Crop Microclimatology, soil and soil moisture

Lecture-2

Contents

- Vegetation environment interaction
- Effects of light on plants and plant response to radiation
- Soil and Soil Moisture Characteristics

Vegetation environment interaction

- Microclimatology is concerned with the study of the climate close to the ground’s surface or very small areas less than 100 meters across.
- Climatic zonation coincides in a broad and general way with **climax vegetation**,
  - The ultimate type that can develop under a particular local pattern of soil parent material, topography, temperature, precipitation, and other meteorological conditions.

Cont. . .

- As a result, natural vegetation has been used as a kind of meteorological "instrument" to define boundaries in the classification of climate,
  - ✓ With the result that savannah, steppe, and rainforest are names for climates as well as vegetation types.
- In 1840 Justus Liebig formulated a hypothesis that plant growth is limited by the nutrient available to it in least quantity.

Cont. . .

- This concept, now popularly known as the **law of limiting factors**, can be expanded to include all environmental factors that contribute to growth.
- Although plant growth is affected by indirect differences in climate, the extremes produce the greatest effects.
- Thus, the climatic extremes of a particular region may be more important in maintaining a vegetation type than the average.

Cont. . .

- An occasional severe period of drought may prevent the development of forest vegetation even though the average annual precipitation is satisfactory.
  - ✓ Cotton cannot be grown in regions that have heavy rainfall during boll formation.
- Climatic extremes have great influence on the distribution of such perennial crops as fruits.

Cont. . .

- Low temperature is required for dormancy, but injury (harm) follows extremely low winter temperatures, and the flowering stage is very sensitive to frost.
  - ✓Relatively high temperatures are required during the growing season.
- The boundaries of agricultural regions are determined by climatic factors.

Cont. . .

- In Africa low rainfall is limiting both in the south and in the north.
- In South America the boundaries are set by low temperatures in the south,
- The harsh conditions of high altitudes and poor soil near the equator, and low rainfall in the northeast and along parts of the Pacific coast.
- In Australia intensive production is confined to coastal areas that have adequate rainfall.

Cont. . .

- The action of any single environmental factor is affected by all other environmental factors; that is, the environment is **holocoenotic**.
- The stress that one environmental factor imposes can sometimes be relieved by making another factor more favorable.
- The compensation of one environmental factor for another is most common near the edge of a species' range.

Cont. . .

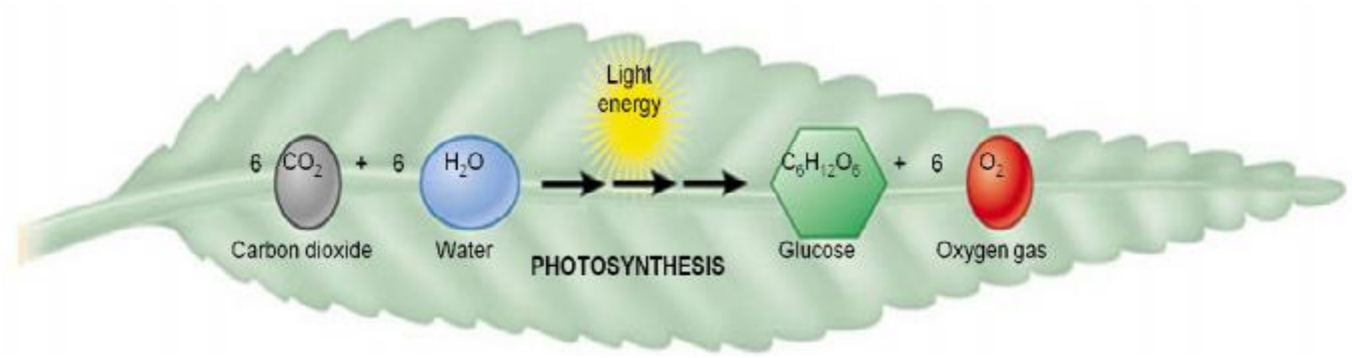
- *For example,*
  - *Spruce (Picea) and fir (Abies) grow in the cooler climates of high latitudes, but both kinds of trees grow at high elevations far south of the region of their best development. Thus elevation compensates for latitude.*

Effects of light on plants and plant response to radiation

- ➢Solar radiation can affect the phonological and physiological /morphological processes of plants.
- ➢Most of its effect and plant response to solar radiation are the following:
  - ✓Photosynthesis, Photo morphogenesis; Photropism; Photoperiodism, Energy balance/temperature, Respiration, Enzyme activity, Transpiration, UV-responses, Mutagenesis etc…

Photosynthesis

- Photosynthesis is the essential process in which plants convert light energy into chemical energy in the form of organic molecules, some of which also serve as building blocks for plant structure.
- It is a chemical process that converts carbon dioxide into organic compounds, especially sugars, using the energy from sunlight



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- The intensity of the sunlight varies with the season.
  - ✓Sunlight is typically most intense in the summer and least intense in the winter.
- The greater the intensity up to a saturation point, the greater the production of food through photosynthesis.

Photo-morphogenesis

- Photo-morphogenesis is the effect of light intensity and quality on plant growth and development.
- Plant shape is determined by light and controlled by pigment phytochrome.

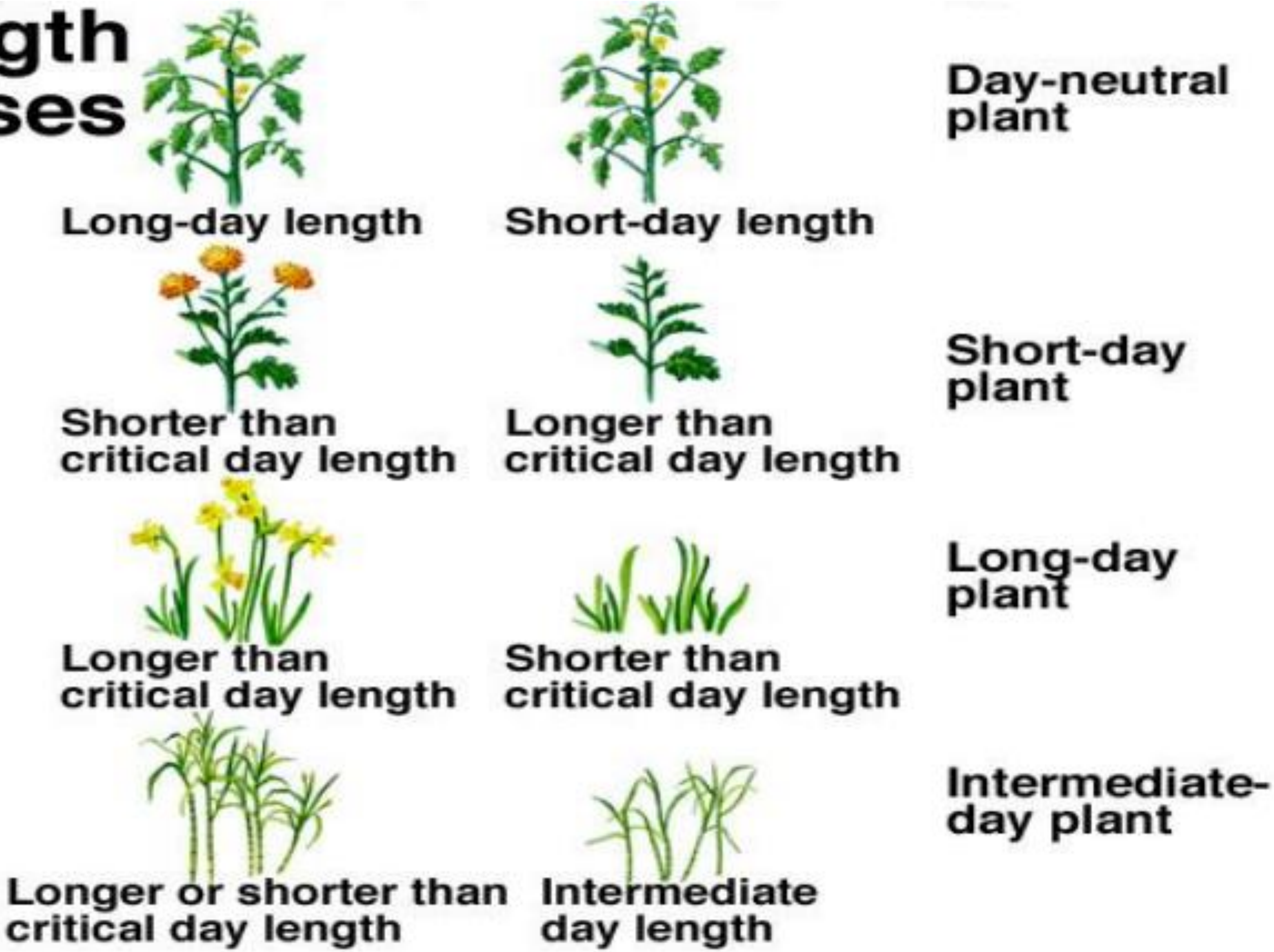
Cont. . .

- Some of the importance's of phytochrome in plant responses are the following:
  - ✓Plants detect ratio of red: far-red light
  - ✓Red light – full sun
  - ✓Far-red light – crowded, shaded fields/greenhouses
  - ✓Yields strong, branched, compact, dark green plants
  - ✓Plants tall, spindly, weak, few branches; leaves light green

Photoperiodism

- Photoperiodism is the length of time plants are exposed to sunlight or darkness.
- It is the effect of the relative length of the daily light/dark period mainly on flowering stage.
- Some plants flower only when the daily light period is above a certain length (long day plants),
- Some when the daily light period is below a certain length (short day plants), and
- Some flower regardless of the length of the daily light period (day neutral plants).

Day Length Responses



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- Short day plants – flower only when day length is less than some critical value (spring, fall).
  - Example: soybean, chrysanthemums, and poinsettia.
- Long day plants – flower only when day length exceeds some critical value.
  - Example, winter barley, red clover, oats, spinach, and winter wheat
- Day neutral – example, corn, grapes, peas, and tomatoes

Phototropism

- Phototropism is Movement of plants toward light or is the directional growth of plant parts (leaves, stems, roots)
  - In which the direction of bending is determined by the direction of the light source.

Crop Canopy Photosynthesis

- What factors affect crop canopy photosynthesis?
  - ☞Interception of solar irradiance by a crop canopy is a function of:
    - ✓The area of leaves per unit ground area (LAI),
    - ✓The absorption, reflection, and transmission spectra of the component leaves,
    - ✓The arrangement of leaves in the crop canopy within a horizontal plane, and
    - ✓The orientation of leaves within a vertical plane of the crop canopy (i.e. the angle between the leaves and the soil surface, leaf angle).

Photosynthesis leaf angle

- ➢The greater the leaf angle, the less will be the photosynthetic rate per unit sunlit leaf area.
- ➢Plant biomass production depends on the
  - ✓Absorption of photosynthetic photon flux density (PPFD) by its leaves and
  - ✓On the efficiency of the plant to convert solar radiation into chemical energy by the photosynthetic process.

Cont. . .

- The amount of absorbed PPFD depends on the
    - Efficiency of radiation interception by the canopy, which in turn depends on plant morphology and physiology.
- The PPFD normal to a sunlit leaf (PPFDi) can be calculated as the PPFD normal to the ground (PPFDo) multiplied by the extinction coefficient (i.e., the cosine of the leaf angle):

$$PPFDi = PPFDo \times k = PPFDo \times \sin(\beta), \text{ Or } PPFDi = PPFDo \times \cos(\alpha)$$

Where α is the leaf angle and β the angle between the leaves and the sun.

Cont. . .

- The vertical angle between the leaf face and horizontal is pictured by alpha (α),
  - While Beta (β) refers to the vertical angle between the leaf face and the sun.
- From the theory of diahelio-tropism (Leaves are perpendicular to the sun),
  - We can inferred that maximal absorption for a leaf would be at a perpendicular vertical angle to the sun ($\beta=90°$).
- We calculated the difference from maximal absorption for each leaf by taking the difference from β angles and 90°.

Cont. . .

- The leaf angle (α) and interception of solar irradiance by a crop canopy are inverse related.
  - ✓ i.e. if the leaf angle increase interception of solar irradiance by a crop canopy will decrease.
  - ✓ Whereas the vertical angle between the leaf face and the sun (β) has direct relation with interception of solar irradiance by a crop canopy.

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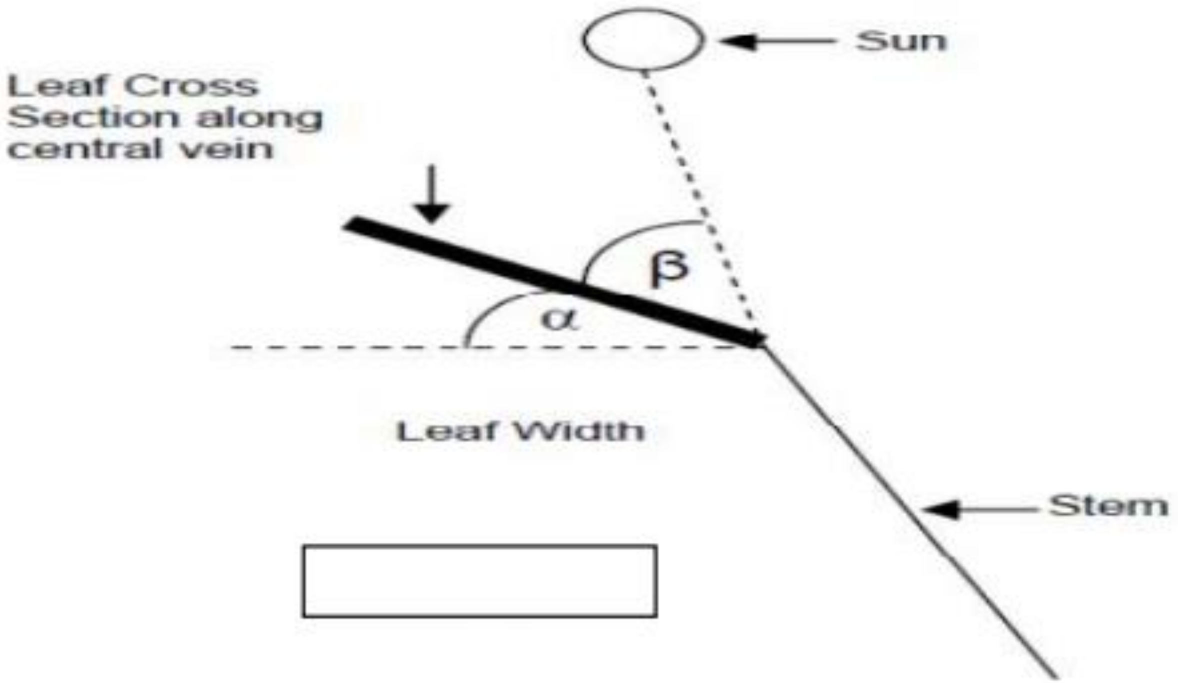

- ***Example***, *Assume that the PPFD incident at the top of the canopy is 2000µmol/m²s and the leaf angle is 30°. Calculate incident PPFD normal to the leaf.*

Leaf net photosynthetic rate

- For an efficient use of solar radiation by crop, the great part of the radiation must be absorbed by the photosynthetic tissues.
- Leaf is the principal photosynthetic functional unit;
  - ✓ Therefore, its efficiency on the capture and use of solar energy determines the vegetable productivity.

Cont. . .

- Maximum crop production requires complete capture of incident solar radiation and can only be achieved with supporting levels of water and nutrients.
- The area and arrangement of foliage (the canopy architecture), determine the interception of solar radiation (LI) by a crop and the distribution of irradiance among individual leaves.

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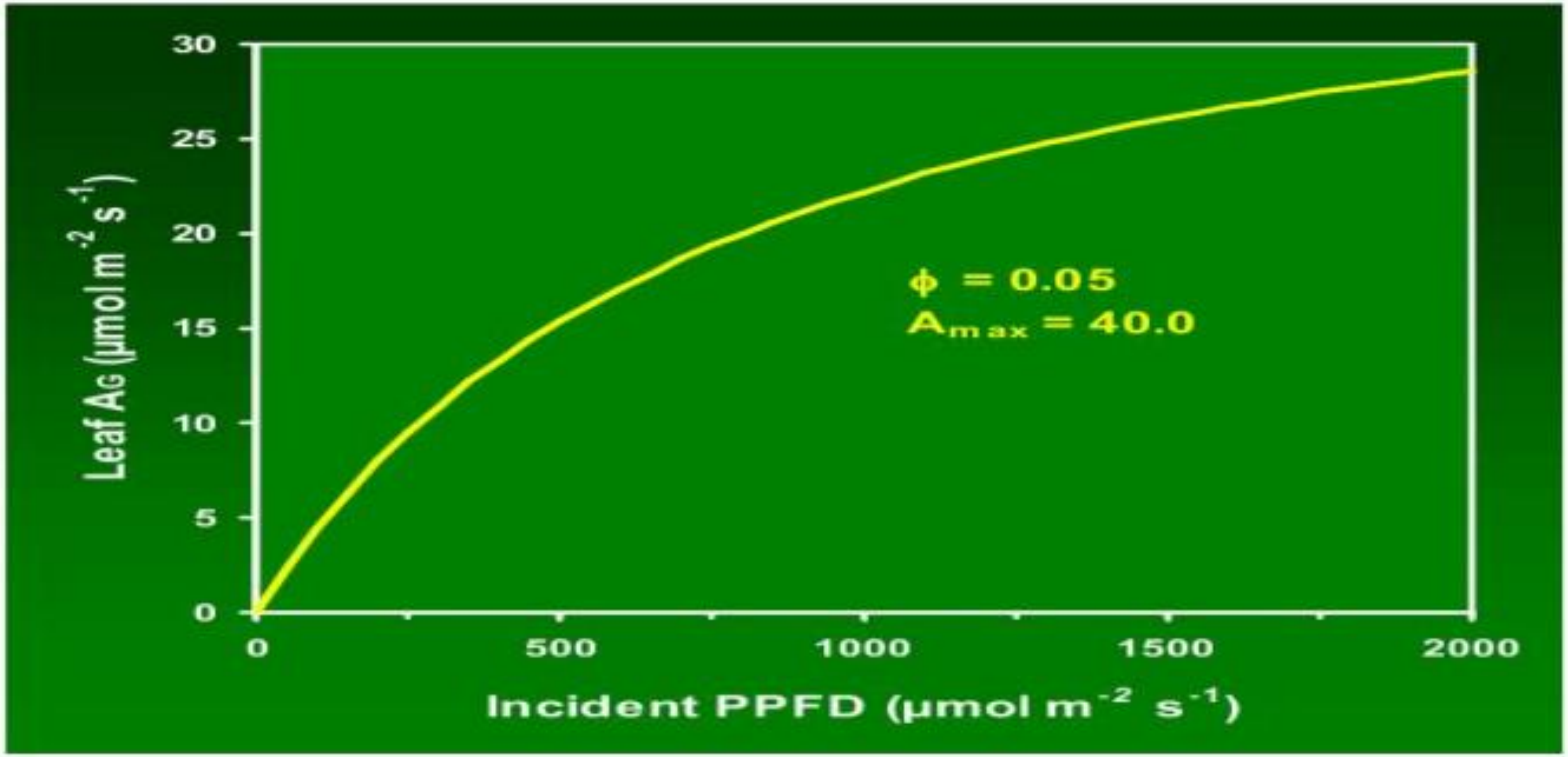
- The photosynthetic response of an individual leaf to incident solar radiation can be described by a photosynthetic response to irradiance (PRI) curve.



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- When considering photosynthetic response to irradiance, the most meaningful measurement of light is the photosynthetic photon flux density (PPFD).
  - ✓PPFD is defined as the number of photosynthetically active photons incident per unit area per unit time.
  - ✓The most common units for PPFD are µmol photons/ m^2s.
- It is important to realize that respiration occurs even in the light,
  - ✓So that the apparent photosynthesis that we measure in the light is actually the balance between respiration and photosynthesis.

Cont. . .

- This apparent (i .e. measurable) photosynthesis is also called the net photosynthesis, or net CO_2 assimilation (AN).
- Once the PPFD normal to the leaf surface has been calculated, the leaf net photosynthesis rate can be calculated using the equation for the PRI curve.

$$AN = \left(\frac{PPFD * \phi * A_{max}}{PPFD * \phi + A_{max}} - R_D \right)$$

- Where, $PPFD$ is the PPFD absorbed by the leaf, ϕ is the initial slope the PRI curve at low $PPFD$, A_{max} is the light saturated value for photosynthesis net of R_D, and R_D is the respiration rate in darkness.

Cont. . .

- In general, low values of R_D and high values of ϕ are most important for productivity in low $PPFD$ environments.
    - ✓In high $PPFD$ environments, high values of A_{max} are most critical.
- ***Example***, *Calculate the leaf net photosynthetic rate at PPFD absorbed by the leaf (PPFDa) is equal to incident PPFD normal to the leaf (PPFDi) of 1147µmol/ m 2 (leaf) s1; and the initial slope the PRI curve is 0.05, the light saturated value for photosynthesis of 40 and assume leaves are optically black.*

Leaf area index (LAI)

- The LAI is other concept for estimate the crop's ability to capture the light energy.
- LAI is broadly defined as the amount of leaf area (m^2) in a canopy per unit ground area (m^2).
  - ✓Because it is a dimensionless quantity,
- LAI can be measured, analyzed and modeled across a range of spatial scales, from individual tree crowns or clusters to whole regions or continents.

Cont. . .

- LAI is a key vegetation characteristic needed by the global change research community. For example,
  - ✓LAI is required for scaling between leaf and canopy measurements of water vapor and CO_2 conductance and flux.

Cont. . .

Determining LAI	
❖ Direct methods – by taking a statistically significant sample of foliage from a plant canopy, – measuring the leaf area per sample plot and dividing it by the plot land surface area – Demerits - It is destructive, time consuming and expensive, especially if the study area is very large.	❖ Indirect methods – Measure canopy geometry or light extinction and relate it to LAI. – Demerits: - In some cases it can underestimate the value of LAI in very dense canopies - It does not account for leaves that lie on each other

Cont. . .

- A general equation for LAI_{active} is:

$$LAI_{active} = 0.5LAI$$

- LAI_{active} take into consideration the fact that generally only the upper half of dense clipped grass is actively contributing to the surface heat and vapour transfer.
  - ✓For clipped grass a general equation for LAI is:

$$LAI = 24h$$

  - ✓Where h is the crop height [m].

Cont. . .

- The surface resistance (r_s) of a leaf is characterized by LAI_{active}:

$$r_s = \left(\frac{r_1}{LAI_{active}}\right) = \left(\frac{r_1}{0.5 * 24 * h}\right)$$

  - ✓Where, r_1 is the stomatal resistance of a leaf.

- ***<u>Example</u>****, the stomatal resistance of a single leaf has a value of about 100 s m-1 under well-watered conditions. By assuming a crop height of 0.12 m, calculate the leaf area index and surface resistance, rs [s m-1], for the grass reference surface.*

PPFD Absorption by a Crop Canopy and canopy net photosynthesis

- Absorption of incident solar radiation (I_A) by a crop canopy consisting of green leaves (in contrast to "black" leaves) can be quantified as:

$$I_A = I_o(1 - \rho_c)\left(1 - e^{-k*LAI}\right)$$

  - ✓Where I_o is incident solar radiation, ρ_c is the canopy reflection coefficient, k is the extinction coefficient, and LAI is the leaf area index of the canopy.

Cont. . .

- ***Example***, *The canopy reflection coefficient* **(*ρc*)** *= 0, incident solar radiation Io = 2000 µmol m-2s-1, the extinction coefficient k = 0.8 and the leaf area index of the canopy LAI = 3, calculate absorption of incident solar radiation (I A):*

- *What LAI is required to absorb the same PPFD for a canopy with an extinction coefficient of 0.5?*

- After complete the above example you should conclude as,
  - ✓The canopy with the more erect leaves will require a 60% greater LAI (i.e., 4.8 ÷ 3 = 1.6) to absorb the same amount of PPFD.

Soil and Soil Moisture Characteristics

- Soil is the unconsolidated mineral or organic material on the immediate surface of the earth.
  - ✓That serves as natural medium for the growth of plants.
- The unconsolidated mineral or organic matter on the surface of the earth that has been subjected to and shows
  - ✓Effects of genetic and environmental factors of climate, and
  - ✓Macro and micro organisms conditioned by relief acting on parent materials over a period of time.

Cont. . .

- Soil is a combination of four major components and their relative proportion is:
  - Mineral (in organic) matters (40-60%)
  - Soil water (20-50%)
  - Soil air (0-40%)
  - Organic material (5%)
- **Soil Texture,** the texture of a soil has an influence on several important soil characteristics including infiltration rate and available water capacity.

Cont. . .

- Soil texture refers to its composition in terms of mineral particles. A broad classification is:
  - ✓Coarse textured soils - sand predominant – “sandy soil”
  - ✓Medium textured soils - silt predominant – “loamy soils”
  - ✓Fine textured soils - clay predominant – “clay soils”
- Water held (WH) system are ideally suited for plant growth in terms of nutrient supply, biological activity and water holding capacities.
- **Soil Depth,** the depth of soil is particularly important where water held systems are proposed.

Cont. . .

- Deep soils have the capacity to store the harvested runoff as well as providing a greater amount of total nutrients for plant growth.
  - Soils of less than one meter deep are poorly suited to WH.
- **Soil Fertility,** in many of the areas where WH systems may be introduced, lack of moisture and low soil fertility are the major constraints to plant growth.

Cont. . .

- ➢Some areas in Sub-Saharan Africa, for example, may be limited by low soil fertility as much as by lack of moisture.
  - ✓Nitrogen and phosphorus are usually the elements most deficient in these soils.
  - ✓While it is often not possible to avoid poor soils in areas under WH system development, attention should be given to the maintenance of fertility levels.

Cont. . .

- **Infiltration-** Is the entry (downward) of water from the surface into the soil.
    - ✓The infiltration rate of a soil depends primarily on its texture.
- Typical comparative table of infiltration is as shown below:

	mm/hour
Sandy soil	50
Sandy loam	25
Loam	12.5
Clay loam	7.5

Cont. . .

- Moisture characteristics of soil are determined by
  - Size and shape of particles and aggregates.
  - Density of packing and hence the amount of space between particles and aggregates where water and air moves.
  - Difference between physical and chemical property of the space of the soil.
- Generally we can classify soil into
  - light soil, medium soil and heavy soil with respect to their soil water holding capacity.

Cont. . .

- **Water Holding Capacity of Soils,** there are four important levels of soil moisture content that reflect the availability of water in the soil.
  - ✓These levels are commonly referred to as:
    - ❖Saturation,
    - ❖Field capacity,
    - ❖Wilting point and
    - ❖Oven dry.
- When a soil is saturated, the soil pores are filled with water and nearly all of the air in the soil has been displaced by water.

Cont. . .

- The water held in the soil between saturation and field capacity is gravitational water.
    - ✓ Frequently, gravitational water will take a few days to drain through the soil profile and roots of plants can absorb some.
- **Field Capacity** is the amount of soil moisture or water content held in the soil after excess water has drained away and the rate of downward movement has decreased.
    - ✓ This usually takes place 2–3 days after rain or irrigation in pervious soils of uniform structure and texture.

Cont. . .

- **The wilting point** is the soil moisture content where most plants cannot exert enough force to remove water from small pores in the soil.
- Most crops will be permanently damaged if the soil moisture content is allowed to reach the wilting point.
- Capillary water held in the soil beyond the wilting point can only be removed by evaporation.
- **Available water** is the Water held between field capacity and the wilting point
  - ✓ "Available" for plant use.

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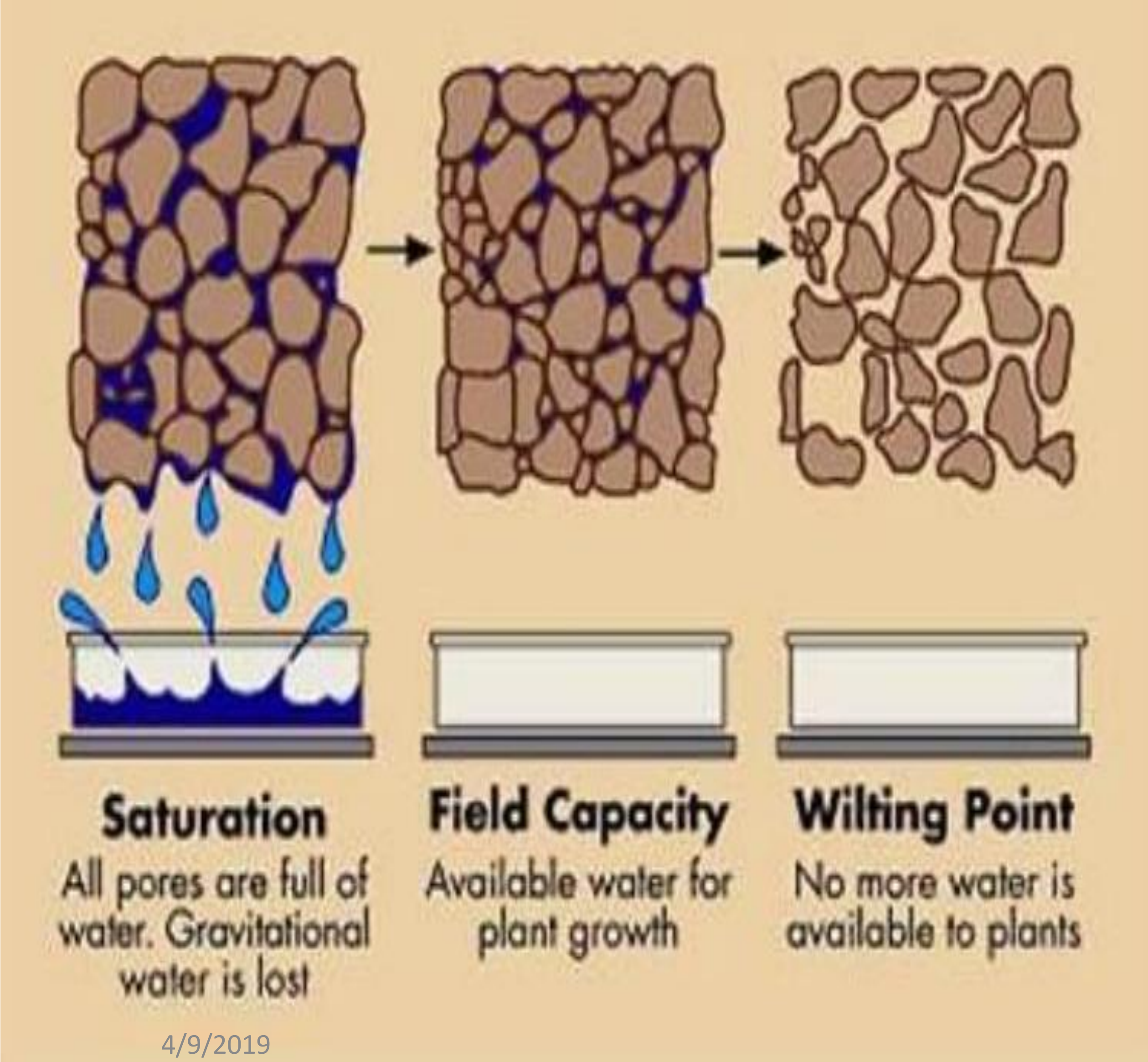
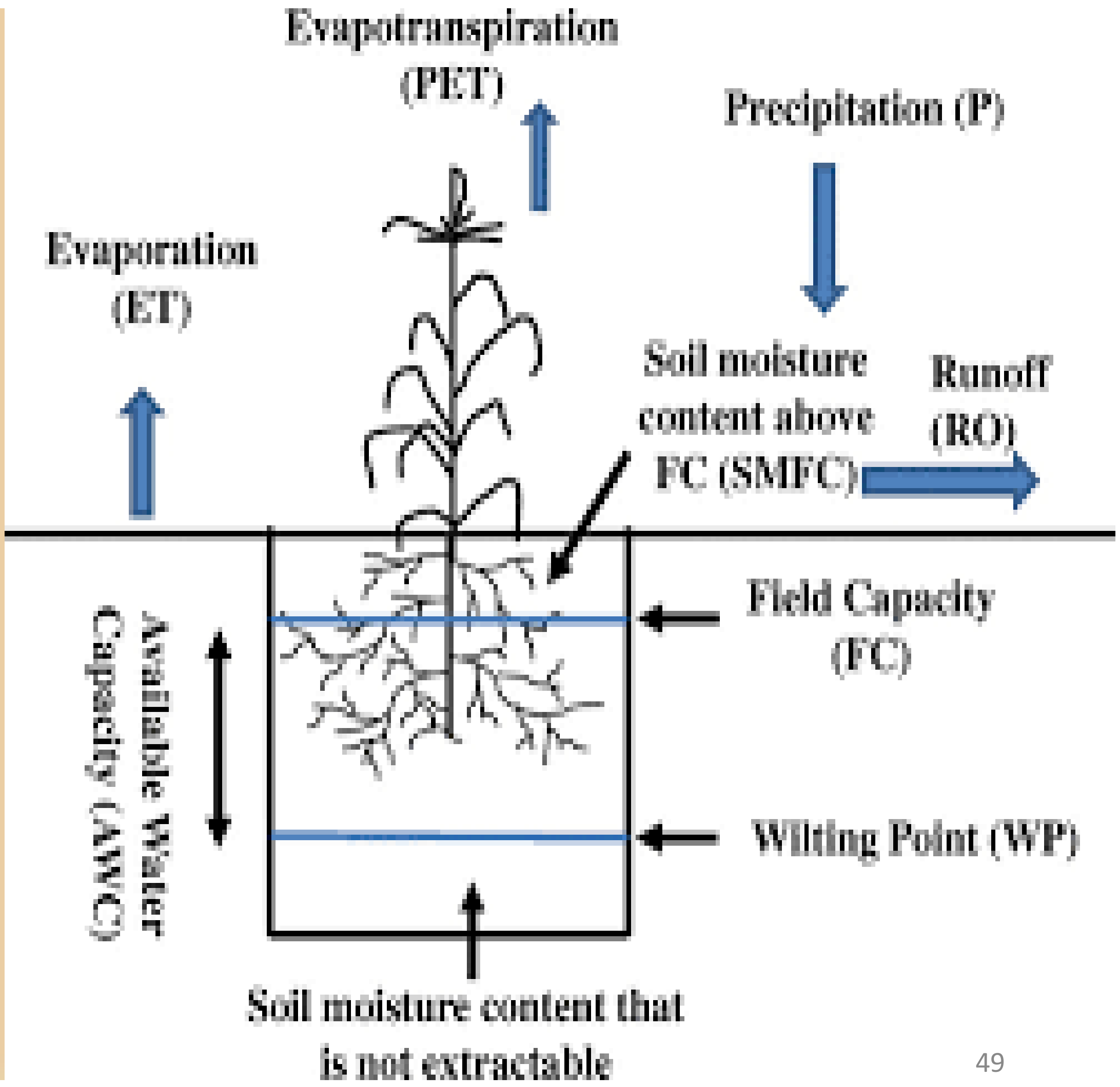


Saturation
All pores are full of water. Gravitational water is lost
Field Capacity
Available water for plant growth
Wilting Point
No more water is available to plants



Evapotranspiration (PET)
Precipitation (P)
Evaporation (ET)
Soil moisture content above FC (SMFC)
Runoff (RO)
Field Capacity (FC)
Available Water Capacity (AWC)
Wilting Point (WP)
Soil moisture content that is not extractable

Cont. . .

- The water holding capacity associated with a particular soil series, the water available for plant use in the root zone is commonly given table below.
  - ✓Available soil water content is commonly expressed as inches per foot of soil.
- The hygroscopic coefficient is the percentage of water remaining in an air-dry soil.
  - ✓The water content at field capacity, wilting point, and the hygroscopic coefficient are all based on the OVEN-DRY reference mass.
- The percentage of water held under each of these conditions can therefore be used to define the following and other forms of soil water.

Cont. . .

- ✓ $Hygroscopic\ water\ (\%) = Hygroscopic\ coefficient$
- ✓ $Capillary\ water\ (\%) = Field\ capacity\ - Hygroscopic\ coefficient$
- ✓ $Available\ water\ (\%) = Field\ capacity\ - Wilting\ point$
- ✓ $Unavailable\ Water\ (\%) = Wilting\ point$
- ✓ $Gravitational\ Water\ (\%) = Water\ content\ - Field\ capacity$

Values of soil characteristics for varies soil texture

Soil texture	θ_{fc}	θ_{wp}	AWC
	---------- in/in or m/m ---------		
Coarse sand	0.10	0.05	0.05
Sand	0.15	0.07	0.08
Loamy sand	0.18	0.07	0.11
Sandy loam	0.20	0.08	0.12
Loam	0.25	0.10	0.15
Silt loam	0.30	0.12	0.18
Silty clay loam	0.38	0.22	0.16
Clay loam	0.40	0.25	0.15
Silty clay	0.40	0.27	0.13
Clay	0.40	0.28	0.12

Cont. . .

- **Soil Moisture Tension** is the degree to which water clings to the soil is the most important soil water characteristic to a growing plant.
- Soil moisture tension increases (the soil water pressure becomes more negative), the amount of energy exerted by a plant to remove the water from the soil must also increase.
- Generally the water powdered into the soil will start at first to occupy the space found in the soil,
  - ✓ Later after sometimes most of the open space will be occupied and gravitational water start to drains down from the block of the soil, these stage was called **filed capacity** of soil.

Cont. . .

- If we consider the crop and the soil is in field capacity, then the water will be available to the crop with out any constraints.
- This is also a stage where the water available in the soil becomes bellow the field capacity and in this case the crop gets its water requirement partially through capillary water.
- When the soil becomes drier, the capillary waters movement will stop and at this point, we call **wilting point,** the stage where the crop cannot extract water from the soil.
- Therefore, at this stage we have hygroscopic water, the water which not available for the crop.
- When we get a condition above field capacity, then this means there is excess water here we call it **water logging**.

Cont. . .

- The negative effect of water logging,
  - ✓Prevents normal agricultural operation
  - ✓Leads to leaching of the soil measurement, soil water or moisture
  - ✓Decreases agricultural yield

❖**Measurement of soil moisture by using Gravimetric method**

- These include the following three steps;
  - ✓First step take a sample of a block of soil on a given depth and find its weight
  - ✓Second step kept the soil block until you are sure moisture is available in the soil
  - ✓Third step find the weight of the over dry soil

Cont. . .

Gravimetric water content = (weight before dry − weight after dry)/ Weight after dry

$$Wg = \frac{w}{s} * 100$$

- ***Example.*** *Calculation of soil water by mass*

  Mass of soil before drying = 75 g
  Mass of soil after drying = 60 g

Soil water balance

- Soil water balance is a moisture accounting system to determine whether the water requirement of the crop is satisfied or not.
- Soil water balance also used to develop an index called water requirement satisfaction index (WRSI).
- The soil water balance equation thus helps in making estimates of parameters, which influence the amount of soil water.

Cont. . .

- ➢Using the soil water balance equation, one can identify periods of water stress/excesses,
  - ✓Which may have adverse affect on crop performance.
- ➢The major parameters to develop soil water balance are
  - ✓Potential evapotranspiration, Actual evapotranspiration, Soil water holding capacity, Crop type, crop cycle and crop coefficient and Planting time.

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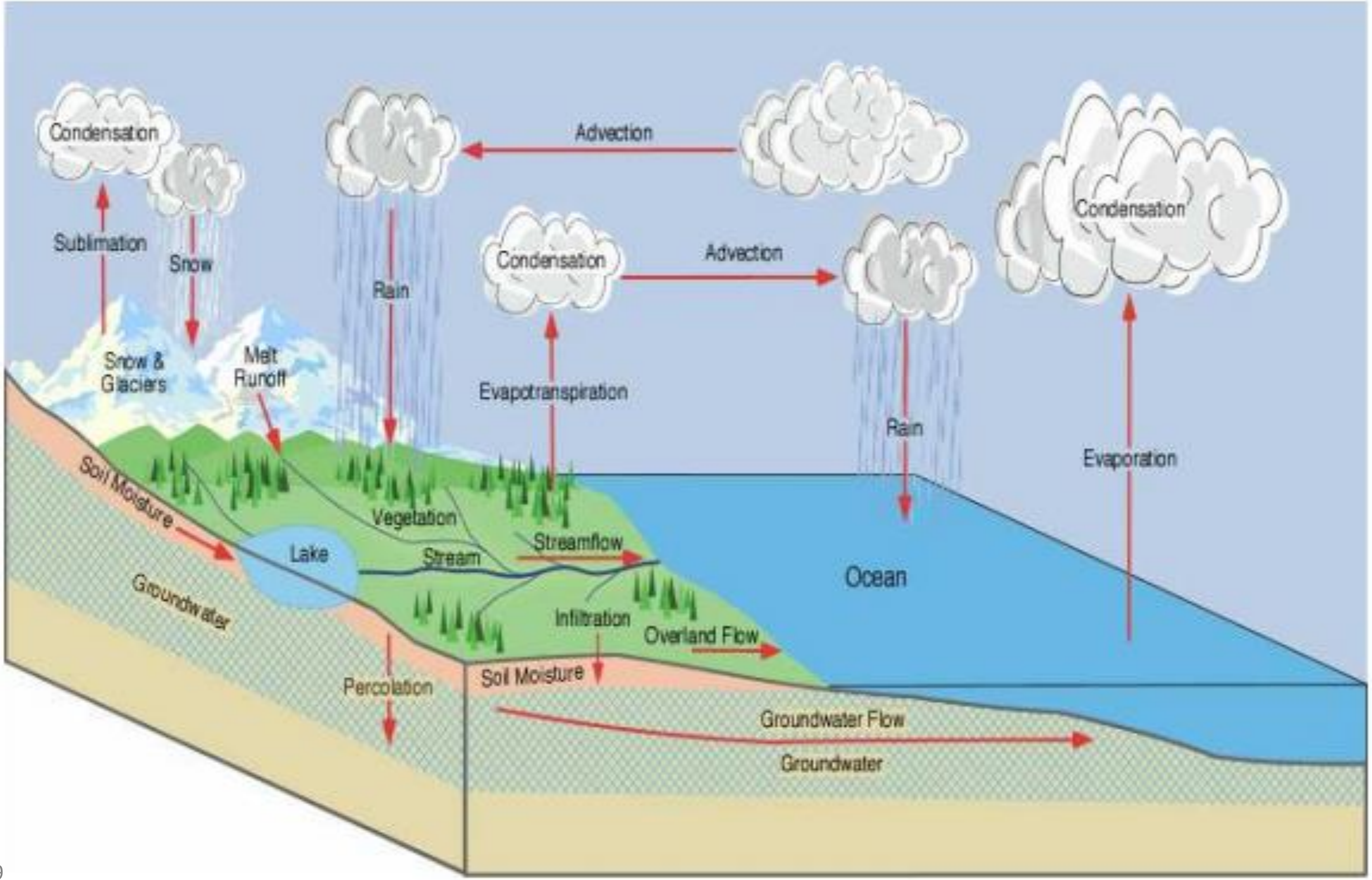


Condensation
Advection
Sublimation
Snow
Rain
Condensation
Advection
Condensation
Snow & Glaciers
Melt Runoff
Evapotranspiration
Rain
Evaporation
Soil Moisture
Vegetation
Streamflow
Lake
Stream
Ocean
Groundwater
Infiltration
Overland Flow
Soil Moisture
Percolation
Groundwater Flow
Groundwater

Cont. . .

- Potential evapotranspiration (PE): is the "water demand of the atmosphere", often referred to as water "requirement" of a conventional crop.
- Actual crops have different requirements, which are related to crop development - early stages require little water and weather conditions.
  - ✓ For example, dry and windy conditions increase water requirement.
- Potential evapotranspiration is the amount of water that would be evaporated under an optimal set of conditions, among which is an unlimited supply of water.

Cont. . .

- In other words, it would be the water needed for evaporation and transpiration given the local environmental conditions.
- One of the most important factors that determine water demand is solar radiation.
- Reference evapotranspiration (ETo) is the rate of evapotranspiration from a hypothetical crop with an assumed crop height of 12cm, a fixed canopy resistance of 70 sm(-1) and an albedo of 0.23,
  - ✓ Closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, completely shading the ground and not short of water.

Cont. . .

- The estimation of the ET(0) can be determined with the combination formula based on the Penman-Monteith approach. For the estimation of daily values, the equation becomes:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_a - e_d)}{\Delta + \gamma(1 + 0.34 U_2)}$$

- **Where,** ET(0) = Reference crop evapotranspiration [mm d(-1)]
  R(n) = Net radiation at crop surface [MJ m(-2) d(-1)]
  G = Soil heat flux [MJ m(-2) d(-1)]
  T= Average temperature [°C]
  U(2) =Wind-speed measured in 2m height [m s(-1)]
  (e(a)-e(d))= Vapour pressure deficit [kPa]
  Δ = Slope of saturation vapor pressure/temperature curve [kPa/°C]
  γ= Psychrometric constant [kPa °C(-1)]
  900= Conversion factor

Cont. . .

$$R_{ns} = 0.771(025 + 0.50\frac{n}{N})R_{a.}$$

- **Where,** Rns=net shortwave radiation [MJ m(-2) d(-1)] n/N : relative sunshine fraction

  R(a): extraterrestrial radiation [MJ m(-2) d(-1)]

$$R_{nl} = 2.45 * 10^{-9}\left[0.9\, {}^{n}\!/_{N} + 0.1\right]\left(0.34 + 0.14\sqrt{e_d}\right)\left(T_{KX}{}^{4} + T_{Kn}{}^{4}\right)$$

- **Where,** Rnl = net long wave radiation loss [MJ m (-2) d (-1)],

  T(kx) =maximum temperature [K] where,(Tmax °C + 273)

  T(kn) =minimum temperature [K] where,(Tmin °C + 273)

  e(d) =actual vapour pressure [kPa]

Cont. . .

- In principle, four climatic variables are required to estimate reference crop evapotranspiration.
  - ✓ Temperature - preferably maximum and minimum;
  - ✓ Relative humidity or vapour pressure;
  - ✓ Wind speed at a height of 2 m;
  - ✓ Solar radiation or hours of bright sunshine.
- *Actual evapotranspiration* (AE)
  - ✓ *Evaporation* is the phase change from a liquid to a gas releasing water from a wet surface into the air above.
  - ✓ *Transpiration* is represents a phase change when water is released into the air by plants.

Cont. . .

- Evapotranspiration is the combined transfer of water into the air by evaporation and transpiration.
- Actual evapotranspiration is the amount of water delivered to the air from these two processes.
- Actual evapotranspiration is an output of water that is dependent on moisture availability, temperature and humidity.

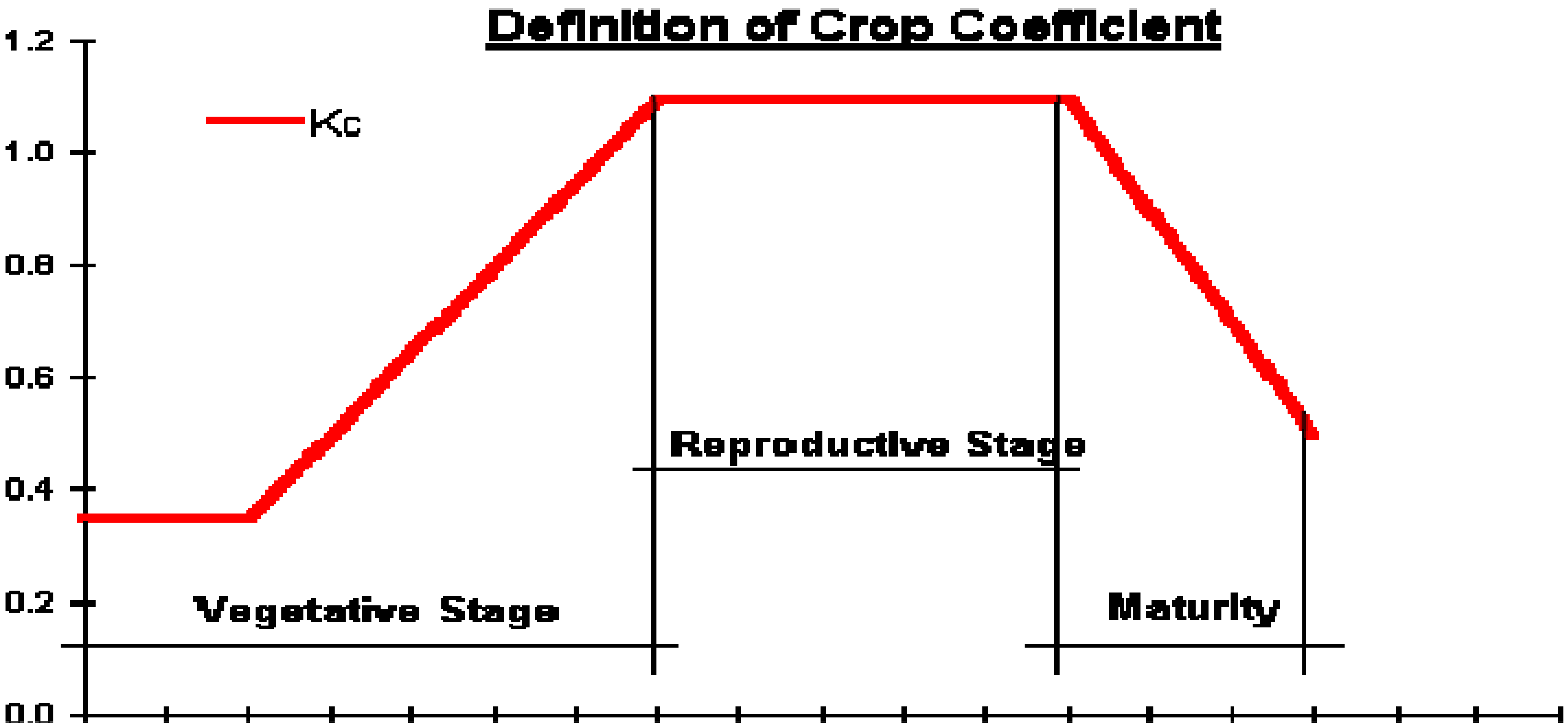
Cont. . .

- Actual evapotranspiration increases as temperature increases, so long as there is water to evaporate and for plants to transpire.
- The amount of evapotranspiration also depends on how much water is available, which depends on the field capacity of soils.
- In other words, if there is no water, no evaporation or transpiration can occur.

$$ET_a = K_c ET_o$$

Growing period and crop coefficient

- As shown below crop water requirements, grow slowly at the beginning of the crop cycle (early vegetative phases) but increase beyond PET at mid-cycle, to drop again when the crop matures.



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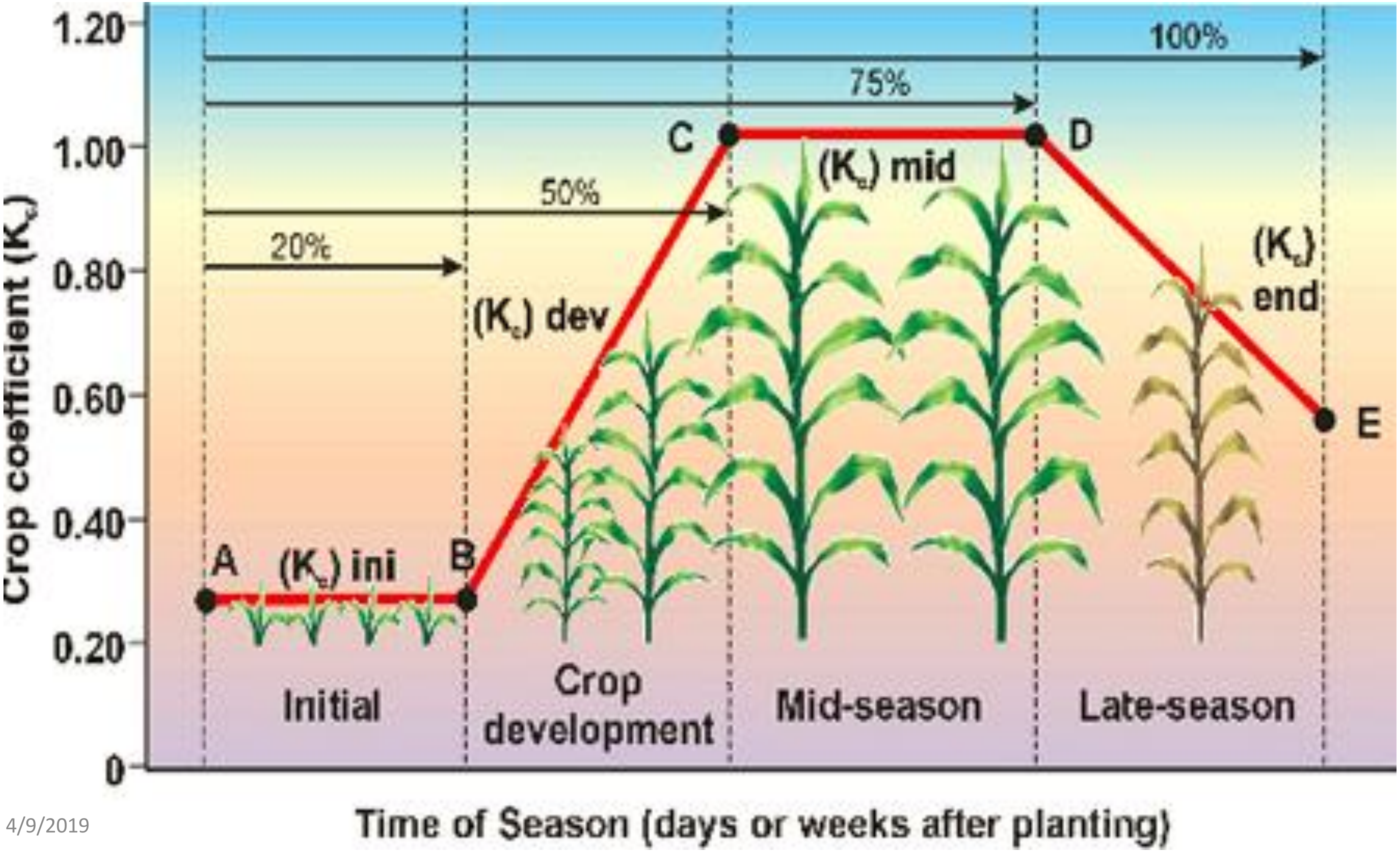
- There are four growth stages to distinguish Crop coefficient (Kc):
  - ✓The initial stage: when the crop uses little water;
  - ✓The crop development stage, when the water consumption increases;
  - ✓The mid-season stage, when water consumption reaches a peak;
  - ✓The late-season stage, when the maturing crop once again requires less water.

Growth and development of a maize crop



Cont. . .

- Characteristics of Kc
  - ☞Kc gradually rises from the planting time
  - ☞Kc greater or equals to 1 at reproduction stage of the crop
  - ☞Kc gradually becomes smaller at maturity stage of the crop
- The grass ETo and crop ET (ETc) are integrated through the single crop water requirement coefficient (Kc).
  - ✓In the single crop coefficient approach, ETc is calculated by multiplying Eto by Kc. (ETc =ETo*Kc)

Cont. . .

- Different crops would have different Kc values.
- The changing characteristics of the crop growth over the growing season as well as the evaporation from the soil influence the Kc at large.

Crop water requirement satisfaction index (WRSI)

- WRSI can be linearly related to crop production in semi-arid regions, using a linear-yield reduction function specific to a crop.
- A number of inputs are required to compute WRSI model over a course of growing season.
  - ✓ The model captures impact of timing of rains
    - Onset date/start of growing season,
    - End of season date and
    - Length of growing period

Cont. . .

- ✓Among soil factors, water holding capacity and water balance are essential, while rainfall (supply) and crop water requirement (demand) are important climatic parameters.
- ✓Crop coefficients (Kc) that define the water requirements of a specific crop at different phenological stages are also important.

$$WRSI = \frac{Rainfall}{ET_c} * 100$$, at a given crop stage

- ✓Where: ETc= crop water requirement (mm)

- ➢The identification of soil water balance will help in adopting appropriate management practices to alleviate the constraint and increase the crop yields.

Cont. . .

- Hence the soil water balance equation in its simplest form of expression is:

Change in soil water = Inputs of water - Losses of water

- **Addition of water to the soil**: Water is usually added to the soil in three measurable ways precipitation (P), irrigation (I), and contribution from the ground-water table (C).
  - ✓The contribution from the ground water will be significant only if the ground-water table is near the surface.
  - ✓So, the inputs of water can be expressed as:

Water Inputs = P + I + C

Cont. . .

- **Removal of water:** Water is removed from the soil through evaporation from soil surface or transpiration through plant together known as evapotranspiration (ET), and deep drainage (D).
- Further, a part of the rainwater received at the soil surface may be lost as surface run-off (RO).
  - ✓ The above three factors are negative factors in the equation.
- The losses of water from soil can then be represented by the following equation.

Water Losses = ET + D + RO

Cont. . .

- **Therefore, the change in the soil water content**, which is the difference between the water added and water withdrawn, can be expressed as:

Change in Soil water = (P + I + C) - (ET + D + RO)

- Soil water balance refers to the amount of water held in the root zone at a given time.
- This amount can be measured, the change in soil water from one measurement to another depends on the contribution of components in the equation.

Cont. . .

- Suppose the amount of water in the root zone at the beginning is **M1** mm and at the end of a given period is **M2** mm (soil moisture at a given time (M1 or M2)),
  - ✓ Thus the equation is expressed as

M1 - M2 = P + I + C - ET - D – RO

M2 + P + I + C = ET + D + RO + M1

Cont. . .

- ***Quiz (5%)**: Estimate evapotranspiration (ET) from the field during 01 to 31 August based on the given information. Soil = Vertisol Crop = Sorghum Period = 01 to 31 Aug Area = 2 ha Given:*

Soil moisture in the profile # on Aug 01 (M1) = 300 mm
Precipitation or Rainfall (P) = 70 mm
Irrigation (I) = Nil
Contribution from ground water (C) = Nil
Run-off of 200 cubic m from 2 ha field (R) = 10 mm
Deep drainage (D) = Nil
Soil moisture in the profile on Aug 31 (M2) = 250 mm

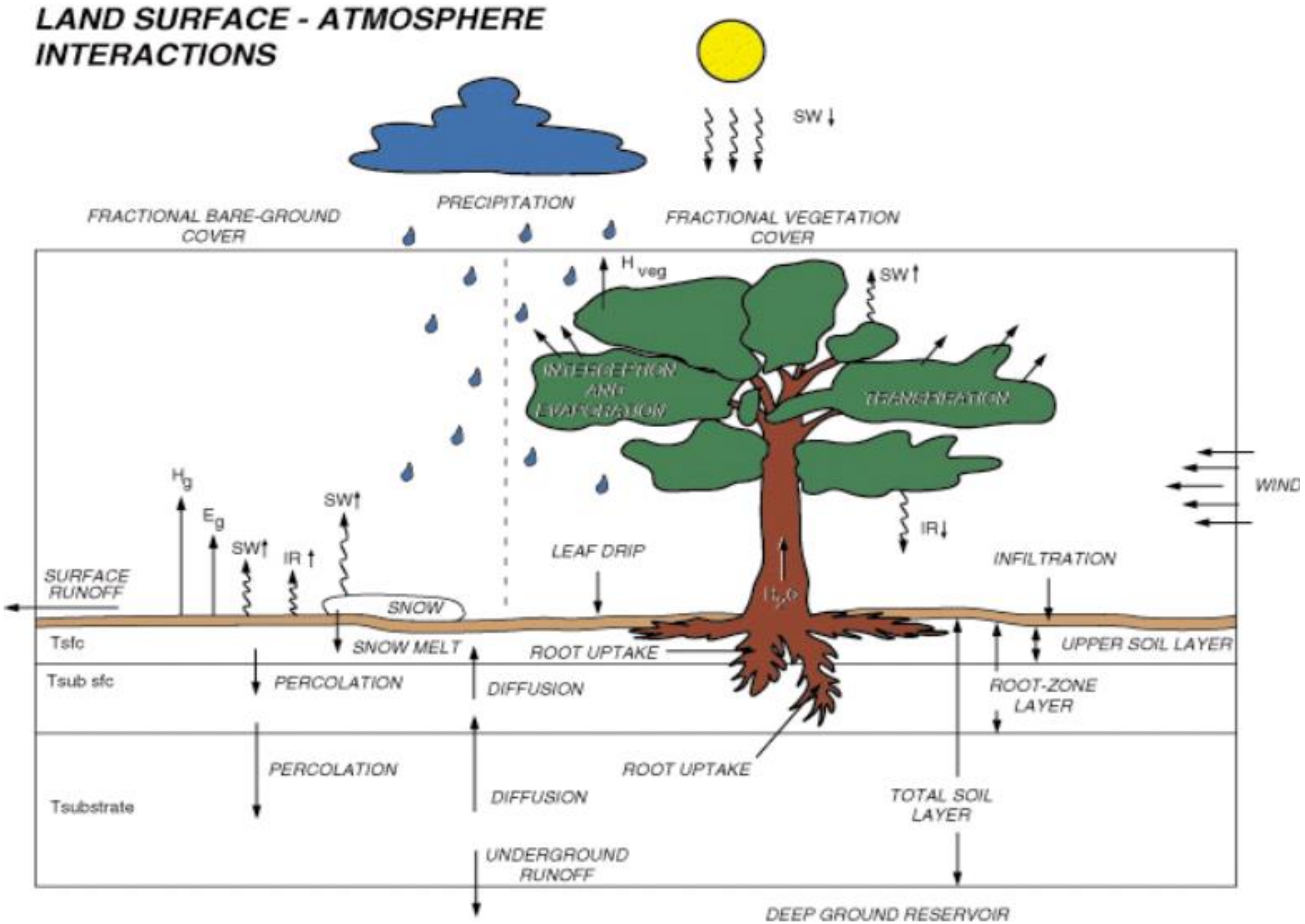
Cont. . .

- ***Example* 2:** *Estimate Deep drainage (D) losses from the field during crop period, 10 June (sowing date) to 30 Sept (harvesting date)? Soil = Alfisol Crop = Millet Area=1 ha*

Given:

Soil moisture in the profile on Jun 10 (M1) = 150 mm
Precipitation or Rainfall (P) = 600 mm
Irrigation (I) = Nil
Contribution from ground water (C) = Nil
Evapotranspiration (estimated) (ET) = 530 mm
Run-off of 200 cubic m from 1 ha field (RO) = 70 mm
Soil moisture in the profile on Sep 30 (M2) = 60mm

Soil-plant-atmosphere relationship



Cont. . .

- Water is a pre-requisite for plant growth. Though renewable, it is a limited resource.
- Increasing demand from civic, industrial and recreational uses of water imply that future Agriculture would be water-constrained.
  - ✓ It calls for devising and applying management practices for enhancing water productivity of crops.
  - ✓ Thus, there is a need to understand soil water balance, and soil water-plant atmosphere relations for conservation and efficient utilization of water.

Cont. . .

- Water is taken up by the plants via its roots, transported to its leaves, and lost to the atmosphere as vapors.
- This continuum involves retention and movement of water within the soil, proliferation of root system in the soil and uptake of water by the plants in relation to evaporative demand.
  - ✓ It needs consideration of fundamental aspects of soil water relations, soil- (plant) root relations, and plant- water-atmospheric relations.

Soil water management

- The basic principle of efficient water use lies in optimizing of the components of the soil water balance in a given area. There are two distinct management periods.
  - ✓The first is the period of rain storage lasting from harvesting of the previous crop till planting of the next crop.
  - ✓Under semi-arid climatic conditions, the soil water management strategies during the period should be to maximize the gains and minimize the losses (ET).

Cont. . .

- The soil water balance during period of the rain storage can be written as follows;

$$\Delta S = P + I + \text{ or } -D + -\text{or } R - ET$$

Where: ΔS= change in water content in the crop root zone

P= Precipitation

I= Irrigation

D= downward drainage

R= Run off

ET= Evapotranspiration

- The determination of ET follows a standard procedure [such as Thornthwaite, 1948 or FAOPenman-Monteith equation].

Cont. . .

☞Crop management regimes include those that reduce the water requirements such as adjusting planting date or using varieties with lower water demand.

- ✓According to Smika (1990), benefit from dryland farming, one must understand the techniques of capturing and storage of soil water to cope with times of water deficit, which is universal in arid regions of the world.
- ✓Rimmington and Connor (1991) asserted that maximum yields in a water-limited environment could come from improving the Water Productivity (WP).

Cont. . .

- ➢A concept of temporal and spatial management of soil water (TSMSW) as a means to ensure effective use of soil water was developed by Jin and colleagues (1999) in North China.
  - ✓Four aspects were studied:
    - ❖Readjusting crop structures and rotations to fit changes in soil water;
    - ❖Increasing soil water resources;
    - ❖Reducing soil water evaporation; and
    - ❖Managing soil water to meet temporal and spatial crop water demand.