Irrigation and Drainage
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Lecture - 58
Irrigation Performance Evaluation

Hai friends, this is our lecture number 58 on Irrigation Performance Evaluation. So, in the previous lecture up to previous lecture we have completed the drainage part. So the next 3 lectures we are going to I mean see the irrigation performance evaluation in the next lecture it will be irrigation economics and in the last lecture.

So we will be going to run irrigation model crop wet and so that is it so we are going to finish wrap up very soon in the following 3 lectures ok. So, in this lectures mostly we will be talking about irrigation performance evaluation.

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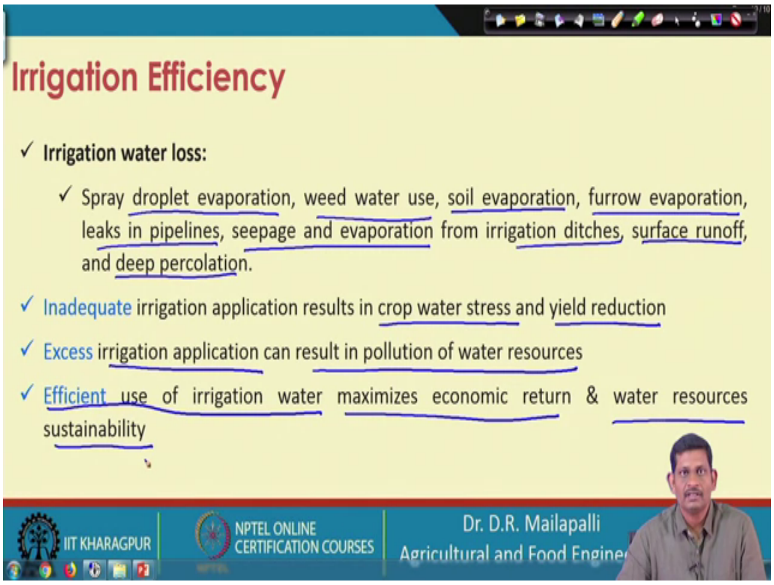

So, the water loss generally may happened through spray droplets in case of sprinkler irrigation, you know weed water use or soil evaporation, furrow evaporation, leaks in pipe seepage and evaporation from irrigation ditches, surface runoff and deep percolation. So, the amount of water you apply in the field can be lost in different you know ways.

So, one in case of sprinkler irrigation so the droplets can evaporate so that is a loss and in case of surface irrigation or any other irrigations. So, it is a weed growth is I mean commonly seen, so that also require some water and soil evaporation, furrow evaporation. So, leaks in a you know pipelines all these losses if you include the amount of water you are giving it is not really utilized by the plant ok, so there is a lot of loss.

So, sometimes this causes the inadequacy irrigation application results you know in crop water stress and yield reduction this is due to inadequacy of water and sometimes you like you excess the water irrigation application can be you know excess. So, that results in pollution of water resources because of the excess water can cause the runoff and the runoff may leave the fields and carry the lot of pollutants and pollute the surrounding water bodies.

So, the efficient use of irrigation water so generally maximizes the economic return and water resources sustainability, so this is what we are expecting a from efficient use of water I mean irrigation water. So, first thing is to get an economic you know returns and the other one is the water resources or sustainable going to be sustainable. So, we have to see whether the irrigation water we are giving is really you know performing the irrigation system is performing well in delivering the irrigation water and lead that leading to you know economic returns and also the sustainability of water resources.

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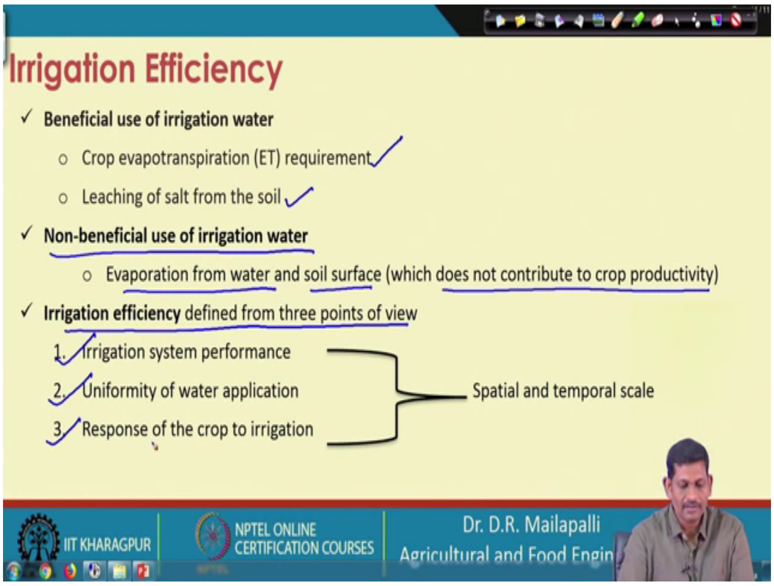

So, the basically the benefits of irrigation water the beneficial we use are 2 types there is a crop evapotranspiration requirement and then leaching of salts from the soil, so these 2 are the beneficial use of the crop production. So, the first one is to grow the crop the other one is to remove the salts from the root zone, so that it would not you know cause any stress osmotic stress on the plants. And then non beneficial use of irrigation water like evaporation from water and soil surface. So, sometimes so these are also I mean you when you apply in the field, so still the water is lying on the ground. So, that we evaporate and also the soil surface which does not contribute to crop productivity it is so that is a non beneficial used.

So, irrigation efficiency defined from 3 point of view. So the one is irrigation system performance and a second is uniform to water application and third response of the crop to irrigation. So, we are going to see the different you know indicators in following these 3 you know the points one is irrigation system performance also in order to understand how the system is performing for a given you know irrigation water.

So, then uniformity of what application so on the system is delivered to the water whether that is really uniformly up applied in the field or not and the third is the amount we given to the field is really taken of the plant beneficial or not. So, in this 3 cases we are going to see the indicators to understand the performance of irrigation water ok.

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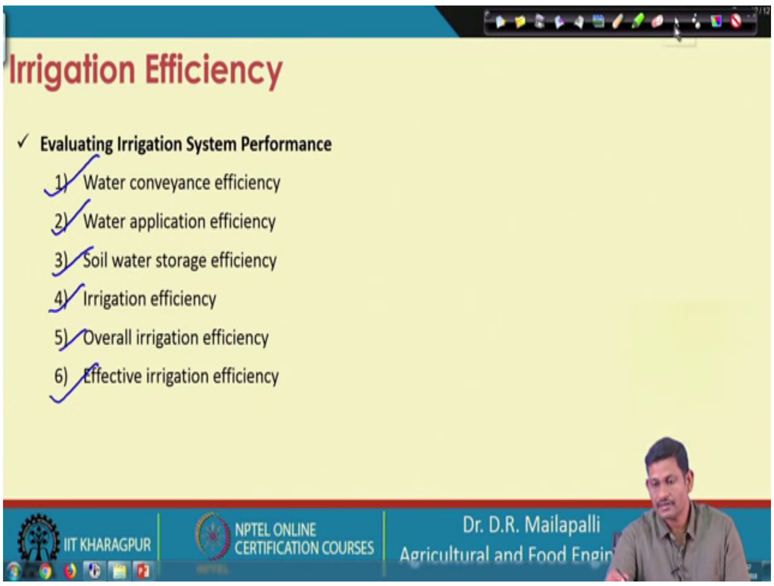

Irrigation efficiency is the first one so this evaluating the irrigation system performance. So, the basically the indicators are 6 and even more in some cases, so the mostly like first one is a water conveyance efficiency. So, that from the canal to the field water I mean agricultural fields the amount of water which you are delivering from canal and given to the field. So, that may not be same, so there is a efficiency term so the system definitely have some efficiencies issues.

So, that is a water conveyance efficiency and then second is the water application efficiency, so the moment you received water from the canals at the field level and then you will be using the irrigation system to deliver to the field. So, then the on form irrigation systems like sprinklers and you know furrows they may not be you know having 100 percent efficient.

So, there we are going to see the application efficiency and then water storage efficiency, the water which is applied to the field should be you know store in the root zone and then beneficially used by the plants. So, then whether the amount which are you which are you know applied the field is been stored in the root zone efficiently are not that so is a efficiency, then irrigation efficiency, the overall irrigation efficiency and then effective irrigation efficiency we are going to see all this indicators in the coming slides.

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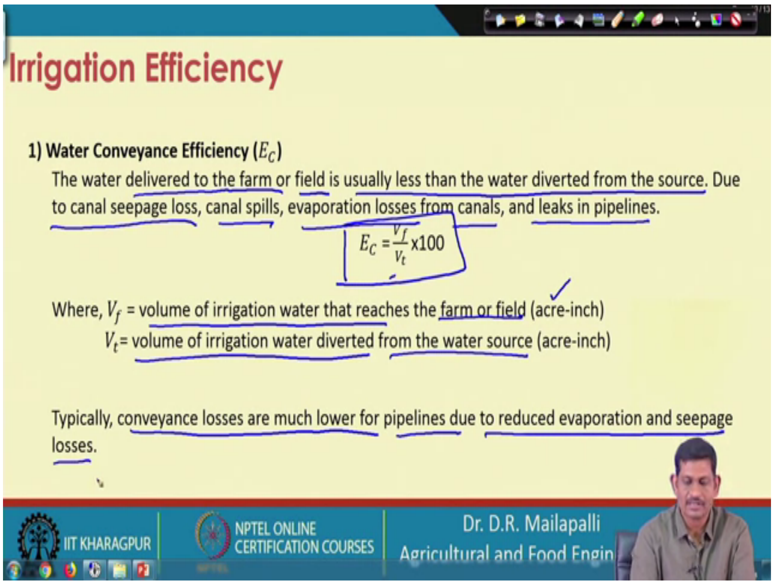

So, let us see the first one is water conveyance efficiency, so the water conveyance efficiency as I said it is I mean the water delivered to the farm or field is usually less than the water diverted from the source that is canals for example. So, due to canal seepage loss canal spills evaporation losses from the canals and that leaks in pipelines. So, it is expressed as V f minus V t, so since it is a fraction if you can multiply with 100 you get EC in percentage. So, that is V f is the volume of irrigation water that reaches to the field or form and V t is the volume of irrigation water diverter from the water source, so that is from the canal.

So, the units could be acre inch or hectares centimeter or hectare millimeters so that is EC. So, the typically the conveyance losses or much lower for pipelines because that is due to less you know the leakages reduce evaporation and seepage losses.

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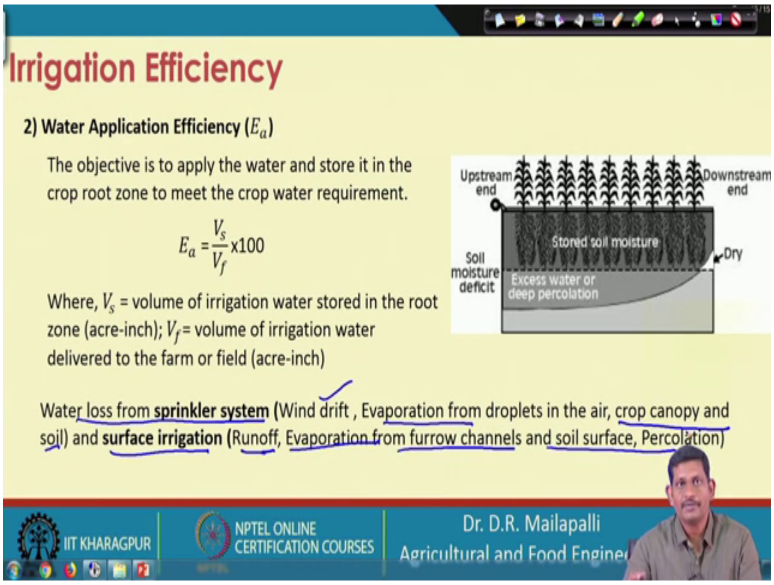

So, now and the next one is water application efficiency, so this is very important as for the un form water management is concerned. So, the objective is to apply the water and store it in their crop root zone to meet the crop water requirement. So, V f is so V f is the amount of water delivered to the field and V s is the volume of water stored in the root zone.

For example here in this case so there is a furrow irrigated field right, so the black one is this one is moisture stored in the root zone right and then there is a still wetting front ok. So, this is what we do not required for the crop because, this is in excess of the crop root zone and this is called excess water or deep percolation and if you see this spot this is a dry spot which did not receive any water. So, there is a dry spot, so you can clearly see the I mean there is a I mean deficit and there is a you know sufficient here.

So, this is upstream and downstream and so water is moving from you know upstream to downstream and this is a soil moisture. So, in this case the amount of water you apply to the field is going away from the root zone in most of the you know cases and there is you know deficit also. So that means, so our objective is to fill the root zone exactly what it requires and since you have the excess and there is a deficit so this is not uniform and efficiency may not be 100 percent. So, that is the reason V s is the stored volume of irrigation water stored in the root zone and V f is the volume of irrigation water deliver to the form field.

So, generally in case of water loss from sprinkler system, so that is due to wind drift and evaporation from the droplets in the air and crop canopy and soil these are the losses. Whereas, in surface irrigation the water may lose or lost through runoff evaporation or furrow channels and surface number percolation so this may happened, so that is the reason the amount you applied in the field may not be 100 percent efficient in storing the root zone ok.

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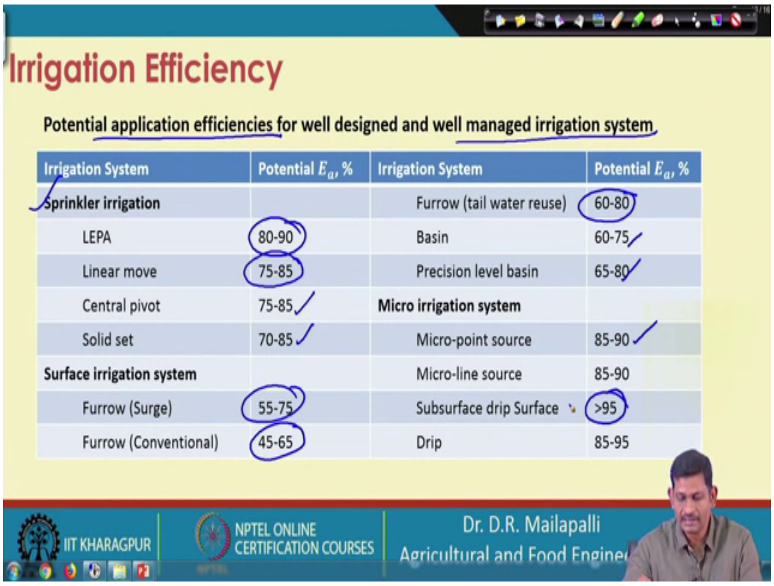

So, the next is so here there is a table showing the potential application efficiencies for well designed and well managed irrigation system. For example sprinkler irrigation this low energy precision applicator it has 80 to 90 percent and linear move sprinklers 75 to 85 percent central pivot 75 to 85 percent and solid set 70 to 80 85 percent.

Whereas in surface irrigation furrow irrigation, so compared to sprinkler irrigation the less efficient and 45 to 65 furrow is a conventional and tail water reuse little bit a higher efficient and precision level basins. So, these are all it will higher efficient efficiency compared to other surface irrigation systems and the micro irrigation systems it can go up to more than 95 percent in case of subsurface drips drip irrigations ok.

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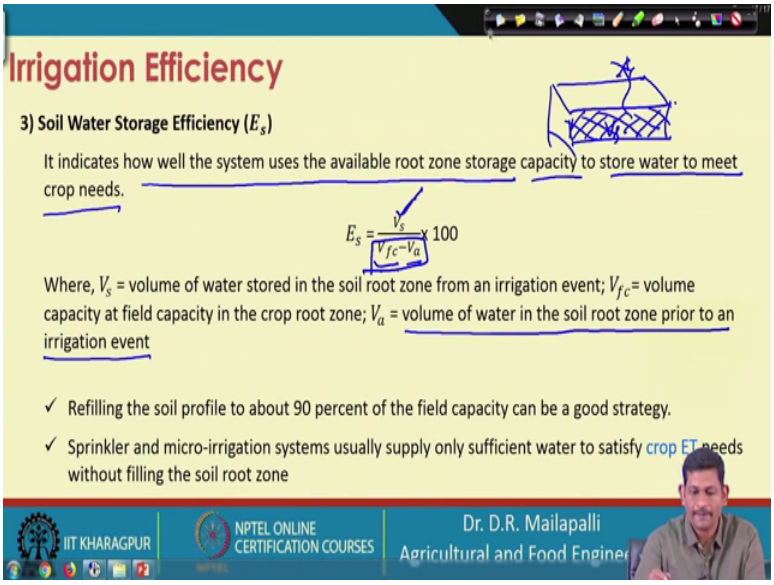

So, these are application efficiencies this overall view and the next is a third indicator, so that is the soil water sorry. So, that is a soil water storage efficiency so this indicates how well the system uses the available root zone storage capacity to store water to meet crop needs ok. So, here you have the storage right you have the storage of root zone right, so you have that V s is that that is storage.

But how efficiently this store water is been utilized by the plant, so here numerator this is a V s is a store water. Whereas, V fc minus V a so V fc is the volume of water at field capacity and V a is a volume of water in the root zone prior to an irrigation event ok. So that means, so here this much volume of water is being used by the crop or by the crop during the last irrigation you know event during the or the previous irrigation event.

So, this is the volume of water stored and this is a effectively the volume of water being used, so we are not completely you know taping the 100 percent of soil water right. So, the part of water is being used for crop production or the evapo transmission load. So, this way the soil water storage efficiency is defined and refilling this soil water storage about 90 percent of the field capacity can be a good strategy.

So, this is a deficit irrigation you know strategy, so the most in 90 percent is a good strategy. But generally I mean we can still go of a 60 percent (Refer Time: 14:09) so manageable allowable deficit. So, sprinkler and micro irrigation systems usually supply only sufficient water to satisfy crop ET it is not like the surface irrigation systems you can go for some kind of deficit so and then forth indicator here is the irrigation efficiency that is Ei.

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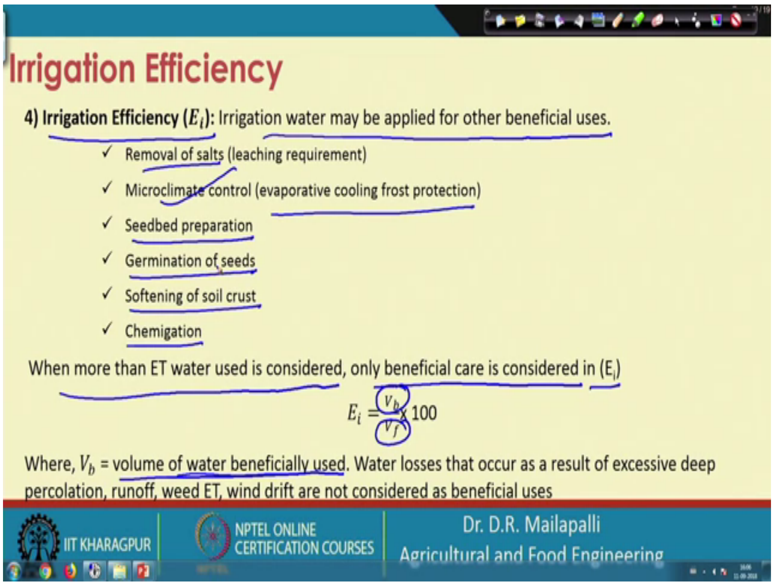

So, irrigation water may be applied for other beneficial uses, for example removal of salts that is a leached fraction and microclimate control suppose the soil is frostily if you can supply water that may you know warm of the soil then and the and the frost can be the defrosted. So, seedbed preparation germination of seeds softening of soil crust and chemigation so right, so chemigation is that means fertigation kind of thing. So, all these activities required water so these when more than ET water used is considered only beneficial care is considered in E i ok.

So, in this V b by V f, so V f is a amount of water applied to the field volume of water and then V b is the volume of water beneficially used. So, you apply lot of water, but the thing is so what beneficially you know the crop is being used for beneficial purpose in order to grow the crop. For example, removal of salts that is a beneficial right and then microclimate control this is all you know used for creating a favorable environment with the crop production, so we need to consider this water and that is V b right by V f by 100 and then next is the fifth one is the overall irrigation efficiency E o.

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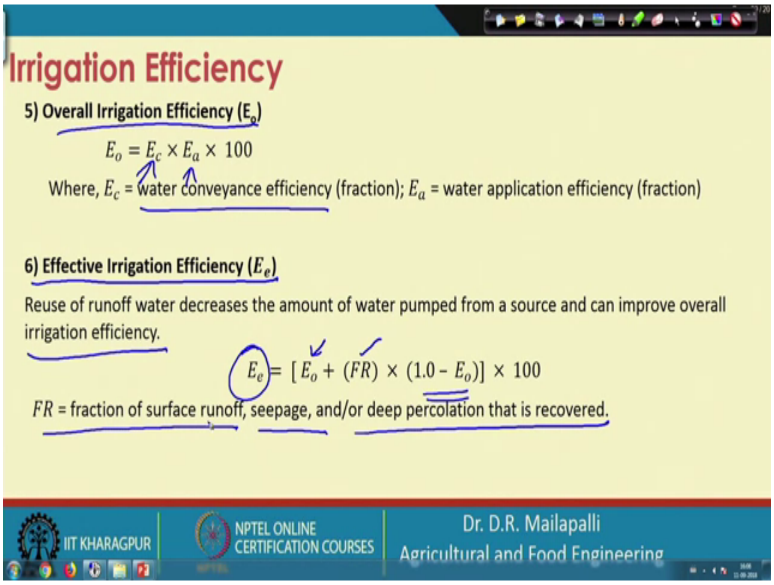

So, that is conveyance efficiency and multiplied by application efficiency. So, water conveyance efficiency in fraction application efficiency in fraction, if you can multiply that you get the overall irrigation efficiency and then sixth one is effective irrigation efficiency. So, what happened sometimes you the runoff which is being generated from the field can be reused right. So, in that case you are a again using the runoff water I mean recirculating as the irrigation water.

So, then the irrigation efficiency we improve so in that case the irrigation the this is called effective irrigation efficiency. So, this is overall irrigation efficiency and then this is FR fraction of the runoff water which is being used as irrigation water. So, that is fraction and one minus E naught right into 100, so this the fraction of surface runoff or seepage or deep percolation that is recovered from the field, so that can be used as irrigation that is a fraction. So, this way the effective irrigation efficiency is been estimated.

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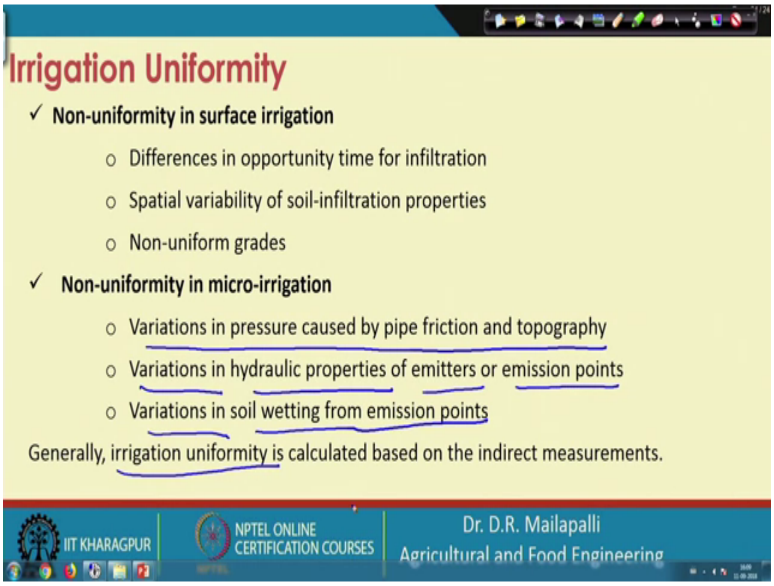

So, now irrigation ,so the second one is the irrigation uniformity, so the whatever we discuss that is all efficiencies and the second you know the case or second performance indicator is the irrigation uniformity. So, here non uniformity in surface irrigation basically that is caused because of differences in opportunity time of infiltrations suppose you have field here.

So, here infiltration is more infiltration is less maybe infiltration is more, so this definitely causes this non uniformity in you know soil root zone ok. So, that is one case and spatial variability of soil infiltration properties, as I said if that is definitely I mean different amount of infiltration depth caused by the infiltration properties of the soil and non uniform grades.

So, the grade is you know not uniform, so definitely here there is a depression and a more infiltration is taking place. So, like that it is right so definitely that is also causing the non uniformity and non uniformity in micro irrigation. So, this is basically variations in pressure caused by pipe friction and topography and variations in hydraulic properties of emitters or emission points and soil wetting from emission points ok. So, these are definitely going to cause this non uniformity in micro irrigation and generally irrigation uniformity is calculated based on the indirect measurements such as.

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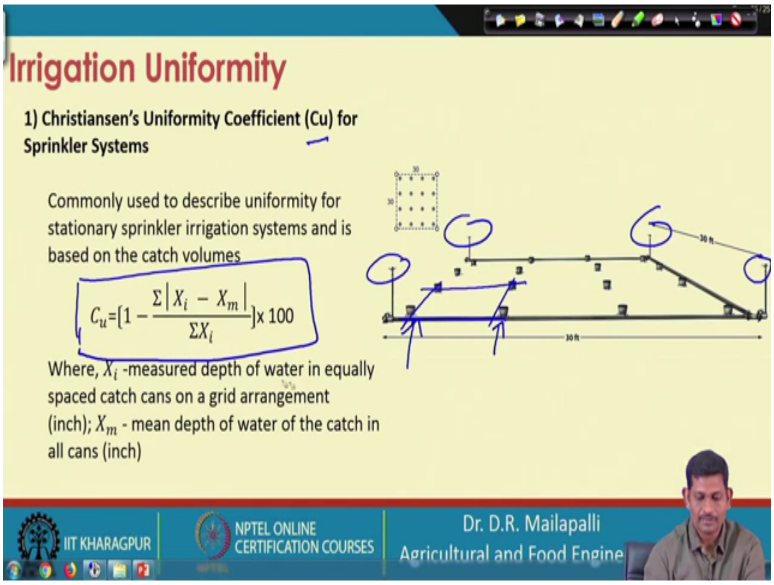

So, the first one is a Christiansen's uniformity coefficient. So, that is mentioned as C u for sprinkler irrigation mostly. So, if you see in case of sprinkler. So, these are the sprinklers for example, in this figure. So, the catch cans or you know arranged in a n a known grid intervals right known grid intervals, and then you are going to collect water for a specific period of time and then after that we are going to see, whether the sprinkler irrigation system is uniform I mean irrigation is uniform distributed or not. So, if you see this is the equation is being used to estimate Cu that is Christiansen's uniformity coefficient.

So, 1 minus X i minus X m by sigma X i into 100. So, that is X i is the depth of water which is measured a each catch can and this is a average depth of all catch cans, and then divided by the sigma X i total the total amount of water, I mean there the depth of the total catch cans ok. So, that is sigma X i. So, X i is measure depth of water equally X m the mean depth of water in the catch cans ok.

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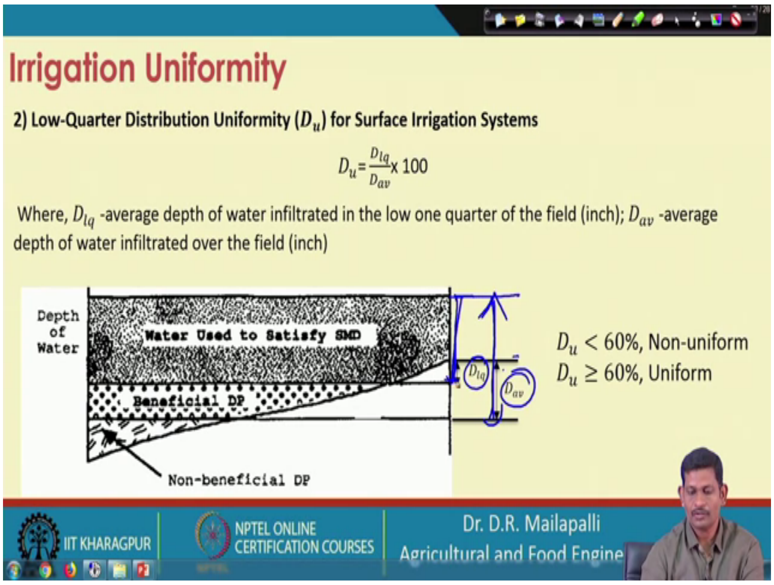

So, the this way you can calculate C u and then the next is the second indicator in case of irrigation uniformity is low quarter distribution uniformity, this is basically applicable for surface irrigation systems. So, if you see this, this is a head end and this is the tail end of furrow irrigated field or board irrigation field. So, water is flowing from head end to tail end and this is a water depth which is been observed at the head end, which is because lot of water in we available here, and then lowest I mean minimum water depth will be available at the tail end ok.

So, if this is the required water, I mean this is a required desired root zone depth. So, this one if you see the deficit and beneficial this is this is a DP and water is used for satisfying assemblies almost deficit ok. So, here D u generally estimated as the depth of the wetting front at the lower quarter divided by average depth of the water, I mean infiltrated water in the field I mean throughout the field into 100 so; that means, if suppose this is one fourth of the field. So, this is lower quarter depth. So, this is lower quarter depth D l q minus average. So, the D a v so that divided by I mean D a v into 100.

So, D u generally less than 60 percent non uniform and D u greater than equal 60 percent this uniform ok. So, depth of water infiltrated in the lower one quarter of the field so; that means, here. So, this one is this one is d D l q and this one is D a v ok; so, not this one. So, this is a lower quarter and this is the average ok.

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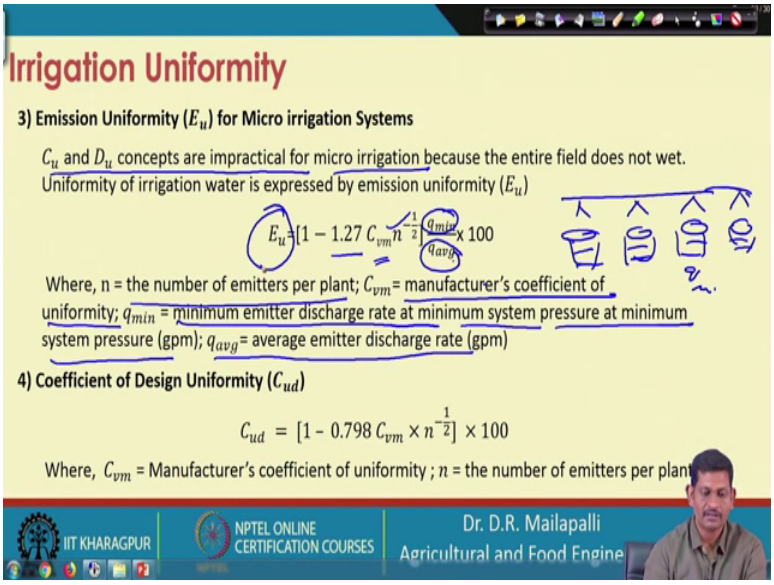

So, then irrigation uniform this is third one. So, that is emission uniformity for micro irrigation systems. So, in case of micro irrigation systems and this is not directly which is I mean it is its not wetting the field completely in case of sprinkler and surface irrigation systems, because if this is a dripper. So, there is a wetting spot here, there is a wetting spot here and it goes like this.

So, there are parches of wetting you know wetting patches are seen in case of drip irrigation system. So, definitely the uniformity is estimated or different. So, here C u and D u concepts are impractical for micro irrigation. So, that is why here E u is introduced that is emission uniformity right which is a given equation like 1 minus 1.27 into C v m, which is manufactures coefficient of uniformity right into n. So, n is the number of emitters per plant ok so, then q min by q average.

So, q min is the minimum emitter discharge rate at a minimum system pressure at a minimum at a see minimum system pressure and q average is average emitter discharge that is g p m. So, this is average emitter discharge and q minimum is the minimum of all emitter discharges. Suppose you have is a emitter here and there is a second emitter third emitter fourth emitter number of emitters. So, q average is the average, I mean if when correct the discharge from each and emitter point ok. So, then you are going to average the flow rate, and q min find out the q min among all the catch cans ok. So, that will if the q min and q average and C v this is a manufacturers coefficient of uniformity for the particular emitter type and you can calculate the emission uniformity ok.

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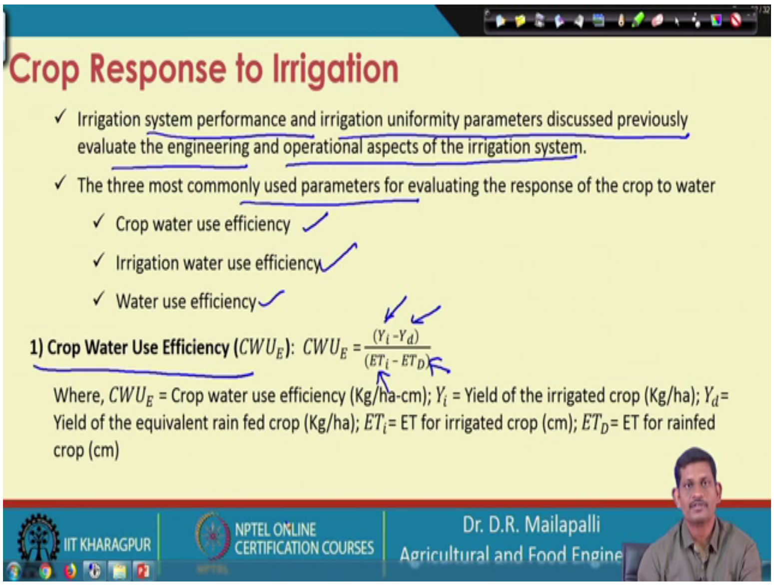

So, then the fourth one is a coefficient of design uniformity the C u d. So, design uniformity. So, there is 1 minus 0.798 into manufacturers coefficient of uniformity and number of emitters into 100. So, this will give the coefficient of design uniformity ok. So, then the third one is crop response to irrigation. So, the first one is the irrigation efficiencies, and second is uniformity and third is the amount of water you give whether how the crop is the responding to the water you applied to the field. So, here the irrigation system performance and irrigation uniformity parameter discussed previously, evaluate the engineering operation aspects of the irrigation system.

So, here the 3 most commonly used parameters in case of crop response to irrigation or crop water use efficiency, irrigation water use efficiency and water use efficiency ok. So, this efficiency we are going to see the first one is crop you water use efficiency CWU E, crop water use efficiency that is yield difference divided by evapotranspiration differences in case of irrigated field and rain fed field. So, Y i is the yield obtained in case of irrigated field and Y d is obtained yield in case of rain fed field and similarly ET i is the evapotranspiration observed in case of irrigated condition and in rain fed condition.

So, this will give the crop water use efficiency. So, here in case of you know generally the crop if you if you grow. So, we do not know how much is irrigation water and how much is a rain rainfall I mean the crop response due to irrigation crop response due to rainfall is not been separated you know not cannot be separated right. So, that is why you need to in experiments separately and then find out the crop water use efficiency. So, this will give the irrigation response to crop yield.

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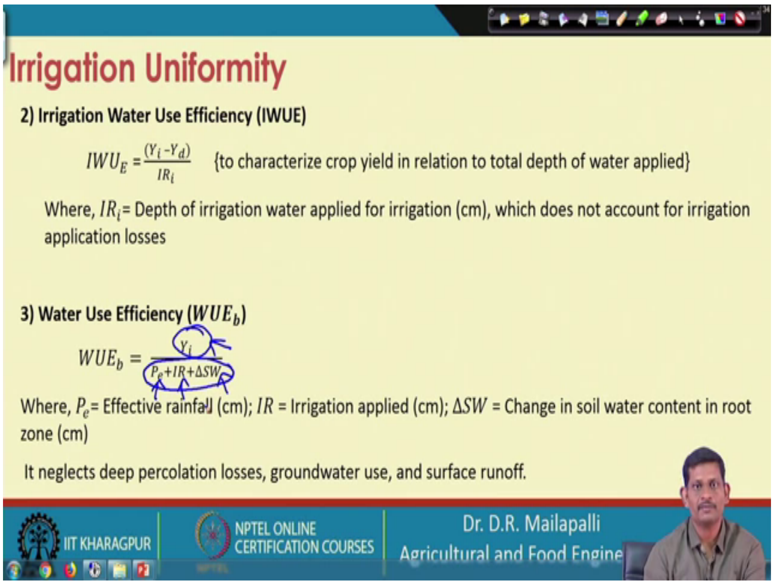

And then so, the next one is the irrigation water use efficiency. So, this is. So, similarly Y i is the yield due to irrigation yield due to rain fed and IR is the irrigation water. So, depth of irrigation what applied in the irrigation, which does not account for irrigation application losses. So, we generally used for beneficial I mean beneficially used irrigation water and then water use efficiency.

So, this in the water use efficiency this is the yield due to irrigation and then. So, this is entire water we applied, generally one is for this is effective precipitation or effective rainfall, and irrigation water applied and the soil moisture which is present in the soil. So, this much water you have applied to the field and then as a result you receive this yield. So, this is the water use efficiency. So, in this we or including that the entire water we applied to the field including the beneficial non beneficial all.

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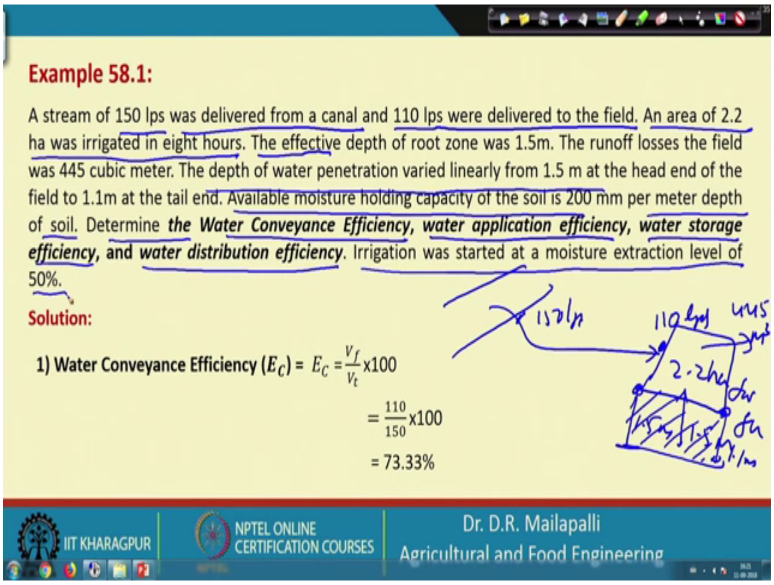

So, here then the example a stream of 150 litre per second was delivered from a canal and 110 litre per second were delivered to the field ok. So, an area of 2.2 hectare was irrigated in 8 hours. So, the here is a 2.2 hectares and this is for irrigated for 8 hours and there is a canal from canal the water is being. So, at this point so, water is 150 LPS whereas, if the field level. So, it is measured as 110 LPS.

And so, now, the effective root zone here is a 1.5 meter and the runoff losses in the field was 445 cubic meter. So, this is 445 meter cube is a runoff from the field. So, the depth of water penetration varied linearly from 1.5 meter at the head end. So, suppose this is the head end and this is the tail end. So, this here is a 1.5 meter whereas, here you get 1.1 meter the infiltration depth ok. So, that is a variation within the soil root zone, then available moisture holding capacity is soil is 200 mm per meter depth of soil.

Determine the water conveyance efficiency, water application efficiency, water storage efficiency and water distribution efficiency irrigation was started at a moisture extraction level of 50 percent. So, 50 percent now when the moisture depletes 50 percent from the field capacity you are going to irrigate. So, with these conditions so, find out the efficiency. So, the first is water conveyance efficiency. So, this is straight forward that is a amount of water been diverted from the canal and received at the field end.

So, the here 110 150 from the canal and 110 at the field level so, it gives a 73.33 percent is a conveyance efficiency.

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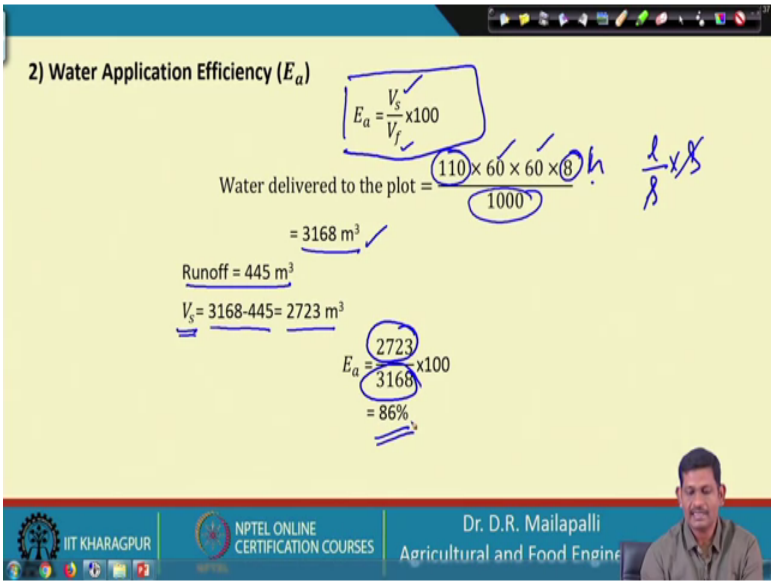

So, next is the application efficiency. So, water application efficiency the formula is, volume of water stored in the root zone applied in the field level. So, water deliver to the plot. So, the 110 at the field level right and this is and this is irrigated for 8 hours ok. So, and then 8 hours is been converted into seconds 60 into 60 right. So and 110 litres 110 litre per second. So, right so then these hours is converted into seconds. So, litre per second and now seconds this gets cancels out and litres. So, litres converting to meter cube we divided by 1000. So, that will be 3168 meter cube of water is being delivered to the field if we irrigate for 8 hours.

So, this one and runoff is given 445 meter cube. So, V s which is really effective right that is this minus this that is 27 to 23 is the volume of water stored in the root zone. So, this is 2723 and 3168 is we applied. So, that will be 86 percent is the application efficiency ok.

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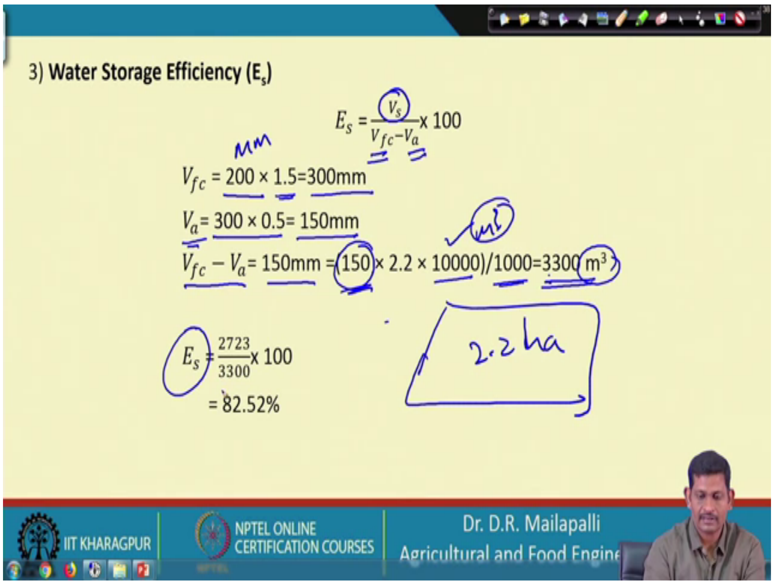

And the next is water storage efficiency. So, water storage efficiency that is V s is the volume of water which is stored in the root zone, and then V fc the volume of water field capacity and V a is the volume of a water exactly just prior to the next irrigation.

So, V fc is 200 into 1.5 because 200 mm per meter depth is the moisture availability so, moisture holding capacity. So, that is 200 into 1.5 is the root zone depth, that will be 300 mm is the water holding capacity in the root zone and V a. So, he said like 50 percent is the when it gets 50 percent if 50 percent of V fc is depleted then irrigation is going to start. So, 50 percent is of 300 mm there is 150 mm. So, if the amount of water the available the water is 150 mm and we start irrigation.

So, V fc minus V a that is 150 mm because this minus this 150. So, then for the entire field if you see this is 2.2 hectares and 150 mm is available water. So, this is a meter cube conversion of meter cube hectares to meter cube and divided by 1000 will give the. So, this is mm; so, mm convert to meters divided by 1000. So, that is 3300 meter cube is the V fc minus V a. now E s is equal to 2723 and V fc minus V a that is 82.52 percent is the water storage efficiency.

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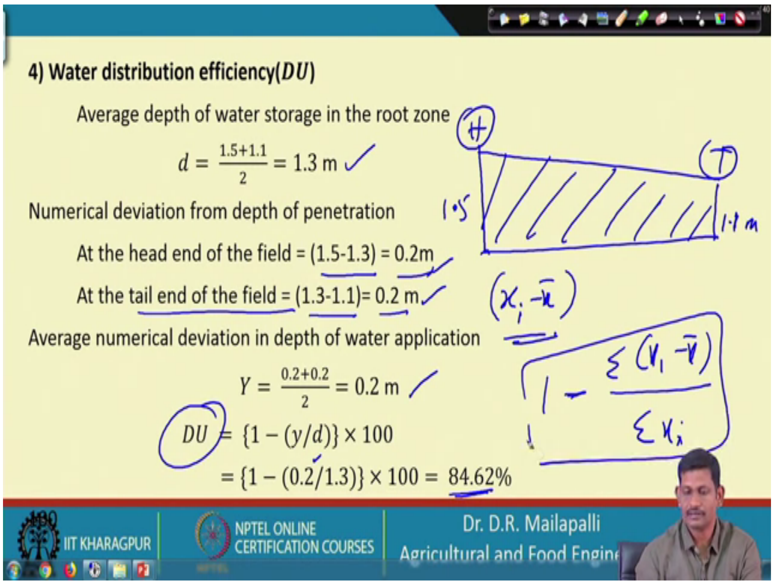

Next is your water distribution efficiency. So, if you see if in the problem it is a given. So, water distribution is taking place by 1.5 at the head end and tail end so, this is up to 1.1 meters right. So, this is a wetting front profile at the end of the irrigation. So, now, depth of water stored in the root zone that is a d, the average depth will be 1.3 meters and numerical deviation from the penetration. So, at the head of end of the field. So, here it is a numerical deviation would be. So, if your xi minus x bar right.

So, that will be 1.5 minus 1.3 0.3 0.2 and tail end 1.3 minus 1.1 0.2. So, now, average numerical deviation right so, that will be 0.2 plus 0.2 divided by 2 this will be a 0.2 now distribution uniformity is equal to 1 minus y by d into 100. So, there is a 0.2 divided by 1.3 equal 84.62. So, this is the similarity of Christiansen's uniformity distribution which is sigma xi minus x bar divided by sigma xi ok. So, this is similar to that.

So with this you conclude this lecture. So, in this basically the irrigation system performance is been is been you know understood by basically the 3 cases. So, the first one is, you know the efficiencies, system efficiencies and second is a I mean uniformity and third one is a response I mean irrigation response to yield ok. So, sorry yield response to irrigation water we applied ok.

So, with this so, the basically whether the system is working efficiently or not and then or we getting the you know economic yield or not. So, all these things will be carried out based on the understanding, how we understood the application efficiencies and then the distributions ok, and then crop water, what you call crop water efficiencies and irrigation efficiencies and water use efficiencies all these things. So, the next lecture we are going to talk about the irrigation economics.

Thank you.