Micro Irrigation Engineering
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Lecture-15
Irrigation Efficiency

Dear participants, I welcome you to lecture 15. In this lecture, we will be discussing irrigation efficiency. In the previous lecture, we discussed the measurement of irrigation water. We emphasized why measurement of irrigation water is important and how measurement can be made by using different devices. Irrigation efficiency can be monitored when the proper measurement is done. We are interested that the amount of water which is given, how it has caused in improving the water use efficiency of the crop?

So, here we will be discussing the concept used in this particular lecture is the performance of irrigation systems. We will be talking about irrigation efficiency; we will be talking about the adequacy and effectiveness of irrigation. It is not only irrigation efficiency, but the overall considering the various other parameters which will be beneficial for overall benefit including the market value, that is also equally important when we are considering the irrigation system design considering irrigation efficiency.

Now, what is irrigation efficiency? So, irrigation efficiency is the ratio between the amount of water used to meet the consumptive use requirement of the crop plus that necessary to maintain favorable salt balance in the crop root zone to the total volume of water diverted, stored, or supplied through a pumping system. So, it expresses the performance of a complete irrigation system or component of any irrigation system.

So, here what we are seeing that when the water is being supplied, in this case, the water is being supplied it is in a closed system and this water is used for both bringing down the temperature and also water is being supplied to meet the crop water demand, meet the evapotranspiration requirement.

What are the different causes which are affecting irrigation efficiency? So, causes for reducing irrigation efficiency could be losses in the storage system, losses while conveying water from the source to the field that is a conveyance system. And then field application losses mean when we apply in the field due to irregular field conditions, this may also cause a loss. So, irregularity in the field is as such an unavoidable situation it exists, that field is undulating field is having a newly ploughed soil, this is cultivated.

There are clots that also you know make it different. So, the evenness of the field, evenness of the system that also, so during application and in the field condition that also makes the difference. So irrigation efficiency of major irrigation projects, hardly it is above 40%. So, in the majority of the places, it is 35% or 40%. So, a huge amount of water goes as a loss.

Now, in order to meet the growing demand of water for food, environment, urban, and industry, it is necessary to improve irrigation efficiency at all points. This means at all points I meant to say from convenience system, from the storage system and as well as when we apply then there should at the time of application also, we should see that there is a minimum loss it takes place.

When we talk of there are different terminologies that are associated here, overall system efficiency. It includes reservoir storage efficiency, conveyance efficiency, and application efficiency. Then storage efficiency, water distribution efficiency, water use efficiency, are the terms that are associated with irrigation efficiency. Let us try to learn deeper about irrigation, these terms.

So, when we say about overall system efficiency, overall system efficiency when we are interested to estimate. So, it is given by

$$E_i = 100(\frac{I+L}{S})$$

Where, I is irrigation requirement, L is leaching requirement and S is the amount of water supplied to the field. So, this can be further elaborated that overall irrigation efficiency it can be given by

$$E_i = 100(\frac{S-DP-RO-O}{S})$$

Where S is the amount of water which had been supplied, DP is amount of water that deep percolated, RO is runoff and O is operational losses.

Due to plant or accidental spillage from the pipeline or overtopping the channels. So, those could be also mean the losses take place either from the pipeline or sometimes from the banks of the channels or canal water minors or distributaries water flows above the channel. So, those are to be accounted while we are finding out the overall system efficiency.

Now, overall system efficiency is the product of the reservoir storage efficiency (E_r), the convenience efficiency (E_c), and application efficiency (E_a).

$$E_i = (\frac{E_r}{100})(\frac{E_c}{100})(\frac{E_a}{100}) \times 100$$

So, we need to evaluate each component. So, reservoir efficiency is one component, convenience efficiency is another component means your overall system consists of several components. So, these 3 components it causing an effect on overall irrigation efficiency.

Now, what is reservoir storage efficiency? Reservoir storage efficiency is given by

$$E_r = 100 \times \left(1 - \frac{V_e + V_s}{V_i}\right) = 100\left(\frac{V_o + \Delta S}{V_i}\right)$$

Where,

V_e= evaporation volume from the reservoir

V_s= seepage volume from the reservoir

V_i= inflow to the reservoir

V_o= volume of out flow from the reservoir

ΔS= change in reservoir storage

So, whatever amount of water has been taken out from the reservoir is divided by the total volume of water flowing into the reservoir.

Conveyance efficiency as the name says that it is a conveyance system. So, conveyance means when the water is being supplied through the canal, minors, distributaries, open canal, and before it reaches to the field. So, from the source water, it is supplied, so when we are evaluating we are telling that conveyance efficiency is given by

$$E_c = (\frac{V_f}{V_d}) \times 100$$

Where,

E_c= the conveyance efficiency (%)

V_f = the volume of water delivered to the farm by irrigation system (m^3)

V_d = the water diverted from the source to the irrigation system (m^3)

So, if we are evaluating these 2 terms they are in the same unit. So, it comes in percentage when we multiply with 100.

Application efficiency is the ratio expressed in the percentage of the volume of water beneficially used by the crop to the volume of water delivered to the cropped area.

$$E_a = \frac{V_s}{V_f} \times 100$$

Where,

E_a= the application efficiency (%)

V_s = the volume of water stored in root zone (m^3)

V_f = the water delivered to the field or farm (m^3)

So, it can be computed for each field of the farm or the entire farm, which means there could be the situation that farms are of different conditions in the field. So, means each subunit of the farm would be of so, at which particular place application efficiency is a less that can be improved instead of considering the entire farm.

So, if the farm is of a smaller size that can be computed if it is a large size it can be made subunits and then the application efficiency can be evaluated. So, means here it is given by Vs by Vf. So, the volume of water is stored in the root zone to the volume of water delivered to the field and so is the volume of water that is stored in the root zone. This is the water that the plant will be used for meeting the evapotranspiration requirement of the crop, the rest of the water whether it is flowing a surface runoff or it goes beyond the root zone depth, is not useful. So, this is stored water in the root zone is important from the application efficiency point of view.

A typical application efficiency which has been reported in the literature from the different irrigation system. So, here you can see for surface irrigation, involves we will discuss in the coming class about the different types of methods of irrigation. So, if we see the surface irrigation system, the range of application efficiency though it is given very high range, such range does not exist in the surface irrigation system.

In the practical sense, this could be very highly efficiently in laboratory conditions, infield, hardly we get 60 to 65%, in a sprinter irrigation system this application efficiency it could be in the order of 65 to 85 this is ok and then micro irrigation system, the application efficiency in the order of 70 to 95%.

Now, application efficiency is applicable to the micro irrigation system. So, here we will be discussing about Christiansen's coefficient. We will be discussing about distribution efficiency, we will be discussing about pattern efficiency, and normally these are the Christiansen coefficient of uniformity that is CU, distribution efficiency, and pattern efficiency; this is more relevant to a sprinkler irrigation system.

As the emission uniformity is concerned, this is relevant to micro irrigation or drip irrigation system. So, irrigation application distributions are usually based on the depth of water, normally in other places, we are putting the volumetric form. So, in the case of a micro irrigation system, we use the volumetric form because discharge coming out of the dripper in a liter per hour, so the amount of water which is collected in a given time in a cylinder.

So, it is expressed in the volumetric unit, but this can be converted in a depth form also. So, normally we use in volumetric form. And then we try to evaluate the statistical parameters and then the values of water distributed in the field, it will depend upon the topography, it will depend upon the infiltration capacity of the soil, it will depend upon the hydraulic characteristics of the particular irrigation system, how it is working? So, this is to be evaluated.

Christiansen uniformity coefficient is mainly intended for the sprinkler irrigation system, where the depth of water is collected from the number of canes means rain gauging kind of a system where the depth of water is collected. And from the number of sample points, we are taking let us say that we are considering 25 samples.

So, from all the 25 value depths of water which is collected that will be evaluated what is the CU value? So, CU will be calculated that is the depth or volume of water of each equally spread container we will get. And then from all these 25 numbers of samples, means the number of samples which are taking we will get the mean value. So, the number of these values are summed divided by the number of samples, we will find out the deviation from Individuals values from the mean.

The next parameter for evaluating the efficiency is a pattern efficiency which is given by minimum depth divided by average. So, minimum depth say, I was giving one example, there is 25 number of observations. So, from the 25 we will take the lowest value out of 25 number of observations. And then the average summation of individual value from 1 to n. So, the average value will be used and multiplied by 100, this will give the pattern efficiency.

These 2 efficiency terms which I discussed that is used for a sprinkler irrigation system. When we are coming to the surface irrigation system, even this can be used for a sprinkler irrigation system also, so low quarter distribution efficiency. So, it is defined as the ratio of infiltration in the lower quarter to the average infiltration over the entire field. So, if we say it is given by

$DU = 100 \times (V_p/V_t)$.

So, here DU is equal to distribution uniformity in percentage for the lower quarter, Vp is the mean application volume in cubic meter or depth in the lower quarter and Vt is the mean application volume or depth for the whole field. Now, your lower quarter means if the whole field is divided into 4 quarters. Now, the lower quarter means we will be as if the water is supplying from the upper reach to the lower reach.

So, in the lowest part what is the infiltration depth? And then mean depth, so when we are considering the average infiltration and then the average infiltration from the lower quarter and average infiltration from the whole field, so this is to be used. So, this is for the mean value, for the lower quarter, and this is the mean application value for the whole field. Then distribution efficiency is obtained. This can be used for surface irrigation and also for the sprinkler irrigation system.

The water distribution efficiency is the ratio between the mean numerical deviation from the average depth of water stored during irrigation and the average depth of water stored during irrigation. So, E_d is the water distribution efficiency is given by

$$E_d = \left(1 - \frac{\bar{y}}{\bar{d}}\right) \times 100$$

Now, the y bar is your average numerical deviation in the depth of water stored from the average depth stored during irrigation. And d bar is the average depth of water stored during irrigation.

So, here we will be getting the values of the number of places where the depth of water which is stored means, this is same as what I was telling that infiltration depth it has taken place from the whole field during the irrigation place. And then we will be taking the deviation from the mean here deviation from each individual mean. So, that particular value these deviations from the mean will be obtained. So, 1 minus y bar by d bar is used to find out the distribution efficiency, water distribution efficiency is a measure of water distribution within the field. So, low distribution means non-uniformity in the distribution of irrigation water, this may be due to uneven land leveling. So, this would be the reason that land is not properly leveled or it is a newly ploughed field where a lot of clots are there, this could be also so a smoothness of the field will also a more relevant to surface irrigation system.

The other 2 important terms are used from the crop production point of view. So, we are using 2 terms one is crop water use efficiency and field water use efficiency. Crop water use efficiency is given by crop yield to the amount of water depleted by the crop in the process of evapotranspiration. So, we say crop water use efficiency means to produce say 1 kg of grain yield what was the amount of water which has been used by the crop to meet evapotranspiration.

So, sometimes it is expressed in kilogram or tons per millimeter of water use for evapotranspiration requirement. Similarly, field water use efficiency is the yield to the total amount of water used in the field. So, it involves evapotranspiration plus all other components of the water requirement that is the field application loss, a special need for water that had been given for leaching.

So, all the components which are associated with the value of WR are more than evapotranspiration and that is useful information that total water how much it is been applied and that has made the yield, how much it has brought to the yield. So, that is a field water use efficiency.

The deep percolation ratio and tailwater ratio, are the 2 components. So, DPR is given by

$$DPR = \frac{V_{DP}}{V_f} \times 100$$

Where V_{DP} is the amount of water lost due to deep percolation and V_f is the amount of water delivered to the field. So, if we are means after the infiltration process the amount of water which is percolating below the root zone depth that amounts if we are able to measure and then the amount of water which has been supplied we can know that what is the deep percolation ratio or deep percolation efficiency.

Tail-water ratio, the amount of water runoff to the amount of water applied.

$$TWR = \frac{V_{ro}}{V_f} \times 100$$

So, runoff amount of water (V_{ro}) if we are able to measure that water which is going out of the field from the border irrigation or the check basin irrigation when the amount of water it is going from the tail end that how much amount of water it has gone out as a surface runoff that amount of water is used to calculate the tail-water ratio.

Another important term comes for adequacy of irrigation. Now, adequacy of irrigation is computed it is not only the irrigation efficiency, other terms are associated with how the uniform water has been applied, and then how much water it is going as surface runoff. But not only water use, but what is the economic value or return which we are getting? So, the adequacy of irrigation is the percentage of the field receiving a sufficient quantity of water to maintain the quality and quantity of production at a profitable level, here market value is important.

So, it is determined by determining the cumulative distribution pattern of the water which is infiltrated or it is the amount of water caught or water that has gone infiltration. So, infiltration volume say as I was telling you about the distribution efficiency or infiltration, so depth of water which is infiltrated at different points in the field. So, suppose the total area we are considering is that 1-hectare area. So, in a 1-hectare area one-tenth of the area how much infiltration it has gone then what is the depth of infiltration at the second area, third area?

And total 1 hectare so 0.1, 0.2, 0.3 like this total area, that will give the cumulative percentage area, but what is the depth of water it has infiltrated. So, let us say that the first 2 centimeter of water it has gone to means the 0.1 hectare then another 0.3 centimeter of water 3 centimeter of 0.2 hectare. So, like cumulative values are obtained, this cumulative frequency distribution is versus infiltration and depth when we are plotting.

So, this particular curve which you will see here, this curve is the cumulative distribution curve. Now, when we are putting here, say a particular desired depth of irrigation is some certain amount. So, this desired depth of irrigation is a certain amount and if you are plotting this is intercepting with the cumulative distribution curve. And let us say that it is 50%, so 50% is the adequacy of irrigation.

So, it showed that the percentage of the field receiving a given amount of water or more. So, 50% of the field is receiving desired depth of irrigation 50% of the field, is getting a lesser amount of water. So, this is the adequacy of irrigation. So, when the desired depth of irrigation fills the soil to field capacity is called is storage efficiency, it is often used as an index to adequacy.

With respect to the adequacy of irrigation, another term is the effectiveness of irrigation. So, the effectiveness of irrigation is qualitative describes the application efficiency, describes the uniformity of water application, and also includes adequacy of irrigation. These 3 terms are important for the effectiveness of irrigation. So, the desired combination of efficiency, uniformity, and adequacy maximizes net profit.

This means all 3 components are important for the net farm profit. So, if we come to what is the relationship between application efficiency and uniformity? Considering the adequacy is constant. Now here what do we see? There are 2 systems which have been considered one is system A and another one is system B mean, there are 2 irrigation systems.

So here in the case of A, we see the curve is flatter as compared to curve B. So, a flatter slope and a smaller range of infiltration depth for curve A indicate system A applies more water uniformly than curve B because there is a steeper curve. Now, here what we see? This cumulative distribution curve for A, the area under this particular curve you are seeing here A_1 and here we see A_2.

And if we are considering the adequacy of irrigation at this point this is the required desired depth of irrigation. The desired depth of irrigation means the amount of water that has been applying to fill up to the field capacity. So, this water has a line in case of A_1, it shows that it is the excess water or it is causing a runoff. Whereas, when we go beyond this point A_2, it gives the information that it is under irrigation.

So, this is excess irrigation, this is deficit irrigation, so improved uniformity. So, here the point is that, if we are getting uniformity, it does not mean that the application efficiency has improved. So, the benefit of high application efficiency must be carefully balanced with the costs which are associated with high uniformity of application.

Means, uniformity of water application as well as the adequacy of irrigation, and then there should be a proper tradeoff between these components. If a proper tradeoff is not considered then we will not be getting the good price value or net profit will not be there.

Then another component of the effectiveness of irrigation is the relationship between adequacy and application efficiency. When we are considering the other component, which I was telling you when we were considering the uniformity, we are considering that uniformity is kept constant.

So, adequacy was decreased, here we are seeing the 2 curves again, this is curve 1 for system 1, which means cumulative frequency distribution curve for system A, cumulative frequency distribution for curve for the system B. Now the adequacy is decreased from 52% to the value of 16% and then the desired depth of irrigation is reduced, means adequacy is reduced from 52% to 16% between curve A and B.

By reducing the depth of application of water from 3.5 centimeter to 3 centimeter at a constant uniformity. The reduction in adequacy improved the application efficiency. And this will be true as long as means a reduction in these 2 values; it is bringing better application efficiency because there is a lesser amount of water which is going as a loss.

But this will be true when the surface runoff, as well as deep percolation losses, take place. And this needs to be balanced for higher profit, which means again I am telling that here there should be a proper tradeoff between balancing between the 3 components. It is not the only efficiency, it is not only the uniformity, but it is also not only the adequacy, but all 3 components are also to be considered while we are interested to get better market price of the produce.

So, these are the references which you can refer to in the books where these terms are explained more in detail. In this particular lecture, we discussed the different terms which are associated with irrigation efficiencies. And the effectiveness of irrigation, adequacy of irrigation, and then all these terms are equally important while we are designing the irrigation system and so to be discussed about all these things in detail. In the forthcoming lecture, we will work out numerical problems dealing with irrigation scheduling, water measurement, and irrigation efficiency, which I discussed in today's class. So, thank you very much and good day.