

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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Amelioration of acidity

1. Application of liming materials

□ Example: CaCO_3 , $\text{CaMg}(\text{CO}_3)_2$, CaO , MgO , CaSiO_3 etc.

$\text{CaMg}(\text{CO}_3)_2 + 2\text{H}_2\text{O} + 2\text{CO}_2 \rightleftharpoons \text{Ca} + 2\text{HCO}_3^- + \text{Mg} + 2\text{HCO}_3^-$

Dolomitic limestone Bicarbonate Bicarbonate

High CO_2 drives the reaction to right

Bicarbonate is very reactive in removing the Residual and exchangeable acidity

Clay or humus H^+ Al^{3+} + 2Ca^{2+} + 4HCO_3^- \rightleftharpoons Clay or humus Ca^{2+} Ca^{2+} + $\text{Al}(\text{OH})_3 + \text{H}_2\text{O} + 4\text{CO}_2 \uparrow$

Bicarbonate (solid)

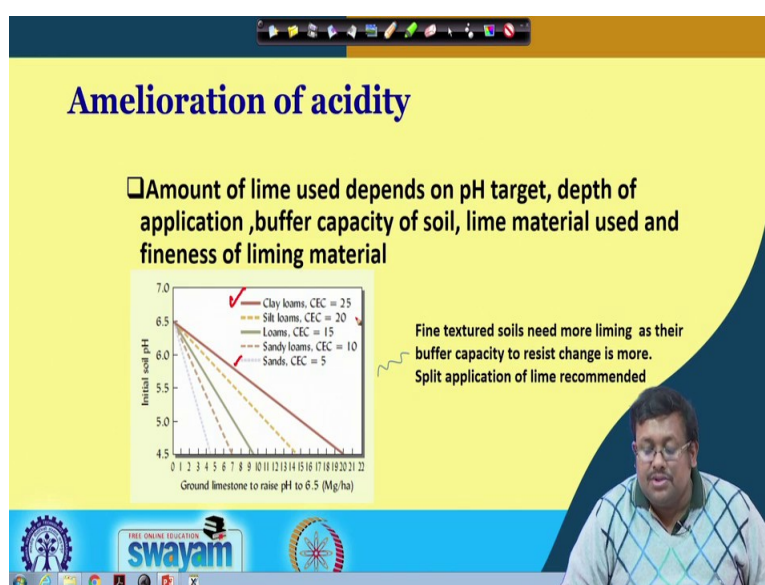
And in this lecture we will be completing the soil acidity which we started the last lecture, and then will be discussing about the Soil Alkalinity as well as you know and also about the soil sodicity and other you know problematic soils. So, in the last lecture, we covered up to this, and we started 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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Amelioration of acidity

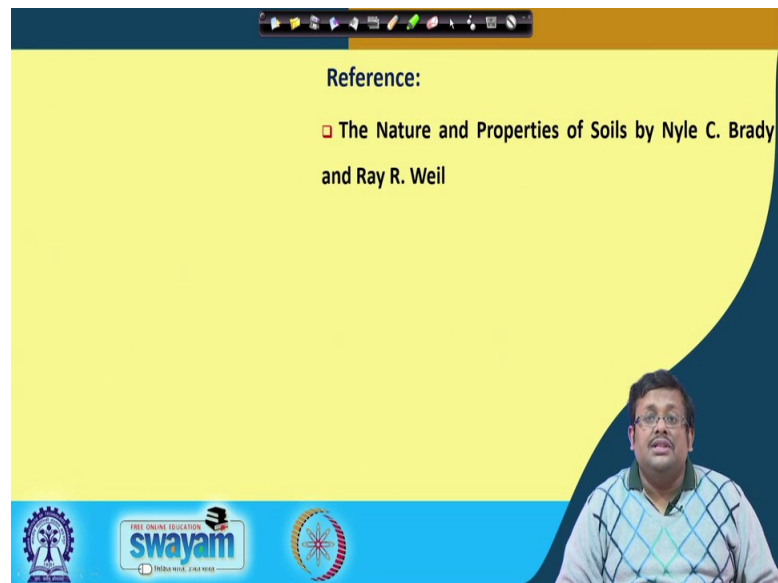
2. Using organic matter
 - They bind with Al and reduce their mobility
 - They complex Al into non-toxic forms
3. Growing adapted plants
 - A very practical solution
 - Crops native to acid soils can be cultivated
 - Through genetic engineering, new resilient varieties are also developed

Logos at the bottom: IIT Bombay, Swayam (Free Online Education), and a circular logo with a sun-like symbol.

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.

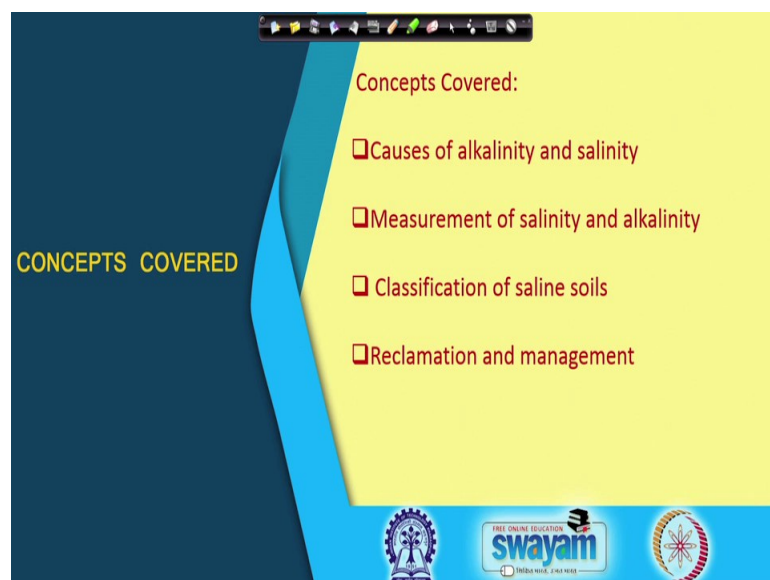
So, these are the beneficial use of you know organic matter in case of acid soil. Another one is the growing of different in the adapted plants. For example, it is very, very practical solution, and you know crop native to acid soil can be cultivated in acid you know prone area. And also through genetic 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.

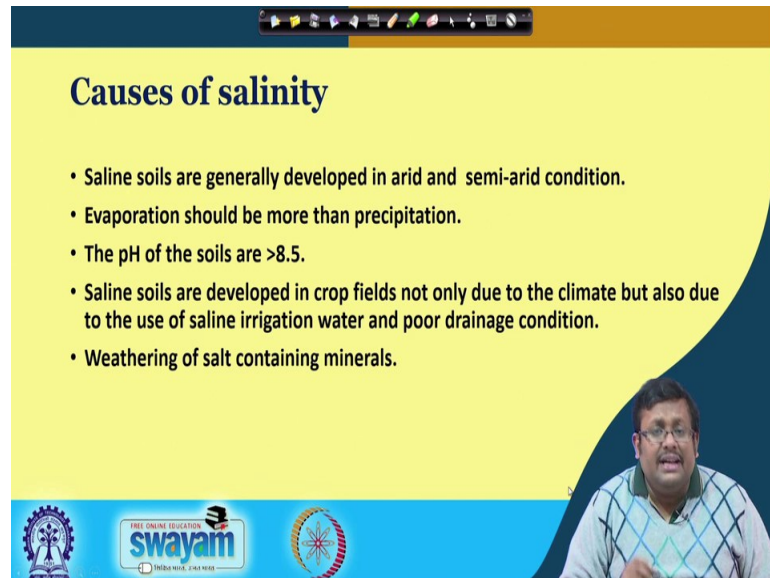
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Now, the concepts which will cover are the causes of alkalinity and salinity, then how we measure salinity and alkalinity, then classification of the saline soil, and then how to

reclaim and management of reclamation and management of those saline and alkaline soil.

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Causes of salinity

- Saline soils are generally developed in arid and semi-arid condition.
- Evaporation should be more than precipitation.
- The pH of the soils are >8.5 .
- Saline soils are developed in crop fields not only due to the climate but also due to the use of saline irrigation water and poor drainage condition.
- Weathering of salt containing minerals.

The slide features a yellow background with a blue header and footer. The title 'Causes of salinity' is in bold black text. The list contains five bullet points. A small video inset of a man is in the bottom right corner. The footer includes logos for 'swayam' and 'THE BBA MHA, CHENNAI'.


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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Causes of high soil pH

- Sources of alkalinity
- Influence of carbon dioxide and carbonates
- Role of the cations (Na^+ versus Ca^{2+})
- Influence of soluble salt level




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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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Sources of Alkalinity

- $\text{Ca}^{2+}, \text{Mg}^{2+}, \text{Na}^+, \text{K}^+$ do not produce H^+ after reacting with water
- These do not produce OH^-
- But OH^- ions are produced from the dissolution of CaCO_3 (Calcite minerals) and HCO_3^-
- The amount of OH^- increases in the soil solutions and it increases the pH of the soil



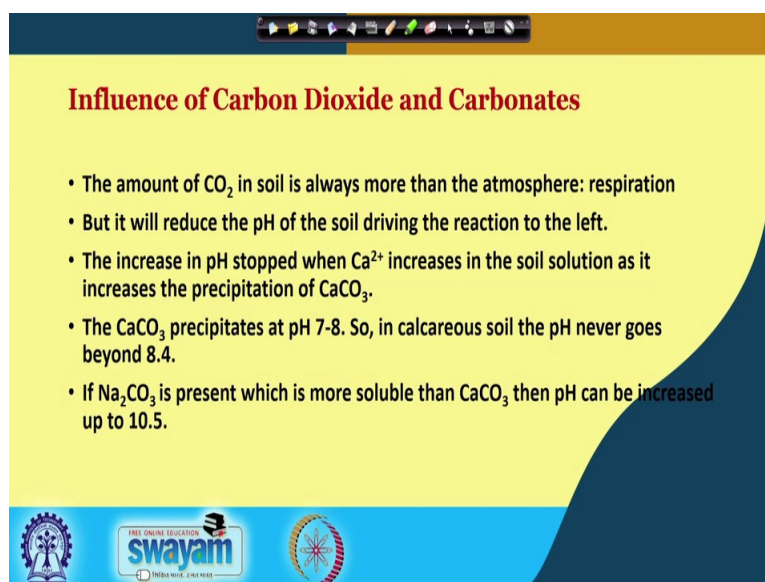
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$$\begin{array}{l} \text{CaCO}_3 \rightleftharpoons \text{Ca}^{2+} + \text{CO}_3^{2-} \\ \text{Calcite (solid)} \quad (\text{dissolved in water}) \quad (\text{dissolved in water}) \\ \text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^- \\ \text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^- \\ \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}_2\text{O} + \text{CO}_2 \uparrow \\ \text{Carbonic acid} \quad (\text{gas}) \end{array}$$

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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Influence of Carbon Dioxide and Carbonates

- The amount of CO_2 in soil is always more than the atmosphere: respiration
- But it will reduce the pH of the soil driving the reaction to the left.
- The increase in pH stopped when Ca^{2+} increases in the soil solution as it increases the precipitation of CaCO_3 .
- The CaCO_3 precipitates at pH 7-8. So, in calcareous soil the pH never goes beyond 8.4.
- If Na_2CO_3 is present which is more soluble than CaCO_3 then pH can be increased up to 10.5.

Logos at the bottom: UGC, swayam, and a circular emblem.

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,

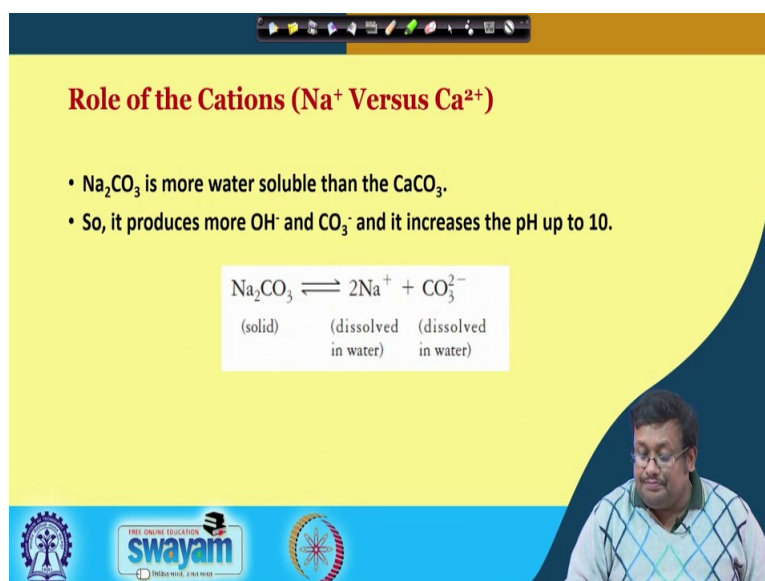
calcium carbonate and carbon dioxide, so the generation of soil alkalinity obviously depends on either the precipitation of the calcium carbonate or the removal of carbon dioxide. So, in which direction the reaction will move will depend on these two factors. First of all, the precipitation of the calcium 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 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 does not help in generation of the soil alkalinity.

Now the increase in pH obviously will stop you know pH stops 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 increases, so obviously, this calcium carbonate will precipitate. And when that it will precipitate 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 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 precipitates 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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Role of the Cations (Na⁺ Versus Ca²⁺)

- Na₂CO₃ is more water soluble than the CaCO₃.
- So, it produces more OH⁻ and CO₃²⁻ and it increases the pH up to 10.

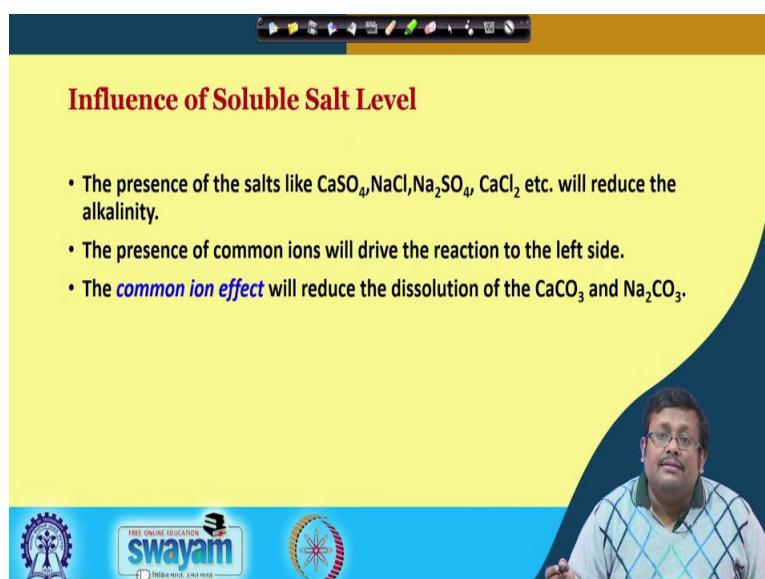
$$\text{Na}_2\text{CO}_3 \rightleftharpoons 2\text{Na}^+ + \text{CO}_3^{2-}$$

(solid) (dissolved in water) (dissolved in water)

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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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Influence of Soluble Salt Level

- The presence of the salts like CaSO₄, NaCl, Na₂SO₄, CaCl₂ etc. will reduce the alkalinity.
- The presence of common ions will drive the reaction to the left side.
- The *common ion effect* will reduce the dissolution of the CaCO₃ and Na₂CO₃.

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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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Development of salt-affected soils

- Accumulation of salts in non-irrigated Soils
- Irrigation-Induced salinity and alkalinity

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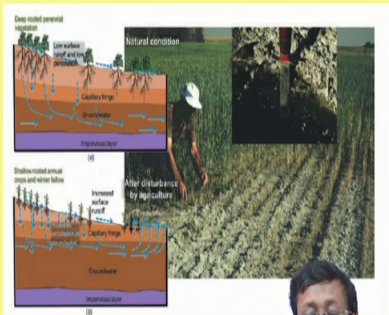
Now, the development of salt-affected soils, obviously, accumulation of salt in non-irrigated soils and irrigation induced salinity and alkalinity are the major reason for salt-affected soil. You can see here a white crust of soil found you know in case of saline you know in highly saline zone of soils.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

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Accumulation of salts in Non-irrigated Soils

(a) Under deep-rooted perennial vegetation, transpiration is high and the water table is kept low.

(b) In case of agricultural crops, the length of the roots are small and it causes groundwater to rise by capillary flow to the surface.



The diagram illustrates the process of salt accumulation in non-irrigated soils. It shows two scenarios: (a) deep-rooted perennial vegetation with high transpiration and a low water table, and (b) shallow-rooted agricultural crops with low transpiration and a rising water table. The photograph shows a field with salt accumulation and a person standing in it.

Logos: Swayam, Ministry of Education, Government of India, and a circular logo with a sun and text.

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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Irrigation-induced salinity and alkalinity



- The irrigated water may contain huge or very less amount of salts.
- If, the field has not adequate drainage system, continuous evaporation accelerates the chance of salt accumulation.
- Salts tend to accumulate at the highest part of the soil surface from which part evaporation loss is the highest.



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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Measuring Salinity

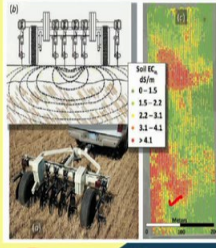
DIFFERENT MEASUREMENTS FOR ESTIMATING SOIL SALINITY

The methods are well correlated, so each can be converted to any other. The EC_e is the most common standard for comparison.


Measured on a soil sample	
EC_e	Conductivity of the solution extracted from a water-saturated soil paste
EC_p	Conductivity of the water-saturated soil paste itself
EC_w	Conductivity of the solution extracted from a soil-water mixture (usually either 1:2 or 1:5)
EC_s	Conductivity of a 1:1, 1:2, or 1:5 soil-water mixture itself
TDS	Total dissolved solids in water or the solution extracted from a water-saturated soil paste ^a

Measured on bulk soil in place	
EC_a	Apparent conductivity of bulk soil sensed by metal electrodes in soil
EC_n	Electromagnetic induction of an electric current using surface transmitter and receiving coils

^aNote that TDS (mg/L) can be converted to EC_e using these relationships between 0 and 5 dS/m: for Na salts, $TDS = 640 \times EC_e$ based on a 1:2 soil:water mixture; for Ca salts, $TDS = 800 \times EC_e$. The dilution effect of varying soil:water ratios must be taken into account when comparing data by the various EC_e and EC_w methods.



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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 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 E_{Ce} 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 E_{Ce}.

The second is E_{Cp} 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 E_{Cp}. Third one is E_{Cw} 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.

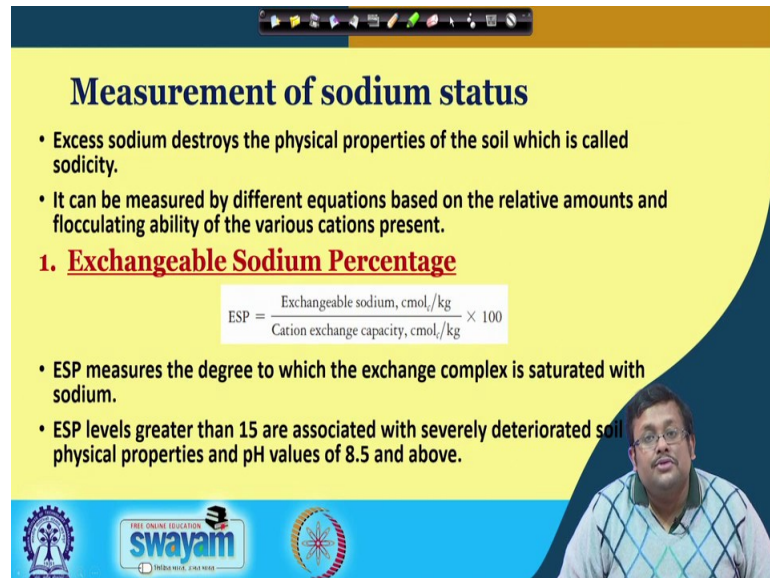
E_{Cs} is basically the conductivity of 1 is to 1, 1 is to 2, and 1 is to 5 soil water in mixture itself. So, when there is a mixture itself we dipped the you know electrode of the EC meter and then it will give us the E_{Cs} rating. Finally, TDS, TDS is total dissolved solids. So, total dissolved solids 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 E_{Ca} which is apparent conductivity of bulk soils says by metal electrodes in the soil. And secondly, E_{Ca} 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 sensors. 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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Measurement of sodium status

- Excess sodium destroys the physical properties of the soil which is called sodicity.
- It can be measured by different equations based on the relative amounts and flocculating ability of the various cations present.

1. Exchangeable Sodium Percentage

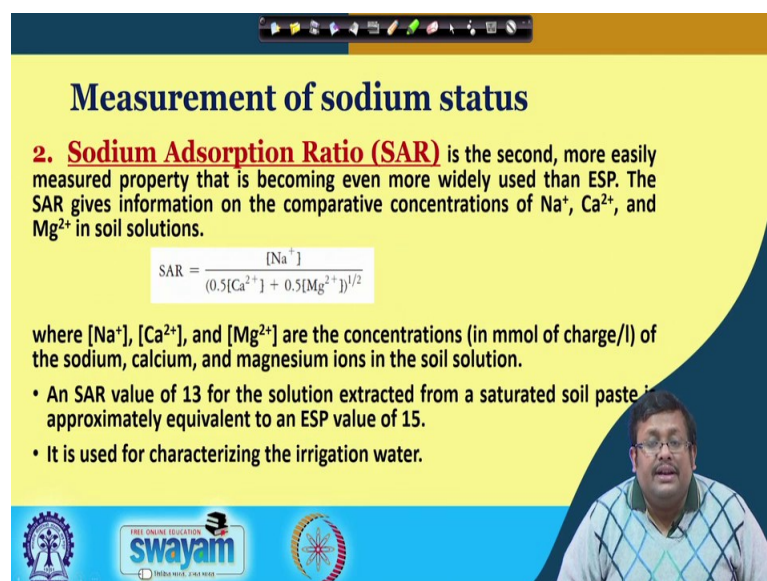
$$ESP = \frac{\text{Exchangeable sodium, cmol/kg}}{\text{Cation exchange capacity, cmol/kg}} \times 100$$

- ESP measures the degree to which the exchange complex is saturated with sodium.
- ESP levels greater than 15 are associated with severely deteriorated soil physical properties and pH values of 8.5 and above.

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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Measurement of sodium status

2. Sodium Adsorption Ratio (SAR) is the second, more easily measured property that is becoming even more widely used than ESP. The SAR gives information on the comparative concentrations of Na^+ , Ca^{2+} , and Mg^{2+} in soil solutions.

$$\text{SAR} = \frac{[\text{Na}^+]}{(0.5[\text{Ca}^{2+}] + 0.5[\text{Mg}^{2+}])^{1/2}}$$

where $[\text{Na}^+]$, $[\text{Ca}^{2+}]$, and $[\text{Mg}^{2+}]$ are the concentrations (in mmol of charge/l) of the sodium, calcium, and magnesium ions in the soil solution.

- An SAR value of 13 for the solution extracted from a saturated soil paste is approximately equivalent to an ESP value of 15.
- It is used for characterizing the irrigation water.

Logos for IIT Bombay, Swamyam, and a circular emblem are at the bottom left. A video inset of a man is at the bottom right.

Now, another important index of sodium status is sodium adsorption ratio or SAR. Now, it is the second most easily measured soil property that is 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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Classes of salt-affected Soils			
Properties	Saline soil (White alkali)	Saline-sodic soil	Sodic soil (Black alkali)
Structure	Very good	Good	Structure less
pH	Around 8.5.	$8.5 < \text{pH} < 10$	> 10
EC	$> 4 \text{ dS/m}$ ✓	$> 4 \text{ dS/m}$ ✓	$< 4 \text{ dS/m}$ ✓
ESP	< 15 ✓	> 15 ✓	> 15 ✓
SAR	< 13 ✓	> 13 ✓	> 13 ✓
Major ions	Mainly Ca^{2+} and Mg^{2+} and SO_4^{2-} , Cl^-	Salts of Ca^{2+} and Mg^{2+} with Na^+	Mainly Na^+ and CO_3^{2-} , HCO_3^-

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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Sodic Soils

- Sodic soils are, perhaps, the most troublesome of the salt-affected soils.
- $E_{ce} < 4$ dS/m but SAR > 13 and ESP > 15 .
- The pH of the sodic soil exceed 8.5, rising to 10 or higher in some cases.
- The high pH is caused due to the presence of sodium carbonate which is highly soluble.
- So, the soil contains a high amount of CO_3^{2-} and HCO_3^- ions in the solution.
- At this high pH cause FA and HA of organic matter to dissolve. When the water evaporates, can give soil surface a black colour. These soils are called black alkali.

FA = Fumaric acid, HA = Humic acid

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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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Physical degradation of soil by sodic chemical condition

- Slaking, Swelling, and Dispersion
- Two Causes of Soil Dispersion-High Sodium and Low Salt Concentration

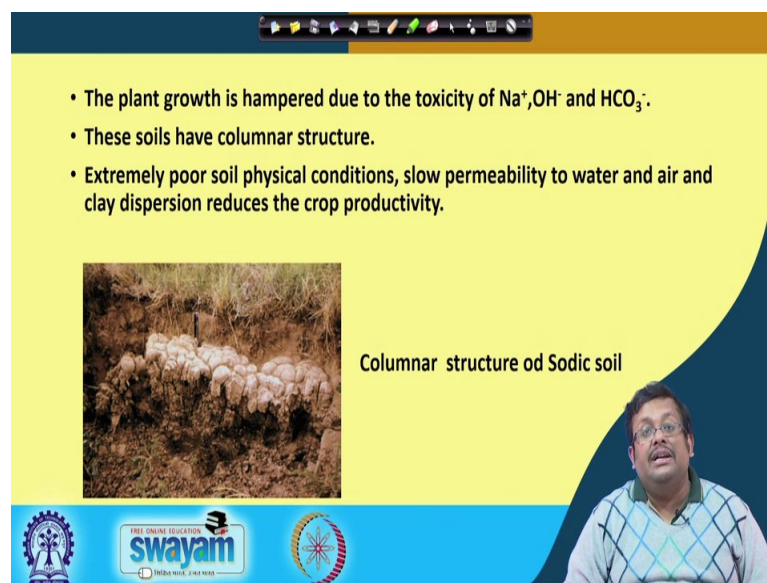
The diagram illustrates the physical degradation of soil by sodic chemical conditions. It shows three scenarios: (a) Without hydrated ions, colloids are too close, causing coagulation. (b) With tightly bound hydrated ions (Ca²⁺, Mg²⁺), colloids are held apart by a thick layer of ions, preventing coagulation. (c) With loosely bound hydrated ions (Na⁺), colloids are too far apart, leading to dispersion. The diagram uses red arrows to show the movement of ions and the resulting state of the soil colloids.

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

So, when there is a complete dispersion; obviously, there will be soil crusting and all this unfavorable condition will be there. And as a result of these, there will be germination problem for the soil 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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- The plant growth is hampered due to the toxicity of Na^+ , OH^- and HCO_3^- .
- These soils have columnar structure.
- Extremely poor soil physical conditions, slow permeability to water and air and clay dispersion reduces the crop productivity.

Columnar structure of Sodic soil

So, the plant growth is hampered due to the toxicity of sodium hydroxide and bicarbonate, obviously this is 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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Leaching Requirement (LR)

The amount of water needed to remove the excess salts from saline soils, called the LR.

The salt balance equation is –

$$S_{iw} + S_p + S_f + S_m = S_{dw} + S_{dc} + S_{ppt}$$

Salt inputs Salt outputs

- Siw- salt from irri water
- Sp- atms deposition
- Sf- fertilizers
- Sm- soil minerals
- Sdw- drainage water
- Sdc- Crop removal
- Sppt- chemical precipitation of sulphate and carbonates

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 S_{iw} which is salt from irrigation water plus S_p which is the atmospheric deposition, then S_f which is salt coming from fertilizers, then S_m that is soil coming from minerals equals to summation is equals to obviously, which is soil which is present in drainage water.

And, then S_c which is crop removal salt through crop removal, and S_{dw} 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.