Soil Science and Technology
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Lecture – 18
Soil Air

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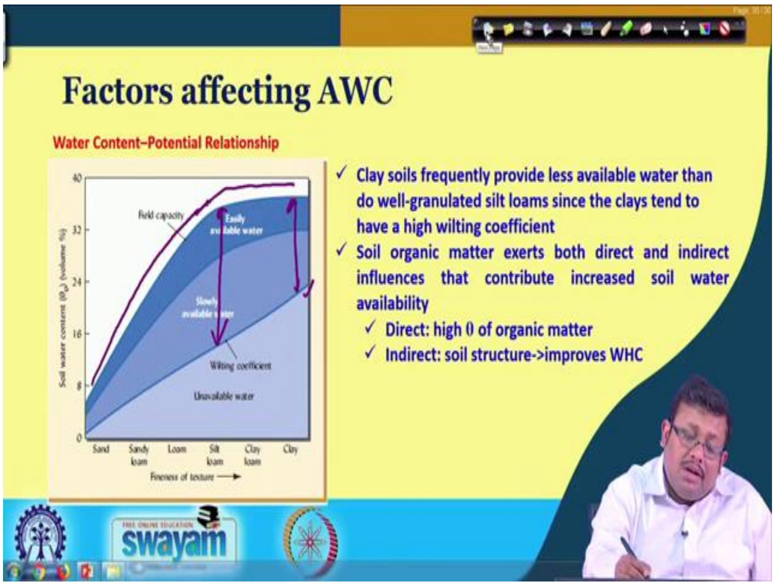

Welcome friends, to this new lecture of Soil Science and Technology. And we will start from the slides where we left in the last lecture. And we were discussing about different volume, we know, different qualitative or different, we know, moisture content of the soil and how it can term them. We talked about field capacity, we talked about permanent wilting point, we talked about hygroscopic coefficient; what is available water content, plant available water content. What is unavailable water, what is gravitational water and then we discussed, you know, what are the factors which affects this available water content in the soil.

So, we talked about soil texture. So, now we shall start about; we shall also talk about some other factors and then we will move to our next topic. So, you can see that also in this picture we can see the different, you know, the effect of soil texture in the volumetric soil water content. And obviously, in case of clay soils where, we know, if they are frequently provide less available water, then do well granulated silt loams since the clay tends to have a higher wilting coefficient, we have already talked about in the last lecture. So, as you can see; obviously, as you are going from sand to sandy loam to loamy soil to silkt loam, there is a continuous increase in soil water volumetric soil water content ultimately levels off.

And obviously, the wilting coefficient also increases and it reaches maximum incase of clay soil, because of high moisture retentive capacity of the clay soil in their macro pores. So, obviously, the difference between this field capacity and wilting point here at clay soil is smaller than this silty loam soil. So obviously, the silty loam soil will have more available water content than that of the clay soil. However, also well granulated soil will have higher, we know, well granulated silty loam will have higher moisture content, available water content than that of clay soils. So, soil organic matter it is also very important. Soil organic matter exerts both direct and indirect influences that contributes increased soil water availability.

Because incase of direct effect, it, we know, high water holing capacity, volumetric water holding capacity of organic matter also adds to the water content of the soil. So, when we add organic matter from outside to the soil; obviously, is total water holding capacity increases. And also indirectly when we apply soil water holding capacity soil organic matter into to the soil, it helps in binding the soil particles, improving the soil structure. When it improving the soil structure a well aggregated soil; obviously, it will increase the water holding capacity. So, as a whole the water holding, you know, application of organic matter seems to increase the water holding capacity or the available water content of the soil.

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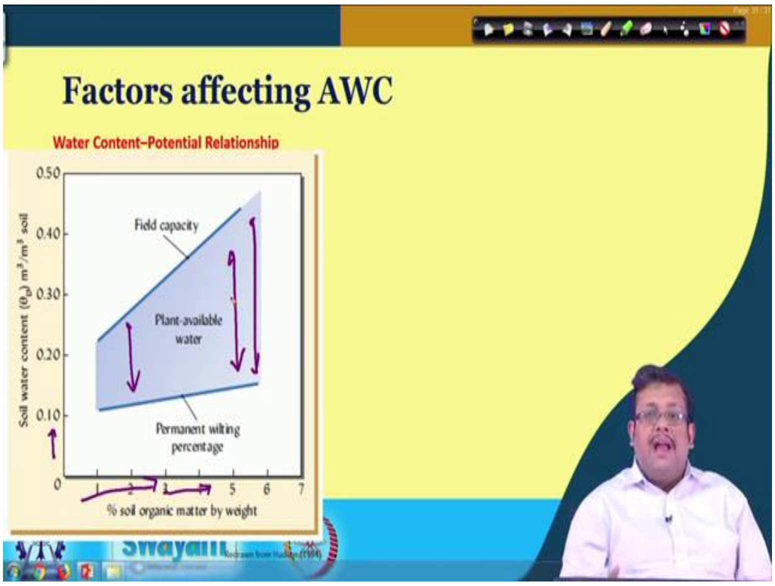

So obviously, in this slide it is also clear that as we increase the percent of soil organic matter by weight, and soil water content and what is the relationship with the soil water content. So, you will see that as the percentage of organic matter is increases, the differences between field capacity and permanent wilting point continuously increasing. And as a result of that, the plant available water or the available water content increases by addition of organic matter.

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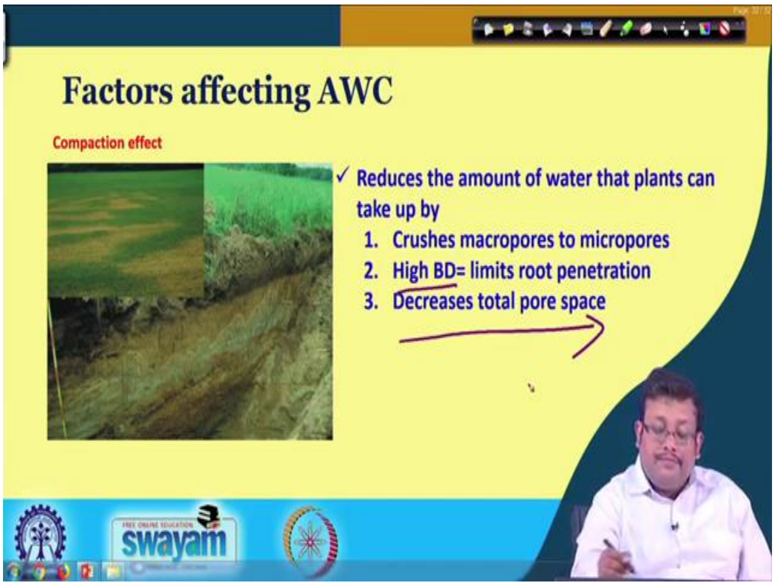

Then finally we shall talk, we should talk about the compaction effect which is very important. Remember that when we compact the soil; obviously, it reduces the amount of water that plants can take off by crushing the macropores into micropores, and also when we do the compaction ultimately it increases the bulk density. So, when there is a high bulk density, it always limits the root penetration and finally, when we increase the bulk density, it decreases the total pore space.

So, by these three different ways, you know, compaction can harm the, we know, the water holding capacity of the soil and obviously, it limits. Higher compaction always limits the water filtration into the soil and the water movement into the soil. So friends, you know, we have finally, finished this topic of, you know, qualitative moisture and then, we know, qualitative moisture, we know, different, different, different, different, different moisture content of the soils and their qualitative types. And so, I hope that you have learned something new, and let us move to our next topic that is the Soil Air.

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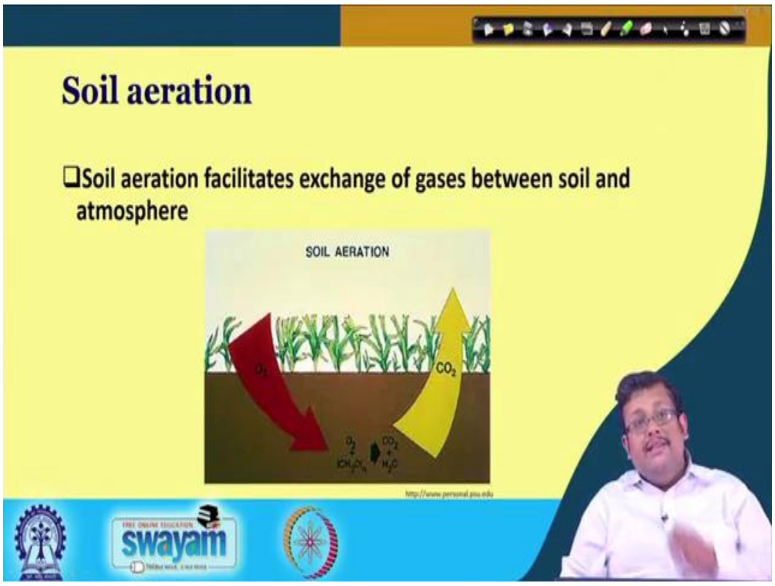

The soil air is very much important. Soil air or the process is called the soil aeration. Soil aeration is very much important and it is basically the exchange of water, and exchange of water and carbon dioxide between the atmospheric air and the soil air. So, soil aeration facilitates the exchange of gases between the soil and atmosphere; as we can see, the oxygen is getting entered into the soil and carbon dioxide is getting, we know; it is released from the soil to the atmospheric air. So, these interchange or these exchange of air between the soil and atmosphere is called the soil aeration.

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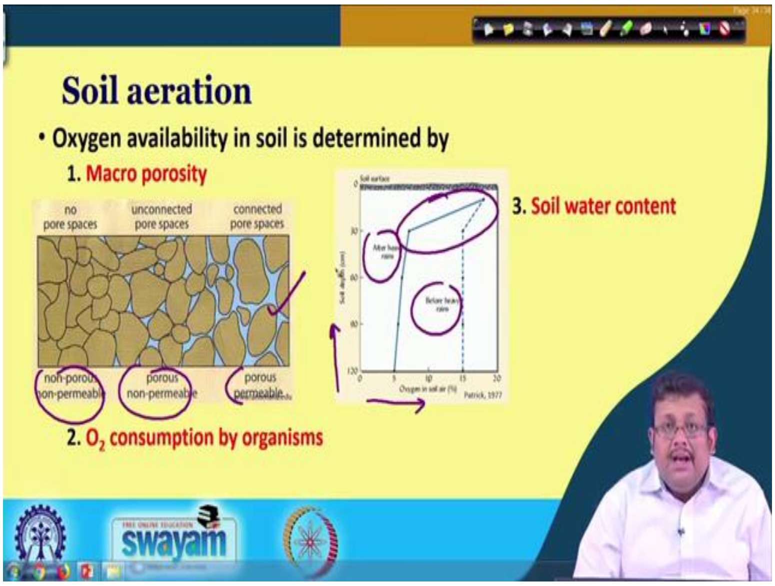

So, we know, soil aeration, we know, in case of soil aeration, the oxygen availability in soil is basically determined by three factors. One is macro porosity, second is the oxygen consumption by organisms, and thirdly and the most importantly that is soil water content. Now, you can see that in case of porous and there are three different condition, one is porous and permeable condition and is porous and non permeable condition and non porous and non-permeable condition.

So obviously, in this case, in the porous and permeable condition, there are interconnected pore space. However, in case of porous, non-permeable there are non inter connected pore space and in the third condition that is non porous and non-permeable, there is no pore space. So, obviously, the first condition here there will be more oxygen availability and there will be more gaseous exchange. Second is important is oxygen consumption by organisms. Now, you know that plant roots also does respiration and as a result of respiration, it consumes the oxygen and releases carbon dioxide and this carbon dioxide increases its partial pressure into the soil air and we will discuss that later on.

So, oxygen consumption by organism is very much important for oxygen availability in the soil layer and finally, soil water content; obviously, the soil water content you will see in this in this in this graph; obviously, we can see the relationship between oxygen in soil air and soil depth. And obviously, you can see the differences between the oxygen in soil air before heavy rains and after heavy rains. Obviously, before heavy rains there will be higher amount of oxygen whereas, after heavy rain there will be lower amount of oxygen because filling of the pore spaces by water removing the air.

So, this is the difference between before and after heavy rains. And these differences is maximum at, we know, at the upper layer of the surfaces you can see. There is a, we know, the change in oxygen in the soil air is drastic in the upper layer of the soil, just after a heavy rain fall.

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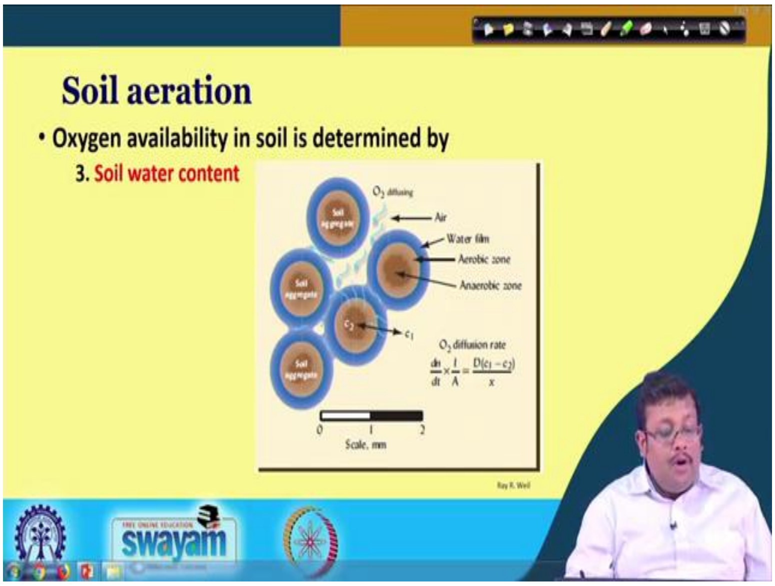

So, another important term another important is, we know we know, function is soil water content for oxygen availability as you can see here, these are individual soil aggregates which are covered by the, we know, thick films of water. And these thick films of water, creates some anaerobic zone and as a result of this anaerobic zone and thick water film, the air cannot diffuse from the atmospheric air to the soil air because diffusion of air through the water is 10,000 times slower than that of diffusion through air.

So, as a result of; if the soil has got more interconnected macro pores the air will or oxygen will diffuse into the soil atmosphere, more readily than that of when water when water is present. Because what you do through the water medium, oxygen diffuses very very slowly.

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So, we know: what is the implication of water content for soil aeration or the water or the oxygen condition oxygen content of the soil. Now, let us see what is the effect of the, if there is an excess moisture. Obviously, when there is an excess moisture, the all the pore space will be filled by the water and leaving no air filled, you know, air filled pores and as a result of that, some plants are very much sensitive to this condition.

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So, as you can see some place dry out permanently, some plants damages permanently however, having said this there are some plants which have made their own physiological adaptation for this water logging condition.

So, when there is a flooded water over the soil surface, we call it water logging condition. And in water logging condition, some plants specially you will see the mangrove will grow, because they have made some own physiological modification. First of all, the one of the physiological modification they have made is called aerenchyma, which are basically cells which supply the oxygen to roots from the atmosphere, some hollow aerenchyma structure and then hydrophytes.

Hydrophytes are the plants which are adapted to grow in water logged condition and they have above water roots to supply their oxygen. So, as a result they can survive in this water logging condition. Especially you will see this type of plant or hydrophytes present in mangrove forest. So, this type of adaptation plant has made for dealing with the dealing for poor aeration condition into the soil.

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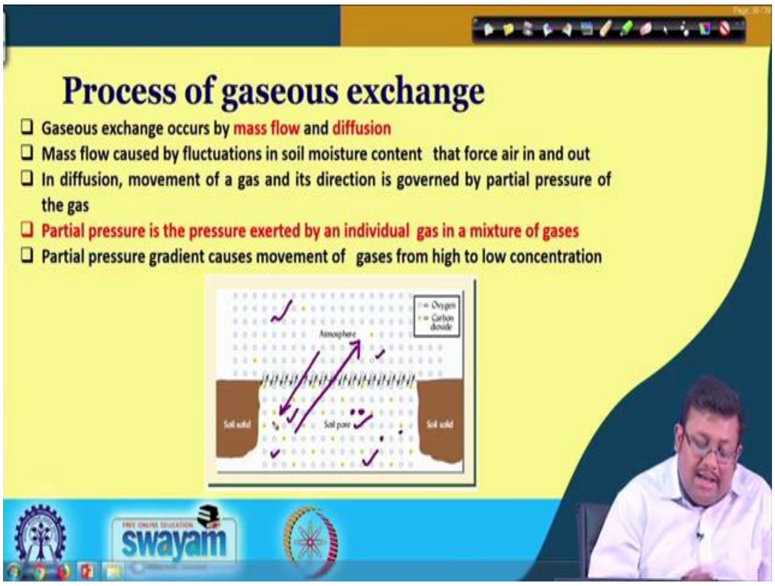

So, what are the different processes of gaseous exchange? Well there are two major processes of gaseous exchange, one is called mass flow and another is called diffusion. Now mass flow is always caused by fluctuation of soil moisture content, that force air in or air out.

So, I mean when there will, you know, mass flow basically occurs through the fluctuation of soil moisture. For example, before rain fall, after rain fall, after a heavy rain fall water enters into the soil and removes the air. So, this is a called mass flow of water from as a result of rain fall. However, in diffusion movement of gas and its direction is governed by partial pressure of the gas. This is very important, partial pressure.

Now, partial pressure what is partial pressure? Partial pressure is the pressure exerted by an individual gas in a mixture of gases. So, if you can see this picture. This picture shows how diffusion takes place within the soil and atmosphere. So, if this is a soil surface and, we know, soil pores, if this is atmosphere these are the soil pores; obviously, these hollow, you know, these are called these are the oxygen molecules and these solid spheres are the carbon dioxide molecules. As you can see, the proportion of carbon dioxide is quiet high in the soil air as compared to atmosphere, and it is the opposite trend can be found for oxygen.

And it is very expected why? Because in soil air, millions of microorganisms are present, in the, we know, millions of microorganism, we know, undergoes respiration and as result of respiration, they consume these oxygen molecules and they produce these carbon dioxide molecules. And as a result of that, the partial pressure and I would say, the proportion of carbon dioxide is quiet higher in the soil air as compared to atmospheric air. And as oxygen is being consumed by the, you know, macro organisms like or aerobic organism like, you know, the plant roots and other aerobic organism; obviously, the proportion of oxygen is lower in soil air as compared to atmospheric air.

So; obviously, you can see the proportion of these two gaseous are different in different condition and as a result, their partial pressure will also vary. And as a result of changes in partial pressure; obviously, you will see the partial pressure of carbon dioxide will be quiet high in case of soil air, than that of atmospheric air and as a result of this partial pressure gradient, the carbon dioxide will diffuse away into atmospheric air and in case of oxygen, this trend is opposite. Because, the partial pressure of oxygen in atmospheric air is higher than that of partial pressure of oxygen in soil air. And as a result, oxygen will diffuse inside the soil.

So, partial this is called partial pressure gradient and this partial pressure gradient is the force that drives the gases to be diffused away from atmospheric air to soil air and soil air to atmospheric air.

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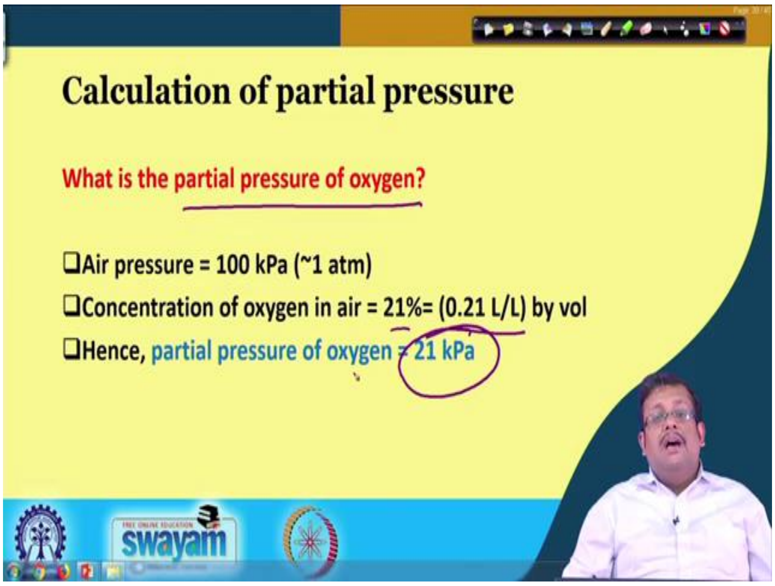

So, how we express partial pressure? Well let us see an example of partial pressure of oxygen. So, if we consider let us assume that air pressure is basically 100 kilo Pascal or 1 atmosphere, and the concentration of oxygen in air we will talk about the atmospheric air is around 21 percent or volumetrically we can say 0.21 liter per liter by volume. So, the partial pressure of oxygen will be 21 kilo Pascal. So, you can see that, this is how we calculate the partial pressure of a particular gas in a gaseous mixture.

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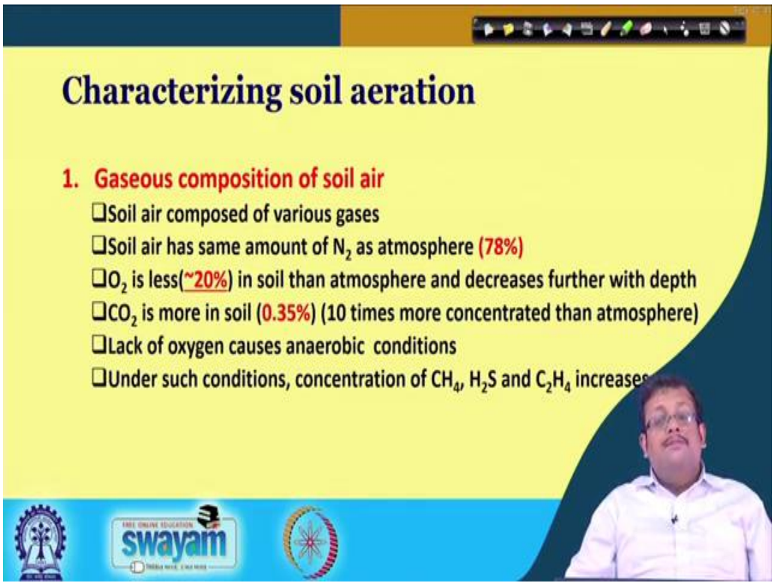

So, how we can characterize soil aeration? The characterization of the soil aeration we can first let us see what is the gaseous composition of soil air. Well the soil air is composed on various gases and soil air has the same amount of nitrogen which is around 78 percent in the atmosphere. So, both soil air and atmospheric air has similar amount of oxygen, that is 78 percent and oxygen is somewhat less, it is generally less than 20 percent or almost 20 percent in soil than atmosphere.

In case of atmosphere, it is around 21 percent. So, as a result the partial pressure of oxygen in atmospheric air is higher than that of partial pressure of oxygen in soil air. And carbon dioxide is more in soil remember that, this is very this is the major difference between soil air and atmospheric air. In case of soil air, the carbon dioxide is more that is 0.35 percent which is 10 times more concentrated then atmosphere. In case of atmosphere you will see, the concentration of carbon dioxide is around 0.03 percent.

So, we are getting 10 times and though the absolute quantity is not so high, but if we consider the relative change between the soil air and atmospheric air, the concentration of carbon dioxide changes 10 folds. And this concentration change is mainly responsible, I mean this concentration change of carbon dioxide incase in the soil air basically results from high amount of respiration activities by different macro fauna, macro flora and micro fauna and micro flora which are aerobic in nature.

And lack of oxygen; obviously, causes anaerobic conditions and under such condition, concentration of, we know, methane, we know, hydrogen sulphide and ethylene all these gases increases. So, the gaseous composition now you have a basic idea about the gaseous composition of soil air, and how it differs from atmospheric air.

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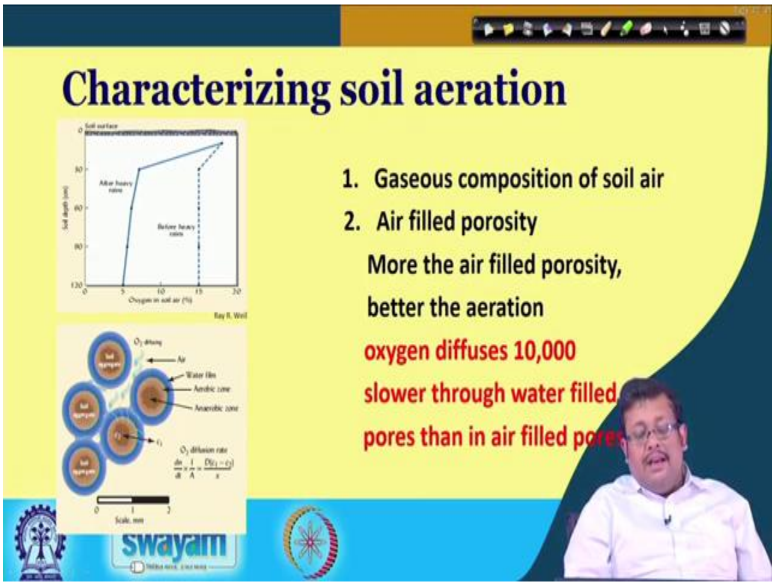

So, gaseous composition of soil air and secondly, the air filled porosity is also important. As I have told you that just after the heavy rain fall, we know, the water enters into the soil, and dries back all the air from the pore spaces and as a result, the water, we know, the water filled pore spaces increases and air filled pores pore spaces decreases. And air filled pore spaces are better for aeration because it helps in oxygen diffusion. In case of water filled water filled pore spaces, there is no good aeration and obviously, oxygen diffuses because, oxygen diffuses 10000 times lower through water filled pores than in the air filled pores.

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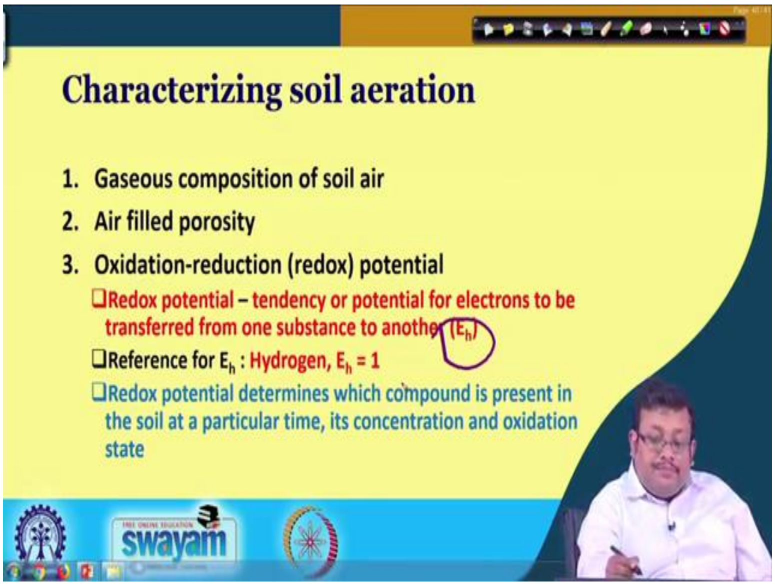

And let us see another very important term that is oxidation reduction potential or redox redox potential. Now, redox potential basically shows the tendency or potential for electrons to be transferred from one substance to another substance and this redox potential we generally term in terms of E_h. So, this redox potential generally it is in case of there should be a reference. So, in case of higher redox potential; obviously, there is a oxidized condition, lower redox potential generally, you know, indicates the reduced condition.

So, there should be some reference. So, in this case hydrogen; obviously, the redox potential is 1 and redox potential basically determines which compound, you know, is present in the soil at a particular time and its concentration and oxidation state. So, we will see that later on in the next slide probably.

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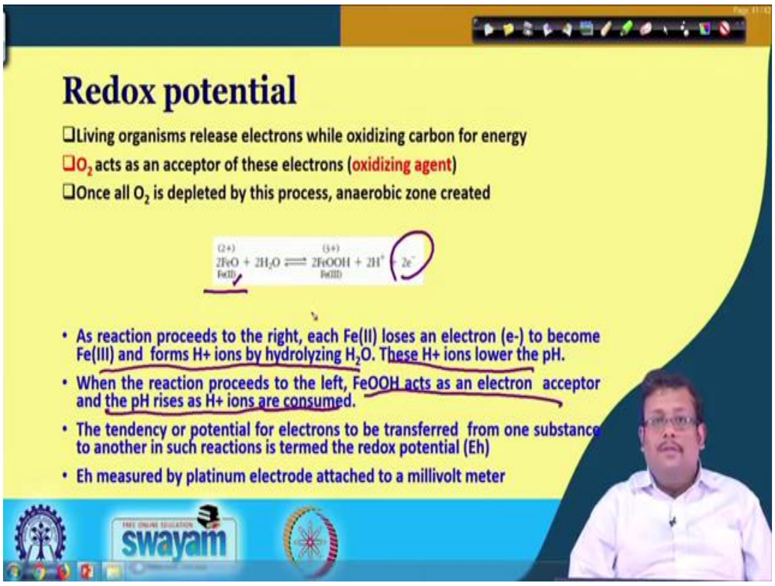

Yes so, redox potential; so, living organisms basically releases, we know, the basically electrons while oxidizing carbon for energy. So, in the soil; obviously, there are some organic carbons organic matter and organic matter contains huge amount of organic carbon. So, this living organism releases electrons while oxidizing carbon energy and these electron is accepted by oxygen. So, oxygen acts as an acceptor of electrons. So, it is or in other words it is an oxidizing agent.

So, once all oxygen is depleted by this process, anaerobic zones is created. So, let us see an example. So, if you go back and see an example; obviously, if you see this iron oxide, where the oxidation number of iron is plus 2, when it reacts with water it oxidizes to form this FeOOH and this electrons. And this electrons is basically being absorbed or being accepted by this oxygen which is further reduced into water will see that later on.

So, as the reaction process to the proceeds to the proceed to the right each Fe(II) losses an electron as you can see here and becomes an Fe(III) and forms H plus ions by hydrolyzing the H_2O. And these H plus ions lowers the pH of the soil. And when the reaction proceed to the left this FeOOH acts as an electron acceptor and the pH rises, as H plus ions are consumed. Because it is a you can see the reaction can go in both direction. And the tendency or potential of electrons to be transferred from one substance to another in such reactions, is termed as redox potential or E_h. And basically we measure E_h by platinum electron which is attached to a millivolt meter and generally redox is calculated in terms of millivolt or volt.

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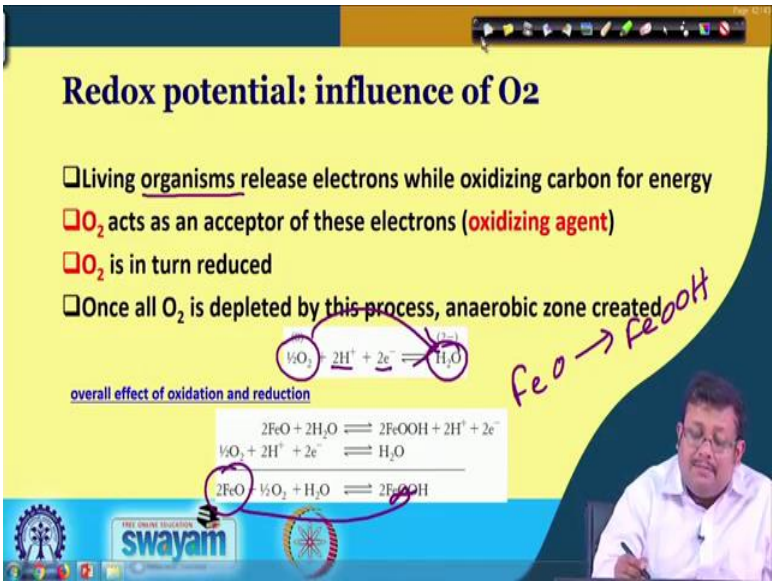

So, living organisms as a, you know let you know, that living organisms releases electrons while oxidizing carbon for energy and this oxygen, acts as an acceptor of these electron or in other words oxidizing agent. And in terms this oxygen get reduced that that all the oxygen reduced by this process anaerobic zone created. So, this oxygen acts as a oxidizing agent accepting electrons, which is related which is released by this living organisms by oxidizing carbon for energy ultimately produces the water.

So, oxygen basically is reduced to water while FeO you know oxidized to FeOOH. So, if we combine both two reaction will get overall effect of oxidation reduction, ultimately we will get the FeO will produce FeOOH. So, this is an example where oxidation reduction potential plays a significant role and it basically, we know, basically indicates the oxidation reduction of, we know, of some different substances.

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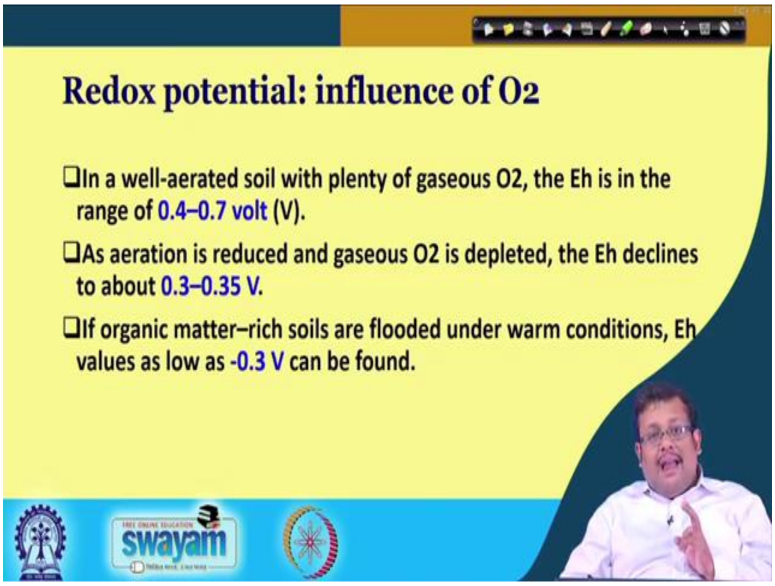

So, what are the different values of oxidation reduction potential? So, in a well aerated soil with plenty of gaseous of gaseous of oxygen in present, the Eh is in the range of 0.4 to 0.7 volt, and as aeration is reduced and gaseous oxygen is depleted, the Eh declines to about 0.3 to 0.35 volt, and if organic matter rich soils are flooded under warm condition Eh values as low as minus 0.3 volt can be reduced. And remember that when there is a high amount of organic matter present in a flooded condition, all the, you know, remember in the flooded. So, in flooded condition, all the air filled pores will be occupied by water. So, there will be no oxygen available for aerobic organisms to further oxidize this carbon.

So, these anaerobic or facultative anaerobic organisms will further act in this condition and these organisms will use some other compound like nitrate, sulphate as in at the electron acceptor instead of oxygen. And as a result of using those nitrate, sulphates and all this different molecules as electron acceptor, they will create a reduced condition or anaerobic condition. And in the anaerobic condition you will see that the Eh will reduced to negative that is minus 0.3 volt. So, different types of anaerobic reaction occurs and as a result of anaerobic reaction in the in the water logged soil, methane and other gases are formed.

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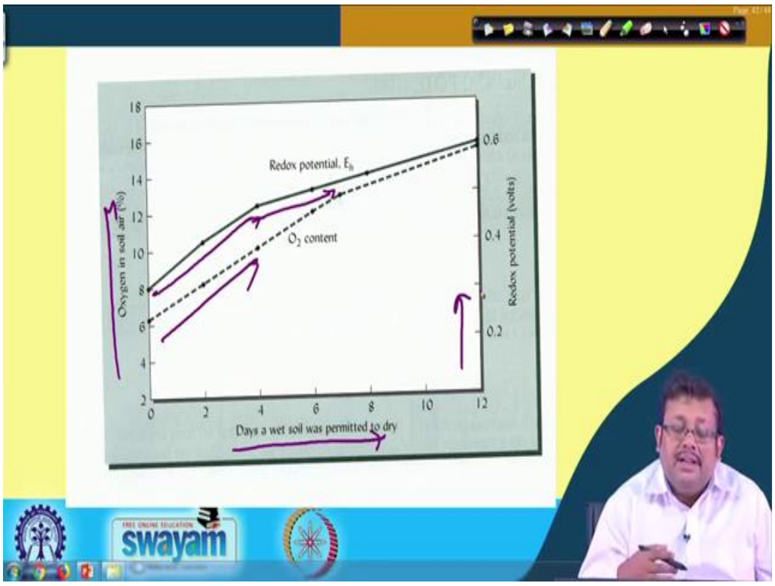

So, this slide basically shows that the relationship between the days a wet soil permitted to dry, days a wet soil permitted to dry in oxygen soil air. So, as you can see after a wet soil that is the saturated soil we allow it to dry, after passing of couple of days the redox potential increases because oxygen will enter into the pore spaces from which the water get evaporated and obviously, you know, as you can see from this curve and as a result of that, redox potential increases simultaneously. So, increase of redox potential indicates oxidation, decrease of redox potential indicates reduction condition.

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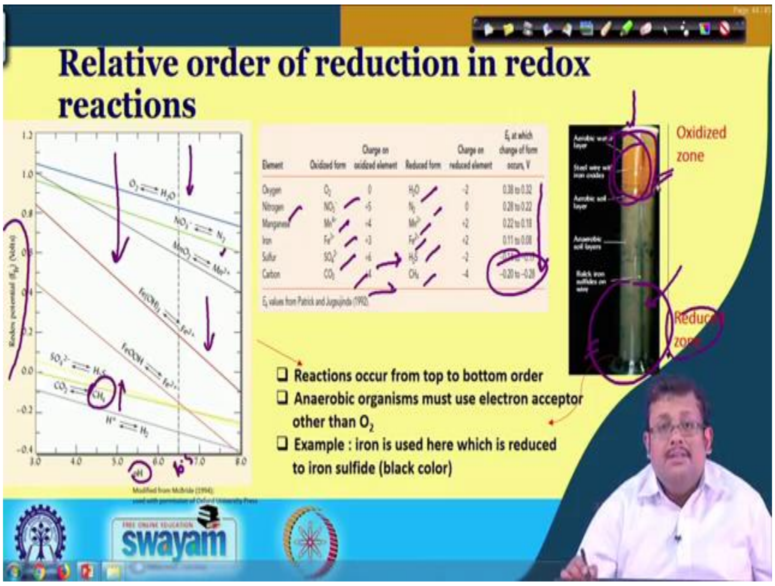

Now, this graph basically shows the relative order of reduction in redox condition, you can see we have presented here the relationship between pH and redox potential and obviously, when the reduction will start. Obviously, it will sends it will tell us in which order the different components which are present in to the soil, will undergo reduction. Now you can see in all this reaction, they are the reaction can go in both direction.

So, in the right side; obviously, the reduced step and the left side that is the oxidized step. So, oxidized stage; so, as the redox potential goes down obviously, the oxygen will be reduced to water followed by nitrate to nitrate will be reduced to nitrogen, gaseous nitrogen. Manganese dioxide will reduced to Mn 2 plus and ferric hydroxide will reduced to Fe 2 plus and so on so forth and ultimately you will see that formation of methane is there.

So, that is why the water logged condition as reduction is going on ultimately there will be release of methane. So, this chart this graph basically shows us the order through which the different, you know, different, you know, component of a soil will undergo reduction and obviously, remember that that the reaction always occur from top to bottom. So, if we conceder what pH 7 if we if we conceder while in pH 6.5; obviously, the nitrate will undergo reduction to nitrogen first and followed by MnO_2 to Mn 2 plus.

And this as basically shows the same thing and this also shows the changes in Eh, when one, we know, oxygen is converted to its reduced form, nitrogen is converted to its reduced form that is nitrate to elemental nitrogen then Mn 4 plus to Mn 2 plus, Fe 3 plus to Fe 2 plus, sulphate to H_2S and carbon dioxide to methane. So, all this reduction processes and you can see the Eh is continuously growing down and ultimately reaches negative when there is a high anaerobic condition.

So, this is also a called Winogradsky column and this Winogradsky column is basically shows a clear division between oxidized zone which you can see here and the bottom at the top, and at the bottom there will be reduced zone. So, basically this, you know, Winogradsky column, we generally insert mud and, we know, mixed with different organic matter and then put some water. And, as a result a iron wire we iron wire can be inserted here to show, you know, to show different changes due to the oxidation reduction.

As you can see as at the top, we know, oxidized zone can be formed; however, at the bottom there will be reduced zone. So, here iron is, you know, we are iron wire. So, at the bottom you can see it is producing the iron sulfide due to reduction condition ultimately producing the black color. However, at the top it is oxidized and producing this red color or orange color zone.

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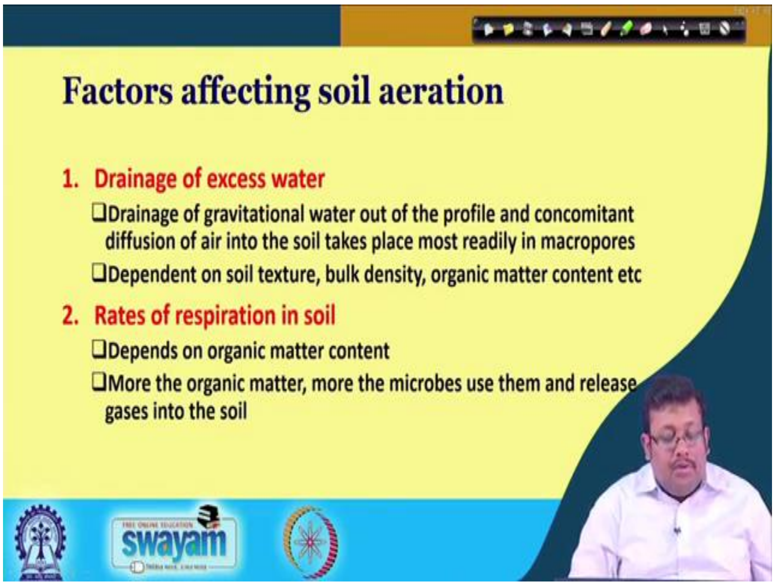

So, what are the factors, which affects soil aeration? There are several factors which affect soil aeration first of all drainage of excess water. So, drainage of gravitational water out of the profile and concomitant diffusion of the air into the soil takes place most readily in macropores you know that and it is basically depended on soil texture, bulk density, organic matter content.

Rates of respiration into the soil because it depends on organic matter content and more organic matter will be there and more microbes will use them and releases gases into the soil. So, more organic matter, more microbes will use and releases more gases. So, rate of respiration will also affects the soil aeration.

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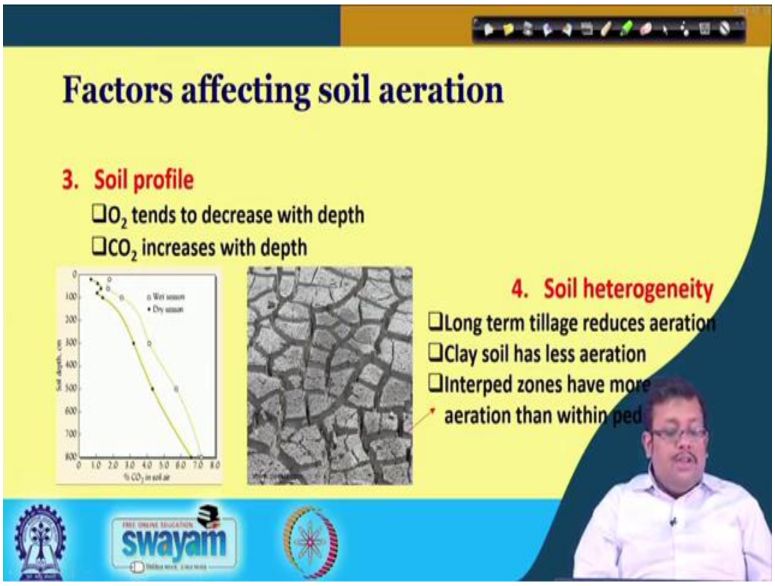

Soil profile as you can see oxygen tends to decrease with depth and carbon dioxide tends to increase with the depth and also soil heterogeneity takes part in, we know, in soil aeration. Obviously, in case of long term tillage reduces the aeration and clay soil has less aeration and obviously, remember that the interped zones have most aeration that within the peds.

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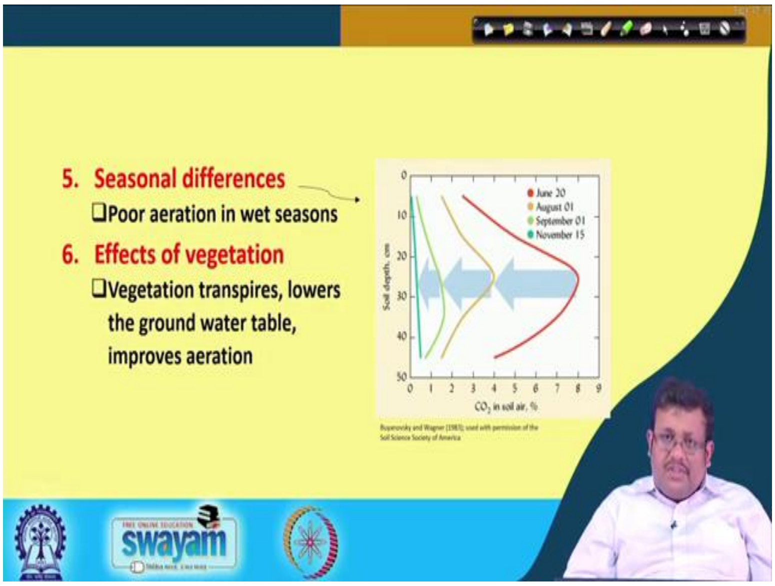

And seasonal differences also influences the aeration status; obviously, poor aeration you can see in the in the wet season, because all the pore spaces will be filled by water. So, aeration or water air movement will be slowed down. Effects of vegetation; obviously, vegetation, we know, transpires through their stomata and lowers the ground water table. And further as a result of this transpiration, it improves the aeration because they are removing the water from the soil creating more pore spaces, which can be occupied by air. And also there is some ecological effects of soil aeration.

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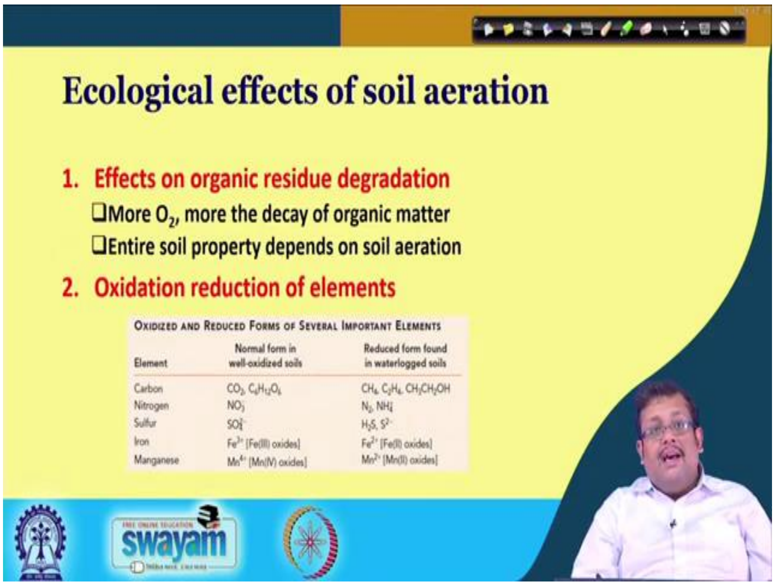

Now, let us wrap up here will start from here from the next lecture and will try to finish this topic and then will move to a new topic. But I hope that you have learned something new in this lecture and if you have any question feel free to email and feel free to ask me any question. So, let us meet in the next lecture with more discussion in soil aeration as well as we will start a new topic that is soil temperature.

Till then thank you and good bye.