Water Management
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Lecture 31
Sprinkler Irrigation System (Continued)

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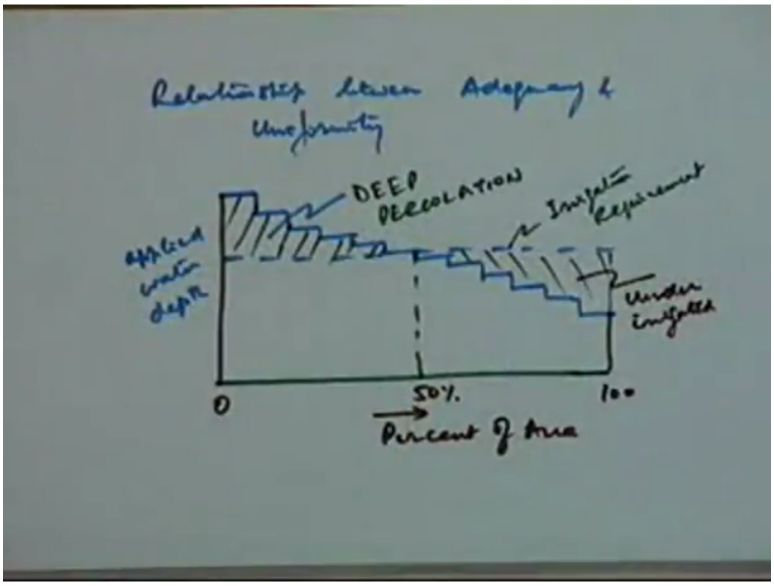

The last lecture we were looking at the relationship between adequacy and uniformity and we had seen that what do we mean by these two terms, what is uniformity and what is adequacy and we had depicted that through this graphical representation.

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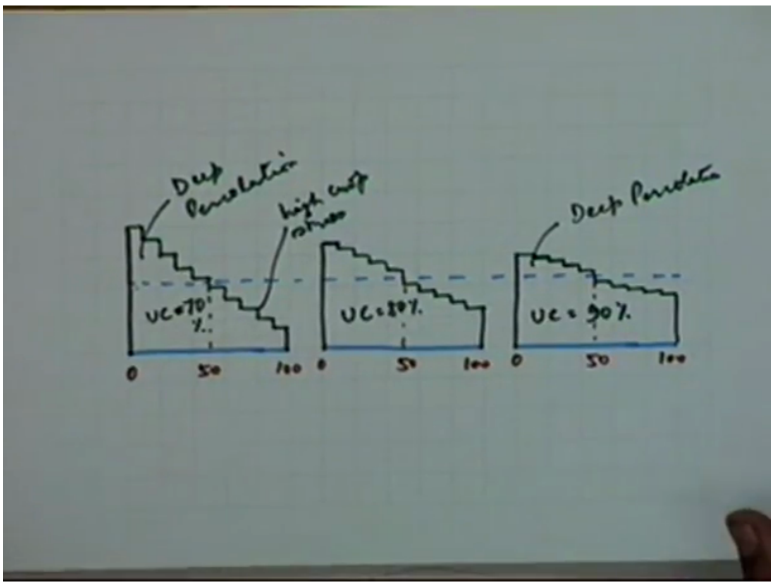

Now if you want to have an idea how these two things vary, how they get interrelated with respect to the change in one you can do that by having a specific case again we are going to select a case where we have the variation of uniformity coefficient for the same level of adequacy so in this case let us assume that the adequacy level is 50 percent in all these three cases.

By the same time the uniformity coefficient varies. In this particular case the uniformity coefficient is low because there is more non uniformity if you look at the expression of the uniformity coefficient the deviations are much higher from the mean in this particular case this is the mean level of irrigation which is applied.

Let us say for our explanation purpose that this is corresponding to a uniformity coefficient of 70 percent, this case corresponds to a uniformity coefficient of 80 percent and this is the case which corresponds to a uniformity coefficient of 90 percent but in each case the level of adequacy is 50 percent that means in 50 percent of the area the depth of irrigation is equal to or more than the required depth of moisture which is required in that particular soil for that condition.

So the deficit is taken care of in 50 percent of the area that is how we have defined the adequacy level. This gives you a another observation which you can make from this representation is that if you look at each of these three cases the adequacy level is remaining same but the still the amount of wastage in this case the deep percolation is much higher in comparison to the deep percolation of this situation that is one observation that means you are you are having more losses which is which is quite evident from the fact that uniformity coefficient is low and we have said that uniformity coefficient will be low the percolation losses will be higher the losses will be of higher magnitude.

But besides that there is another very important aspect that the deficit is also much much higher in some of the areas. So what will be the effect of that deficit there will be higher stresses in some portion of the area. This portion will have very high crop stress so the stress level in the crop will be much higher because of the higher level of the deficit, whereas in the case of this last situation where the uniformity coefficient is very high though the deficit is there but that deficit might not create any any ill effects on the crop the crop might not have effect to the extent that the yield is affected.

So though this deficit is the order of magnitude it depends what is the order of magnitude of this deficit and you know that the soil the extraction pattern of the soil is varying with respect to the the crops there are some crops which can extract more moisture from the same soil, there are some crops which can extract plus moisture because it is a function of what type of root system the crops are, so there might be some crops where you can afford to have a lower level of uniformity coefficient but there is a limiting level which you cannot go beyond, if you go beyond that then it is going to effect the yield of the crop.

So this relationship is very important to be understood if you have to design your systems properly that is it is not only the adequacy which has to be taken into consideration you have to take into consideration the uniformity along with the adequacy and these two items they are related with many other parameters also which will try to look into but let us let us try to go deeper into the real design aspects how these two items the uniformity coefficient and the adequacy they have been utilized to formulate some guidelines through some in the form of either the design charge or in the form of some tables which can be in turn utilized to go in for the first level of designs which will give you some indication regarding the matching of these two parameters and you can choose from that set of relationships or the design charge.

In this particular case I am going to give you a table which will help the designer to pick up the relevant values of these parameters which are acceptable parameters and then come out with a design which is the may be the starting value of the design. So in all these things since so much research has been done in most of the situation you will find that there are some guidelines either in the form of tables or in the form of charts which are available even the company’s work and who are manufacturing the sprinkler systems they are given like lot of design material which can help the designers in selection of those relevant combinations of equipment because ultimately the type of parameters which you are which you can visualize at this stage are sizes of these nozzles, the sizes of the pipes, spacing between the sprinklers or the spacing between the laterals all these are the relevant parameters and we will reach that stage but let us look at some other related item before we reach there.

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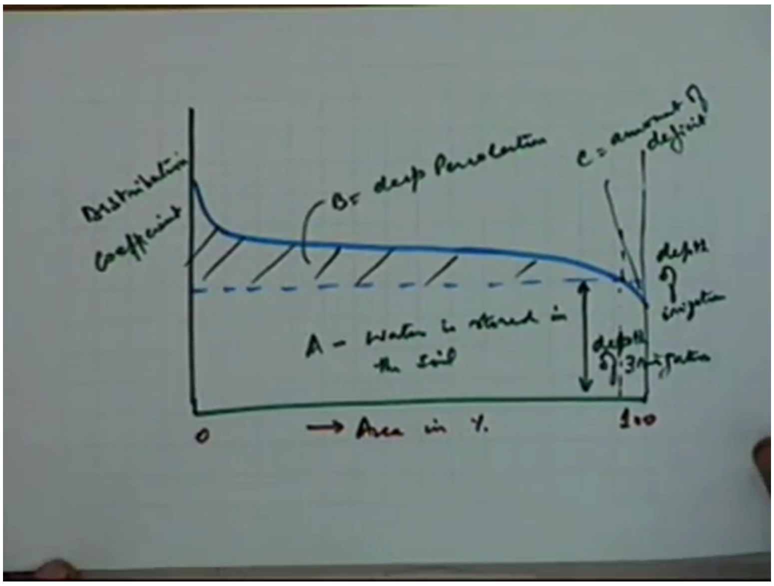

Now if we construct with respect to the distribution coefficient how if on this side I take the depth of irrigation and I assume that the the applied water pattern is normally distributed which is not very wrong assumption. You might find that the distribution pattern is something which you have already drawn but I am drawing in a continues form if this is the area in percent and this we have said is the this level will give you the adequacy level in this particular case and this is the area I will call it area A water stored in the soil, this area this is the area B which represents deep percolation and this area C represents the amount of deficit.

So in other words this is the depth of irrigation, this is corresponding to a specific uniformity coefficient and specific level of adequacy.

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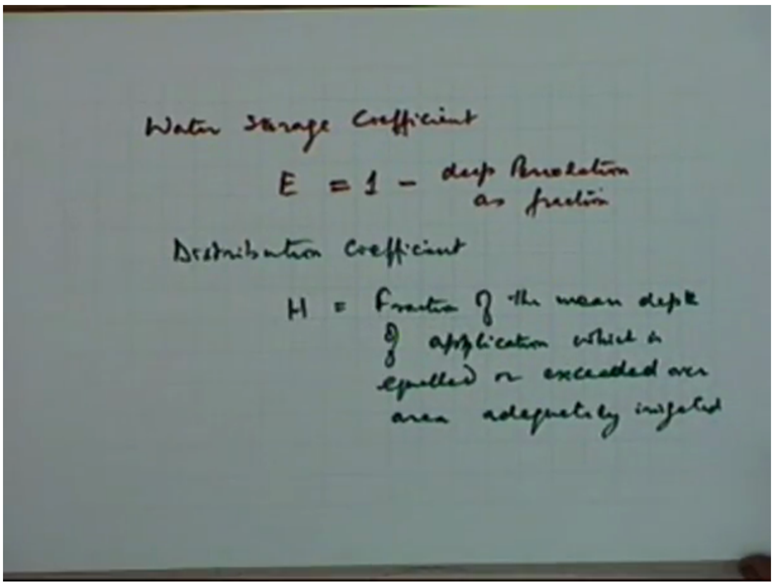

And there are two terms which are defined to relate these these two parameters and these two terms are water storage coefficient which is designated as E which is nothing but 1 minus the deep percolation expressed as fraction and the other term is distribution coefficient which is represented as H and this H is basically defined as the fraction of the mean depth of application which is equal or exceeded over area which is adequately irrigated that is how these two terms have been defined.

Basically this term gives the relationship between the percolation loss and is called the water storage coefficient because this will give you how effectively the water help in stored in the soil, whereas distribution coefficient will give you something about the distribution of the water which has been stored in terms of how valid has been distributed.

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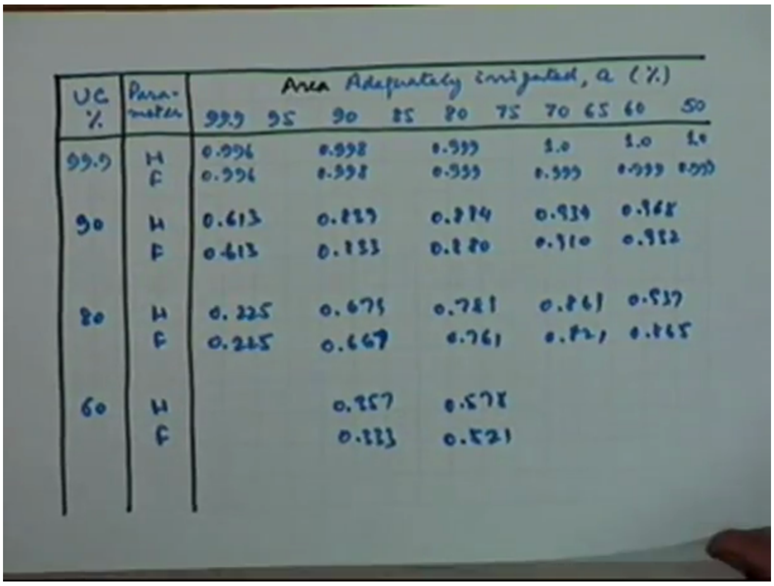

UC %	Parameter	Area Adequately irrigated, a (%)									
		99.9	95	90	85	80	75	70	65	60	50
99.9	H	0.996		0.998		0.999		1.0		1.0	1.0
	F	0.996		0.998		0.999		0.999		0.999	0.999
90	H	0.613		0.839		0.874		0.934		0.968	
	F	0.613		0.833		0.880		0.910		0.952	
80	H	0.225		0.675		0.781		0.861		0.937	
	F	0.225		0.667		0.761		0.821		0.865	
60	H			0.357		0.578					
	F			0.333		0.521					

So that these two items are used in the table which has been brought out to relate the two parameters uniformity coefficient and the area adequately irrigated which is small a. I will give you only a part of the table for some in between values just to give you the idea how these items vary from one level of uniformity coefficient to the other levels and from one level of small a which is the area adequately irrigated or level of adequacy from a very high level of adequacy to a low level of adequacy.

And for these two parameters which is the distribution coefficient and the water storage coefficient, you will find that this particular relationship then in term can be used effectively for the preliminary designs and we will take up a small example to show that how you can make use of those table. Let me take a very low value of okay for 80 percent uniformity coefficient the values go down drastically when you want to have a higher level of adequacy and see here that these values are achievable values, these values are the one which have been tested in the fields.

So the scope of the application of these type of tables is very anonymous in the sense that you can avoid doing experimentation in different locations of the World, all the state has been compiled and made available for the researchers so that they can avoid duplicating the effect unnecessarily from one place to another place. And in some cases you might have to again go in for some of these the validation of some of these parameters if there are some local effects which are known to be predominant.

For example in the case of 60 percent of uniformity coefficient you might not be able to achieve anything when you have 60 percent uniformity coefficient these levels of adequacy are not achievable. You have only values which are starting some way here and these also are very reduced values in comparison that means if you have this type of uniformity coefficient the adequacy level, the distribution coefficient as well as the water storage coefficients will be very drastically reduced for higher levels of adequacy.

So these are some that the table is complete table will be given to you along with the resource material.

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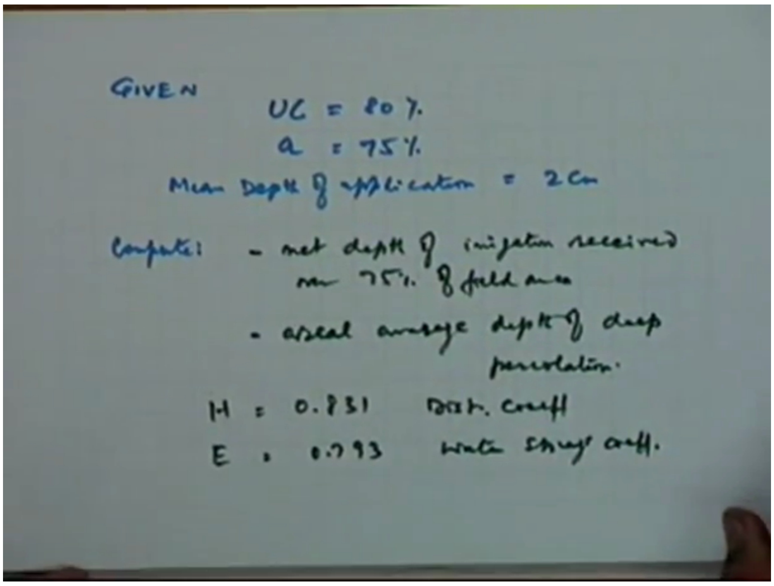

Now let us have a look how we can make use of this table for some of the actual exercises and we will take one case where you have been given some data the data which is given as that you have the uniformity coefficient of 80 percent, the adequacy level is 75 percent and the mean depth of application is 2 centimeters with this known data you want to compute you want to compute what is the net depth of irrigation received over 75 percent of the field or the level of adequacy and secondly you will also like to know what is the areal average depth of deep percolation, what are the deep percolation losses these are two items which you will be interested in.

Now using the table you can find out for the 80 percent of uniformity and against a value of adequacy level of 75 percent the value of distribution coefficient H is found to be 0.831 as the distribution coefficient and the water storage coefficient is 0.793.

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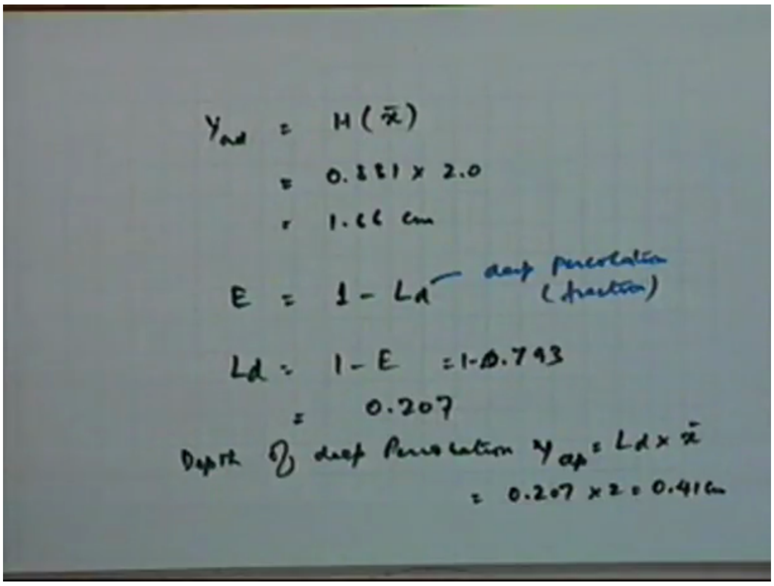

So the way you have defined the distribution coefficient if you take the depth equal to or exceeded over the area adequately irrigated as Y ad as a depth which is equal to or exceeded over the area which is adequately irrigated is the area small a. So this depth which is equal to or exceeded over the adequately irrigated area can be expressed now as the distribution coefficient times the mean depth.

And since you know the H value is 0.83 times and the mean depth is 2 centimetres that means the depth which is equal to or exceeded over the area of adequately irrigated segment of the field is only 1.66 centimetres. Similarly the relationship between the water storage coefficient and the deep percolation if I take L d as the the deep percolation in fraction then the water storage coefficient is 1 minus the deep percolation because of the fact that they are no surface none of losses and that is if there are (())(25:13) of losses they will have to be incorporated here.

So since the apiary assumption in our sprinkler irrigation system is that we do not let any (()) (25:26) of occurs we can safely take this as the only loss and the water storage coefficient can be expressed as 1 minus L d. So knowing the E value L d can be found out now which is 1 minus 0.793 so it is 0.207 that is again in fraction so if you want to know the depth of deep percolation in terms of the absolute units of centimetres that we can call the Y dp is equal to L d into the average depth of application which is 2 centimetres so you have into 2 which is 0.41 centimetre.

So your depth of deep percolation is 0.41 centimetres that is how you can make use of that information which is made available in the table for different levels of uniformity coefficient and for different levels of adequacy.

Now as I was mentioning the in the last lecture that in many situations where you might be able to enhance the uniformity coefficient by adjusting the the spacings this is possible is quite likely that you might enhance the uniformity coefficient if you take the spacing between the sprinkler or the spacing between the laterals are reduced or in other words what you doing is that you are having more of overlap. So through that additional overlap you can reduce the inaccuracies or the unevenness of the distribution and that is what makes the uniformity coefficient go higher.

But we have to see that is that a cost is that a cost of equipment is at the cost of operational cost going up. All these things they have to be evaluated before you make such any such decision.

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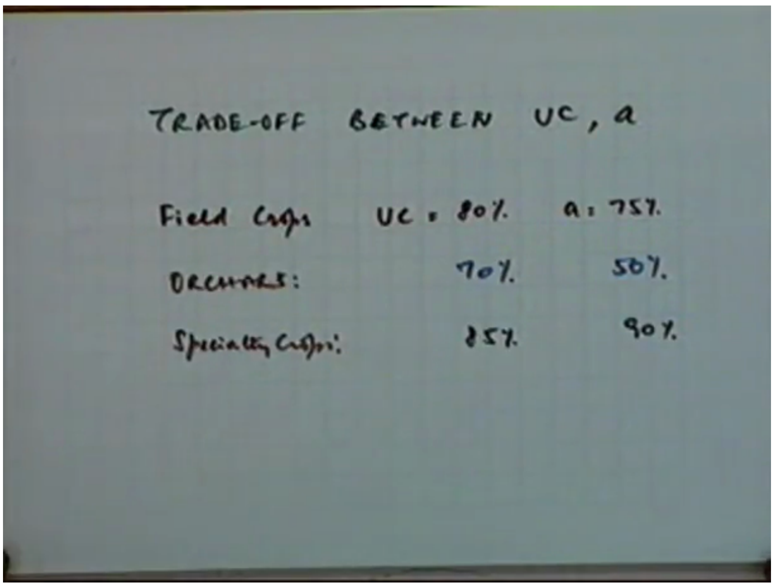

So in terms of again in terms of the different varieties of the crops the different sectors or different types of crops they are recommended levels which are been are been brought forward after experience all over the World and that is what is the trade-off we can say that was the trade-off between the uniformity coefficient and the adequacy levels.

Recommendations which have been given are with respect to three categories that if you have field crops the uniformity coefficient which are achievable as well as they are reasonable in terms of the cost, in terms of how much gain you get, how much is the advantage if you go in for those additional cost with respect to the crops is found that if you are you have in the field crops you should go in for something like this combination that uniformity coefficient of 80 percent and adequately level of 75 percent.

Whereas if you have the Orchards then the uniformity coefficient of a lower level as well as the adequacy level of lower order of magnitude might suffice your requirement because in the case of Orchards you can afford to have this combination and if you have speciality crops which are high value crops then the these levels are recommended. So that is again these are only the order of magnitude is no hard and fast tool that you have to stick to these but you might find that you will quite reasonably comfortable if within these ranges.

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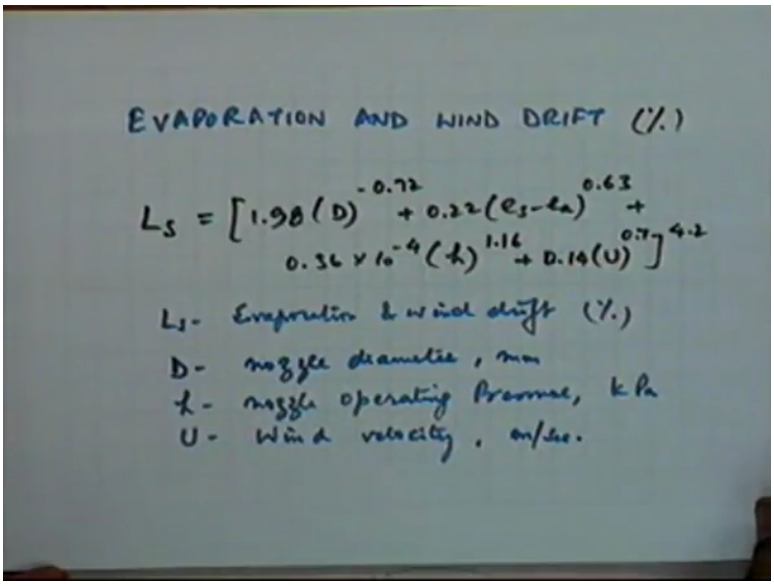

Next we will try to take up a very important aspect which is related to this method of irrigation that is the process of Evaporation And Wind Drift you will find that in this method the evaporation is very significant because of the fact that the surface area which is exposed to evaporation is much larger. In the case of the conventional flooding methods or surface irrigation systems which we have considered so far they also evaporation is there but the evaporation can only take place from the surface of the water and the surface area is much less.

Now you will ask why that is what you want in (())(32:40) no but that yes see what she what she is saying is that in the case of conventional irrigation methods there can be more losses because of the fact that the water is coming through a channel system and there can be convenience loses but those convenience loses we are not comparing we are comparing we are looking at the evaporation losses yes there can be evaporation losses from the channels also that is again in many irrigation system the surface irrigation systems you might use the buried pipes also or you might use the line canal which will reduce the convenience losses.

The evaporation losses can also be reduced if you use the buried pipes which are not running under pressure but that is not very normally normally it is not used is avoided but even even then and that is one segment where you might save some water. What I am trying to compare is that when you have the water flowing in the field at that level if you compare with the water which you are spraying in the field the surface area which is exposed to the evaporation process is much much higher because of the fact that you are having droplets.

The drops which are coming on to the ground now the total area is exposed to the process of evaporation and smaller the drops the higher will be surface area that is the reason when you have the disintegration of the jet into very small particles the level of evaporation will be still higher. But it is a very complicated process because there are many other there are many other processes which are involved because when you are having the sprinkler irrigation system operating even the environment is also changing, the water is coming on to the canopy of the crop which is which will again also induce some other change in environment.

So this process is still not very very crystal clear that what are the various levels of activities which are prevalent in the in this particular zone, what happens to the overall level of activity that is the reason that is also difficult to separate the components like evaporation and the wind drift. The evaporation has been considered through again through some level of analysis, there are relationships which have been put forward and these relationships are either in the form of charts or the equations which are result of regression analysis.

The wind drift is another component which is very important to be considered what do we mean by the wind drift? The wind drift is that as we have seen that wind they starts the distribution pattern of the individual sprinkler. There can be many possibilities one is that if you have a very big area the distortion has taken place, the wind has drifted some of the amount of water from one location which was when the water which was supposed to be within the circle of influence of a particular sprinkler head it has got drifted and gone to a area which is beyond this circle.

But still if you look at the overall field it still might have remained within the field, it has not gone beyond the area under application or area which is to be irrigated that you might say that it is not a loss, it is not a effective loss still the water has remained within the area which was supposed to be irrigated only thing is that displacement has taken place and that displacement is for the all the individual irrigation factors.

In certain cases if there is some nozzle which is at the periphery the water might get drifted and might be lost from the area which was supposed to be irrigated, it might go and be dumped into some other area which was not which you are not even intending to irrigate. So the wind drift effect also has to be considered very carefully that how much is the loss because of the wind drift and how you have to account for it.

All these both these factors they have been put together just from the aspect that they are in many cases is very difficult to separate the two is something like evapotranspiration the way we consider the evapotranspiration. So in this particular case the loss due to evaporation and wind drift is taken in conjunction and we will look at the expression how we can order this particular component, what are the parameters which are what are the elements which are important to be considered for considering this loss and how it has been taken into account.

The vapour pressure is assumed to be having the maximum effect and this component which is the evaporation and wind drift expressed in percentage is given as L s to 1 this is again a equation which is regression equation, it has been calibrated from the known data this is the total equation where L s we have said is evaporation and wind drift and percentage D is the nozzle diameter the nozzle of the sprinkler head the diameter of that in millimetres, small h is the nozzle operating pressure in Kilo Pascal and U is the wind velocity in meters per second.

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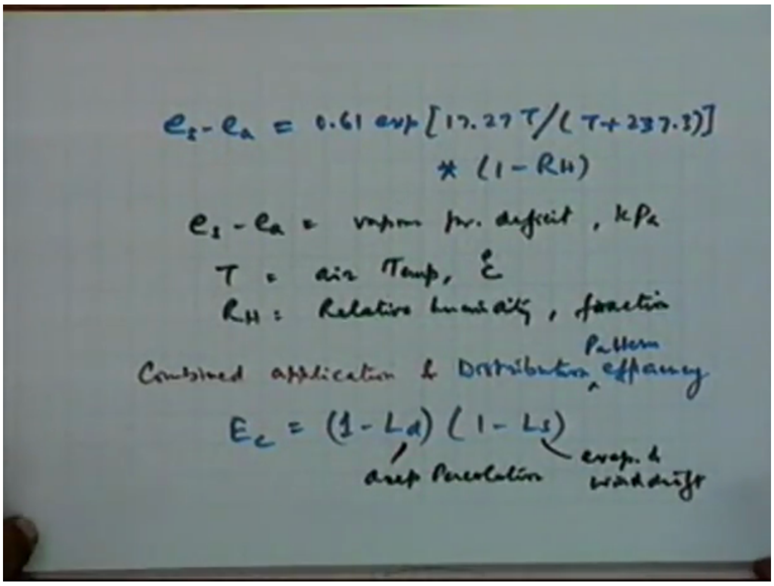

Furthermore the vapour pressure deficit if you have the values of e s and e a available you can directly find out the vapour pressure otherwise relationship has been given which is given the value of the vapour pressure in terms of the temperature and relative humidity which is more often available in the actual situation in most of the places where you have observatory you will have the temperature data and the rate of humidity data and this is the relationship which is used for into 1 minus relative humidity.

So here this vapour pressure deficit is given in Kilo Pascal, T is the air temperature in degrees centigrade and relative humidity has a fraction this is expressed in fraction. So once you have the loss due to evaporation and wind drift then you can easily find out the combined application and distribution efficiency. If we call E c as the combined efficiency which include the application efficiency as the distribution pattern efficiency the way we are defining it that is nothing but the these two elements where L d is the deep percolation expressed as fraction and this is the evaporation and wind drift loss expressed as fraction.

So once you have this that give you the level of efficiency which you can achieve under the varying conditions of evaporation and wind drift.

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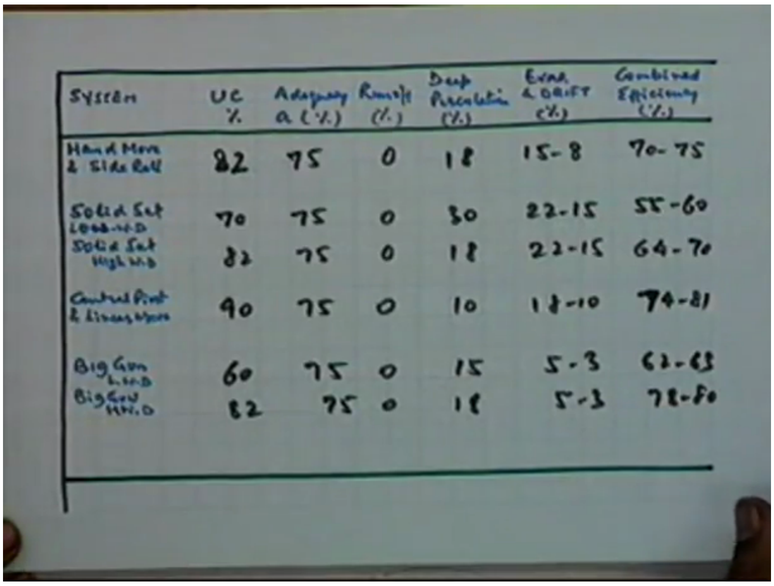

System	UC %	Adequacy a (%)	Runoff (%)	Deep Percolation (%)	Evap & Drift (%)	Combined Efficiency (%)
Hand Move & Side Roll	82	75	0	18	15-8	70-75
Solid Set Low W.D	70	75	0	30	22-15	55-60
Solid Set High W.D	82	75	0	18	22-15	64-70
Central Pivot & Linear Move	90	75	0	10	18-10	74-81
Big Gun L.W.D	60	75	0	15	5-3	62-63
Big Gun H.W.D	82	75	0	18	5-3	78-80

Again there is another relationship which is established for different types of irrigation system which we have in the beginning we had mentioned about them and the system we have said was varying from hand move to side roll system is what we are discussing so far then the solid set system these two systems the solid set system with the low wind design and with the high wind design this we are going to discuss subsequently that how we can incorporate the wind conditions in the design itself.

And there is a method which is used to have enhanced efficiencies by considering a particular way of designing the system. Then the central pivot and the linear move which is the similar system but the way of operation is different and the big gun system again with the low wind design and with the high wind design conditions these values which are expressed here they are again the design values which are achievable they are attainable and they give the combination of these will give you the first level of design which is possible which you should aspire far.

Uniformity coefficient system for this type of system is found to be closer to this which can be achieved with the adequacy level of 75 percent, run off is to be avoided, the deep percolation loses are of the order of around 18 percent and the evaporation and drift losses are of the order of 15 to 8 percent and the combined efficiency which is achievable is of this order of magnitude.

Similarly for the solid set system these are the order of magnitudes of in this particular case the adequacy level has been intentional kept at 75 percent so that you can compare the methods, how the methods are compared for the same level of adequacy for if the level of adequacy will change then your other efficiencies will also accordingly change. So this is deliberately set at 75 percent that if you have the same level of adequacy how the other things are influenced by the different types of method which you might adopt.

You can see the uniformity coefficient is maximum for the central pivot system and the combined efficiency is also quite reasonably good in comparison to the other methods, you can also observe in the case of big gun your evaporation and wind drift losses are minimum because of the fact that the drop sizes are much bigger in the case of big gun that is one thing and then the drift losses since the bigger sizes of crops are there the drift losses will also reduce.

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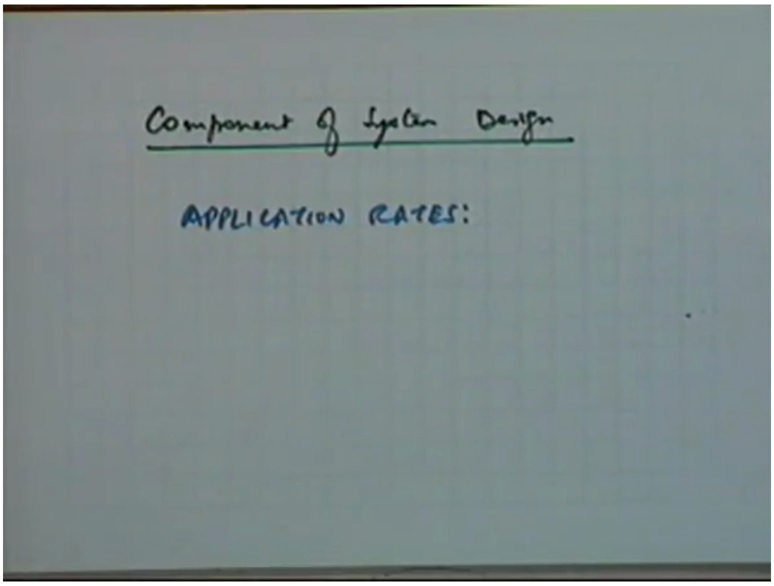

Next we will go to the component of system design we will take up one by one the important components which need to be looked into for the purpose of system design and the first component which is very important to be considered is the application rate or the rate of applications which are required to be considered or required to be used. For example when you look at the rate of application, you have also to consider that the rate of application can be looked at from two angles one is the gross rate of application and the other is the net rate of application.

Because what you are applying through the system has to (())(52:23) further losses also. So all those all those losses which are taking place there might be some water which is not reaching the ground though is getting is leaving the nozzle but it is not reaching the ground because the evaporation some because of the evaporation, some part because of the drift also it might not be reaching.

So when you are looking at the application rates you have to see, we have to use those rates which are to be applied in conjunction with the relevant losses prevailing at that particular location. You cannot you cannot generalize these application rates irrespective of which place you are considering this this system to be installed that is what we will look into along with the other details which are very important when you look at this application rates.

Because it is not just the application rate it has to be considered in conjunction with is that application rate is commence rate with respect to the distribution pattern, what is the pressure because that will be decided by the pressure which is under which the water is being made available. So all these things since they are related we are looking them in conjunction with the other relevant items.

But what I wanted to make certain was that you cannot take the application rates in isolation, it has to be with respect to that local conditions that is the mistake which most of the designers will make, if they do not consider the local losses the losses of evaporation and the wind drift which are very specific to the local areas, okay. So with that we stop here today any question?