Forest Hydrology: Lec. 11

Lecture content

- Evapotranspiration
  - Evaporation
  - Transpiration
  - the water balance
  - the surface energy balance
  - soil moisture deficit models
- field measurement of evaporation

Learning Objectives

- Define the controls on evapotranspiration: the surface energy balance and transpiration
- Define *Potential* evapotranspiration and *Actual* evapotranspiration
- Describe Vegetation canopy controls on the leaf *stomata* and transpiration
- Focus concepts of energy and energy balance
- Define *Sensible heat* and *latent heat* and the *Bowen ratio*
- Discuss the energy balance methods of calculating evapotranspiration.
- Describe field measurements of evapotranspiration

A knowledge of evapo-transpiration is important because

- **Over the long term, the difference between precipitation and evapo-transpiration is the water available for direct human use and management. Thus, prediction of water resources availability requires a quantitative understanding of evapotranspiration.**

- **Most of the water 'lost' via evapotranspiration is used to grow the plants that form the base of the earth's ecosystem. Understanding relations between evapotranspiration and ecosystem type is a requirement for predicting ecosystem response to climate change.**

- **Much of the world's food supply is grown on irrigated land. Efficient irrigation requires knowledge of crop water use (transpiration).**

Water is removed from the surface of the Earth to the atmosphere by two distinct mechanisms:

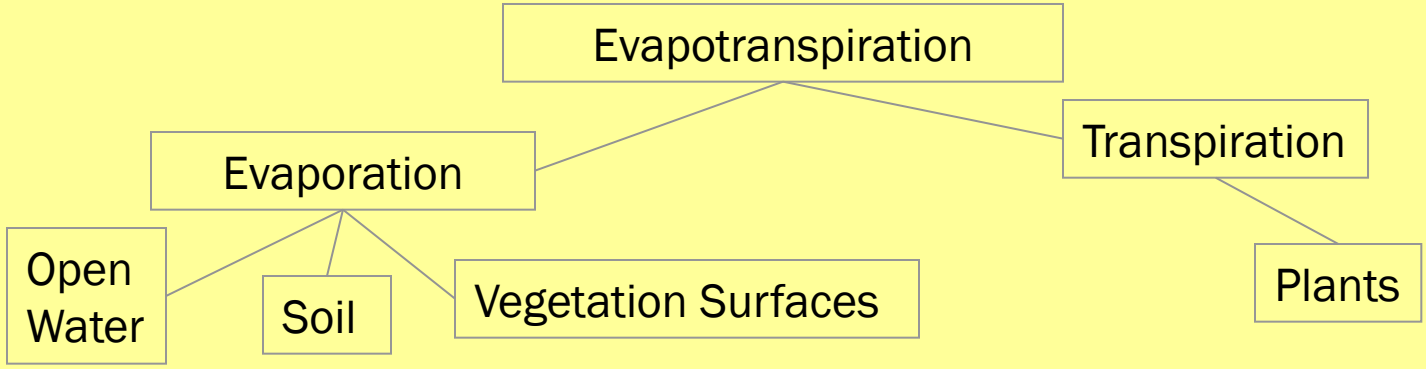
Evaporation

and

transpiration

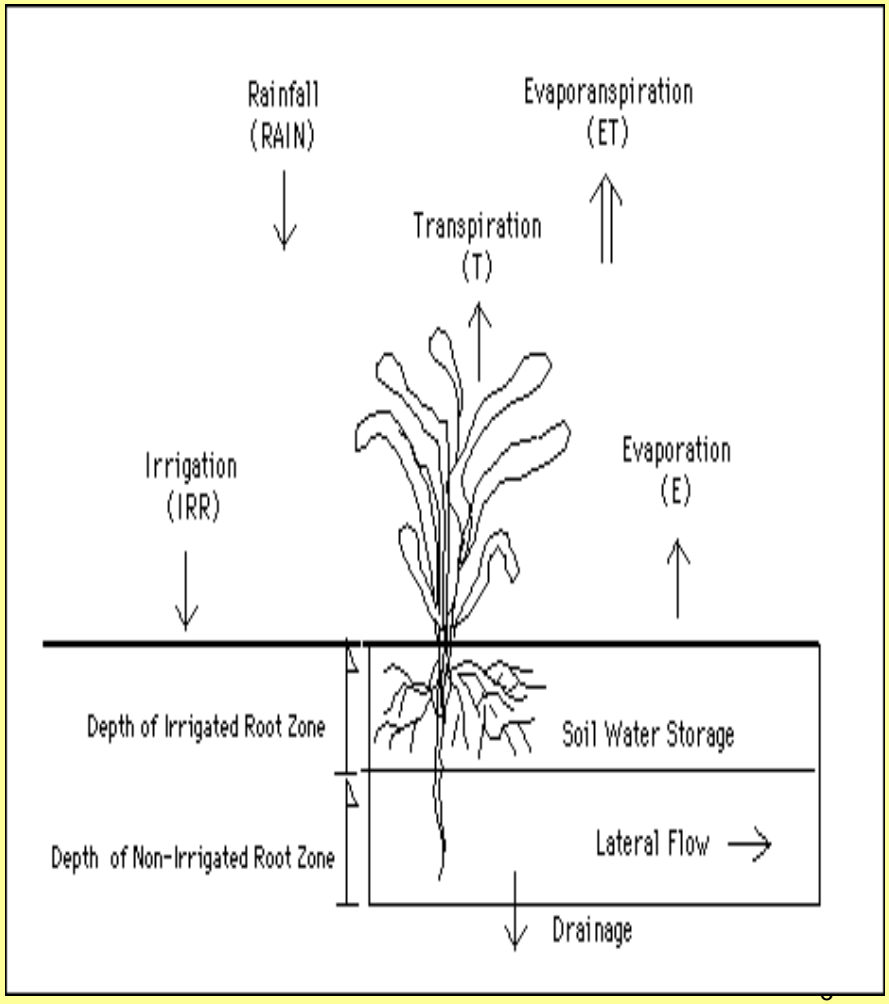
Evapotranspiration (ET)

- Composed of two subprocesses
  - ***Evaporation*** occurs on surfaces of open water or from vegetation and ground surfaces.
  - ***Transpiration*** is the removal of water from the soil by plant roots, transported through the plant into the leaves and evaporated from the leaf's stomata.
- Typically combined in mass balance equations because the components are difficult to partition.



So, what is the key point here?

- Evapotranspiration includes a variety of vaporisation processes, including evaporation from open water, bare soils and water on vegetation surfaces and transpiration from plants.



Measuring evaporation - water balance

Evaporation = Change in water level - rain in

Requires a ‘pan coefficient’ if open-water evaporation is to be compared

What controls evapotranspiration?

- Meteorological factors
- Nature of evaporative surface

Requirements for Evapotranspiration

- **Evapotranspiration requires a source of water, a source of energy and a vapour pressure gradient**

- vapour pressure deficit (vpd) is a measure of the drying power of the air**,**

- the larger the vpd the greater the atmospheric demand for water and the greater can be the evaporation rate

- **At typical surface temperatures, it takes about 2450 J of energy to evaporate 1 g of water.**

The rate of evapotranspiration at any instant from the Earth's surface is controlled by four factors

(1) Energy availability. The more energy available the greater the rate of evapotranspiration. It takes about 600 calories of heat energy to change 1 gram of liquid water into a gas.

(2) The humidity gradient away from the surface. The rate and quantity of water vapor entering into the atmosphere both become higher in drier air.

factors controlling ET, contd

(3) The wind speed immediately above the surface.

Many of us have observed that our gardens need more watering on windy days compared to calm days when temperatures are similar. This fact occurs because wind increases the potential for evapotranspiration. The process of evapotranspiration moves water vapour from ground or water surfaces to an adjacent shallow layer that is only a few centimetres thick. When this layer becomes saturated evapotranspiration stops. However, wind can remove this layer replacing it with drier air which increases the potential for evapotranspiration.

(4) Water availability. Evapotranspiration cannot occur if water is not available.

Availability of water

- Over land surfaces, water may be limited in availability.
- Rates of ***actual evapotranspiration*** are reduced from the ***potential*** rates that would occur under given meteorological conditions if water was not limiting.

Some key definitions

- Potential evapotranspiration (PE, PET or E_p) is the rate at which water would be lost to the atmosphere from the soil-vegetation surface if water is not limiting (i.e. adequate supply). It is a function of atmospheric conditions and the nature of the surface.

- Actual evaporation (AE or E_a) - **Evaporation and transpiration which occur when water supply is limiting.**

PE is a useful concept because it can be predicted from information readily available from climatological stations.

Evapotranpiration units

Evapotranspiration is measured in

mm day^{-1} or mg m^{-2} s^{-1} for leaves

Evaporation

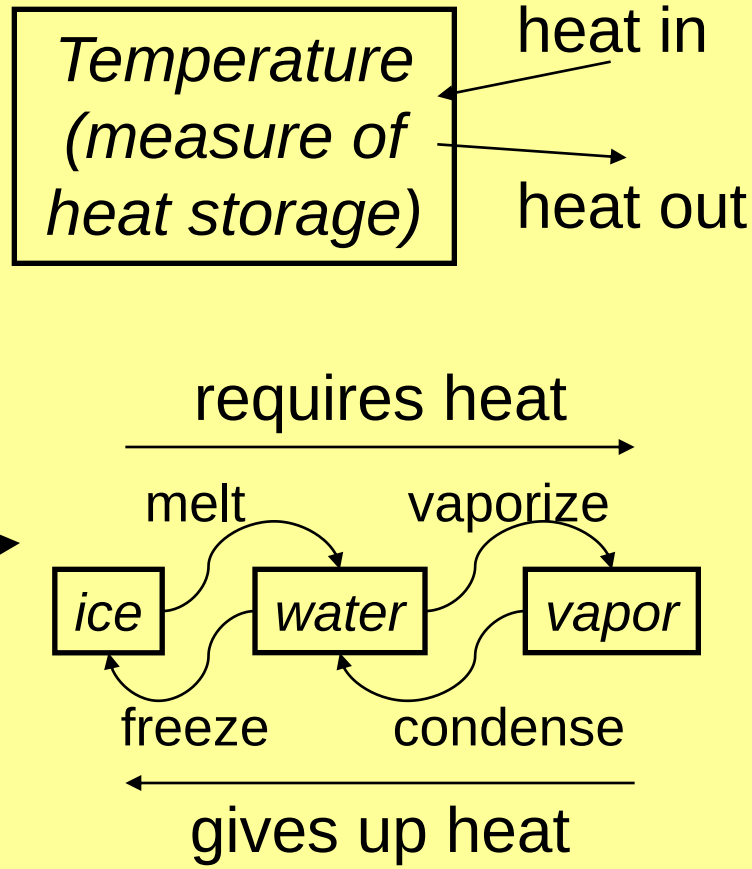
- Evaporation occur when water is converted into water vapor. The rate is controlled by the availability of energy at the evaporating surface, and the ease with which water vapor can diffuse in the atmosphere.

- Evaporation is the rate of liquid water transformation to vapor from open water, bare soil, or vegetation with soil beneath.

- In the case of vegetation growing in the soil, transpiration is defined as that part of the total evaporation which enters the atmosphere from the soil through the plant.

Energy balance principles

- "Energy" and "heat" are equivalent
- Energy in – energy out = Δ energy storage
- Δ energy storage ≡ either
  - Δ temperature
  - Δ "phase" of water (solid, liquid, gas)



Some applications of energy balance principles

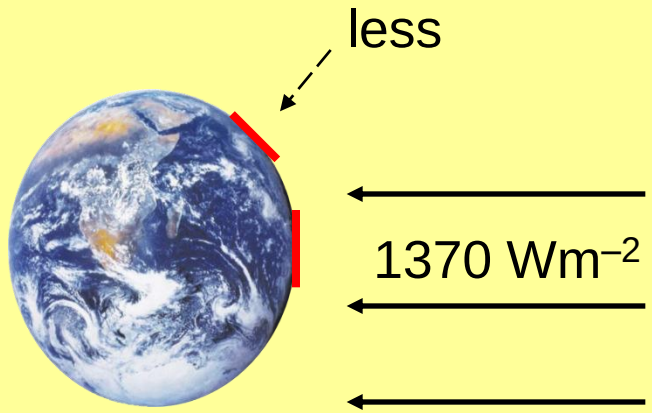
- Global climate change, partly caused by increasing concentrations of atmospheric CO_2
  - Changes in energy transfer between Sun, Earth, Atmosphere
- Evaporation and photosynthesis in vegetation
  - Heating, cooling, energy for conversion of CO_2 and sugar to O_2
- Snowmelt and snow crystal formation
  - Formation and melting of ice

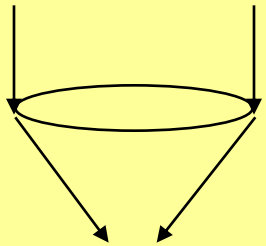
Units for measuring energy

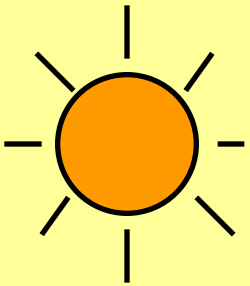
- Joule (J): (mechanically) 1 J is amount of energy expended in accelerating a 1 kg mass by 1 m/sec for 1 sec
  - *specific heat* of water is 4185 J/deg/kg
  - a *calorie* is 4.185 J
- Latent heat (correct term is “enthalpy”) of:
  - *fusion* (melt-freeze) is 335,000 J/kg
  - *vaporization* is 2.5 million J/kg
- Watt (W): Joule per second
  - A person uses about 2,500 kilocalories/day ≈ 10 million Joules/day ≈ 120 Watts

Energy per unit area

- Solar radiation at top of atmosphere (the “solar constant”) is 1370 Wm^{-2}
- A tilted surface intercepts less energy per unit area
  - this is why Sun angle causes variability & seasons
- Focusing of Sun’s rays increases Wm^{-2}
- Diffusing of Sun’s rays decreases Wm^{-2}







Methods of energy transfer

- Radiation: electromagnetic waves propagate through space
  - all bodies radiate, warmer bodies more
  - interactions depend on wavelength
- Conduction: molecule-to-molecule
  - hot to cold temperature
- Convection: mixing in air or water enhances transfer
  - sensible: temperature difference
  - latent: change of phase