Generating momentum on water and forests in the Balkans project

GeMBalkans

Generating momentum on water and forest management

Basics of forests hydrology

Prof. d-r Ivan Blinkov

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DBU Deutsche Bundesstiftung Umwelt

Landesforsten Rheinland-Pfalz Wald. Werte. Wahren.

CNVP Building a Greener Economic Environment

Tirana, 24.9.2019

Basics of forests hydrology

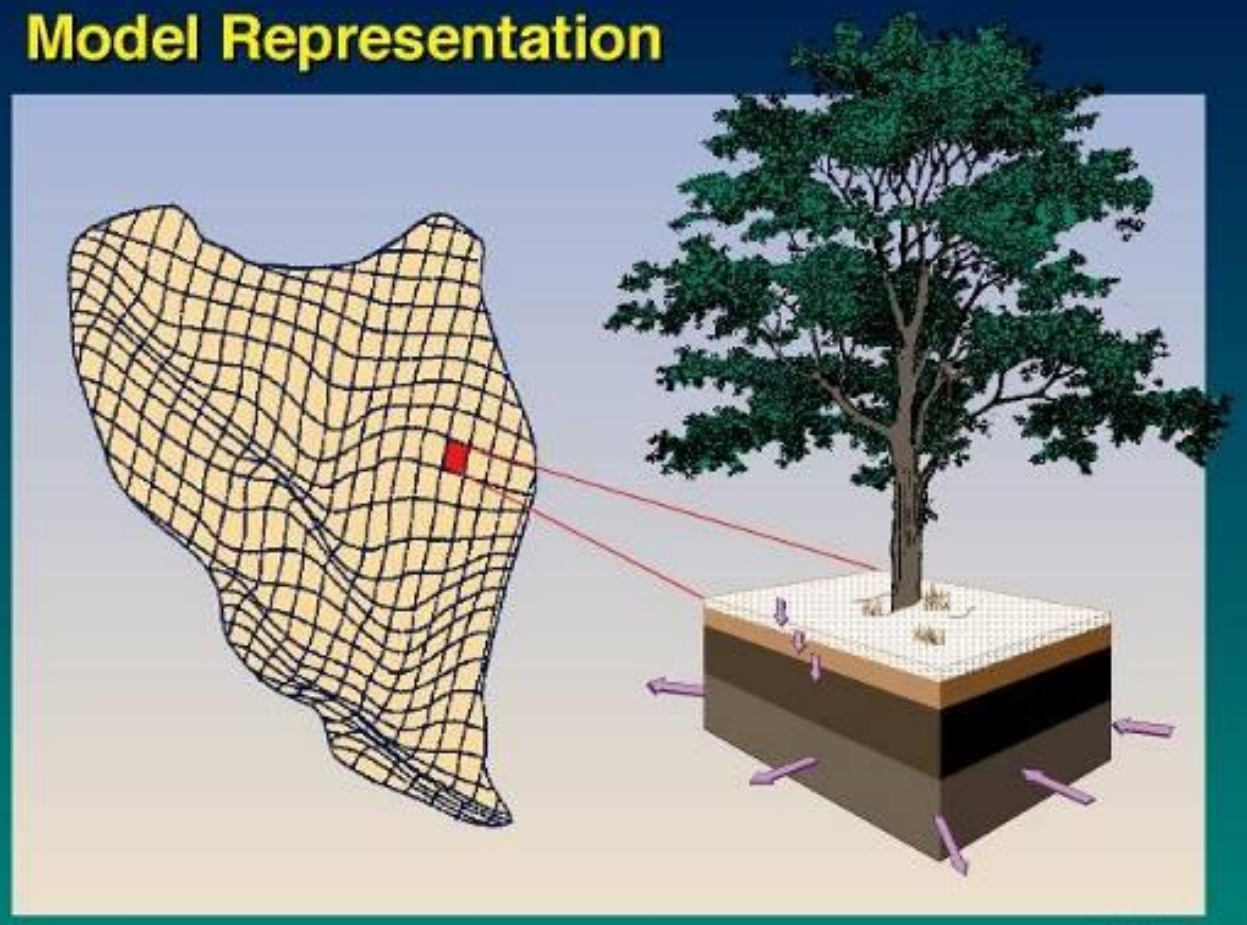


Figure 1. Model representation of a watershed.

HOW AND HOW MUCH FORESTS AND FOREST MANAGEMENT MAY CONTRIBUTE TO:

1 - OPTIMIZING THE WATER CYCLE IN TERMS OF PROVIDING WATER RESOURCES

AND

2- MITIGATION OF WATER RELATED HAZARDS

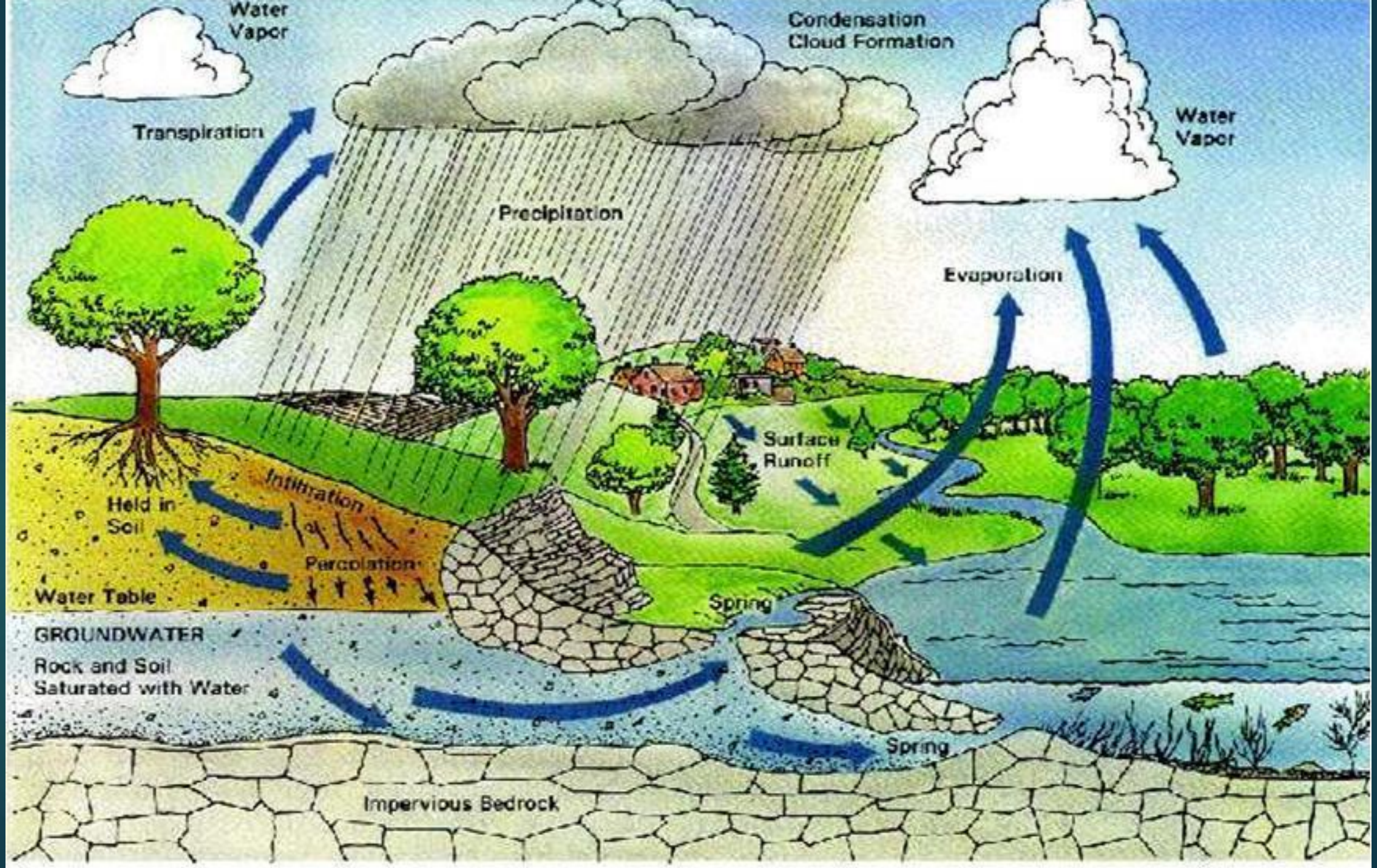
Why is it important

	Serbia		Bulgaria		Albania	Belize	Bhutan	Burundi	Macedonia
Designation function	1000 ha		1000 ha		1000 ha	1000 ha	1000 ha	1000 ha	1000 ha
Forests	**2720**	**100,0**	**3738**	**100**	**772**	**1366**	**2575**	**476**	**998**
Production	1787	65,7	2387	63,9	611	N/A	N/A	N/A	N/A
Protect. of soil and water	598	21,9	439	11,7	131	N/A	2575	276	N/A
Conservation of biodiversity	163	6,0	572	15,3	40	N/A	N/A	N/A	N/A
Social services	164	6,0	220	5,9	N/A	N/A	N/A	N/A	N/A
Multiple use forest	8	0,3	120	3,2	N/A	N/A	N/A	N/A	3N/A
Other woodland	**508**		**23**		**262**	**200**		**N/A**	**143**
Protecti. of soil and water					24				N/A
Protection of soil and water	**598**	**100**	**427**	**100**	**796**	N/A	**2575**	**276**	**0-zero N/A**
production of clean water	39	6,5	227	53,1	N/A	N/A	N/A	N/A	N/A
desertification control	33	5,5	0	0	N/A	N/A	N/A	N/A	N/A
avalanche control	0	0	0	0	N/A	N/A	N/A	N/A	N/A
erosion, flood protection	466	77,9	200	46,8	N/A	N/A	N/A	N/A	N/A
other soil and water	60	10,0	0	0	N/A	N/A	N/A	N/A	N/A

Forests have a crucial impact on the amount of surface water, as well as soil and groundwater. Only some of the rainfall will reach the surface of the soil in the forest, as some of them will be kept in the tree crowns; and evaporation and transpiration will take place from the trees.

The larger the forest cover, the more water retained.
This in turn reduces the amount of water flowing as a surface leak and as an outflow from the basin.

European Environment Agency., 2015


Water Vapor
Condensation Cloud Formation
Transpiration
Water Vapor
Precipitation
Evaporation
Surface Runoff
Infiltration
Held in Soil
Percolation
Water Table
Spring
GROUNDWATER
Rock and Soil Saturated with Water
Spring
Impervious Bedrock

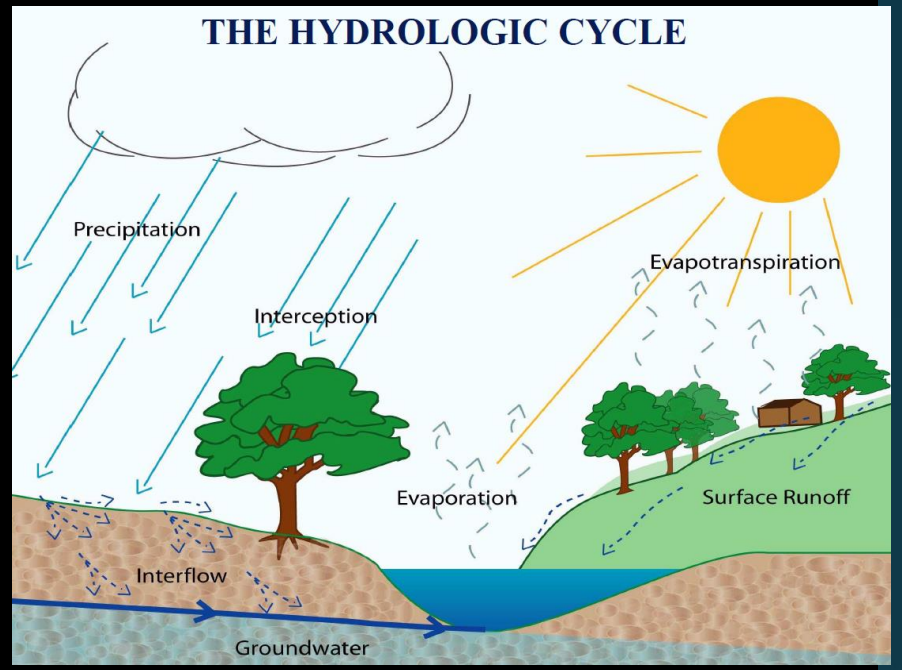
Factors affecting water balance:

- physiographic conditions,
- relief characteristics
- altitude
- pedological-geological characteristics
- vegetation characteristics
- degree of forest cover
- precipitation amount, pluviometric regime, air and soil temperature and humidity
- land management,
- watershed management

- In forest ecosystems, water balance differences additionally depend on:
- Structure, composition, crown cover, age of forest stand
- Forest activities

Water Balance Equation

- $P = E + W + F$ (mm)



- P – Precipitation [mm] $P = Pv + Ph + Fst$
- Pv – vertical precipitations (rain, snow, hail ...)
- Ph - horizontal precipitation (fog, drifting ...)
  Fst – leaking along the tree branches and stem)

E - Summarized evaporation (mm) $E = Ei + Es + Et$
Ei - evaporation of the water retained on the crown and stems
Es - evaporation from the beginning
Et – transcription

F - general water runoff (mm) $F = Fov + Fg$
Fov - surface runoff

Fg - ground runoff

Interception

The amount of rainfall that is retained in the crowns of forest trees and shrubs and the lower part of grass and grassy plants in natural ecosystems and then evaporates into the atmosphere, not reaching the soil surface, is called interception.

The amount of precipitation retained by interception (Ic) depends on several factors:

intensity of precipitation (and = mm / min),

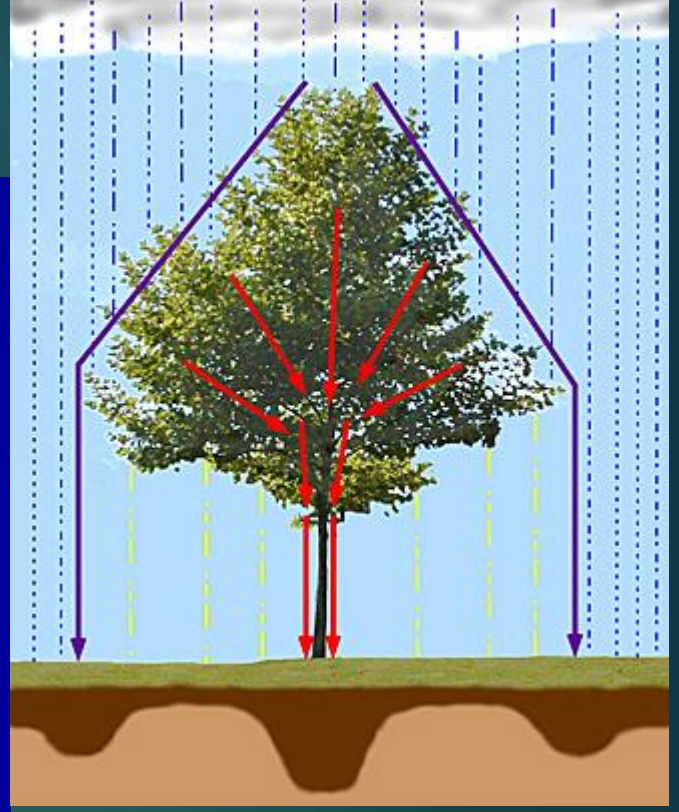
seasons,

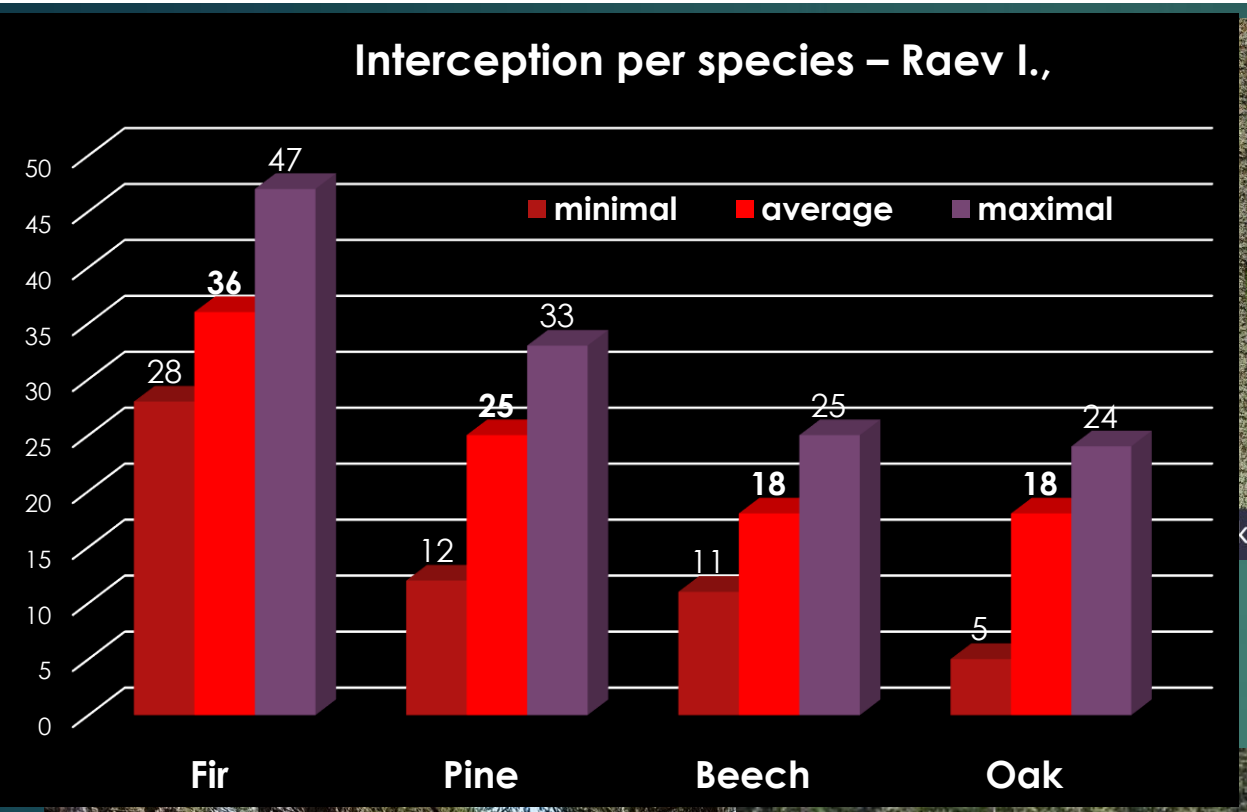
geographical position of the catchment area

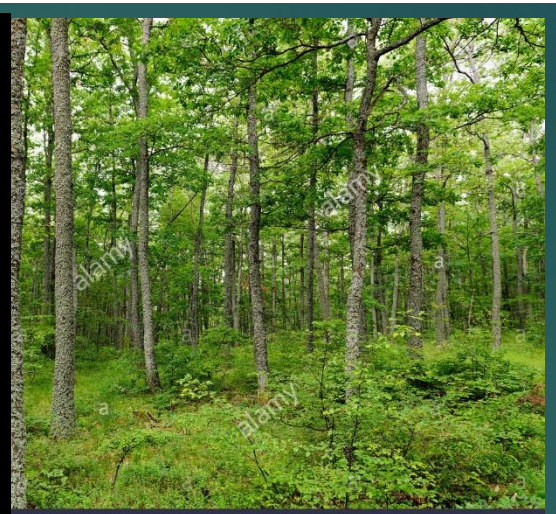
exposure of the main wind direction area. winds,

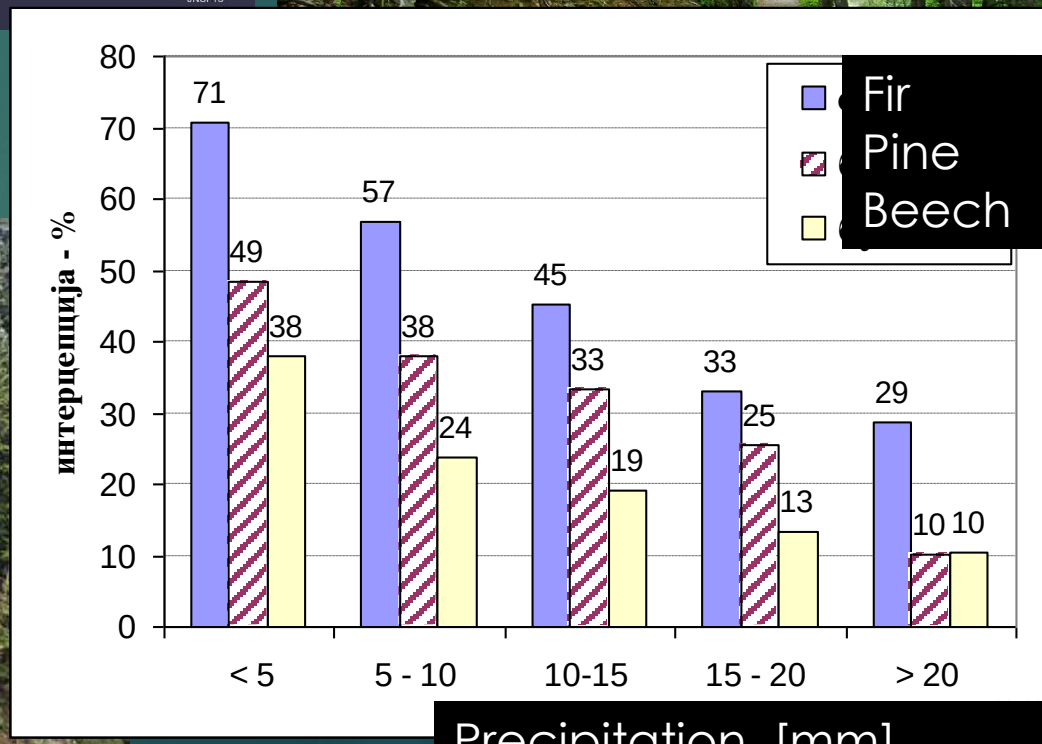
biological properties of forest trees (leaves or conifers, crown shape, bark type, leaf mass, crown development,

characteristics of the standsn (coverness, age, composition




Interception per species – Raev I.,
minimal
average
maximal
50
45
40
35
30
25
20
15
10
5
0
28
36
47
12
25
33
11
18
25
5
18
24
Fir
Pine
Beech
Oak

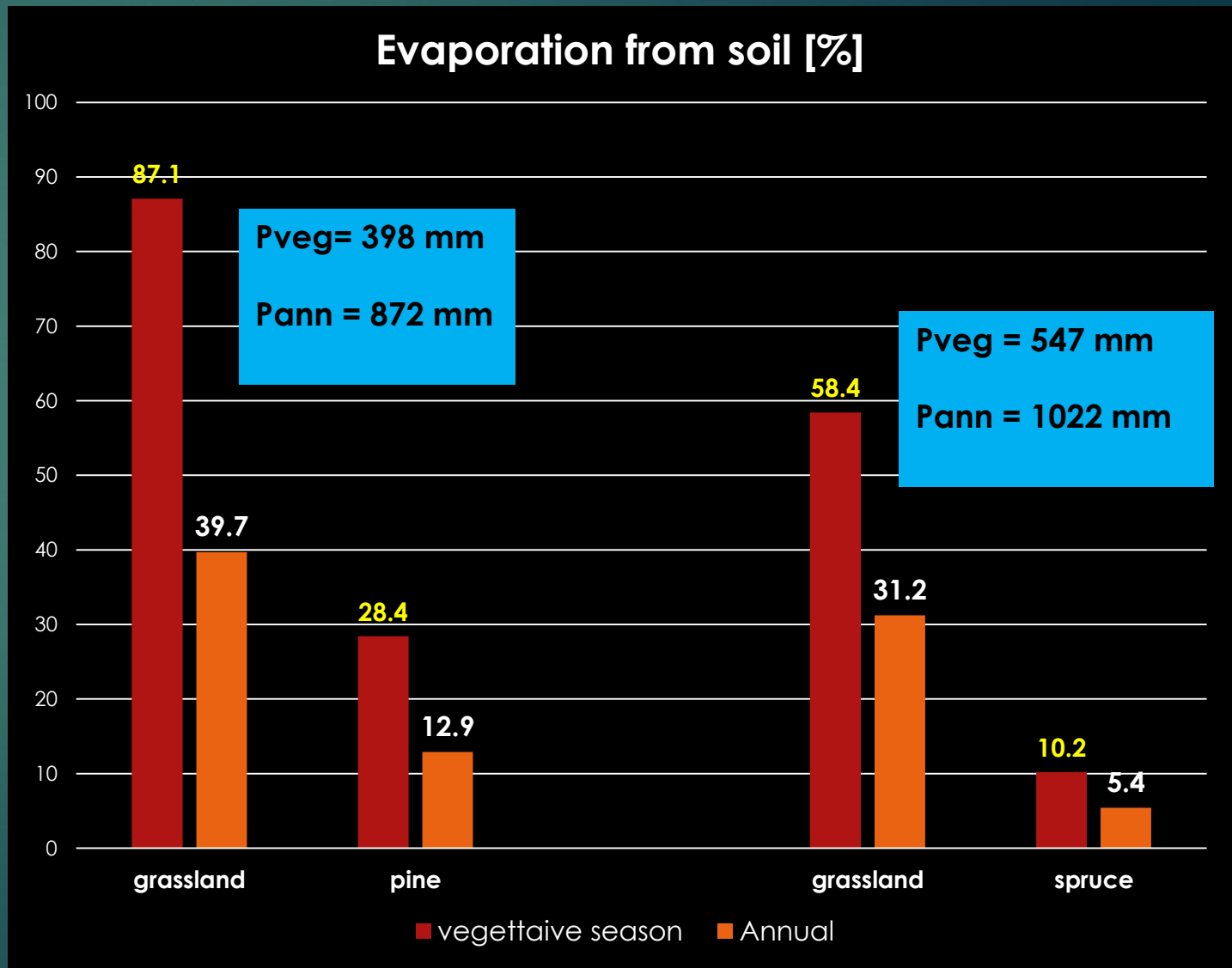



Fir
Pine
Beech
интерцепција - %
80
70
60
50
40
30
20
10
0
71
49
38
57
38
24
45
33
19
33
25
13
29
10
10
< 5
5 - 10
10-15
15 - 20
> 20
Precipitation [mm]

Evaporation (Es) .

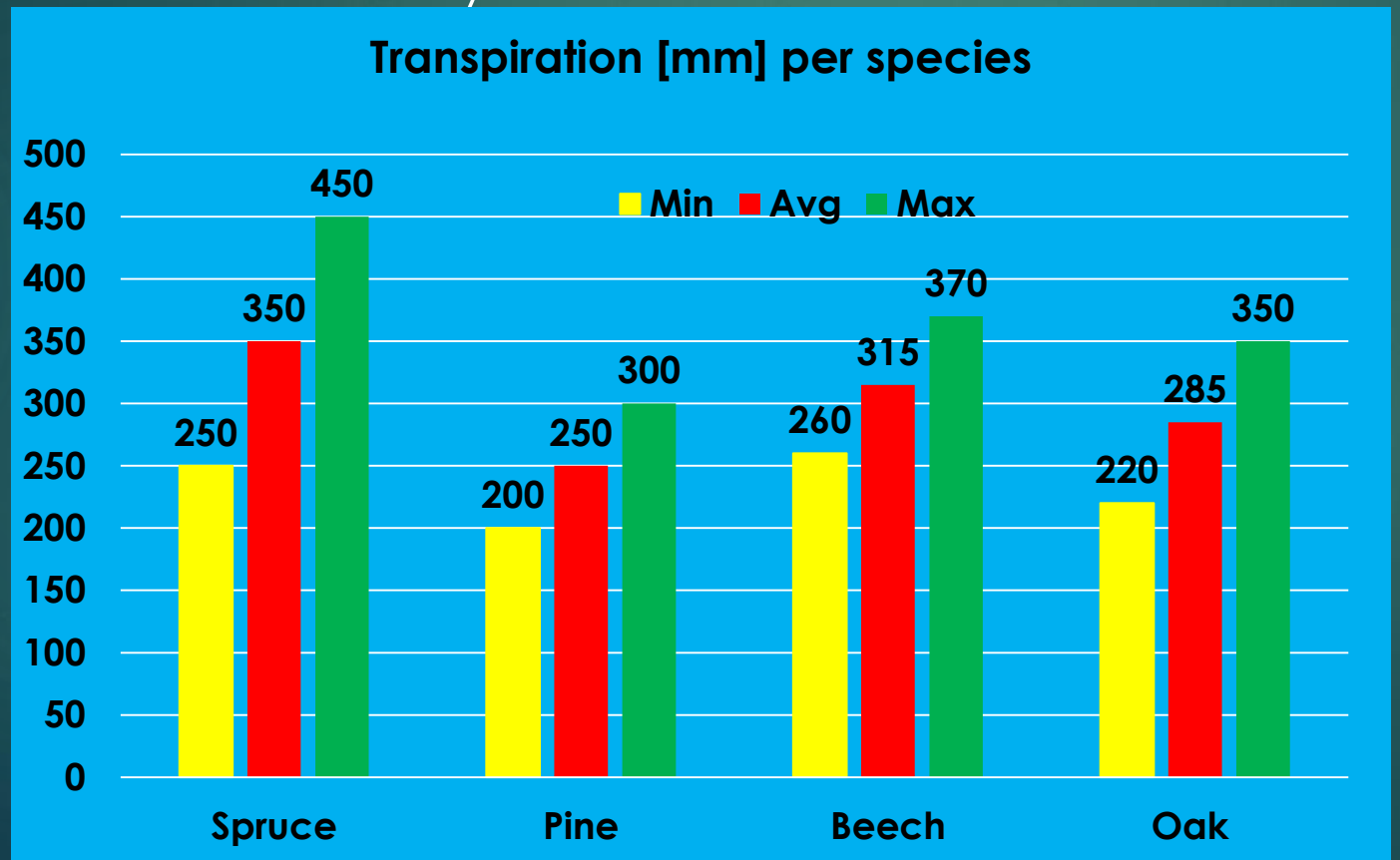
Evaporation from the soil surface consists of 2 parts:
- physical evaporation of water from the forest bed and
- physiological evaporation of water from the ground flora.

Evaporation depends on:
Available energy - the sun as a source of energy;
Water temperature measured on the surface,
the wind speed,



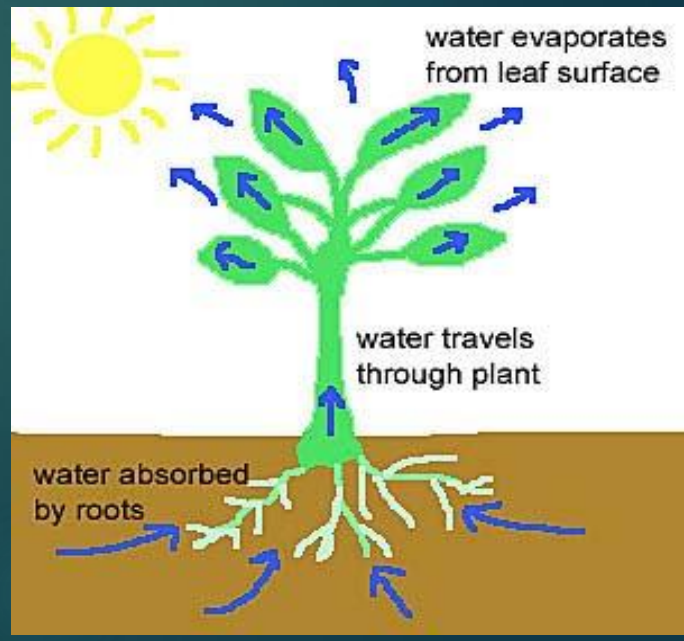
Transpiration

- The **transpiration** depends on the biological characteristics of the wood species and bushes (litters, cetins) and certain conditions of location (temperature and relative humidity, wind velocity, exposure, annual time (vegetation or non-vegetation period etc.). For forest vegetation, these values are within the range of 31,3% - 45,0% of the total annual amount of returns, which also directly affects the retention.
- .

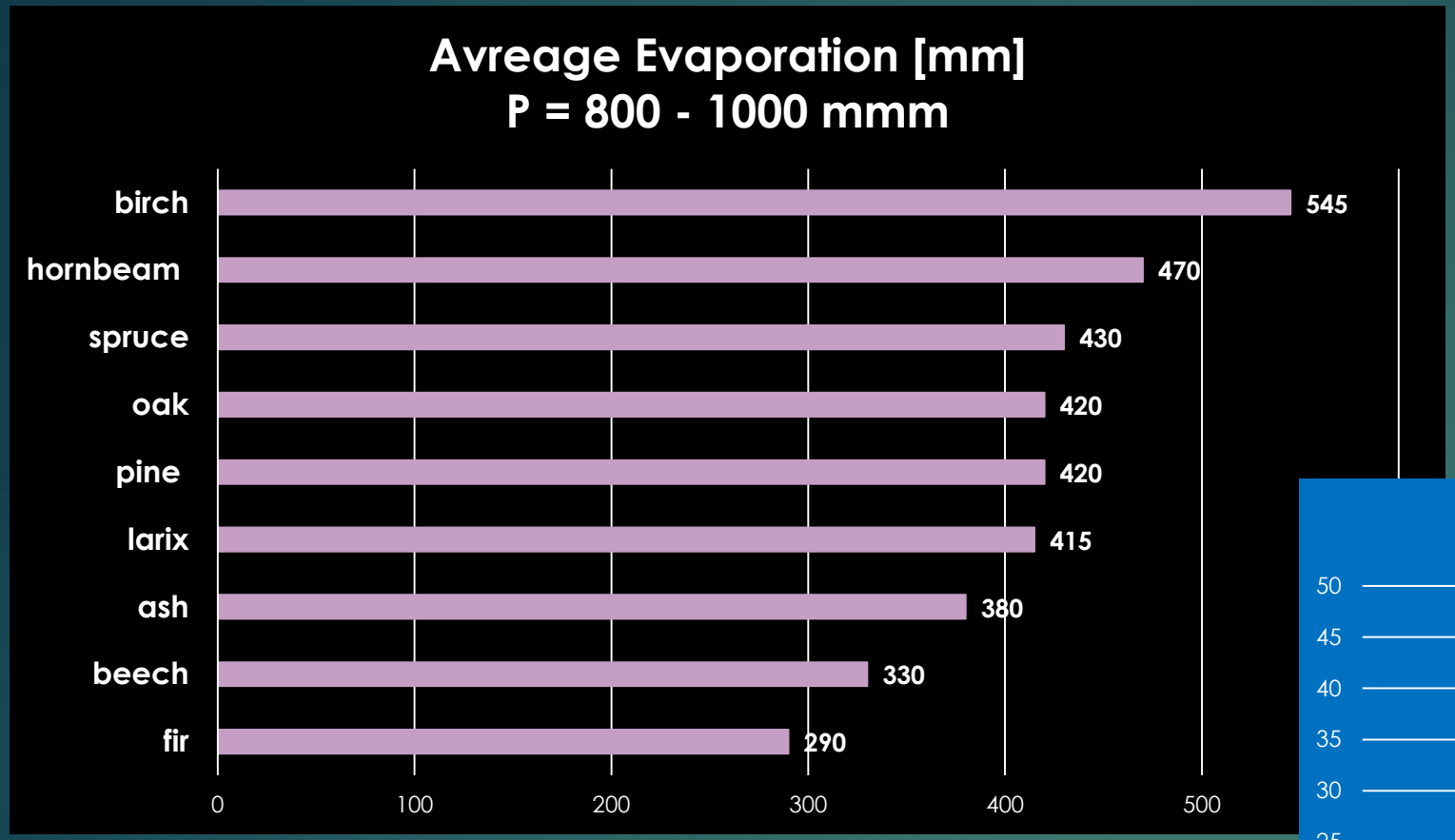


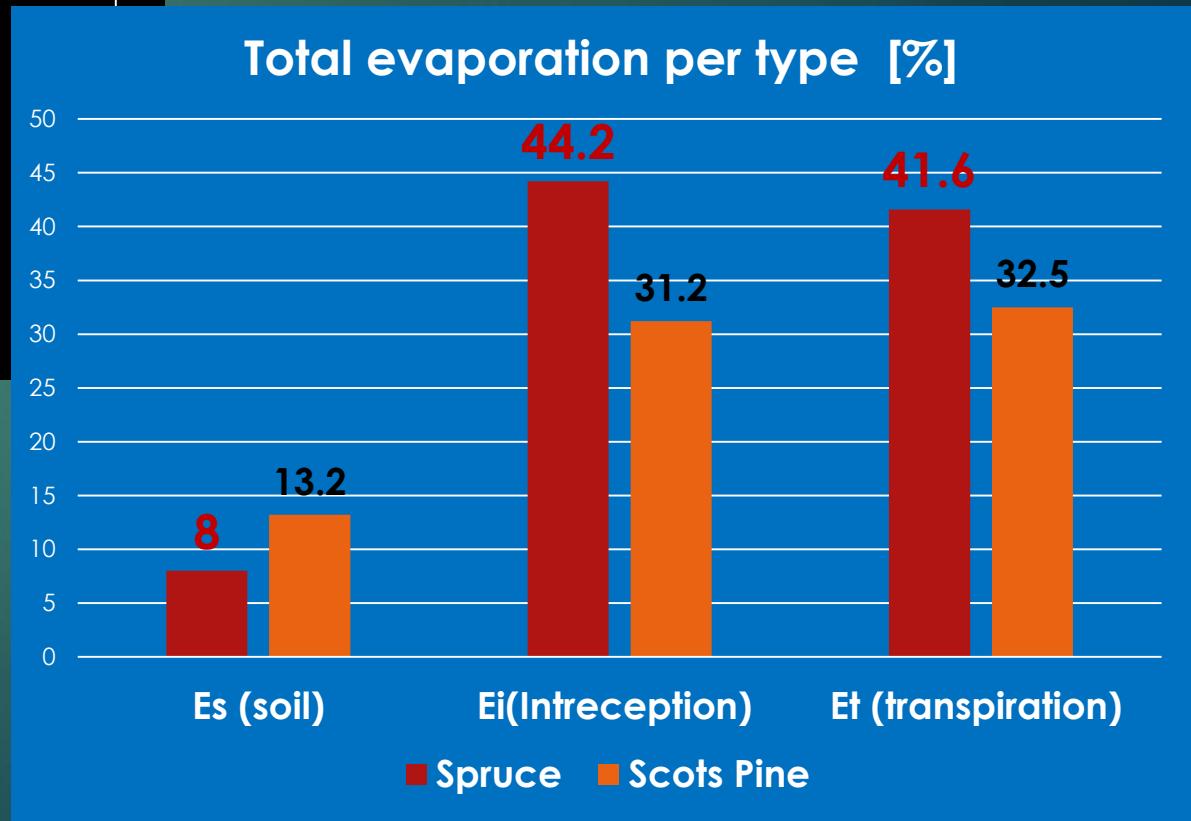
The transcription process consists of three stages:

- absorption (root zone);
- translocation (transport of water through the trunk);
- transpiration (evaporation of water through the leaves).

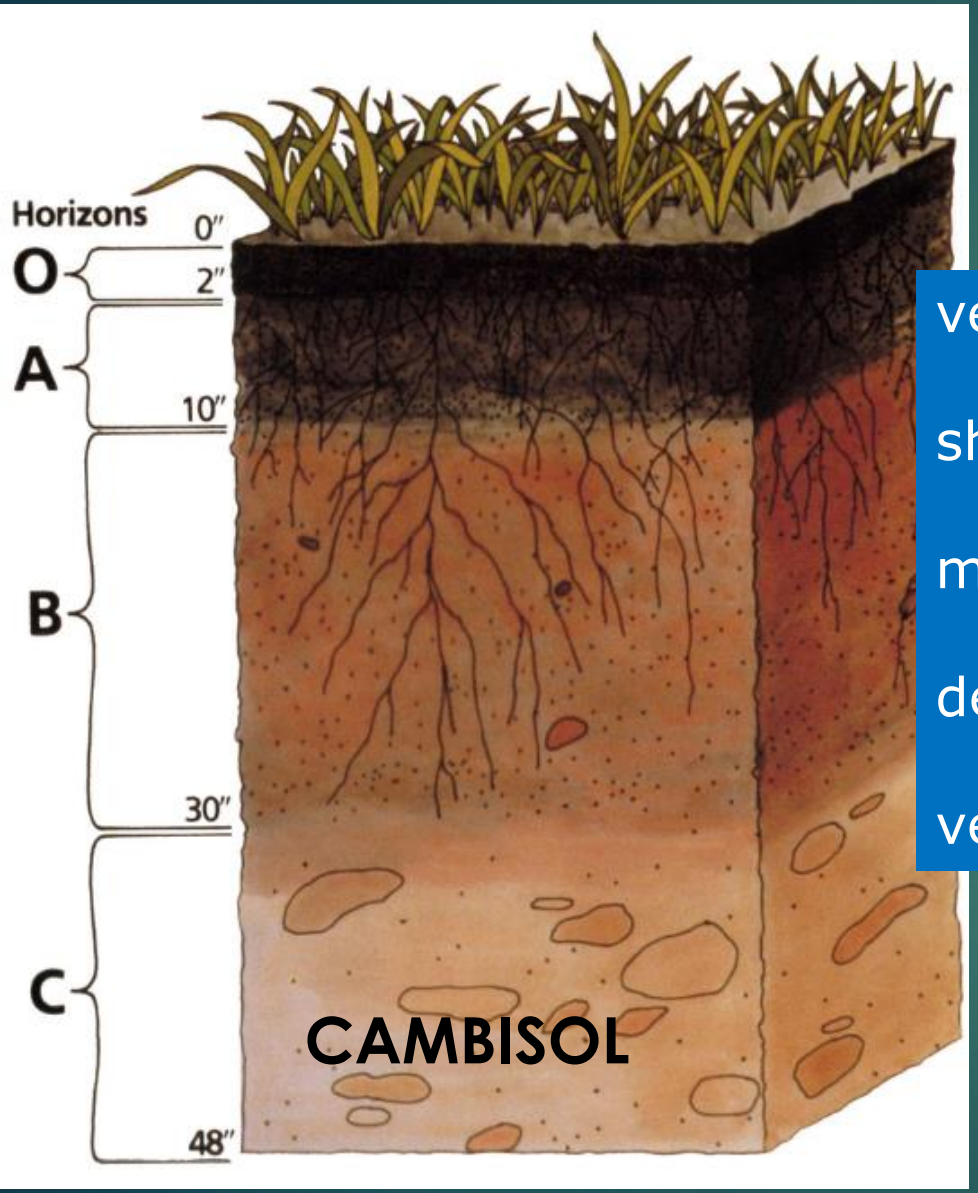


Vegetation and total evaporation





SOILS - “sponge effect”



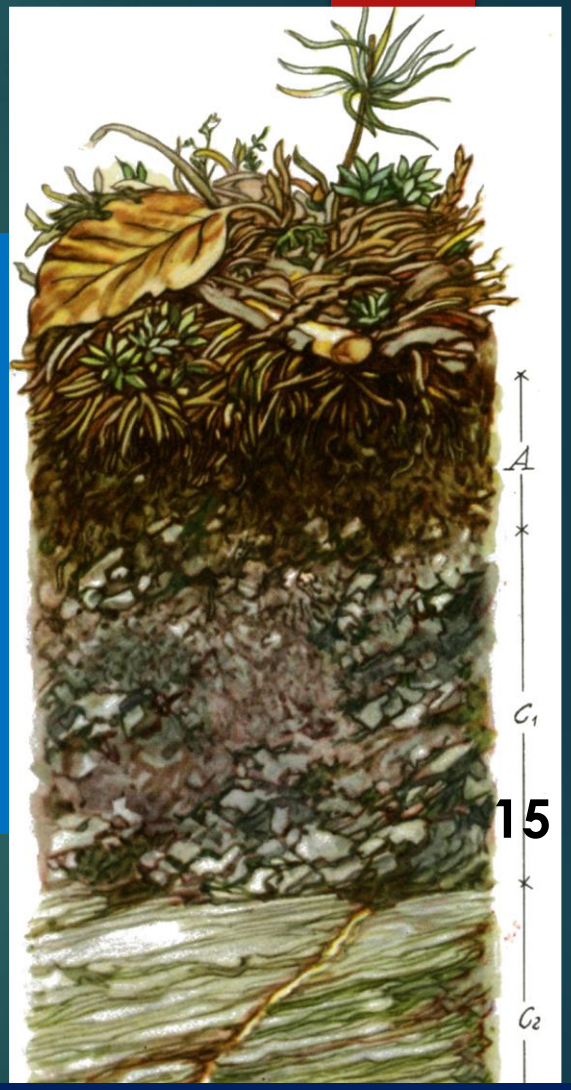
very shallow (less than 25 cm),

shallow (25 cm-50 cm),

moderately deep (50 cm-90 cm),

deep (90cm-150 cm) and

very deep (more than 150 cm)



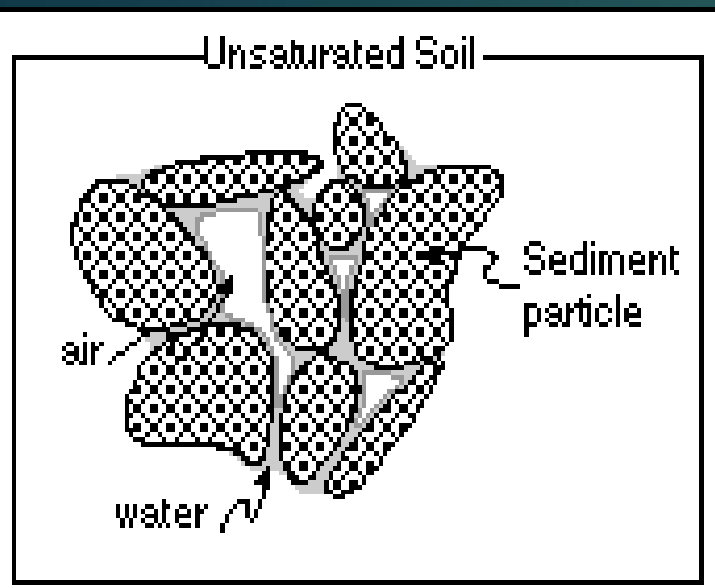
Ranker

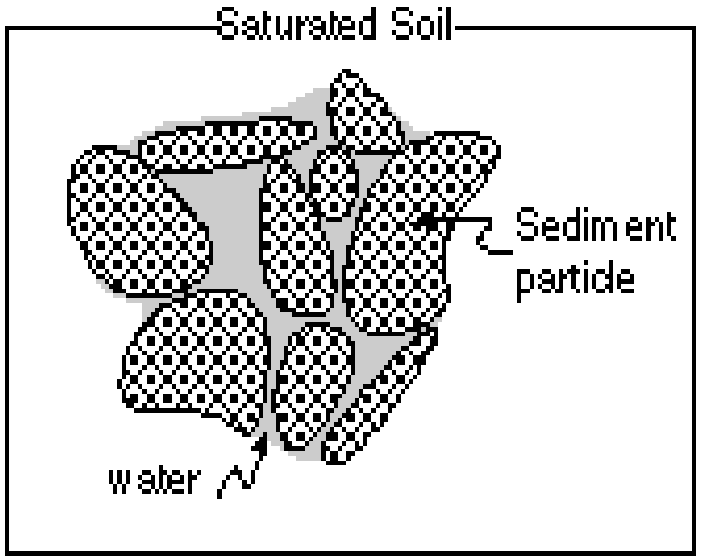
Water movement in forest ecosystems

- In forest ecosystems this complex process is directly influenced by various factors.
- Part of the water that reaches the soil surface is infiltrated into it, and part run on the surface.

  Part of the infiltrated water penetrates deeper into the soil , and part of it run subsoil.
- The rest of the soil that deeply penetrates the soil feeds underground releases and causes underground swells.

  ,





- The volume of soil (B) consists of a volume of dry matter (Ws), a volume of water (Ww) and a volume of steam (Wp).
- Soil pores contain water in all 3 aggregates.
- Soil porosity is the ratio between the sum of the pore volume (water and steam volume) to the total volume.
- Saturation of a soil occurs when all the pores are completely filled with water. Theoretically, the content of the saturated water should be equal to the content of the pores, but in the soil there are so-called pores. There are gas "pockets", so the content of saturated water is 5-8% lower.
- The forces that hold water into the soil do not allow it to flow quickly. In a fully saturated soil, water responds to the force of gravity like any other free body. When the water content is lower than the saturation point, then other forces affect the movement of the water. osmotic potential (O) and gravity potential (W)

$\frac{\Delta H}{L}$

Darcy law

- The movement of water in the soil can be understood as the difference in total potential energy between 2 points of soil. Water moves from the highest point to the lowest potential point, which means it can move from low to high water content locations.
- The movement of water through saturated layers is defined by the Darcy's law
- $$Q = K * A * \Delta H / L$$
- Q – discharge (m^3/s)
- A – cross profile (m^2)
- $\Delta H / L$ - hydraulic gradaient , altitude difference (m)
- K – coef. of permeability

Infiltration

The movement of fallen rainwater through the pedological profile is called infiltration.

The deeper penetration of water is called percolation.

The maximum velocity at which a maximum amount of water can enter the soil is called the infiltration capacity.

The rate at which water penetrates the soil at any time is called the infiltration rate.

The infiltration process is affected by:
the water content already in the soil;
soil saturation with water;
porosity of the soil (soil);
the thickness and type of forest cover;
biological activity and content of organic matter;
the ability to moisten the surface layer;
ice, soil freezing processes;
the quality of infiltrated water, (quantity of suspended solids, waste, etc.);

Vegetation and infiltration

- One of characters of forest soils is the better structure then other soils, with a large presence of parts of root systems of forest trees and shrubs. Forest soils have much better air-water regime compared to other types of soils. The more the soil is able to retain a larger amount of water, the greater the retention capacity.According to Embermaer data, the absorption capacity of the forest starts up to 25% in relation to the total average annual return quantity. The values of infiltration of water in the forest are different and range from 25-44% of the average annual return quantity. The speed and amount of infiltration are different depending on the type of trees. This is conditioned by the root system, the quality of the forest, as well as the conditions for chimerization and mineralization in the forest floor.

- According to Klotzli, the infiltration time of 100 mm of water (t) and the percentage of surface runoff (p) from the total runoff are:
- pasture with compacted soil, t = 3 ^{h} ; p = 51-78 %
- normal pasture , t = 2 ^{h} ; p = 3-15 %
- coppice beech stand , t = 20 ‘ ; p = 10 %
- high beech stand, t = 2 ‘ ; p = 0 %.

Runoff

Runoff in forest ecosystems is a very important component of water balance.

A mathematical representation of the runoff is the runoff coeficicnet expressed through introduced and so on. swelling coefficient - η. Runoff coefficient represents the relationship between fallen and swollen precipitation.

Theoretically, coeff. Of runoff may range from 0-1, (0-100%), but for a natural watershed generally the catchment ranges from 0.10 to 0.75.

Land management activities and hydrological parameters (FAO, 2000)

Impact	Basin size [km^2]						
	0.1	1	10	100	1 000	10 000	100 000
Average flow	x	x	x	x	-	-	-
Peak flow	x	x	x	x	-	-	-
Base flow	x	x	x	x	-	-	-
Groundwater recharge	x	x	x	x	-	-	-
Sediment load	x	x	x	x	-	-	-
Nutrients	x	x	x	x	x	-	-
Organic matter	x	x	x	x	-	-	-
Pathogens	x	x	x	-	-	-	-
Salinity	x	x	x	x	x	x	x
Pesticides	x	x	x	x	x	x	x
Heavy metals	x	x	x	x	x	x	x
Thermal regime	x	x	-	-	-	-	-

Legend: x = Obervable impact; - = no observable impact

Forest, Forest Activities and Runoff Coefficient

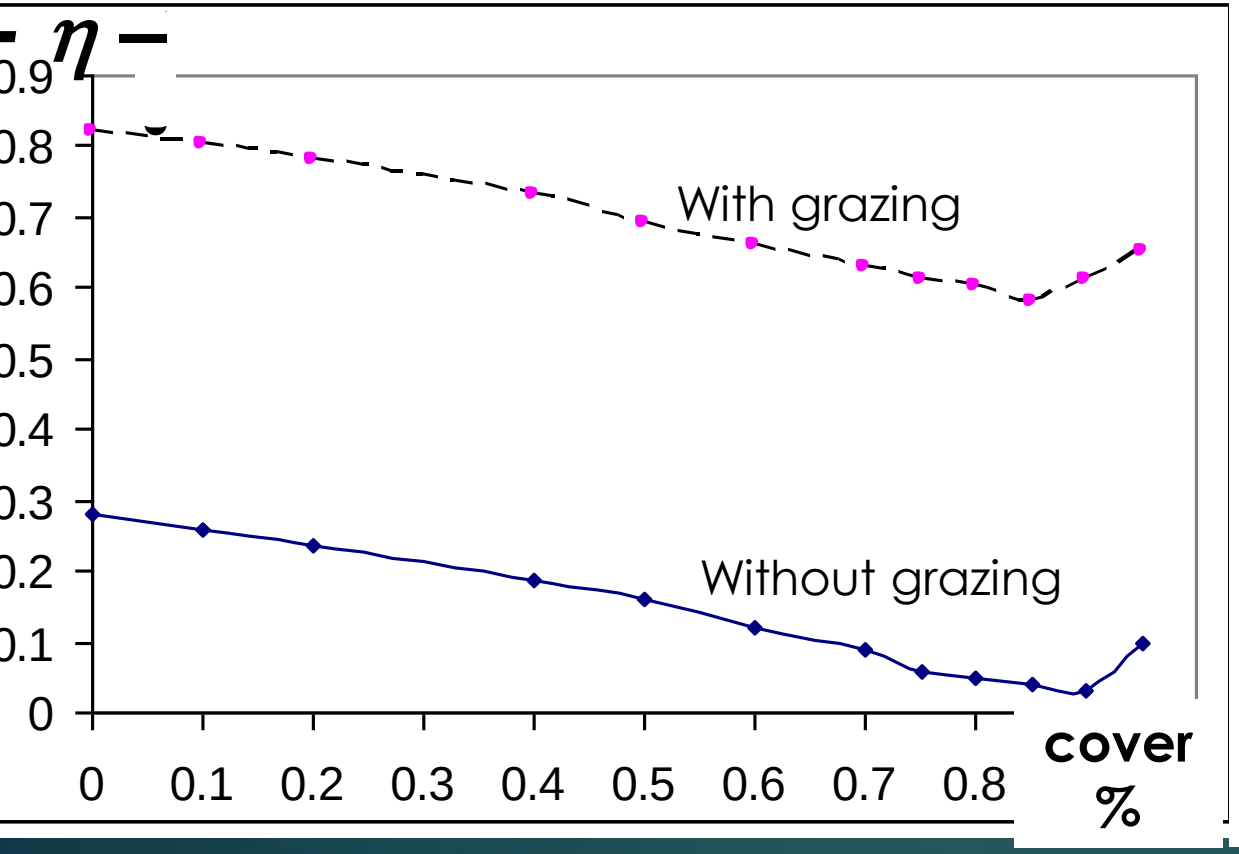
Runoff coefficient depend on slope of terrain and cover type

cover	Slope of terrain in [%]			
type	17,5	36,5	57,7	83,9
grassland	0,82	0,9	0,95	
scots pine	0,17	0,25	0,33	0,48
spruce	0,03	0,05	0,08	0,34
beech	0,02	0,03	0,04	0,05

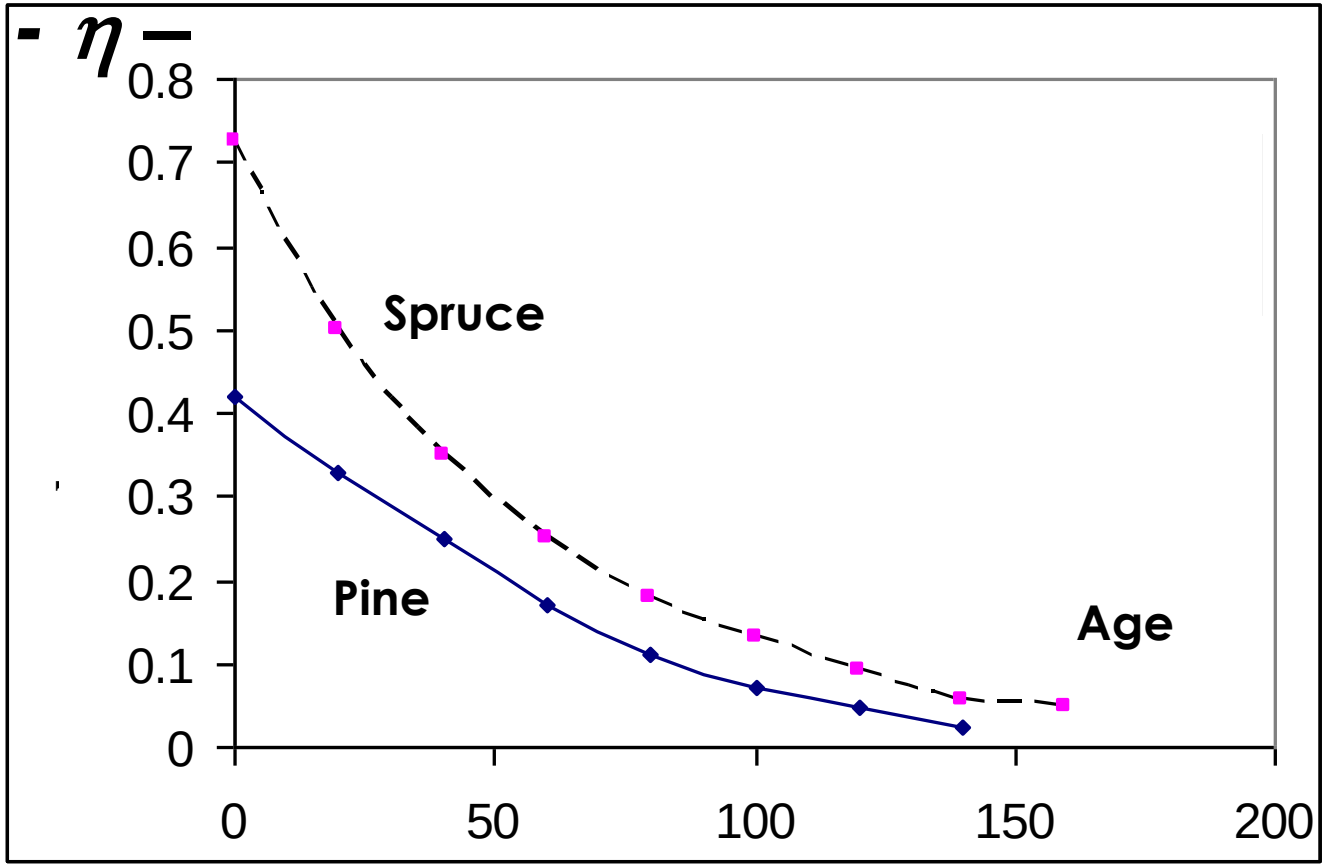
- According to Maran and Lotha, (thinning) and reducing of coverness up to 0.5, runoff increased up to 2.5 times, and if we continue with the thinning and r Up to 0.2, runoff ncreases 7 times.

According то Schaffhauser (1982 – Austria)
Runoff coffecient is
Forest stands - almost 0
bushland - 0,017
grassland - 0 0,187
Ski-trail - 0,364
Meadow with grazing – 0,601

Runoff Coefficient - η – depend on cover percent and grazing



Runoff Coefficient - η – depend on age of stands od Scots Pine and Spruce



- Depend on the cover percenti on forest, the runoff coeficient - η – is:
- C =85% (broadleaved forest , $\eta = 0.342$,
- C = 98% (mixed conifer-broadleaved forest), $\eta = 0.313$.
- - mountain grasslands $\eta = 0.412$,
- - bareland with sparce vegetation $\eta = 0.518$.

Hydrological element	Selective Cut	Shelterwood logging	Clear Cut
Interception in crown (% of total precipitation)	8	5	0
Retention in the forest floor (% of precipitation)	10	7	4
Infiltration (% of precipitation)	76	63	53
Surface runoff (% of precipitation)	6	25	43

- According to Angelov and Petkov (1960), surface runoff in acacia plantations is 2 times smaller than in black pine plantation under the same planting conditions.

  According to Marinov (1984) in the Melnik river basin the coefficient of surface runoff in oak, beech and acacia at a slope of 64-75% ranges from 0.01 - 0.22,
  in black pine stands under the same conditions, coef. ranges from 0.21 - 0.45.

  According to Hibbert (USA, 1969), with a 1% reduction of forest cover, the runoff increases by 4.5 mm. This is some kind of gradient for the runoff .

  Also interesting are the data from Patrick (USA), who experimented in mixed oak forest (oak and maple) at a slope of 40-65% in two plains with an area of 34.7 and a control of 38.8 ha. Average rainfalls were 1450 mm.
  The average annual total runoff was 630 mm or runoff coeff = 0.43.

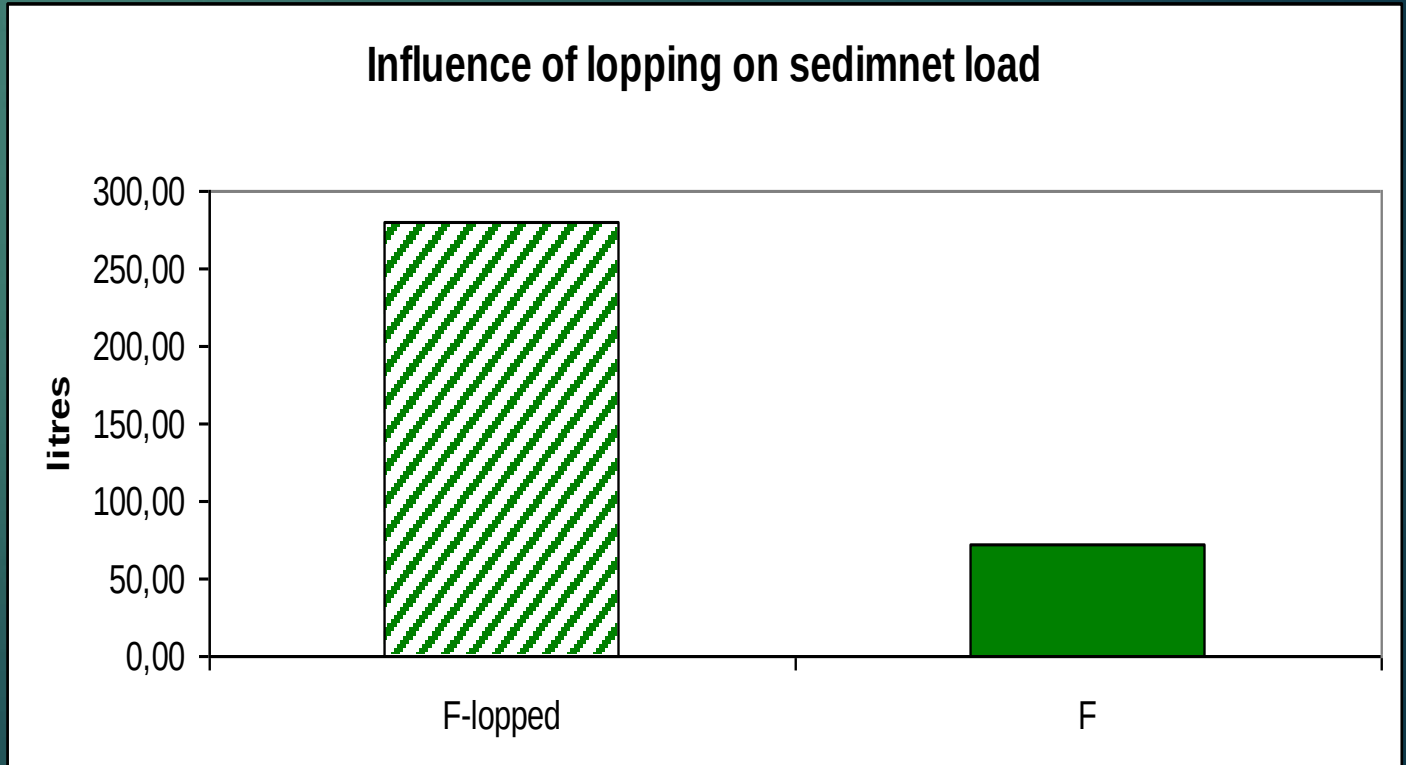
- Then selective logging was carried out on 13% of one catchment.
  After 5 years of logging, there were no significant changes in the basin. Then the whole basin was cut and cleaned and all the wood material removed. In the first year after clear cut , the runoff coefficient increased to 0.69, compared to the control basin where it was 0.434.
  Since the logging preserves humus and forest cover, over the years the growth of the offspring reduces swelling so that after 10 years of pure logging from a hydrological point of view, the plantation has returned to its original position.

Non capilar porosity and runoff

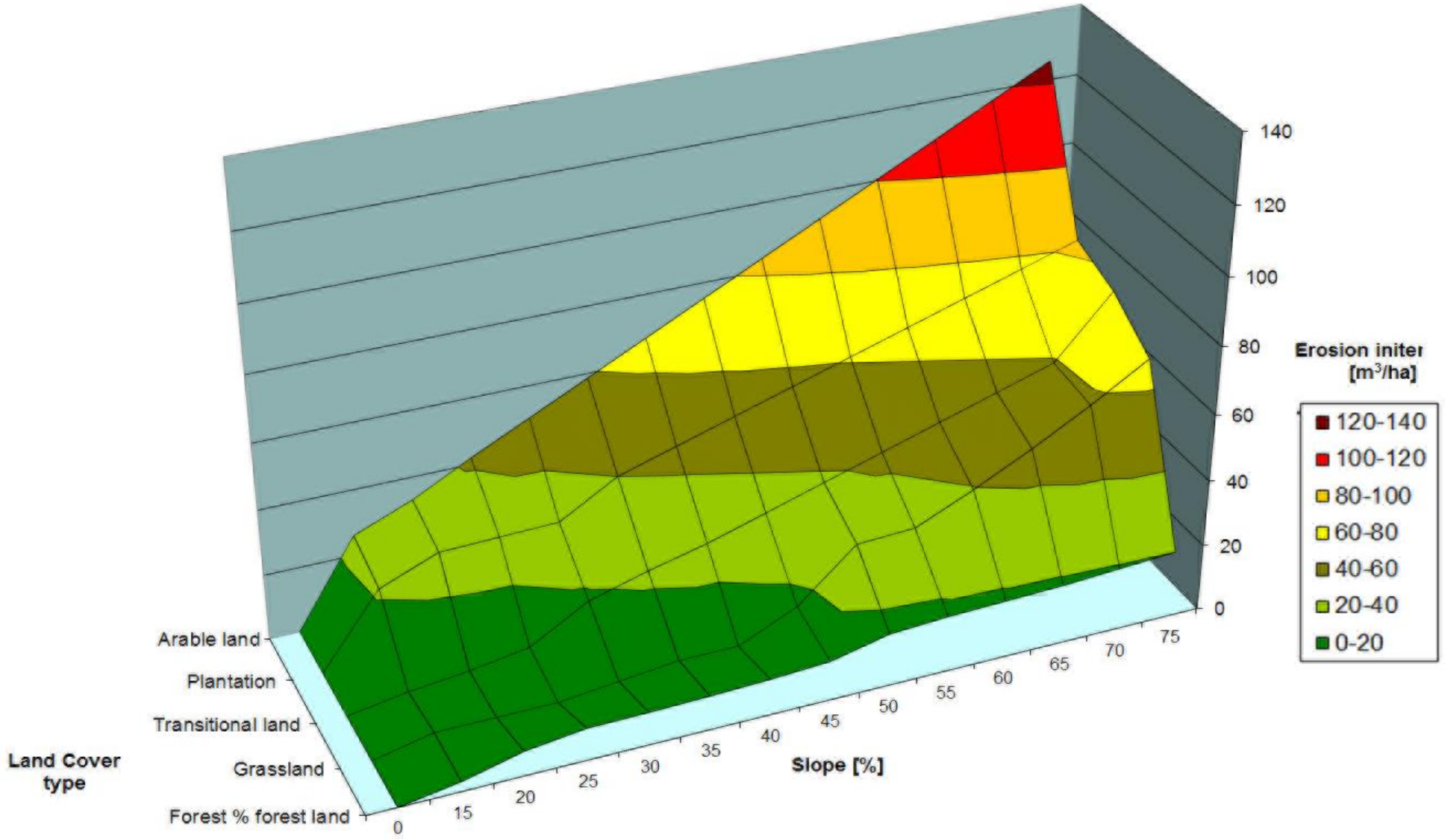
- According to Tarasvili (1955), in the Caucasus, in the Beech-Carp forest with high intensity of thinning, the non-capillary porosity is 5.6-11.0%, and in the un-thinned same forest is 11.6-16.6 %.
- Cegelisvili (1967), cite that even 15-20 years after the clear cut, the non-capillary porosity is from 5.1 to 6.1%, after the gradual cuts of 6.6 - 8.8%, and after the thinning or selective cut, practically is 12,5 – 115, 8 (as in the control forest).

LC and slope	runoff l/m²	sediments gr/l
arable land - bare 25%	14	54,7
meadow - 25%	4,5	3,3
grassland - 50%	2,7	1,1
pine forest - age 45	0,13	0

Sediments



Erosion as a function of slope and land cover [m³/ha]



Resume

The impact of forest ecosystems on the movement of water is mainly reflected in the ability to retain large amounts of water, which is closely related to its distribution, ie. equilibrium flow in the hydrographic network and sources at periods when flow is weaker or stronger.

Interception ranges from 13 - 35% of total annual precipitation, transpiration accounts for 31.3 - 45.0%, evaporation from the soil is about 5-12%.
The ability of coniferous plants (pine, fir, spruce) to retain greater amounts of moisture in regions with dry climates adversely affects the entire ecosystem. mm.

The water infiltration values of forest soils are varied and range from 25-44% of the average annual amount of rainfall.
According to the literature, depending on the type and possibilities of the soil, up to 1 m depth of 500-2000 m3 water per hectare is retained. The Tao responds to 50 - 200 mm rainfall

Intensive rainfalls and peak of discharge

- During intense rainfall, the forest ecosystem can retain water to a certain extent, but then after saturation of the soil, a surface runoff occurs.
  This depends on a number of factors, intensity of rain, total amount of rain, pre-soil moisture etc.
-

  One of the key elements is that in the torrent fluid besides the liquid there is a solid phase-sediments . Sometimes volume ratio is almost 1: 1.

A well-preserved forest ecosystem protects against erosion and minimizes the amount of sediment and the total flow of two-phase fluid.

IN a case of extreme precipitation events even in a small basins up to 100 km2, influence of forest is limited.

Last Slide

It's not over...

Thank you for your attention