Water Management
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Lecture 05
Soil, Water, Plant Relationships (Continued)

I will take you slightly back and try to define those terms which we are defining in general terms. Instead we will try to use some symbols so that later on we will find it easier to take care of these items. So far we have used only the moisture content in the volumetric manner but many a times you will find that the moisture content when you try to make the measurement on the moisture content you will have to do in the laboratory environment and there you will take a sample, dry it in the oven and then find out what is the moisture content.

That is the very usual manner which you find out the moisture content. But again for all practical purposes when you use these moisture contents in the various formulations you will find that the moisture content which you want to convert into that is the volumetric moisture content. So the relationship, what is the relationship between the moisture content which is measured in terms of percentage by weight and the moisture content in percentage by volume? This is the relationship, make use of the bulk density.

This theta f c is the field capacity moisture content in the volumetric terms and that you can find out from the moisture content by weight and using the bulk density along with that. This is a very usual thing. Similarly if you want to know what is the moisture content at the wilting point? This will be the relationship.

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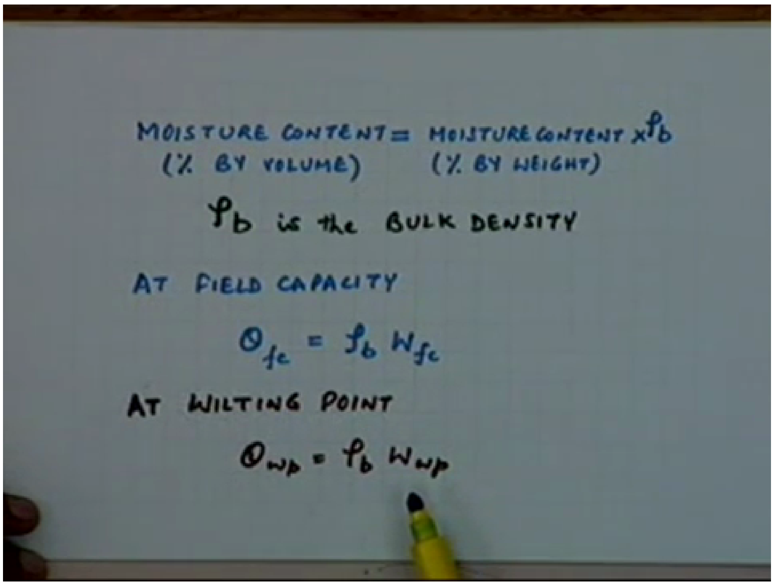

So you can take the samples at the wilting point, take the samples at the field capacity level, find out what is the moisture content in the volumetric terms from the laboratory samples which you have tested and you have found out the moisture content by weight. This is something which we had not dealt with and this is a very useful thing which we will require in the subsequent various items which we will be covering later on. Now look at the total available water which we have defined earlier.

Now the total available water is the difference between the moisture content at the field capacity and the wilting point but we were talking in terms of per metre depth of the soil but whenever you are talking in terms of the total available water it is with respect to a crop.

So when you bring the crop into picture because the crop might not be extracting moisture from a profile which is going very deep. The profile up to which the moisture is extracted by the crop is dependent on the root zone depth. This R D is the root zone depth.

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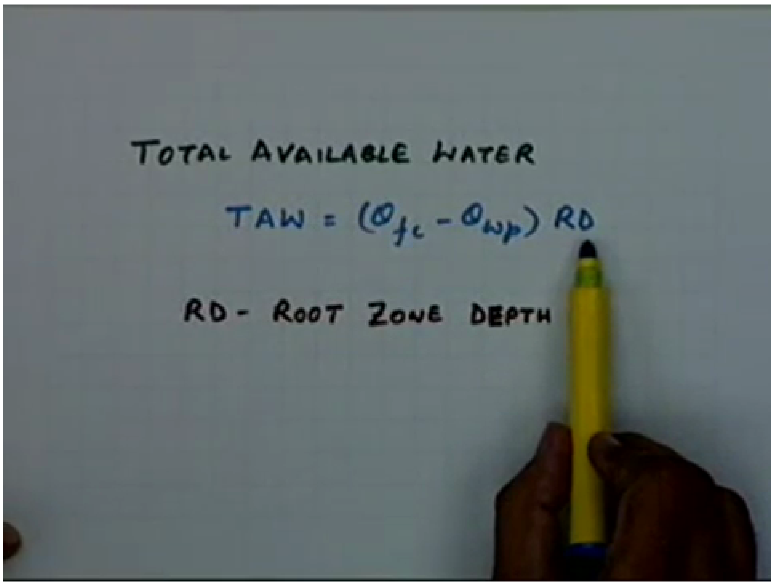

That means the quantity of water which will be the total water which will be available for consumption by the crop will be a function of these two moisture contents, the moisture content at the field capacity and the moisture content at the wilting point and also will be a function of what is the root zone depth? Up to which depth the root system of the crop can extract moisture from? That is what is the root zone depth.

Then next another aspect which we had not discussed and I will like to bring in that aspect here at this juncture we had seen this that if you take the soil profile you have the saturation level, you have the field capacity level and this particular moisture is not available to the crop because it is going to be drained out.

This is the gravitational water, this component from the saturation level to the field capacity level is going to be drained out under the forces of gravity and is not available and the moisture below this level which is between the permanent wilting point and the oven dry soil where you can only extract this moisture by drying it in the experimental setup in the laboratory by putting it in oven. So this moisture is also not available because it is hygroscopic moisture.

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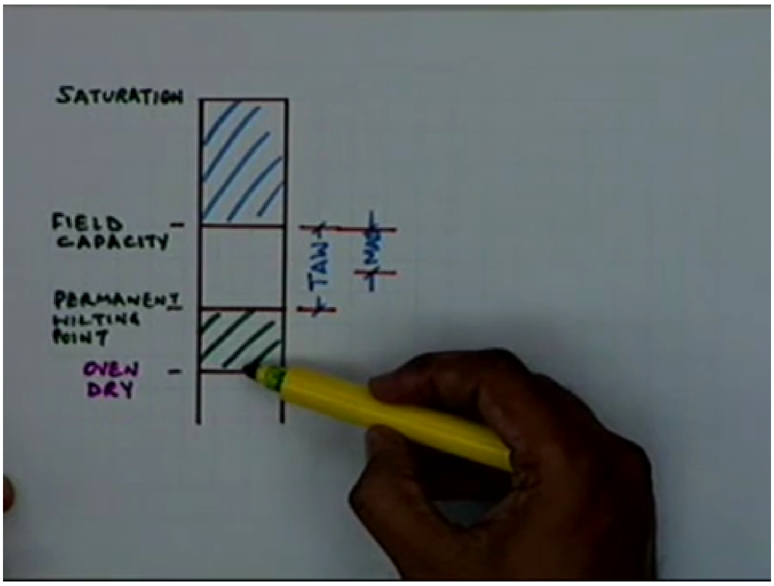

Only this moisture is the total available water which is available for crop growth. But within this also there is another term which is brought in here is the M A D which is the management allowed deficit which is somewhere between the field capacity and the permanent wilting point. Now this management allowed deficit, why it is called deficit?

Because you are creating the deficit in the soil by extracting by letting the water or the moisture leave the soil because of various usages, because of the consumptive use requirements of the crop which we had started with in the last class. Because of that you are letting this deficit be created in this region which is the region between the permanent wilting point and the field capacity.

Since you cannot let the moisture be depleted up to the permanent wilting point, you are letting the moisture only be depleted up to a level which is the level which is defined by the management allowed deficit. From the management aspect, from the management practices what is the level up to which you can let the moisture be reaching in this zone that is what is the management allowed deficit and if we look at this, this is some fraction of the total available water.

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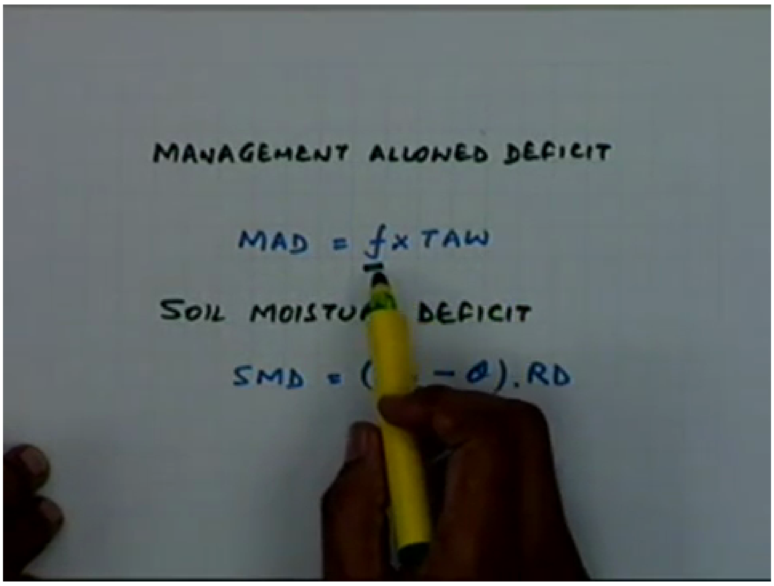

Now this fraction f is a variable thing. This is a very important aspect to be understood that this is not a fixed thing. This will vary with respect to many parameters, with respect to many constraints. The soil constraints, the crop constraints, all those constraints will decide what should be the optimum value of f and that is what the total water management is dealing with.

Now this evaluation of f is the major aspect which has to be looked into which needs to be evaluated and which is a very important aspect from that angle. And the soil moisture deficit is again something which is a term which is used very often. It is expressed in terms of the moistures at the field capacity level and the moisture at some time t.

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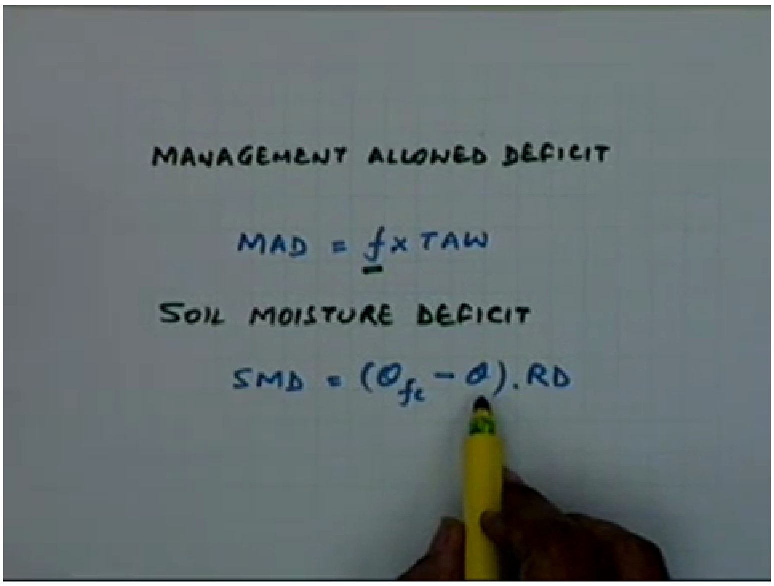

It can be the moisture at any particular instance. So from that angle S M D, the soil moisture deficit is a variable. It can represent the content of the soil at any particular level because many a times you will find that you want to decide, you want to know when to irrigate? Now there is no such fixed time which has to be put as a limit on you or as a constraint on the farmer that he must irrigate at a particular specific moment. It is not necessary.

He might be given interval that within this interval he must irrigate before a particular time which can be decided by this factor f. But at the same time it is not necessary, if there is no constraint on him that he cannot irrigate. Let us say any time before this particular constraint he can decide to irrigate at anytime within a particular range of time. So from that angle it will be very important to find out what is the soil moisture deficit at a particular instance and that will be decided by the moisture content at that instant.

From there you can find out how much is the soil moisture deficit? Why the soil moisture deficit is required? Why the soil moisture deficit is important as far as the farmer is concerned? Because he must know that this is the deficit which has to be satisfied, which has to be cater to in terms of the irrigation water. Now in the last lecture we had started with the consumptive use.

We had started looking at the consumptive use that what are the various items which are playing a role in deciding what is the consumptive use requirements of the crop and we had started looking at these three major items which are the transpiration because of the leaves, the water used for building up of the tissues and the evaporated water from the soil.

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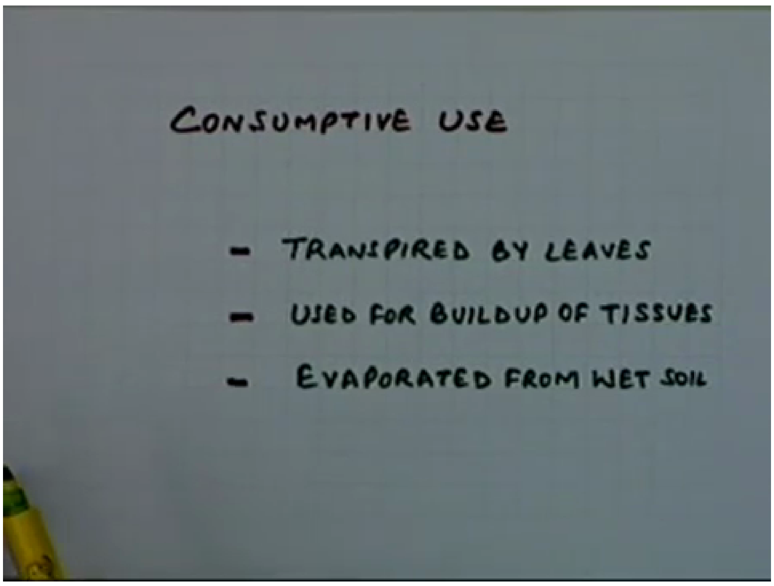

But to give you a complete picture let us look at this segment which is a segment which represents one individual field of a farmer. It is that is the ultimate unit where you can apply all your water balance. So if we apply a water balance to the ultimate unit of the farmer which is one individual field then this representation can be made. Let us try to look at various items of this individual field of the farmer. This is the field of the farmer, this is the ground surface and this is the level which represents the root zone depth.

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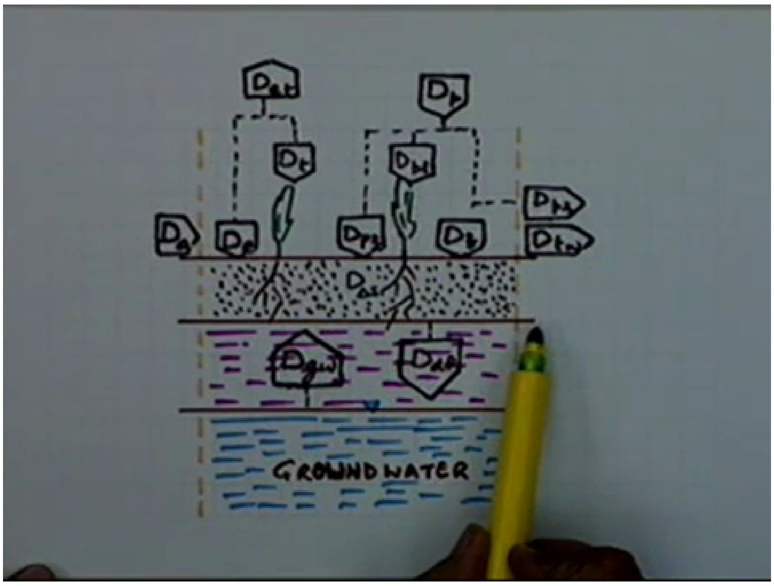

That the roots of these plants are extending up to a particular level and that depth which is being used for extracting the moisture by the root system is the root zone depth. So, on this side this is one boundary. This is a boundary, let us say this is boundary A. You do not want the water to extend beyond this whatsoever water you are applying. You can make this application very (())(14:17) if you do not let any water move beyond this particular zone.

So let us say that this is boundary B which is of your interest as far as the water application is concerned. Then this is another boundary which is boundary C which is depicting the beginning of the field. This vertical boundary is depicting that this is the starting point of the field. Is that clear? And similarly this boundary D depicts the finishing line of the field.

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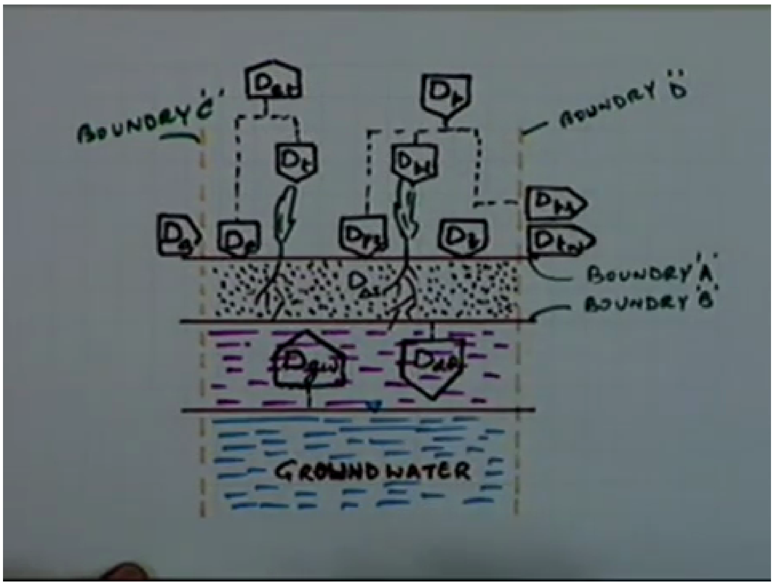

So you have a control volume which is this volume starting from this to this and from here to here, this is the volume which is the volume of the soil in which you want the water balance to be evaluated or to be looked at. And what are the various components of the water balance? There are the components which is, let us say what is the natural component? The natural component is the precipitation.

So D p is the precipitation, the depth of precipitation which is occurring over this field and that precipitation can be further subdivided into various components and one is that some part of this precipitation might be intercepted by the leaves of the plants or the foliage. That intercepted water may not reach the ground surface or ultimately it will be evaporated from the leaves surface and it will be (lo) lost as far as this particular volume is concerned, the volume of our interest.

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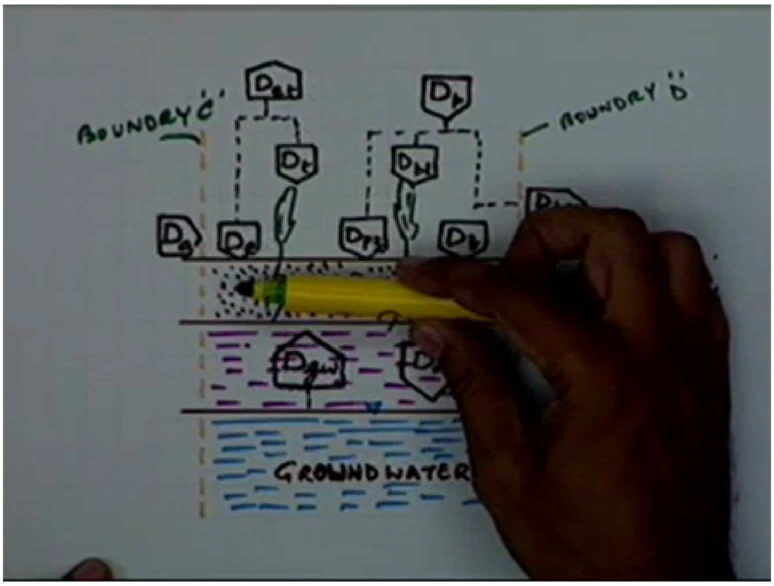

So this is that amount which is being intercepted. Then some part of the precipitation is coming on to the ground surface and is infiltrating into the soil, okay. There is still some part which is going outside this volume of our interest and is lost as far as this volume is concerned. It might be running off the field. So it is lost in the form of surface run off. The precipitation, its sub division and what is retained in the soil that is taken care of, okay.

Then coming to the component which is the lost component is shown the other way around. The evapotranspiration is another component which is active and the evaporation is combined or is composed of two segments. One is the evaporation and the other is transpiration. The transpiration is taking place from the plants and the evaporation is from the soil. So this soil of the field there is some water which is getting evaporated from the soil of this controlled volume and these two things put together they are the evapotranspiration component, okay.

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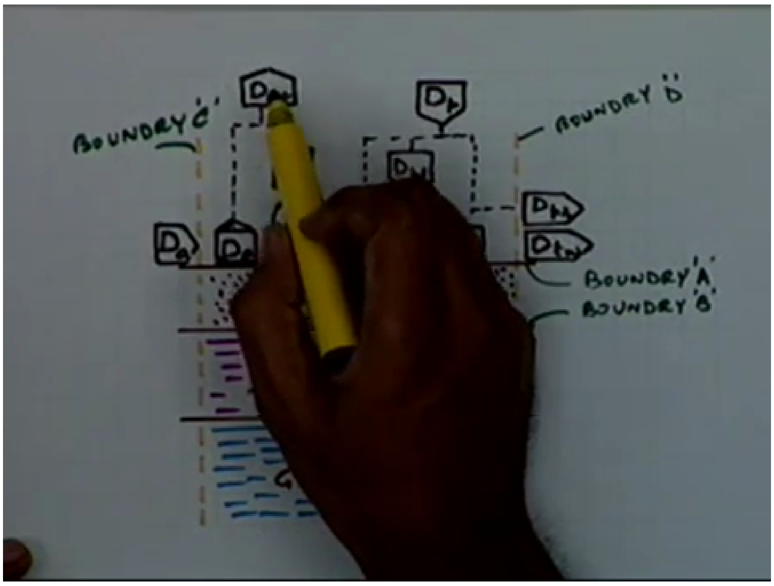

What are the other components if we are interested in the water balance because that is what we are trying to analyse. In all our irrigation designs, all the methods they are going to concentrate on this water balance. How the water balance is being looked into as far as the individual field is concerned? So this component is the component D A which is the irrigation water. You are applying some irrigation water and if it is a surface irrigation system you are applying the irrigation water at this end, at the upstream end.

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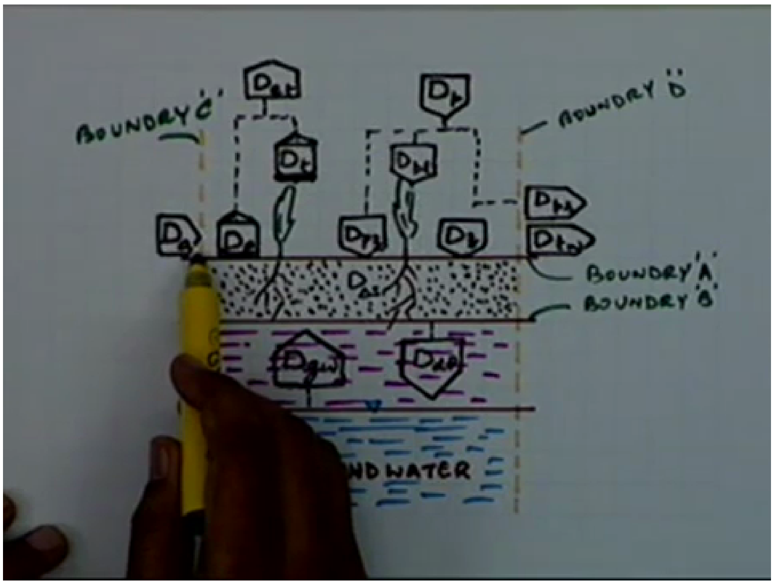

This end you can say that this is the upstream end of the field and this side is the downstream end of the field. The water which you apply through irrigation is the component D A. This D A is travelling over the surface of the field. Some component of this D A goes into the soil which is the component D Z and the remaining part, if there is some surplus water which cannot be, because in general you will find that these fields will be having some slope or it also depends on what is the rate of application.

So if the infiltration which is letting the water go into the soil, the rate of that infiltration is much less, there will be some water which will be travelling downstream and a stage might come that it will be running off the field and there will be the component D t w.

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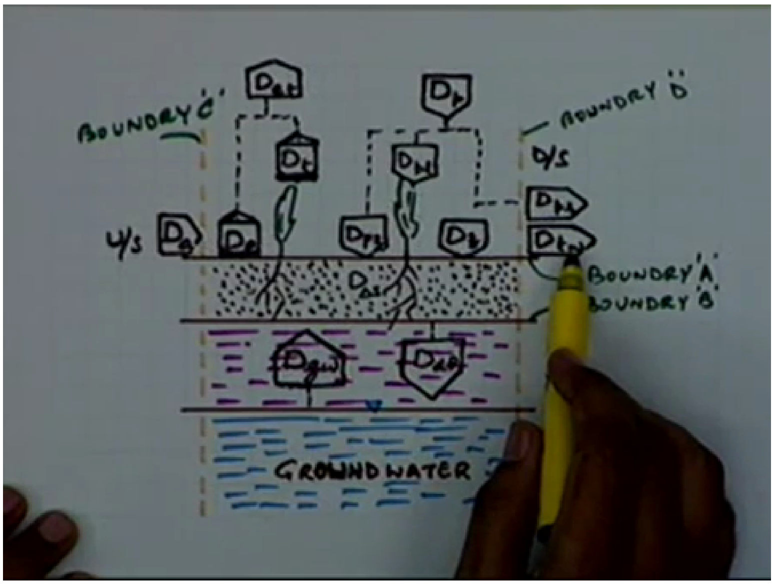

The component which has gone into the soil in the form of infiltrated water that is the component D Z. So this D A is divided into two components. Some part which goes into the soil in the form of infiltration and some part which runs off the field and goes over the surface or beyond the downstream end of the field and is lost as far as this volume is concerned. What are the other components?

We have one more component which is very important. One is the deep percolation, the water which has infiltrated into the soil either because of the precipitation which has been infiltrated into the soil or because of the irrigation water which has been infiltrated into the soil, some moisture will be going down beyond this level, beyond this boundary B. If the moisture content of the soil is such that it has gone beyond the field capacity level, in that situation you will find that the deep percolation can occur.

There will be some portion of the water which will be percolating beyond this zone the boundary B. Similarly there is a chance that depending on where the groundwater table is this level shows the groundwater table.

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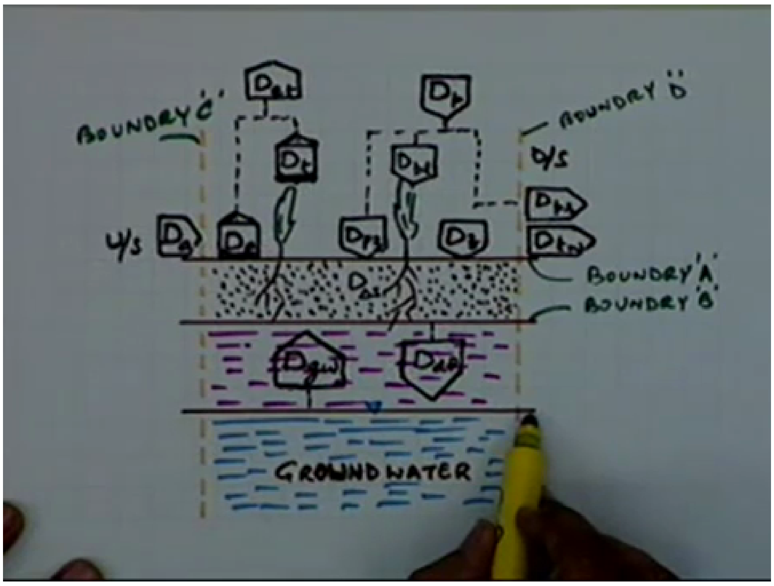

Depending on the groundwater table and depending on the soil properties there can be some water which can be travelling upwards in the form of capillary water and that might reach the area of interest or the volume of this particular soil which is the root zone depth volume and it can contribute to the root zone depth. So this can be a positive contribution as far as the groundwater contribution is concerned.

So this can also be taken into consideration. So this takes care of all the individual components which are active in this field as far as the moisture availability is concerned. Yes?

Student: Sir, the D t w is going out of the field. There can be some volume of water coming into the field from the other fields. Suppose in the very near to the upstream end there is another (())(23:46). So there can be D t w of that component coming into outfield.

What he wants to find out is he is saying that this D t w which is the outflow from this present field, the field in question, it might be contributing to the next field which is the adjoining field but that in this particular case is taken care of by D A because that component is the additional. You cannot separate the two whether it is the irrigation water or whether it is the surplus water which has come from the previous field.

That will account for. As far as the next field is concerned we will take that into D A. So that will be additional component or we will say that this D A might be composed of the irrigation water which has come from the source and the water which has come as a runoff from the previous field. So that can be taken care of. There is no problem, okay. So now the basic question was down to keeping track of this specific volume which is our volume of interest and looking at the various components.

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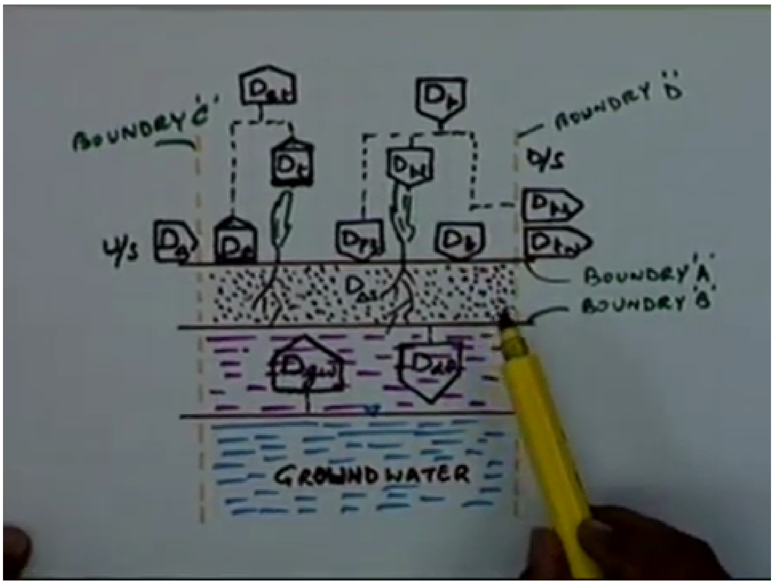

That is what we had started with that the consumptive use will have to be looked at from all those angles. Now you can visualise that the consumptive use can be thought of having two major components. Some part of the consumptive use is taken care of by the natural rainfall and some part of the consumptive use is taken care of or is satisfied by the artificial irrigation if required.

So if the natural rainfall is not in a position to take care of the consumptive use requirements of the crop then you need to supplement that additional water, that need or that demand of the crop through artificial means which is the irrigation component. So the effective rainfall comes in that context. What is the effective rainfall? We have looked at the rainfall that the rainfall, some part of that is taken on to the surface of the leaves which subsequently evaporates but that is a very small component.

Majority of it goes into the soil and depending on the intensity of the rainfall some part of that rainfall might travel off the surface or off the area of our interest which is the field and we will be lost as far as the field is concerned. So whatsoever amount of rainfall is retained in the soil in the zone of our interest that is what is known as the effective rainfall.

Any rainfall which goes as losses either in the form of depopulation or in the form of surface run off, it is lost as far as the crop consumption or the crop requirement is concerned. So the effective rainfall is that component which is retained in the soil for subsequent use by the crop.

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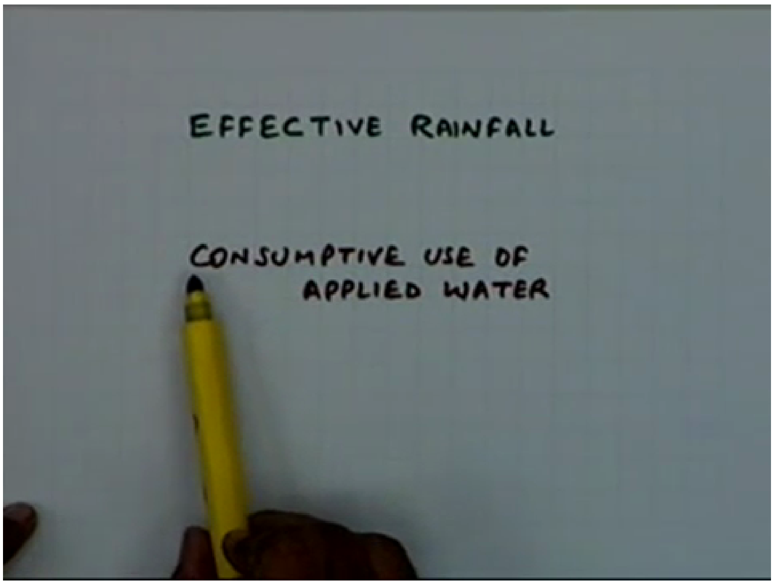

And consequently the term which is called consumptive use of applied water is also defined. The consumptive use of applied water is the requirement of the crop which is in addition or which is satisfied by the natural rainfall that is the consumptive use of the applied water. I think it should be the consumptive use of the applied water is that requirement which is not taken care of by the rainfall.

It is the requirement which has to be taken care of by the artificial means over and above the rainfall contribution which has been experienced on that particular location. Then let us look at the other properties of the rainfall which influence the effectiveness of the rainfall. The one property which influences the effectiveness of the rainfall is its intensity.

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The intensity of rainfall, what do we mean by that? The rainfall can be expressed in the form and in terms of maybe depth per unit time, okay. How much depth you have observed in a unit time that is what gives you the intensity. Now if the intensity is very high which means you are getting a very large depth of rainfall in a very short period then the chances are the drop sizes will be very large. So in that situation if you take this soil structure there are chances that the soil structure will be disturbed.

When the drop size is very large the top layer of the soil maybe around 2 3 centimetres that will be having lot of impact because of these large size of the drops and it will disturb this structure and it will have a tendency to seal these pores with finer particles and subsequently it will reduce the infiltration rate.

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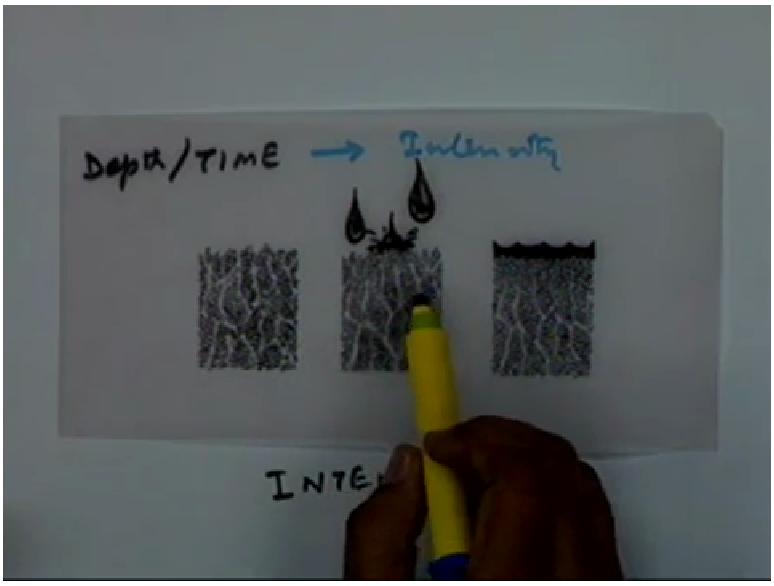

So because of that reduction in the infiltration rate you will find that most of the water will run off the surface and since the infiltration rate is very low the runoff will be exercise and the amount of water which will be stored in the soil will be reduced. So if the intensity of the situation is very high then the total volume which has been experienced on the particular area that might be very high but what has been retained in the soil is going to be very low.

So it is not of much use and moreover this destruction of the top layer and sealing of the pores will also influence the filtration rates and consequently the amount of moisture which is going to be stored into the soil. The other aspect of rainfall is the distribution. So if you look at the distribution, what do we mean by the distribution of rain? The distribution of rain it can be in two aspects. One is the spatial distribution and the other is the temporal distribution.

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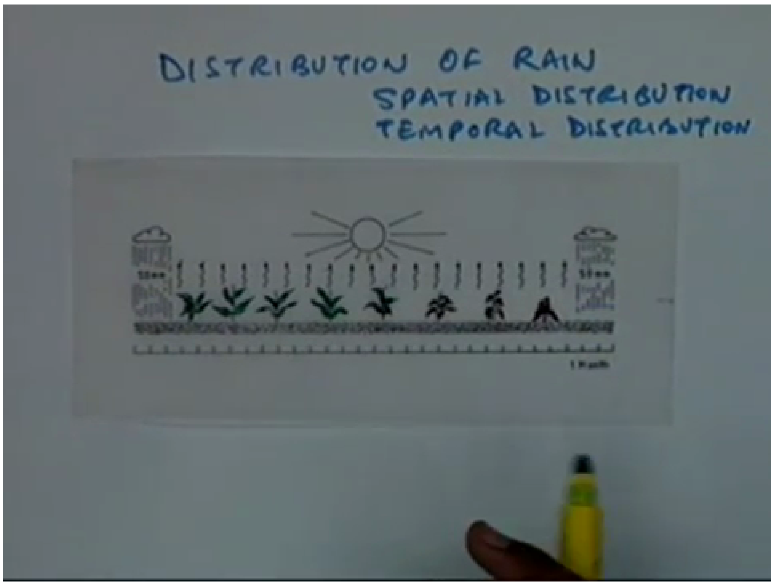

Spatial distribution will be what is the variability of the rainfall intensity in space from one field to another field. If your fields are separated by around few kilometres you might find that in one field you have obtained lot of rainfall, the other filed it might not be having any rainfall observed. But as far as the basic computation is concerned because let me just give you an idea that if this is the total area, this area you observe the rainfall at some points. It is basically a point observation.

So if you have three rain gauge stations which are let us say this is around 10 kilometres apart, this is around 15 kilometres apart, there is lot of distance between them because you cannot install the rain gauge at each location. So whatsoever you observed, in 1 hour you have observed 10 millimetres of rainfall at this location, you have observed 100 millimetres of rainfall at this location and around let us say 30 millimetres at this location.

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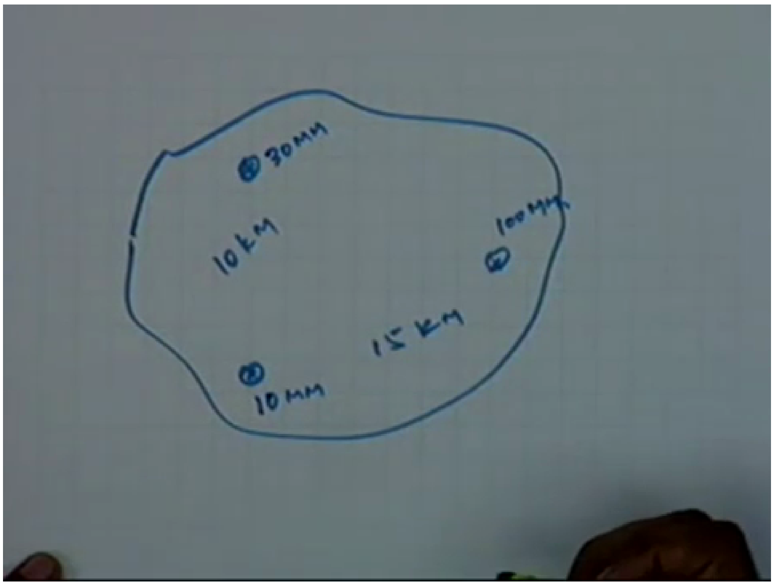

Now you will use some technique by which you will try to find out what is the area which is represented by each of these locations. Is that has to be done. Otherwise you cannot exactly say that up to this particular area this is having some 100 millimetres rainfall and then suddenly it becomes 30. That is not the way one should look at. So what you normally do is that use some (())(34:54) techniques and you try to say that on this total area you might be having a representative rainfall of 50 millimetres, okay.

Or you might divide this into different smaller areas and you can say that this is the subdivision. In this area you are having 100 millimetres rainfall, in this area you are having 30 millimetres rainfall, in this area you are having 10 millimetres rainfall. But in actual practice it is quite likely that this area might be having 80 millimetres whereas your method says that it should be 10 millimetres.

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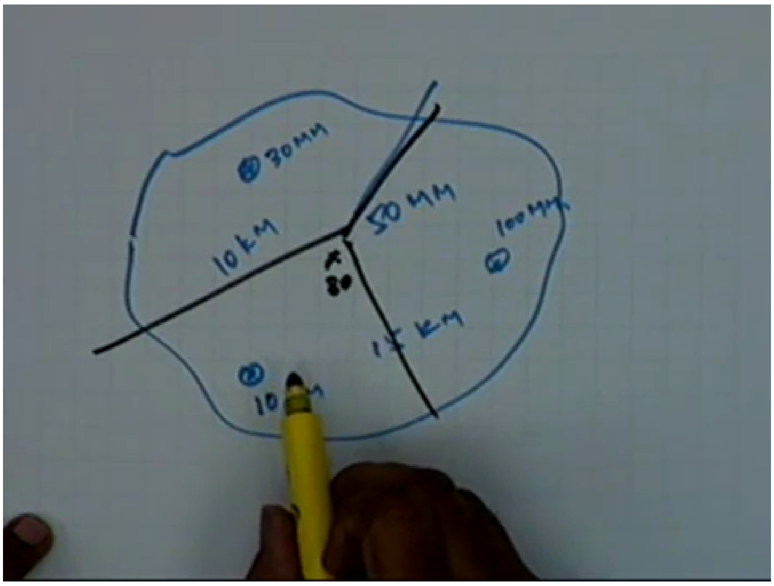

So that is one thing the spatial distribution. That is only the problem in the practical problem in assigning the areas. That is only one problem. What we were discussing was that if let us assume that that problem is not the one which we are concerned with at this juncture. That is the spatial distribution problem which right now we are not. We can assume that there are methods by which you can know how much actually has occurred in that particular location.

But right now we are concerned with the temporal distribution that in time how this rainfall occurs if 100 millimetres occur at one particular time, does it equal into saying that if this 100 millimetres would have occurred at four different timings distributed in time at let us say within one month period.

If the first rain shower had come in the beginning of the month, the second came somewhere after around let us say one week, the third came after two weeks and the fourth came after three weeks, is that total quantity which has been observed, is it equal into having one shower of 100 millimetres at one particular time? That is what is important to look at and that is what is the temporal distribution.

So if we look at from that angle let us say that there is a shower of 50 millimetres which has occurred in the beginning of the month, the next one has occurred only at the end of the month which is of the similar size. But what has happened to the crop? The crop, it has started decaying after a level when the moisture content in the soil has gone below a level which is not tolerable by the crop, maybe something close to the wilting point level.

So that is what is important to realise that if this shower of 50 millimetres and 50 millimetres would have been distributed in time in such a manner that it was spaced in time in such a way that by the time the soil moisture was depleted to an extend that it needed replenishment, another shower was observed and there was some retention of moisture in the soil due to this next shower.

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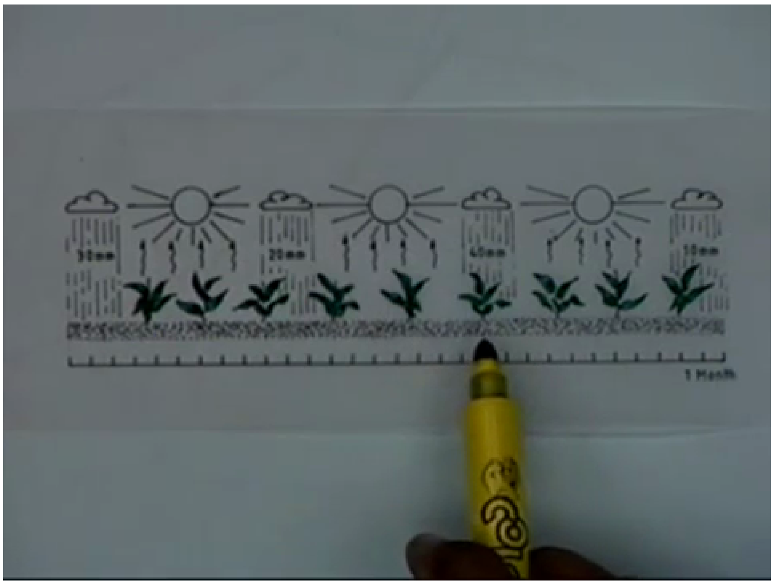

By the time you reached here there was again another shower. So in between the moisture is leaving the soil because of the evapotranspiration activity which is on all along. So if the rainfall is distributed in time then it is very beneficial from the crop production but if it is not distributed in time, if it is concentrated at particular point of time then it might not be that beneficial, okay.

Next we will look at the terms which we have been using in defining our various components of the water balance of the field. We have somewhere mentioned about the effective root zone depth. What do we mean by the effective root zone depth? We have said that it is that depth from which roots of an average mature plant are capable of absorbing soil moisture, okay.

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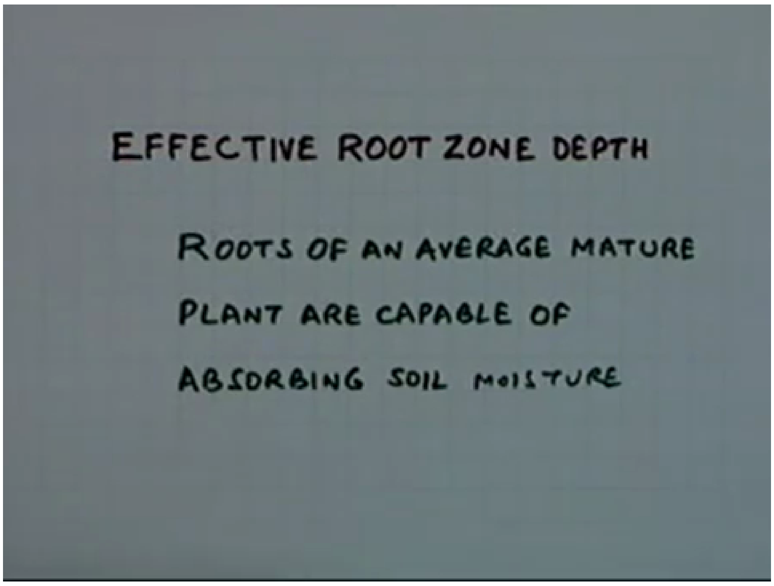

Now the effective root zone depth is characteristic of the crop. Different crops will have different root zone depths and in literature you will find that all these information is readily available. These are some of the crops which I have selected to just show you what can be the variation. You can see here that in the case of potato, the root zone depth is much different than when you compare it with the corn or when you compare it with the wheat.

Not only the depth, even the spread that also varies. So these properties will be very important to know about when you will ultimately decide what will be the spacing between the crops? What should be the depth of or what should be the stream size which you should use? What should be the depth of infiltration which is needed or what should be the infiltration opportunity time?

All these terms I am coining at this juncture which we will learn about later when you will go into the specific designs. All these things are dependent on the root zone depth of the crop you are dealing with.

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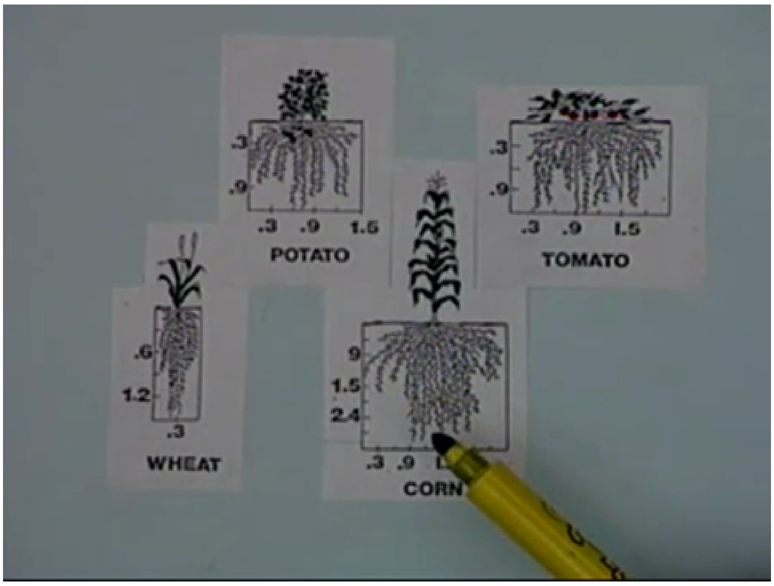

This root zone depth can also vary if you have the soil (charateris) characteristics willing. For example you have deep soils, the root zone depth might be slightly more than the (sha) shallow soils. If you have the shallow soils where the profile of the soil is limited you might get some hard rock after some depth of soil. So in that situation the root zone depth might not be in a position to reach the depth which it will reach if you have the deep soils, okay.

Then they are categorised in terms of shallow rooted. All the crops you can divide them in terms of the roots zone depth in terms of shallow rooted crops, moderately deep rooted crops, deep rooted crops and very deep rooted crops. So these are the (catego) categorisation to just classify the various crops in different subgroups from the point of their root zone depth.

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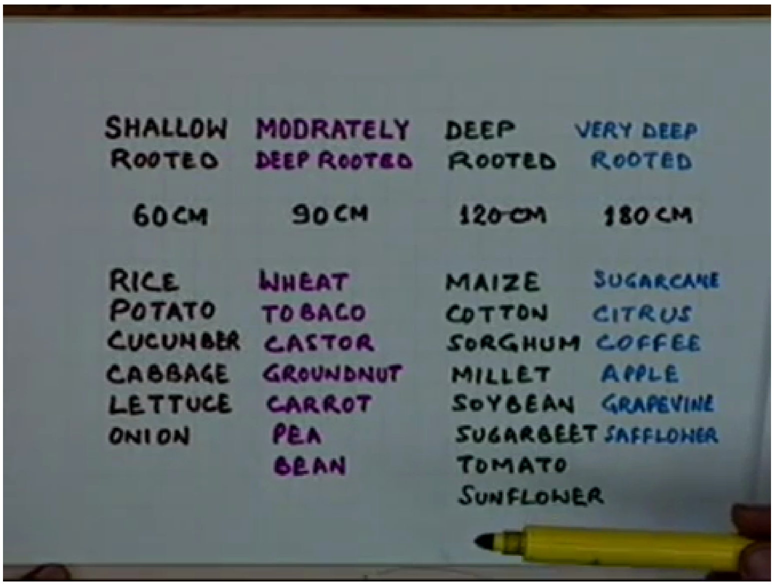

So these are some of the examples. For example this rice, potato, cucumber, cabbage, lettuce, onion they come under the shallow rooted crops group. Whereas the crops like maize, cotton, sorghum, millet, soybean, sugar beet, tomato, sunflower they come into the deep rooted category. Now one more thing that when you say 60 centimetres of depth it is not true that no root of that particular plant will be extended beyond 60 centimetres.

It is just the average depth which is from where majority of the moisture will be extracted. There can be some fake roots which might go beyond that but that is not what decides the root zone depth of the crop. The effective root zone depth is the depth from where majority of the roots will be extracting moisture, okay. Then along with the effective root zone depth there is another aspect which is equally important. What is the moisture extraction pattern? Now what do you mean by moisture extraction pattern?

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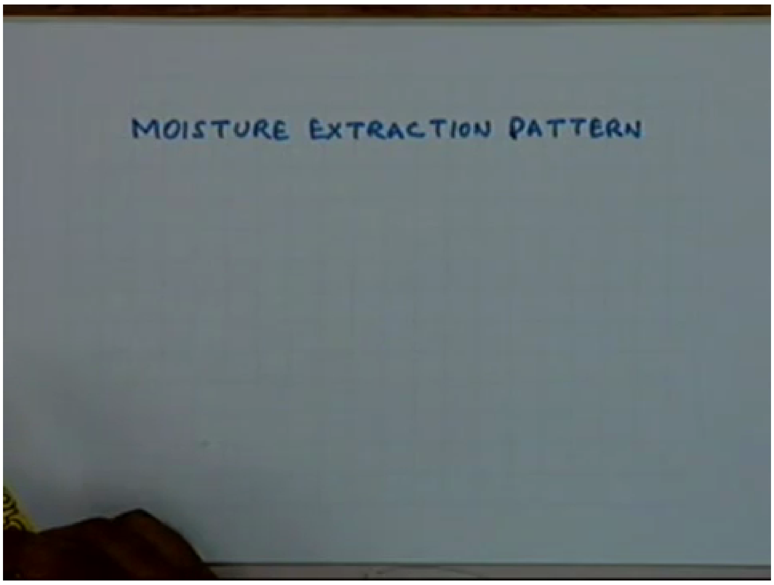

If you try to take any specific crop and look at what is the moisture extraction level from different depths, if you divide the total depth, this is the total root zone depth. Now this depth if I divide into four equal parts and try to evaluate that in each of these layers the top one fourth of the root zone depth, how much of that moisture is being extracted by the root system in comparison to the other subsequent depths? You will find that this is the pattern, this is a very generic pattern which will be prevalent in most of the crops.

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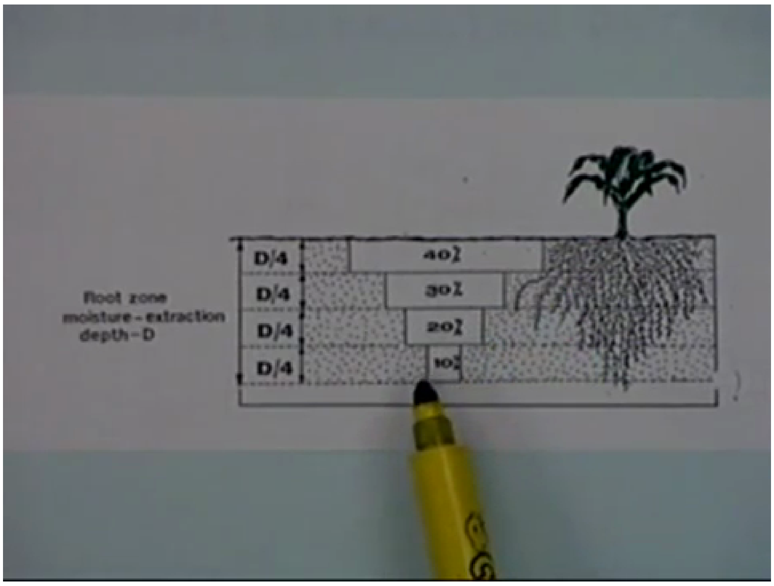

Majority of the moisture will be extracted from the top portion of the soil, the top one fourth of the soil. The percentages can vary but the pattern will be quite similar. And then in the subsequent the lowest depth, this part of the root zone depth might be extracting the minimum moisture.

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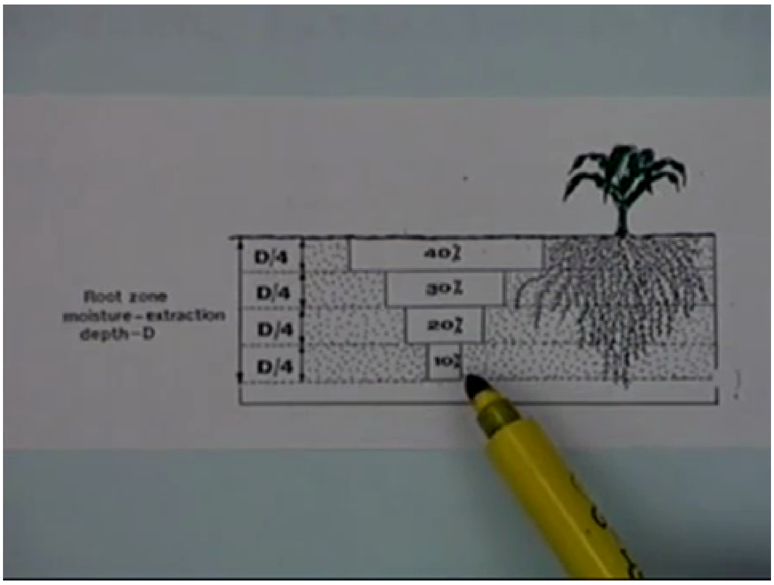

Now this particular knowledge about this pattern is very important because now you look at the deficit. The deficit which we have assumed to be uniform over the total depth is not true. The deficit is different because in the top portion more deficits will be created. As you go down into the root zone depth the deficit will be less in comparison.

So in other words if you are trying to replenish this deficit, the replenishment can also be equal and the replenishment in the deepest portion of the soil maybe the minimum required than at the top portion.

This particular knowledge will be very important when you will be designing the systems and when you will try to allocate the water and when you will look at the various efficiencies, how you can improve upon the efficiency of the irrigation application, there you will find that this aspect of the moisture extraction pattern will be come into the rescue of most of designs and there will be a very important aspect. Any question at this level? Okay then we will stop here.