2. Crop water requirement

2.1. General

- The quantity of water, regardless of its source, required by crop in a given period of time for its normal growth under field conditions.

\[ \text{CWR} = \text{ET} \text{ or } \text{CU} + \text{application losses} + \text{conveyance losses} + \text{special needs} \]

- Is the total amount of water and the way in which a crop requires water from the time it is sown to the time of harvest.

- Different crops will have different water requirement and the same crops may have different water requirement at different place depending upon climate, type of soil method of cultivation and useful rainfall etc.

- Crop water requirement serves as the basis for the design of the capacity of reservoir and canal, irrigation scheduling and management.

2.2. Duty and delta of a crop

**Duty (D):**

- Relationship between the volume of water and the area of the crop it matures.

\[ D = \frac{A}{Q} \]

- Duty represents the irrigation capacity of a unit water (ha/m\(^3\)/s).

- A: command area and Q: continuous discharge required for the base period.

- The duty of water at the head of the water course will be less than the duty of water on the field; because when water flows from the head of the water course and reaches the field, some water is lost as transit losses.

- Duty of water, therefore, varies from one place to another and increases as we move downstream from the head of the main canal towards the head of branches or water courses.

**EX. 1**

A reservoir with a live storage capacity of 300 M m\(^3\) is able to irrigate 40,000 hectares a year. The crop period is 60 days. What is the duty?

**Solution**

Discharge of water used for the base period:

\[ Q = \frac{Vol}{T} = \frac{300 \times 10^6}{60 \times 24 \times 60} \]

\[ Q = 57.870 \text{ m}^3/\text{s} \]

Duty of water / irrigation capacity of a unit water is

\[ D = \frac{40,000 \text{ ha}}{57.870 \text{ m}^3/\text{s}} = 691.2 \text{ ha/m}^3/\text{s} \]
2. Crop water requirement

2. Duty and delta of a crop...

**Delta (Δ):**
- Each crop requires certain amount of water depending up on the area to be cultivated. If area to be cultivated is large the water required will be large, the reverse is also true.
- The total depth of water required by the crop for its full growth may be expressed in cm is called Delta.
- Suppose certain amount of water is applied to a crop from a time of sowing till the crop matures and if the applied water is not lost or used up by any means then there will be a thick layer of water standing all over the field. The depth or height of this water layer is known as delta for the crop.

V is total volume of water required for the base period and A is command area.

**EX. 3**
Water is released at a rate of 7m³/s at u/s of the headwork, if the duty at the field is 120 ha/cumec and the loss of water in transit is 30%, find the area of the land that can be irrigated.

Solution
area of land to be irrigated = 7.7*120 = 888 ha

2. Crop water requirement

2. Duty and delta of a crop...

**Delta (Δ):**

EX. 2
If rice requires about 15 cm depth of water at un average interval of 12 days, and the cropping period of rice is 132 days, find the delta of rice.

Solution
water is required at an interval of 12 days for a period of 132 days
The rice will be watered 132/12 times = 11 times
Each time 15 cm depth of water is required
Therefore Delta / total depth of water required will be

Δ = 15 * 11 = 165 cm

2. Crop water requirement

2. Duty and delta of a crop...

**Relation between Duty and Delta**
- Assume a crop of base period B in days, D duty of water in hectare per cumec and Δ be the depth of water for a crop in meter.
- From the definition of delta, duty and base period 1m³/s flowing continuously for B days mature D hectares of land under the crop or 1m³/s continuously for B days gives a depth Δ, over D hectares of land.
- The total amount of water applied to this crop during B days. By definition of duty:

\[ V = (1 + 60 * 60 * 24 * B)m³, \quad V = 86,400 * Bm² \]

The depth of water applied on this land 1ha = 10⁴ m²

\[ \Delta = \frac{V}{A} = \frac{86,400B}{D} \]

Where: B in days, Δ delta in m and D in ha/cumec
2. Crop water requirement

2.3. Optimum utilization of irrigation water

- If a crop is sown under absolutely identical conditions, using different amounts of water depths, the resulting yield will not be the same.
- The yield increases with water and reaches a certain maximum value and then after falls down, see figure below.
- The quantity of water at which the yield is maximum, is called the optimum water depth.
- Optimum utilization irrigation generally means, getting maximum yield with any amount of water.

2.4. Irrigation efficiency

- Efficiency is the ration of the water output to the water input, and is usually expressed as percentage.
- The design of the irrigation system, the degree of land preparation, and the skill and care of the irrigator are the principal factors influencing irrigation efficiency.
- Loss of irrigation water occurs in the conveyance and distribution system, non-uniform distribution of water over the field, percolation below crop root zone, and with sprinkler irrigation evaporation from the spray and retention of water on the foliage.
- Water is lost in irrigation during various processes and, therefore, there are different kinds of irrigation efficiencies as shown below:
  - **Conveyance efficiency** (ηc): it is the ratio of the water delivered into the field from the outlet point of the channel, to the water pumped into the channel at the starting point.

Ex 4

A stream of 12 l/s was diverted from a headwork and 10.5 l/s is delivered to the field. An area of 1.2ha was irrigated in 6hrs. The effective root zone depth was 1.2m. the runoff loss in the field was 50m

- **Irrigation efficiency.**

\[
\eta = \frac{1 - d}{D} \times 100\% 
\]

\[
D = \frac{\text{sum of } D_i}{D} 
\]

\[
d = \frac{\text{sum of } d_i - D}{D} 
\]

\[
\eta = \frac{1 - 0.15}{1.05} \times 100\% = 85.7\%
\]

Water is lost in irrigation during various processes and, therefore, there are different kinds of irrigation efficiencies as shown below:

Ex 4

A stream of 12 l/s was diverted from a headwork and 10.5 l/s is delivered to the field. An area of 1.2ha was irrigated in 6hrs. The effective root zone depth was 1.2m. the runoff loss in the field was 50m

- **Irrigation efficiency.**
The values of consumptive use (CU) can be different for different crops, by crop characteristics.

Crop water requirement (CWR)...
- Evaporation
  - Evaporation is the process whereby liquid water is converted to water vapour (vaporization) and removed from the evaporating surface (vapour removal).
  - Water evaporates from a variety of surfaces, such as lakes, rivers, pavements, soils and wet vegetation.
  - Energy is required to change the state of the molecules of water from liquid to vapour are direct solar radiation and, to a lesser extent, the ambient temperature of the air provide this energy.
  - The driving force to remove water vapour from the evaporating surface is the difference between the water vapour pressure at the evaporating surface and that of the surrounding atmosphere.
  - As evaporation proceeds, the surrounding air becomes gradually saturated and the process will slow down and might stop, if the wet air is not transferred to the atmosphere. The replacement of the saturated air with dry air depends greatly on wind speed.

- Transpiration
  - Transpiration consists of the vaporization of liquid water contained in plant tissues and the vapour removal to the atmosphere.
  - Crops predominately lose their water through stomata. These are small openings on the plant leaf through which gases and water vapour pass.
  - Nearly all water taken up is lost by transpiration and only a tiny fraction is used within the plant.
  - Transpiration, like direct evaporation, depends on the energy supply, vapour pressure gradient and wind.
  - The transpiration rate is also influenced by crop characteristics, environmental aspects and cultivation practices. Different kinds of plants may have different transpiration rates. Not only the type of crop, but also the crop development, environment and management should be considered when assessing transpiration.
Factors affecting evapotranspiration

LAI is the ratio of total upper leaf surface divided by the surface area of the land.

Evapotranspiration (ET)

- Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes.
- Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area.
- When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process.

Evapotranspiration (ET) Units

- The evapotranspiration rate is normally expressed in millimeters (mm) per unit time.
- Water depths can also be expressed in terms of energy received per unit area, energy required to vaporize free water known as latent heat of vaporization ($\lambda$), is a function of the water temperature.

<table>
<thead>
<tr>
<th>depth</th>
<th>volume per unit area</th>
<th>energy per unit area</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm day$^{-1}$</td>
<td>m$^3$ ha$^{-1}$ day$^{-1}$</td>
<td>MJ m$^{-2}$ day$^{-1}$</td>
</tr>
<tr>
<td>1 mm day$^{-1}$</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>1 m$^3$ ha$^{-1}$ day$^{-1}$</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>1 MJ m$^{-2}$ day$^{-1}$</td>
<td>0.408</td>
<td>4.08</td>
</tr>
</tbody>
</table>

Weather parameters, crop characteristics, management and environmental aspects are factors affecting evaporation and transpiration.

Weather parameters: radiation, air temperature, humidity and wind speed. The evaporation power of the atmosphere is expressed by the reference crop evapotranspiration (ETo).

Crop factors: The crop type, development stage, crop height, crop roughness, reflection and ground cover. Crop evapotranspiration under standard conditions (ETo) refers to the evaporating demand from crops.

Management and environmental conditions: soil salinity, poor land fertility, the presence of impenetrable soil horizons and pests and poor soil management may limit the crop development and reduce the evapotranspiration.
2. Crop water requirement

2.6. Factors affecting evapotranspiration

- Reference (ETo)
  evaporation power of the atmosphere

- Crop evapotranspiration
  under standard (ETc)
  excellently managed, large, well-watered fields

- non-standard conditions (ETc adj)
  non-standard conditions generally requires a correction.

\[ \text{ETc} = \text{ETo} \times K_c \times K_{adj} \]

\[ \text{ETo} = \text{ETo} \]

2.7. Reference crop evapotranspiration (ETo)

- The evapotranspiration rate from a reference surface, not short of water is called ETo.
- The reference surface is a hypothetical grass reference crop with specific characteristics “with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m\(^{-1}\) and an albedo of 0.23.”
- ETo is used to estimate evaporative demand of the atmosphere independently of crop type, crop development and management practices.
- The crop evapotranspiration under standard conditions, denoted as ETc, is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions.

2.7. Reference crop evapotranspiration (ETo)

Average ETo for different agroclimatic regions in mm/day from 1 to 9

<table>
<thead>
<tr>
<th>Regions</th>
<th>Mean daily temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cool -10°C</td>
</tr>
<tr>
<td>Tropics and subtropics</td>
<td></td>
</tr>
<tr>
<td>humid and sub-humid</td>
<td>2-3</td>
</tr>
<tr>
<td>arid and semi-arid</td>
<td>2-4</td>
</tr>
<tr>
<td>Temperate region</td>
<td></td>
</tr>
<tr>
<td>humid and sub-humid</td>
<td>1-2</td>
</tr>
<tr>
<td>arid and semi-arid</td>
<td>1-3</td>
</tr>
</tbody>
</table>