Soil Science and Technology

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Lecture – 17
Qualitative Description of Soil Wetness

Welcome friends to this new lecture of Soil Science and Technology and the topic of this lecture is Qualitative Description of Soil Wetness. And in the previous lecture, we talked about different types of flow, which occurs within the soil. We talked about saturated flow, then we talked about unsaturated flow and vapor movement.

In the saturated flow, we discuss about Darcy's law and how it affects the water movement from one part of the soil to another part of the soil and what are what is hydraulic as, you know, hydraulic conductivity and how we measure hydraulic, you know, how hydraulic conductivity affects the movement of water and what are the different types of factors which are responsible for changing the hydraulic conductivity or the movement of water. Then we talked about unsaturated flow.

Remember that, in case of unsaturated flow, it is mostly occur through micro pores, because macro pores are drained out during this time. And then, we talked about the water vapor movement from one part of the soil to another part of the soil due to different types of gradients. So today, we will start a new topic that is qualitative description of soil wetness.

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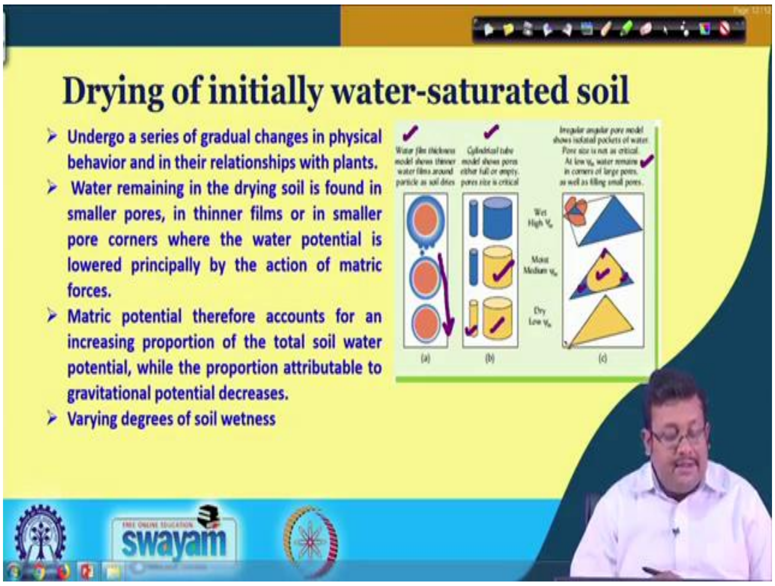

So, let us start. So think of when you are having a totally, you know, saturated soil and you want to want to dry that soil with the application of different, you know, matric potential or suction.

And as a result of that, it will undergo a series of gradual changes in physical behavior and in relationship with the plan, because if you dry the initial water saturated soil ,you will see that it will undergo a series of gradual changes. And we know these gradual changes we will discuss and water remaining in the drying soil is found in small pores and in thinner films or in smaller pore corners, where the water potential is lowered principally by the action of matric forces.

So, in our previous lecture, we saw these 3 model for water movement and this is basically water film thickness model. If you remember, there we talked about cylindrical tube model or which basically shows different size differences of different pores. And finally, we talked about this irregular angular pore model.

If you remember we discussed that when there is thick water film around a particular surface and, you know, it is the water is present in saturated condition and ultimately the potential will be high, and when we dry that particle or soil gradually, the thickness of the water will go down and ultimately, with increasing suction or matric forces further the thickness of the water film around the around the particle will go down and we know one.

So, thus the water will always move from a particle around which the thick water film is present to a particle around which very thin water film is present. So, based on the matric potential, water will move from one place to another place. Then in the cylindrical tube model if you remember, we talked about that when we are draining the initially saturated soil in the intermediate phase obviously, the first this macro pores will emptied out and the micro pores will be still remaining filled with water and in the extreme dry condition, both the pores will empty will be empty.

And the finally, you know, during the angular pore model we talked about some isolated pockets of water when we dry the soil and water will start drying from the middle part and there will be some amount of water at the corner of this angular pore because of wearing about a matric section.

And ultimately some amount of water will still remain in these corners due to high amount of matric suction. So, this happens when you dry a particular; you know, initially wet saturated soil but matric potential therefore, accounts for an increasing proportion of the total soil water potential, while the proportion attributable to the gravitational potential decreases.

So, when we dry an initial initially water saturated soil with the application of matric pressure or matric forces, the matric potential will be predominant and we know as compared to the gravitational potential. And as a result you will see varying degrees of soil wetness.

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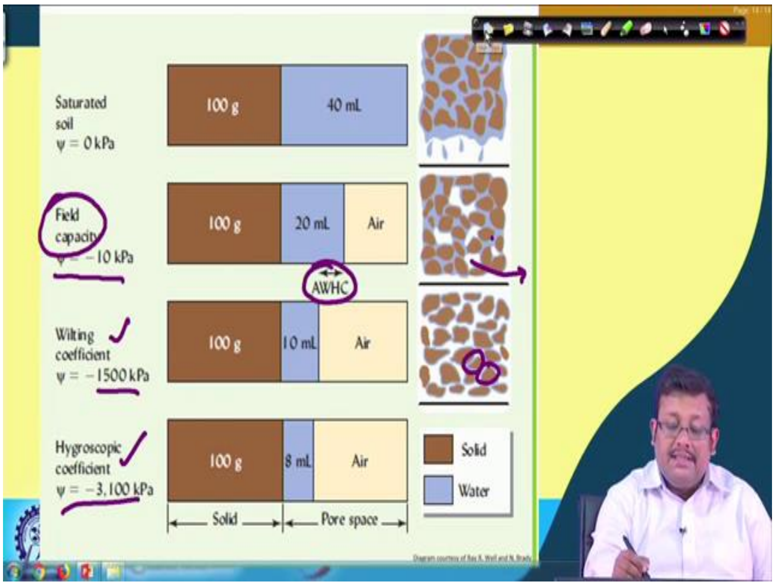

So, let us see. These are different varying degrees of soil wetness. As you can see, in the first condition is called saturated condition, second condition we call it field capacity, third condition we call it wilting coefficient and finally, the hygroscopic coefficient.

Now, in the saturated condition; obviously, you see the total water potential is 0 kilo Pascal and obviously, all the macro pores and micro pores are filled with water. So, you we are actually assuming that we are, we know, the weight of the soil is 100 grams and 40 ml is water is present to fill up all the micro pores and macro pores and it is a saturated condition.

Now through the application of matric forces, if we start draining this water or when the draining will start from this place; obviously, you will see that the water will first drained out from this macro pores leaving only those micro pores filled with water.

And as a result of that, we call it a field capacity. So, remember that in case of saturated soil and in case of field capacity, the only difference is the water will move or water will go away from this macro pores and this water is called gravitational water. So, after removal of the gravitational water; whatever water is remaining in the micro pores and this is called field capacity and this field capacity the potential around the field capacity is variable, generally it is not very much we cannot definitely say, but it generally varies from minus 10 kilo Pascal to minus 30 kilo Pascal.

And further when we are dry the soil from the field capacity, we will see the water is further going down and ultimately a very thin layer of water will remain around the soil particles and we will call this water content as wilting coefficient or permanent wilting coefficient. And this permanent wilting coefficient generally the potential is around minus 1500 kilo Pascal and we call it permanent wilting point because at this point, plant will start, the plant wilt cannot be further recovered.

So, this is a permanent in nature. Although, the water will still be present into the soil, plant cannot extract that water. So whatever water is present in between the field capacity and permanent wilting point is called available water or available water holding capacity of the soil. So, this is the amount of water that plant can efficiently use. And whatever water is present below the wilting coefficient or permanent wilting coefficient plant cannot use.

Now, if you further dry the soil below the permanent wilting coefficient, you will see that at the extreme matric potential there will be further, we know, only extreme matric potential, only the structural water or the water which are strongly absorbed over the clay surface will remain. And at this condition, we will call it hygroscopic coefficient and remember the hygroscopic coefficient occurs at a matric potential of or the soil water potential of minus 3100 kilo Pascal.

So, again you can see we are starting from a saturated soil when all the soil pores are filled and then we are applying the suction. And, as a result the gravitational water is draining out and further it reaches the field capacity with a potential of minus 10 kilo Pascal to minus 30 kilo Pascal. And then, we further dry the soil ultimately reaches to wilting coefficient at minus 1500 kilo Pascal, and the difference between the field capacity and field capacity and wilting coefficient is called the available water content of the soil which is plant available water, I would say and below the wilting coefficient at hygroscopic coefficient, only few amount of water is structurally attached to the soil, you know, the clay particles.

So, these are different, we know, these are different stages of soil wetness. So, let us see and discuss them individually.

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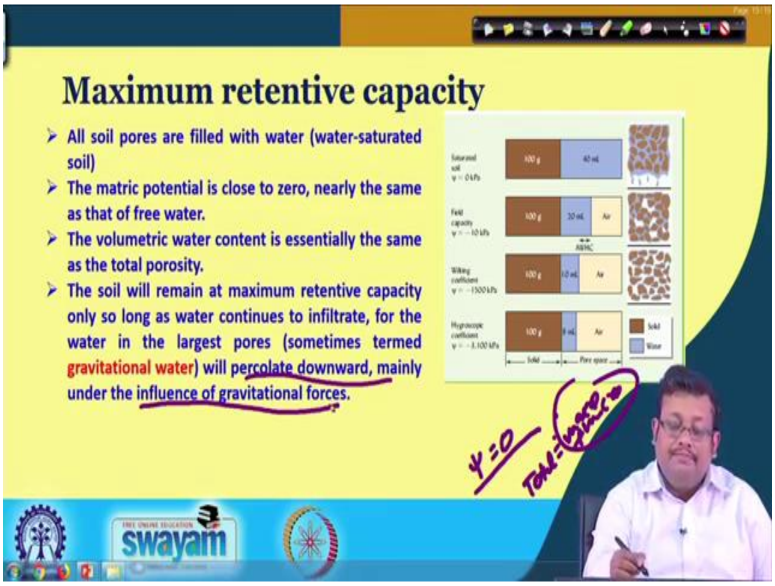

So, let us start with this water saturated condition. We call it maximum retentive capacity of the soil, because all the pores spaces are filled, both macro pores and micro pores are filled in this condition. Now, the matric potential in this case is close to 0, nearly the same as the that of free water because here we will assume most of the time the total water potential will be almost 0, because all the soil pores are filled with water.

Now, the volumetric water content is essentially the same as the total porosity, because whatever water will, we know, present that will saturate all the micro pores or macro pores and the total porosity total pore is equal to macro pore and micro pores. So, all the macro and micro pores are, all the macro and micro pores are filled with the water. So, the volumetric water content is essentially the same as the total porosity. The soil will remain at maximum retentive capacity only so long as the continuous daily filtrate.

So, when the infiltration stops obviously, the gravitational water from the macro pores will drain out due to the influence of gravitational forces. And these movement, we know, that the gravitational water will percolate downward mainly under the influence of gravitational forces. We have already discussed what is percolation in our last lecture.

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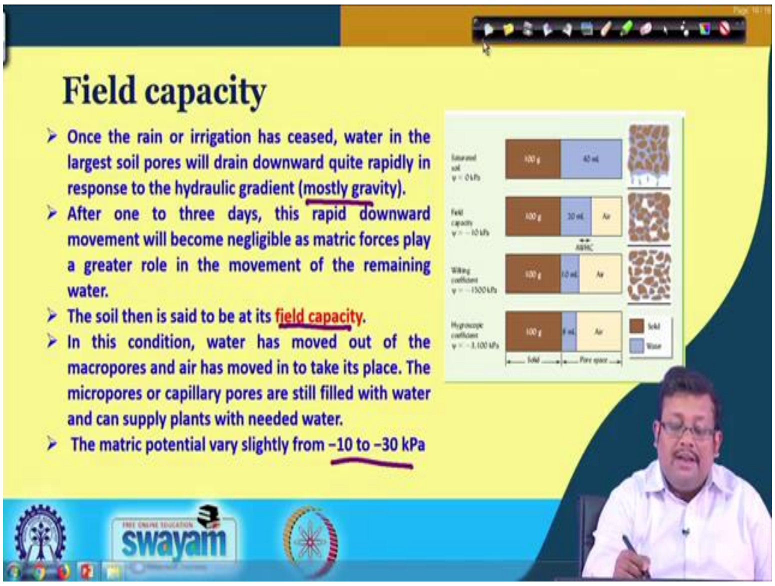

So, I am not going into details of percolation. So, let us talk about the field capacity. Now in the field capacity, once the rain or irrigation has ceased the water in the largest soil pores will drain downwards quite rapidly, we know we know, in response to the hydraulic gradient and mostly by the gravity. This is what we called gravitational water and after 1 to 3 days, this rapid downward movement will become negligible and this matric forces play a greater role in the movement of the remaining water, with the with the movement of the remaining water and at this condition, we will call that the soil is at its field capacity.

Now remember that in this condition, water has move down from this macro pores and air has move into take, air has moved in to take its place at the macro pores and the micro pores or capillary pores are still filled with water and can supply plants with needed water So, the matric potential in the field capacity may vary from minus ten to minus 30 kilo Pascal. So, it is not definitive. It can vary between minus 10 to minus 30 kilo Pascal.

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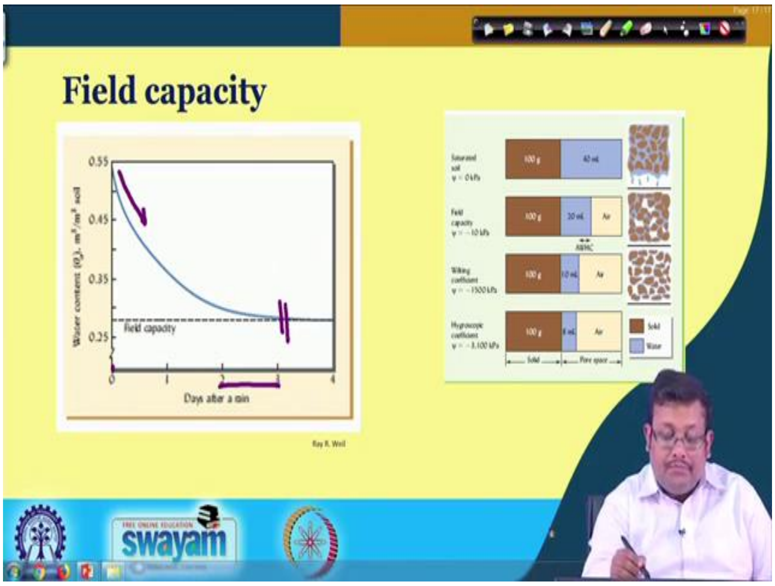

So, if you see what I have told in the last slide, basically is depicted by, this picture is basically depicting this. So, here is the plot showing the relationship between days after a rainfall and water content what is basically volumetric water content.

So, if you see that when the days after the rain fall after 1 to 2 to 3 days after almost 2 to 3 days, the volumetric, the water content will, we know, will go down. So, at the 0 day just after the rain fall obviously that will contain the highest amount of water, because all the pores spaces will be filled and further it will go down and ultimately we will see that after 2 to 3 days, it will reach the field capacity.

So generally, after a flush of rainfall it takes around 2 to 3 days of draining to reach the field capacity and attaining a, we know, moisture content which is equivalent to the field capacity.

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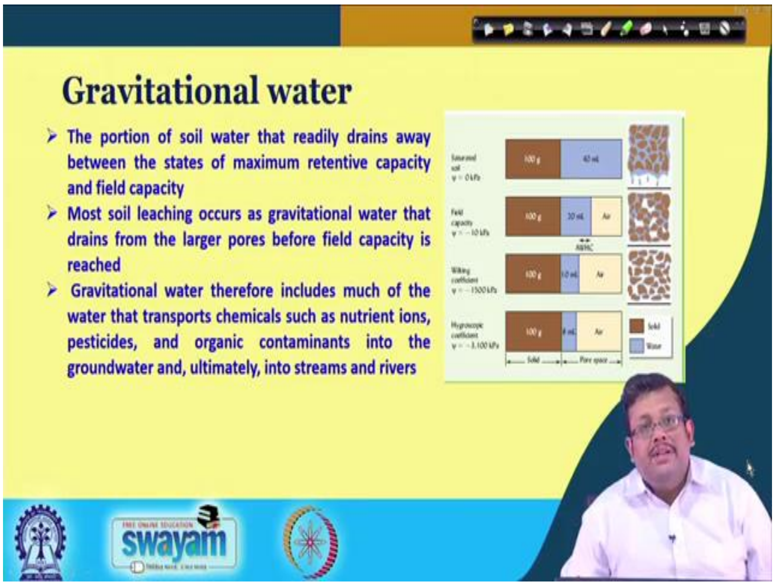

So, again what is gravitational water? Gravitation water is the portion of soil water, that readily drains away between the states of maximum retentive capacity and field capacity and most soil leaching occurs as gravitational water that drains from the larger pores before field capacity is reached. And remember gravitational water; therefore, includes much of the water that transports chemical, such as nutrient ions, pesticides and organic contaminants into the groundwater and ultimately into streams and rivers.

So, this gravitational water which drains readily from the macro pores after a flush of rainfall and reaches the field capacity after 2 to 3 days, this gravitational water includes much of the water that transport chemicals; for example, nutrient ions, pesticides and organic contaminants in the groundwater ultimately into streams and rivers. So, this is very important for planning the irrigation schedule, we know, for planning the application of different fertilizers, how you have to manage your fertilizer dose by considering this gravitational water mediated movement ok.

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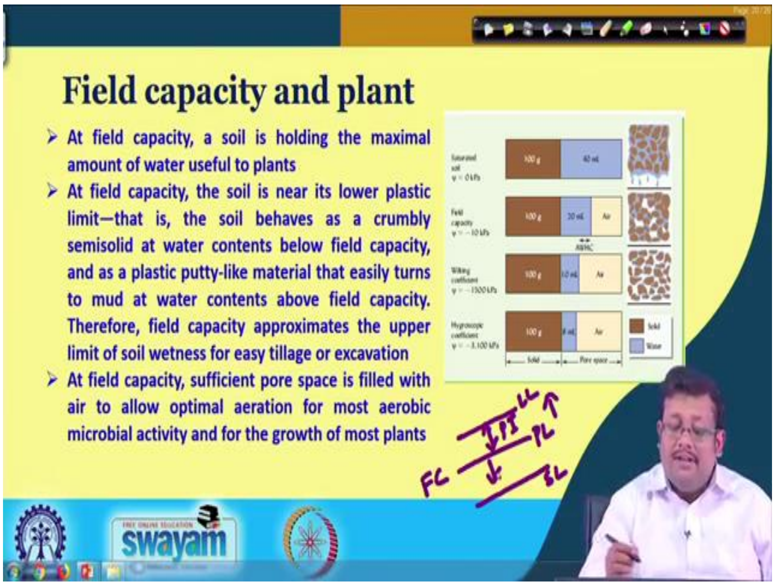

So, what is the relationship between field capacity and plant, why field capacity is important for plant growth?

So, remember that at field capacity, soil is soil is holding the maximum amount of water useful to the plants. If you remember that the difference between field capacity and permanent wilting point is called the available, soil available water and this is the amount of water that is available to the plant for their growth. So, another important thing I would like to mention that you remember when we discuss our soil consistency lecture, we discuss about several atterberg limits and those several atterberg limits were we talked about liquid limit. Then we talked about plastic limit and then we talked about shrinkage limit and all these things.

So, we also talked about the differences between this liquid limit and plastic limit we call it plasticity index. So, it is a range in which the soil behaves like plastic. So, it says that in case of field capacity, it basically is equal to the lower plastic limit.

So, plastic limit is equal to field capacity and above the field capacity, above the field, we know, field capacity the soil will behave like a plastic putty like material that easily turns into mud at water contents above the field capacity. And below the field capacity that is the plastic limit, the soil behave will behave like a crumbly semi solid and it will help in tillage excavation.

So, for tillage I would say that field capacity approximates the upper limit of soil wetness. So, we should maintain the field capacity and we should not apply water beyond the field capacity for tillage, because it will, we know, resists the tillage operation because it will produce the mud.

So, we always should tillage do the all the tillage operation below the field capacity, and at field capacity sufficient pore space is filled with air to allow optimum aeration for most aerobic microbial activity and for the growth of the most plants. So, field capacity is very much important as far as the plant growth is concerned.

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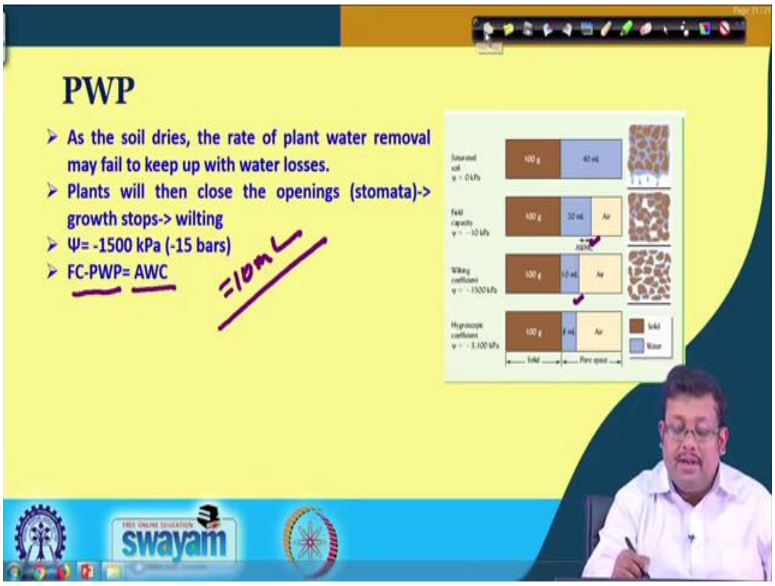

So, let us see what is permanent wilting point. Now, permanent wilting point or PWP, that as the soil dries, the rate of plant water removal may fail to keep up with the water losses. So, then what is the way through which plant remove the water? We know, the ways transpiration through stomata. So, at this time, where the soil further grows, we know, dry, the plants will close the stomatal opening because the soil water is not further available. So, when they will close the stomata, their growth will stop and as the grow stops, it will start wilting.

However, at minus 1500 kilo Pascal soil water potential or minus 15 bar soil water potential, the soil wetness will reach the permanent wilting point, because below which the soil the plant cannot regain its original growth and it will be permanently wilting.

So, again the difference between the field capacity and permanent wilting point is available water capacity. In this case, this is if you consider the field capacity, at the field capacity there is 20 ml of water is present and at the permanent wilting point only 10 ml of water is present, so the difference between 20 ml to 10 ml. So, in this case available water content will be 10 ml for this particular soil.

So, now you have the basic idea about the implication of field capacity and permanent wilting point as far as the growth of the plant is concerned.

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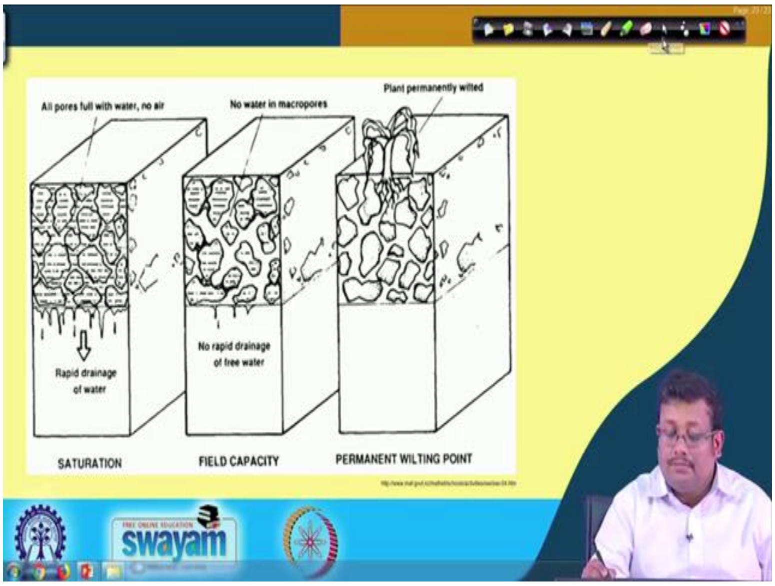

So, let us go back and see as a summary. This slide will show difference between saturation, field capacity and permanent wilting point. As you can see, in case of saturation all the pores are filled with water, there is no air and there will be rapid drainage of water and as the soil further dries, there will be no rapid drainage of free water, because free water is already been drained out and leaving only the micro pores which are filled with water and macro pores will be emptied and occupied by air sometime.

So, permanent wilting point is the point where all the water, most of the water is being removed and ultimately the plant is permanently wilted. So, this slide shows a very good summary of whatever we have discussed so far.

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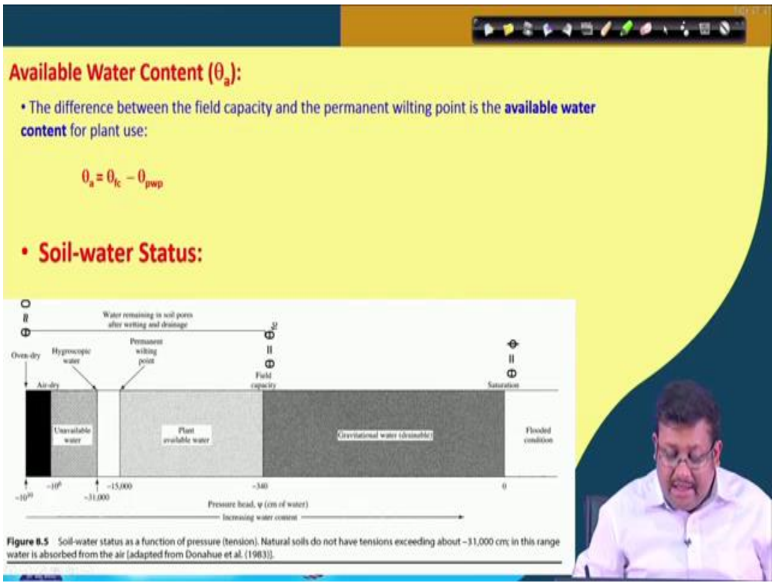

So, let us move forward and see the formula of available water holding capacity.

So, the difference between the field capacity and the permanent wilting point is the available water content. And if we volumetrically express it, it is theta a equal to theta fc minus theta pwp, and theta pwp. So, this is called the available water content and. So, this picture will also give you a good idea about this differences.

So, if you see at the time of saturation, there is a so the below beyond the saturation, there will be flooded condition and at saturation the potential is 0 and below at from the saturation to field capacity obviously, we are getting the gravitational water which is drainable and below the field capacity to permanent wilting point there is a plant available water and this permanent wilting point to hygroscopic coefficient.

Remember that, hygroscopic coefficient occurs at around minus 31000 kilo Pascal, I am sorry, it occurs at around 3100 kilo Pascal and so. And basically it will be further, the water which is present below hygroscopic coefficient is unavailable water and at the time of air drying and at the time of oven drying, there will be practically no volumetric water content.

So, I hope that now it is, all the terms are clear to you. And these are the volumetric moisture content at saturation, field capacity and oven dry condition and as well as permanent wilting point.

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Now, hydroscopic coefficient, hydroscopic coefficient is remember that although plant roots do not generally dry the soil beyond the permanent wilting percentage, if the soil is exposed to the air, water will continue to be lose by evaporation and water molecules in this case remain, are very tightly held, mostly being adsorbed by the colloidal soil surface and as I have told you, the water potential will be minus 3100 kilo Pascal at this hydroscopic coefficient.

And the water is thought to be in films, thought to be in the films only 4 to 5 molecules thick and it is held so tightly that much of it is considered nonliquid and can move only in the vapor phase. And this is basically unavailable to the plant. So, this hygroscopic water which is presented at the hygroscopic coefficient is unavailable to the plant.

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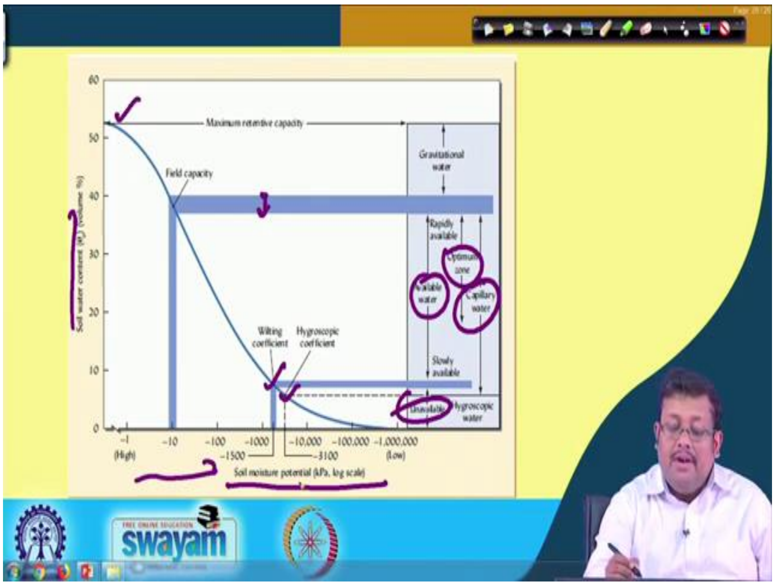

So, this slide basically shows the relationship between the soil moisture potential in kilo Pascal, which is presented in the log scale and in the x axis and soil water content; obviously, it is a volumetric soil water content, so, of a particular type of soils, as we can see as we are increasing the, as we are decreasing the soil water potential from high to low; obviously, the soil will dries down and this is the water the soil water curve. And you can see at this point there will be maximum water retentive capacity. And since it after removing the gravitational water, it will reach its field capacity, and the field capacity is expressed in terms of the shaded area to indicate that there is no clear cut definition or clear cut demarcation of the field capacity. It varies from soil to soil, it varies from minus 10 to minus 30 kilo Pascal and after we remove further water from field capacity, it will reach the wilting coefficient and further to hydroscopic coefficient.

So, the difference between the again the difference between the field capacity and wilting point is the available water and this is the optimum water zone. And remember that whatever water is present inside the, we know, for the for the for the availability to the plant is basically most in the most of it is capillary water and hygroscopic water below hygroscopic water occurs at around minus 3100 kilo Pascal and below the permanent wilting point the water is called unavailable water.

So, again available water is field capacity to permanent wilting point, unavailable water is below permanent wilting point, hygroscopic coefficient occurs minus 3100 kilo Pascal, capillary water is mostly present between the hygroscopic coefficient to field capacity. And the most optimum water efficiency can be found within the field capacity and permanent wilting point.

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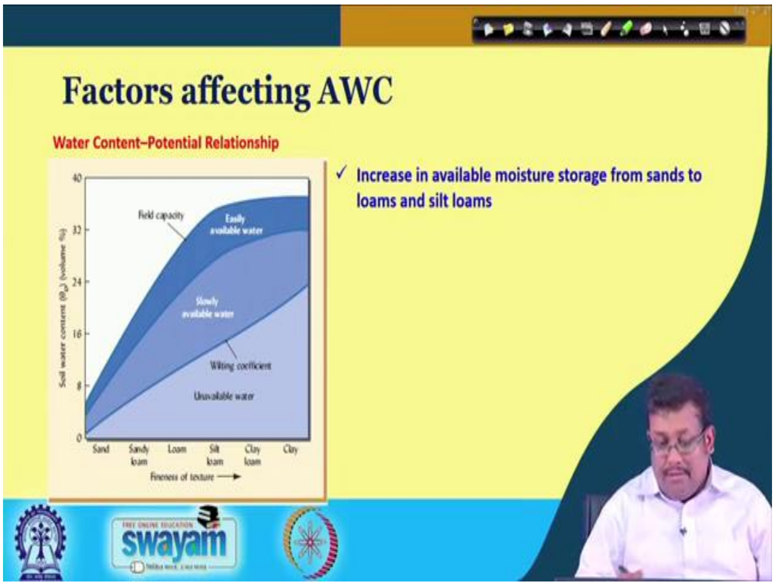

So, what are the factors which affects the available water content? Well this slide shows the relationship between the fineness of textural affect for the soil water content; obviously, you can see that as we are going from sandy soil to sandy loam to loam and clay loam soil; obviously, their field capacity increases. The field capacity increases up to silt loam and then levels out, but in case of clay; obviously, their wilting point is quite high, the wilting point is quite high. So, the plant available water is low in case of clay as compared to the silt loam soil.

So, increase in available moisture storage from sands to loams and silt loam can show you this increase in field capacity. However, in case of very fine textured soil like a clayey soil due to their increase wilting coefficient, the plant available water is also low as compared to silty loam soil.

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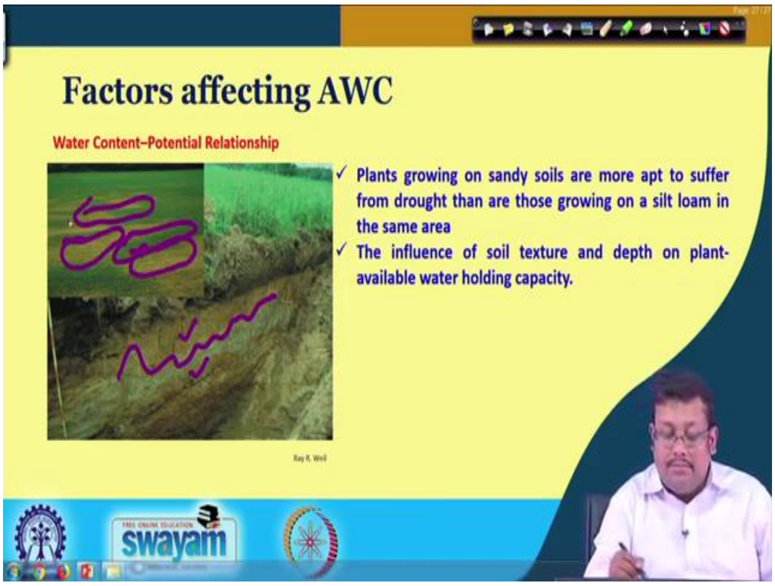

And obviously, there are some, water content is very much important and, we know, plants growing on sandy soils are more apt to suffer draught than that of those growing in a silt loam at the same area. The influences of soil texture at depth of plant available water holding capacity can be seen in this picture. As you can see, the spatial distribution between this dry zone and the greenish zone and when we excavated the when the site is excavated, the soil below it you can see the uneven thickness of silt and sand.

So, this is at the boundary between this silt and sand; obviously, silt will have higher water holding capacity than the below sand. And as a result of this uneven thickness of silt content or silt mantle, there will be uneven distribution of water holding capacity or available water content because silt can hold more water then sand. And as a result of that, you will see some spatial variation in distribution of this dry zone and green zones.

So friends, we have covered a considerable portion of this different soil water content and then we discussed about their different terms and what are their implication for plant growth, what are the field capacity and permanent wilting point, all these things. So, let us wrap up here. In the next lecture we will start from here and we will try to finish this topic in the next lecture and then we will start a new topic that is soil aeration in the next lecture.

So till then thank you and goodbye, and we will again meet in the next lecture of science and technology.

Thank you.