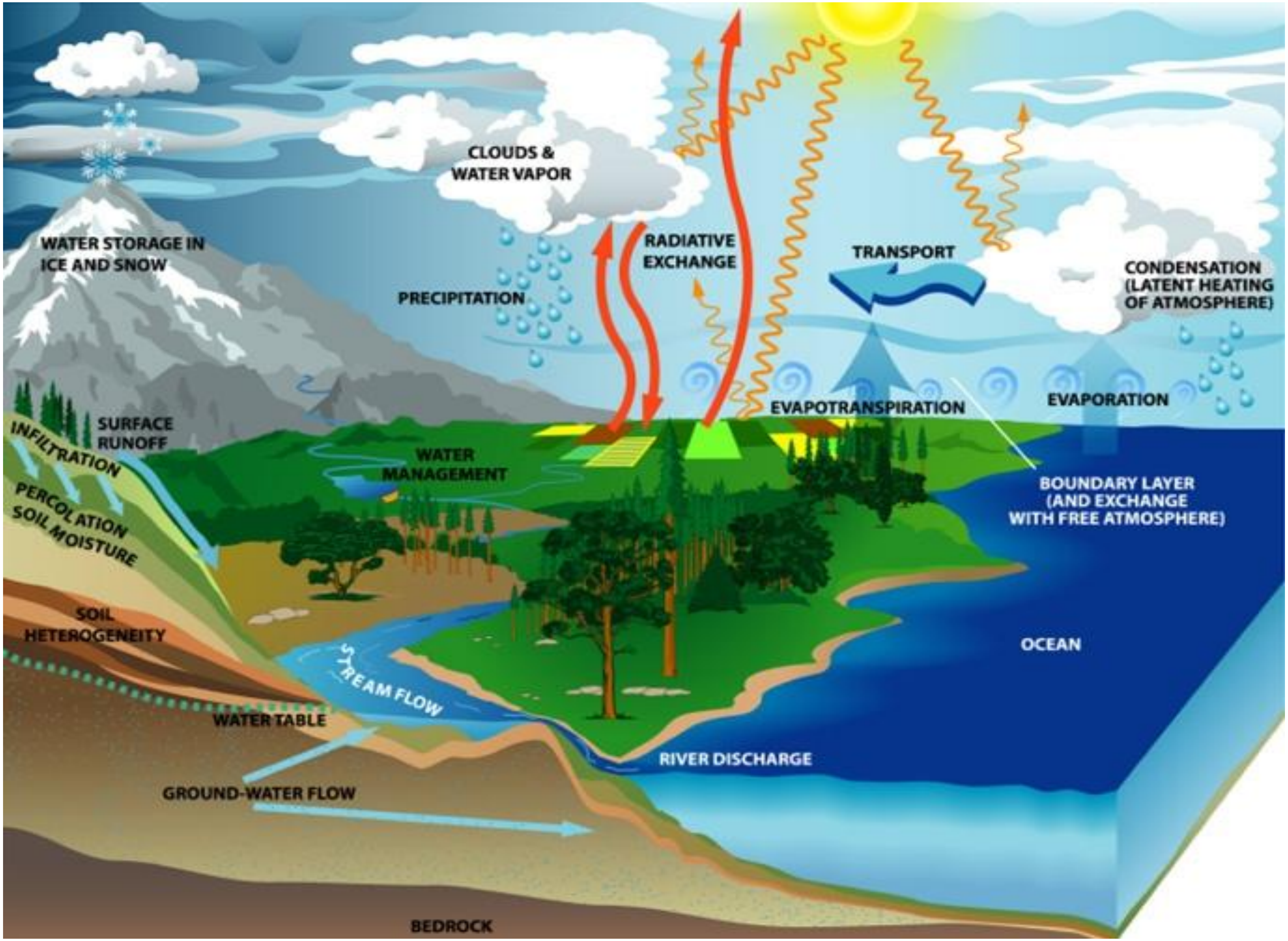
evropský sociální fond v ČR | EVROPSKÁ UNIE | MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY | OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Tento projekt je spolufinancován Evropským sociálním fondem a Státním rozpočtem ČR InoBio – CZ.1.07/2.2.00/28.0018

Lesson Content

- Large and small hydrological cycle - exchange of water between soil, vegetation and atmosphere
- Solar radiation and water in forest ecosystem
- Interception, Transpiration – „Cooling system“ of plants
- Soil water, percolation and infiltration, moisture regime, water availability, underground water, surface runoff
- Water flow within trees
- Water budget (balance) in forest ecosystem
- Application in forestry


WATER STORAGE IN ICE AND SNOW
CLOUDS & WATER VAPOR
PRECIPITATION
RADIATIVE EXCHANGE
TRANSPORT
CONDENSATION (LATENT HEATING OF ATMOSPHERE)
SURFACE RUNOFF
INFILTRATION
PERCOLATION
SOIL MOISTURE
WATER MANAGEMENT
EVAPOTRANSPIRATION
EVAPORATION
BOUNDARY LAYER (AND EXCHANGE WITH FREE ATMOSPHERE)
SOIL HETEROGENEITY
STREAM FLOW
OCEAN
WATER TABLE
RIVER DISCHARGE
GROUND-WATER FLOW
BEDROCK

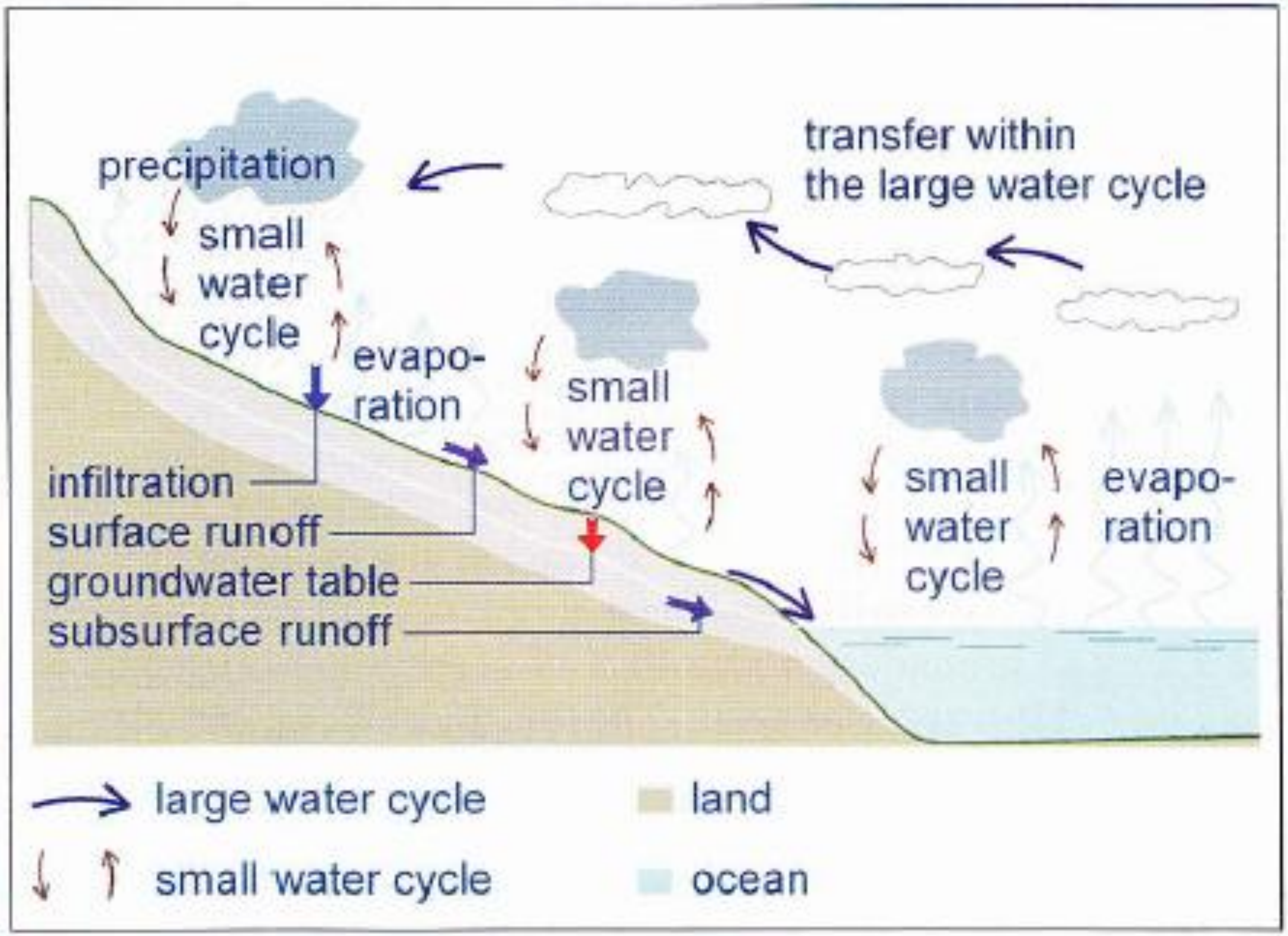
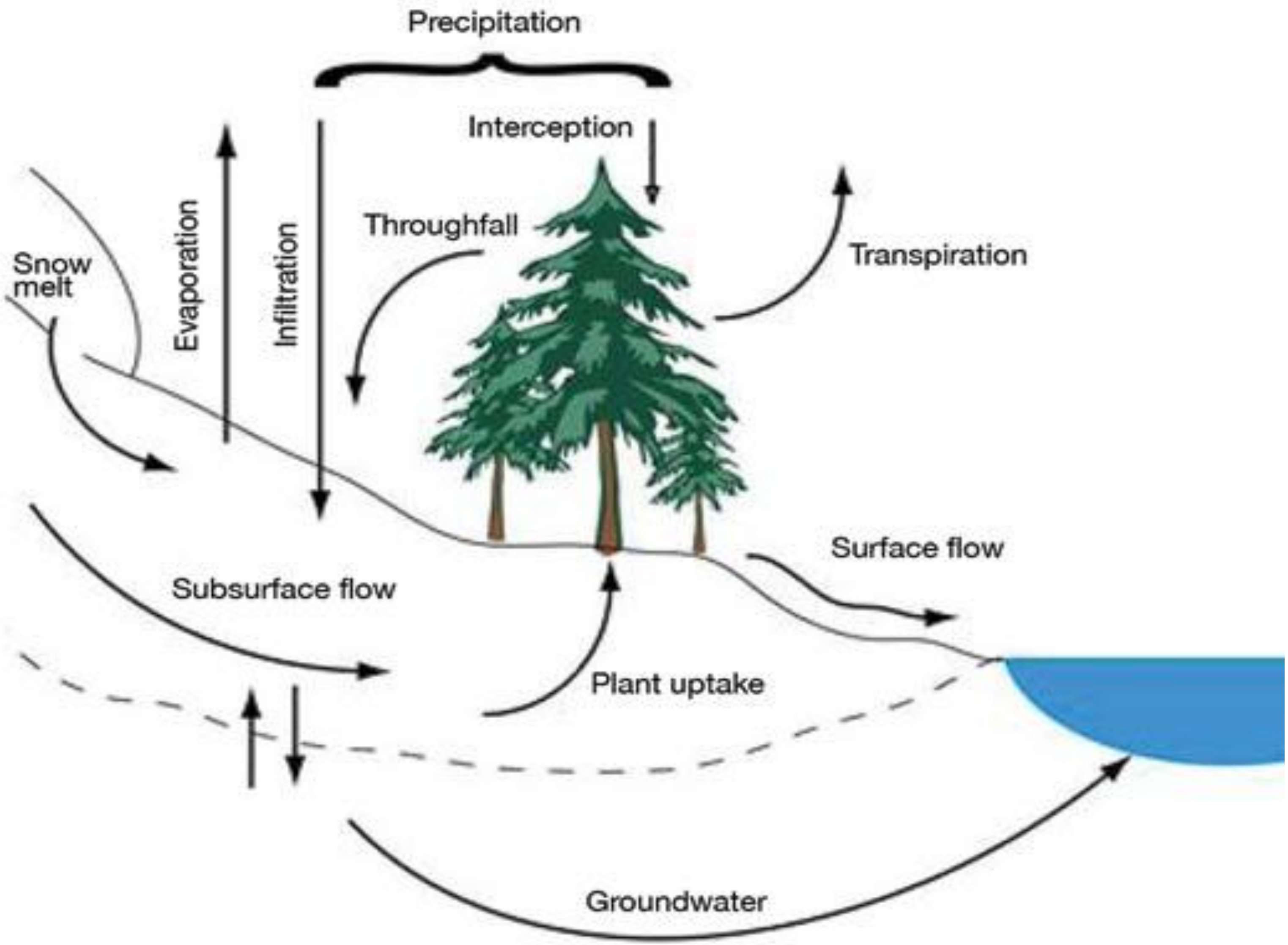


Fig. 1 The large and small water cycles on land.

Main components of water balance



Precipitation and interception

- **Precipitation** – main input of water to the ecosystem (rain, snow, fog . Precipitation in open area, under canopy (througfall, stem flow), unit mm or l/m2, 400-2000 mm in Central Europe
- **Interception** – is the fraction of annual precipitation that falls but does not reach the ground. This fraction ranges from 10 to 50% (90%) of annual precipitation, depeds on crown density
- **Leaf Area Index – LAI ,** defined as the projected area of leaves over a unit of land (m^2 m^{-2}), so one unit of LAI is equivalent to 10,000 m^2 of leaf area per hectar.
- **Seasonal variation in LAI** may be estimated by determining a mid-season maximum value and then reducing this in proportion to the amount of leaf litterfall collected periodically throughout the year (Burton et al., 1991).

Water (wapor transfer) from vegetation as a function of solar radiation (heat)

Energy exchange between vegetation and the environment involves a number of processes.

PAR – **P**hotosynthetically **A**ctive **R**adiation

NIR – **N**ear-**I**nfrared **R**adiation

The **total radiation** incident on any surface is the sum of

1) direct short-wave radiation from the sun
2) diffuse short-wave radiation from the sky
3) reflected short-wave radiation from nearby surfaces
4) long-wave radiation from atmospheric emission
5) long-wave emitted from nearby surfaces.

Evaporation from Wet Surfaces

The amount of water vapor held in a saturated atmosphere increases exponentially with temperature; the degree of saturation is often expressed as the **relative humidity**.

The **dew point (rosný bod)** is the temperature at which the water vapor pressure equals the saturated vapor pressure.

The **water vapor pressure deficit (sytostní doplněk)**

is an important term in many models of evaporation and represents the difference between the vapor pressure at saturation and the actual vapor pressure, determined by the amount of water vapor in the air (Jones, 1992).

Evaporation (transpiration) from dry plant canopies

When the surfaces of leaves are dry, water loss take place by transpiration through stomata. Transpiration from a dry canopy is related to the evaporation rate imposed by the effects of the air saturation deficit

- **Water loss from leaves** is controlled by the evaporative potential of the air, the water supply from soil, and the **stomatal conductance** of leaves
- **Stomatal conductance** declines in response to drought because plants sense tho soil moisture content of their root systems (role of abscisic acid (ABA)=specific hormon)
- **Stomata** are pores inthe leaf surface that can be opened or closed by the plant regulate the rates at which CO2 enters the leaf and water is lost (**transpiration**)

Potential and actual evapotranspiration

- **Potential evapotranspiration** (PET) is the rate of water loss from a **free water** from water surface, leaves and soil under a given weather conditions (max rate of loss water from free water table)
- **Actual evapotranspiration** (AET) is evaporation from the interior of leaves or the soil in given (actual) weather conditions (with limited water content)
- Several methods of estimating PET and AET e.g. Penman-Monteith equation
- Amount of evapotranspiration in Central Europe =40-90% from whole precipitation ammount

Water storage and movement in the soil

- **Water storage** = water adsorbed in the pore space to soil particles
- Soil is **water saturated** when all pores are filled with water
- If the larger pores fill with water, water begins to drain under influence of gravidity = **saturated flow**
- When the adhesive forces that hold water in films on soil particles equels the gravitational pressure= **field capacity i.e** the quantity of water retained by a soil after gravitional water has drained (**about -0,03 Mpa)**
- At water contents below field capacity, water moves throuh the soil by **unsaturated flow** – in response to gradient of **water potential=**potential **l** energy of water relative to pure water at the soil surface
- **Pressure gradients** associated with gravity and matrix forces control most water movement through soil

Cont.

- The rate of water flow through soil depends on the gradient in water potential and resistance to water movement. This resistence depends on **hydraulic conductivity** and the length of the column through which water travels. Infiltration is a simple example depends on soil texture and aggregate structure.
- **Preferential flow** - infiltration of rainwater into the soil through macropores
- **The permanent wilting point –** is the soil water potential (about-1,5MPa) at which most mesic plants wilt because of they cannot obtain water from soils
- The difference in the water content between field capacity and permanent wilting point (water - holding capacity) provides an estimate on the **plant-available water** (see Fig.4.8., p.105 and also 4.11)

Water movement from soils to roots and through the trees

- Water moves from soil to the roots of transpirating plants by flowing from **high to low water potential** (root hairs and mycorhizal hyphae
- Rooting depth reflects a compromise between **water and nutrient availability**
- **The vapor-pressure gradient from leaf surface to the atmospher is driving force** for water movement through plant
- Liquid water moves from the soil through roots upward in vascular tissue (xylem)
- The movement of water through trees (**sapwood**)is dependent on the difference in the **energy state of water from point to point** in the system (fig.4.11, p.108) – difference between dry and wet soil, day and night…

How we summerize water balance?

- **Water input** is main determinant of **water outputs** from ecosystems
- The **water loss** from ecosystem equals the input in **precipitation and water storage of plants** to loss of water with **evapotranspiration and runoff** (see Chapin, pp. 114-115)
- Evaporation of water intercepted by the canopy is greatest in **ecosystem with a high surface roughness** (vertical irregularities in the heigt of the canopy surface)
- Vegetation structure and climate govern evapotranspiration rate when soil moisture is adequate
- **As soil moisture declines**, the control over evaporation shifts from canopy structure to soil moisture

Water Balance

Storage

Water in soil and aboveground and belowground biomass

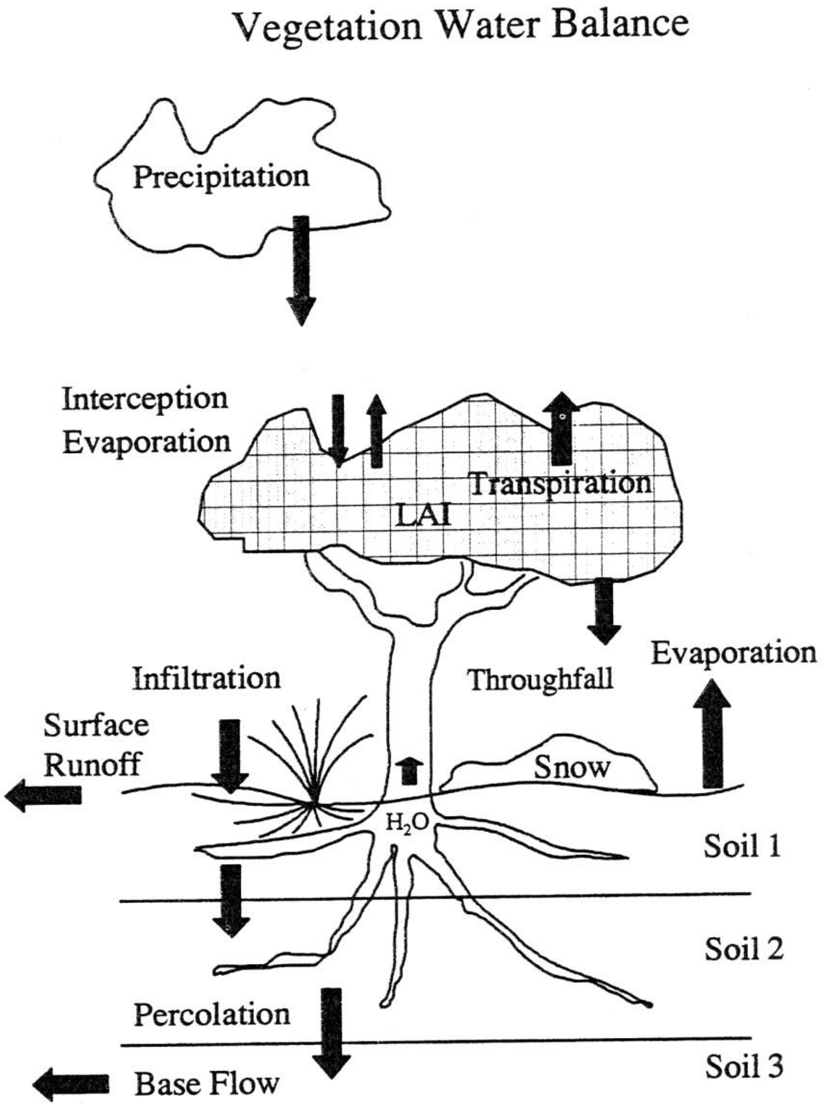
Inputs

Precipitation, Interception, Throughfall,
Stemflow, Infiltration, Percolation, Underground water

Outputs

Transpiration, Evaporation
Surface Runoff, Base Flow

Water balance in forest ecosystem



B=Wa+R-ET-Op1-DOp2

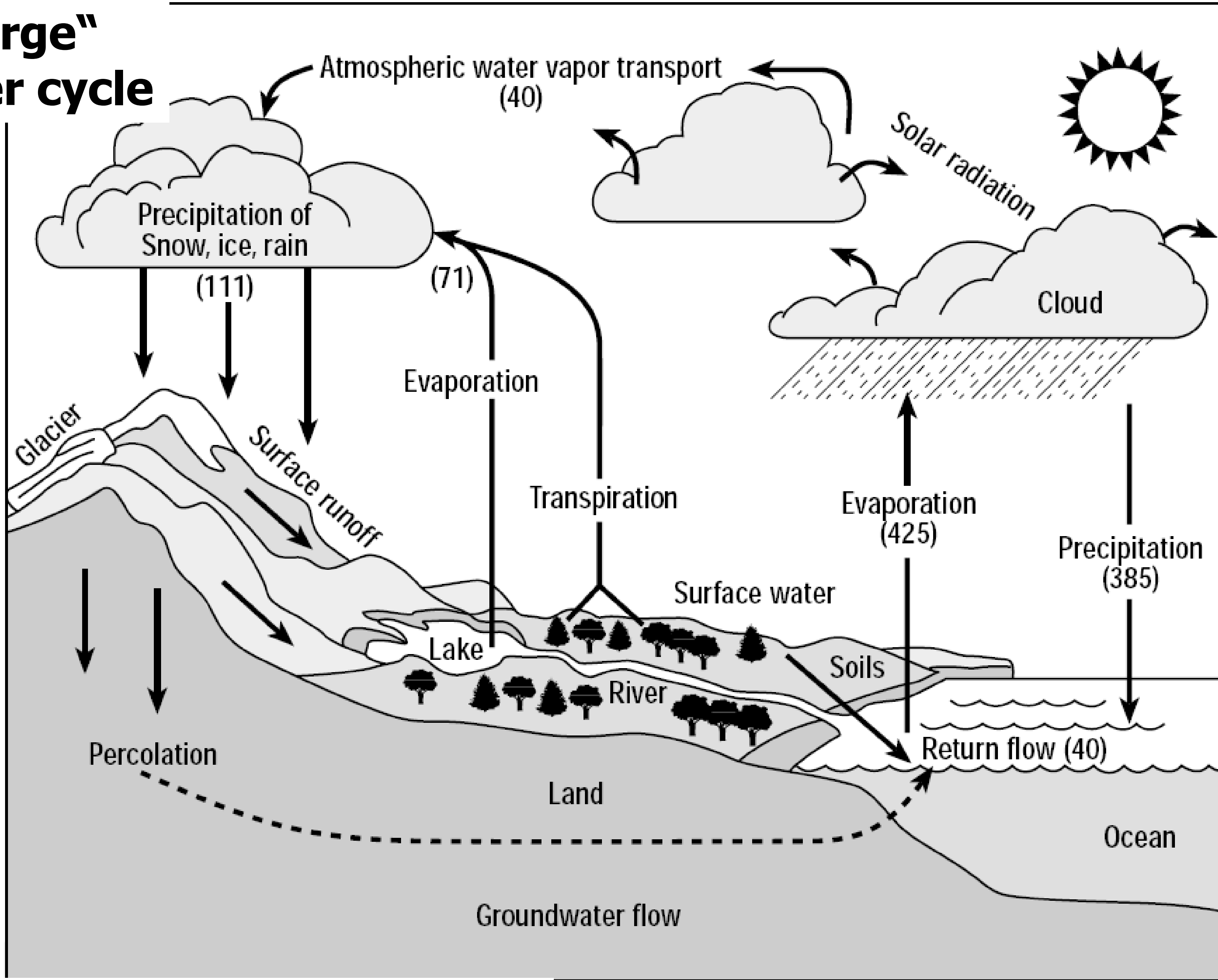
B = water balance
Wa= actual water storage (above and undergroud)
R = precipitation
ET = evapotranspiration
Op1 = hydrological output (infiltration+percolation)
DOp2= diference between base input and optput (incl.runoff)

Review questions

- What are the main input and output components of water balance in forest ecosystems
- How the solar radiation influenced hydrological cycle and exchange of water between soil, vegetation and atmosphere
- How we define evapotranspiration and what are the main factors influenced it
- Describe movement water within the soil and availability of water for plant (trees)

Attatchemens

„Large" Water cycle



Water balance in 10^{12} m^3 $year^{-1}$

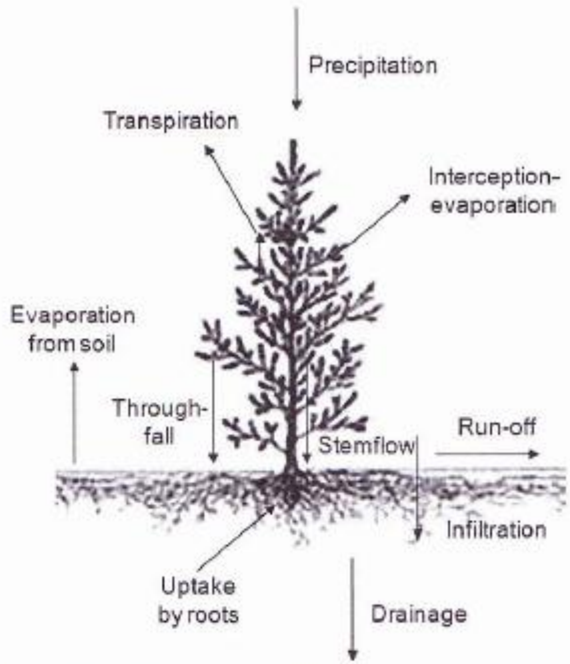
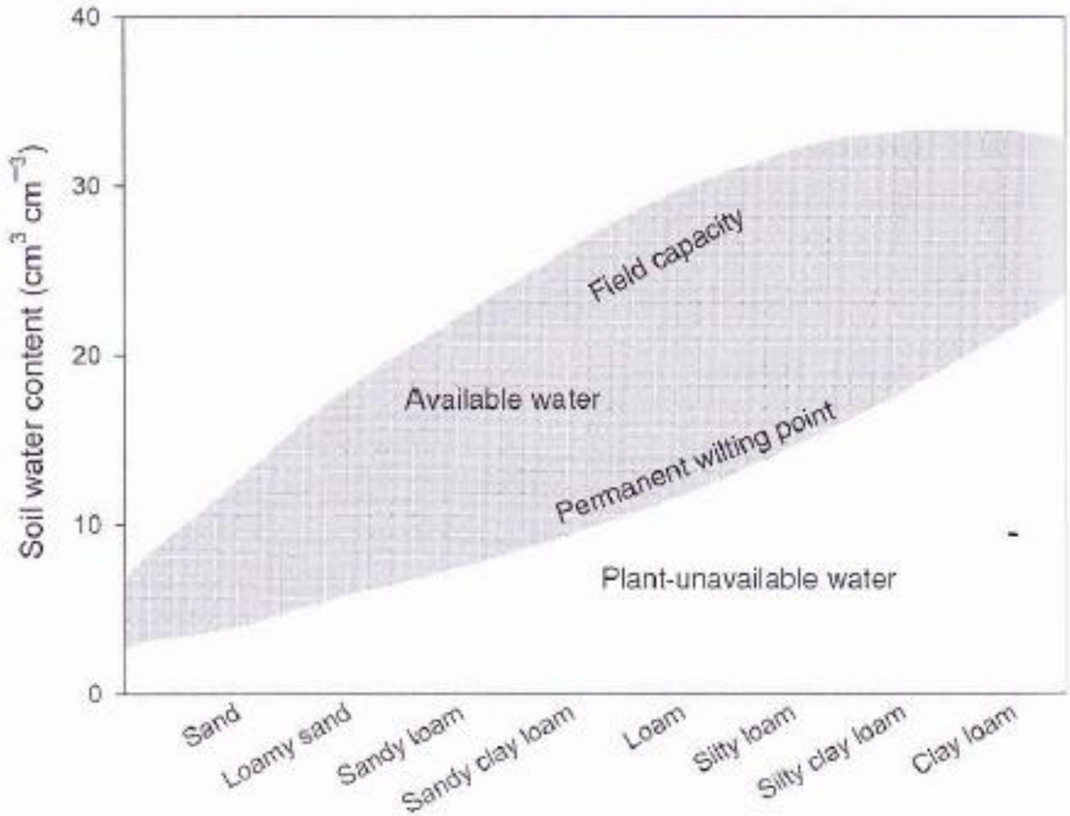


Figure 5.9 The main components of the water balance of an ecosystem. Note that transpiration is shown as a two-step process with the first step from the interior of the leaves to the interior of the canopy and the second step to the atmosphere.

Figure 5.19 Plant-available water as a function of soil texture. From Kramer & Boyer (1995).



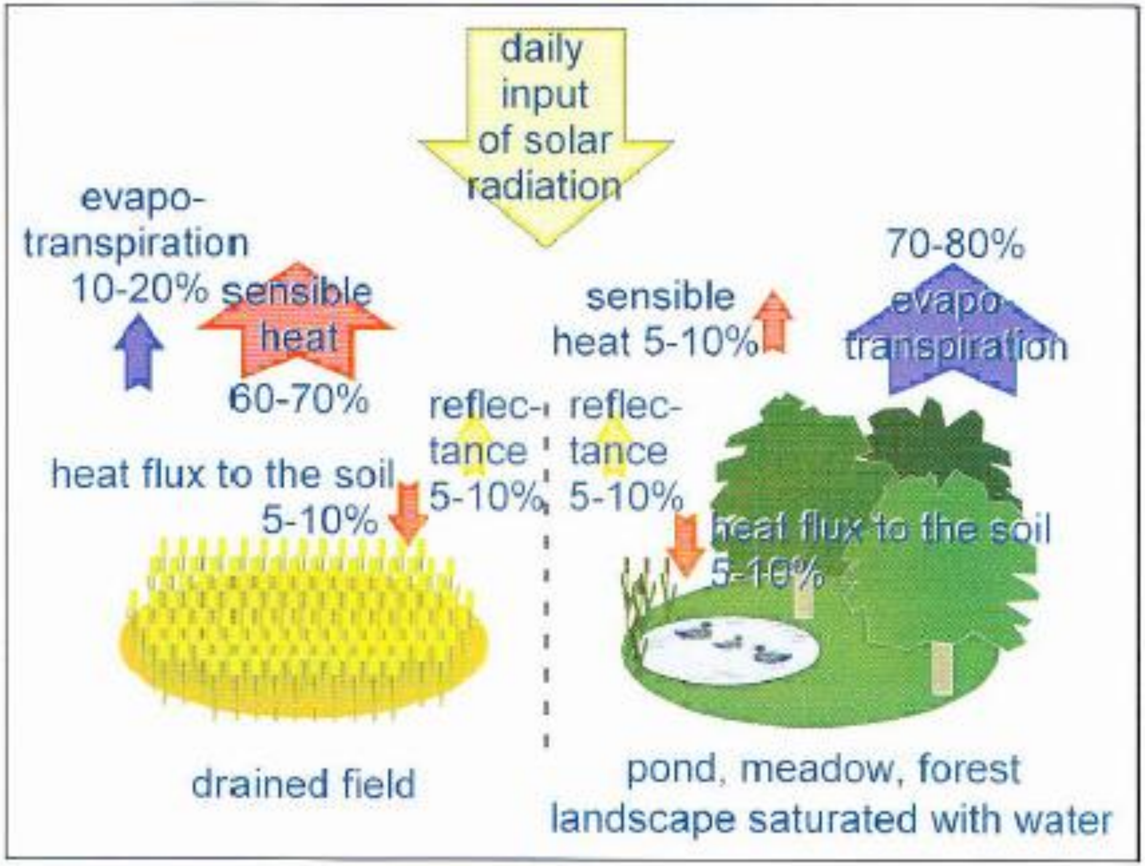


Fig. 4 **The distribution of solar energy on drained land and on a landscape saturated with water.**

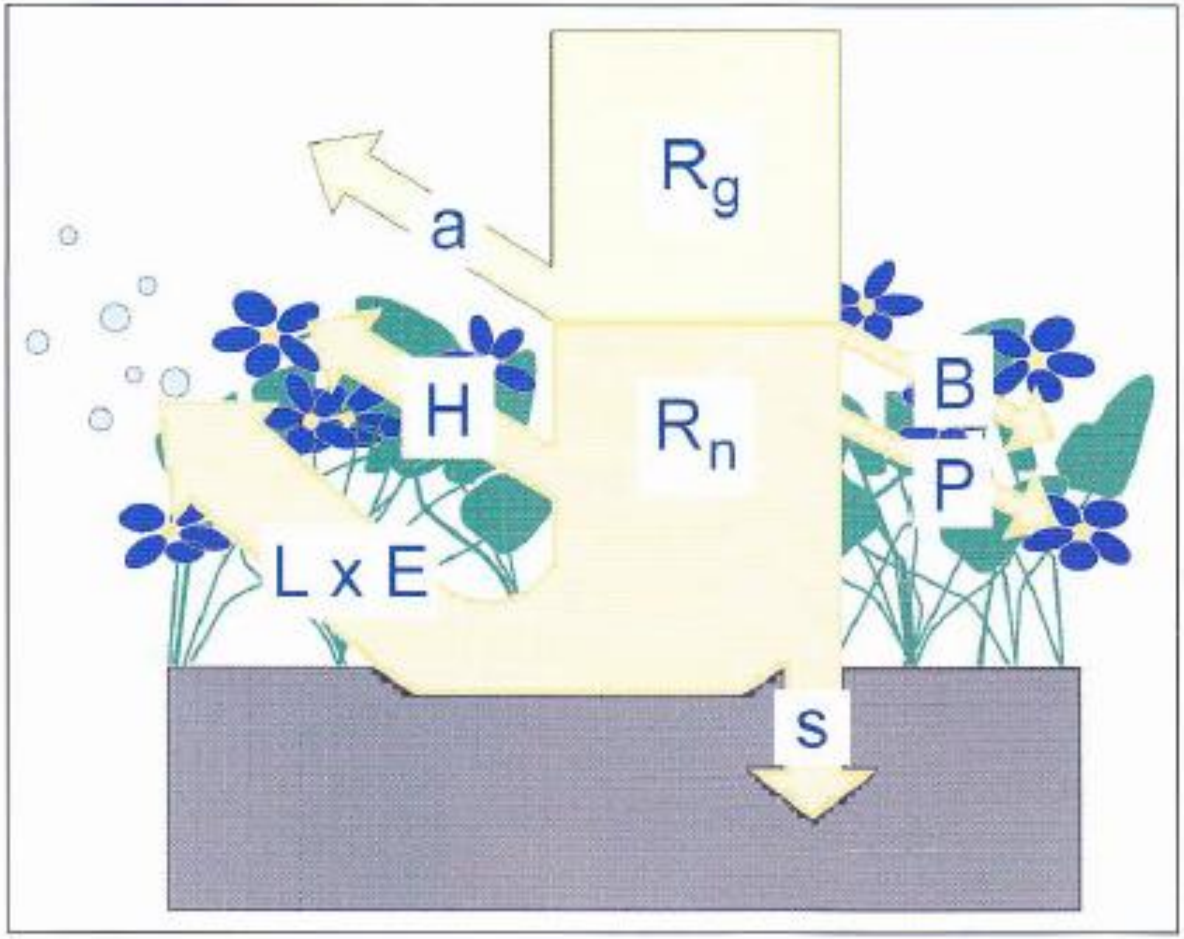
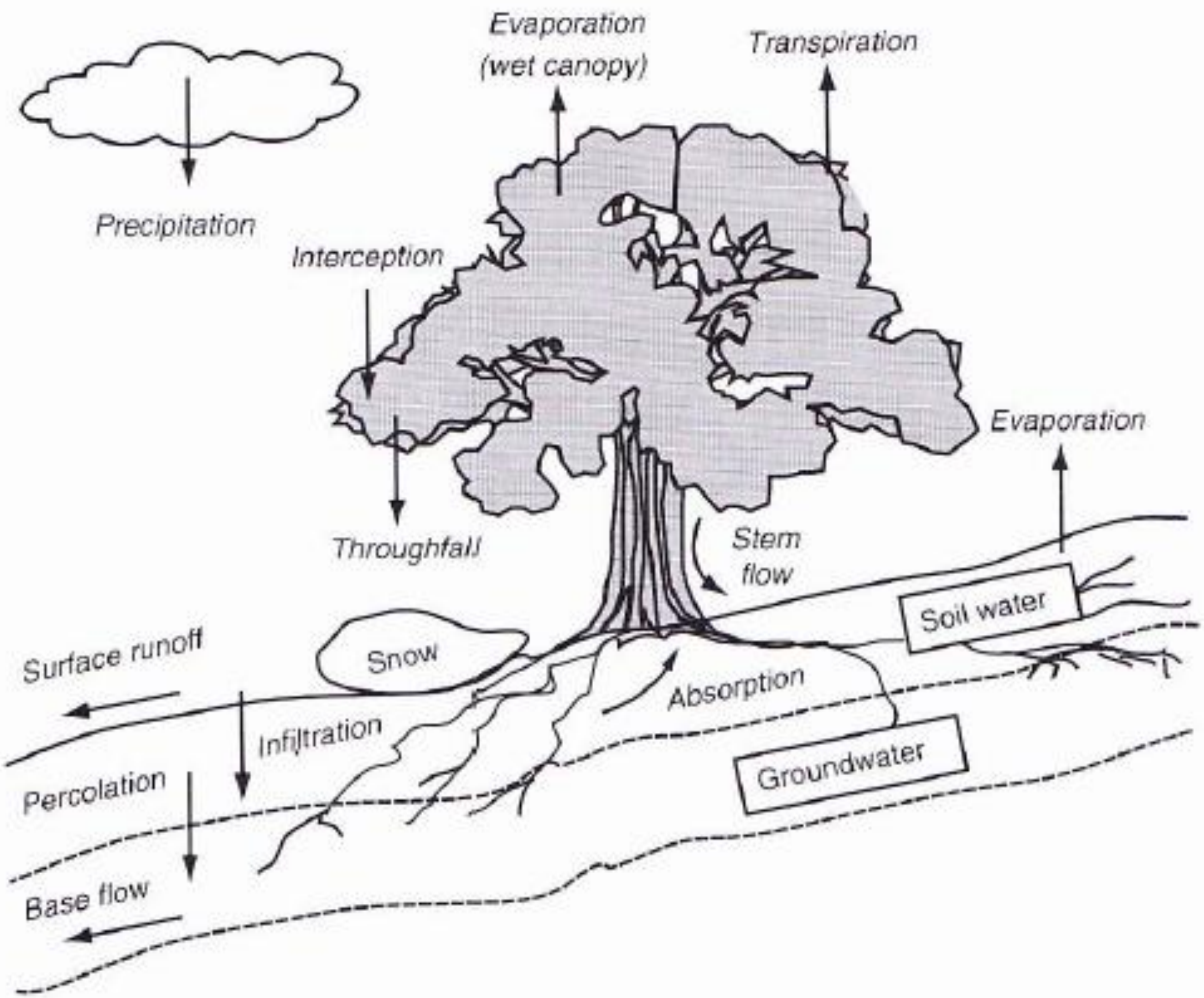
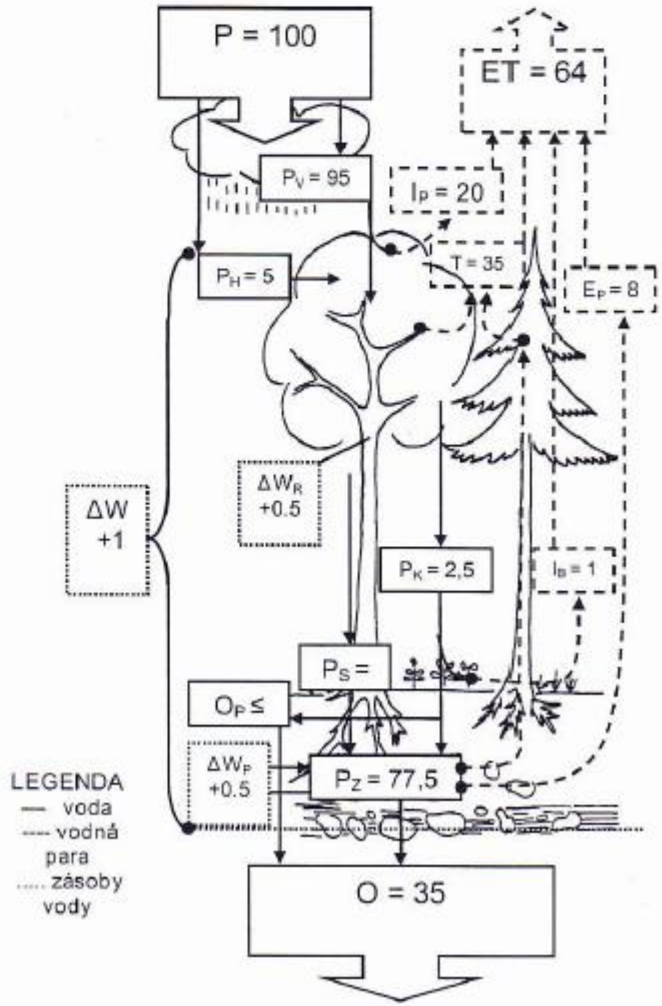


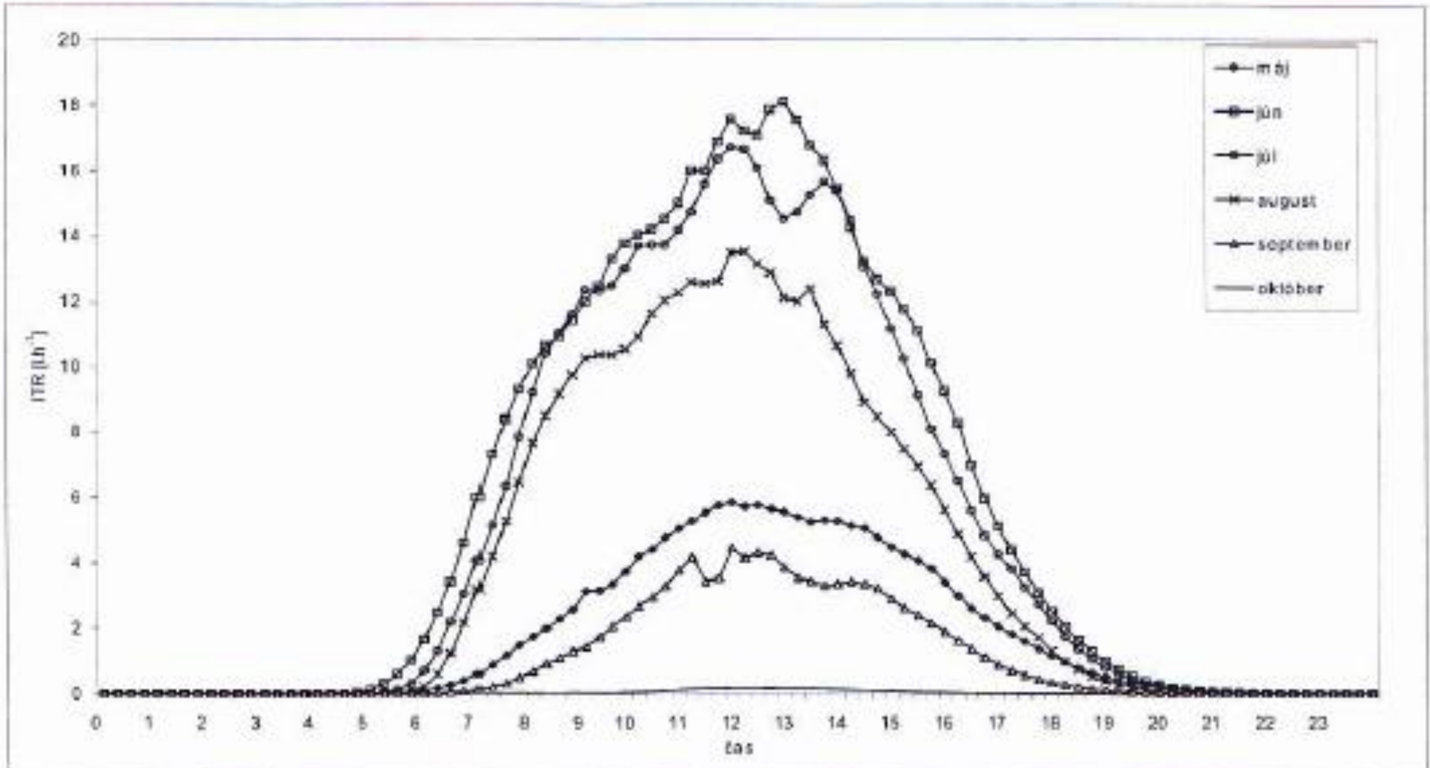
Fig. 5 **The distribution of solar energy on vegetation.** Rg – global radiation, Rn – net radiation, a – albedo (reflected radiation), H – sensible heat, L × E – latent heat x evapotranspiration (evaporation from soil and vegetation), s – flow of heat to the soil, B – accumulation of heat in the biomass, P – consumption of energy for photosynthesis.



Major water fluxes in an ecosystem

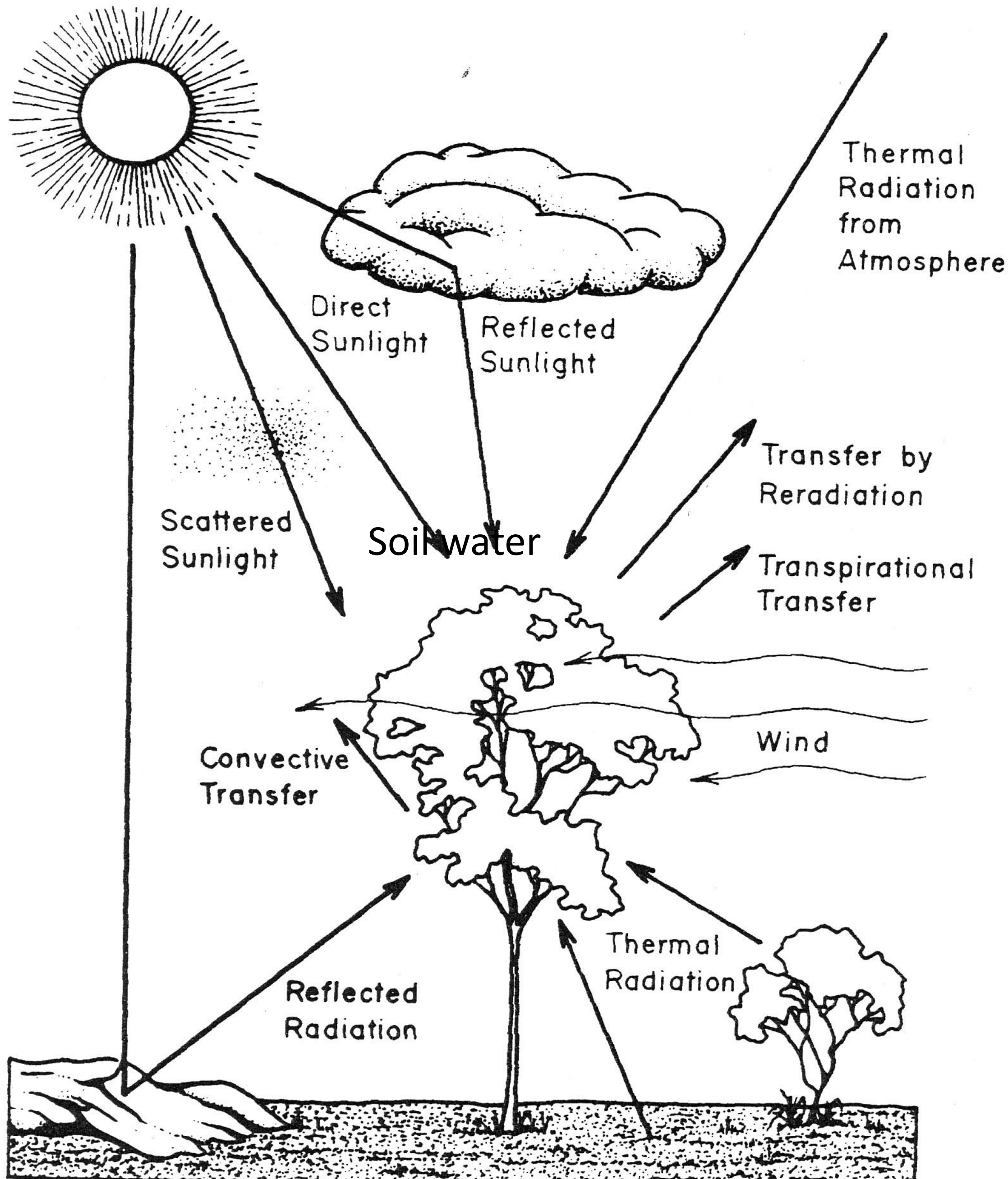


Obrázok 15a. *Vodná bilancia lesného porastu za obdobie roka na príklade zmiešaného smrekovo--jedľovo-bukového porastu s prevahou buka v orografickom celku Poľana, lokalita Hukavský grúň (850 m n. m.). P – celkové zrážky voľnej plochy, PV – vertikálne zrážky (dážď, sneh), PH – horizontálne zrážky (z hmly, námraza), PK – podkorunové zrážky, PS – stok zrážok po kmeňoch stromov, PZ – zasakovanie zrážok do nadložného humusu a pôdy, OP – povrchový odtok, O – odtok povrchový a odtok podzemnej vody, IB – intercepcia bylinnej etáže, IP – intercepcia stromovej etáže porastu, EP – výpar z pôdy, T – transpirácia stromovej etáže porastu, ET – evapotranspirácia, ΔWR – zmena zásoby vody vo fytomase, ΔWP – zmena zásob vody v pôde a nadložnom humuse, ΔW – celková zmena zásob vody v nadzemnej a podzemnej časti porastu (*S_{TŘELCOVÁ} *et al. 2006)*

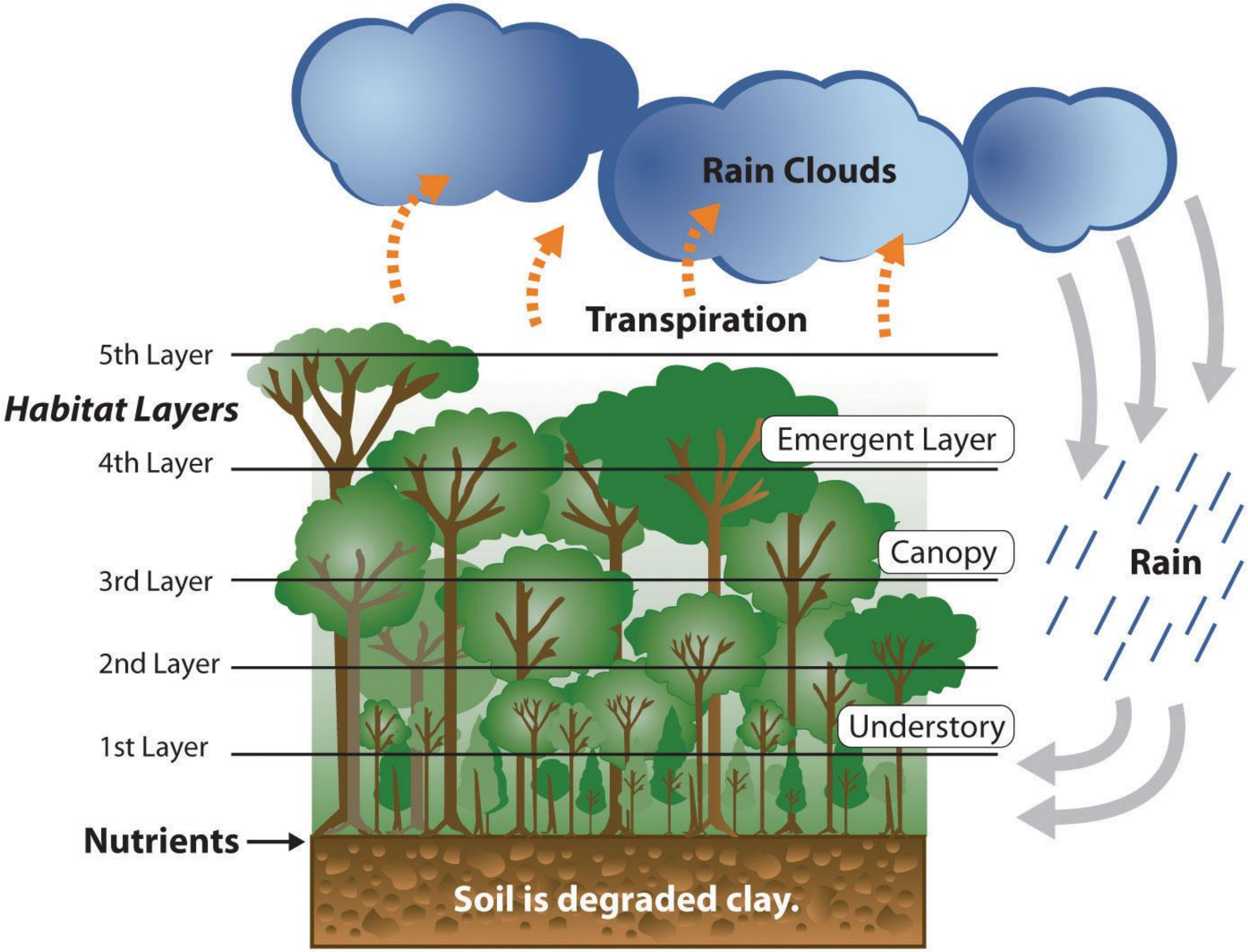


***Obrázok 16.** Priemerné denné priebehy intenzity transpiračného prúdu (ITR) úrovňového buka pre jednotlivé mesiace vegetačného obdobia 1996 v lokalite Poľana – Hukavský grúň v nadmorskej výške 850 m (Střelcová a Minďáš 2000)*

Water Cycle


Thermal
Radiation
from
Atmosphere
Direct
Sunlight
Reflected
Sunlight
Transfer by
Reradiation
Scattered
Sunlight
Soil water
Transpirational
Transfer
Wind
Convective
Transfer
Thermal
Radiation
Reflected
Radiation

Evaporation, Interception, Transpiration



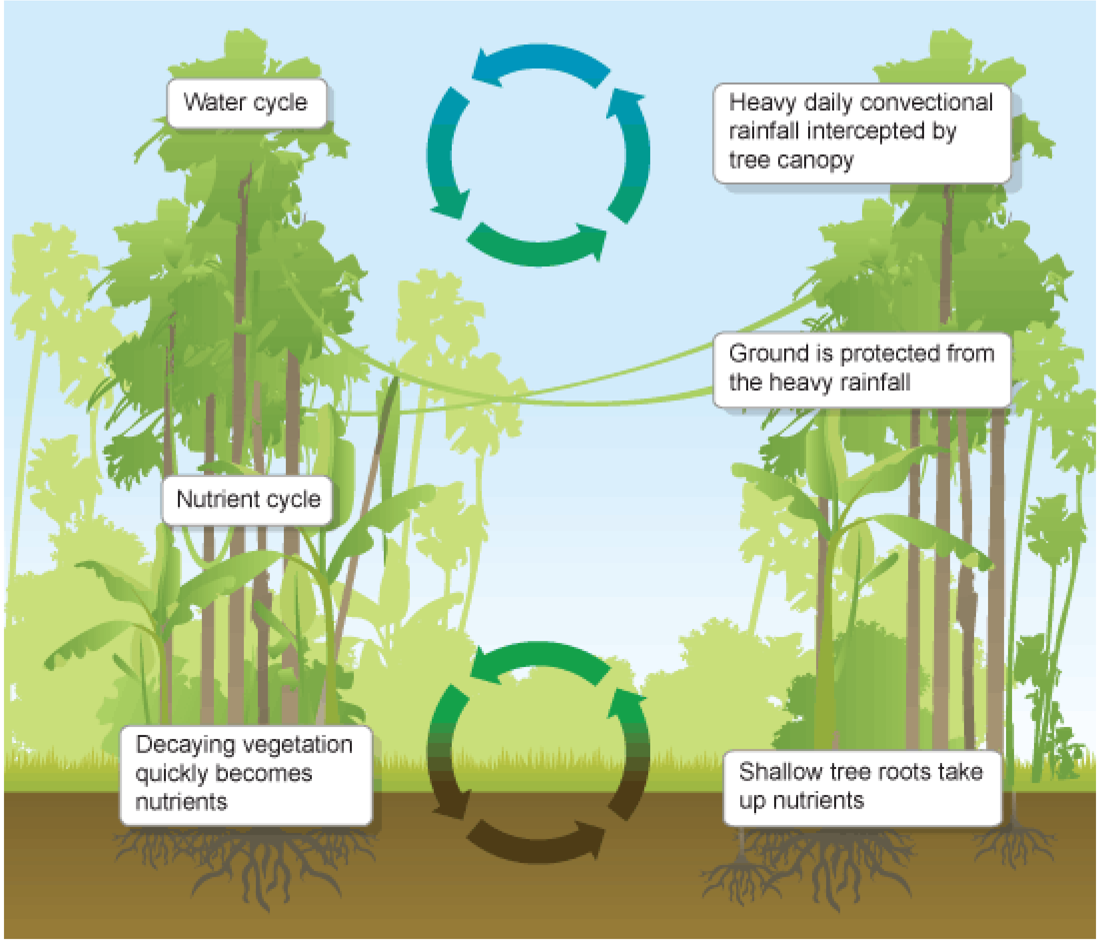
Precipitation on the open air

Throughfall

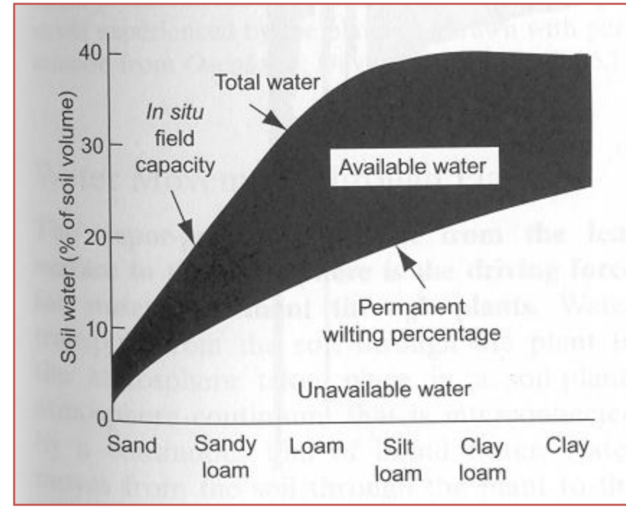
Stemflow

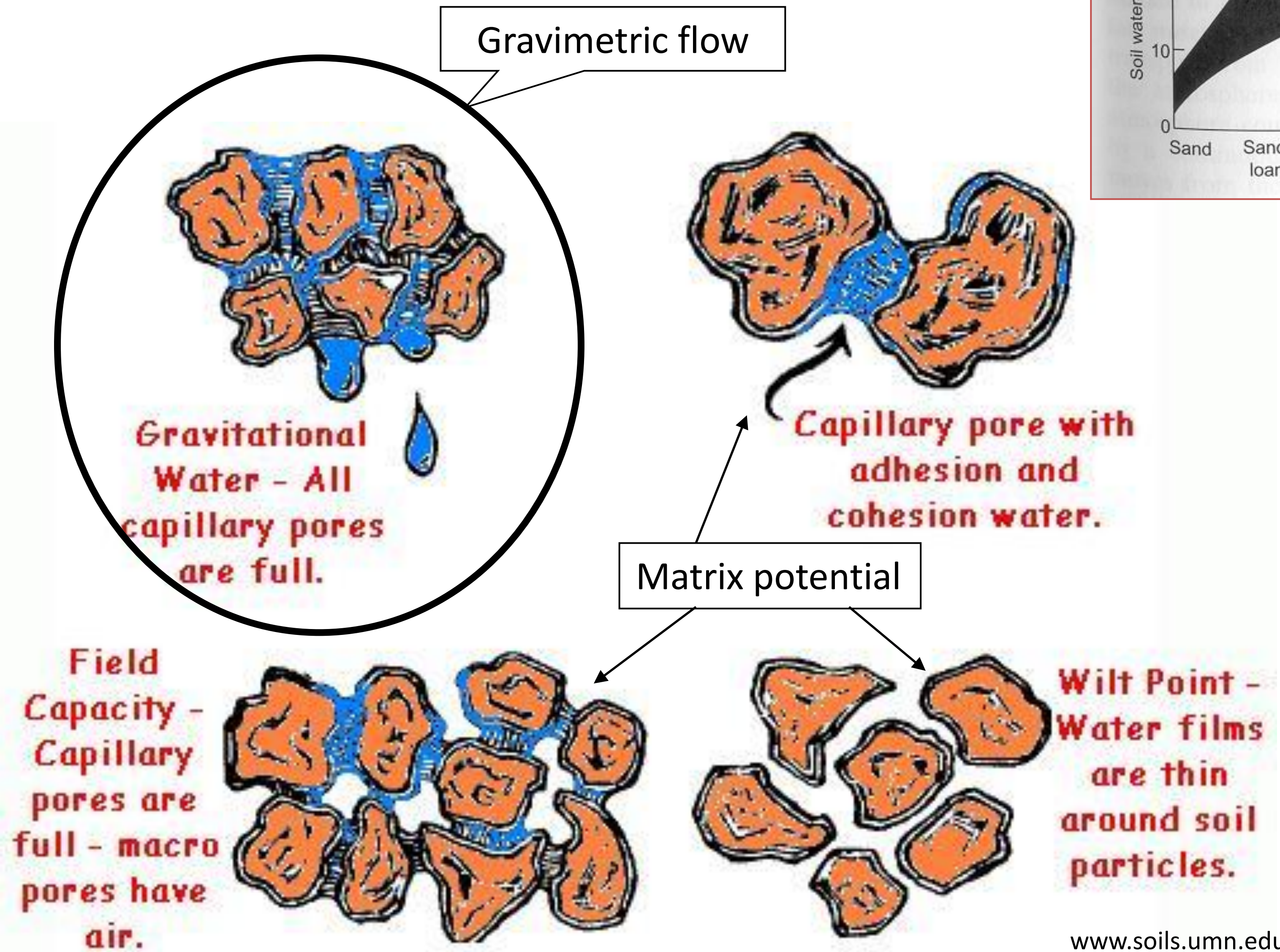
Infiltration

Application in ecology and forestry



Water in soil





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