Water balance of the forests

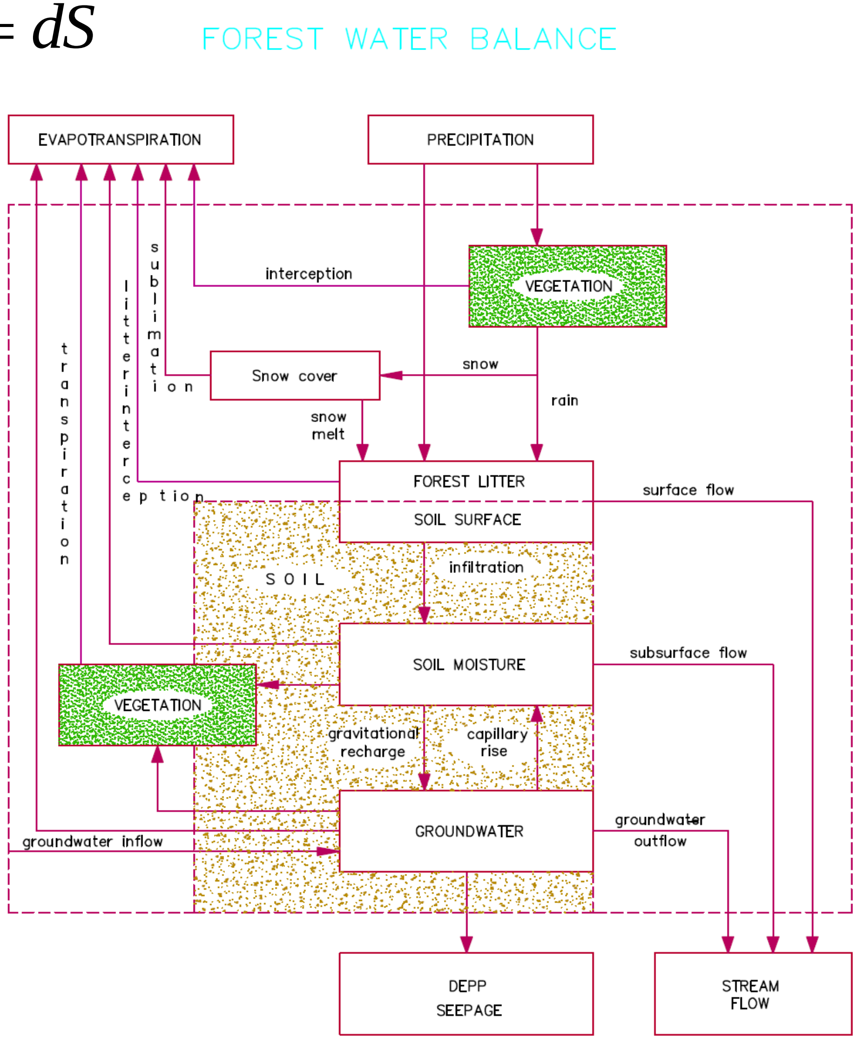
Zoltán Gribovszki
University of West Hungary, Faculty of Forestry,
Institute of Geomatics and Civil Engineering,
Department of Water Management

Forest Water Balance

$$P + p - E_{su} - T_{soil} - T_{gw} - R_{s,g} - \mathrm{Re}_{gw} = dS$$

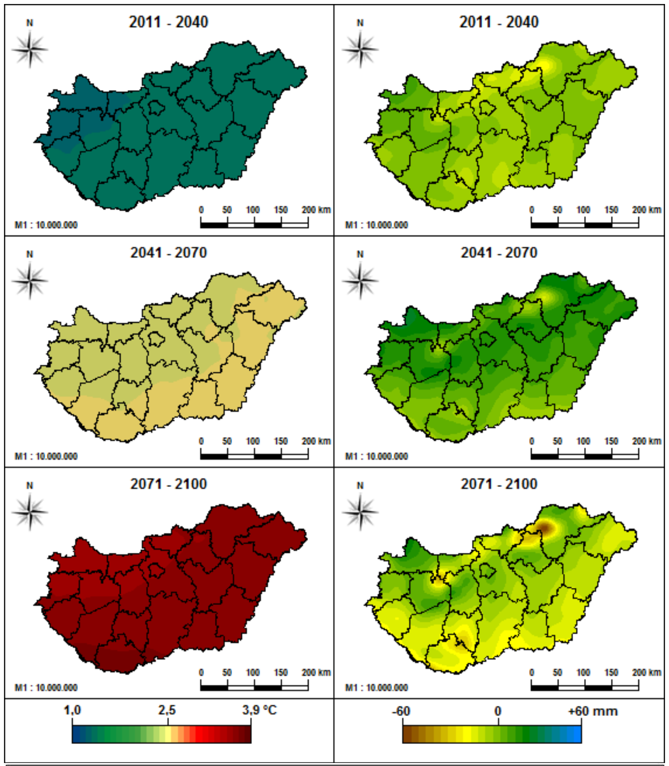
Where:

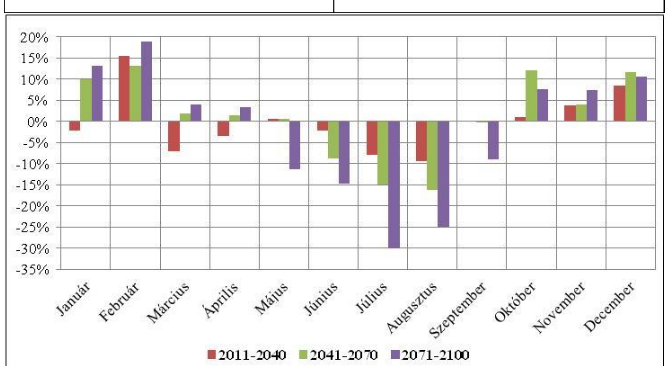
P: fluid and solid macro-precipitation;
p: fluid and solid micro-precipitation;
Esu: interception (canopy and litter);
Tsoil: transpiration from vadose zone;
Tgw: transpiration from groundwater;
Rs,g: surface and subsurface runoff;
Regw: groundwater recharge;
dS: change in storage.

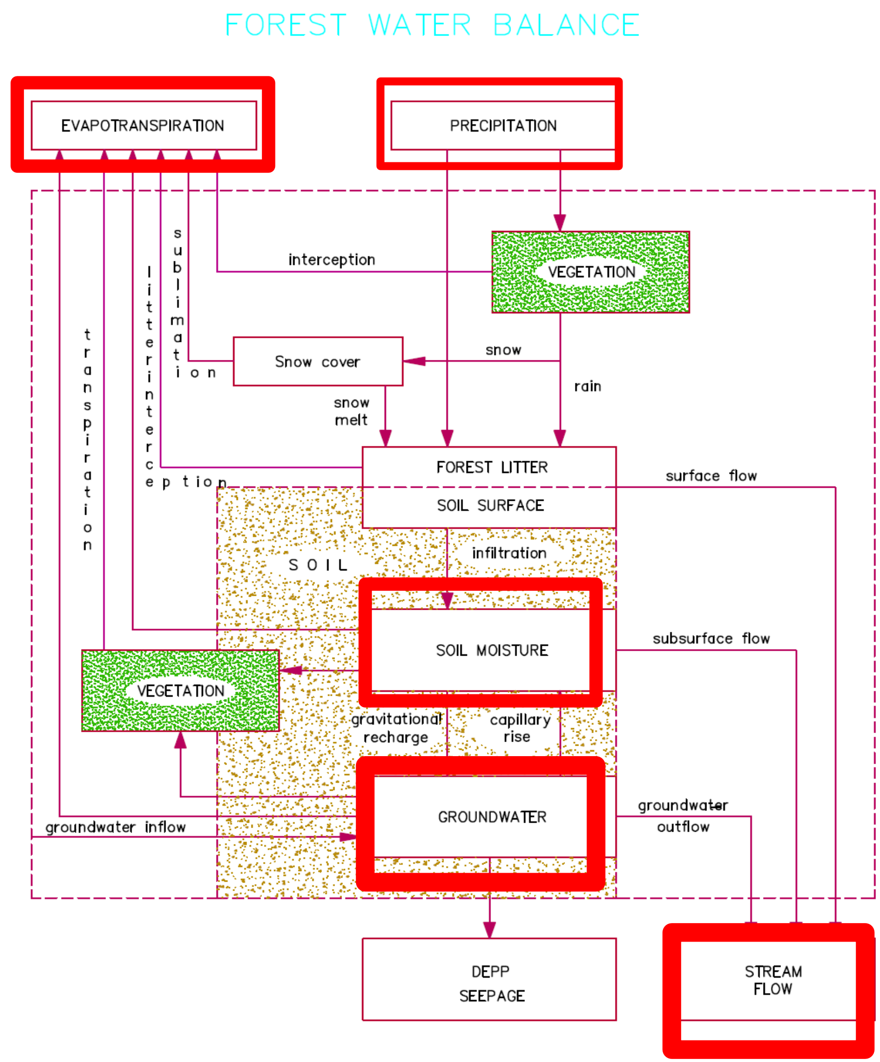


Kucsara 1996

Climate change





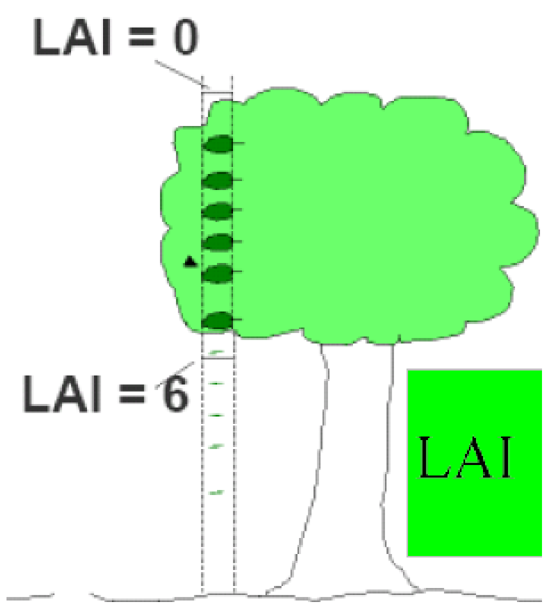


Evapotranspiration (ET)

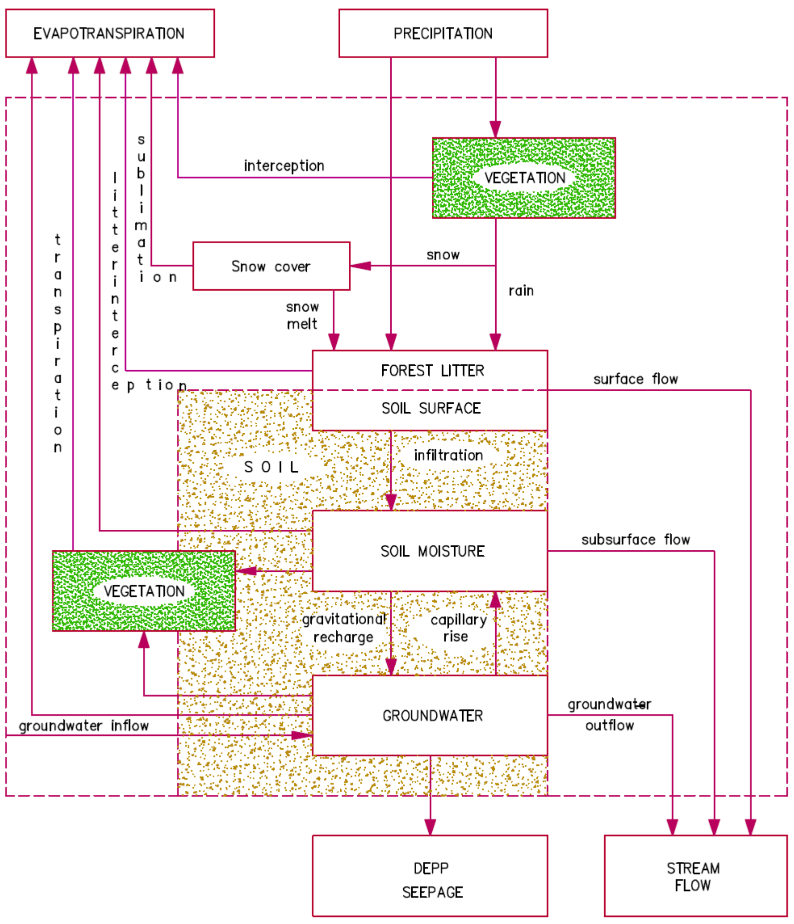
ET 90% of the P in Hungary

- Interception (40% of P)
- Transpiration (50% of P)

$$LAI \equiv \frac{\text{total area of leaf surface above ground area } A}{A}.$$



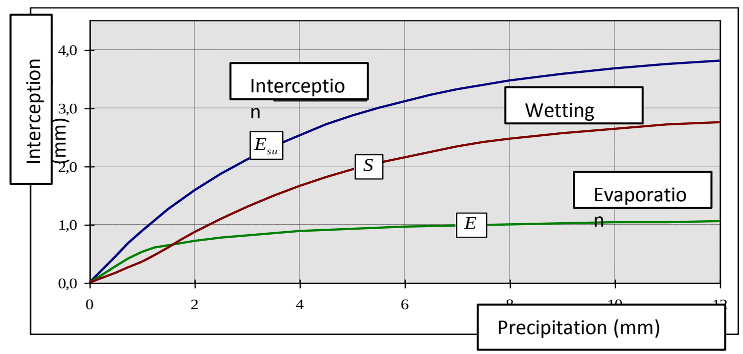
FOREST WATER BALANCE

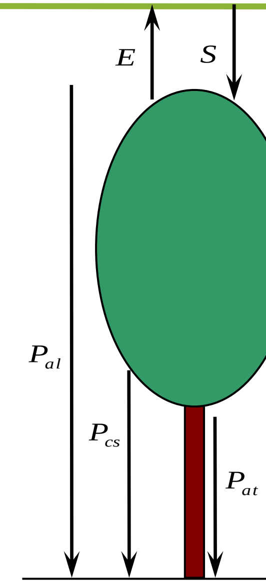


Interception

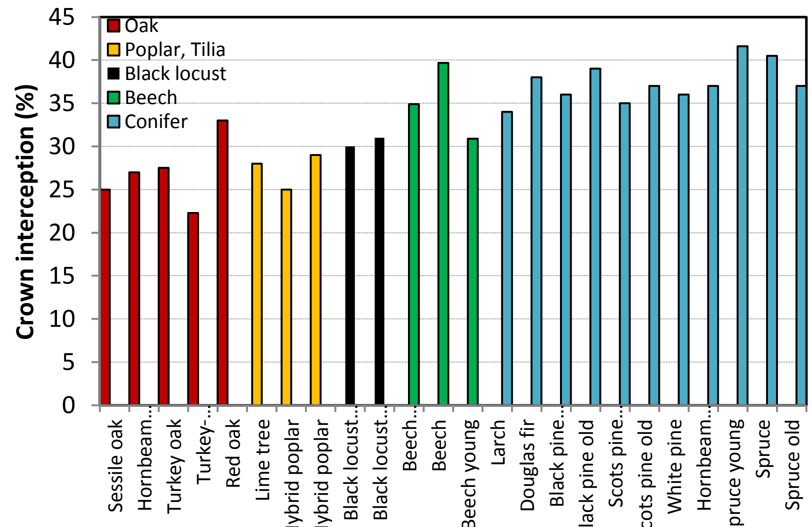
$$P = \underbrace{P_{al} + P_{cs} + P_{at}}_{} + \underbrace{S + E}_{}$$

$$P = P_{atot} + E_{su}$$





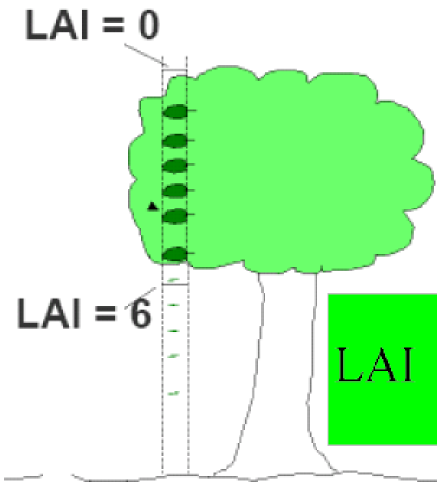
- Crown Interception
  20-40%

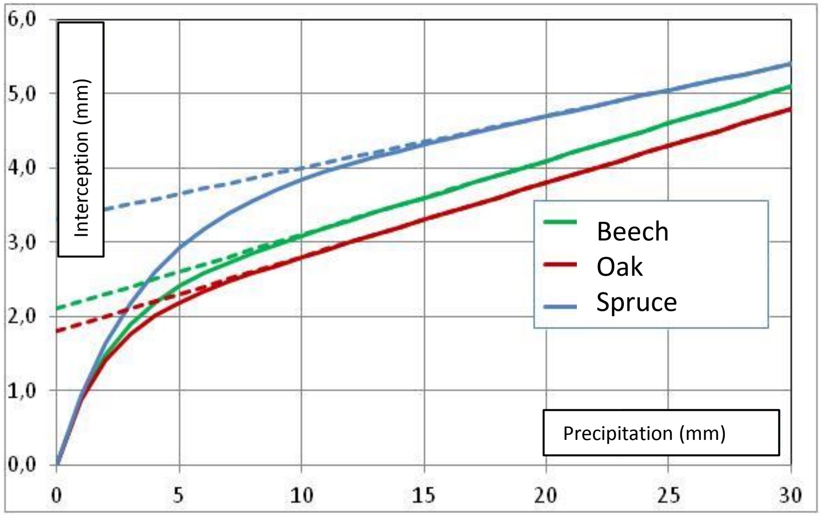


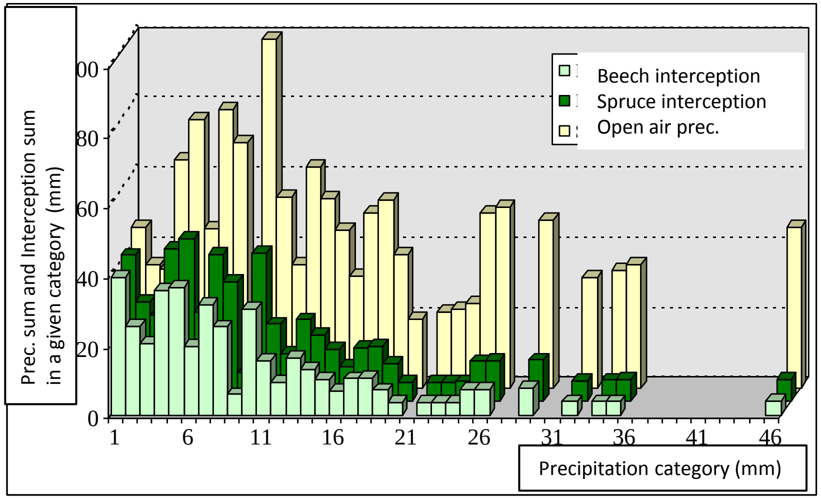
- Forest Litter Interception
  (El=Patot-Peff)
  1-5%, 5-15%

Interception

- CCI: greater (with high intensity) but less prec. event, higher temperature
- Crown Interception: (LAI?) ↓ ↑
- Forest Litter Interception: (Litter mass?) ↓ ↑





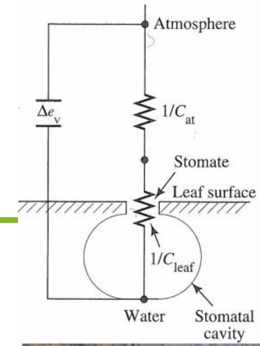


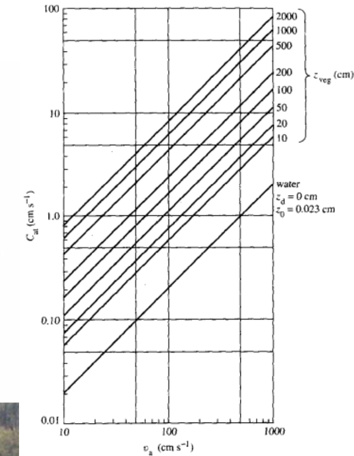
CCI: Climate Change Impact

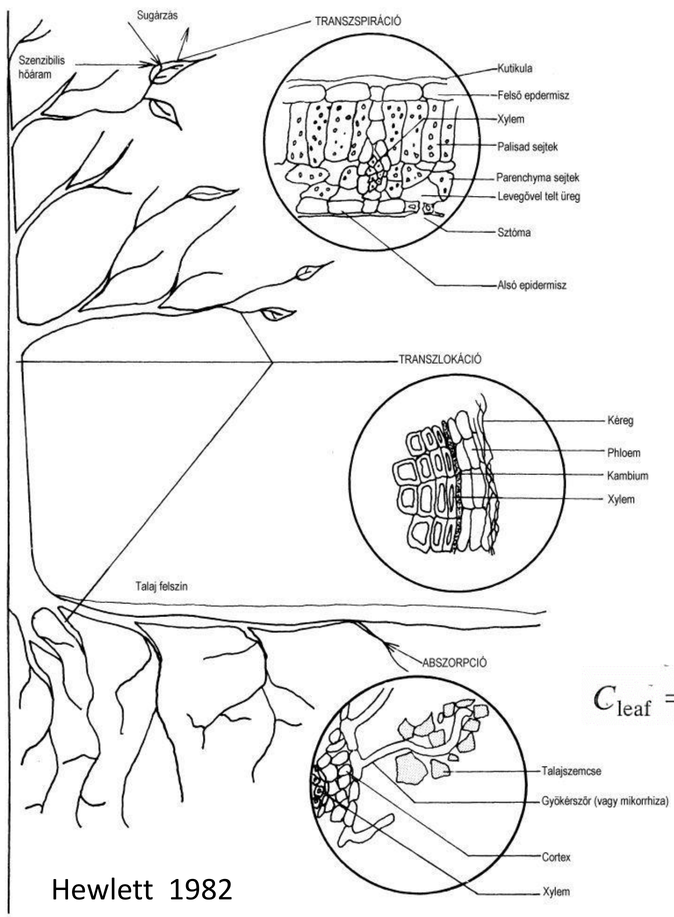
Transpiration

- LAI ~ C_{can}
- Roughness ~ C_{at}

$$ET = \frac{\triangle(K+L)+\rho_a c_a C_{at} e_a^*(1-W_a)}{\rho_w \lambda_v \left(\triangle + \gamma\left(1+\frac{C_{at}}{C_{can}}\right)\right)}$$

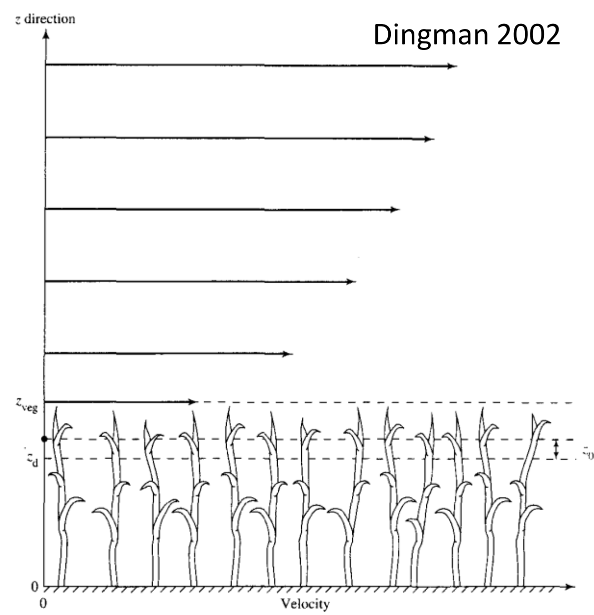


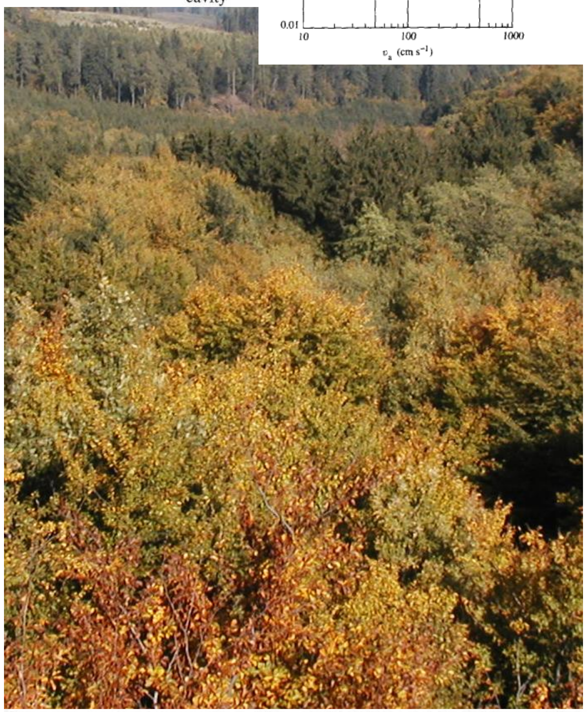




Hewlett 1982

Dingman 2002





$$C_{leaf} = C_{leaf}^* \cdot f_k(K_{in}) \cdot f_\rho(\Delta\rho_v) \cdot f_T(T_a) \cdot f_\theta(\Delta\theta),$$

$$C_{can} = f_s \cdot LAI \cdot C_{leaf},$$

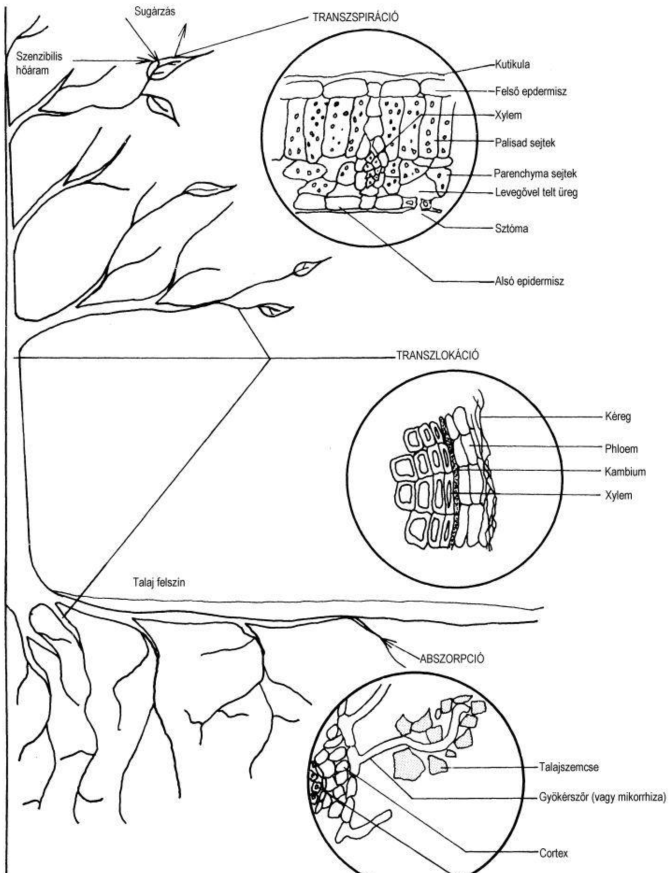
Dingman 2002

Land Cover	C^*_{leaf} (mm s^{-1})	LAI	a	z_{veg} (m)
Conifer forest	5.3	6.0	0.14	25.0
Broadleaf forest	5.3	6.0	0.18	25.0
Savannah/shrub	5.3	3.0	0.18	8.0
Grassland	8.0	3.0	0.20	0.5
Tundra/nonforest wetland	6.6	4.0	0.20	0.3
Desert	5.0	1.0	0.26	0.1
Typical crop	11.0	3.0	0.22	0.3

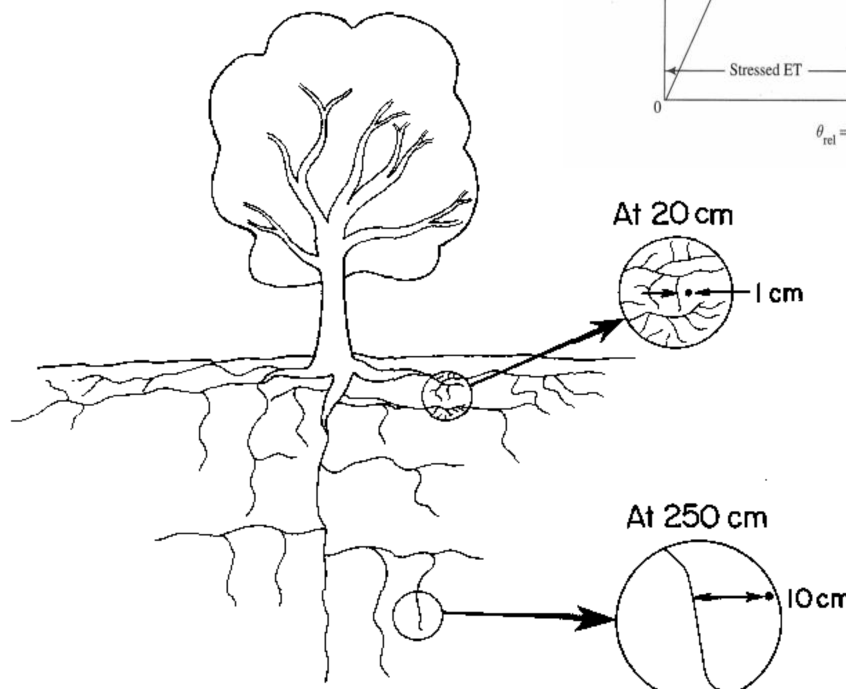
Data from Federer et al. (1996).

Subsurface Water - Transpiration

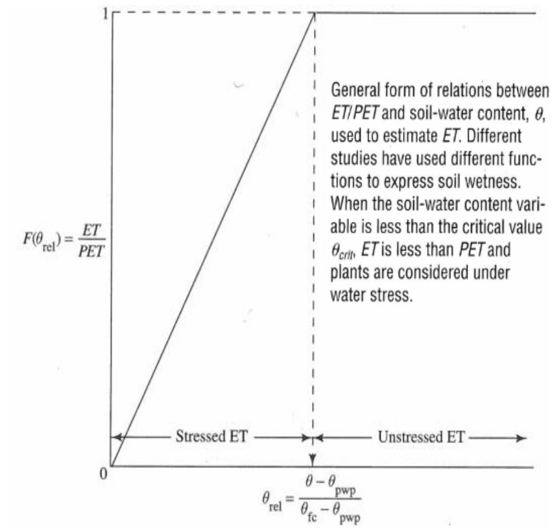
- Deeper Roots – Greater Water Resources,
  Less Stress (for survival of longer droughts)



Hewlett 1982



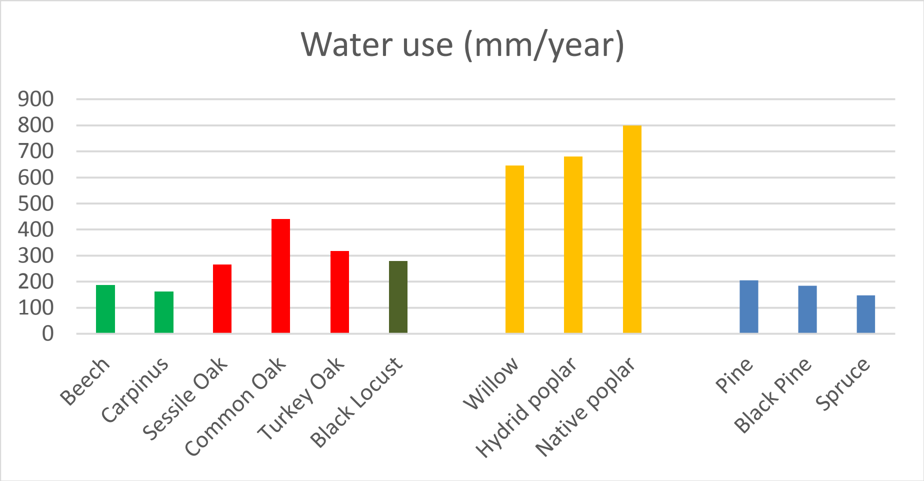
Hewlett 1982

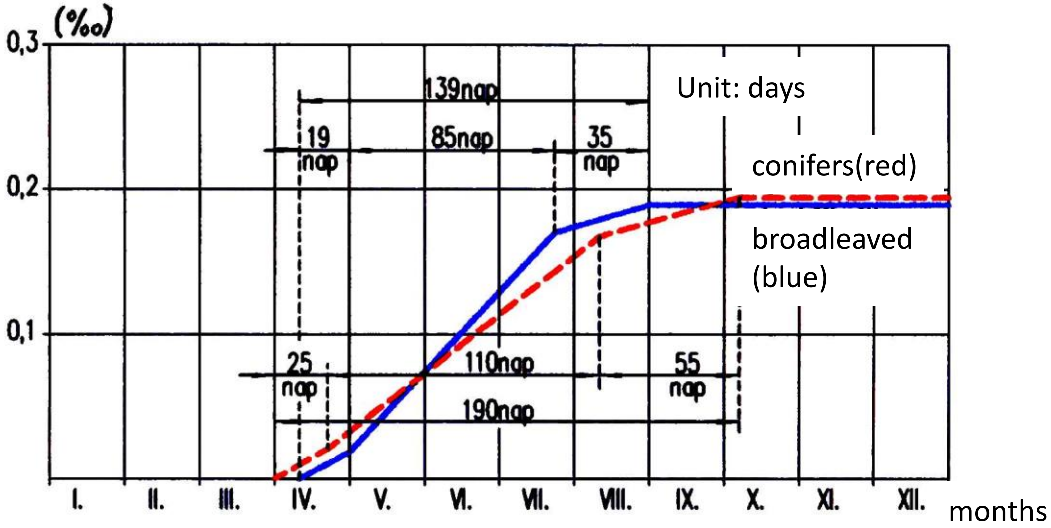


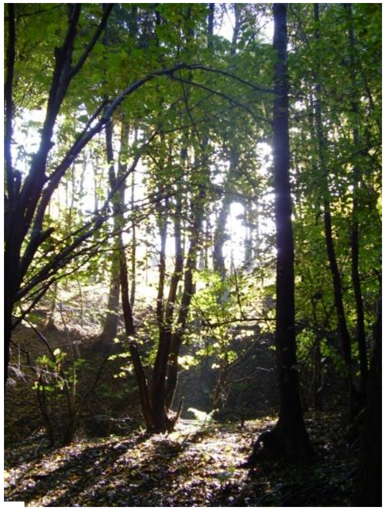
Dingman 2002

Transpiration

- Transpiration water use (CCI: TVU increases)
- Growth periods (CCI: longer)

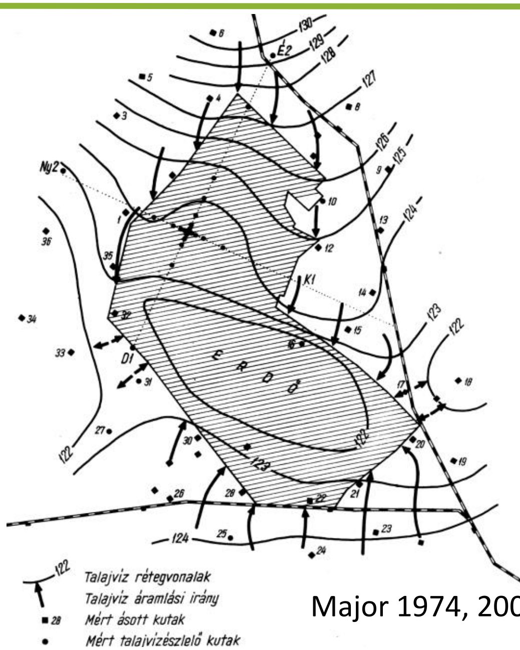




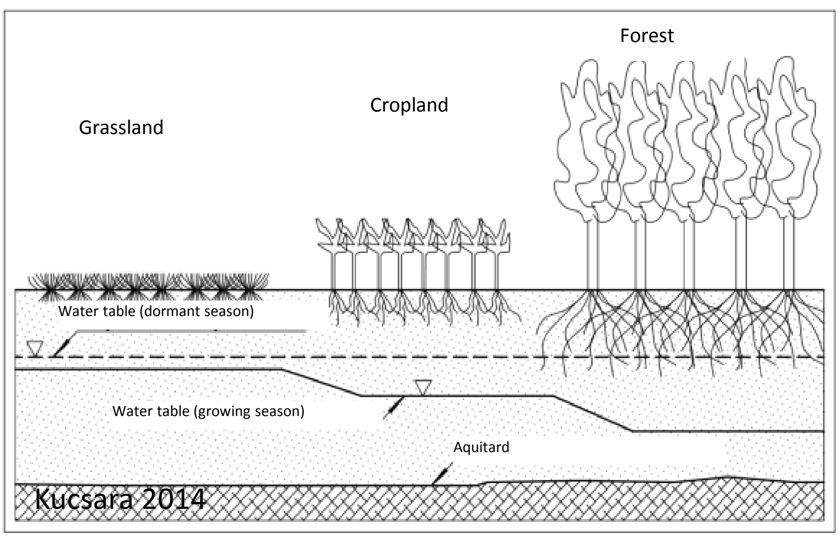


Groundwater use

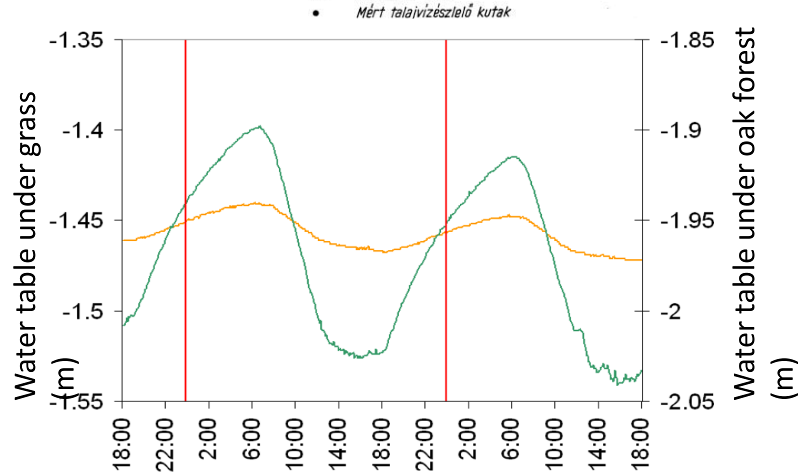
- Forest in lowlands: Highest transpiration if roots can reach at least capillary zone (4-5m) , Schoeller (1962)
- Under forests groundwater table is deeper
- Forest (KST) vs. Grassland in Geat Plain (Móricz 2012)
  Forest ET (785 mm) 30% more than Grassland ET (623 mm).
  Groundwater uptake of forest (243mm) is 3-fold than grass (85mm)



Major 1974, 2002

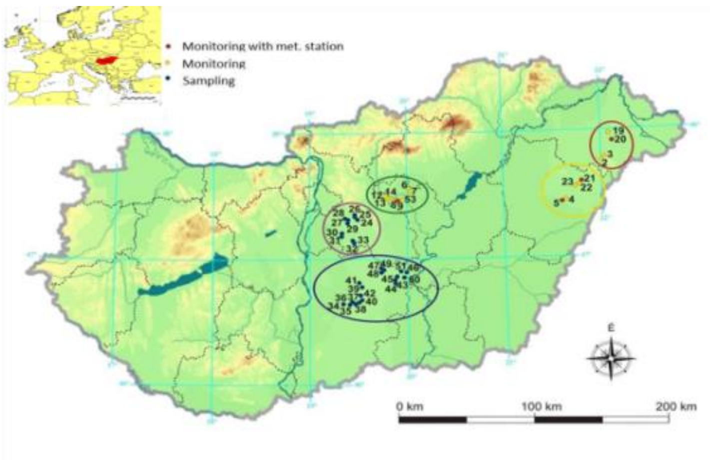


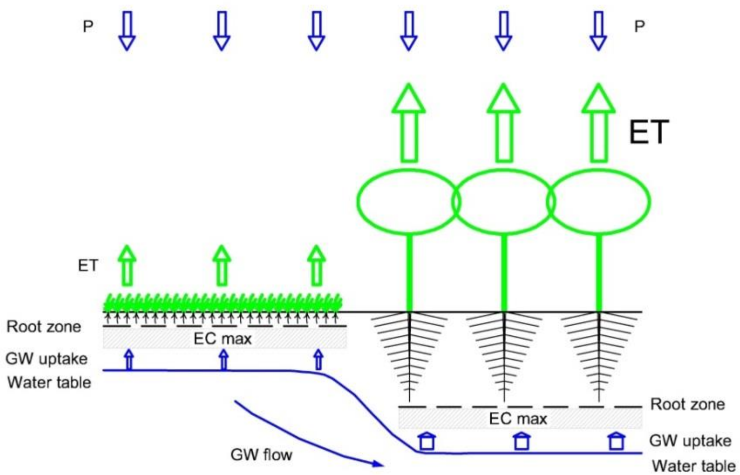
Kucsara 2014



Grass (yellow), Oak (green) Móricz et al. 2012

Forest and salinization

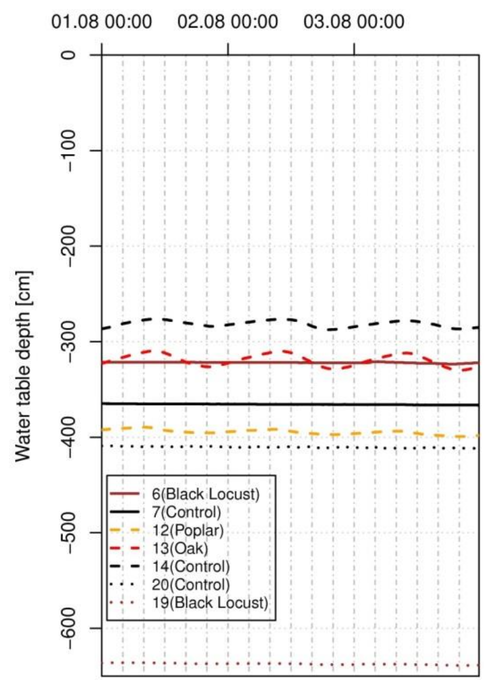


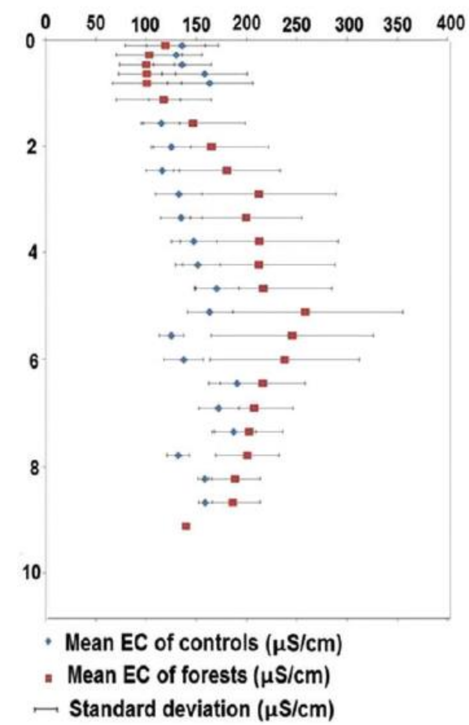


Forest vs. GW (TAKI, SOE and ERTI project):

Regional scale: 108 sample points (Forest – Agricultural plot).

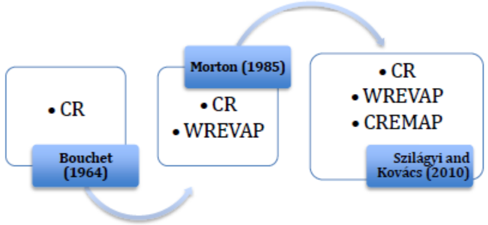
Intensive monitoring: 18 points





Tóth et al. 2014

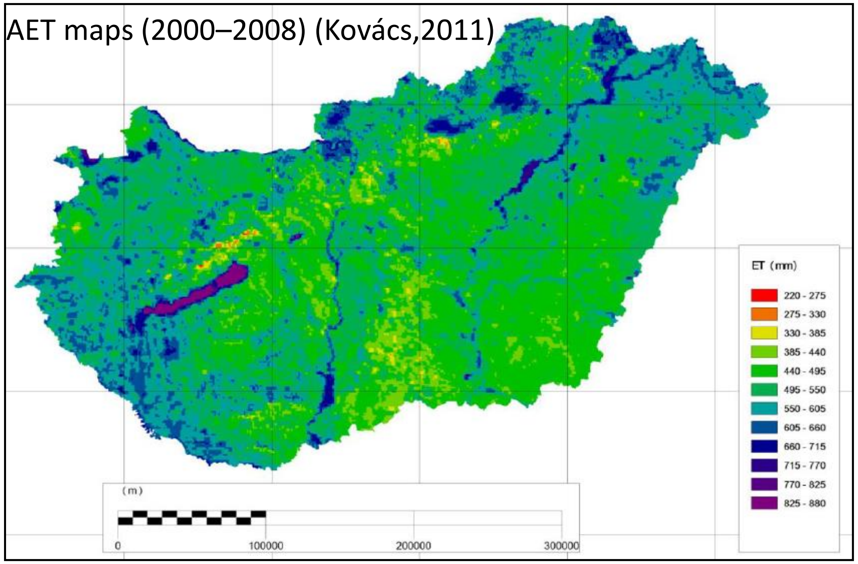
Remote sensing ET



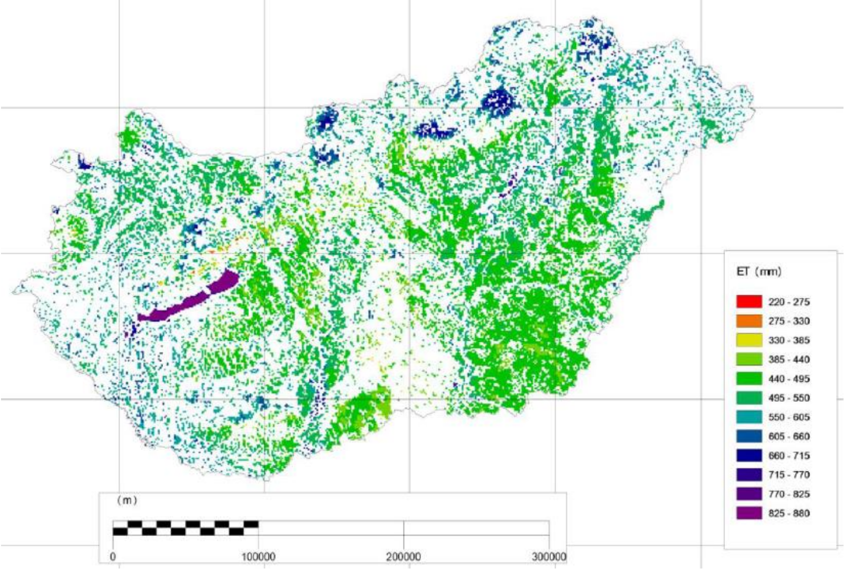
- Actual ET (Szilagyi-Kovács 2011)
- Complementary approach

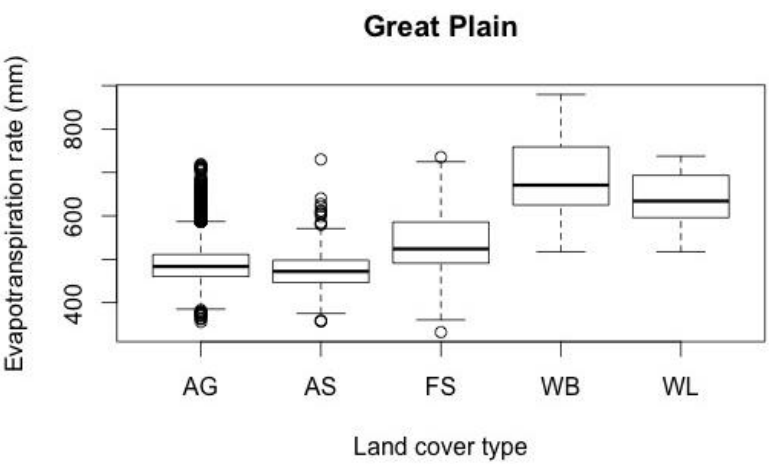
$$ET = 2E_w - E_p$$

  - Ew, wet surface pot ET (Priestley-Taylor eq.),
  - Ep, act. pot ET (e.g. Penman eq.)
- MODIS surface temp. – lin. transf.



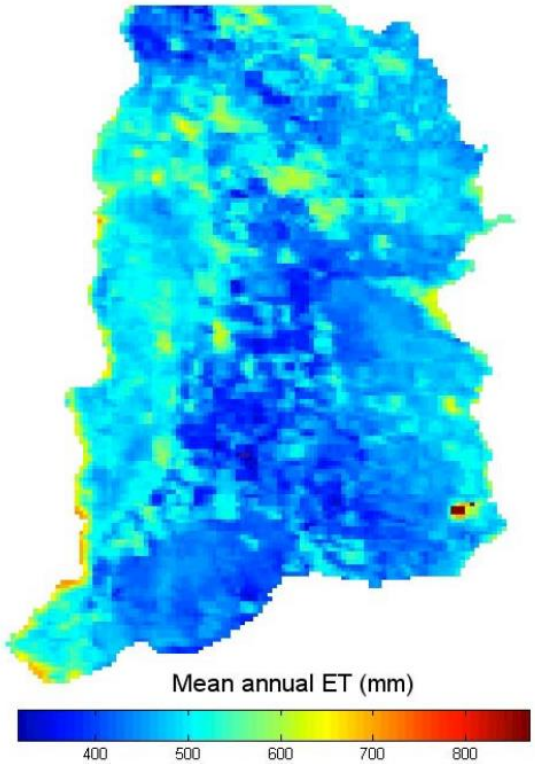
AET maps (2000–2008) (Kovács,2011)

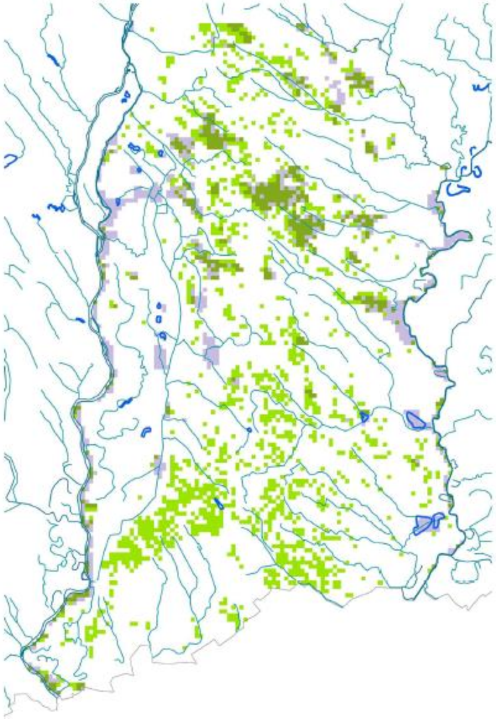




Remote sensing based ET

- P-ET (recharge) and forest (Szilágyi et al 2012)

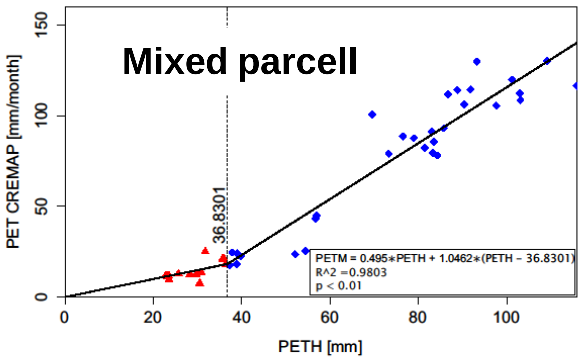


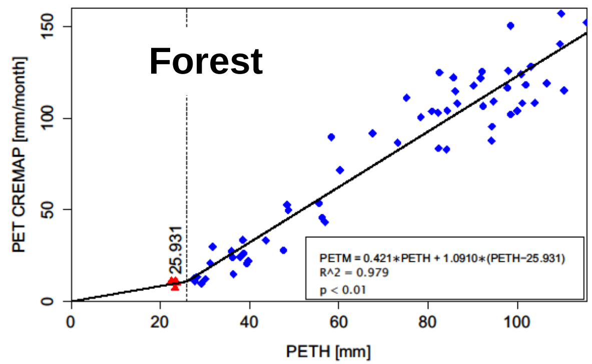


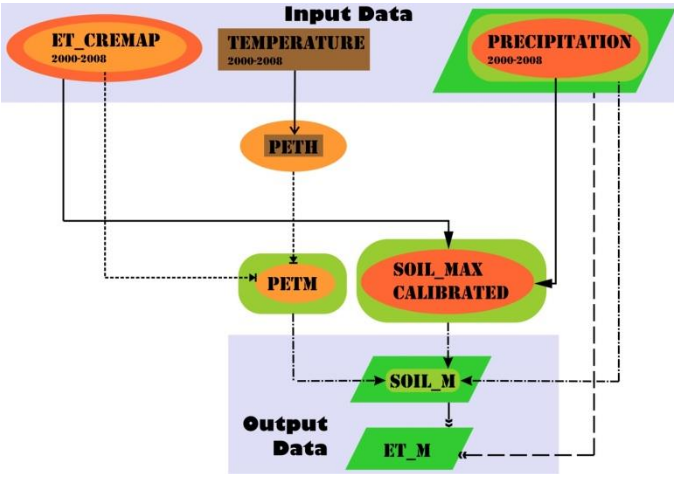
Magenta: negativ recharge (P-ET), Green: forests

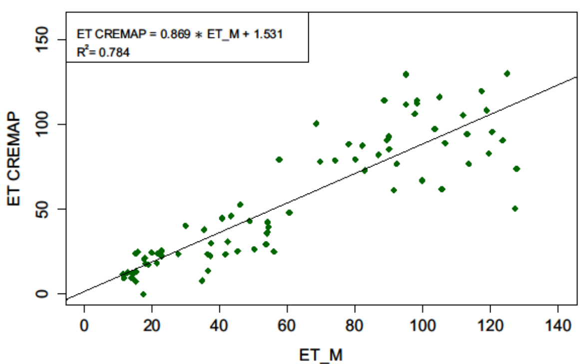
Thornthwaite approach

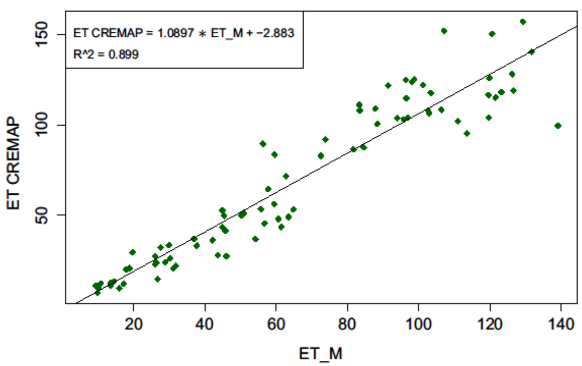
Monthy time step model











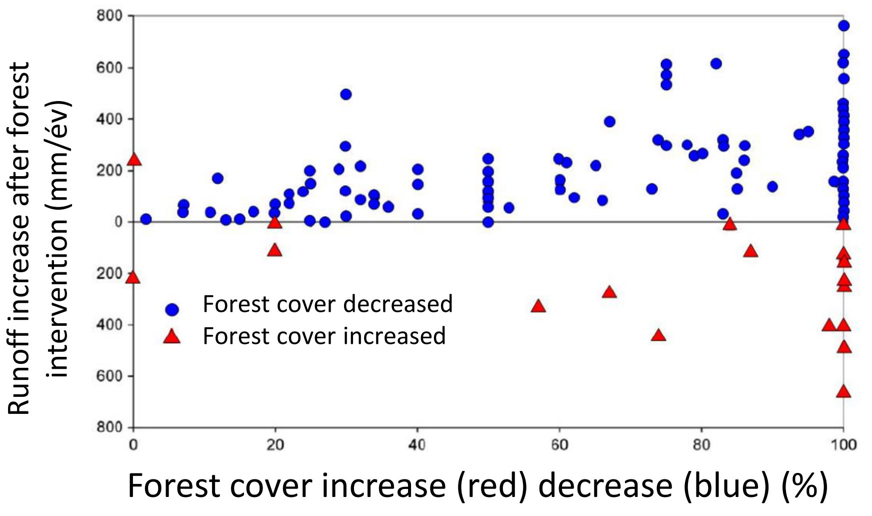
SOIL_MAX: 277 mm (mixed), 503 mm (forest),
Rooting Depth: 1.8 m (mixed), 3.3 m (forest).

Herceg et al. 2014

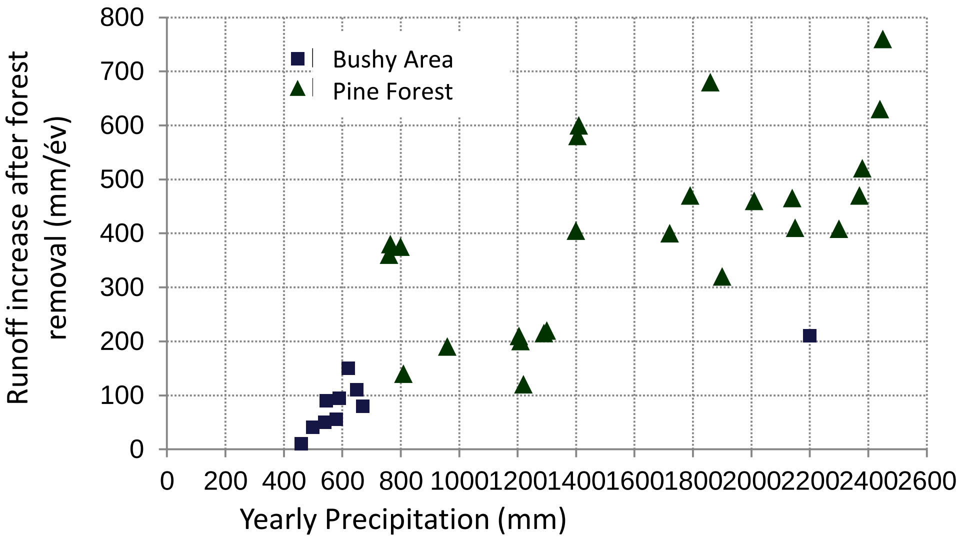
	1980/2010		2010/2040		2040/2070		2070/2100	
	mm	%	mm	%	mm	%	mm	%
ET_M of mixed parcel	42 (32)	100	44 (35)	105	46 (36)	110	47 (36)	111
ET_M of forested area	47 (36)	100	49 (38)	103	52 (39)	109	53 (39)	111
$SOIL_M$ of mixed parcel	232 (42)	100	222 (49)	95	220 (53)	94	207 (61)	88
$SOIL_M$ of forested area	340 (62)	100	324 (67)	95	312 (74)	92	303 (82)	89
$SOIL_M$ Min. mixed	101	100	86	84	82	80	53	52
$SOIL_M$ Min. forest	237	100	211	89	218	92	161	68

Runoff (long term)

- Water yield (cumulative discharge)



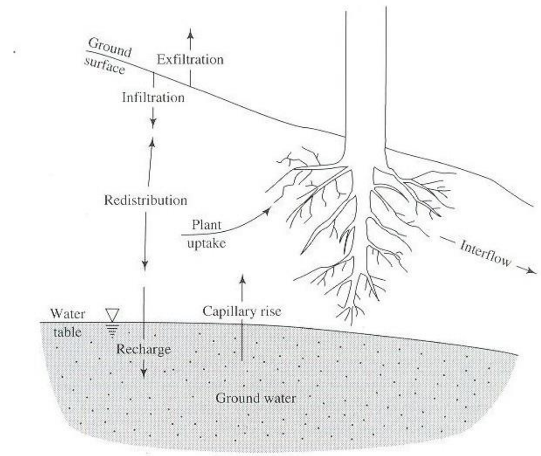
Andresian 2004



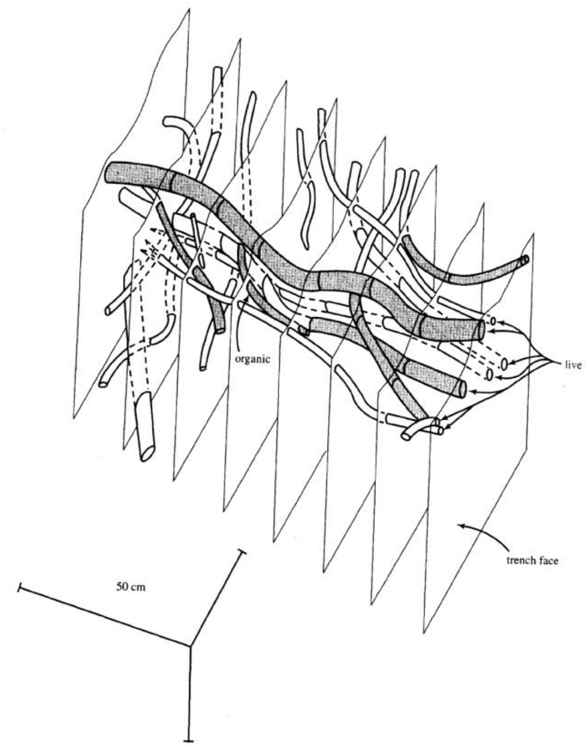
Bosch –Hewlett 1982

Surface - Subsurface water

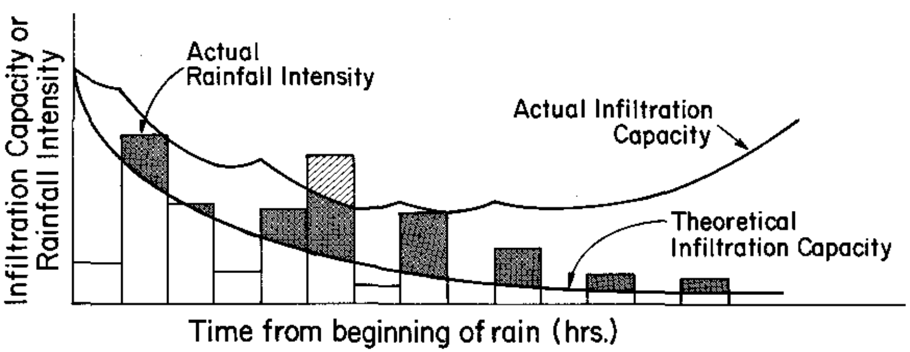
- Infiltration
- Interflow



Dingman 2002

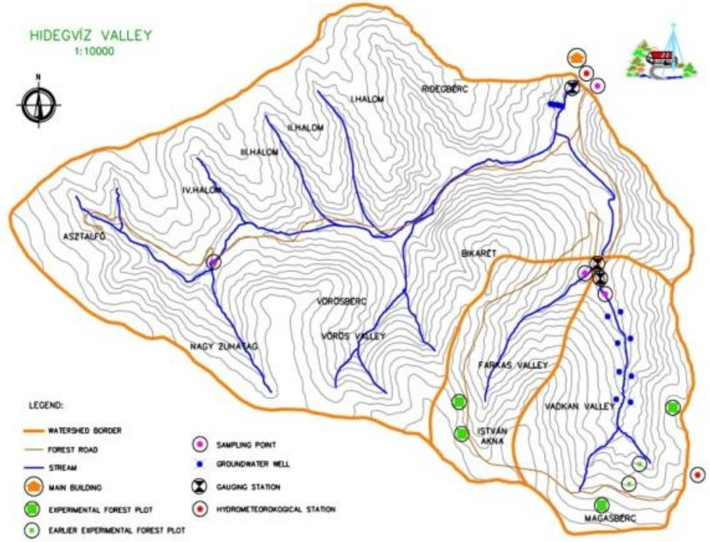


Dingman 2002

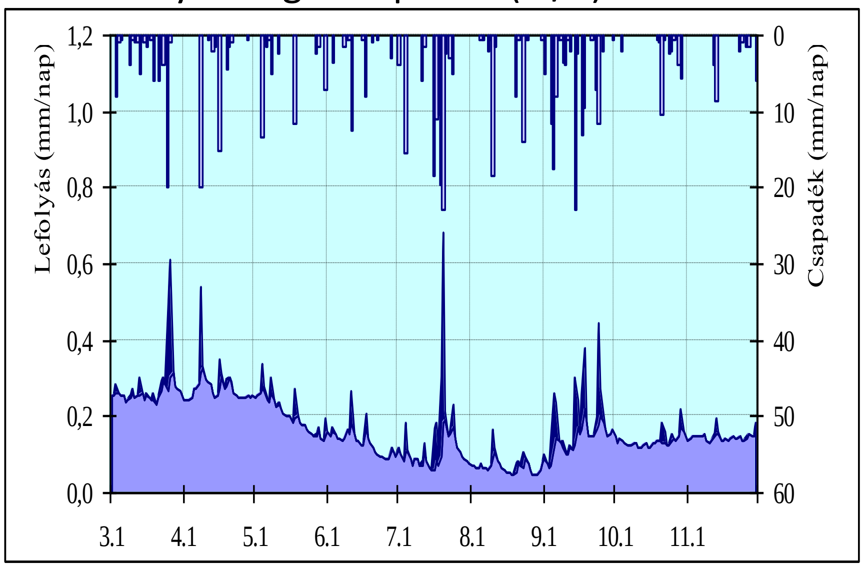


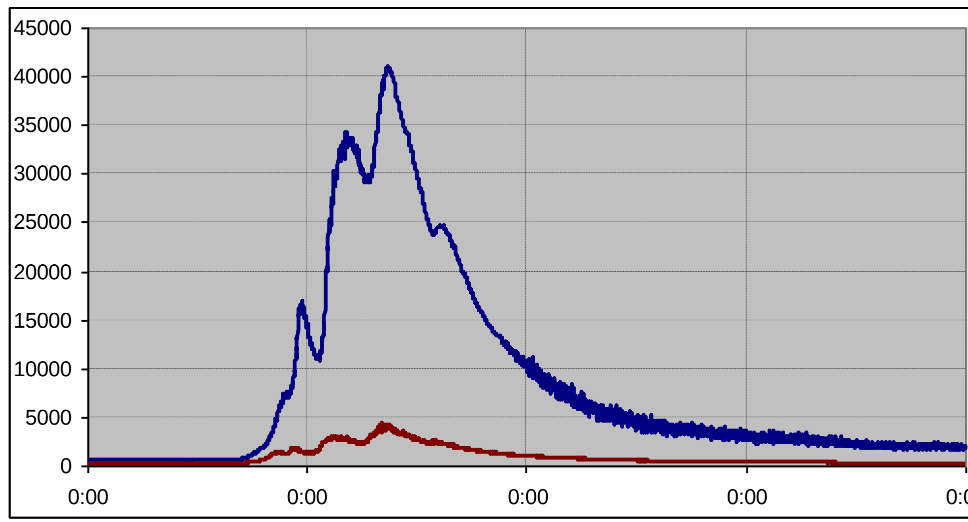
Hewlett 1982

Forest and runoff



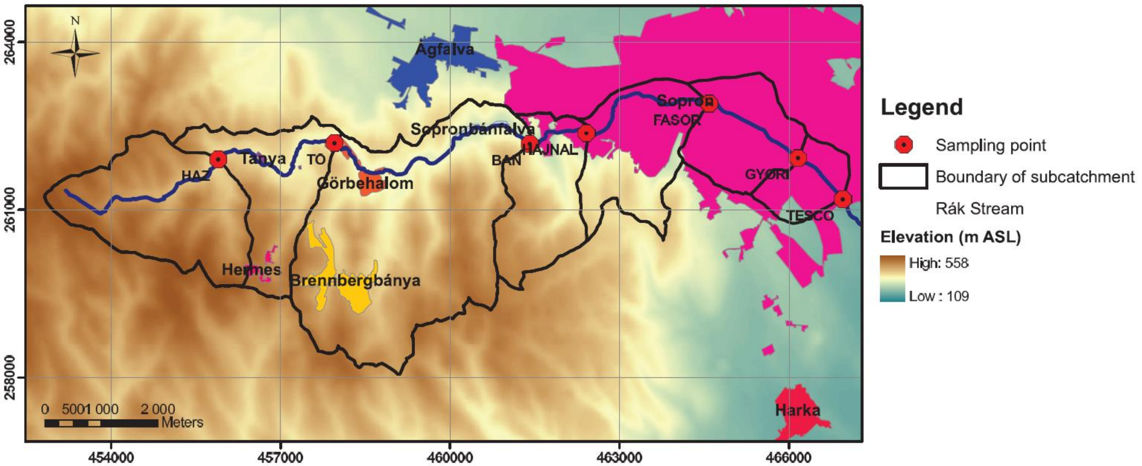
- 68.5 mm rainfall induced flood
- VA A= 0.95 km^2 P=64600 m^3 Q= 2572 m^3 Hydrologic response (Q/P)=0.04
- HAZ A= 6 km^2 P=408000 m^3 Q=34580 m^3 Hydrologic response (Q/P)=0.08

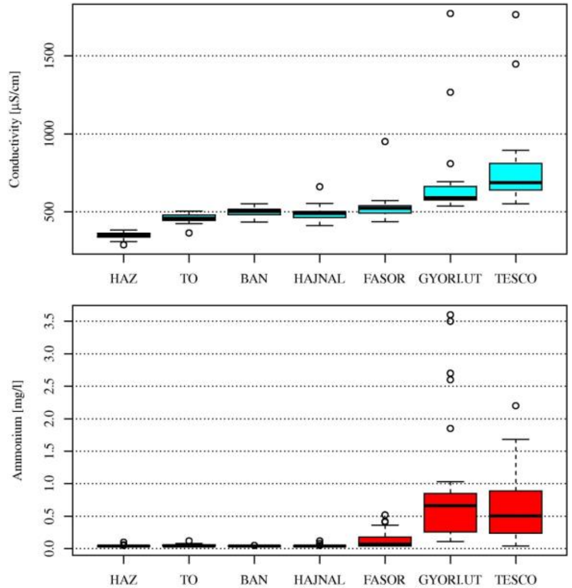


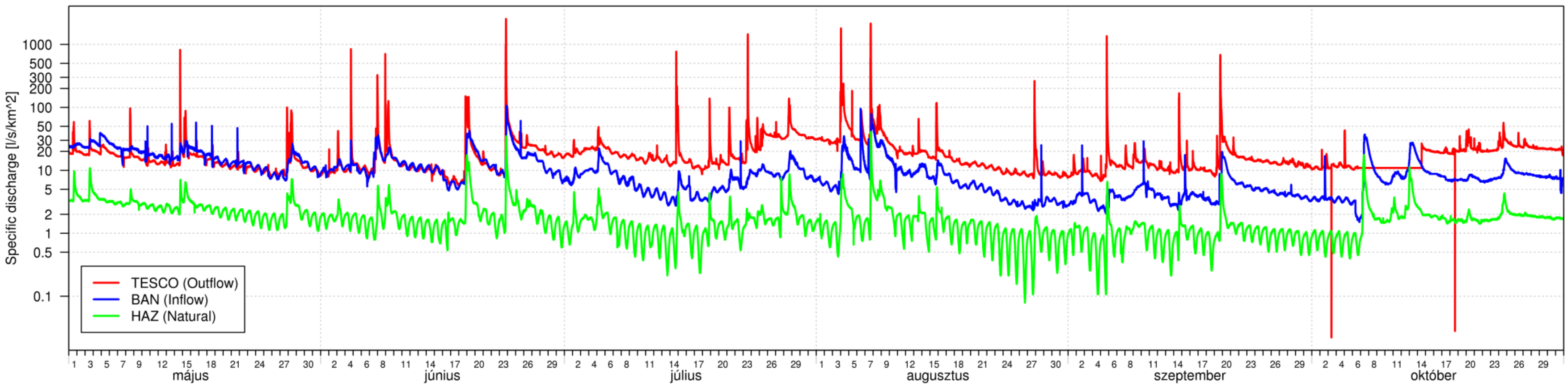


Kucsara 2014

Forest and runoff



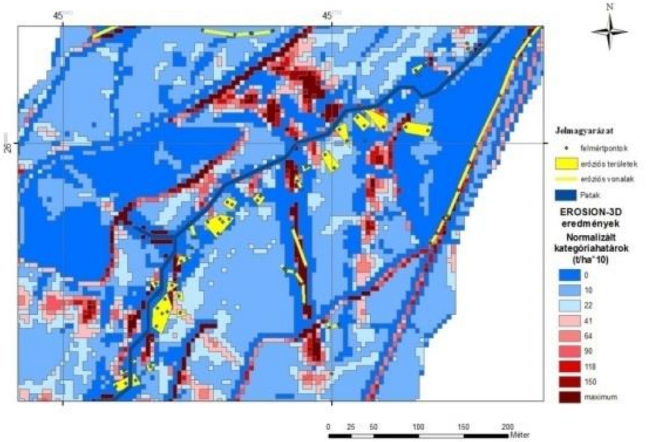




Gribovszki et al. 2012

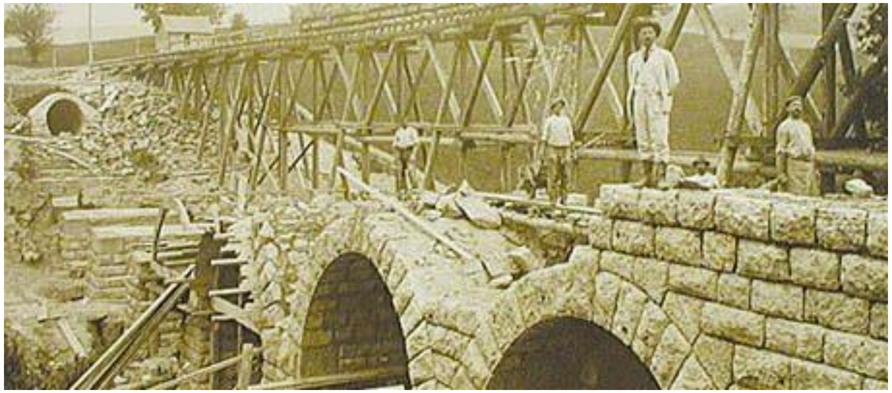
Erosion (surface)

- Decrease of kinetic energy of raindrops:
  - though increase rain drop size,
  - but litter and understory vegetation distribute kinetic energy (720-1)
- Big infiltration capacity.
- Roughness of surface, surface cover with forest litter.
- Erosion in line: Dust roads
- Erosion rate:
  - arable land: 70-280 t/ha/year
  - grassland: 1.5 t/ha/year
  - forest: 0.1-0.7 t/ha/year;
  - clearfelling: 1-2 magnitude higher erosion rate



Springs – Water resources

Water Supply of Vienna



Kucsara 2012

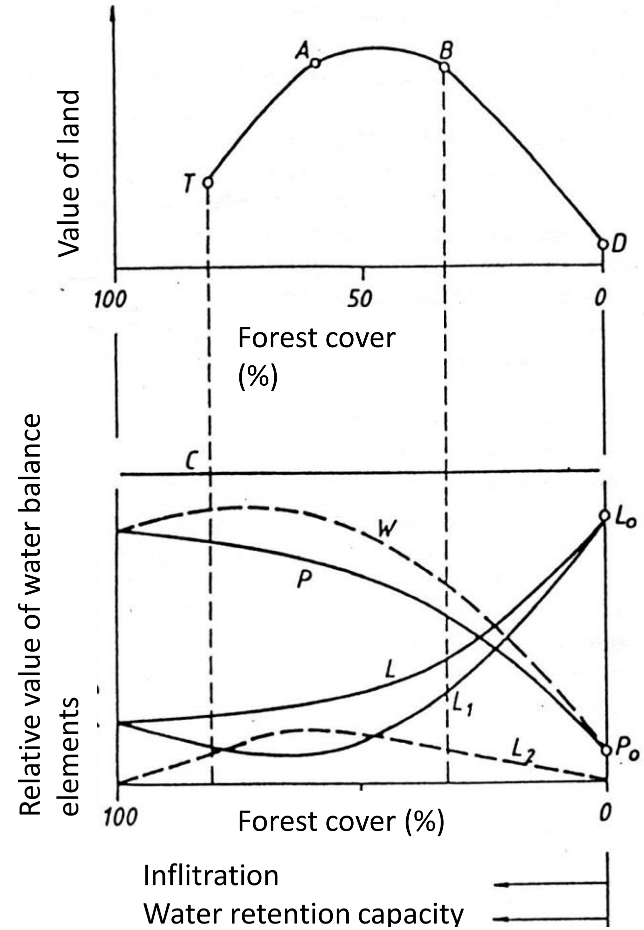
Forest – Water Conclusions

- Forests have strong influence on water balance
- Great ET and infiltration capacity
- Significant retention and detention capacity
- Cause delaying of flood waves, decrease peak flow
- Increase baseflow and permanence of springs
- Protect from erosion
- Water from forest is good quality

- Cause delaying of snow melting
- Decrease water table and use high amount of gw
- In floodplain cause longer lasting flood waves

- Forests are able to reduce the impacts of climate change:
  - Reducing temperature (with higher ET if there is enough water)
  - Balancing water resources in time (baseflow stabilization, flood wave reduction)
  - Inducing local rainfall on regional scale?

BUT Take care: Forest use more water than any other ecosystem type



C: precipitation
P: evaporation
L_1: surface runoff
W: storage
L: runoff
L_2: subsurface runoff (baseflow)

Thank You For Your Attention!

Acknowledgements: Research is also supported by “Agroclimate.2” (VKSZ_12-1-2013-0034) EU joint national funded research project.

HUNGARIAN GOVERNMENT
NATIONAL RESEARCH, DEVELOPMENT AND INNOVATION FUND
INVESTING IN YOUR FUTURE