Water Management
Doctor A. K. Gosain
Department of Civil Engineering
Indian Institute of Technology Delhi
Lecture 04
Soil, Water, Plant Relationships (Continued)

In the last class we were discussing the soil moisture conditions and I had mentioned that there are different soil moisture equilibrium points which are defined. And those points we have defined in the form of field capacity, saturation level and moisture wilting point. Today I will start with the soil moisture classification. The soil moisture which is available in the soil is available in the form of hygroscopic moisture, capillary moisture and gravitational moisture.

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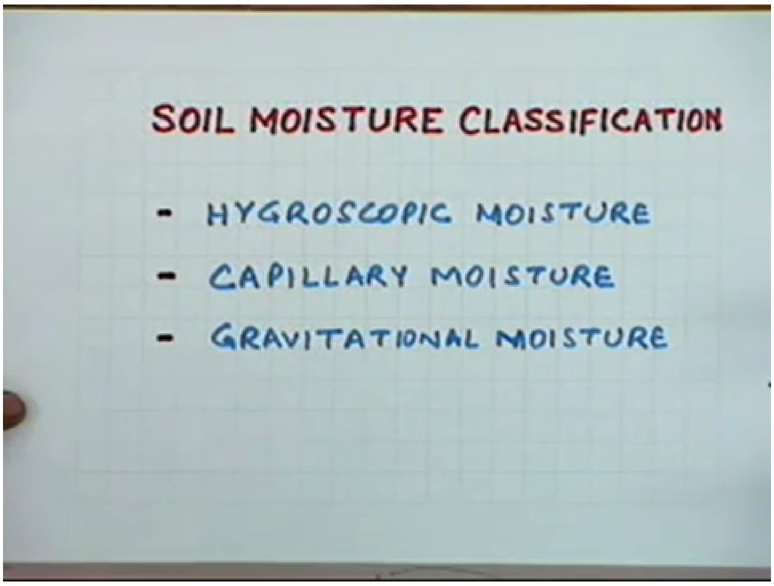

This is only one broad classification which was given by BRIGGS as early as 1897. This classification has been improved upon by many other researchers. They have gone in for different sub classifications of the moisture which is retained in the soil. There are basic forms of moistures can be again further subdivided but for all practical purposes these three classes of moisture availability is the general moisture availability in the soil. Let us try to look at these classes one by one.

What is hygroscopic moisture? What is capillary moisture? And what is gravitational moisture? Because this has its importance in knowing which part of the moisture is really useful to the crops and that is going to decide how much irrigation is needed. So this aspect of soil moisture classification has a lot of importance in the area of irrigation water management. So you have to be very careful and understanding what are the various forms in which the moisture is available.

Let us take a look at a soil particle. If this is a soil particle this soil particle can have the first layer of moisture which is very closely struck to the soil particle. This layer is called the layer of adhesion.

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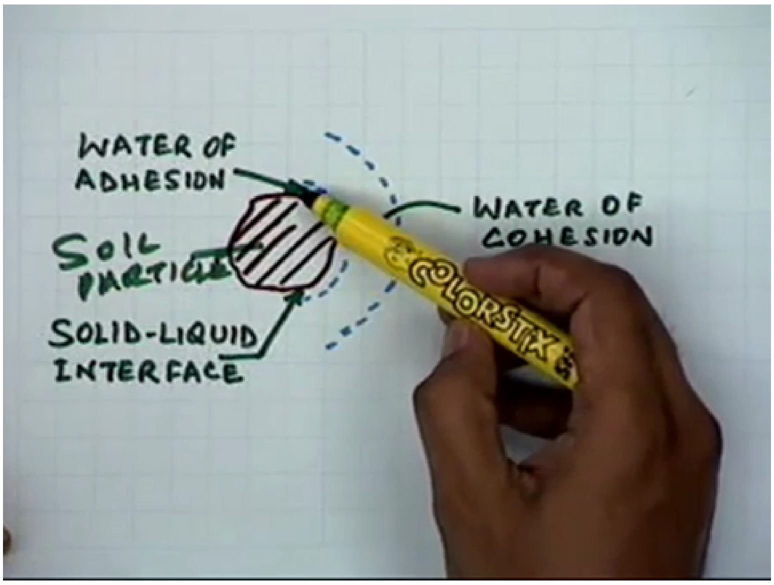

That is what is the moisture which is clung to the soil particles with the adhesive forces, okay. The next layer of moisture, this broad layer of water is the water of cohesion. This layer is the layer which is formed around the soil particle because of the cohesive forces because of the molecular attraction of the water particles and this cohesion will keep on reducing as you go further from the soil particle. So this part basically is the capillary water.

This part which is stuck to the soil particle in the form of thin layer because of the cohesive forces is the capillary water which is available in the soil. And this part which is cling to the soil particles because of the adhesive forces, what is it known as, hygroscopic water. Now this part is I can say that this is hygroscopic water.

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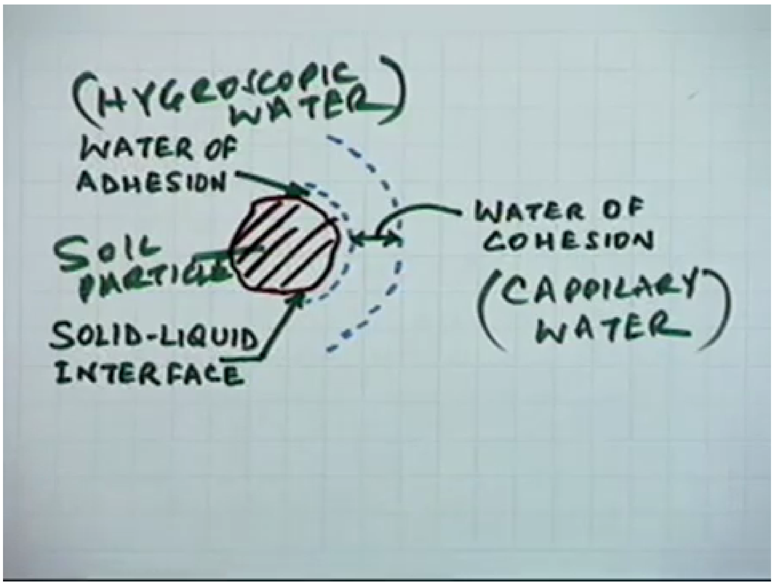

As we had discussed earlier also that both these layers, the thin layer which is the hygroscopic water as well as the capillary water, they are having different soil moisture tension and we had also discussed briefly that what do we mean by soil water tension. The soil water tension is the amount of force which has to be applied on the water molecules to extract them from the pores, okay.

This can be there are different units with which they can be made. It can be made in bars or it can be made with atmospheres. 1 atmosphere is approximately equal to 1033 centimetres of water. So the tension equal into 1033 centimetres of water.

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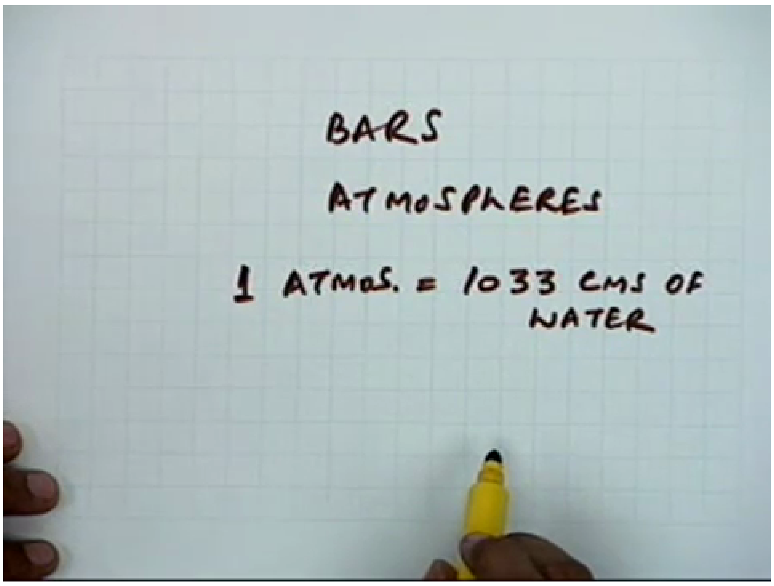

If we represent the tension which is prevalent on the water because of the soil particle at the solid liquid interface which is just the thinnest possible layer of water, they will be approximately at a tension of around 10000 atmospheres. So you can realise you can (visu) visualise that the water which is clinging to the soil particle at the solid liquid interface in the form of the thinnest possible layer that can be as much as 10000 atmospheric tension.

Whereas if you look at this interface which is between the hygroscopic water and the beginning of the capillary water which is this interface, here the tension will be of the order of 31 atmosphere.

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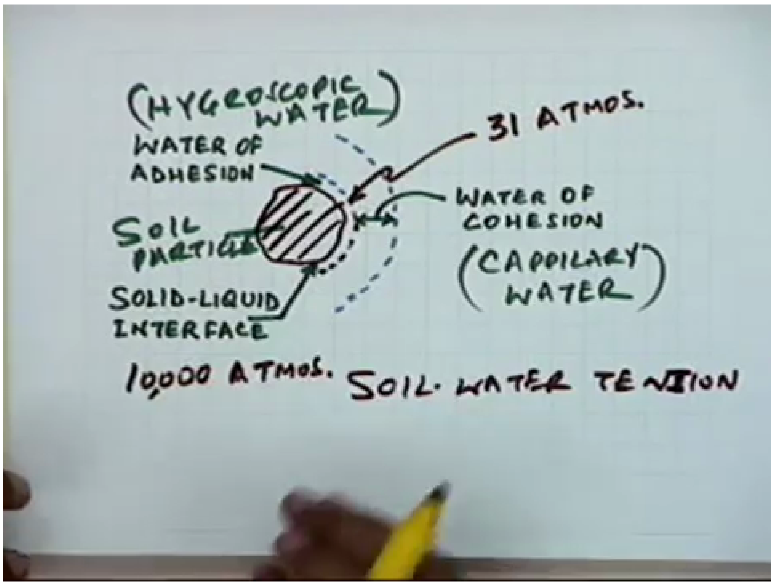

Approximately we are talking in terms of just the average values though it can also vary from soil to soil to a certain extent. But this is the average value which is applicable at this interface. So you can visualise that the tension increases as we go closer to the soil particle and to extract the moisture which is closer to the soil particle you will have to apply more force or the root system has to apply more and more force.

Similarly in this film also in this layer if you look at the variation, the variation can be from 31 atmosphere to the outermost portion which is this part of the layer will be at one third of atmosphere.

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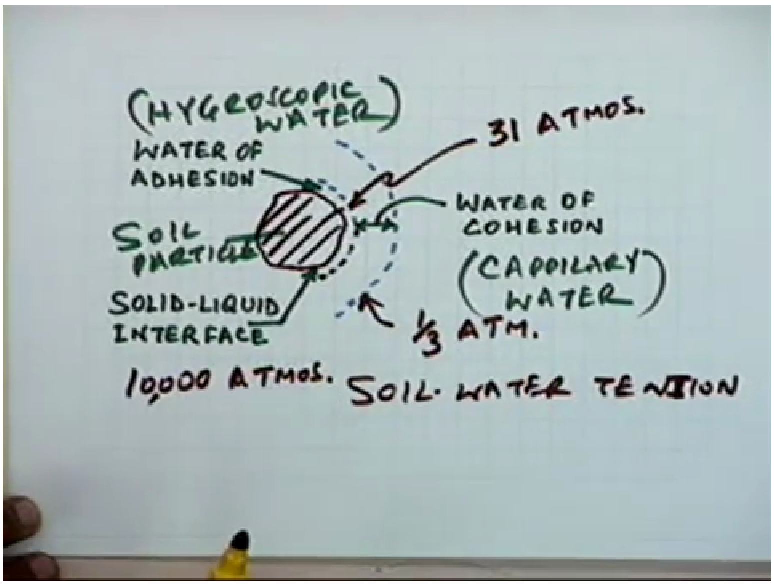

So again there is a variation, there is a gradient of atmospheric tension from this part of the layer to the outermost part. Now in terms of the equilibrium points which we have looked at or which we have defined in the last lecture, the equilibrium points in terms of the wilting point, the field capacity and the saturation level. You can define those points here. This p interface which is between the capillary water and beyond the capillary water any water which will be available on this side of the layer that can be drained out under the forces of gravity.

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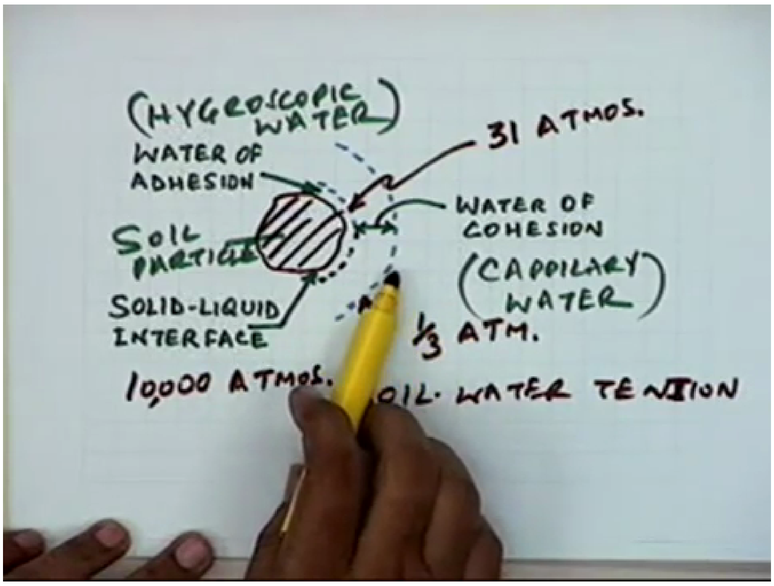

So anything on this side of the layer will be the gravitational water. So all this water which is available it might be able to have a thicker layer for a moment if more moisture is available.

But that layer will reduce to this size of the layer after sometime because of the natural drainage under the forces of gravity. So you can also say that this part on this side of the layer you have water which is known as gravitational water, okay.

So this level where you have one third atmospheric tension this will be the field capacity level. It is what is the field capacity level whereas this level where you have a tension of 31 atmospheric will be called as permanent wilting point. And anything beyond this field capacity level will be approaching the saturation stage. So when there are no pores occupied by the air then there will be the saturation stage.

So that is what in terms of with respect to one soil particle you can look at what it means. So there are many soil particles which are arranged in a soil and these are the capillaries.

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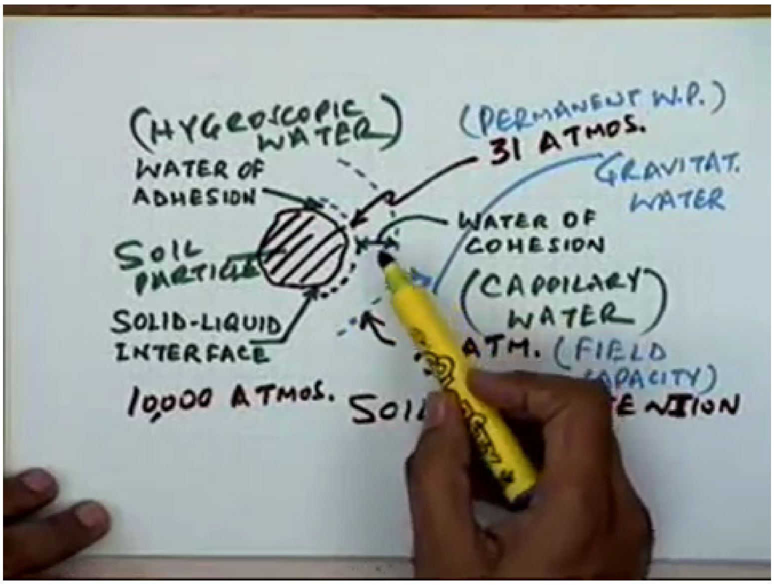

Now the amount of water which will be available within the soil would be a function of all these processes plus the size of the capillaries plus their arrangement, the way they are arranged, all those things are going to decide how the water is going to be available in the soil and that will in turn decide how it is going to be used or how much of that will be used. Let us look at the same thing in another manner.

Now instead of one soil particle I have drawn a column of soil and in that column I am trying to differentiate or I am trying to look at only the moisture portion. This part it is still extending.

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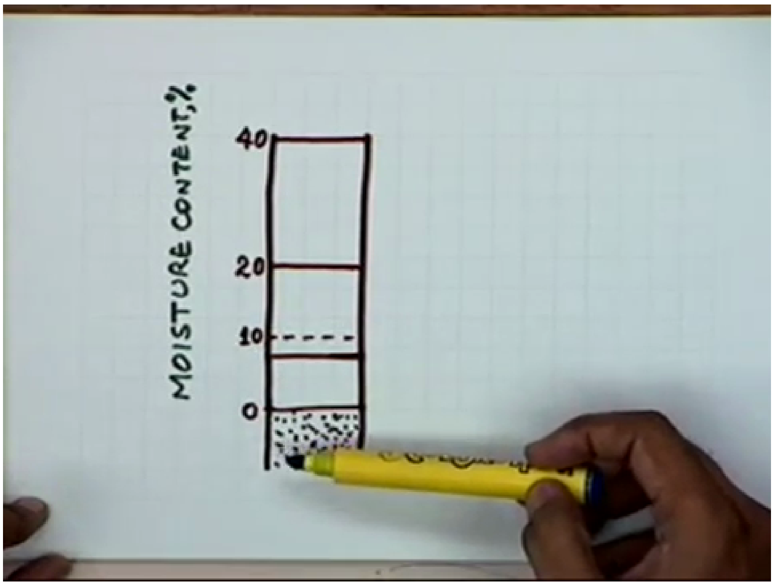

The amount of soil particles available, that I am not going to concentrate. So if you look at only the moisture component and you express that in terms of percentage this is again for a typical soil. These percentages are not fixed numbers. Then if you look at all these different classes of soil, this part of the soil which is between 0 percent to 10 percent will be or maybe less than 10 percent I will say, this part between this and this level this is hygroscopic moisture. This is the hygroscopic water.

This part as we have seen that this is the one which is attached to the soil particles because of the adhesive forces and is not available to the crops for their production. Whereas this part is the capillary water and this amount is termed as gravitational water.

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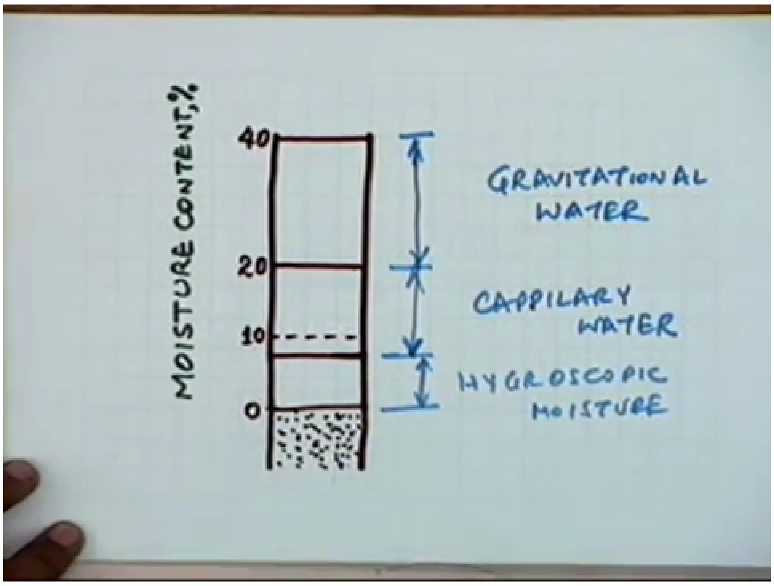

So looking at the proportions you will find that in general the gravitational water is the maximum. That is the water which can be removed from the soil by the forces of gravity. If you let the soil drain under the forces of gravity it will drain out this surplus water which is the gravitational water out of the soil. So this is basically as far as the crop production is concerned this water is superfluous. We can term this water as superfluous water.

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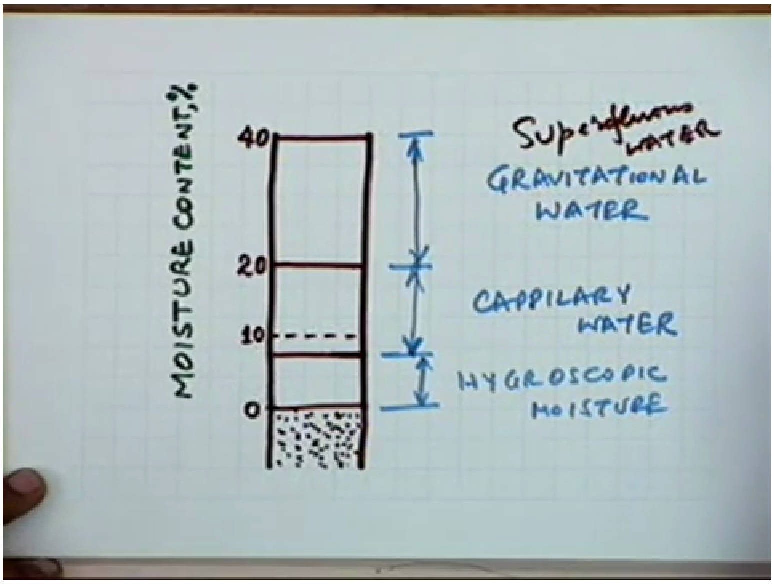

It is not of any use as far as the crop production is concerned because it cannot be retained in the soil. The gravitational water you will normally find under the circumstances when you have a very heavy rain and because of that rain all the pore spaces have been filled up with the water. It has attained a state which is the state of saturation. So saturation level will be somewhere here. This you can say that this is the saturation level. So this is the point where you will call the soil to be saturated.

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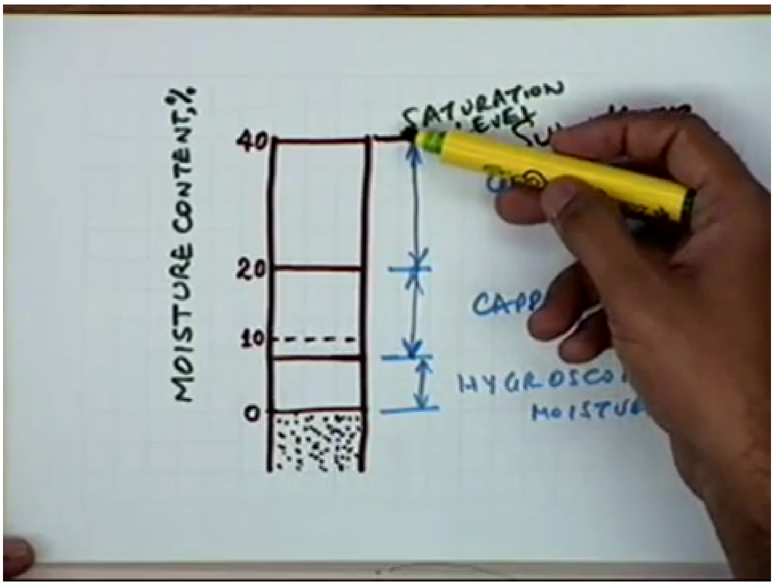

And once all the water which is surplus water or which can be drained out has been drained out which is quite a big quantity of water then you will attain the next level which is the field capacity level. So this level will correspond to the field capacity level where all the moistures with its superfluous has been drained out and the moisture which is available now is the one which is held because of the capillary forces and of course because of the hygroscopic forces also.

This next level is the level where you will have the wilting point but that level is a level slightly within the capillary zone itself. This whole is capillary water but a part of capillary water which is very close to the interface between the hygroscopic and the capillary that cannot be extracted by the root system.

So, the root system fails to extract any further water beyond a particular level in a capillary zone and that level is somewhere above this level of the hygroscopic water. That level is known as the wilting point. So these three moisture equilibrium points which we have defined earlier these have this physical significance when you look at a soil column.

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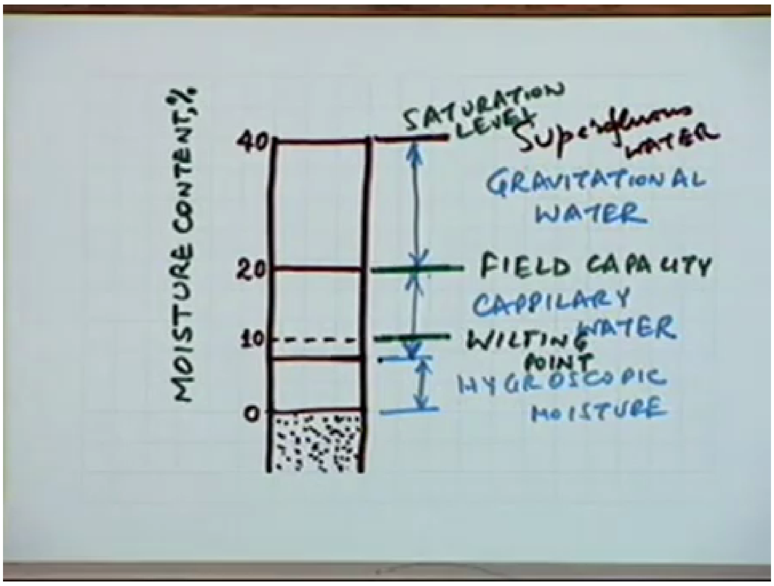

Yesterday somebody was asking a question on these aspects. What was that question?

Student: Sir, why the plant cannot use the water below the wilting point?

Yes, you wanted to know why the plants cannot use the water below the wilting point and I had told you that it is basically a tug of war between the root system and the soil particles. The root system can exert a force on the water to extract that moisture and if the force is more than what is being exerted by the soil particles then it can extract that atmosphere. But if the force is less than what the soil particles are exerting then it is not in a position to extract the moisture.

So that is a function of the crop types. There are some crops which have root systems which are more forceful and they can extract more moisture, they can extract at a level which is much more than another crop which is quite delicate or which is more sensitive crop. So wilting point from that angle there was another question that somebody wanted to know, is the wilting point a fixed thing or it varies with the crops? So from that angle it has to vary with the crop.

A crop which is more rugged will have a wilting point which is lower than the wilting point of another crop which is more sensitive or which is more delicate. So when you come to the selection of the crops, later on we will take that into consideration and from that angle the wilting point has a variable level for different crops. Now after this let me show you the variation of all these different moisture equilibrium points when we go from one soil to another soil.

Now this is a depiction which is a plot between the water content expressed in centimetres per metre, depth of soil versus different soils and the soils vary from sand, fine sand, sandy loam, fine sandy loam, loam, silt loam, light clay loam, clay loam and clay. So you can say that this part is the sandy soils or the coarse soils, this is represented by the medium soils and the later portion is the clay soils which are fine soils or heavy soils.

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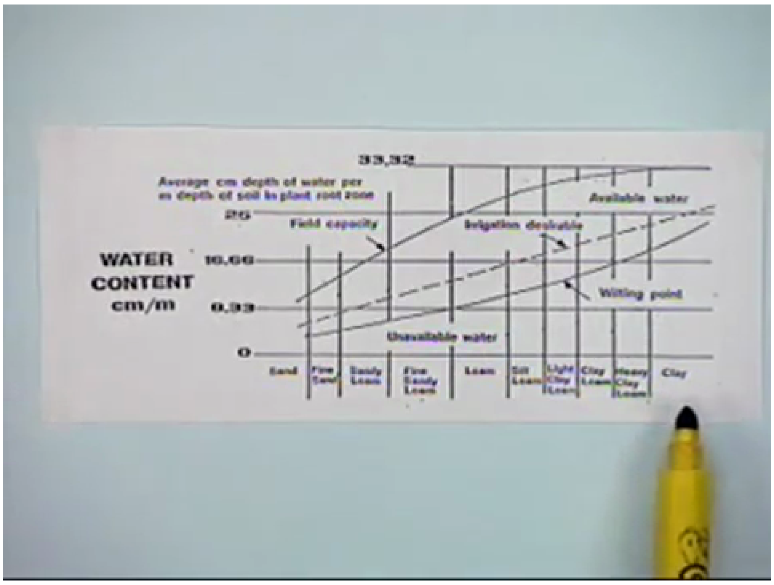

And the plot is this is the field capacity. How the field capacity changes? It is now we are looking at another aspect that within different soils what is the variation of these three equilibrium points? So far we have seen the three equilibrium points in generality in terms of what do we understand by them? But now I am trying to depict what is the variation between different soils when we look at these equilibrium points specifically the field capacity and the wilting point because these are the two limits which define what is the available moisture content.

So if you look at the field capacity, the field capacity level for sandy soils or for the light soils is very low in comparison to the soils which are heavy soils.

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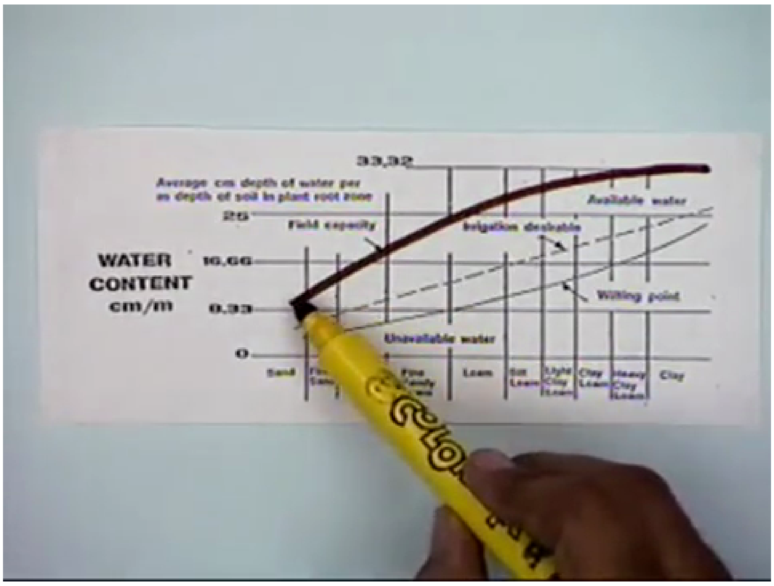

That means if you look at the amount of water available at the field capacity level in these soils is much less. It increases with the fact that as the soil becomes more and more clay or if the clay contents are more it will have the tendency to have more absorption at the field capacity level. The amount of water available at the field capacity level in absolute terms is much higher. But does that mean that the clay soils are more useful as far as the crop production is concerned? No, it is not necessary.

We will try to look at why it is not necessary. If you plot the wilting point, how the wilting point varies when we go from one soil to another soil? And if we look at the range of soils which are available in nature you will find that this is the variation of the wilting point.

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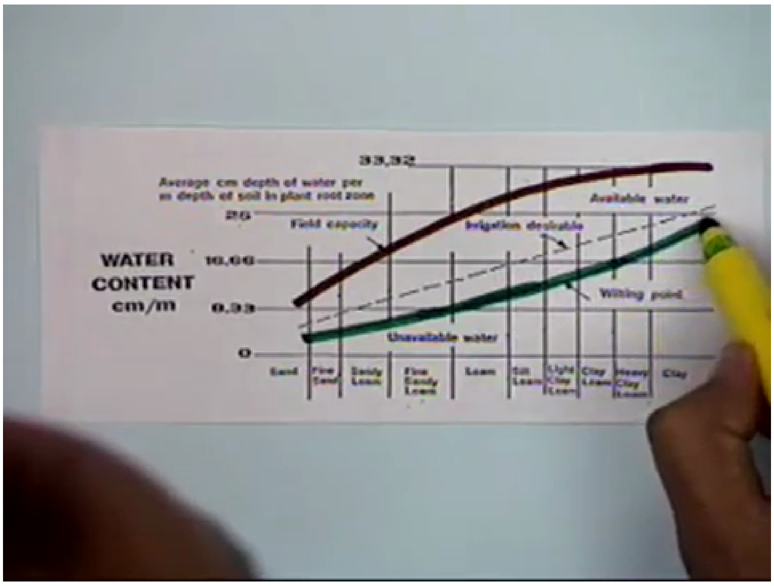

It has a similar trend as of the field capacity. The field capacity also was having upward trend whereas in the case of wilting point the shape is slightly different and that is what is very important aspect that is increasing of course when we go from the course soils to the fine soils. What does that mean? It means that in the case of fine soils though the amount of moisture which is available at the field capacity level is very high at the same time the amount of moisture at which the wilting point takes place or the wilting point occurs is also very high.

So in other words you can say that though in the clay soils there will be lot of moisture available in the soil but still it will not be available to the crop. The crop will not be in a position to extract that moisture from the soil. Whereas in comparison in the case of light soils you will have a low value of moisture availability at the field capacity level and the wilting point also takes place at a level which is very low.

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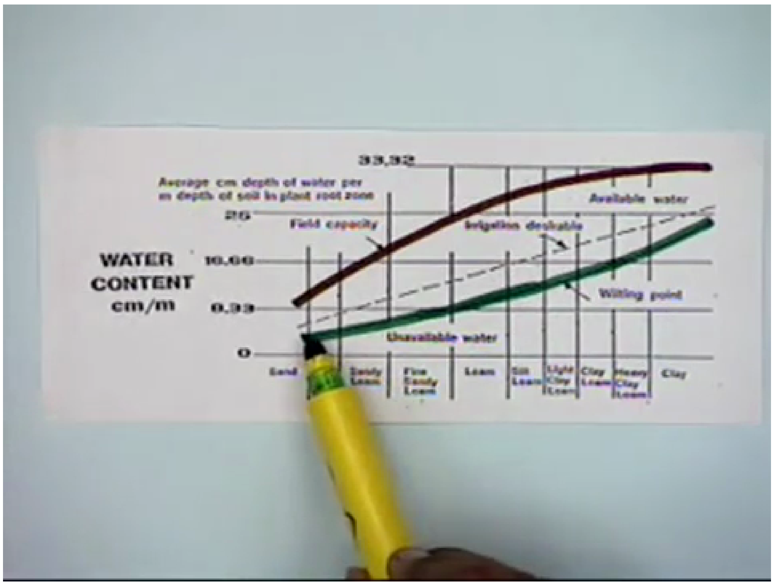

So in terms of the moisture availability, what is the moisture availability as far as the crop production is concerned? I can say the available moisture content, what is that? That is the difference between the two levels. So if I want to know what is the available moisture content at this point where I have a loamy soil it will be nothing but it will be the difference between the field capacity level and the wilting point level for that soil.

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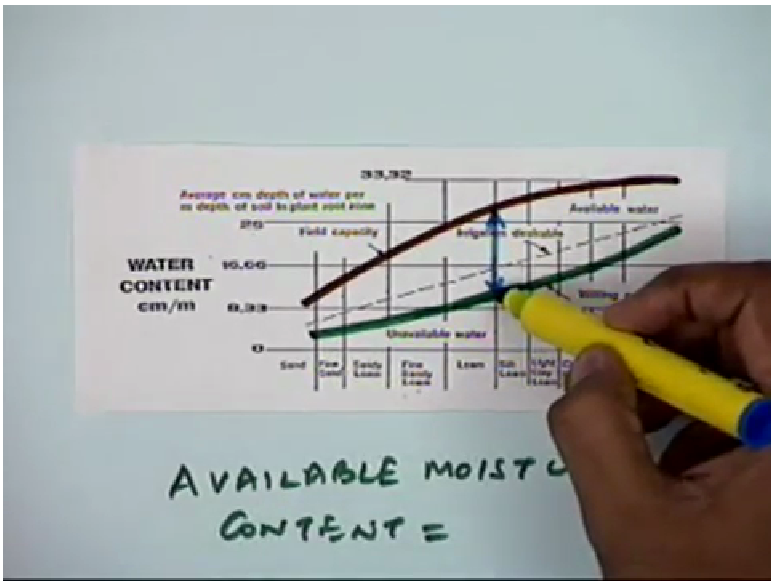

So this difference is what is the available moisture content which is the field capacity moisture content minus the moisture content at the wilting point.

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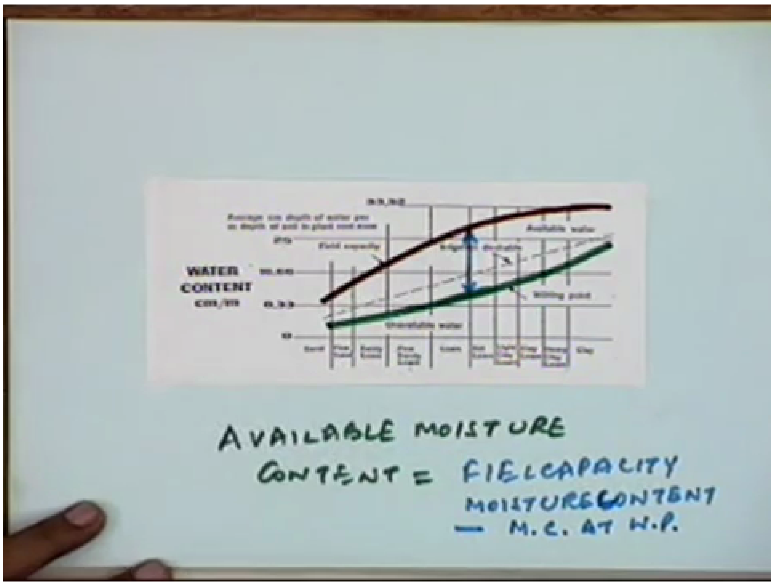

Now if you compare for any other soil for example if we take this soil which is the sandy soil or if we take the clay soil, in both these cases the moisture availability is much lower. That is where the convex and concave shape of these two curves they are beneficial at least to ensure that if the soil is of this type you will have more available moisture. You are looking at this dotted line also. What does that signifies?

This dotted line which is this line, this signifies that what is the time or what is the level at which the irrigation is desirable because if you let this moisture content of the soil go below this line then it is going to have a permanent effect on the crop yield.

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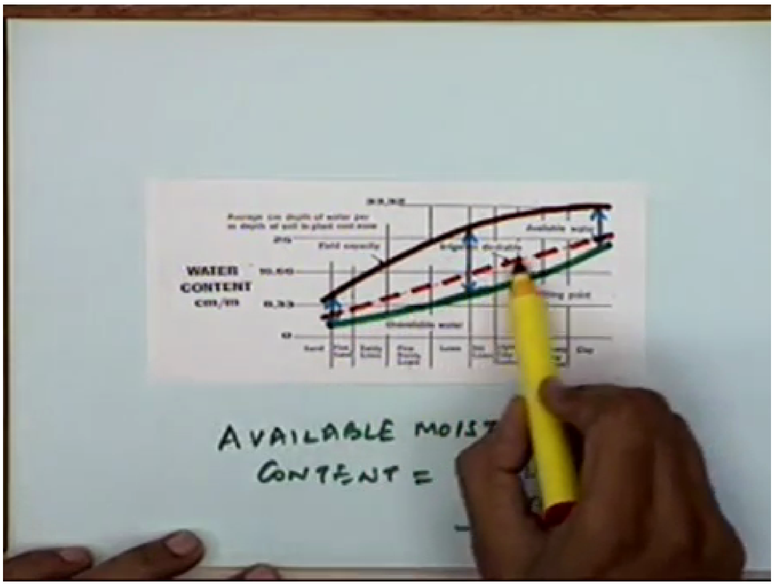

It will deteriorate the crop yield to some extent. The more you go closer to the wilting point it will have more and more harmful effects on the yield. The yield will be reduced. So as far as the irrigation is concerned you must provide the irrigation, you must supply the irrigation water much before the wilting point and that level also changes with the soil types. And this is the dotted line is the line which depicts the desirability of irrigation in the soil. Any question?

Student: (())(33:49)

You want to know whether we can interfere in the soil and change the wilting point. The wilting point as we have already discussed is not only a function of a soil, it is also a function of the crop. So you can change the wilting point by changing the crop type. If you know that your that particular area is the irrigation water is not assured, you are not having any guarantee that you will get the water whenever it will be desired then in that case you might not be willing to take risk.

You might decide on some crop which is more rugged which can sustain the deficit in the availability of moisture, okay. If you know that it is not going to have any problem to get water whenever you desire then you can go in for crops which are more delicate, which might be able to fetch you more money. As a farmer you will look at how much money you can get.

So there are some crops which are more useful crops from the point of your getting money and you might go in for those crops.

But at the same time those crops might be more delicate because in case you do not get the water, you might lose them altogether. So from those angles this is the management decision and that is what we are going to take a look at how precisely we should decide on those aspects. Later in the course we will come to those points also where we will look at that what are the characteristics of the crop? What are the characteristics of the soil?

How we can put them together and how we can match their demands? And we also look at the supply availability. What is the surety of the supply availability and how much deficit can be expected? Knowing all those details that is where we are going to look at the management tools. What can be done? What are the possible options available with us? Now this is another depiction of the same thing but in terms of the soil moisture tension for different soils.

The three soils which have been picked up, this is the experimental data which has been observed in the field and then plotted with respect to the moisture content and the soil moisture tension in bars. This top line with the crosses is the one from silty clay loam. This is the silty clay loam and the next one is the loamy soil, the silty loam and the third one is the sandy soil, this is the sandy loam.

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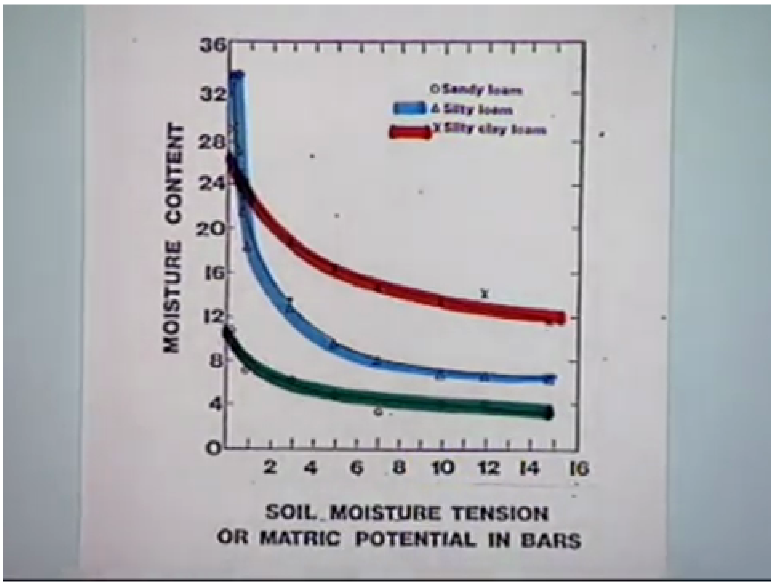

So in all the three cases the loam has been taken so that the variation is not very much. Within the loam you will have one with the higher sand contents, one with having predominant silty contents and the one which is having the clay contents. Within those three you can see here that again the same thing is depicted. You had seen that this level is which level? This is the saturation level where you have the soil moisture tension almost nil, negligible.

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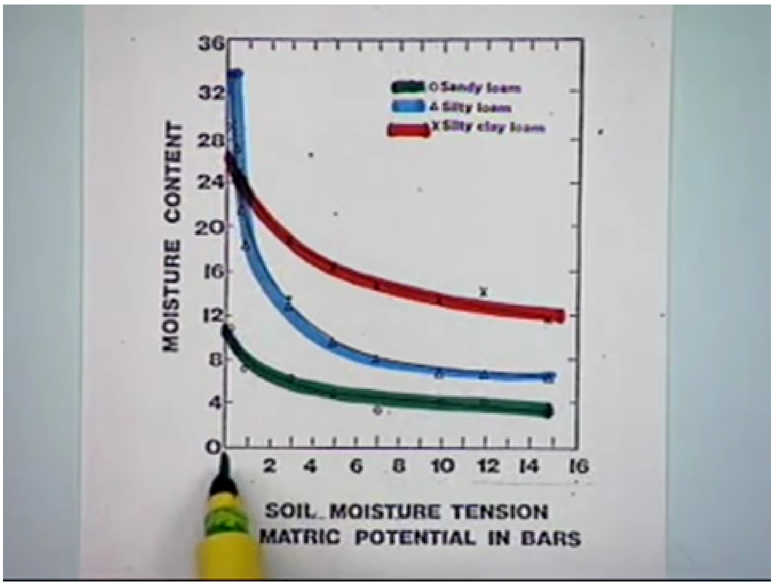

So, that level is the saturation level. Then after that you have one third will be somewhere here, very close to that. That will be somewhere here. It will be the field capacity level. It means immediately after the saturation level when the soil moisture tension goes to around one third bars because bars and atmospheres are quite close, difference is very small. In the case of bars it is 1026 centimetres of water tension.

So from this point onwards when you reach somewhere around 15 atmosphere, that is a place when you are quite close to the wilting point. It is after this the wilting point will approach.

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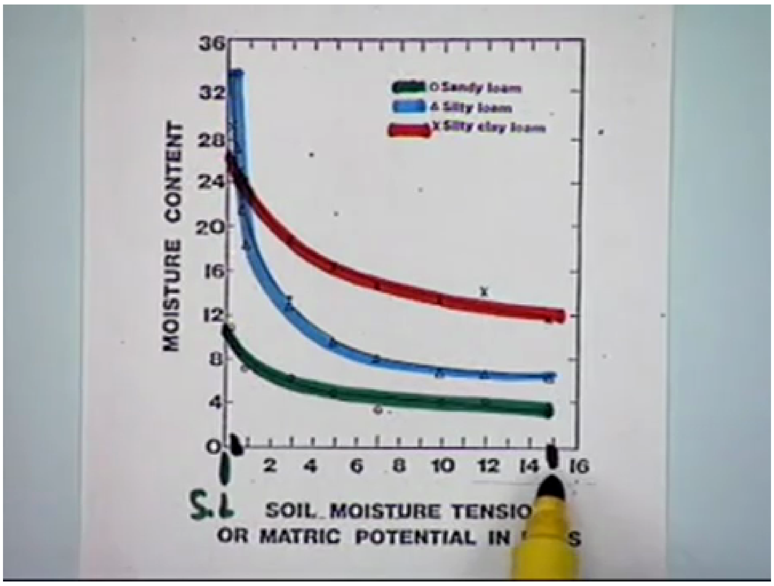

So this level you are not waiting till you approach the moisture tension beyond let us say somewhere this level. This is the area which is important area. This is the area where you have to see that what is the moisture content available.

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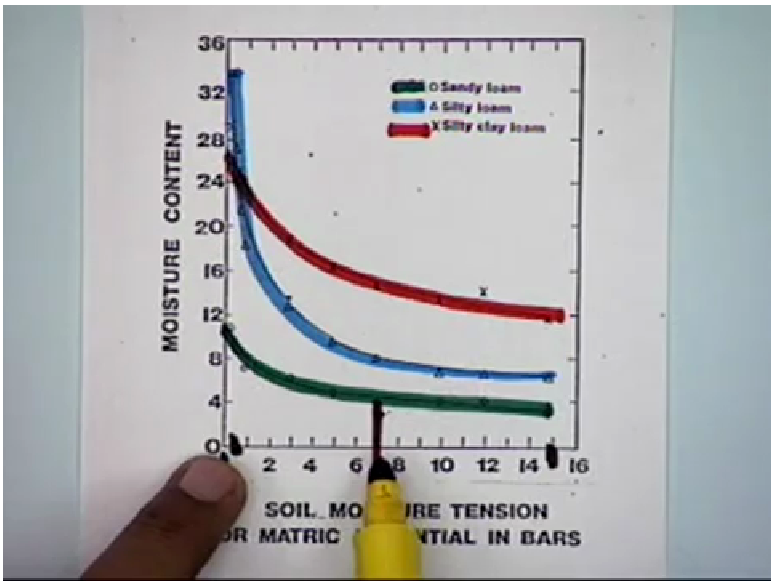

So in these two soils, the soil which is clay loam and the sandy loam soil, in both these soils the availability is very small. Availability is the difference at this level and this level whereas in the case of silty loam the availability is really appreciable. This part of the curve is so steep. This is the place where you have if one third is somewhere here so from here to here you have this much available moisture.

It is just the repetition of the same thing but I wanted to show you the results of some experimental data which has been plotted and it depicts the same influence which we have made. Next we will start looking at, so far we have been dealing with the characteristics of soil and how it interacts with water. And the third component when we started the topic of soil, water, and plant relationships, this is the third component which we should start looking at how the plants interact with the remaining two components?

The first thing which will come to your mind is that what are the requirements of a crop in terms of water? How much water crop requires? Is that question has to be answered? If you want to use the water judiciously we must know how much is the requirement of crops as far as a specific crop is concerned. Does it change with the variety of the crop?

So if you look at the major factors which influence the water requirement of the crops, these are the three major factors, one is the crop and its variety. Which crop is in question, because each crop will have its own requirement? Then the soil conditions and third factor is the climate.

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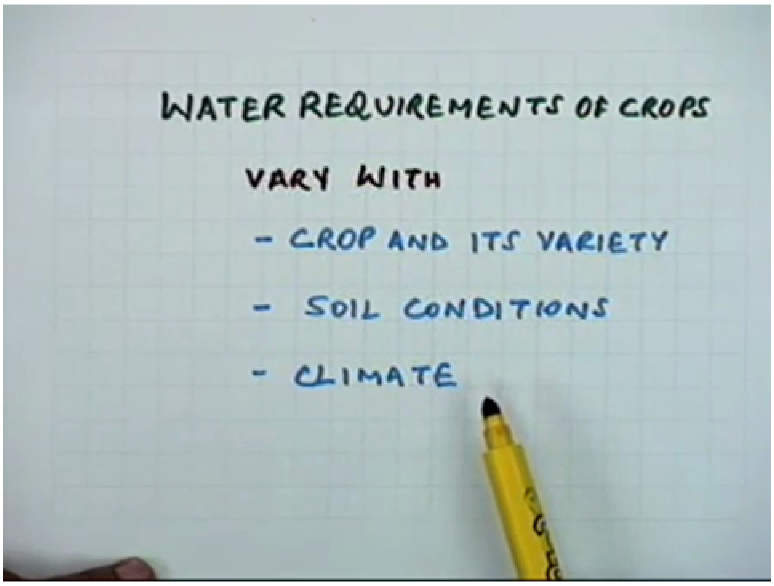

When we look at the crop and its variety it is quite obvious that when you have a small plant its requirement will be different. If in comparison you are comparing with a plant which is much bigger in size and it has more foliage, it has more leaf areas, the requirements. Because, where the crops uses water? It uses water for the building up of tissues, it uses water to get some nutrients from the soil and that is where the water serves as the transporter.

It is used as a medium to transport the nutrient in the salts from the soil to the plant for its building up for its biological activities. But in terms of the actual consumption of the moisture by the plant which is only for building up the tissues, it is very small, it is just a fraction. Most of this water which is coming into the crop is getting transpirated. It transpires, it travels through the root system into the crop and then leaves into the atmosphere through the leafs.

And that process is known as the process of transpiration. So the crop variety will decide what is the amount of moisture which is required? That is one aspect, then within the crop if you look at the total span, the total growth period of the crop, there is a time when you sow the seed, after this the seedling will be there and then it will start growing. The size of the plant will also change. A time will come when it will mature.

Though there are in between processes also when the fruit will be there, the fruit will ripe and then the maturity of the crop, depending on the type of the crop you are considering. So this total period is known as the crop growth period. Within the crop growth period also you will find that the water requirements changes. Those aspects we will look at in detail later on.

Right now we can say that the crop and its variety is one of the major factors which will decide what is the crop water requirement. The soil conditions, just now we have looked at the various soil conditions and we have also mentioned that when the soil is at a field capacity, the soil moisture tension is the minimum. As you go from the field capacity level more towards the wilting point, the soil moisture tension is going to increase.

So that is the reason that the water requirement of the crop will be influenced with respect to the soil condition. The requirement of the crop will be there but how much it will be consuming it will be a function of what is the soil condition. So there is an optimum requirement, there is a requirement which is constrained requirement with respect to soil condition. That is what is the difference. That is what is we are trying to bring out.

Then thirdly the climate is the major factor in terms of deciding what will be the water requirement because of the fact that it is the climate which will decide what is the amount of evapotranspiration, okay. We have just mentioned that what the transpiration is. The other active process which is responsible for the loss of moisture from the soil is evaporation. So, if we want to know what is the water requirement, we express the water requirement of the crop in terms of consumptive use.

So, consumptive use is the term which is used to express the water requirement of crops for its production. The total water requirement of the crop for its production is what we term as consumptive use. It will be composed of, as we have just mentioned that the amount of water which is transpired by the leaves that is one component of the consumptive use, requirement of the crop. The second component is the amount of water which is used for building up of the tissues.

That is the real requirement as far as the (crom) crop is concerned in terms of its building up, the growth of the plant. Even transpiration is also essential component though the amount of water which is transpired is much higher in terms of the quantity when we compare it with the amount which is used for building up of the tissues. And the third component which is responsible for making up the (comp) consumptive use is the evaporation from the wet soil.

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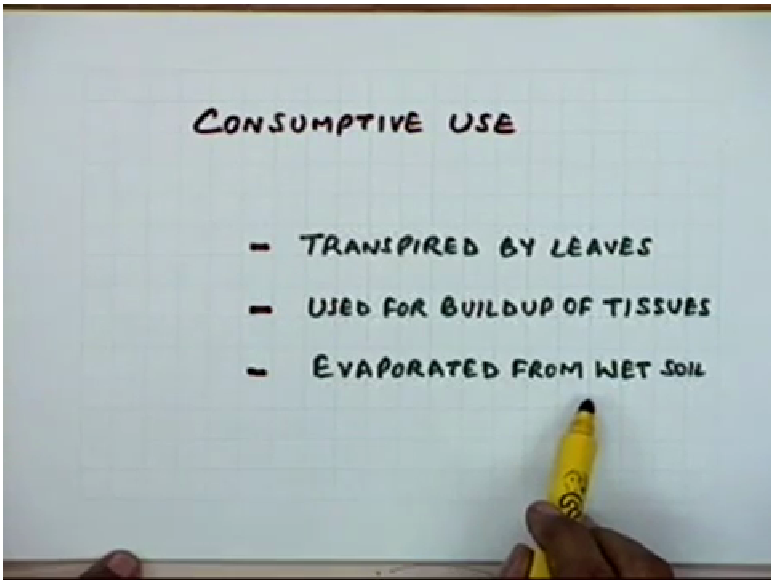

So that is also one of the constituent of the consumptive use though it might not be directly responsible for the crop production. But as far as the requirement is concerned the total requirement which is to be looked at when you look at the irrigation requirement, this part has to be included, okay. I think we will stop here for today. Any question? I can answer any question if you have.