NUMERICAL ANALYSIS OF CONSUMPTIVE AND NON-CONSUMPTIVE WATER USE

- ✓ In simple, it is the quantity of water used by the vegetation growth of a given area (water which is taken from the source cannot be returned back).
- ✓ Expressed in terms of depth of waters.

Effective rainfall:

Part of rain water percolate below the root zone of the plants and part of rain water flows away over the soil surface as runoff.

This deep percolation water and runoff cannot be used by plants.

In other works, part of the rainfall is not effective. The remaining part is stored in the root zone and can be used by plants. This remaining part is so called effective rainfall.

CONSUMPTIVE WATER USE

- ❖ **Evaporation** is the transfer of water from the liquid to the vapour state.
- ❖ **Transpiration** is the process by which plants remove moisture from the soil and release it to air as vapour.
- ❖ **Consumptive use or evapotranspiration (C_u)** for a particular crop is defined as the total amount of water used by the plant in transpiration (building of plant tissues, etc.) and evaporation from adjacent soils or from plant leaves in any specified time. The values of consumptive use (C_u) may be different for the same crop at different times and places. It is expressed as hectare cm (depth of water consumed by evaporation and transpiration during crop growth).
- ❖ **Effective rainfall (R_e):** precipitation falling during the growing period of a crop that is available to meet the evapo-transpiration needs of the crop is called effective rainfall. It does not include the precipitation lost through deep percolation below the root zone of water lost as surface runoff.

CONSUMPTIVE IRRIGATION REQUIREMENT (C I R)

Defined as the amount of irrigation water that is required to meet the evapotranspiration needs of the crop during its full growth.

$$CIR = C_u - R_e$$

It is consumptive use but exclusive of effective precipitation.

NET IRRIGATION REQUIREMENT (N I R)

Amount of irrigation water required at the plot to meet the evapotranspiration needs of water as well as other needs.

N I R = C_u – Re + (water lost as percolation in satisfying other needs such as leaching)

FACTORS AFFECTING CONSUMPTIVE USE OF WATER

- Evaporation which depends upon humidity
- Mean monthly temperature.
- Growing season of crop and cropping pattern.
- Monthly precipitation in the area
- Irrigation depth or depth of water applied for irrigation
- Wind velocity in the locality
- Soil and topography
- Irrigation practices and methods of irrigation.

ESTIMATION OF CONSUMPTIVE USE

Consumptive use estimation

- **Direct measurement**
  - Tank and lysimeter methods
  - Field experimental plots
  - Soil moisture studies
  - Integration method
  - Inflow and outflow studies for large area
  - Vapour transfer method
- **use of equations**
  - Penman method
  - Blaney – criddle method
  - Hargreaves class A pan evaporation method

TANK AND LYSIMETER METHODS

- Tanks are containers set flush with the ground level having an area of 10m square and 3m deep
- Larger the size of the tank greater is the resem balance to root development.
- Consumptive use is determined by measuring the quantity of water requirement to maintain constant moisture conditions within the tank for satisfactory proper growth.
- In lysimeters, the bottom is pervious.
- Consumptive use is the difference of water applied and that draining through pervious bottom and collected in a pan.

- In this method, a water tight tank of cylindrical shape of dia 2m and depth of about 3m is placed vertically on the ground. The tank is filled with sample of soil.
- The bottom of the tank consists of a sand layer and a pan for collecting surplus water. The plants grown in lysimeter and measuring device should be the same as in the surrounding field.
- The consumptive use of water is estimated by measuring the amount of water required for the satisfactory growth of the plants within the tanks.

$Cu = W_a - W_d$

$W_a \longrightarrow$ water applied

$W_d \longrightarrow$ water drained off

- It is expensive method. Vapour transfer method and field plot method are more reliable compared to this method.

FIELD EXPERIMENTAL PLOT

- Irrigation water is applied to the selected field experimental plots in such a way that there is neither runoff nor deep percolation.
- Yield obtained from different fields are plotted against the total water used and as basis for arriving at the consumptive use, those yields are selected which appear to be most profitable.

- It is seen from the observations that for every type of crop, the yield increase rapidly with an increase of water used to a certain point and then decrease with further increase in water.
- At the „break in the curve" the amount of water used is considered as the consumptive use.

- We selected a representative plot of area and the accuracy depends upon the representativeness of plot (cropping intensity, exposure etc.)
- It replicates the actual sample field conditions
- Less seepage loss should be there: evapotranspiraton = inflow + rain + outflow --- the draw back in this method is the lateral movement of water takes place although more representative to field conditions. Also, some

correction has to be applied for deep percolation as it cannot be ascertained in the field.

- To determine seasonal consumptive use.
- Measurement of water supplied to the crops through effective rainfall and irrigation and changes in the soil moisture reverses during the growing season are made. It is then correlated with yields Vs water supplied to the crop.

SOIL MOISTURE STUDIES OR VAPOUR TRANSFER METHOD

- This method is suited to area where soil is fairly uniform and ground water is deep enough so that it does not affect the fluctuations in soil moisture within the root zone of the soil.
- Soil moisture measurements are done before and after irrigation.
- The quantity of water extracted per day from soil is computed for each period.
- A curve is drawn by plotting the rate of use against time and from this curve, seasonal use can be determined.
- Expressed in terms of volume. Acre feet or Ha-m

INTEGRATION METHOD

- In this method, it is necessary to know the division of total area under irrigation crops, natural vegetation, water surface area and base land area.
- This method is summation of products of

{[Consumptive use for each crop X its area] + [Consumptive use of native vegetation area X its area] + [Water surface evaporation X the water surface area] + [Evaporation from base land X its area]}

- In this method, annual consumptive use for the whole are is found in terms of volume.
- Expressed in acre feet or ha –m.
- Total evaporation = total consumptive use x total area.
- Annual consumptive use = total evaporation.

- Thus, the annual consumptive use for the whole of the area is found, in acre feet or hectare-meter units.

INFLOW-OUTFLOW STUDIES FOR LARGE AREAS

$$U = \underbrace{[I - P]}_{\text{Inflow}} + \underbrace{[G_s - G_e]}_{\text{storage}} - \underbrace{R}_{\text{outflow}}$$

U ⟶ Valley consumptive use (ha-m)

I ⟶ Total inflow during 12 months

P ⟶ Yearly precipitation on valley floor

G_s ⟶ Ground storage at the beginning of the year.

G_e ⟶ Ground storage at the end of the year

R ⟶ Yearly outflow

Annual consumptive use is found for large areas (yearly).

PENMAN METHOD

The potential evapotranspiration (consumptive use) is given by the formula

$$E_T = \Delta H + 0.27\, E_a / \Delta - 0.27$$

Where,

$H = R_A[1-r]\ [0.18 – 0.55\ n/N] – \delta T_a^4\ [0.56 – 0.092\ e_d\ [0.10 + 0.9n\ /N]$

$E_a = 0.35\ [e_a – e_d]\ [1 + 0.0098\ u_2]$

H – Daily heat budget at surface in mm/day

r – reflection coefficient of surface (albedo)

n – Actual duration of bright sunshine in hours

N – Max. Possible hour of bright sunshine

R_A – Mean incident solar radiation at the top of the atmosphere on a H_L surface, expressed in mm of evaporable water per day.

δ - Stefan Boltzmann constant (2.01×10^{-9} mm/day)

T_a^4 - mean air temperature in ˚K (273 +˚C)

e_d – actual mean vapour pressure in the air in mm of Hg.

Ea – evaporation in mm of evaporable water per day

e_a – saturation vapour pressure at mean air temperature in mm of Hg

u_2 – mean wind speed at 2m above the ground (miles/day)

u_1 - measured wind speed in miles per day at height h in feet

∆ - slope of the saturation vapour pressure Vs temperature curve at the mean air temperature.

BLANEY – CRIDDLE FORMULA

$$C_u = K P /40 [1.8t = 32]$$

$Cu = K \sum f$

Where, Cu – Monthly consumptive use in cm

K – Crop factor, determined by experiments for each crop under the environmental conditions of particular area.

t – Mean monthly temperature in ˚C

P – Monthly percent of annual day light hours that occurs during the period

If, f = P/40 (1.8t + 32) then Cu = K ∑f

This formula is used throughout the world for estimating seasonal water requirements.

The above formula involves the use of crop factor, the value of which is to be determined for each crop and for different places. At present , this information is not available in India . This formula, does not take into consideration the factors such as humidity, wind velocity, elevation etc. on which consumptive use depends.

HARGREAVES CLASS A PAN EVAPORATION METHOD

- In this method, evapotranspiration is related to pan evaporation by a constant K, called consumptive use coefficient.

K = Evapotranspiration (E_t or C_u)/Pan evaporation (E_p)

$$E_t \text{ or } C_u = K \times E_p$$

- Consumptive use co efficient is different for different crop and is different for the same crop at different places.
- It also varies with the crop growth and is different at different crop stages for the same crop.
- Where specific data are not available, the average values can be used as recommended by Hargreaves.

NON CONSUMPTIVE WATER USE

- ✓ It means that after use, the water is return to the source for use by others in d/s
- ✓ This water may be used by municipalities, industry, and recreation purpose or by the environment.

✓ It will not cause harm to water user"s d/s. (Ex: water used for hydroelectric projects, beautification of ponds, etc.

PROBLEMS

1. Wheat is to be grown at a certain place, the useful climatologically conditions of which are tabulated below in Table. Determine the evapotranspiration and consumptive irrigation requirement of wheat crop. Also determine the field irrigation requirement if the water application efficiency is 80%. Make use of Blaney-criddle equation and a crop factor equal to 0.8.

Month	Monthly temperature in C averaged over the last 5 years	Monthly percent of day time hour of the year computed from sunshine	Useful rainfall in cm averaged over the last 5 Years
Nov	18	7.2	1.7
Dec	15	7.15	1.42
Jan	13.5	7.30	3.01
Feb	14.5	7.10	2.25

Solution:

Cu = K ∑f; f = P/40(1.8t + 32), where K = 0.8

Month	Monthly temperature in °C averaged over the last 5 years (t)	Monthly percent of day time hour of the year computed from sunshine (p)	Useful rainfall in cm averaged over the last 5 Years (R_e)	f = P/40(1.8t + 32)
Nov	18	7.2	1.7	11.59
Dec	15	7.15	1.42	10.55
Jan	13.5	7.30	3.01	10.27
Feb	14.5	7.10	2.25	10.31
Total			8.38	42.72

Cu = K ∑f = 0.8 x 42.72 = 34.18

Consumptive irrigation requirement = C_u - R_e

= 34.18 – 8.38

= 25.8 cm

Field irrigation requirement (F I R) = C I R/ n_a

(Where n_a --- water application efficiency)

F I R = 25.8/0.8 = 32.25cm

QUANTIFICATION OF WATER REQUIREMENTS FOR IRRIGATION, DRINKING AND NAVIGATION

INTRODUCTION

- The irrigation requirement (IRR) for crop production is the amount of water, in addition to rainfall, that must be applied to meet a crop's evapotranspiration needs without significant reduction in yield.
- Evapotranspiration (ET) includes water that is needed for both evaporation and transpiration. Evaporation is the change of water from liquid to vapor form.
- Evaporation occurs from all moist or wet surfaces, including soil, water, plant, and other surfaces.
- Transpiration is evaporation from plant leaves through small openings in the leaves called stomata.
- Both evaporation and transpiration occur in response to climate demand.
- ET is greatest on hot, dry days and lowest on cool, humid days. ET must occur to avoid plant water stress.
- Plant water stress will occur if ET is limited because water is not available to plants. Water stress will occur quickest on high climate demand days.
- Water stress is avoided by rainfall or by irrigating to provide a crop with the water needed for evaporation and transpiration.

CALCULATING IRRIGATION REQUIREMENTS

- To avoid water crop water stress, rainfall and irrigation must be sufficient to meet the crop's ET requirement. This means that for any period of time during the crop growing season, the net irrigation requirement (NIR) is the amount of water which is not effectively provided by rainfall:

NIR= ET - ERAIN

Where NIR= net irrigation requirement

ET= evapotranspiration

ERAIN = effective rainfall.

- NIR is irrigation water which is delivered to the field and available for the crop to use.
- This is primarily water which is stored in soil in the crop root zone, although some of the water which is evaporated from water, soil, and plant surfaces during application also effectively reduces climate demand.
- The gross irrigation requirement (IRR) is the amount that must be pumped. IRR is greater than NIR by a factor which depends on the irrigation efficiency (EFF):

$$IRR = NIR / EFF$$

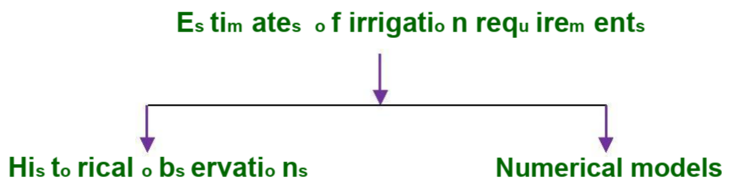
Where IRR = gross irrigation requirement (inches),

NIR = net irrigation requirement (inches),

EFF = irrigation efficiency (decimal fraction).

- ERAIN is that portion of rainfall which can be effectively used by a crop, that is, rain which is stored in the crop root zone. Therefore, ERAIN is less than total rainfall due to interception, runoff and deep percolation (or drainage) losses.

ESTIMATING IRRIGATION REQUIREMENTS



HISTORICAL OBSERVATIONS

If a crop has been repeatedly grown at a given location, and if a long-term record has been kept of irrigation water applied, this record can be used to estimate future uses.

Historical data may be found in crop production guides or obtained from growers or irrigation system managers who have considerable field experience with a given crop and irrigation system.

NUMERICAL MODELS

Numerical models may be based on statistical methods or on physical laws which govern crop water uptake and use.

SCS METHOD

The SCS method is a statistical regression method that allows monthly crop irrigation requirements to be estimated based on three factors: monthly crop ET, monthly rainfall, and soil water-holding characteristics, data that are readily available at most locations.

The model has the following characteristics:

- It estimates irrigation requirements for monthly or longer time periods only.
- It estimates either mean or extreme values of irrigation requirements, based on rainfall drought frequency data used.
- It estimates irrigation requirements for crops grown on deep soils with no shallow water table present.
- It estimates irrigation requirements for systems that irrigate the entire soil surface.

AFSIRS Model

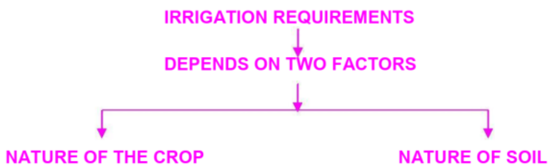
AFSIRS is an acronym for Agricultural Field Scale Numerical Simulation Model. It is a computer simulation model based on a daily water budget of the crop root zone.

The AFSIRS model has the following characteristics:

- It estimates irrigation requirements for daily, weekly, two-week, monthly, seasonal, and annual time periods.
- It requires many inputs which describe crop, soil, irrigation system, and management factors which affect irrigation requirements.

Few long-term historical data bases exist. Also, these data bases may not be readily extrapolated to other sites, thus they may have limited use for estimating irrigation requirements for irrigation system design or consumptive use permitting purposes. For these reasons, numerical models have been developed and are used to estimate irrigation requirements for a wide range of crop and production conditions.

FACTORS AFFECTING THE IRRIGATION REQUIREMENTS



NATURE OF THE CROP

Different crops require specific amounts of water at various stages of their growth and ripening.

Some crops need more water whereas others required less water.

For example, paddy crop is transplanted in standing water and requires continuous irrigation whereas others crops like wheat, gram or cotton do not require so much water.

For cereal crops like wheat, irrigation is needed before ploughing, at the time of flowering and at the time of development of grain.

NATURE OF SOIL

TWO IMPORTANT TYPES OF SOILS

SANDY SOIL | **CLAYEY SOIL**

SANDY SOIL is highly porous and has high permeability that is ability to transmit water across it. Therefore, sandy soil has very poor water retaining capacity when the crops standing in sandy soil are irrigated, the water quickly percolates down. The soil and the plants are not able to absorb adequate amounts of water. So the crop cultivated in sandy soil need more frequent irrigation.

CLAYEY SOIL has much less permeability and greater water retaining capacity than sandy soil. So when the crops grown in clayey soil are irrigated, the plants get time to absorb sufficient quantities of water. Therefore, the crops cultivated in clayey soil need irrigation less frequently. The crops, such as paddy, which need more water, are preferably grown on clayey soils.

Application of right quantity of irrigation water

- ✓ Ensure high efficiency of water use by the crops
- ✓ Reduces nutrient losses through leaching
- ✓ Results are better aeration of the soil. the right amount of irrigation at the right time can help in increasing food production.

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