Forest Hydrology: Lec. 15

Lecture content

- 1. Transpiration
- 2. Evaporation from the leave surface
- Sensitivity analyses of the Penman-Monteith equation
- Work on Student's reports

Application 1

Compute the evapotranspiration rate from the canopy at a pine forest in August.
The following typical conditions apply:

Zveg=1650 cm;
LAI=2.8
Cleaf=0.2 cm/s
P=1013 mb
Rin= 0.00694 cal cm-2 s-1
Albedo=0.18
Rout=-0.00138 cal cm-2 s-1
Ta=19.2°
Relative humidity=0.54
Wind velocity=300 cm/s

Sensitivity analysis

Group 1:

Analyse the effect of weather conditions

Group 2:

Analyse the effect of Zveg, of LAI and of fs

Group 3:

Analyse the effect of soil moisture and Cleaf

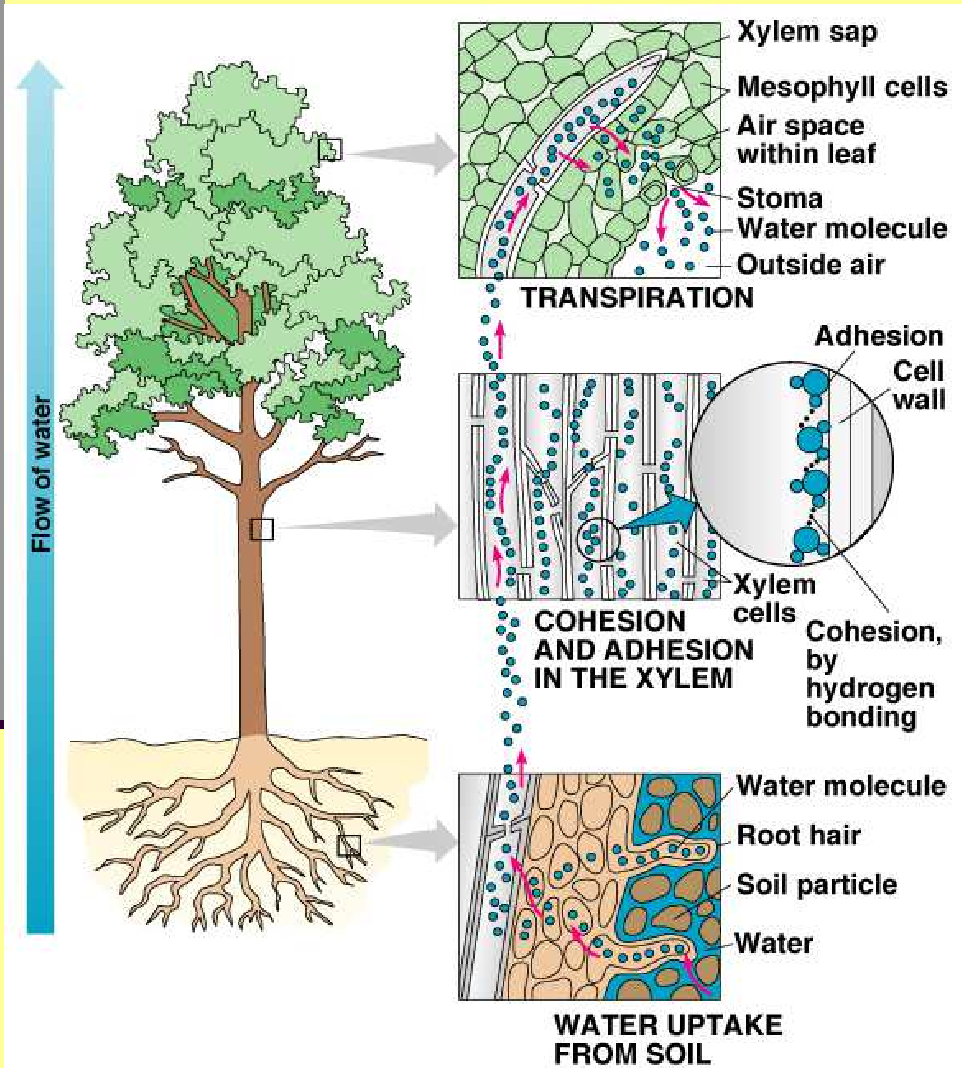
The Penman-Monteith equation (Transpiration)

Equation obtained based on the energy balance and introducing the canopy conductance

$$L = \frac{\Delta R_n + \gamma \rho_a c_p \left(e_s(T_z) - e_z \right) / r_a}{\Delta + \gamma (1 + r_c / r_a)}$$

$$E = \frac{\Delta R_n + \gamma \rho_a c_p c_a \left(e_s(T_z) - e_z \right)}{\left[\Delta + \gamma (1 + c_a / c_c) \right] \rho_w \lambda_w}$$

The transpiration processes



Transpiration is the evaporation of water from the vascular system of plants into the atmosphere.
The entire processe involves:

Absorption of soil water by roots.

Translocation in liquid form through the vascular system of the roots, stem and branches to the leaves;

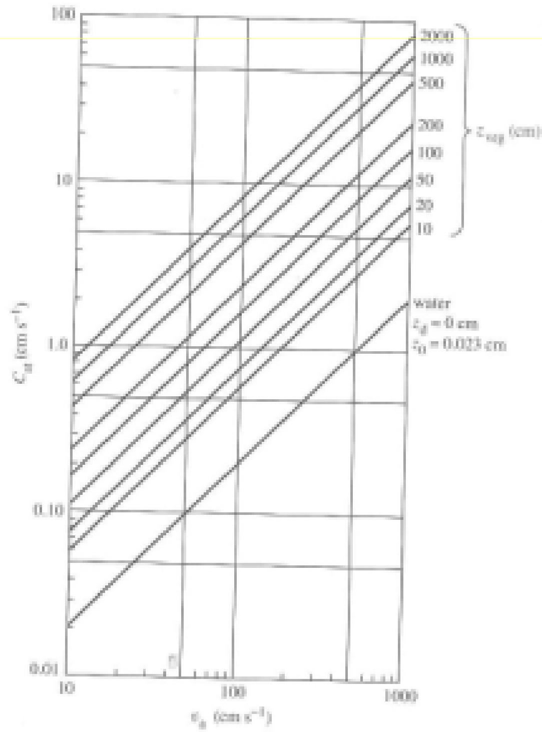
The water vapor in the stomatal cavities then moves into the ambient air through openings in the leaf surface called stomata.

The atmospheric conductance

Equation obtained based on the energy balance and introducing the canopy conductance

$$E = \frac{\Delta R_n + \gamma \rho_a c_p c_a \left(e_s(T_z) - e_z\right)}{\left[\Delta + \gamma (1 + c_a / c_c)\right] \rho_w \lambda_w}$$

FIGURE 7-9
Relation between atmospheric conductance, C_{at}, and wind speed, v_a, for vegetation of various heights, z_{veg}. Relation for typical water surface is also shown. It is assumed that v_a is measured 2 m above the vegetation canopy and that atmospheric stability is near neutral.



Atmospheric conductance: Changes with Wind and With Vegetation Heigth

Increases with wind
Increases with Veg Height

Note the log dependence!

The leaf and canopy conductance

Equation obtained based on the energy balance and introducing the canopy conductance

$$E = \frac{\Delta R_n + \gamma \rho_a c_p c_a \left(e_s(T_z) - e_z\right)}{\left[\Delta + \gamma(1 + c_a / c_c)\right]\rho_w \lambda_w}$$

TABLE 7-7
Transpirational Leaf-Area Indices, L_t, for Various Plant Communities.

Community	Leaf-Area Index
Desert	<1
Tundra	1
Grassland prairie	1
Savannah	1–3
Deciduous hardwood forest[a]	3–7
Tropical forests	>9
Temperate conifer forests	10–47

Information from Woodward (1987), Gholtz (1982), and other sources.

[a] Maximum seasonal values for mature forests.

A vegetated surface can be thought of as a large number of leaf conductances which act in parallel.
However, the total area of the traspiring surface of these leaves is not the same as the area of ground beneath them.
So, we define the Canopy Conductance as:

$$C_c = LAI \cdot C_{leaf}$$

The transpirational LAI

The LAI used here is the transpirational leaf-area index.
These values account for the facts that stomata are distributed over the needles of soem conifers but are found only on the undersides of most flat-leaved plants.
It is subject to variations in time (growing season)

$$LAI = \frac{Total\, area\, of\ traspiring\, surface}{A}$$

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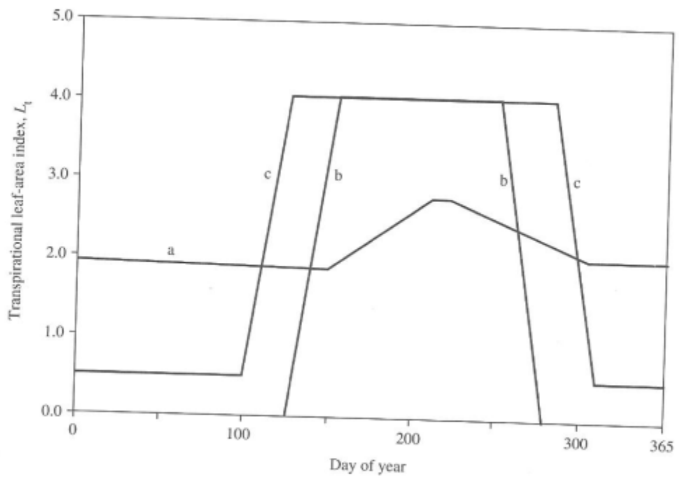
[a] Maximum seasonal values for mature forests.

FIGURE 7-12
Annual variability of transpirational leaf-area index, L_t, in (a) a pine forest in southeast Britain (Stewart 1988), (b) a hardwood forest in New Hampshire, and (c) a hardwood forest in North Carolina (both from Federer and Lash 1978).



The Leaf Conductance – 1. C*leaf and the dependence on weather and water availability

The Leaf conductance C*leaf at maximum stomatal opening is determined by
the number of stomata per unit area, and
the size of the stomatal openings.

Hardwoods		Conifers	
Species	C^*_{leaf}	Species[a]	C^*_{leaf}
Gray birch	0.37	Douglas fir (c)	0.83
Big-tooth aspen	0.33	Sitka spruce (c)	0.71
White oak	0.33	Sitka spruce (1)	0.45
Yellow birch	0.31	Sitka spruce (2)	0.30
Black oak	0.30	Grand fir (c)	0.42
American elm	0.29	Red pine (c)	0.32
Quaking aspen	0.29	Red pine (1)	0.23
Black cherry	0.29	Red pine (2)	0.12
Red maple	0.29	Red pine (3)	0.11
American beech	0.25	Red pine (4)	0.091
White ash	0.24	Western hemlock (c)	0.22
Sugar maple	0.22	Ponderosa pine (c)	0.11

[a] Symbols in parentheses indicate leaf age: c is current year; 1–4 are previous years.

The Leaf Conductance – 2. C*leaf and the dependence on weather and water availability

Plants control the size of the stomatal openings, and hence leaf conductance to respond to:

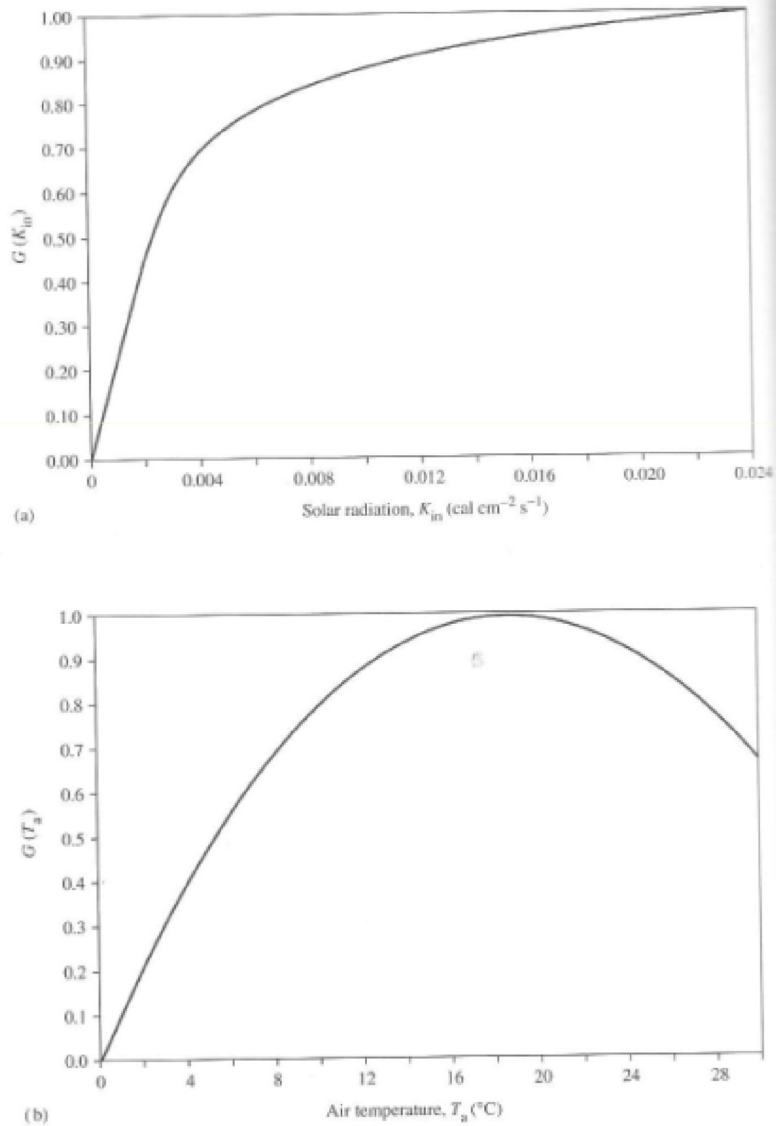
1. Light intensity
2. CO2 concentration
3. Leaf-air vapor pressure difference
4. Leaf temperature
5. Leaf water content

A model which summarises four of the five dependencies is:

$$C_{leaf} = C^{*}{}_{leaf} \cdot G(R_{net}) \cdot G(W_a) \cdot G(T_a) \cdot G(\Delta_\theta)$$

The Leaf Conductance – 3. dependence on solar radiation and temperature

FIGURE 7-11
Effects of (a) solar radiation, K_{in}, (b) air temperature, T_a, (c) vapor-pressure deficit, $\Delta\rho_v$, and (d) soil-moisture deficit, $\Delta\theta$, on relative leaf conductances (see Table 7-6). After Stewart (1988).



The Leaf Conductance – 3. dependence on air rel humidity and water availability

FIGURE 7-11 (continued)