Soil Science and Technology
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Lecture - 29
Soil Salinity and Alkalinity

Welcome friends to this new lecture of week-6 of Soil Science and Technology.

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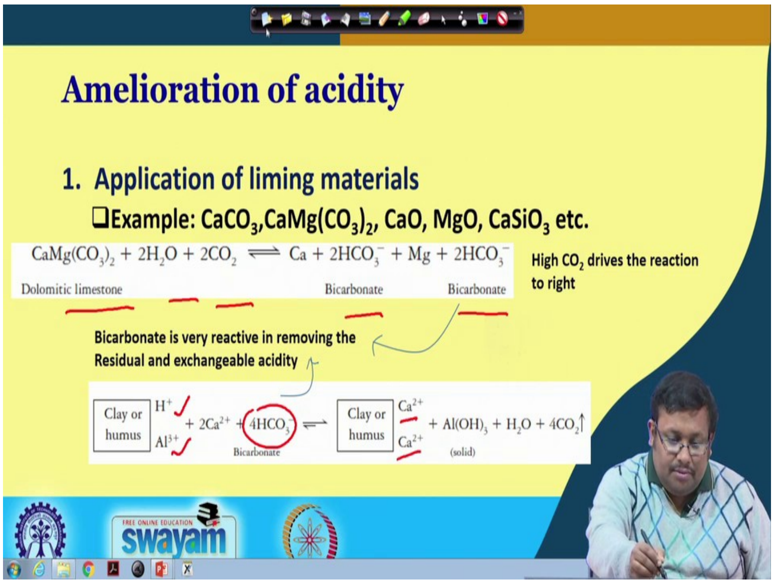

And in this lecture we will be completing the soil acidity which we started the last lecture, and then will be discussing about the Soil Alkalinity as well as you know and also about the soil sodicity and other you know problematic soils. So, in the last lecture, we covered up to this, and we started about we are going to start about the amelioration of the soil acidity. Now, amelioration of the soil acidity is generally done by application of liming materials that generally you know the most common apply you know the most common material which the you know the farmers and you know apply for correcting the soil acidity is called the lime or calcium carbonate.

Some other examples of liming materials are dolomitic limestone that is calcium magnesium carbonate, and then calcium oxide, magnesium oxide, calcium silicate etc. as we can see here. Now, I have given here the reaction of dolomitic limestone as you can see the dolomitic limestone is you know reacting with the water as well as the carbon dioxide. And this carbon dioxide basically you know occurs into the soil due to microbial respiration and as a result of that you know the bicarbonate and you know bicarbonate ions are formed.

Now, this bicarbonate is very reactive in removing the residual and exchange acidity. So, you can see this bicarbonate ion can remove these exchangeable H plus and Al_3 plus. And you know and ultimately these exchange sites are occupied by the calcium ions, and this is how the application of liming material you know ameliorate the problem of soil acidity.

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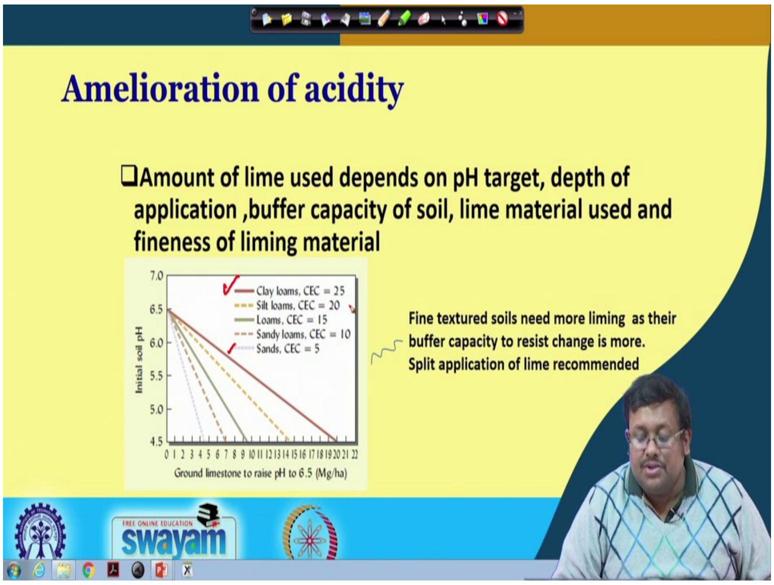

So, let us move ahead and see what is the relation between the ground limestone to raise the pH to a certain pH that is 6.5 an initial soil. So, you can see the amount of lime used depends on the pH target the depth of the application, then buffer capacity of soil liming material used and the fineness of the liming material. Obviously, the fine texture soil you know fine texture soil need more liming and as there buffering capacity as the buffer capacity to resist you know the change is more and you know the split application of lime is thus recommended.

So, you know in case of fine texture soil obviously the buffering capacity is more because of high cation exchange capacity. And so you can see here in this in this graph, obviously, there you know five different types of soils starting from clay loam to sands as you can see that clay loam is exhibiting the highest CEC. So obviously, you know the ground lime stone required to raise the pH to 6.5 is you know is quite higher in case of clay loams as compared to sands.

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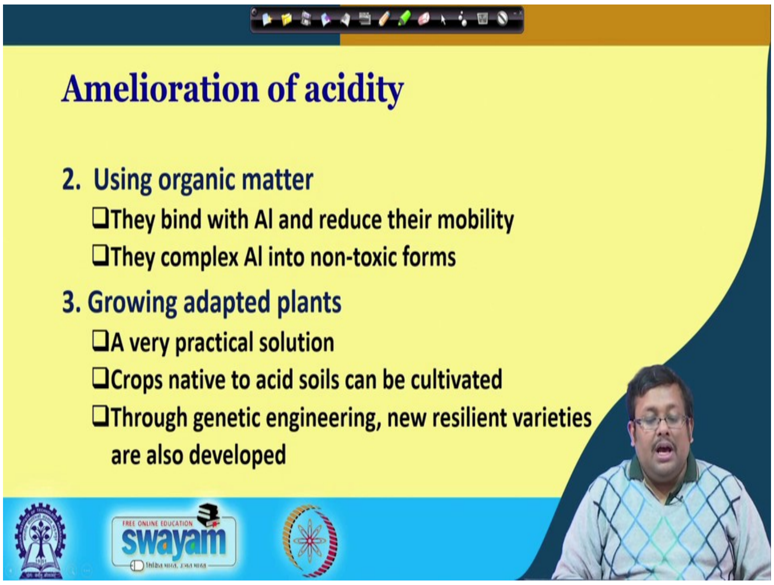

So, let us move ahead and see what are the other ways of ameliorating the soil acidity. Obviously, using organic matter is another way because they bind with the aluminum and reduce their mobility and aluminum you know in they are very toxic in you know in acid soil. And the complex aluminum this organic matter basically the humus you know the humus portion basically they form complex with aluminum into the non-toxic forms.

So, these are the beneficial use of you know organic matter in case of acid soil. Another one is the growing of different in the adapted plants. For example, it is very, very practical solution, and you know crop native to acid soil can be cultivated in acid you know prone area. And also through genetic engineering and new you know resilient varieties can you know is being developed all the time by plant breeders. So, we can use those tolerant crops for this type of region.

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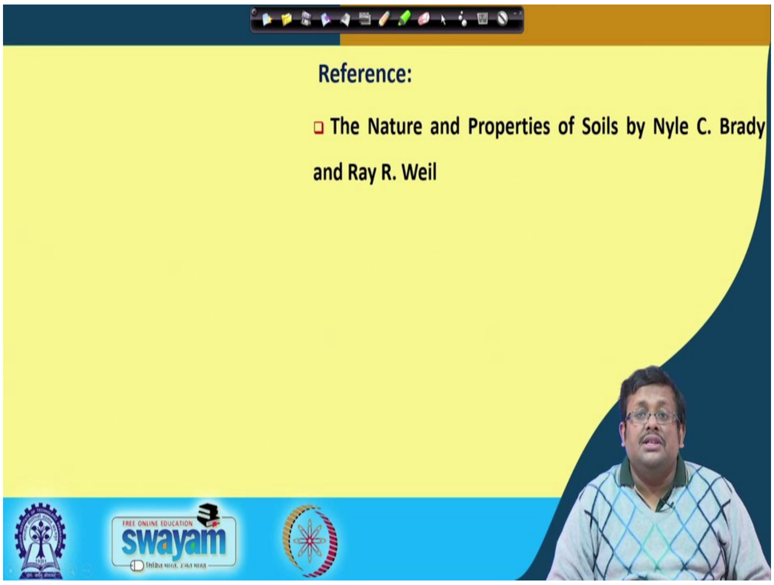

So, guys we have completed this soil acidity and the references again The Nature and Properties of Soil by Nyle C Brady. So, I hope you have gone some you have got some knowledge about the soil acidity. Obviously, let us move ahead and see what is soil alkalinity and salinity. So, these are two important problematic soils which is which we are going to discuss now.

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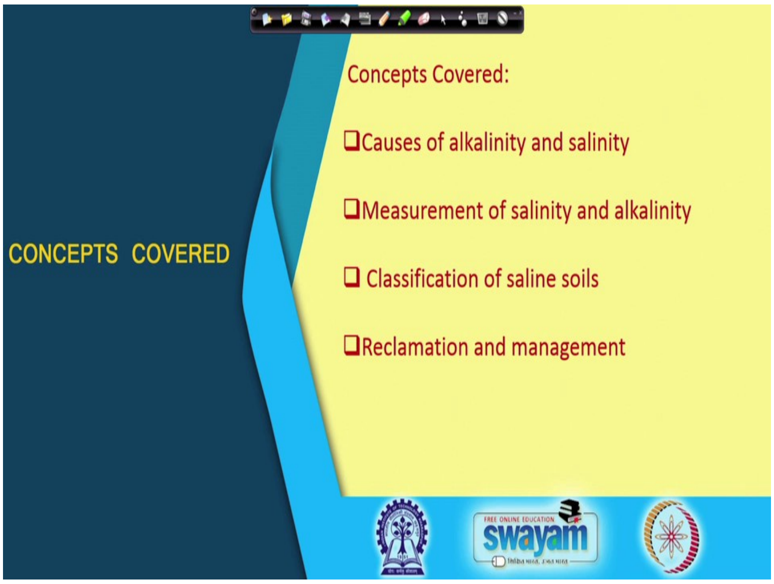

Now, the concepts which will cover are the causes of alkalinity and salinity, then how we measure salinity and alkalinity, then classification of the saline soil, and then how to reclaim and management of reclamation and management of those saline and alkaline soil.

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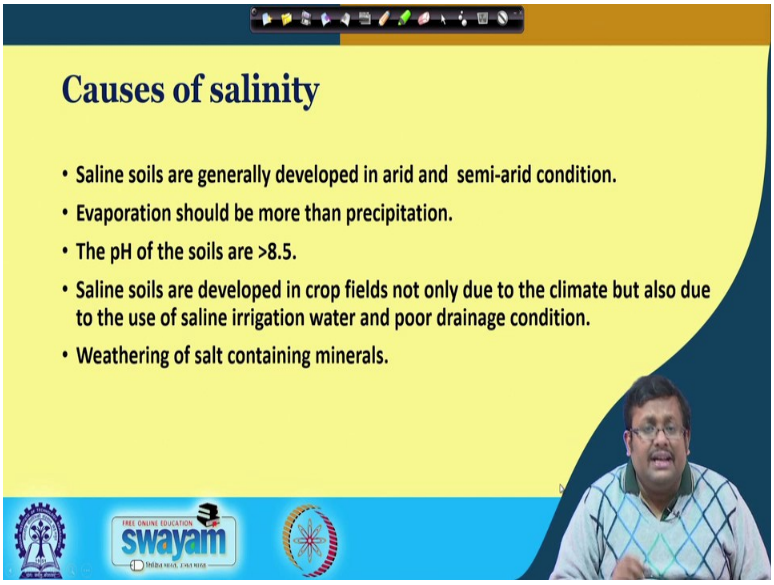

Now, let us see the what is the causes of salinity. Obviously, saline soils are generally developed in arid and semi-arid condition. And in this condition you know that evaporation or evaporative demand is more higher and evaporation should you know is more is higher than that of precipitation. So, as a result of that the pH of the soil you know you know are generally you know sometime greater than 8.5 or less than 8.5.

So, saline soils are developed in crop field not only due to the climate, but also due to the use of saline irrigation water and poor drainage condition and weathering of salt containing material. So, these are couple of reasons of this you know soil salinity problem.

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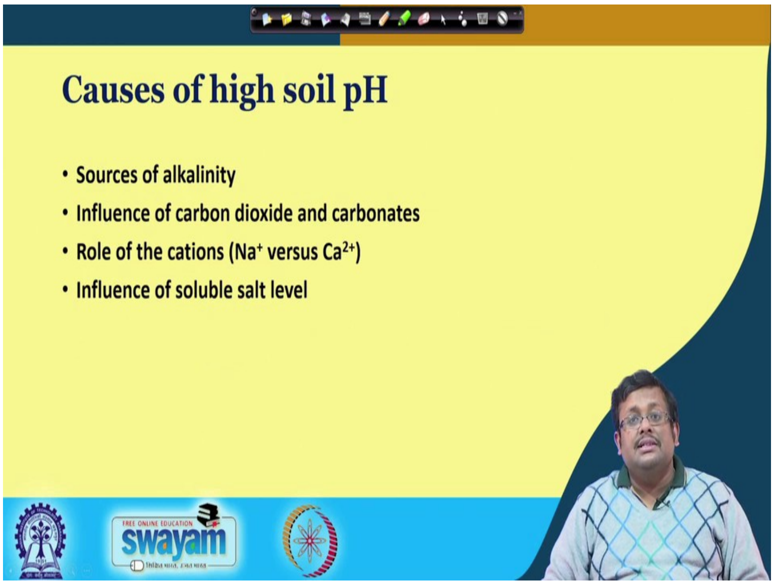

So, let us move ahead and see what is the reason behind and what are the causes of high soil pH or soil alkalinity. Now, there are different you know different ways of creating soil alkalinity; first of all the different sources of soil alkalinity and also their influences of carbon dioxide and carbonates for development of soil alkalinity. Finally, there are roles of cations like sodium versus you know calcium and then influences of soluble salt. So, we will discuss them one by one.

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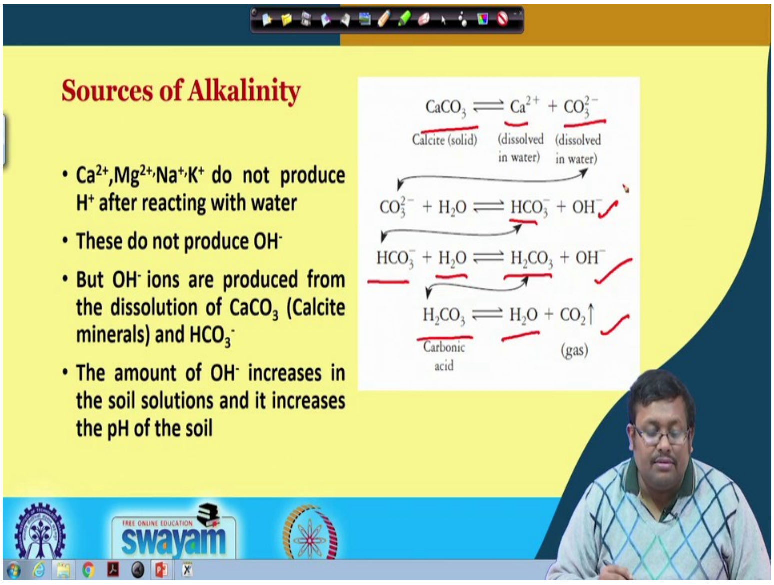

So, let us start with the source of alkalinity. Now, you know that calcium magnesium sodium potassium do not produce you know protons after reacting with the water as aluminum do aluminum does. So, these basically these are the basic cations, this basic cations do not produce you know also hydroxyls. So, these basic cations do not produce proton or hydroxyls. However, these hydroxyl ions are produced from the dissolution of calcium carbonate that is calcite minerals and bicarbonate. So, so as you know as you can see here the calcium carbonate and calcite been dissolved into calcium 2 plus and carbonate these carbonate is basically dissolved in water.

So, further this carbonate reacts with water to produce bicarbonate as you can see the hydroxyl ion is continuously generating. Then in the next step these bicarbonate is again you know will react with water to produce carbonic acid and then again the hydroxyl ions. And this you know carbonic acid again will disassociate to form H_2O and carbon dioxide. So, you can see these calcium carbonate basically due to the presence of carbonate, they are basically generating this hydroxyl ions. And as a result of this you know generation of this hydroxyl ions, ultimately this the soil pH is getting increased. So, these this is one of the reason of getting this alkaline soil. So, remember this equation this equation will be required for understanding our next slide.

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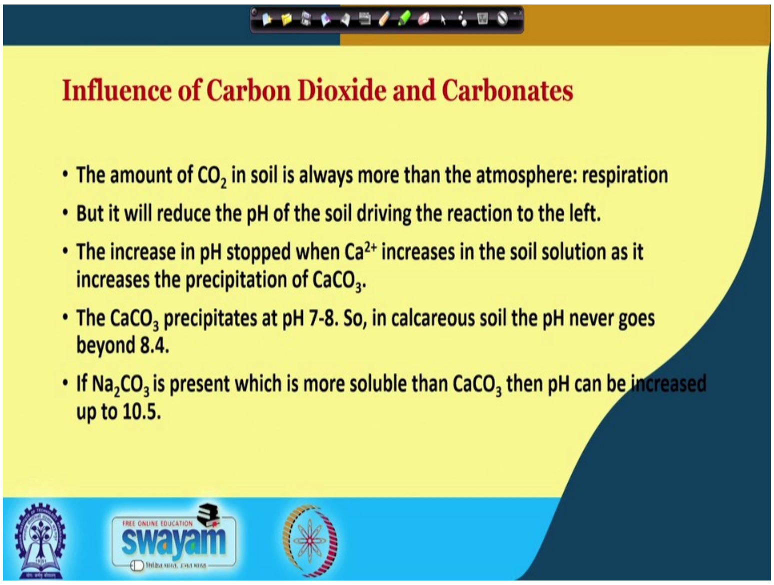

So, if we see here, what is the influences of carbon dioxide and carbonates. So, if you go back you can see here that the carbon dioxide is generating. So, the starting obviously, calcium carbonate and carbon dioxide, so the generation of soil alkalinity obviously depends on the either the precipitation of the calcium carbonate or the removal of carbon dioxide. So, in which direction the reaction will move will depends on these two factor. First of all, the precipitation of the calcium carbonate and as well as the evaporation or the removal of carbon dioxide which is produced.

So, if we see the amount of carbon dioxide in soil is always more than atmosphere because of respiration you know that, but it will reduce the pH of the soil driving the reaction to the left. So, if you see the previous reaction again if the concentration of the carbon dioxide you know is higher, obviously the reaction will drive in the in the left direction, so the reverse direction. So, obviously, there will be reduction of the pH. And as a result of you know so this carbon dioxide do not help in generation of the soil alkalinity.

Now the increase in pH obviously will stop you know pH stop and when calcium increases the soil solution as it increases the precipitation of the calcium carbonate. Now, you see the previous slide, calcium carbonate dissolution is required for the generation of alkalinity. However, if the calcium concentration in the soil solution increase, so obviously, this calcium carbonate will precipitate. And when that it will precipitated obviously, the dissolution will be reduced. So, when the dissolution of the calcium carbonate is reduced, obviously, there will be less generation of alkalinity or the soil alkalinity generation will be stop there.

So, the calcium carbonate precipitates at pH 7 to 8. So, in calcareous soil the pH level goes to never goes beyond 8.4. So, this is very important calcareous soil is the soil where you will have high amount of calcium. So, calcium carbonate precipitated at pH 7 to 8, and in calcareous soil thus the pH never goes beyond 8.4, because calcium carbonate is not further dissolving out. And however, if sodium carbonate is present which is more soluble than calcium carbonate, obviously, the pH can be increased up to 10.5. And this type of pH you can see in case of sodic soil or alkaline soil, we will see that.

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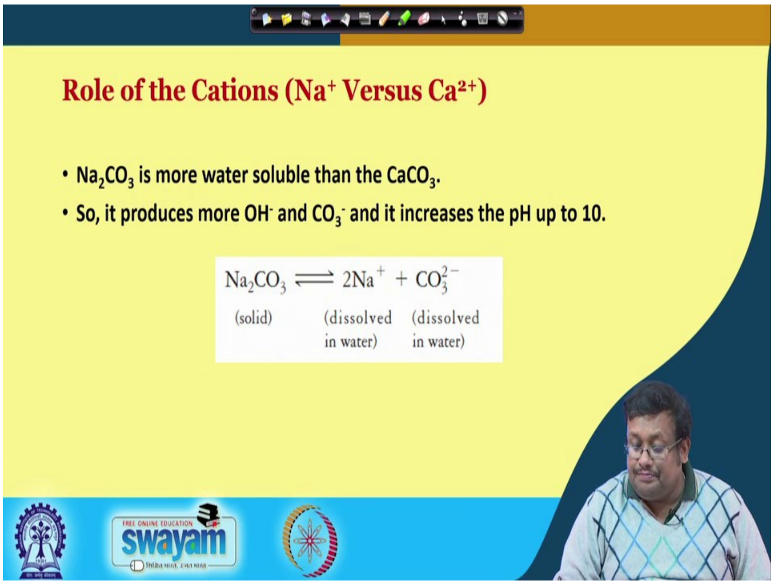

So, further another causes the role of cation that is sodium versus cation calcium. So, sodium carbonate is more water soluble as I have already told you sodium carbonate is more water soluble than that of calcium carbonate. So, it produces more hydroxyl and carbonate and it is and it increases the pH up to 10. So, obviously, you can see here sodium carbonate is dissolving to produce the sodium cations as well as carbonate and which I will you know ultimately increase the soil pH this carbonate.

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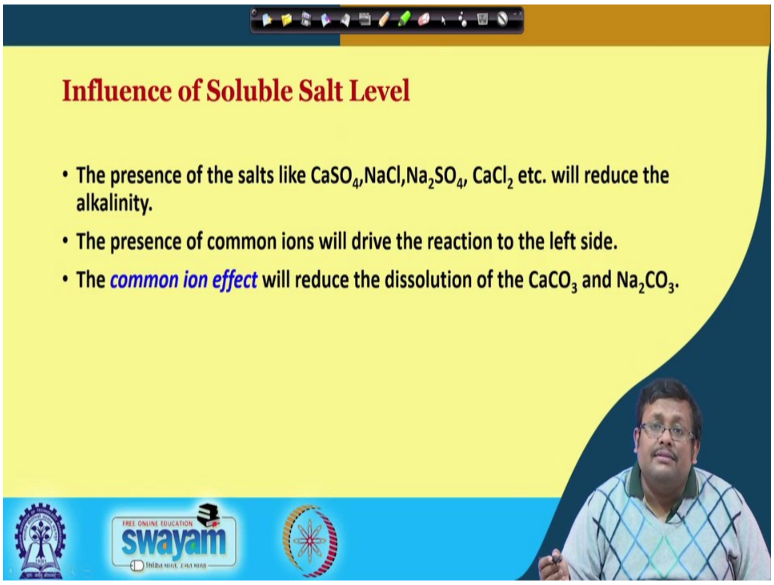

Now, another cause is influence of soluble salt level. So, the presence of salt like calcium sulphate, sodium sulph, chloride sodium sulphate calcium chloride these are neutral salt. So, will reduce the alkalinity because the presence of common ions like in case of you know the presence of common ions for example, in case of sodium chloride. So, the common ion here is sodium. So, the presence of sodium or in case of calcium sulphate, the presence of calcium will drive the reaction to the left side.

So, this is called common ion effect and this common ion effect will reduce the dissolution of calcium carbonate and sodium carbonate because already the common ion is present in the soil solution. So, as a result of these when these type of salts are presents into the soil solution, obviously the reaction will go to the left side and obviously, the soil saline soil alkalinity will reduce or soil alkalinity development will be stopped.

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Now, the development of salt-affected soils, obviously, accumulation of salt in non-irrigated soils and irrigation induced salinity and alkalinity are the major reason for salt-affected soil. You can see here a white crust of soil found you know in case of saline you know in highly saline zone of soils. So, so these are two important reason behind development of salt-affected soils.

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So, in case of accumulation of salts in non-irrigated area, you can see here under the deep-rooted perennial vegetation as you can see here. So, this is a deep-rooted perennial vegetation you know transpiration, obviously, is high and the water table is kept low. So, this is one condition. So, if we go for agriculture operation there, so in case of agricultural crops, the length of the roots are small obviously, because they are the field crops.

So, you know the length of the shorter length of the field crops shorter length of the root of the field crops causes groundwater to rise by capillary flow to the surface. And as a result of this, these you know this groundwater laden with salt will go to the top of the surface and then deposit there, and as a result there will be salt formation or salty soil formation. So, these are two reason of saline soil development in non-irrigated soil.

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However in case of irrigated condition you know the irrigated water may contain huge amount of huge or very less amount of salts. And if the field has not adequate drainage system, continuous evaporation accelerates the chance of salt accumulation, because the salt laden water will move towards the surface of the soil by capillary movement and then there will be the deposition of the salts. So, salt tends to accumulate the highest point of the soil surface from which part evaporation loss is the highest. So, this is very important point you should keep in mind.

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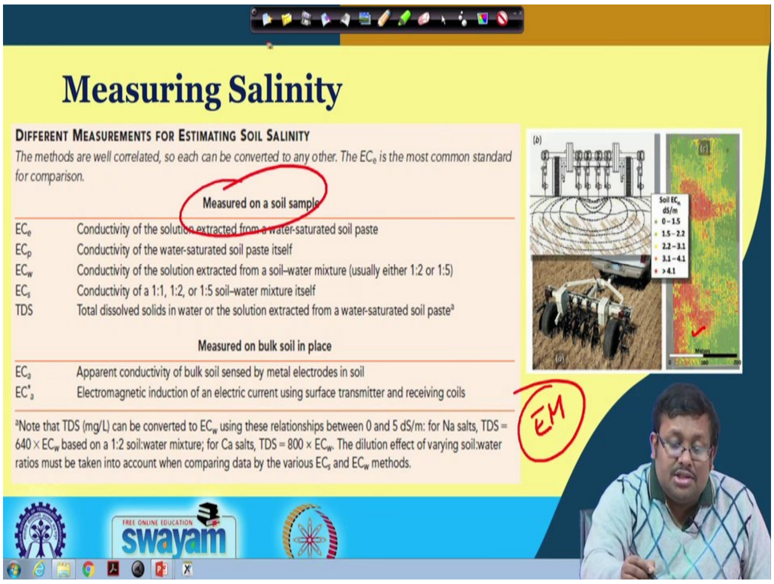

Now, how we measure the soil salinity. Obviously, there are different methods for measuring the soil salinity. You know if we if we want to measure a, if we want to measure the soil salinity of a sample soil sample itself, obviously, there are four to five different ways. First of all ECe which is basically the conductivity of the saturated extract from you know water saturated soil. So, we will make a soil paste and we keep it overnight and we extract the water and measure the conductivity. So, this is called ECe.

The second is ECp which is the conductivity of the water saturated soil paste itself. So, if we measure the conductivity of the soil paste itself, we call it ECp. Third one is ECw that is conductivity of the solution extracted from salt soil water mixture usually either 1 is to 2, or 1 is to 5. It is one of the major you know most common adapted practice in laboratory measurement of soil salinity. So, generally we measure the you know 1 is to 2, 1 is to 2 soil water suspension we make it 1 is to 2 soil water suspension, and then we dip the electrode to get the electrical conductivity.

ECs is basically the conductivity of 1 is to 1, 1 is to 2, and 1 is to 5 soil water in mixture itself. So, when there is a mixture itself we dipped the you know electrode of the EC meter and then it will give us the ECs rating. Finally, TDS, TDS is total dissolved solids. So, total dissolved solids in water or the solution extracted from the water saturated soil paste. So, it measures this salinity.

And another the other two method for measuring salinity in bulk soil is in place in place is ECa which is apparent conductivity of bulk soils says by metal electrodes in the soil. And secondly, ECa which is electromagnetic induction and of an electric current using surface transmitter and receiving coil. So, there is a instrument called EM instrument. So, this EM instrument basically measure these electromagnetic induction and indirectly it measures the salt content the of the soil.

So, nowadays some advanced sensors are measure a advance sensors are produced in the on the go you know basically they are on the go censors. They are fitted into the driving vehicle. And this driving vehicle basically surrounds that field you know go through you know different parts of the field, and as a result is as a result of that we can see there is a real time generation of soil salinity map. So, these are some advanced method of producing the salinity map which are you know generally being adopted in you know in advanced countries like US and Europe. So, these are some common methods of measuring the soil salinity.

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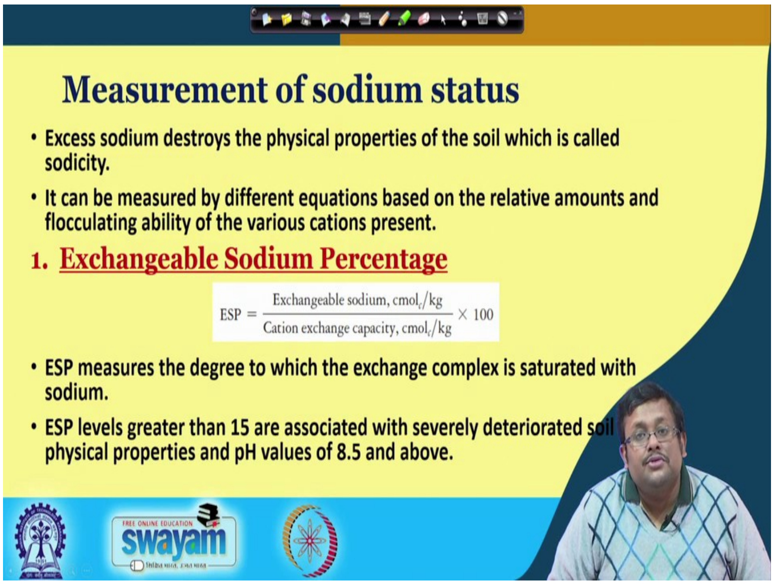

So, let us go ahead and see what is the measurement of sodium status. So, now, we have covered the salinity saline soil. Now, let us move towards the sodium soil. Now, excess sodium destroy the physical properties of the soil which is called the sodicity, and it can be measured by the different equation based on the relative amounts at the flocculating ability of the various cations present.

So, one of the major indicator of sodium status is ESP or exchangeable sodium percentage, that the formula of ESP is basically exchangeable sodium over the cation exchange capacity by multiplied by 100. So, ESP measure the degree to which the exchange complexes is saturated with sodium. Remember that the cutoff value of ESP is 15. If the ESP value of a soil is greater than 15, with the soil is considered as a sodic soil. And pH values of those soil is generally greater than 8.5.

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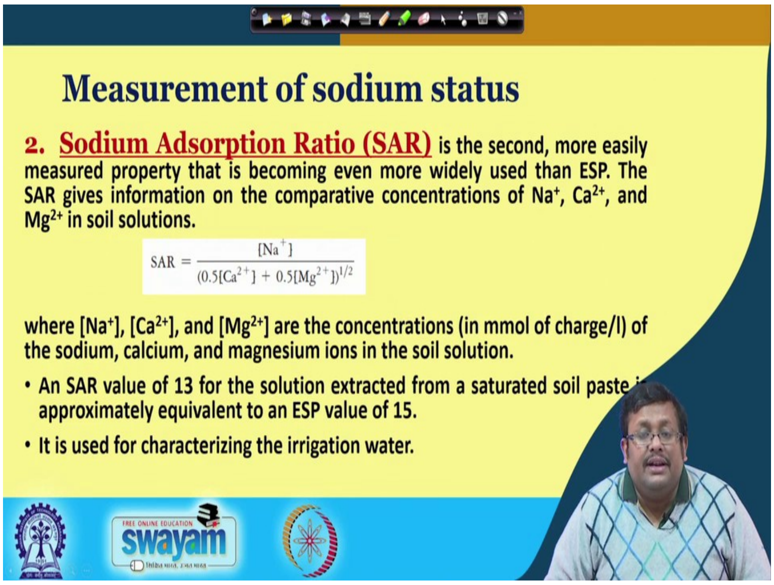

Now, another important index of sodium status is sodium absorption ratio or SAR. Now, it is the second most easily measured soil property that the its becoming more widely used than ESP. And the SAR gives formation information of the comparative concentration of sodium, calcium and magnesium in soil solution. Now, you can see the formula of SAR is basically the sodium concentration over the you know over the square root of half of calcium concentration and half of magnesium concentration.

So, when sodium, calcium and magnesium are the concentration in millimole you know millimole of charge per liter of the sodium, calcium and magnesium ions in the soil solution. So, in SAR value again remember that in case of SAR the cut off value is thirteen. So, when the SAR value goes beyond 13, that means, it is sodic soil. Now, SAR value SAR value of 13 is equals to ESP value of 15. So, these are basically equivalent now it is basically used for characterizing the irrigation water.

So, we have learned there are two index of soil sodium status or you know sodium status of irrigation water. One is the ESP that is exchangeable sodium percentage the cutoff value is 15. If it is more than 15, then the soil is sodic. If it is less than 15 soil is non-sodic. And there is a another sodium adsorption ratio or SAR which is where the cutoff value is 15. If it is more than 15, then it is you know if it is more than 15, then it is sodic soil. If it is less than 15, that is non-sodic condition.

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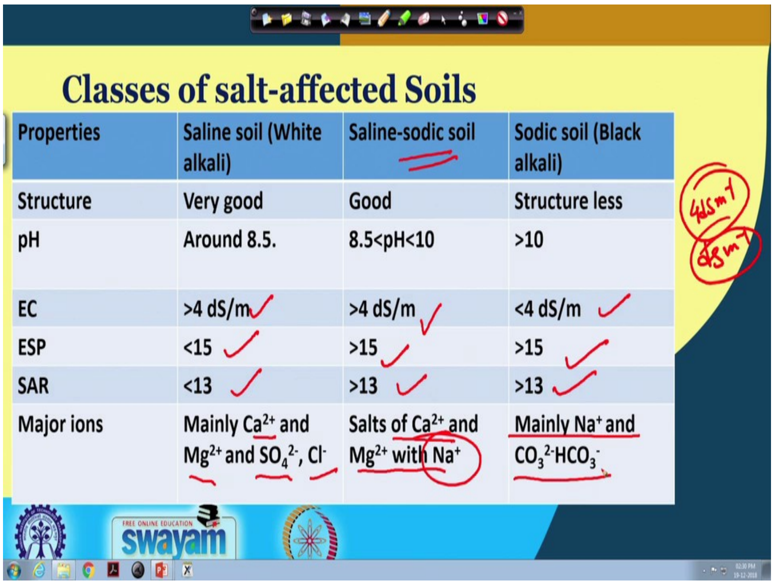

Now, you know classes of salt-affected soil, obviously, the classes of salt effected soil you can see there are three different types of soil, obviously, one is saline soil or you know white alkaline soil, and saline sodic soil and finally, the sodic soil which is black alkali soil. Now, the regarding the structure the saline soil has very good structure where as the saline sodic soil has good structure. However, sodic soil the structure is destroyed, we will discuss why.

The second pH in case of saline soil is around 8.5. And in case of saline sodic soil it is it is from 8.5 to 10. And in case of sodic soil, it is generally greater than 10. Now, in case of EC e obviously, in case of you know oh remember one thing I forgot to mention that in case of saline and non-saline soil the cut off value is 4 deci siemens per meter. Now, this is deci siemens per meter is the unit of measuring the electrical conductivity and 4 is the critical value. So, the 4, when the soil is having more than 4 deci siemens per meter you know electrical conductivity then the soil is saline; and when it is less than 4, then the soil is normal.

So, you can see here in case of saline soil, obviously, the EC is greater than 4 deci siemens per meter. In case of saline sodic soil it is also greater than 4 deci siemens per meter. However in sodic soil it is less than 4 deci siemens per meter. In case of saline soil, obviously, it is non sodic. So, it is less ESP is less than 15. So, in case of saline sodic soil, since the term sodic is there, obviously, the ESP will be greater than 15, and obviously, in case of acidic soil there will be higher ESP or greater than 15 ESP. The SAR in case of saline soil is obviously, less than 13. And in case of saline sodic soil it is greater than 13, because the sodic term is there. And in case of it sodic soil, obviously, it will be greater than 13.

What are the major ions? Now, major ions in case of saline soils are calcium, magnesium, sulphate and chloride. And in case of a saline sodic soil, obviously, salt of calcium and magnesium with some amount of sodium. However, in case of sodic soil, they are mainly sodium and carbonate and bicarbonate. So, propound the predominance of sodium in the soil exchange complex mainly makes the soil sodic in nature. So, we have we have seen the classification of the salt-affected soil.

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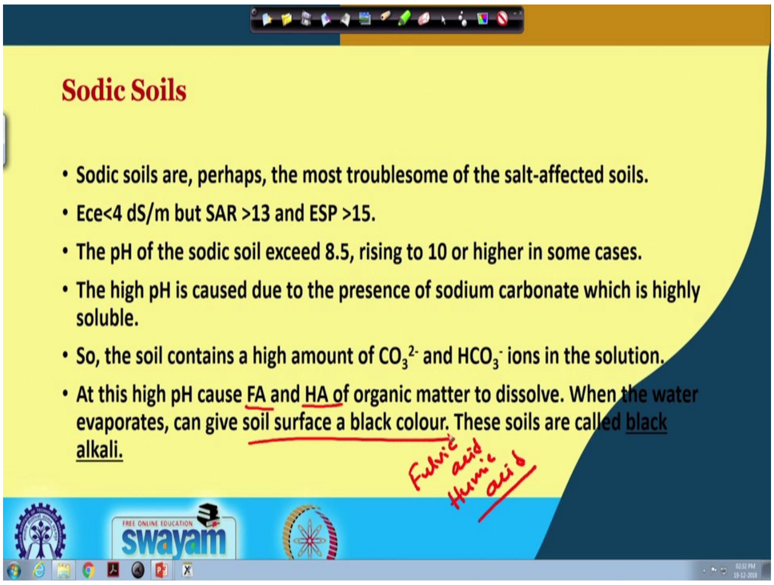

So, let us go ahead and see some more important aspects of sodic soil. The sodic soil are perhaps the most troublesome salts of salt-affected soils. And basically the EC is less than 4 deci siemens per meter, but the SAR that is the sodium absorption ratio is greater than 13 and ESP is greater than 15. And the pH of sodic soil exceed 8.5 rising to 10 or higher in some cases. And the high pH is caused due to the presence of sodium carbonate which is highly soluble.

So, the soil contains high amount of carbonate and bicarbonate ions in the solution, obviously, because so either way they are either there is a sodium carbonate or sodium bicarbonate ions in the solution. They are producing high amount, their presence in the high amount. And at this high pH cause you know at this high pH when the pH goes beyond 8.5 sometimes 10. The fulvic acid and humic acid I will discuss this later on in details with fulvic acid and humic acid these are two fraction of humin you know these are two important fraction of soil humus. We will discuss in details when will discuss the soil organic matter.

Now, for this time for the time being you remember that this fulvic acid and you know humic acid, fulvic acid and humic acid, these two are at high pH they will dissolve. And when the you know water evaporates it can give the soil surface a black colour because humus is by nature black in colour at this soils thus are called the black alkali soils. So, sodic soils are also known as black alkali soil when they are black in colour due to the due to the you know due to the dissolution of fulvic acid and humic acid due to high pH condition.

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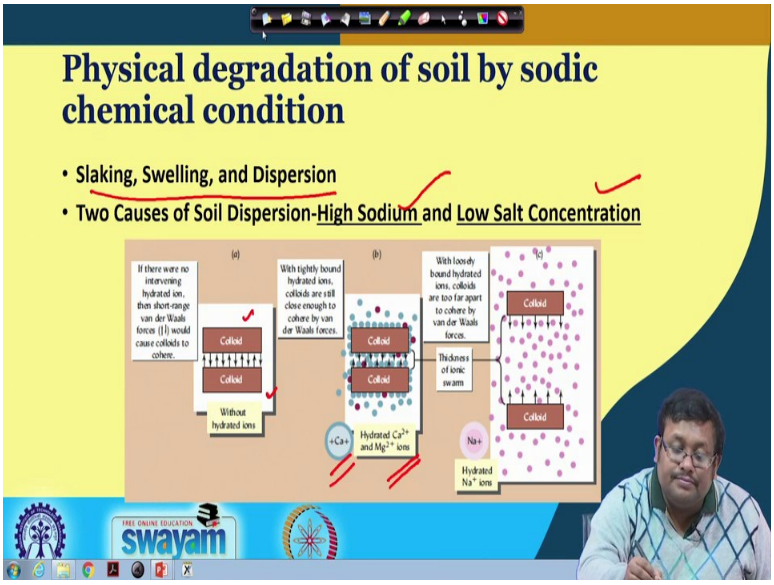

Now, why this sodic soils creates physical degradation. Now, you see here, obviously, when the exchange complex is dominated by sodium they create this slaking swelling and dispersion. And obviously, there are two causes of soil dispersion one is high sodium and low salt concentration obviously. So, you know that in case of soil colloid we have already learned that without if there is though there is no hydrated ions. So, if there no intermingled hydrated ion short range Van der Waals force would cause collide to the and form the you know coagulation or form the you know the aggregates.

So, the Van der Walls force will dominant in case of in case of absence of any hydrated iron. And when this tightly bound hydrated ions like calcium are present in the in the colloids, the colloids has still close enough to cohere by Van der Walls forces you can see here. So, the presence of calcium can produce the soil coagulation. However, when the loosely bound hydrated ions like sodium is present collide you know collide are too far apart to cohere by the Van der Walls force, then as a result of that there is a complete dispersion.

So, when there is a complete dispersion; obviously, there will be soil compare soil crusting and all this unfavorable condition will be there. And as a result of the as a result of these, there will be germination problem for the soil because all the germination problem for the plant because all the individual soil particles will clog the soil. And they will restrict the water and air movement from atmosphere to the, you know from atmosphere to the soil and ultimately this will also reduce the germination of the plant. So, this ultimately creates a very very unfavorable condition for crop growth.

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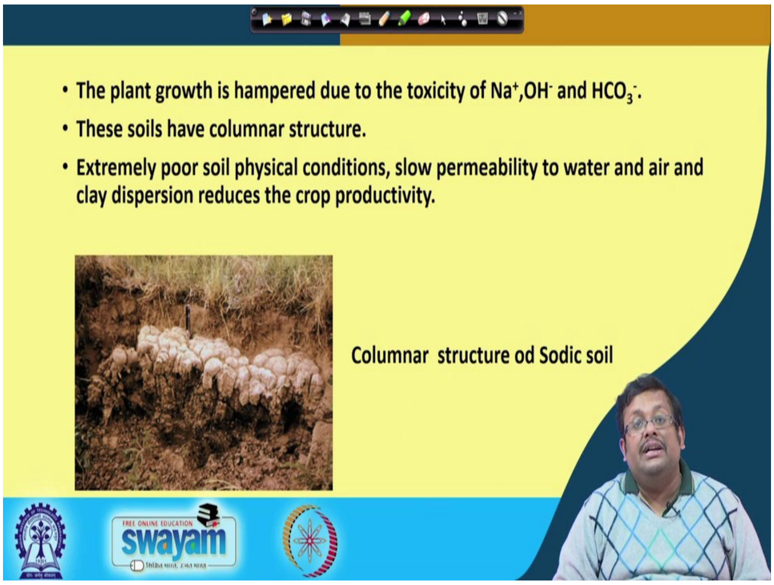

So, the plant growth is hampered due to the toxicity of sodium hydroxide and bicarbonate, obviously this another reason. So, toxicity the plant growth is hampered due to the toxicity of sodium hydroxyl and bicarbonate. And these soils have basically have columnar structure; we have learned about the columnar structures. So, these alkali soils will show you the columnar structure and you can see in this picture. And they are having extremely poor soil physical conditions, slow permeability to water and air and clay dispersion reduces the crop productivity. And so these are some features of these are some features of soil alkalinity or alkaline soil.

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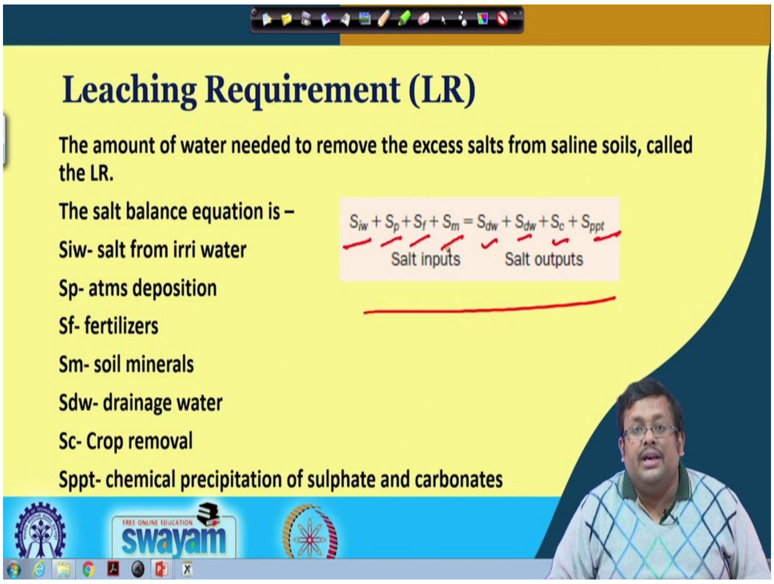

So, what is the leaching requirement? This is another important term. So, the leaching requirement is basically the amount of water needed to remove the excess salts from the saline salt called and you know let us see the what is the salt balance of equation. So, salt balance equation shows that is Siw which is salt from irrigation water plus Sp which is the atmospheric deposition, then Sf which is salt coming from fertilizers, then Sm that is soil coming from minerals equals to summation is equals to obviously, which is soil which is present in drainage water.

And, then Sc which is crop removal salt through crop removal, and Sdw which is salt removed through drainage water and obviously, salt precipitated. So, chemical precipitation of the sulfates and carbonates, these are also important. So, these four process and these four process generally balances themselves. So, this called salt balance equation.

So, guys let us stop here and we will start from here in the next lecture, and then will see the equation of leaching requirement and we will solve you know we will solve some problems of leaching requirement.

Till then thank you.