Soil Fertility and Fertilizers
Professor Somsubhra Chakraborty
Department of Agriculture and Food Engineering
Indian Institute of Technology, Kharagpur
Lecture 59
Agricultural Productivity and Environmental Quality (Contd.)

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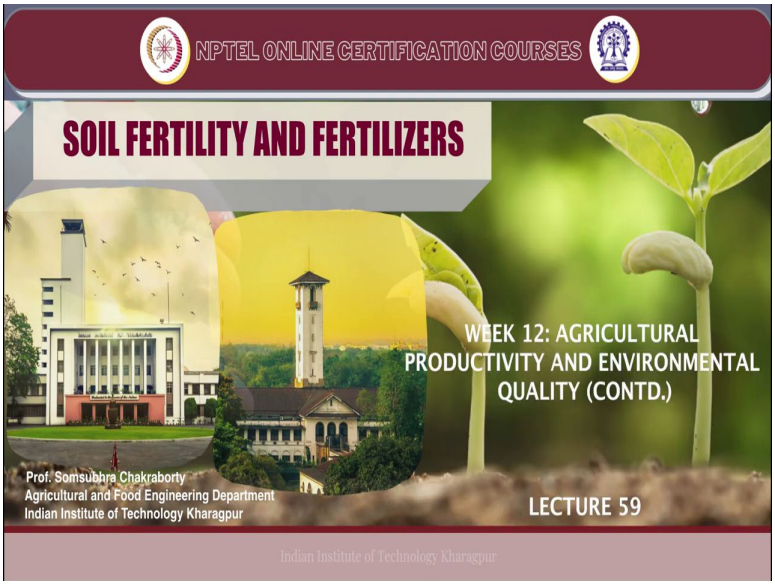

Welcome friends to this Lecture Number 59 of NPTEL Online Certification Course of Soil Fertility and Fertilizers. And we are currently at week 12 where we are discussing agricultural productivity and environmental quality. In our previous couple of lectures, we have discussed the issues related to agricultural productivity and environment. We have started our discussion regarding with the carbon sequestration.

And then we have seen how agricultural practices are important for carbon sequestration, why carbon sequestration is important for sustaining our environment. And then, we have discussed about the environmental problems or pollutions which are related to excessive use of chemical fertilizers. And then, in the last lecture, we have discussed in details about the stubble burning issue in India, why farmers prefer stubble burning, what are the reasons and what are the health impacts and other environmental impacts of stubble burning.

And also, we have tried to find out the solutions for the stubble burning. Now, in this lecture, we are going to see some of the impacts of conservation agriculture as compared to the conventional agriculture. We know about conservation agriculture in detail, I mean we have discussed the conservation agriculture in details.

However, now, in this lecture we are going to compare the impact of conservation agriculture with the conventional agriculture and then we are going to see the impact of this conservation agriculture on some soil physico-chemical properties, structural stability, bug density, infiltration of water and so on. So, this lecture is focused on conservation agriculture and its impacts on soil physical properties and hydraulic properties.

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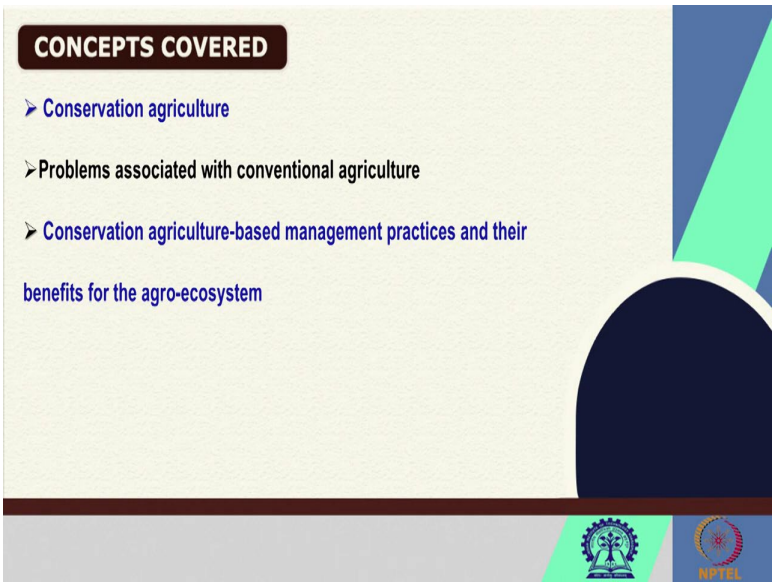

These are the concepts which we are going to discuss in this lecture. First of all, there will be a recall of the definition of conservation agriculture. And then, we are going to discuss the problems which are associated with conventional agriculture. And then, we are going to discuss the conservation agriculture-based management practices and their benefits for the agro-ecosystem. So, these are the major topics for this lecture.

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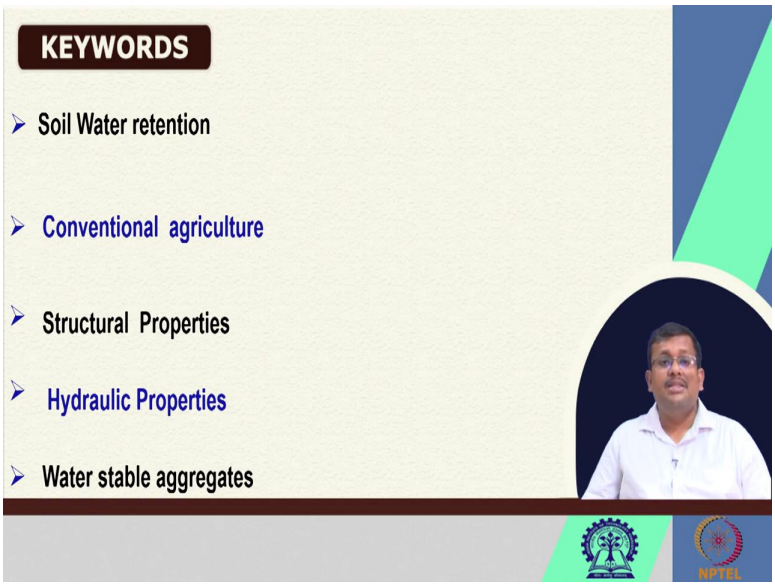

And these are the some of the keywords for this lecture, soil water retention, conventional agriculture, structural properties, hydraulic properties and water stubble aggregates.

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So, we all know that green revolution has increased food grain production by many fold with adoption of high yielding varieties, extensive tillage and intensive inputs use etc. Since last 5 decades we are seeing, 5 to 6 decades we are seeing the impact of green revolution in India and several new high yielding varieties have been introduced, we are focusing now on extensive tillage, intensive input use, and as a result, there has been an increase in food grain production also.

So, the intensive, but at the same time this intensive cultivation has led to degradation of natural resources such as soil, water, vegetation, etc. So, although we have received the beneficial impacts of fruits of green revolution, at the same time we have also continuously reduced the quality of natural resources and we have degraded the natural resources like soil, water, and vegetation.

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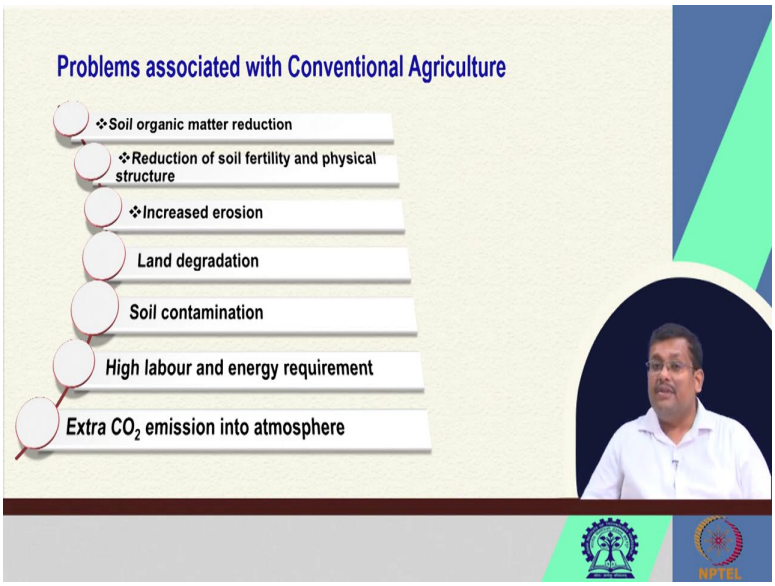

Now, what are the problems which are associated with conventional agriculture? If we list those major problems, first of all soil organic matter reduction. As we know that continuous cultivation can reduce the soil organic matter and that is why we have advocated the carbon sequestration. And also, when there is a loss of organic matter that will also link to the reduction of soil fertility and physical structure because organic matter is the one of the major fractions which maintains the soil fertility and physical stability because of the binding capability.

However, when there is a loss of organic matter, there is a reduction of soil fertility and physical structure also. Increase erosion, land degradation, soil contamination, then high labor and energy requirements and extra carbon dioxide emission into atmosphere, so all these are the problems or harmful impacts of conventional agriculture. When there is an increased erosion that accelerates the land degradation.

Also, use of chemical fertilizers can reduce the soil quality and increase the soil contamination then also that involves a high labor and energy requirements, extra carbon

dioxide emission requirements. So, all these are problems which are associated with conventional agriculture.

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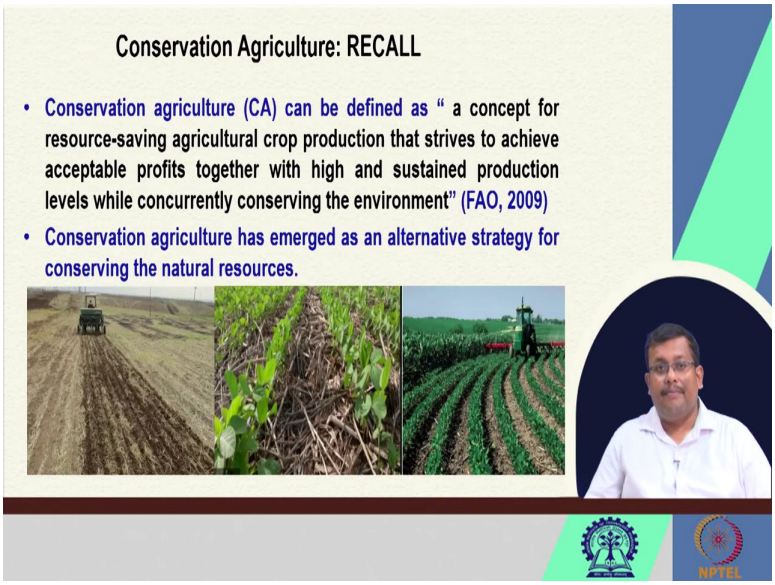

Now, let us recall the definition of conservation agriculture. So, conservation agriculture can be defined as a concept for resource saving intercultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. This is a FAO definition which was given in 2009. So, again, remember this is a concept of resource saving agricultural production, which achieved the acceptable profits together with high end sustained production levels, while concurrently conserving the environment.

So, not only we are focusing on increasing our agricultural products, but at the same time, we are not deteriorating the environment we are maintaining the environment, we are conserving the environment. So, this is the crux of the conservation agriculture. The conservation agriculture has emerged as an alternative strategy for conserving the natural resources. Of course, when you talk about the conservation of natural resources, the conservation agriculture has become an important tool nowadays which we can use for conserving these natural resources.

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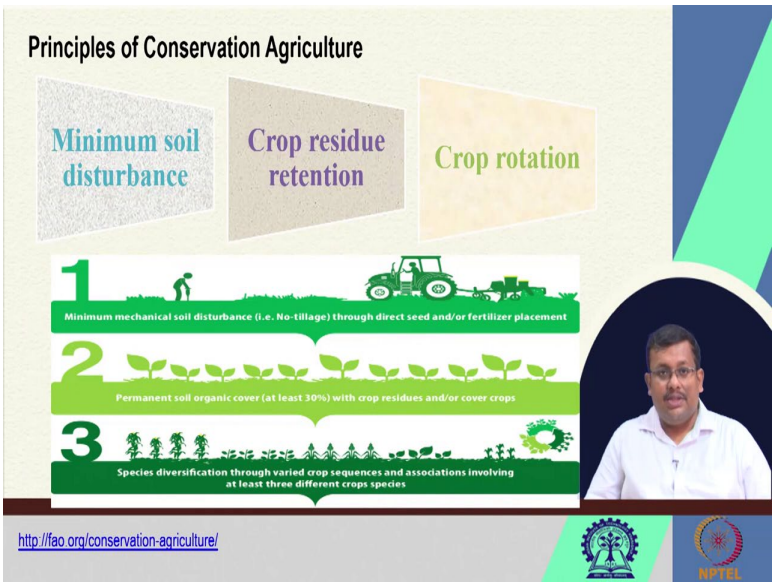

Now, what are the principles of conservation agriculture? We know that there are major three principle, first of all, minimum soil disturbance and then crop residue retention and crop rotation. So, these are the three major I would say pillars of conservation agriculture. First of all, minimum mechanical soil disturbance, there is no tillage through direct seed and or fertilizer placement.

Secondly, permanent soil organic cover at least 30 percent with crop residues and or cover crops. And finally, species diversification through vary crop sequence and associations involving at least three different crop species. So, these three are the major principles of conservation agriculture, while we minimize the soil disturbance that will conserve not only the organic matter, that will increase the organic matter content or stock of organic carbon in the soil, then permanent soil organic cover.

So, when there is a permanent solar organic cover at least 30 percent using the crop residues that also can favorably impact the soil physico-chemical properties. And finally, when we are rotating different crops, we are maintaining the species diversification. When there is a species diversification that can also improve the agricultural products and maintaining the soil fertility.

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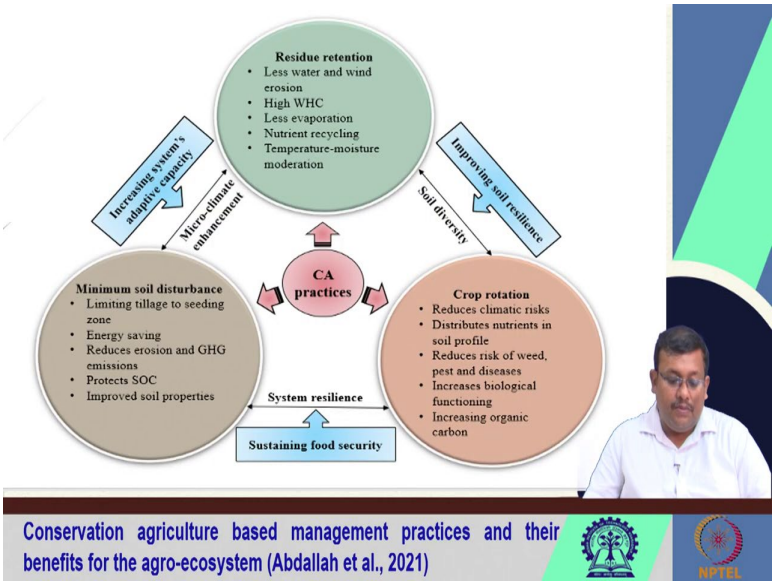

Now, if we see the conservation agricultural practices, there are several ways and let us see. First of all, residue retention is one of the major ways of conservation agriculture. So, when we retain the residue that helps in less water in wind erosion, high water holding capacity, less evaporation and then nutrient recycling and temperature moisture moderation. So, all these are impacts of residue retention.

And then we can see crop rotation which reduces the climatic risk and then distributes the nutrients in soil profile and then reduces the risk of weed, pest and diseases and then increases biological functioning, and finally, increases organic carbon. And minimum soil disturbances is another important conservation agricultural practice we know that it helps in limiting the tillage to seeding zone and then energy saving, it reduces the erosion and greenhouse gas emission and then it protects the soil organic carbon, and finally, it improves the soil properties.

So, we can see that there is a linkage between this minimum soil disturbance and residue retention. So, that is basically microclimate enhancement, so it increases the system's adaptive capacity when we minimize the soil disturbance and we retain the residue. And at the same time, there is also a linkage between residue retention, crop rotation because that can improve the soil resilience by maintaining the soil diversity.

And then also here there is a relationship between minimum soil disturbance and crop rotation so that basically helps in system resilience use and served by sustaining the food security. So, you can see all these three pillars of residue retention, crop rotation and

minimizing the soil disturbance are connected and they connectively they achieve the major goals of conservation agriculture, which are increasing the system adaptive capacity, improving soil resilience and sustaining food security. So, these are the three major objectives of conservation agricultural practices.

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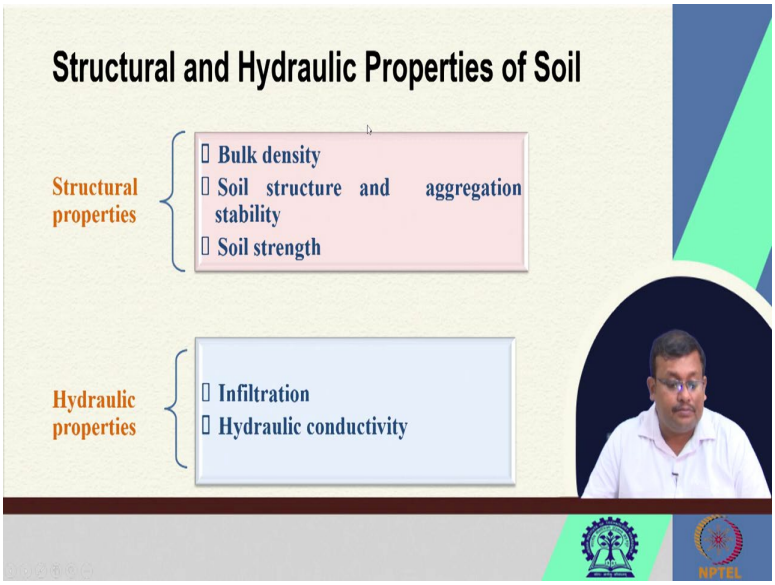

Now, when we talk about the structural hydraulic properties of the soil let us discuss what are the structural and hydraulic properties. Of course, structural properties when you talk about that encompasses the structural properties are basically bulk density, soil structure and aggregation stability and then soil strength and then hydraulic properties are infiltration and hydraulic conductivity.

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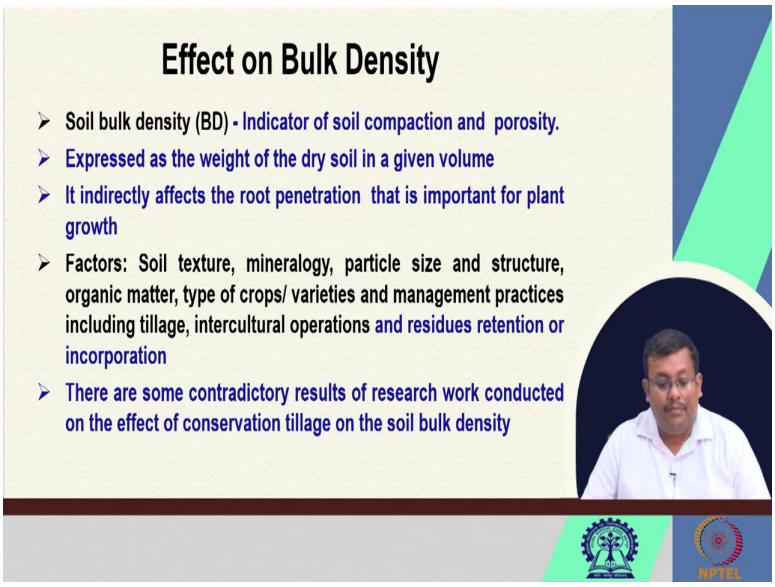

Now, let us see what are the impacts of conservation agricultural practices on soil bulk density. Now, soil bulk density is an indicator of soil compaction and porosity and it is expressed as the weight of dry soil in a given volume. And it indirectly affects the root penetration that is important for plant growth because if the bulk density is high then root will not penetrate there will be hindrance for germination of the crop so we can see that how important the soil bulk density is.

So, what are the factors which impact the soil bulk density? Soil texture, then mineralogy, particle size and structure, organic matter, type of crops or varieties and management practices including tillage, intercultural operation, residues retention or incorporation, all these impacts the bulk density. Because when there is a light texture soil their bulk density will be different than heavy texture soil.

Mineralogy helps in determining the bulk density. Then tillage operations help determines the bulk density because when there is a heavy implement in an intensive tillage that will increase the bulk density and create hard a pan. Inter cultural operations are also important for moderating the bulk density. So, all these are very important, I would say regulators of bulk density. Now, there are some contradictory results of research work conducted on the effect of conservation tillage on the soil bulk density of course.

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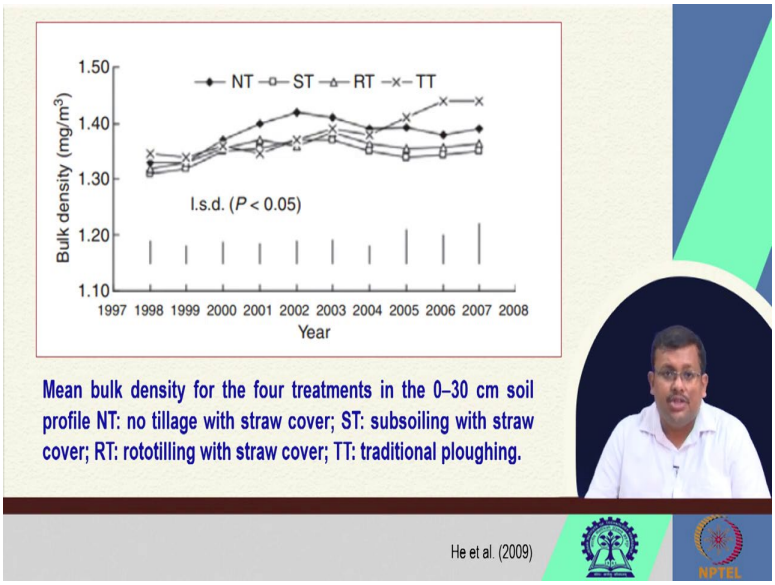

Now, let us see the mean bulk density for the four treatment. So, here we can see here four treatments, one is NT, that is no tillage with straw cover, then ST stands for subsoiling with straw cover, then RT stands for rototilling with straw cover, and TT stands for traditional ploughing. So, one thing you can see in case of traditional ploughing the mean bulk density has increased.

However, for all the conservation practices the mean bulk density has decreased. So, we can see that the conservation agricultural practices have better impact on bulk density and they can reduce the bulk density of the soil by incorporating more organic matter in the soil.

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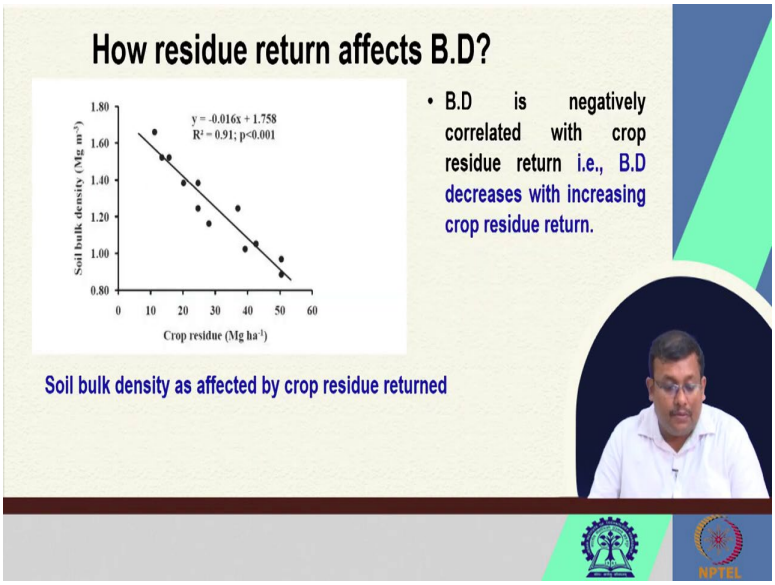

Also, we can see that in this graph, there is a B.D is negatively correlated with crop residue return that is B.D decreases with or bulk density decreases with increasing crop residue returns. So, as we incorporate more crop residue you can see soil bulk density will decrease and there is a linear relationship. So, more incorporation of crop residue as a result of conservation agriculture can help in reducing the soil bulk density.

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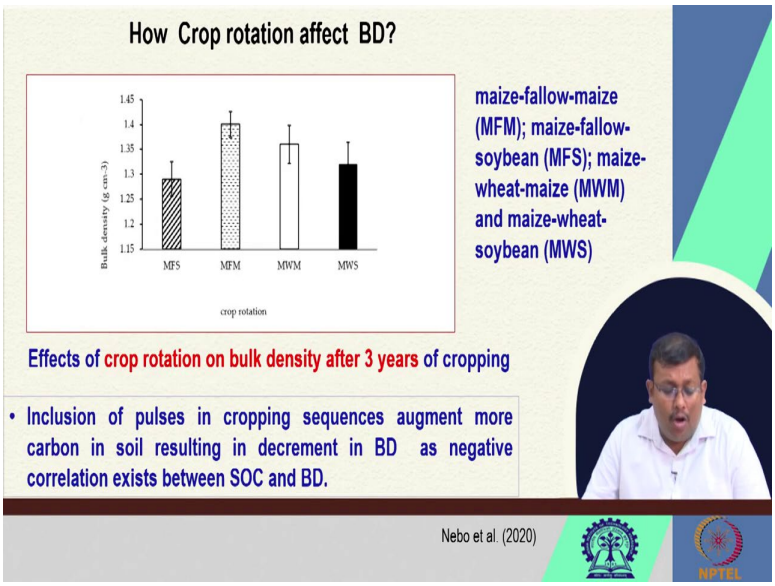

Also, we can see in this slide that there are four different crop rotation, here you can see MFS stands for maize-fallow-soybean, MFM stands for maize-fallow-maize, MWM stands for maize-wheat-maize, and MWS stands for maize-wheat-soybean. So, we can see this graph shows the effects of crop rotation on bulk density after 3 years of cropping. One thing we can see that inclusion of pulses.

So, when there is a soybean like here you can see maize-wheat-soybean, so and then you can see MFS, so here also incorporation of pulses here so it augments more carbon in the soil, which results in decrement in bulk density as negative correlation exists between associate bulk density.

So, we know that, there will be more incorporation of organic carbon if we incorporate the pulse crop in the crop rotation and that will decrease further the bulk density. So, you can see comparative, when we comparing the bulk density of different crop rotation, when there is an incorporation of pulses, there is a decrease of bulk density of soil.

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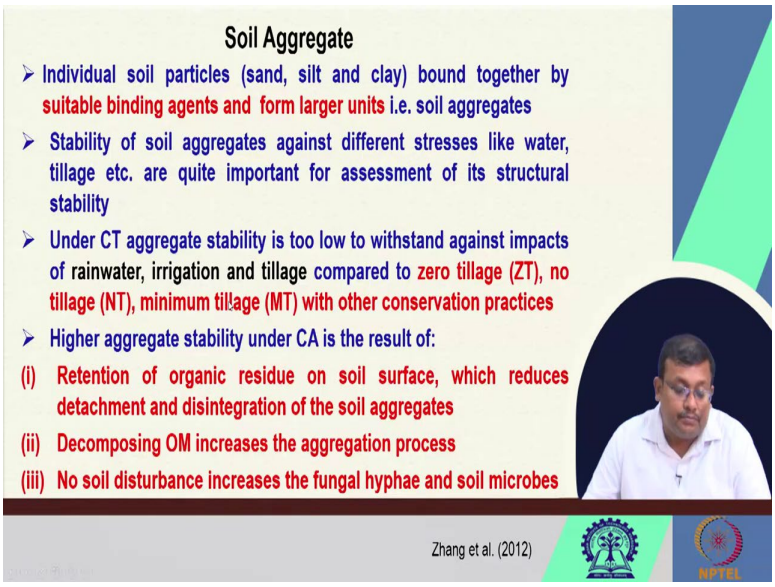

Now, let us see the impact of solid aggregates. Now, individual soil particles like sand, silt and clay bound together by suitable binding agents and form larger units that is soil aggregate. So, stability of soil aggregates against different stresses like water, tillage etcetera are quite important for assessment of structural stability.

Under conventional tillage aggregate stability is too low to withstand against impacts of rainwater, then irrigation and tillage compared to the zero tillage, no tillage, minimum tillage with other conservation practices. And higher aggregate stability under conservation agriculture is the result of three major processes. First of all, retention of organic residue on soil surface, which reduces detachment and disintegration of the soil aggregates.

Secondly, decomposition of organic matter increases the aggregation process and then no soil disturbance increases the fungal hyphae and soil microbes. So, these are the three major reasons which impacts the aggregate stability under conservation agriculture because the fungal hyphae acts as a binding agents for the aggregates.

And then when there is a decomposition of organic matter that will also help in binding the soil particles and retention of organic residues will also help in reducing the detachment and disintegration of the soil aggregates. So, this is how we can see in case of conservation agriculture we get the higher aggregate stability.

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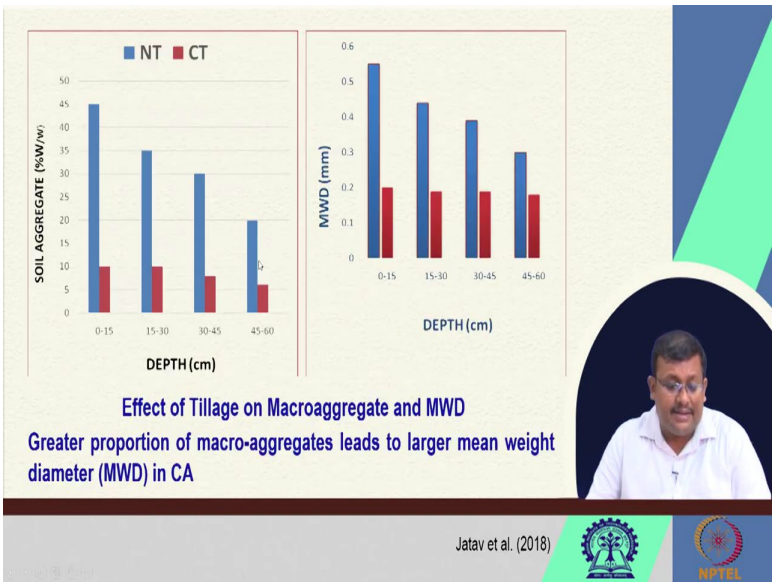

Also, in this slide we can see side by side the impact of conservation agriculture and the conventional tillage on soil aggregate stability and mean weight diameter. So, we can see soil aggregate is more in case of no tillage condition as compared to the conventional tillage. And mean weight diameter is also higher in case of no tillage as compared to the conventional tillage. So, the greater proportion of macroaggregates leads to larger mean weight diameter in case of conservation agriculture.

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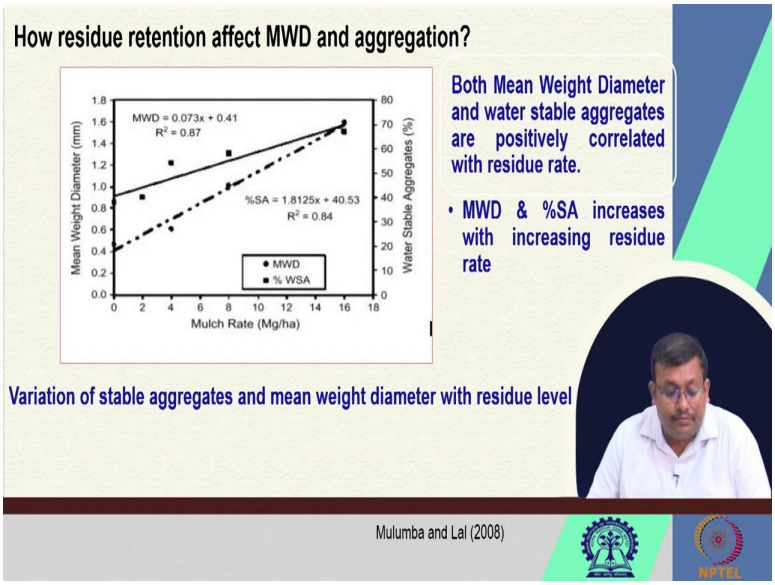

Also, we can see here as the mulching rate is increasing, the mean weight diameter is also increasing. So, both mean weight diameter and water stable aggregates and also you can see

the water stubble aggregates are also increasing. So, there is a positive relationship between the mulching rate with the mean weight diameter and water stubble aggregates.

So, both mean weight diameter and water stubble aggregates are positively correlated with residue rate and mean weight diameter and percentage of water stable aggregates increases with increasing residue rate. And so, that shows the importance of conservation agricultural practices for improving the soil physical condition.

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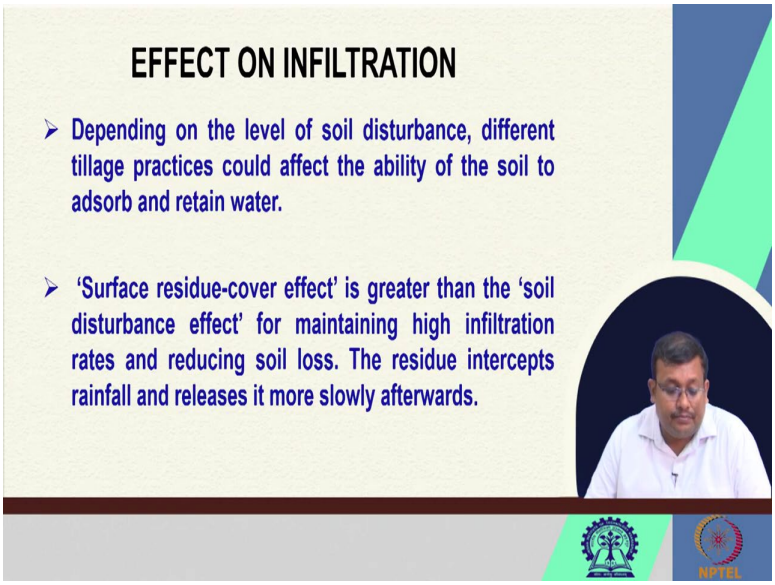

What are the effects on infiltration, water infiltration? Now, depending on the level of soil disturbance, different tillage practices could affect the ability of the soil to adsorb and retain water. Now, surface residue cover effect is generally greater than the soil disturbance effect for maintaining high infiltration rate and reducing the soil loss. So, the residue intercepts rainfall and releases it more slowly afterwards.

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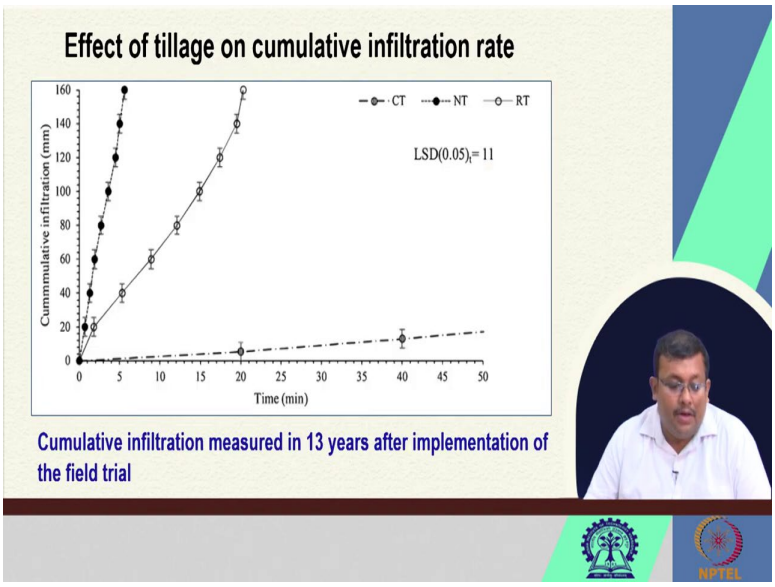

We can see here the cumulative infiltration rates which is measured in 13 years after implementation of the field trial. We can see in case of the conventional tillage in cumulative infiltration rate is increasing at a slower rate. However, in case of conservation agricultural practices we can see there has been a huge increase or steep increase in cumulative infiltration rate in both these two conditions.

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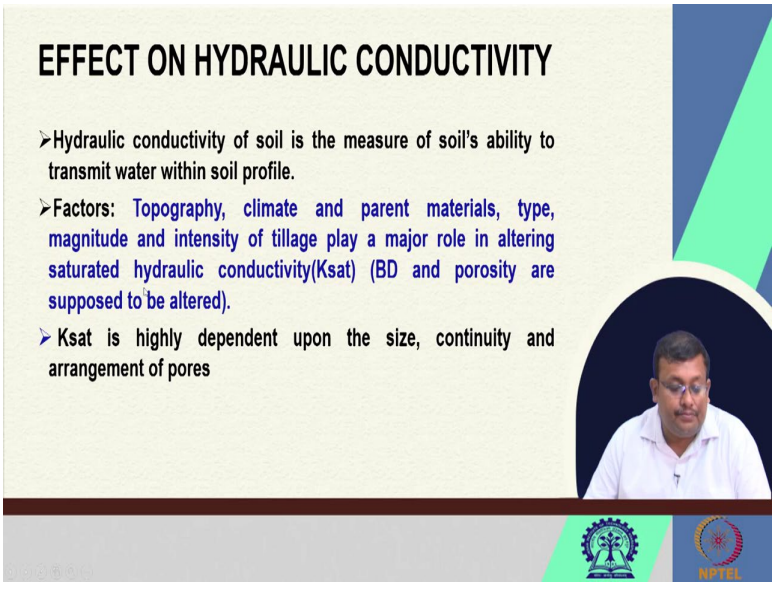

Also, if we can see the effect on hydraulic conductivity. Now, hydraulic conductivity of the soil is a measure of soil's ability to transmit water within soil profile. What are the factors which impact the soil hydraulic conductivity? Like topography, climate and barren material type, magnitude or intensity of tillage also plays a major role in altering the saturated

hydraulic conductivity. And also, because bulk density and porosity are also supposed to be altered. Now, Ksat a saturated hydraulic conductivity is highly dependent upon the size, continuity and arrangement of pores.

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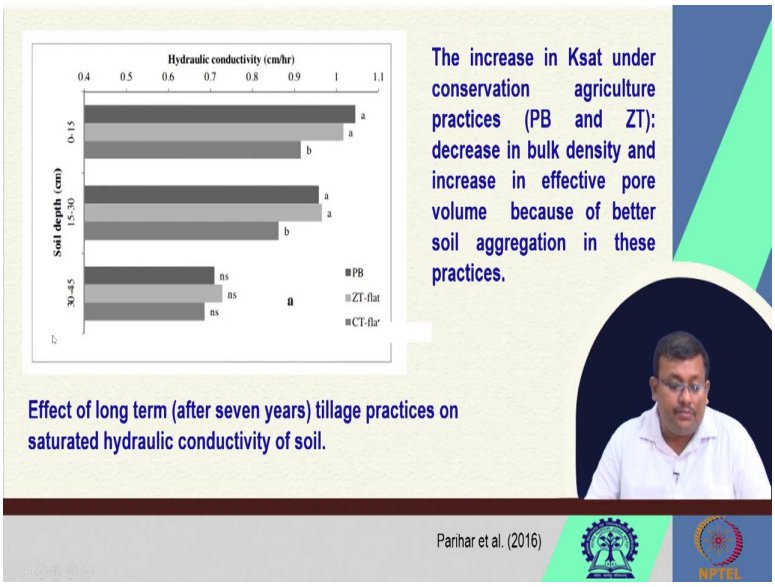

So, we can see the increase in the saturated hydraulic conductivity under conservation practices. It decrease in bulk density and increase in effective pore volume because the better soil aggregation in these practices. So, as a result there is an increase in saturated hydraulic conductivity we can see from this graph.

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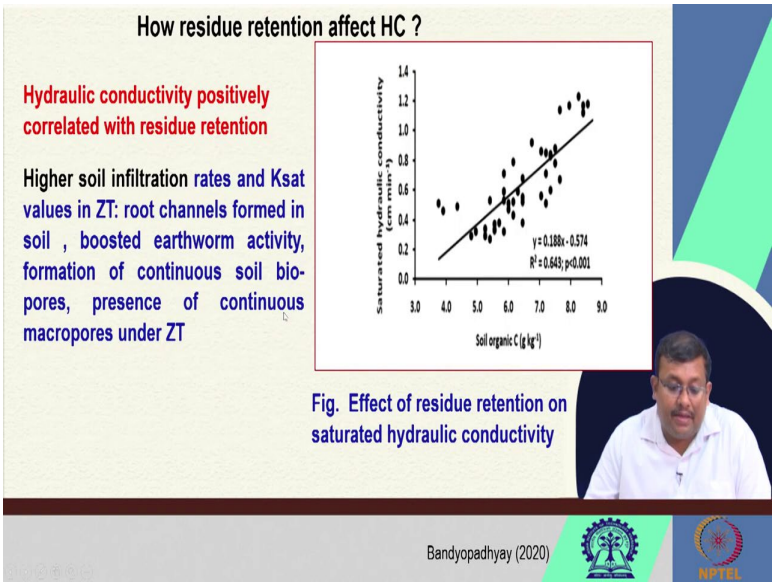

Also, we can see that hydraulic conductivity positively correlated with residue retention. So, higher soil infiltration rates and saturated hydraulic conductivity values in zero tillage we can see because of in this zero tillage we can see formation of root channels in soil and then boosted earthworm activity because of zero tillage. And then formation of continuous soil bio-pores and presence of continuous macropores. So, these are facilitated by zero tillage and as a result, there will be higher soil infiltration.

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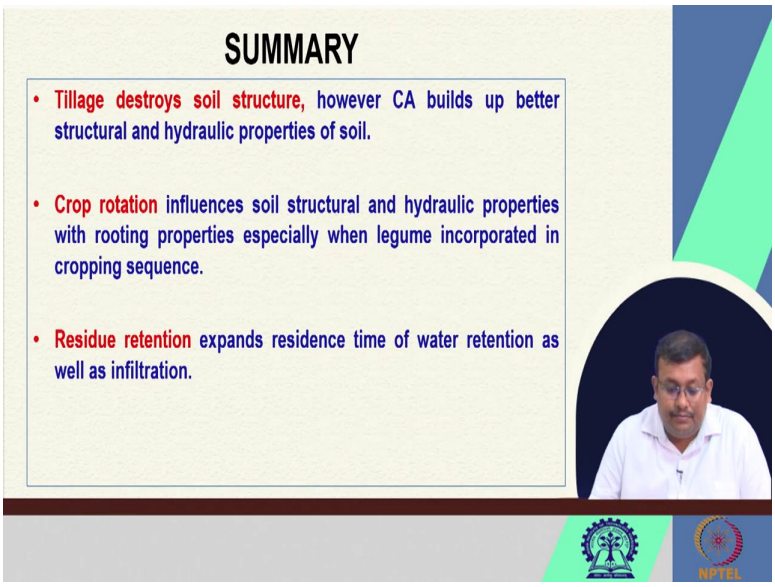

So, summarily. We can see that tillage, the conventional intensive tillage destroys soil structure, however, conservation agriculture builds are better structural and hydraulic properties of the soil. When we go for crop rotation that influences the soil structural and hydraulic properties with rooting properties especially when legume incorporated in cropping sequence.

Because when we incorporate the legume in the soil that fixes not only the atmospheric nitrogen, but also after their cultivation, we incorporated them in the soil to improve the soil fertility. And as a result, not only they are incorporating the nitrogen, but also, they are incorporating organic matter because we are mixing the crop directly in the soil. So, that increases the soil organic matter and positively impacts the soil structural and hydraulic properties.

Also, residue retention expands the residence time of water retention as well as infiltration. So, these are the benefits of conservation agricultural practices as compared to the conventional agricultural practices.

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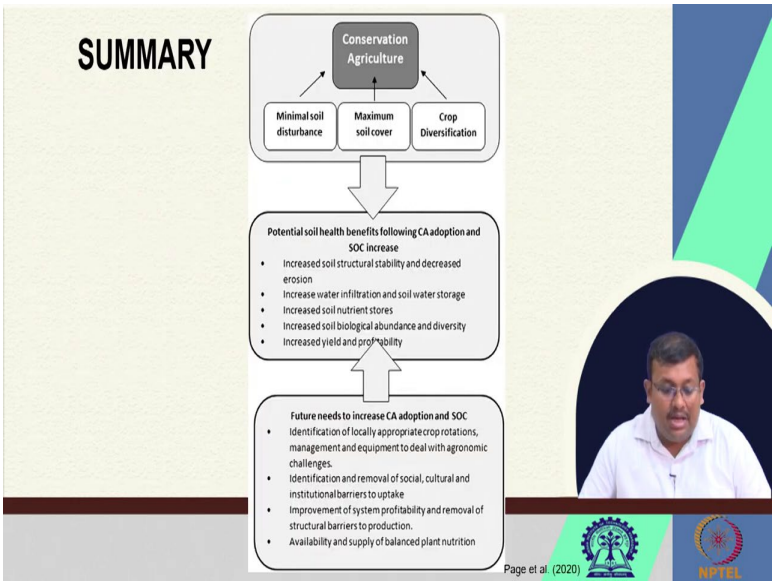

Now, if we see the conservation agriculture, we can see the, of course, these are the three pillars we have discussed minimal soil disturbance, then maximum soil cover and crop diversification. So, we can see summarily that potential soil health benefits following the conservation agriculture adoption and SOC increase we can see increased soil structural stability and decreased erosion.

We can also see increased water infiltration in soil water storage, increased soil nutrient stores and then increased soil biological abundance and diversity and increased yield and profitability. So, these are the impacts of this conservation agriculture. So, future needs to increase the conservation agriculture adopting and adoption and soil organic carbon so we need to identify the locally appropriate crop rotations, management and equipment to deal with agronomic challenges.

Then we need to identify and remove the social, cultural and institutional barriers to uptake these conservation agriculture practices. We should also improve the system profitability and removal of structural barriers to production. And finally, we should ensure that there is availability and supply of balance plan nutrition. So, these are the overall benefits, which you can harness from adopting the conservation agriculture. So, guys, this makes the end of the Lecture Number 59.

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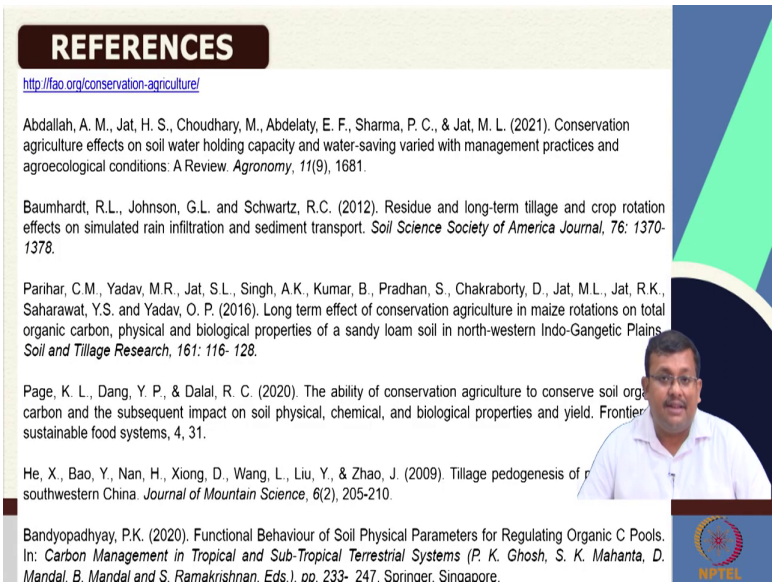

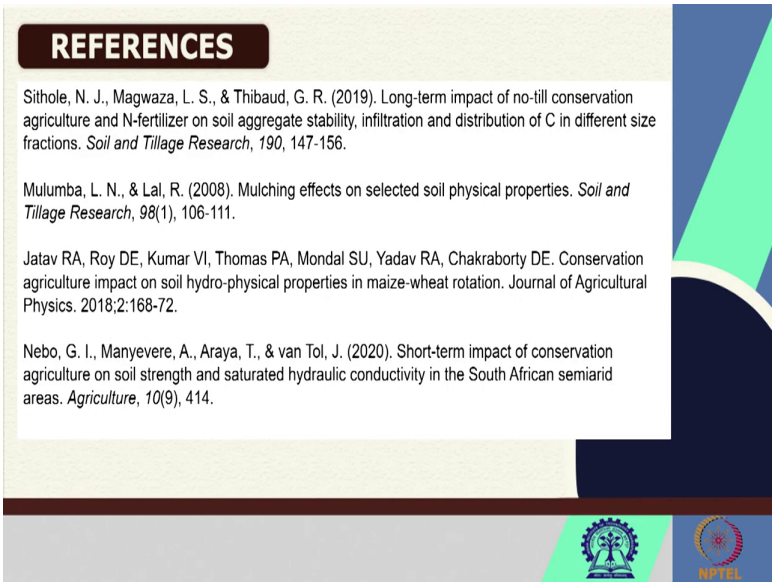

These are the references which I have used for this lecture and please go through these for more knowledge on conservation agricultural impacts on soil physical properties. So, let us wrap up this lecture and let us meet in our Lecture Number 60 to discuss some other issues of agricultural productivity and environmental issues. Thank you.