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DEPARTMENT OF AGRICULTURAL ENGINEERING

COURSE CODE & NAME: 19AGB303 & Irrigation and Drainage Engineering

III YEAR / VI SEMESTER

UNIT : II WATER RESOURCES AND IRRIGATION REQUIREMENT OF CROPS

TOPIC 2.5. : Crop Water Requirement, Water- Duty and Delta – Effective Rainfall

Water Requirement and Consumptive Use

- Water requirement of crop is the quantity of water, required by a crop or diversified pattern in a given period of time for their normal growth under field conditions.

- It includes ET and other economically unavoidable losses.

Consumptive use (CU): It is the sum of the volumes of water used by crop over a given area in producing plant tissue, in transpiration (T), and that evaporated (E) form adjacent soil or plant foliage.

Since the volume used in producing plant tissue is negligible (<1%), CU can be approximately equal to ET.

WR= CU = ET

How to calculate WR?

WR include the unavoidable application losses (AL) eg.

Percolation

Seepage

Runoff

WSO
Land preparation,
Pre-sowing
Irrigation

WR = ET + AL + WSO

In terms of source of water it is expressed as - WR = IR + EP + S
Where, IR = Irrigation requirement
EP = Effective precipitation
S = Soil profile moisture contribution

Irrigation requirement (IR) :
The total amount of water required to supplement precipitation (EP) and soil moisture contribution (S) to meet crop water needs for optimum growth and yield.

IR = WR - (EP + S)

Optimum water requirement

(OWR) : It is the amount of water required during the growing season to produce highest crop yield.

NIR and GIR

Net irrigation requirement:
It is the depth of irrigation water exclusive of precipitation and ground water contribution or other gains in soil moisture, that is required for plant growth; the amount of irrigation water required to bring the soil moisture level in the effective root zone to the field capacity.
NIR = (CU – EP) + AL

Gross irrigation requirements (GIR): A gross irrigation requirement in **mm/day** was calculated by considering irrigation efficiency as 65%. (Doorenbos and Prutt, 1997).

$$\text{GIR} = \frac{IR}{Application\ efficiency}$$ **mm /day**

Irrigation frequency : It refers to the number of days between two successive irrigation

during the periods without precipitation

Duty of Water (D)

This is defined as the area that can be irrigated with a continuous non-stop supply of irrigation water at the rate of one cumec or cusec throughout the base period. It is expressed as acre/cusec or hectare/cumec.

Delta (Δ)

This the depth of water required by a crop during the crop season to meet its requirements. This does not have any relevance to the area of the cropped field. It is expressed in mm or cm.

Effective rainfall

Dastane (1974) has defined effective rainfall as “that portion of the total annual or seasonal rainfall which is useful directly and/or indirectly for meeting the crop water needs in crop production at the site where it falls but without pumping”. Thus, it is the portion of rainfall that does not include losses due to surface runoff, unnecessary deep percolation and residual moisture after harvest. Effective rainfall is suggested for use in planning and operation of irrigation projects.

A number of factors affects effective rainfall :

- rainfall characteristics,
- land topography,
- soil and crop characteristics,
- management practices, carryover
- moisture content
- ground water contribution.

Determination of crop water requirements

A . Direct measurements

1. Transpiration ratio method
2. Depth- interval – yield approach
3. Lysimeter experiments
4. Soil moisture depletion studies
5. Field experimentation
6. Water balance method

B – From climatic data

1. Pan evaporation data
2. Estimation by climatic parameters.

Methods of Crop Water Requirement Determination

1. Direct Measurement of Evapotranspiration

Plant water use is an important management input, thus, it is critical to know ET. Some of the methods are discussed here.

2. Aerodynamic Methods

The vapour pressure of the air and air flow velocities can be measured at several levels above a plant canopy.

By evaluating these measurements, the instantaneous evapotranspiration rate can be determined.

Summing these instantaneous measurements provides an estimate of evapotranspiration for a day.

Vapour pressure is a measure of the tendency of a material to change into the gaseous or vapour state, and it increases with temperature

3. Soil Water Balance Methods

Soil water is the sources for evapotranspiration, and several methods have been used to relate changes in soil water to plant water use. The soil water balance can be expressed as:

$$ET = Aw_e + AW_b + P + d_g + U_f + R_i - R_o - d_p$$

Where,
ET = amount of evapotranspiration during the period,
AW_e = amount of soil water in the root zone at the end of a period,
AW_b = amount of soil water in the root zone at the beginning of a period,
P = total precipitation during the period,
d_g = gross irrigation during the period,
U_f = groundwater contribution to water use during the period,
R_i= surface water that runs onto the area during the period,
R_o = surface runoff that leaves the area during the period, and
d_p = deep percolation from the root zone during the period.

Info bank :

- Soil water content can be measured using neutron scattering techniques.
- Deep percolation is difficult to measure and is often assumed to be insignificant unless substantial rainfall occurs or large irrigations are applied
- A significant problem with the soil water balance technique is that repetitive measurements must be made throughout the season.
- One week is usually the shortest period for using the soil water balance method to estimate ET

Factors affecting irrigation water needs

1. Climate and crop growing season
2. Crop characteristics
3. Soil factors
4. Crop management practices –

Mulching, cover crop, pest and disease management etc, crop rotation, Intercropping, soil moisture monitoring and scheduling

Intercropping

Cover cropping

A number of methods are in practice for determining effective rainfall. These include, field water balance approach, drum culture approach for rice, and empirical relationship (SCS method).The water requirement of different crops are given below:

Crop	Water requirement (mm)	Crop	Water requirement (mm)
Rice	1200	Tomato	600 – 800
Wheat	450 – 650	Potato	500 – 700
Sorghum	450 – 650	Pea	350 – 500
Maize	500 – 800	Onion	350 – 550
Sugarcane	1500 – 2500	Chillies	400 – 600
Sugarbeet	550 – 750	Cabbage	380 – 500
Groundnut	500 – 700	Banana	1200 – 2200
Cotton	700 – 1300	Citrus	900 – 1200
Soybean	450 – 700	Grapes	700 – 1200
Tobacco	400 – 600	Mango	1000 – 1200
Beans	300 – 500	Turmeric	1200 – 1400

Crop Duty

I DUTY

Duty- Area of the crop irrigated/ Volume of water required.

Or

It is the number of hectares of land irrigated for full growth of a given crop by a supply of 1 cumec of water continuously during the entire base period of that crop.

Base period : The period between the first watering at the time of sowing and the last watering before harvesting.

Crop period : duration from the time a crop is sown (planted) to the time it is harvested.

1.1 FACTOR AFFECTING THE DUTY

1) Soil Moisture

•In clayey soil less water is required since its retentive capacity is more.

•Pervious soil it will be more.

2) Topography

•Uniform distribution depends on topography.

•If the area is sloping the lower portion will get more water than the flat portion, & hence Water requirement is increase.

3) Nature of rainfall

•If rainfall is high over the crop period water requirement becomes less, otherwise it will be more.

4) Nature of crop irrigated

•Dry crop required less water where as wed crop required more water.

5) Method of cultivation:

If the fields are properly ploughed it will have high retentive capacity & the number of watering are reduced.

6) Season of crop

•Less irrigation water is required for rainy season crop and the duty increased.

•If the crop grown in summer, more irrigation water is required & the duty gets decreased

7) System of Irrigation

•In perennial irrigation, continuous supply of water is given & hence water table is kept high & percolation losses is minimized

•In inundation type wastage is more by deep percolation.

8) Canal Condition

•Well maintained canal will have more duty as the losses is less.

IMPORTANCE OF DUTY

- It helps us in designing an efficient canal irrigation system.

- Knowing the total available water at the head of a main canal, and the overall duty for all the crops required to be irrigated in different seasons of the year, the area which can be irrigated can be worked out.

- if we know the crops area required to be irrigated and their duties, we can work out the discharge required for designing the channel.

IMPROVING DUTY

1. The water losses can be reduced by having the irrigated area nearer to the head of the canal.
2. Evaporation losses can be minimized by using the water as quickly as possible.
3. Water losses can be minimized by lining the canals.
4. The cultivators should be trained to use water economically without wasting.
5. The soil properties should be studied by establishing research stations in villages.

(1) Proper Ploughing:
Ploughing should be done properly and deeply so that the moisture retaining capacity of soil is increased.

(2) Methods of supplying water:
The method of supplying water to the agriculture land should be decided according to the field and soil conditions.

For example,
◦Furrow method for crops sown in rows
◦Contour method for hilly areas
◦Basin for orchards
◦Flooding for plain lands

(3) Canal Lining:
It is provided to reduce percolation loss and evaporation loss due to high velocity.

(4) Minimum idle length of irrigation Canals:
The canal should be nearest to the command area so that idle length of the canal is minimum and hence reduced transmission losses.

(5) Quality of water:
Good quality of water should be used for irrigation. Pollution en route the canal should be
avoided.

(6) Crop rotation:
The principle of crop rotation should be adopted to increase the moisture retaining capacity
and fertility of the soil

DELTA (Δ).

The depth of water required every time, generally varies depending upon the type of the crop.

OR

The total water depth required for a particular crop to reach maturity conditions

 Crop period-the time from the instant of its sowing to the instant of harvesting.
 Base Period-time b/w the first supply of water to the land and the last watering before harvesting

RELATION BETWEEN DUTY AND DELTA

$$\Delta = 8.64 B/D$$

Where,

- Δ=Delta in meter
- D = Duty in Ha/cumec
- B = Base period in days

8.64 – conversion factor ((to convert days and cumecs to meters)

Duty (D) represents the area that can be irrigated with **1 cubic meter per second (cumec) of water throughout the base period.** A **higher duty** means that a given volume of water can irrigate a larger area.

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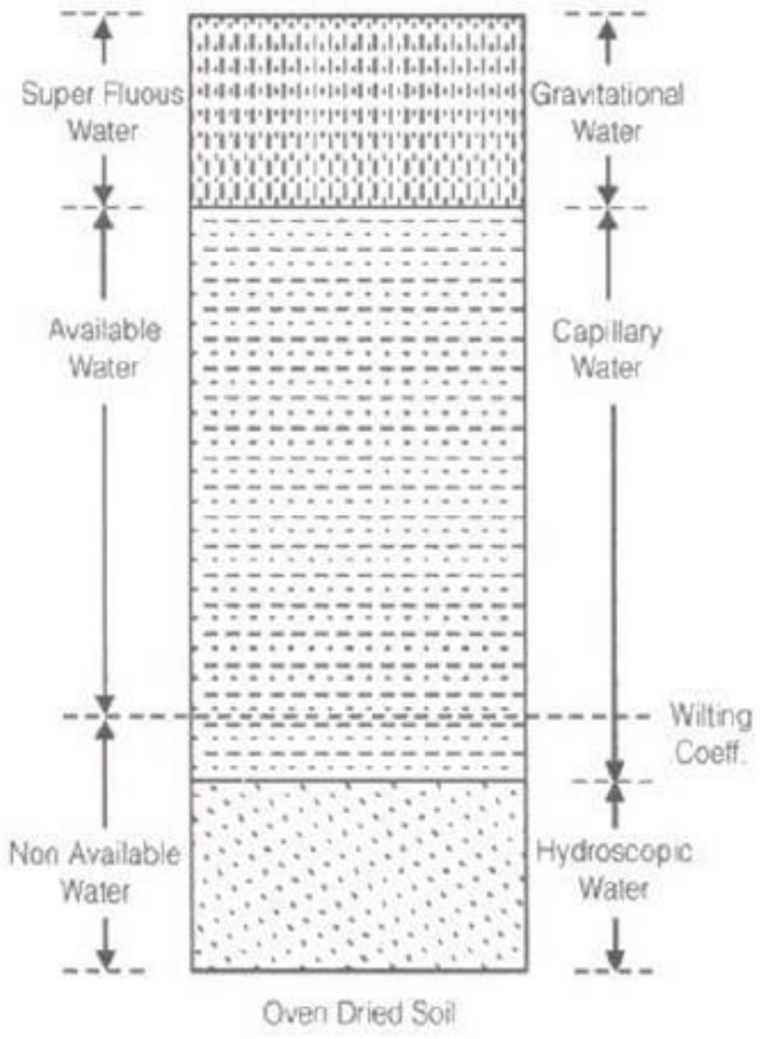
Duty and delta are always inversely proportional

CROP WATER REQUIREMENTS OR MOISTURE USE OF CROP

Soil moisture

- It refers to a soil's water content when practically all pore spaces are filled with water.
- Water present in the soil may be to classified under three heads

1. Hygroscopic water
2. Capillary water
3. Gravitational water



1.Hygroscopic water

Water attached to soil particles through loose chemical bonds is termed hygroscopic water. This water can be removed by heat only. But the plant roots can use a very small fraction of this soil moisture under drought conditions.

2.Capillary water

The capillary water is held within soil pores due to the surface tension forces (against gravity) which act at the liquid-vapour (or water-air) interface.

3.Gravitational water

Gravity water is that water which drains away under the influence of gravity. Soon after irrigation (or rainfall), this water remains in the soil and saturates the soil, thus, preventing circulation of air in the void spaces.

(1) Available moisture for the plant=Fc-Ǿ

(2) Readily available moisture for the plant = FC - Mo

Here FC= field capacity

φ = wilting point or wilting coefficient below plant can't survive.

Mo= Readily available moisture content

Permanent wilting point

The water content at which plants wilt and can't recover, even when given enough water. At this point, the soil is dry and plants can't extract any more water. The soil water content is at or below -1.5 MPa, and the remaining water is too difficult for plant roots to absorb. As the soil dries out, the water it retains becomes tighter, making it harder for plants to access. Eventually, the plant's water uptake can't meet its needs, and it wilts and dies

$$\boxed{\text{Available water} = \text{FC} - \text{PWP}}$$

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(3) Frequency of Irrigation $= \dfrac{weight\ /\ readily\ available\ moisture\ depth}{consumptive\ use\ rate}$

(4) $F_C = \dfrac{weight\ of\ water\ stored\ in\ soil\ of\ unit\ area}{weight\ of\ same\ soil\ of\ unit\ area}$

where, weight of water stored in soil of unit area $= \gamma_w \cdot d_w \cdot 1 \cdot$

Weight of some soil of unit area $= \gamma \cdot d \cdot l$

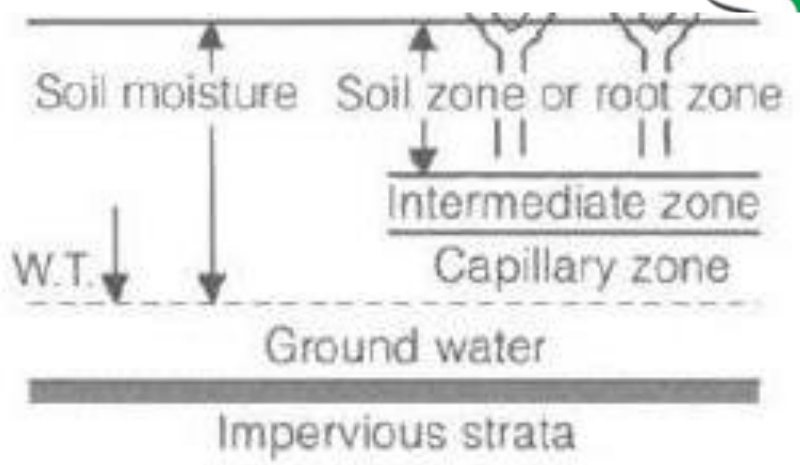
dw= depth of water stored in root zone.

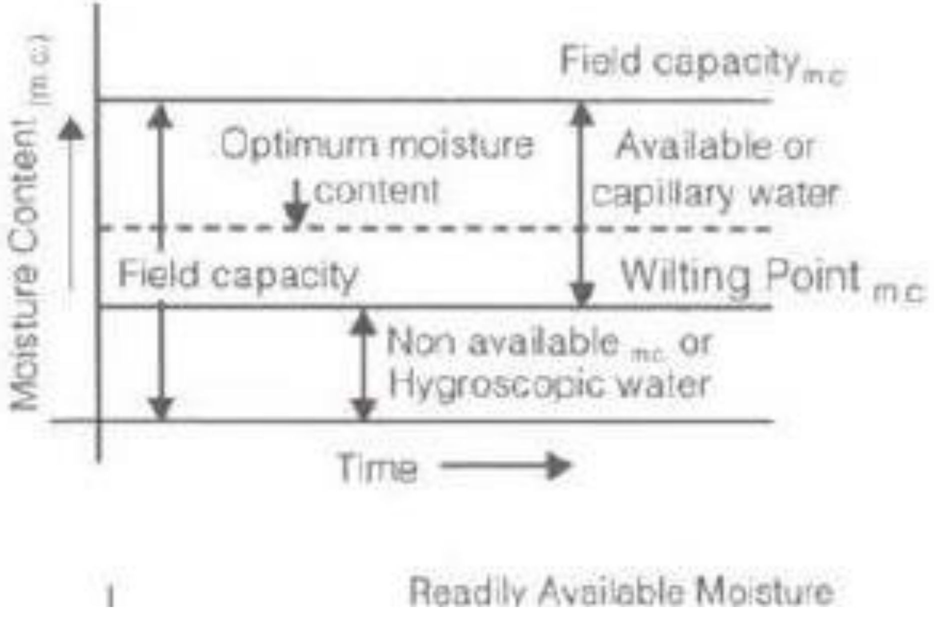
(5) $d_w = \dfrac{\gamma \cdot d}{\gamma_w} \cdot F_C \quad \gamma \rightarrow$ dry unit wt. of soil

(6) Available moisture depth to plant $d_w' = \dfrac{\gamma . d}{\gamma_w}(F_C - \phi)$

(7) Readily available moisture depth to plant $d_w' = \dfrac{\gamma . d}{\gamma_w}(F_C - m_o)$

(8) $F_C = n / G$ where, G = specific gravity and n = porosity





- ❖Crop water Requiremnt
- ❖Base period vs crop period
- ❖Crop duty vs delta
- ❖Effective rainfall
- ❖Available water/Soil Moisture
- ❖Factors influencing WR
- ❖Measures to improve crop duty

THANK YOU..."