Micro Irrigation Engineering
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Lecture - 06
Evapotranspiration

Hello everybody. Welcome to lecture 6, Evapotranspiration. Lecture 6, is very important for irrigation subjects not only for micro-irrigation but when we deal with irrigation engineering or even drainage engineering. Evapotranspiration plays an important role and let us try to learn evapotranspiration.

What are the different processes which are involved in evapotranspiration? So, here are our basic topics which we will discuss in evapotranspiration. What are the different terminologies which are used and then in this lecture, we will also deal with factors which influence evapotranspiration processes, and then there are various ways to estimating evapotranspiration? So, one of the approaches is the Water Balance approach. So, we will deal with all these concepts in this particular lecture.

Now, when we come to the hydrologic cycle, if we look at the hydrologic cycle you can see here the precipitation is the input component of the hydrologic cycle. When precipitation in the form of rainfall or snow or any other form where it takes place, it falls on the ground or on vegetation, and then part of this water is intercepted by the vegetation, plant foliage, and then it comes on the ground surface.

So, when it is falling on the ground surface, there is one particular process which is a very important process known as infiltration. So, infiltration takes place and when the infiltration goes for a longer period then this water goes to percolation, and then that causes a rise in the water table. Now, in infiltration, when the precipitation or rainfall is more than the infiltration rate of soil some part of the rain will generate as surface runoff.

And when it goes there it appears as a spring or it appears as a base flow above the ground surface. So, surface runoff appearing as spring appearing as various other processes, and then it becomes a water body. The other part of the hydrologic cycle is evaporation. So, part of the water which is available above the ground surface, on the land surface, or over the water body, got evaporates and condenses.

Condenses, it forms a water vapor, it forms cloud then condensation takes place again it is the process and then from the plant body with from the leaf foliage, what we see transpiration takes place. So, evapotranspiration, when we see it as one of the major components of hydrologic cycle that affect crop water demand and quantification of evapotranspiration, is important from an irrigation planning point of view, irrigation design point of view.

Now, evapotranspiration here there are two terms involved. One is Evaporation and the other one is Transpiration. What is the Evaporation? It is the process by which water is lost to the atmosphere in the form of vapor from natural surfaces, such as free water, bare land, or from live or dead vegetation. Transpiration is another component of evapotranspiration and it is the process by which water is lost in the form of vapor through plant leaves.

So, when we say evapotranspiration, it is a combined loss of water from soil or the plant surface and also transpiration that is a plant transpiration surface to the atmosphere through vaporization of liquid water.

So, these two terminologies, this the effect in the evapotranspiration means, they are combined terms are evapotranspiration. Now, left side of the figure, if we see the transpiration is taking place from vegetation from the leaves of the plant. Evaporation is taking place from this while from the bare soil and temperature and humidity are influencing the water flowing.

The precipitation it occurs causes the increase in the soil moisture content that water which is stored in the soil pores that is available for the plant to transpire evapotranspiration takes place.

So, here on this particular left side of the figure, you will see the evapotranspiration both the components are shown. There are vegetations, in the vegetation when you see the leaves which are contributing to transpiration process, soil which is contributing to evaporation.

So, bare land, water surfaces are responsible for the evaporation process. Water that is stored in the soil is available soil water. So, evaporation takes place from the water available in the soil that is available soil water and then transpiration takes place through the process when the water is taken by the root uptake. Now, when we see any plant which is now growing from sowing to the harvesting stage, the leaf area index means ground cover increasing by the plant foliage.

Accordingly, the transpiration process or component of the transpiration is increasing and as the ground cover or leaf area index of the ground is increasing. The soil evaporations say the contribution of evaporation from the soil surface is decreasing and this is the trend which we see. But its combined effect of this evaporation and transpiration is crop evapotranspiration. So, when the crop is small or we can say its height is less.

The water is predominantly lost by soil evaporation that is what is explained in this particular right side of the diagram. But once the crop is well-developed means it is completely covering the soil, transpiration becomes the main process. So, evapotranspiration rate is normally expressed in millimeters per unit time, we express in millimeters per day or when we make it weekly.

So, this can be weekly evapotranspiration, how much so, we use this value in millimeters per day. In a week time, how much evapotranspiration is computed that is used for the design of the irrigation system. Now, there is various terminology which we use in evapotranspiration. So, one terminology is potential evapotranspiration. As the term, it said that potential evapotranspiration means the evapotranspiration that occurs when the ground is completely covered by actively growing vegetation where there is no shortage of soil moisture.

PET concept, means potential evapotranspiration concept was introduced by Thornthwaite as earlier as in 1948. And he established an expression where potential evapotranspiration is directly related to the temperature of a particular place. Consumptive use is another terminology that is used in evapotranspiration. So, CU we call as a consumptive use in a short form and it is the loss due to evapotranspiration water that is used for its metabolic activity.

The CU value, exceed by evapotranspiration by the amount of water used for digestion, photosynthesis, transport of minerals, and photosynthates. Its structural support of the plant and overall total growth of the plant. This difference between ET and CU is just a difference of 1%. So, ET and CU are used means synonymously or one can use CU or ET both the terms are used simultaneously.

And there is another term that is used as a Reference Evapotranspiration and symbol wise it is a standard symbol, we denote it ET_o or ET zero. So, it is the potential evapotranspiration for a specific crop usually, it is grass or alfalfa and set of surrounding advective conditions. Reference crop evapotranspiration from an extensive surface of green grass of a uniform height of 12 centimeters.

It is actively growing, it is completely shading the ground, with an albedo of 0.23, and having ample water supply is called reference crop evapotranspiration. And it is the modified term because there were some other investigators, also gave that is Wright, Doorenbose, and Pruitt, Allen has brought this terminology in 1998 where he standardize the crop height as 12 centimeters. Other investigators/researchers have given different values of crop height.

But in all these cases they are it has been advocated that it is fully covering the ground that is one case, the second one there is no limitation of soil moisture content. So, this reference evaporates it provides evaporative demand of atmosphere independent of the type of crop, growth the stage, and management practices which is being followed.

Now, the other part which is used in evapotranspiration means other terminologies which are used here that is crop evapotranspiration. We call it actual crop evapotranspiration. This means it is the evaporation of the crop under standard conditions. The standard conditions here mean, what is the moisture content available in the soil? How is the ground cover it is there? And then what are the soil as well as management conditions? Which are there.

So, a standard condition means the crop is disease-free means it is fully active and then it is well fertilized. This is the important part that it is disease-free and well fertilized. So, that the rate of withdrawal of water from soil moisture, it is adequately being taken out and for meeting the evapotranspiration requirement. Optimal soil moisture content and then it is producing its growth, biometric growth and all that and then optimum production.

So, from a foliage point of view production can suppose it is a leafy vegetable. So, optimum production means it is giving optimum yield or the optimum number of leaves from the grain point of view and it is having the optimum production that could be another way of expressing optimum production. Now, adjusted crop evapotranspiration, crop evapotranspiration for the different management, environmental condition, pest disease, low fertile soil, soil moisture stress, etc.

So, the value of ETc needs to be adjusted as per the conditions that exist in the field. Now, this particular right-side diagram which you see here the climate means, basically it is influencing. So, the atmosphere practically provides energy for withdrawing the water. So, the atmosphere when we talk about it involves climate means, what are the radiation characteristics? How much is the longwave radiation?

What is the intensity of radiation? And this radiation causes an increase or decrease in the temperature, wind speed, direction of the wind, humidity that influence and then grass reference crop. So, crop where it is grown in your well water crop, and then what is this particular grass? It is Alfalfa or green grass. So, whatever amount of water is used for meeting the evapotranspiration is called reference evapotranspiration which you see is given by ET_0.

Now, this reference evapotranspiration when we are multiplying with the crop coefficient or K_c factor which is your crop coefficient factor or K_c factor with ETo then it comes to ET_c. That is the actual crop evapotranspiration, ET_c.

So, what are the different factors which influence evapotranspiration? In this particular slide, these particular factors are explained. So, energy for vaporization is a latent heat that is influenced by solar radiation. What is solar radiation? It is available at what intensity solar radiation it is falling which is an important part. And then what is the temperature?

More will be the solar radiation higher will this is directly responsible for higher temperature and then there will be high evapotranspiration. Then vapor transport from the evaporative surface. What is the wind speed? And from which direction wind is blowing? So, and then what is the humidity of atmospheric humidity in the surrounding where the crop is being grown? So, transport of the water vapor from one place to another place will take place depending on the wind speed.

And the direction of the wind and that is also influencing the evapotranspiration magnitude of the evapotranspiration value. Vegetated surface, what is the type of the crop which is being grown? What is the routing system? And how much is the soil moisture content? And how it is covering? So, these also influence and then the intensity of solar radiation which is falling on the vegetative surface its albedo as well as emissivity. This also causes the value of evapotranspiration.

So, just now, when I was telling you about vegetation, it influences evapotranspiration. So, what is the type of crop? What is the variety of crops? Any crop it is passing through different developmental stages. So, one is your initial stage and another one is the crop development stage.

The third one is the crop maturity stage or crop late-season stage. So, these four stages influence the value of crop evapotranspiration.

So, here when we talk of crop type, it will be you know crop type, what is the architecture of the crop? What is the height of the crop? And how does it influence the aerodynamic resistance of the canopy and to latent or sensible heat flux? A taller crop with a more dense crop has got higher water use rate for similar surface resistance. So, means higher height crop has got more crop water intake.

Leaf Area Index, the amount of plant when we call up about the leaf area index so, amount of plant foliage exposed to direct solar irradiance and amount of shaded plant foliage expose to transmitted and reflected diffuse solar radiation. So, means more the leaf area index more will be the evapotranspiration. So, LAI which is a leaf area index 3 to 4 sufficient to maximize transpiration and fully shading the ground.

Crop Roughness, the type of vegetation cover is a roughness rooting characteristic this also influences the evapotranspiration process. The particular type of crop, what type of photosynthesis pathways in plant species affect the evapotranspiration.

So, these are some of the crop bases. Now, we can see here how evapotranspiration takes place. So, water available in the soil pores are being extracted by the root system it goes to the stem, and from the stem, it comes to the plant canopy, and then transpiration takes place. And then what are the type of management practices whether there is a lot of grasses also along with the main crop.

So, that will be also affecting the soil, and then what is the soil moisture available. So, if the different types of practices are being maintained. So, evapotranspiration of the crop depending on the soil moisture condition depending on the particular pest or disease are tagged in the plant that needs to be adjusted. So, practically if there is you know without crop and then it is taken or if it is fully covering vegetation.

So, that is your ETo, now ETo multiplied by Kc we will give you evapotranspiration requirement of the crop and when it is having limited soil moisture content are due to some or other problem insect pests disease then ETc is going to be affected and that value of ETc need to be adjusted.

Now evapotranspiration is a very important process and from an irrigation point of view, it needs to be determined and this needs to be determined or then this can be measured directly or it can be estimated. So, if it is to be determined directly there are methods. So, one is by using a lysimetric method or lysimeter. The other one is by using field experiments by using soil moisture depletion studies or by using the water balance approach.

An indirect way of measurement or estimation can be solely temperature based it can be using the energy balance or radiation-based it can be by using the temperature as well as other climatic parameters. So, the combined approach can be estimated by using a pan evaporimeter that can be used. The pan evaporimeter values can also be used to determine the evapotranspiration requirement of the crop.

Direct measurements methods are time-consuming. These are expensive but this gives a relatively precise estimate and that is normally advocated provided one has adequate facility to determine the direct evapotranspiration measurement.

Now, in this particular slide, you can see here a concept of conservation of mass principle has been used to determine evapotranspiration of the crop. So, practically before I come to this particular slide, let me just show you the next slide, and then I will come back to this slide.

So, here the principle of the conservation of mass which we are putting that inflow, outflow and change in the inflow minus outflow is a change in the soil water storage or soil moisture content.

So, inflow minus outflow is the concept that has been used in the conservation of mass principle. So, what are the inflow component? Inflow component is your irrigation, P is precipitation, precipitation can be rainfall when we are considering due to surface inflow of water that is surface inflow means, your water entering into the control volume.

There is a lateral inflow means below the soil that inflow is taking place in the lateral direction. There is a contribution of groundwater that is a capillary rise because of the high water table. The outflow component is the runoff component. Lateral outflow means water is going out of the control volume; L is the water that is used for leaching purposes for leaching of salts. DP the deep percolation means water which is going deep;

Because when the water is continuing giving irrigation. So, some part of the water goes beyond the root zone depth that is a deep percolation and there is another component that is being withdrawn which we are talking about evapotranspiration. So, inflow minus outflow is a change in the soil moisture content, which is given by

$$\Delta S = D_{rz}\left(\theta_f - \theta_i\right) = inflow - outflow$$

Where change in soil moisture content (ΔS) , θ_f refers to the final moisture content, θ_i refers to the initial moisture content, and D_{rz} is the depth of root zone.

Now, coming back to the previous slide which is shown here that means a system which we are taking now, this system is basically a soil system in which we are considering a control volume. Control volume means it is where we are considering our study area. And in this study area, your boundary is defined. Now, in this boundary we are taking different in the direction arrows are particularly showing; what is the input component what is the output components.

$$Inflow = I + P + SFI + LI + GW$$

So, inflow you can see here I that is irrigation, then P is another input component, LI is another component. P is precipitation, I is irrigation LI is the lateral inflow to into the control volume. So, water which is coming this is your sub-surface flow means soil moisture is transporting from the adjoining area to the study region and then the groundwater, groundwater because of the high-water table.

So, there is a capillary movement or water table is contributing to the soil build-up of this soil moisture content. Now, another component is SFI, SFI is the surface flow into the control volume. So, there is some kind of runoff that is coming from the adjacent land into the control volume in your study region. Now, the outflow component when we are looking so, outflow component is given by

$$Outflow = RO + LO + L + DP + ET$$

So, LO is your lateral outflow. There is another outflow component is the deep percolation (DP) water which is being come from the inflow and that is causing so, it is going beyond the root zone depth r which is used for leaching of the salt (L) and another is runoff (RO) which is water going out of the control volume. Now, when we balance these components.

And these components are so, after balancing, we get evapotranspiration. And this particular system is considered in the effective root zone depth. So, your control surface or control volume is considered in the effective root zone depth. So, when we are making balance means, if we can maintain means measure all these components, then we can get the balance in terms of evapotranspiration which is given as

$$ET = I + P + SFI + LI + GW - RO - LO - L - DP - D_{rz}(\theta_f - \theta_i)$$

So, on this concept, a lysimeter is used where various components which are inflow and outflow, can be measured. So, the last lysimeter is a device that is installed in a crop field for which we were interested to determine the evapotranspiration requirement of the crop. So, there will be two lysimeters, one lysimeter where you are maintaining exactly the ideal condition. There is no shortage of water you are maintaining, you are growing Alfalfa or green grass than the actual crop which is being grown in the field this we are growing.

So, you are measuring water loss. Loss means the water which is used by the plant for evapotranspiration or gain when we take coming to mean something which has been added by precipitation it has come from the adjoining area. So, soil and crop conditions in the lysimeters are kept the same as surrounding field conditions. This measurement involved which could be weighing or non-weighing type of Lysimeter.

We are putting a scale or floating the Lysimeter in water by water is suitable heavy liquid in which the lysimeter can float. And any change in that liquid is computed against water loss or water gain that will depend you know initially the first day when you are adding that will be gain. But at the end of 24 hours you find there is a loss, those loss components are found out.

So, if the crop is of shorter height means or short duration, then the Lysimeter is of the smaller size it is used and it said volume will be less than is a two cubic meter. And then if tall crop like sugarcane or any other crops, which are taller than the Lysimeter could be a larger size it could be mean so, 3 to 4 cubic meter and the depth can be also increased.

Now, a typical Lysimeter concept it is being shown here the Lysimeter which has been you know installed in the field and the crop is grown. The adjacent area there are in the same crop is grown and then the irrigation or rainfall it is occurring and then it is building soil moisture content. When the soil moisture content goes more than the saturation then it will cause deep percolation it will go as drainage.

It may also in the rain, rainfall is very high then it will form runoff and then part of the water which is going as evapotranspiration. Now, these components can be measured by using non-weighing type Lysimeter or weighing type Lysimeter. In a non-weighing type of lysimeter, we are measuring different components of soil moisture content by using several devices and though the change in the soil moisture values is used as an evapotranspiration value means, the loss in the soil moisture content is measured.

So, this is what you are seeing this can be you know there is a metal or plastic membrane which is kept driven into the soil and then a permanent device or access tube or neutron probe you know, soil moisture measuring gadgets are installed in the Lysimeter where the change in the soil moisture content is measured. When we are talking about weighing type Lysimeter this particular device is flow means kept over a load cell.

Now, load cell, displacement in the load cell is measured by using the scale or in terms of weight. That load cells are you know we are measuring in the strain gauges. What is the displacement in a given? So, these things are measured and then the amount of water which is transpired are in different components, which I explained to you in the previous slide those are monitored and then it is the evapotranspiration is measured by using.

So, water is applied in a given quantity means the amount of water is measured; measured quantity of water is applied which call it irrigation and it is in the same amount as in the surrounding area overflow and deep percolation if it occurs, those are also measured means all the component rather I will say these are measured. So, water received through irrigation, precipitation, excluding overflow that is a runoff we can say the deep percolation, the balanced soil moisture content.

So, water constitutes means, the water used by the crop in the process of evapotranspiration is balanced are measured. So, just now, I have shown you that the two types apply and then, of course, Lysimeter is a device which is measuring the evapotranspiration giving precise estimate but there is a certain limitation here also that reproduction of actual field condition. It becomes difficult and one is getting the ideal water table condition that exists in the Lysimeter if it is closed from the bottom.

So, as well as certain field conditions mean the natural density of the soil which is existing in the field, as well as you know the soil, maintaining soil texture, becomes a difficult task, but over time when we are conducting an experiment for a long time it maintains the same kind of condition as outside.

So, in this particular lecture, we discussed evapotranspiration, evaporation, and what are the different climatic as well as vegetative factors which influence the evapotranspiration process. We also explained about how to determine evapotranspiration by using the lysimeter. There are other methods of estimating evapotranspiration as well as determining measuring soil moisture content and then depletion of the soil moisture content that will be discussed in the forthcoming lecture.

So, this will be discussing. You may refer books which are given here by Allen et al, which is FAO 56, is a very important manual which is from the Italy Rome, the head office is available. So, this is available on the net. The book by Professor A M Michael that Irrigation Theory and Practice, as well as Larry James book it is also a very useful book you can refer. There is quite a good amount of literature available and so you may refer.

This way I am closing here lecture 6 and I understand you have understood this particular lecture and thank you very much and good day.