Micro Irrigation Engineering
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Lecture-21
Irrigation methods

Hello participants, now we are starting a new topic of the subjects on micro irrigation engineering. This new lecture is on irrigation methods. We discussed in previous classes on fundamentals of fluid mechanics, we discussed about soil-plant-water relationship, and we dealt with irrigation scheduling. There we discussed in irrigation scheduling, we discussed about how to schedule irrigation, and what should be the depth of irrigation.

So, the next part of this thing is when we know the amount and timing of irrigation, and how to apply irrigation water. This is equally important because whatever water we are giving it should be made available to the plants as maximum as possible. So, that the water is stored in the root zone depth, it can be used by the plant for meeting its evapotranspiration requirement.

So in this particular lecture on irrigation methods, we will deal with different types of irrigation methods. We will also deal with the hydraulics of surface irrigation methods and relative comparison among these methods.

As we know, the contribution of irrigated agriculture to total agriculture production in India, ranged from 55 to 60%, and if we are interested to use this water effectively so that contribution of irrigation water can bring more area under irrigation. And as far as our studies say that, the overall efficiency of existing irrigation projects the application efficiency or irrigation efficiency of these projects ranges from 30 to 35%.

Whereas, the ideal projects have reported that we can achieve irrigation efficiency up to 50%. So, the irrigation methods will play important role in order to get higher irrigation efficiency. We know adequate water supply is important for plant growth and when rainfall is not sufficient, we need to give irrigation to meet its requirement.

Now, there are different methods of application of irrigation water and these methods have their own advantages and disadvantages. The selection of a particular method depends upon the local conditions available there means a type of soil, type of crop to be grown, and the main thing is the economic status of the person who is adopting a particular method. So, irrigation water can be applied to the crops by flooding the field.

We can say by flooding the field or by applying water beneath the soil surface means the water will come from beneath the soil surface by controlling the water table or supplying the water under pressure that is pressurized irrigation or by applying water in the form of droplets that is by drip irrigation. So, when we broadly classify irrigation methods we can put surface irrigation, sub-irrigation, sprinkler irrigation, and drip irrigation.

The name says that surface irrigation means water is applied over the land surface. So, overland flow takes place on the soil surface. When we say sub-irrigation means we are giving water beneath the soil surface and then water comes to the root zone of the plant. So, this is sub-irrigation.

When we say sprinkler irrigation system means we are applying water in the form of spray by creating adequate pressure by using an appropriate nozzle and then from the nozzle water is sprinkled in the form of spray and then it falls on the ground surface, it falls on the leaves of the plant also. And when we say drip irrigation means we are applying water drop by drop. So, let us go for each of these four methods which I have told in little more detail.

So, coming to the surface irrigation, under surface irrigation there are 3 broad methods one is border another one is check basin and the third one is furrow irrigation. So, this border can be a straight border, which we will discuss in detail. So, let us just know that their classification, the border can be a straight border or contour border. Similarly, a check basin can be rectangular in shape or is laid on contour or it can be made a ring means the basin can be circular in shape.

Furrow irrigation can be a deep furrow that looks like a channel and then the crop is grown on the ridges or it can be a shallow furrow, where just by running smaller depth of water is supplied.

So, deep furrows can be straight or contour, which means straight when the slope means land slope is within the permissible level, then straight furrows are used for irrigation.

If it is a sloping land, then the furrows are laid along the contour or we can say across the land slope. Now, the straight furrows can be laid long on level land, or if it is on little sloping land then that slope can be truncated, and then one particular furrow can have two different slopes or three different slopes as per the requirements and that length can be truncated that is a graded furrow. Similarly, corrugated furrows could be straight or contour. So, as I told you, this could be straight or they can be laid on contours.

A sprinkler irrigation system, there is quite a big classification, when we will come to the sprinkler irrigation particular lecture, we will go into more detail but here just we can have it means this could be a rotating head sprinkler system or a perforated pipe where the water is spilling out in the form of a spray or a tiny streams out of the perforations made on the pipe and these pipes could be made up of a metallic pipeline, aluminum pipeline. Now, slowly these particular perforated pipe systems are not adopted because the clogging or blocking of the pores is causing problems. So, a rotating head system is more prevalent in the field. And then drip irrigation system, so, there is a big classification it comes under drip irrigation system which also we call it as a micro irrigation system. So, we will go into detail in the coming classes.

Now, here you can see these are all the methods which I have explained to you these are shown in these particular different photos. This is scientifically designed. So, the way it is being displayed, in these figures, in these photos, it looks quite nicely it has been designed but normally such a designed system, in the field, you may not find particularly in surface irrigation systems.

So, if you look at this particular left-most corner of this photograph, here it is a furrow irrigation system. So, furrows are made in a systematic way, and water is allowed to flow. If you come just below this, on the left side, drip system. On the drip system, online point source drippers are attached and you are seeing that how the water is emerging out of the drip line.

Below that, you find that there is a surface irrigation system and then for each individual plant or tree you find there is a ring has been formed. So, this is a ring basin or check basin irrigation system which is also one of the means of giving water as the basin irrigation. Then when we come from the top here what we are seeing, the water is coming out of a sprinkler nozzle. So, set of sprinkler nozzles and then the aerial view of these, the water is sprayed from a sprinkler nozzle is being shown in a given landscape. So, this is a beautifully shown photograph. Then in this particular, just below we see here that here there is a furrow irrigation system. These furrows are laid across the slope. So, these furrows laid across the slope and so, these are contoured for which irrigation is being given in this one.

Here, what we are seeing, is a sub-surface drip irrigation system that has been laid and then water is being you can see this is one sub-surface drip pipe, this is another sub-surface drip pipe and then the crop is a maize crop. So, corn is being grown, and then how the water is spreading this one. So, the root growth is also shown here, and then here we see these are micro sprinklers which are put up in a crop.

So, this is a micro sprinkler this is another sprinkler irrigation system, and then here this is a furrow irrigation system, and the water to each furrow is given through a gated pipe. So, a pipeline where the holes are made and these holes mean they are connected with another smaller pipe and then each individual pipe is supplying water to each individual furrows. So, pipes are connected. So, these are all photographs which are showing, demonstrating the different types of irrigation methods.

Now coming to more detail about the surface irrigation method. So, surface irrigation as it says that is the application of water by gravity flow means there is enough velocity is maintained through gravity flow. So, water moves over the land surface by using inertial force. So, in a surface irrigation system, either the entire field is flooded. So, this could be basin irrigation or it can be a border irrigation system or the field where the water is fed into a small channel which we call a furrow, or we are giving supplying water to strips of land which we called as a border.

So, surface irrigation has advantages. It is a simple method, it does not need any expensive equipments, and therefore it requires minimum capital investment. It does not need very high energy or pressurized system. So, the energy cost means on the application of energy or power supply is required minimum. So, this is a low energy cost system. There are some disadvantages that it is less efficient than the pressurized system. Because the water is not smoothly reaching all the points of system as we find in the pressurized pipe irrigation system.

So from the application point of view, it is not efficient. In a lower area or upper area, they have their own problems means the lower area gets flooded so water lagging, and when the water stagnates for a longer time the salinity problems it comes. And this is a common problem in the majority of the canal commands which we find that there was no problem as such when these canals were not operating.

But after the canals have come and people started over-irrigating and then large area because of the high water table it has caused the problem of waterlogging and soil salinity has become a problem. Land leveling is another important issue and unless it is not level land that all part of the field is not able to get an adequate amount of water which is an expensive item or expensive component in surface irrigation.

It needs large flows to reach water at each point of the field and water application is not uniform means more water is available at the head reach or upper reach of the field when compared to the lower reach of the field.

So, any surface irrigation system whether it is furrow irrigation, whether it is a border irrigation system, or it is a basin irrigation system, it passes through four basic phases. So, phase one is the advance phase. So, the advance phase means if you see the diagram here at once means the irrigation stream is introduced at the one end of the border or basin are furrow. So, water is introduced at this one end.

So, when an irrigation stream is introduced into the field and when water reaches the downstream end of the field, it will continue to move toward the downstream end of the field that

is the advanced phase or movement of the waterfront advanced movement is taking place. So, this movement of the water when the irrigation stream is introduced is advance phase. Now, when it reaches up to the downstream end and the storage phase begins.

So, the storage phase begins when the A advance phase ends and it occurs only if inflow to the field continues water has advanced to downstream of the field means as long as once we are continuing the water supply. So, the storage phase will begin and then the storage phase means the buildup of water level in the basin, in the furrow, in the border it will continue. So, what we are seeing when the waterfront when you are plotting a diagram. So, this kind of advance curve will develop, and then when you are continuing means this here it has ended. When you are continuing this water supply then there will be a depth of water it will increase and then there will be a storage phase. Now, the third part is the depletion phase. Now, this is your storage means there is a certain depth of water that has accumulated over the land surface.

The depletion phase begins when the B phase that is the storage phase ends. So, means we are cutting off the inflow. So, at the end, when the depth of flow at the inflow ends and of the field becomes zero. So, depletion will start means the depth of water will start diminishing when the irrigation supply is cut off and what happened when irrigation supply is cut off then recession phase will become; so, the nature of the recession phase in the border irrigation system, as well as in the furrow irrigation system this is the behavior of the recession.

But the recession, in the case of basin irrigation, will be different because once we are cutting up the water supply the length of the basin is not as long as furrow or border strip. So, this will be more or less parallel to this particular axis. And so, when we are talking about different phases the advanced phase as well as means advance means your distance of travel is plotted with time.

So, the advance phase is represented by curve A, let us say when there is a particular stream supply it has been supplied, and then this is another advance curve that is for the B curve. When we are plotting. So, this is your advanced curve this is one case, this is another case and this is your recession phase. So, when there is a difference, we are seeing that in this A. So, what happened why this difference in the advanced curve could be. So, it could be because the

advancement of the stream it is slow means it is going slow. So, what could be the reason means here one reason that yeah the stream size is matters, one is that streams as it matters. Another one is the slope is flat that could be the region, or another one is the infiltration capacity of the soil.

So, infiltration capacity of the soil also matters and the third one is that the hydraulic resistance means either soil is newly ploughed it could be the reason, some clots could be another mean smoothness of the land surface is not there, or there is some crop which is grown. So, this affects the behavior or nature of the graph when we are plotting.

Now, another point of consideration, when we are designing a surface irrigation system, it is important that the amount of these two curves when we are plotting. These two curves should be as far as possible, they should be parallel. So, infiltration opportunity time or we can say the time which requires the water to pond it is uniform from one end to the other end that is a theoretical consideration.

So, at the upstream end, there are more means infiltration will be more and as you go to the downstream end, the infiltration is going to be less. So, the difference between the time of water when we say infiltration opportunity time. So, it is the difference between the time of waterfront reaches a particular point let us say this is the particular point and the time at which tail water recedes from the same point is the infiltration opportunity time or time of ponding.

So, it reaches a particular point. So, say this is the point it has reached, and then it starts receding from the same point. So, the difference in this particular time. So, say this is one time it could be a few minutes here when it is there and then when the irrigation stream is cut off, it starts receding. So, this time difference if you are taking it. So, say this is t1, this is a t_2. So, t_2 minus t_1 is the time which was available for the irrigation stream to infiltrate and this time is infiltration opportunity time.

Now, what we are seeing is a border irrigation system. Surface irrigation systems could be border irrigation, it can be furrow irrigation, it can be basin irrigation. So, what is border irrigation? In border irrigation system field is divided into strips by parallel ridges. So, these are

the ridges; this is one ridge, this is secondary, this is the third ridge, this is fourth means like this these are the ridges.

So, these ridges are parallel to each other, and then it has got a certain height which guides the water to flow, which means each strip is irrigated separately. So, water is supplied from this end and it reaches. So, this is the advancement of means when the water is being introduced. So, this is the advancement of the stream. So, we call waterfront advance and when irrigation stream is cut off.

So, when it is a cutoff this is starts disappearing. So, this is your recession phase. So, these borders can be laid along the slope. So, we call it as a straight border and when means this particular slope it exceeds the safe limit, the fields are undulating or leveling is not feasible these borders can be laid across the slope and these borders are called contour border.

Here, what we are seeing, you can see how the border specification is made. So, this border can be you know this is a width of the border you can see here, how they are given and this is a prevailing land slope and this is the length of the border. So, normally, the width of the border ranges from 3 to 15 meter. The length varies depending on the particular type of soil texture.

So, it can vary from 60 meter to 300 meter. So, when it comes from the coarse textures soil to the fine textures soil what we are finding that the length of the border is increasing. Similarly the slope of the border, so, border slope is varying which we are seeing that for sandy loam soil it is a higher slope because infiltration there is a chance that infiltration will be more in case of coarse texture soil, so, the slope is given more in case of coarse texture soil and in fine textures soil slop is so, this is the range, in general, it is adopted.

Based on the research studies carried out by investigators and they have recommended what should be the appropriate size of the stream for different types of soils you know soils having different infiltration rates and then prevailing land slope. So, with the prevailing land slope let us say that sandy soil having an infiltration rate of 2.5 centimeter per hour, having a slope between

0.2 to 0.4%, and the irrigation stream size will be 10 to 15 liter per second per meter width of the border.

So, let us say that if the width of the border is say 15 meter then the irrigation stream size will be in that case 50 liter per second. So, we will select depending on the particular type of soil it is there, and then one can select the stream size.

Hydraulics of border irrigation system, the flow in a border strip is a case of spatially varied unsteady open channel flow with decreasing discharge means discharge is decreasing with space. It is true that when you are introducing a stream what happened initially the stream size and part of this water will be infiltrating. So, it will be reducing. So, part of the water, it will be reducing the stream size and when it will go further it will advance further.

So what are the different variables which influence the movement of water, advancement of the waterfront? It will depend upon what is the size of the stream, it will depend upon the slope of the land, and it will depend upon the infiltration characteristics of the soil. Of course, that is the type of soil rather we can say and then the resistance to flow offered by soil surface and vegetation cover. So how do you know when I was telling that when the water is being supplied to the border. So, how the infiltration; so, infiltration what you are seeing at the upstream end it is taking place more as compared to the downstream end.

So, this is the place where infiltration. So, this is uneven distribution, and when it is not properly designed you may find that at the upstream end the water will go more deeper and then at the downstream end so, the behavior of the water infiltrating below the soil surface from the upstream end to the downstream end of the border this will be the infiltration trend.

Check basin means dividing the field into smaller units, these are means in case of the border, it's a long strip here this strip is divided into a number of each smaller unit area. So, that each unit has a nearly level surface. So, bunds or ridges are constructed around the area forming a basin within which irrigation water can be given or controlled. So, basins are filled to the desired depth, and water is retained until it infiltrates into the soil.

Basin irrigation is adopted normally in land having gentle slopes and basin normally these are used for close-growing crops mainly for the rice, jute. These crops require more water for ponding. So, basin irrigation is very meant suitable for such crops, of course, other crops can also be grown. And particularly ring basin irrigation when it is to be given that is used for a wide spacing crop for the orchard.

So, especially this particular method is adopted to irrigate grain, fodder crops in heavy soil where water is absorbed slowly and is required to stand for a relatively long time to ensure adequate depth of irrigation.

So, you are seeing here this is a ring basin irrigation. So, water is given in the ring and then the remaining area in between one tree to another tree that is dried, that remains you know irrigation is not given. Here what you are seeing is a rectangular basin and then these are the temporary bunds. So, that the water cannot spill over from one end to the other end. So, a considerable amount of water is used for infiltration, as well as the land is also getting wasted when we are giving.

So, in the case of the basin irrigation system water covers the basin rapidly to ensure good uniformity. There are some disadvantages, now these disadvantages are these ridges it interferes movement of equipment when intercultural or harvesting operation is done. And it requires land grading, shaping of the land so that is the one essential requirement to apply a uniform depth of water in each smaller unit area. Labour requirement is high for making these ridges if it is made manually and the considerable area is lost due to the formation of ridges and bunds.

Hydraulics of check basin irrigation system it is more or less same as border irrigation system means irrigation water when it is introduced. So, what happened initially water is spreading the entrance means it is spreading to cover the full width of the basin and then the horizontal as well as the lateral movement of water it takes place. So, advancement of waterfront after the initial spreading it takes place means after the lateral movements then the advancement of water it takes place.

And then rise of water level when the irrigation stream is continued for a longer time then what happens when it has reached to the downstream end there will be a rise of the depth of water and then after it has reached an irrigation stream is cut off then subsidence of water level will take place. So, there are four phases, and when you are plotting a graph, let us say this is your advance curve and when the irrigation stream is cut off then recession stops. So, since the length of the basin is small. So, the recession curve when you are drying is a parallel curve to the x-axis. So, infiltration opportunity time in the case of basin irrigation is not uniform as compared to furrow irrigation.

So, furrow irrigation is another method of surface irrigation and here furrows are developed between the crop rows and the size and shape of the furrow. So, what you see this is one furrow, this is also a furrow which one is constructed in sandy soil, another one is constructed in clay soil, and the spacing between furrows means here the crop is grown on the ridge, where the crop is grown and these are the smaller channel.

So, when say if it is grown, a furrow is made in sandy soil. So, what we see, the spacing between the furrows if it is two-wide then what happened, the water which is moving in the lateral direction, the movement of water will be lesser. So, part of the area will be dry. So, that is not advisable to use wider spacing in the case of sandy soil whereas these furrows when spacing is adopted in clay soil.

So, what we see that the water movement in the horizontal as well as the lateral direction it takes place. So, the plant in this ridge is getting an adequate quantity of water. So, in the case of furrow irrigation systems, horizontal as well as lateral movement of water takes place and these furrows are also used for disposal of runoff water.

Furrows are used for row crops which are grown say maize, sorghum, sugarcane these are the crops and it is well adapted to irrigating crops which are subject to injury due to ponding conditions so this is, and root rotting takes place, so, it is better to use furrow irrigation system

and when there is a problem when the soil is sandy in that case one should be careful about deciding the spacing between the furrows.

And you can see here this is the furrow irrigation system where these are all the straight furrows which have been done and they are best suited when the land slope does not exceed 0.75%. And when they are laid across the slope these are the contour furrows. So, these are beautiful; you can see these particular photos which are showing how the furrows have been made and then the crop is being grown.

Why furrow irrigation is recommended in surface irrigation when means the total area which is coming in contact with the water is just only half to one-fifth of the land surface. Therefore, it is reducing the puddling and crusting of the soil. Earlier cultivation is possible because part of the area remains dry and then it reduces the labor requirement in land preparation and irrigation compared to the check basin method of irrigation.

In order to evaluate the infiltration takes place, normally, infiltration test, it is done when the water ponding takes place in the case of basin irrigation or border irrigation system by using the double ring or single ring infiltrometer. But in the case of the furrow irrigation system since water is in dynamic condition. So, the inflow outflow method is recommended to use for finding out the infiltration rate.

So, in this case, when we are evaluating the infiltration through furrow irrigation system we use the inflow outflow method and in this particular method furrow is divided into the number of sections and at each section, the water is measured using Parshall Flume or a similar type of devices. Furrow cross-section and spacing are measured at each section and the rate of water advance and the depth of infiltration at each section is evaluated.

So infiltration from a furrow is determined by, this one your, accumulated depth of infiltration is given by accumulated inflow at how much time a particular time in a furrow, the water has been introduced by the stream. So, that will be accumulated flow means stream size multiplied by the time it will be the in accumulated inflow.

And then after measuring the cross-section area and depth of flow that will give the accumulated storage. So, accumulated infiltration depth is accumulated infiltration which we are getting from here divided by the weighted area of the test section this will give the depth of infiltration.

Maximum non-erosive stream size. So, the maximum non-erosive stream size is given by

$$Q_m = \frac{0.6}{S}$$

Where S is the slope of the furrow. This is an empirical relationship which is adopted and then one can also find out what is the depth of water applied during irrigation.

So, this can be given by equation that average depth of water applied during the irrigation d is given by

$$d = \frac{q \times 360 \times t}{w \times L}$$

q, is the stream size which is applied in liter per second and then multiplied by t, w is the furrow spacing I mean between two furrows what is the spacing and length of furrow and 360 is unit constant. So, depending on the unit which we are using the 360 will be used.

Corrugation is just meant these are small furrows and here the smaller depth of water is applied. So, these corrugated furrows are constructed to direct the water flow down the slope and these are used for irrigating non-cultivated crops, close-growing crops such as small grains, or pasture grain on the steep slope. It may be in conjunction with the border irrigation on land with relatively flat slopes to help in obtaining uniform coverage with water.

So, corrugations can be made by using simple bamboo corrugators or by using cultivators equipped with small furrower or similar implements. So, these are the small furrows which are known as corrugated furrows for pasture or grass or you know small grain crop that can be grown it does not need.

Sub-irrigation is another method where water is applied below the ground surface and by maintaining an artificial water table at some depth depending upon the soil texture and depth of

plant root. So, what we are seeing here suppose the plants, you are seeing here plant, this is the root system and then there exists a water table. So, water movement takes place from the water table to the root zone of the crop by capillary action.

So, controlling the water table, control of the water table is done scientifically. So, means it is not feasible at all the places but there are some certain places where the water table can be controlled. So, there is a control structure what we are seeing here is an artificially made control structure and when we want to raise the water table. So, with the help of control structure mean there is water supply it will cause the rise of the water table, and then when the water table goes higher we will regulate the water supply, and then it will go as drainage.

So, supply, as well as drainage, are controlled artificially these are very special kinds of situations, and are in natural conditions such situations exist in our country. So, water reaches the plant root through capillary action water may be introduced through open ditches or mole drainage system this method requires a special site condition this is what I am telling that it needs a special site condition to have complete control on water table now.

So, far I have discussed about different methods of surface irrigation. We will be entering into the micro irrigation system why micro irrigation system should emphasize. Let us try to compare with the existing conventional surface irrigation methods. So, one indicator in terms of water-saving. So, in a conventional irrigation system, we waste a lot of water when the water is applied over the land surface losses occur due to percolation, losses occur due to runoff, losses occur due to evaporation which is possible with the help of micro irrigation system.

You are giving just 40 to 70% of the water it can be saved over a conventional irrigation system. Runoff and deportation or negligible or there is no such type of thing provision are not made. So, there is no provision for percolation loss, there is no provision for surface runoff. Water use efficiency, from the water use efficiency point of view, we see in most of the irrigation project and then when it is means combined with the surface irrigation system they hardly we are able to get irrigation efficiency up to 50%.

When it is efficiently managed the irrigation project with surface irrigation hardly we are able to get 50%. So, the huge amount of water goes as a loss whereas in micro irrigation system one can achieve the water use efficiency of up to 95%. There is a saving in labor, labor engagement per irrigation is higher than other methods of improved irrigation system. So, here and then labor is required only for operation or periodic maintenance in the case of a micro irrigation system.

As far as surface irrigation when we come to the different soil types, percolation is more in the case of light soil, in case of sandy loam soil, and when it comes to the heavy soil or clay soil runoff takes place. Whereas in micro irrigation system it can be applied to a variety of soil all types of soil and so, that is the another added advantage and then besides this, there are many other added advantage that when you are applying water in conventional irrigation system it is taking time to reach to the end of the field.

Whereas in micro irrigation system entire field can be instantaneously it can be brought under irrigation system. So, in a shorter period, we can complete the irrigation process as compared to surface irrigation.

So, let us summarize this lecture we discussed about different methods of irrigation. These methods surface irrigation methods where border, check basin, furrow irrigation methods we discussed about the hydraulics of surface irrigation. We also discussed about comparative differences in how these conventional irrigation systems and micro irrigation systems how and what is the comparison in different you know performance indicators. And then we will be now entering the forthcoming lecture on micro irrigation.

You can refer to these books for this particular topic and also you can refer internet references and so, thank you very much for your patient hearing.