Soil Fertility and Fertilizers
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Lecture 08
Soil Nitrogen for Plant Nutrition (Contd.)

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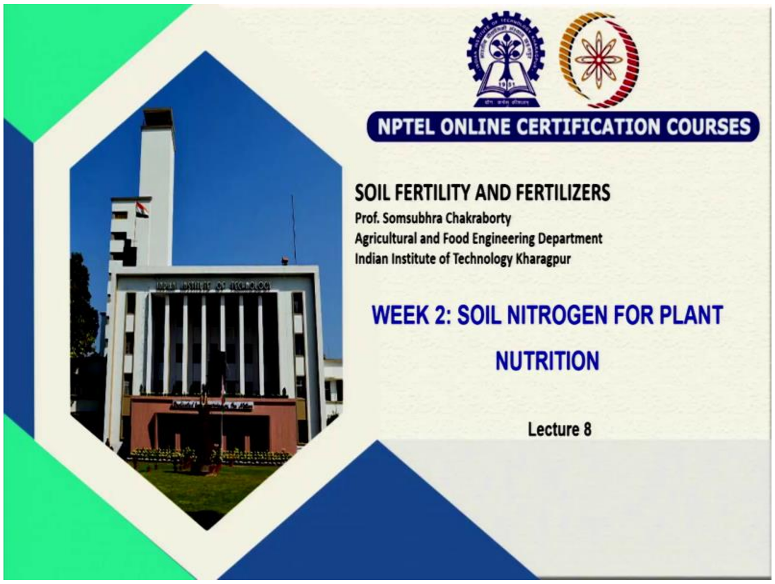

Welcome friends to this third lecture of week two of this NPTEL online certification course of Soil Fertility and Fertilizers. And in this week, we are talking about Soil Nitrogen for Plant Nutrition. We are going to start our Lecture 8 our third lecture of week two. And in our previous two lectures of this week, we have discussed about the, we discuss about what are the different inorganic forms and organic forms of nitrogen present in the environment and how they are related to plant nutrition, what are the available forms and what we have also seen the nitrogen cycle.

And also we have seen we have discussed some of the important nitrogen processes in the soil like mineralization, then nitrification and also some substrates within the mineralization like amminization and ammonification. And also we have discussed briefly about denitrification and also volatilization. We have seen the importance of carbon to nitrogen ratio for determining the mineralization as well as immobilization. We have also discussed the impact of different environmental factors like temperature and moisture nitrification process.

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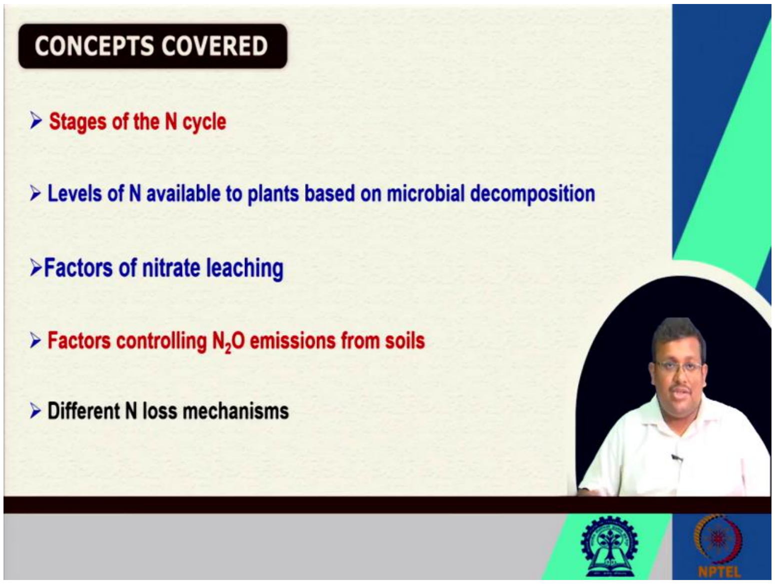

So, in this lecture, we are going to cover this lecture, first of all stages of the nitrogen cycle, also we are going to discuss the levels of nitrogen available to plant based on microbial decomposition, we are also going to discuss factors of nitrate leaching, and factors controlling nitrous oxide emission from soils, and finally, different nitrogen loss mechanisms. So, these are the major concepts which we are going to cover in this week.

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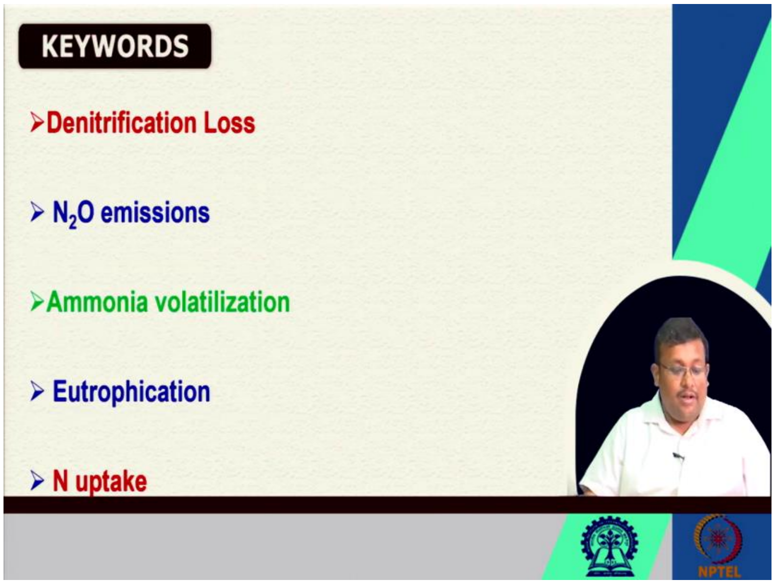

And also these are the keywords which we are going to discuss the identification loss nitrous oxide emission, ammonia volatilization, eutrophication and nitrogen uptake.

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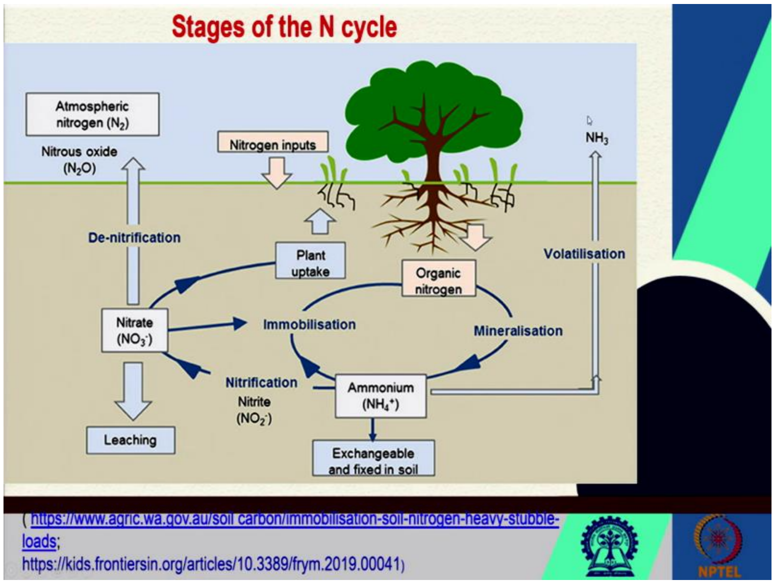

So, if we see the details of soil nitrogen cycle we can we have already discussed important processes. So, for example, there are different types of nitrogen inputs like fertilizers as well as atmospheric deposition we have discussed these in details. And then from there we have plant uptake and also from the organic form of nitrogen gets converted into inorganic forms by mineralization process and we get the ammonium form.

And this ammonium form is either exchange and fixed in soil minerals or they undergo immobilization process and convert back to organic form of nitrogen. Some amounts of ammonium nitrogen will convert to a night try it as well as nitrate through the process of nitrification.

And you know that there are several bacterias which are responsible, from ammonium to nitrate Nitrosomonas is responsible and from nitrite to nitrate Nitrobacter is responsible and these nitrate is either taken by the plant or the loss from the soil to the leaching process or they are back to the atmosphere by denitrification process in anaerobic condition. So, ultimately they produce the nitrous oxide, and finally, the denitrification process they convert back into atmospheric nitrogen.

And these ammonium is also converted, they also released in the atmosphere through ammonia volatilization process. So, these are the different stages of a nitrogen cycle we have discussed this already in details.

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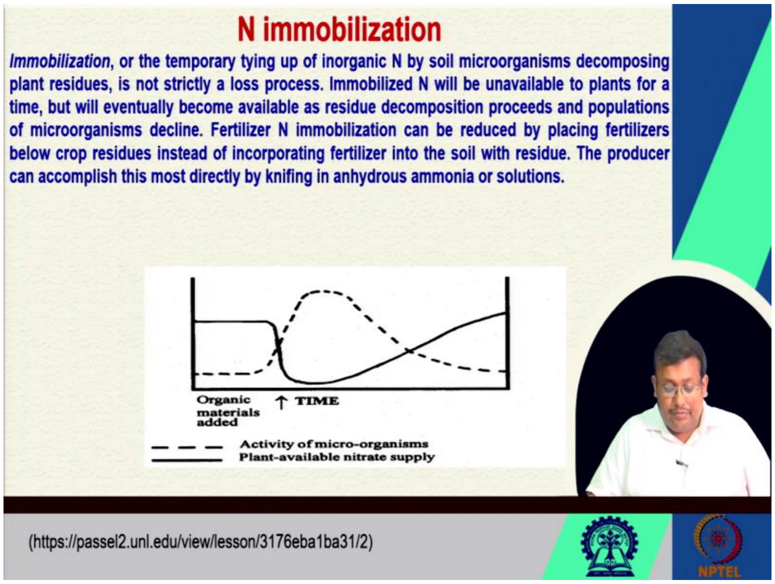

Now, let us see some important concepts for nitrogen immobilization. Now, immobilization on the temporary tying up of nitrogen, so basically immobilization can be termed as a temporary tying up of inorganic nitrous and by soil microorganisms, decomposing plant residues. So, it is not a strictly loss process. So, we cannot tell that immobilization is a strictly loss of nitrogen as we can say in case of leaching, why?

So, immobilized nitrogen will be unavailable to the plants for a time, but will eventually become available as residues, decomposition proceeds and population of microorganisms decline. So, what happens that when immobilized are basically immobilization can occur in the microbes body. So, when the microbes die, they decompose their organic nitrogen decompose and further goes back to the environment as inorganic form of nitrogen.

So, fertilizer nitrogen immobilization can be reduced by placing fertilizer below crop residues instead of incorporating fertilizer into the soil with residues. So, generally this strategy is being used for reducing the nitrogen immobilization. So, the producer can accomplish this most directly by knifing in anhydrous ammonia solution.

So, here you can see that these graph is showing the activity of microorganism, changes in the activity of microorganism and plant available nitrate supply with respect to time. So, you can see temporal variation of these two aspects. So, we can see when we are adding organic material, so activity of the microorganisms will increase because organic matter will serve as a source of carbon or in other words source of energy for them.

So, you will see that there is a boom of microbial population here, but at the same time plant available nitrate supply will decline because they will, when there is a population increase of microorganism they will utilize this plant available nitrogen to immobilize and ultimately you will see there is sudden decrease of plant available nitrogen supply.

However, with the passage of time the population will further decrease with a concomitant increase in plant development nitrates supply because when the population will die the decomposition process will convert this organic form of nitrogen into further back to inorganic form. So, that is why the plant available nitrate supply will also increase. So, this is how this immobilization is dependent on microbial population and also presence of plant available, presence of different types of organic material and, of course, to C:N ratio.

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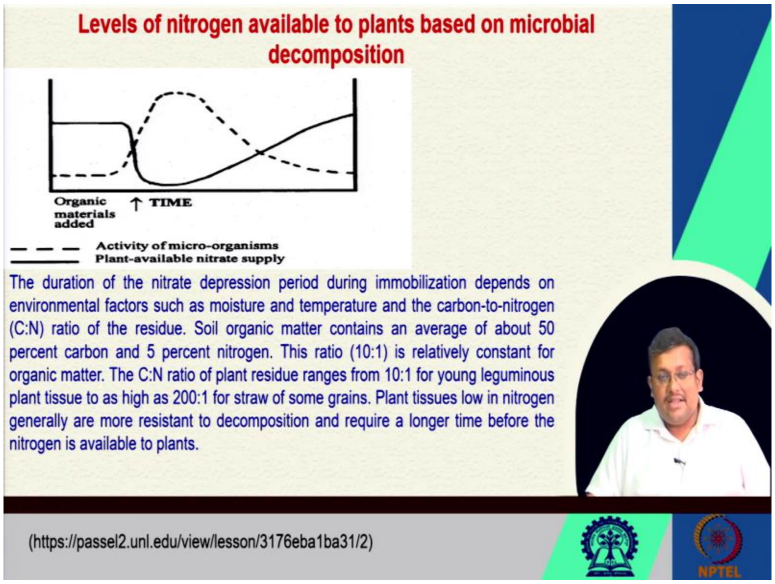

Now, remember that that duration of the nitrate depression period during this immobilization, we can see here this is the nitrate depression period. So, the duration of the nitrate depression period during immobilization depends on environmental factors such as moisture and temperature and the C:N ratio of the residue. And we have discussed this in details, why?

When there is high C:N ratio, why? There is immobilization we have already discussed. So, remember that soil organic matter contains on average about 50 percent of carbon and 5 percent of nitrogen. So, the C:N ratio is 10 is to 1. So, it is relatively constant for organic matter. Now, the C:N ratio or plant residue ranges from this 10 is to 1 for young leguminous plant tissue to as high as 200 is to 1 for straw or some grains.

So, plant tissue low in nitrogen generally are more resistant to decomposition and require a longer time before the nitrogen is available to the plants. So, these are some practical implication of immobilization process.

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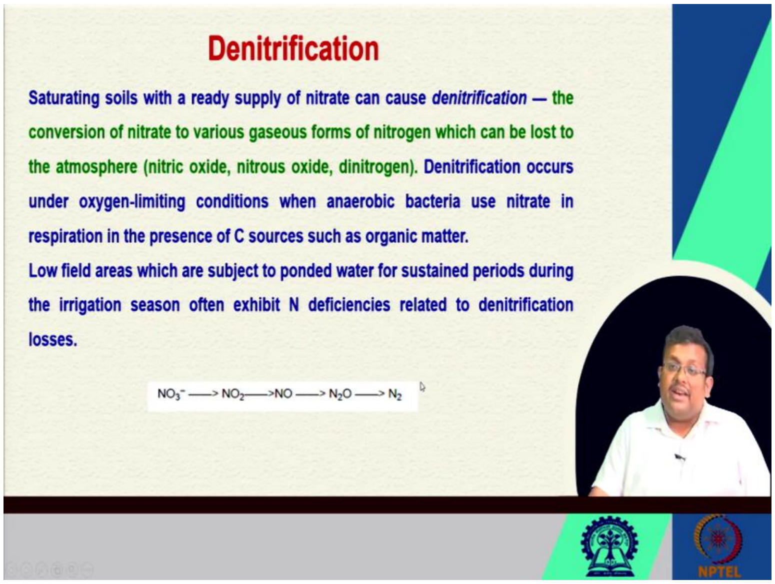

Now, the next important process in the nitrogen cycle is denitrification process. So, when the soil is saturated with water that will remove all the air which are occupied there in the post space. So, saturating a soil with water will create an anaerobic condition. And in this anaerobic condition whatever nitrate is there in the soil will convert back to the various gaseous forms of nitrogen, which will be ultimately loss to the atmosphere.

So, first it will convert it into the, nitrate will convert into nitric oxide then nitrous oxide and then dinitrogen. So, this process is known as denitrification. If you see that the name itself suggests it is a conversion of nitrate to other forms, so it is denitrification. Now, denitrification occurs under oxygen limiting condition as I have already mentioned. When anaerobic bacteria use nitrate in respiration in the presence of carbon sources such as organic matter.

So, in the anaerobic condition there is no oxygen available for these bacteria, so, they utilize these nitrate and then they reduce this nitrate back to different gaseous form and ultimately to nitrogen gas. So, low field areas which are subject to ponded water for sustained period during the irrigation season often exhibit nitrogen deficiencies related to denitrification losses. So, of course, when there is a low lying soil area which are saturated with water or ponded water that will create anaerobic condition.

And of course, in this anaerobic condition there will be conversion of nitrate to nitrogen gas. So, here you can see first nitrate will convert into nitrogen dioxide then nitric oxide then nitrous oxide and finally to nitrogen gas and ultimately they will release back to the atmosphere. So, this process is that denitrification process.

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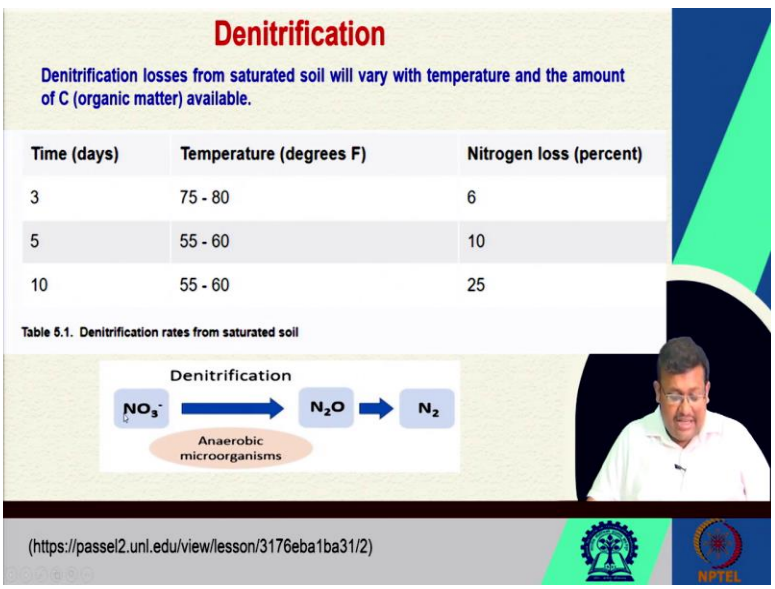

Now, denitrification losses from saturate soil will vary with temperature and the amount of carbon or organic matter which is available. So, here you can see for different time days like 3 days, 5 days and 10 days, if the temperature is 75 to 80 degrees. So, we can see that nitrogen loss is only 6 percent. However, if the temperature is more conducive for the bacterial growth we can see 10 to 25 percent.

So, as the time increases, and if the temperature is favorable for the growth of the microbes, then we can see that increase nitrogen loss for denitrification process. So, of course, this denitrifying bacteria becomes inactive when there is a high temperature. So, these as I have already told you this denitrification basically mediated through anaerobic microorganisms which convert these nitrate to nitrous oxide and finally to nitrogen gas.

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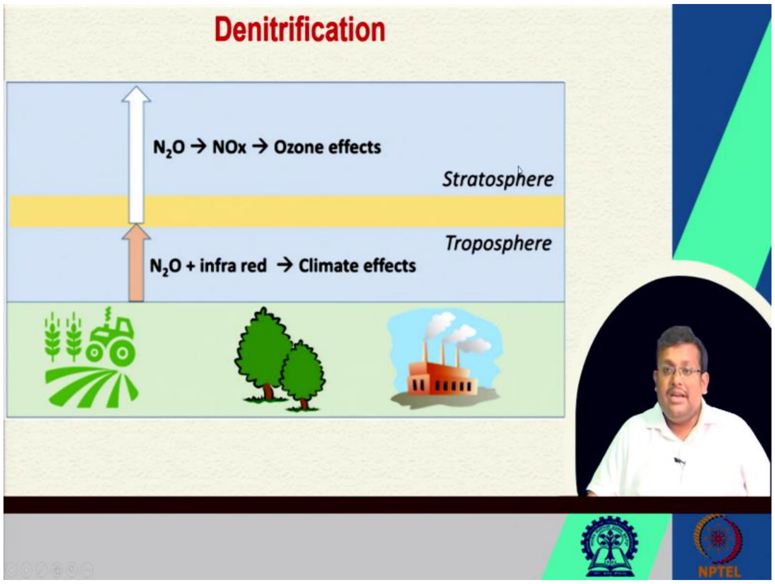

So, also when these different types of gases like nitrous oxide released back into the atmosphere, they can create different types of hazardous climatic effects in troposphere and stratosphere. So, here we can see that these nitrous oxide or in other words these NOx or nitrogen oxides are interfering with the ozone layer in the stratosphere and ultimately they are causing some damages in the stratosphere. Similarly, nitrous oxide has its effect on troposphere also.

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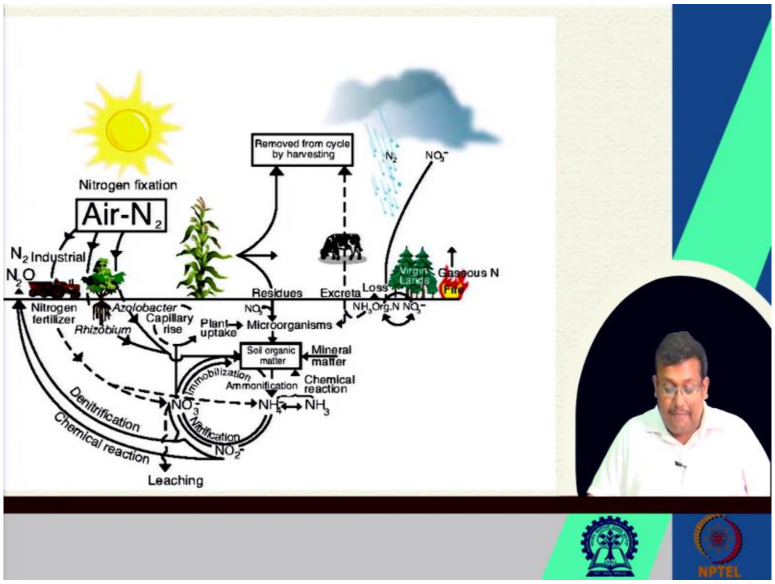

So, if we see the snapshot of these nitrogen cycle again we are sure that these nitrogen fixation goes through either through industrial process from here or through rhizobium through symbiotic nitrogen fixation and also through a free living nitrogen fixing bacteria like Acetobacter. So, although basically fix the nitrogen, atmospheric nitrogen into organic forms.

And of course, these nitrogen and these nitrogen and from the industrial process the nitrogen fertilizer and from these rhizobium ultimately it goes through soil organic matter and from nitrogenous fertilizer, it also goes through different processes. And also you can see here denitrification occurs in the reverse direction of nitrification.

So, these nitrogenous fertilizer first it will convert it to ammonium form and these ammonium will go back to the nitrite and this nitrite will go to the nitrate, these nitrate will be up taken by the plant or they will be lost by leaching or they can go back to the atmosphere by the denitrification process.

So, this is how and from the soil organic matter the soil organic matter the source of soil organic matter is the bodies of microorganisms, plants as well as animals. So, this is how, I mean when we go for the crop harvest that will remove the nitrogen through harvesting. So, this is called crop removal. And here you can see fixation of nitrogen from rainfall. And so, different types of nitrogen mechanisms are described in this slide.

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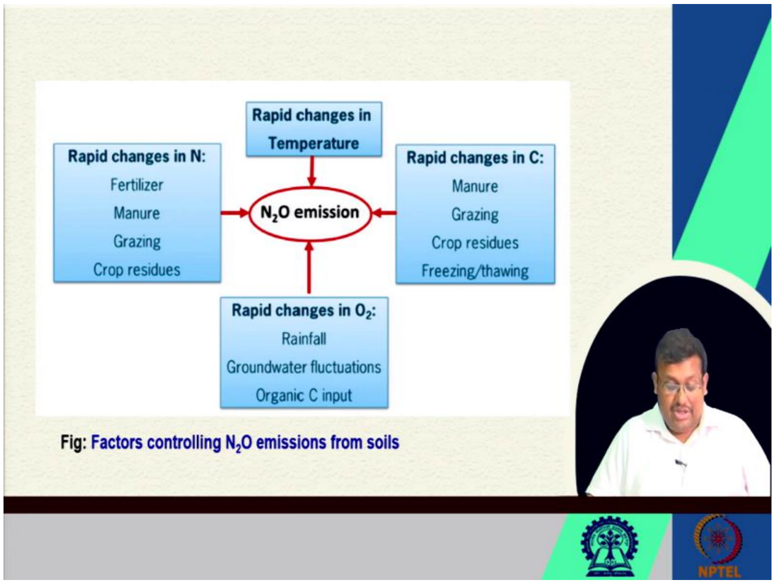

So, the nitrous oxide emission is are generally governed by four major factors one is rapid change in temperature of course, and rapid changes in carbon, rapid changes in oxygen and rapid changes in nitrogen. So, rapid changes in carbon like addition of manure, then grazing, crop additional crop residues freezing thawing these will impact the nitrous oxide emission.

Also rapid changes in oxygen like when there is a rainfall increased amount of rainfall will also help in nitrous oxide emission, then groundwater fluctuation, organic carbon inputs all these will play an important role for nitrous oxide emission. Then finally, rapid changes in nitrogen like fertilizer application, manure application, grazing and crop residues these also have significant impact on nitrous oxide emission. So, these are major factors which are controlling the nitrous oxide emission.

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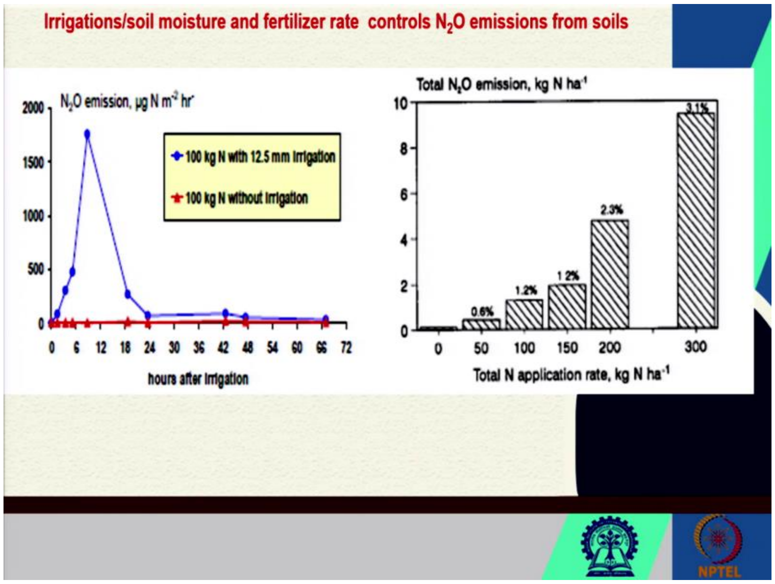

So, in these two plots we can that irrigation of soil moisture and fertilizer rates both controls the nitrous oxide emission from the soil. So, in this plot we can see that in the x axis we are plotted the hours and the y axis we have plotted the nitrous oxide emission. So, here this blue line shows 100 kg of nitrous and with water for 12.5 millimeters of irrigation and here this red line is showing 100 kg of nitrogen without irrigation.

So, of course, when there is a moisture that will increase the anaerobic condition and that will increase or augment the denitrification and nitrous oxide emission. Similarly, the total nitrogen application rate as we increase from 0 to 50, to 100 to 150, then 200 to 300 we can see there is concomitant changes or increase in total nitrous oxide emission also. So, that shows the impact of total net application as well as the moisture in the soil.

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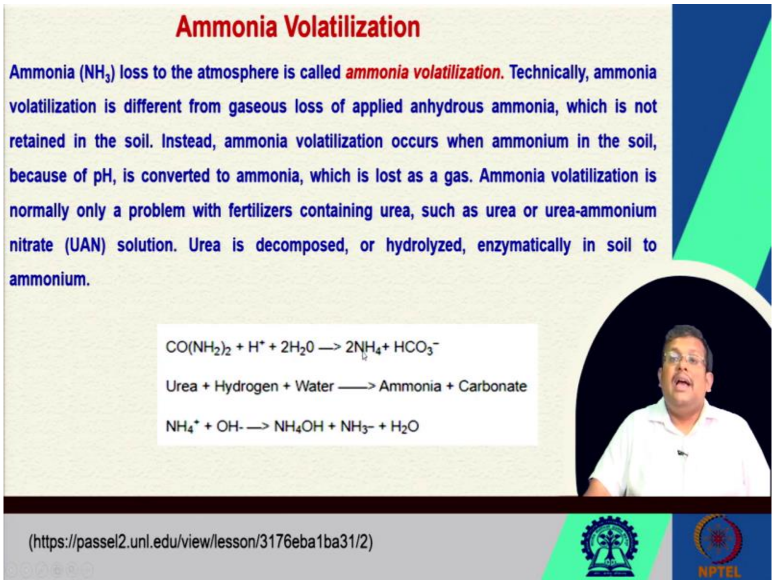

Now, what is ammonia volatilization? Ammonia when it lost I mean when there is a loss of ammonia into the atmosphere that is called ammonia volatilization. Technically, this ammonia volatilization is different from gaseous loss of applied anhydrous ammonia which is not retained in the soil. Instead, ammonia volatilization occurs when ammonium in the soil because of the pH, pH is the major controlling factor, so because the pH is converted to ammonia which is lost as gas.

So, due to the high pH when ammonium ion which is present in the soil converts into ammonia gas which is lost to the atmosphere this is called ammonia volatilization. Now, ammonia volatilization is normally only a problem with fertilizers containing urea, such as urea or urea ammonium nitrate solutions.

Now, what happens when urea is decomposed or hydrolyzed and enzymatic in soil to ammonium. So, here you can see this is urea which is hydrolyzed to form the ammonium ion and these ammonium ion in the alkaline condition they will convert into ammonia gas and then will release back to the atmosphere and that will be called ammonia volatilization.

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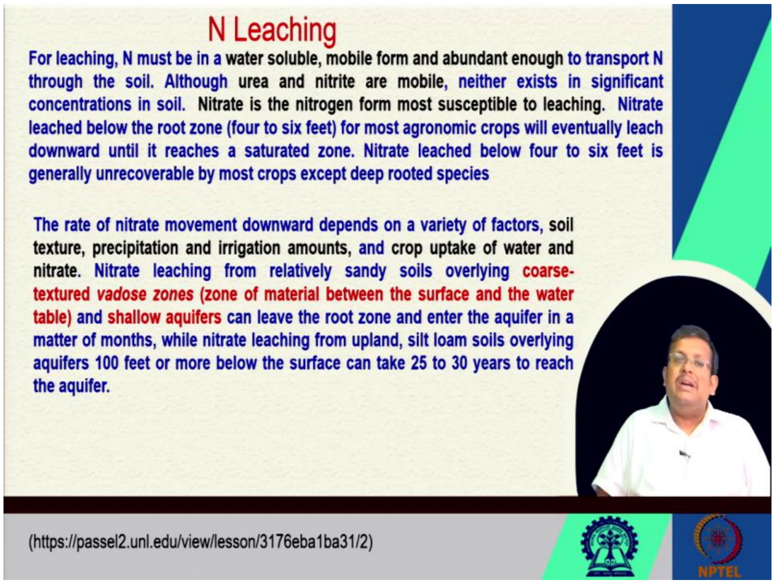

The another important nitrogen loss, pathway of nitrogen loss is nitrogen leaching, specifically nitrate leaching because nitrate is among, this is the major inorganic form of nitrogen which is generally lost while leaching. Now, for leaching nitrogen must be in water soluble mobile form and abandon enough to transport nitrogen through the soil. Now, although urea and nitrite are mobile, neither exist in significant concentration in soil.

Nitrate is the nitrogen for most susceptible to leaching. So, nitrate leached below the root zone that is 4 to 6 feet for most agronomic crops will eventually leach downward until it reaches a saturated zone. Nitrate leach below 4 to 6 feet is generally unrecoverable, so we cannot recover it back by most crop except deep rooted species. So, the rate of nitrate movement downward depends on a variety of factors for example, soil texture, precipitation and irrigation amounts and crop uptake of water and nitrate.

So, if we see there is a coarse textured soil for example, sandy soils, which is overlying a coarse textured vadose zones, you know, what is the vadose zones, vadose zones is a zone of material between the surface and the water table. So, if there is a nitrate leaching issue in this sandy soil core sandy soil, and of course, if there is a shallow aquifer, they can leave the root zone enter the aquifer in a matter of months.

On the contrary, from upland silt loam soil overlying which is overlaying an aquifer of 100 feet or more that will take 25 to 30 years to reach the aquifer for the nitrates. So, depending on soil texture, and also the amount of water present, the nitrate movement basically changes from one soil to another soil. Nitrate leaching is more in case of coarse textured oil.

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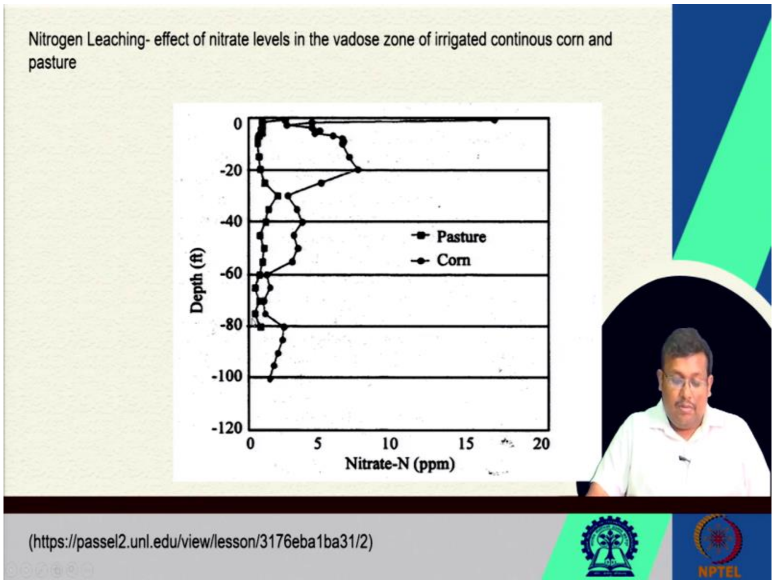

So, here you can see there is an experimental results where we can see nitrogen leaching effect in the vadose zones of irrigated continuous corn and pasture. So, you can see here this is the nitrate leaching for pasture and here this is the nitrogen leaching nitrate, leaching for corn.

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Now, next important issue with nitrogen is eutrophication. Now, eutrophication is an environmental problem and it generally occurs when the water body any water body is become, any water but it becomes very rich with these nutrients like nitrogen and phosphorus that will support the bloom of algae ultimately exhausting all the dissolved oxygen and creating an oxygen depleted condition, we are going to discuss that in detail.

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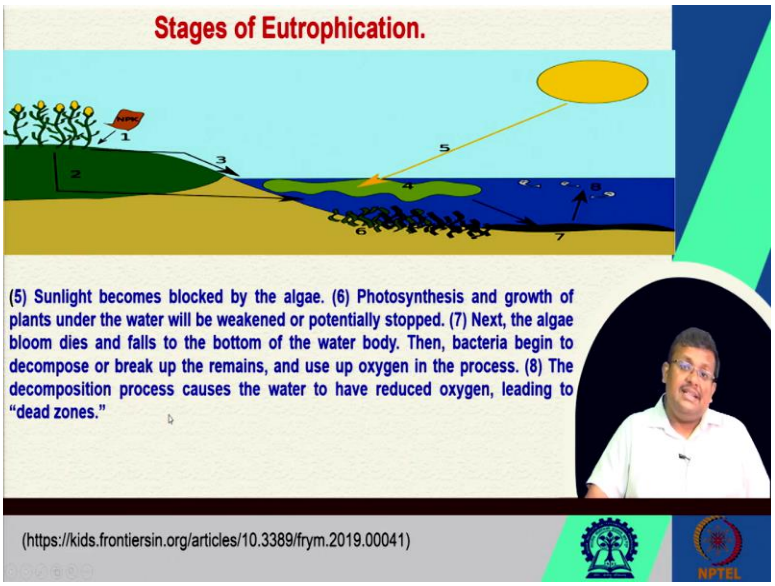

So, what are the stages of the eutrophication? There are generally four stages of the eutrophication, first stage you can see this is the excess of nutrients suppose you are applying huge amount of NPK fertilizer in the soil and the ground and it will, so, that will ultimately go to the water body. Second step is some nutrients become dissolved in water and leach are leak into the deeper soil layers eventually they get drained into the water bodies such as lake or ponds.

So, here you can see this is a second pathway. Third is some nutrients runoff from over the soil and ground directly into the water, so, this is a third. Fourth one is the extra nutrient causes algae to bloom. So, there will be an algal bloom, when there is an excess amount of nutrient in the water body. Then in the fifth stage, sunlight becomes blocked by the algae when there is this of course we can see the sunlight is getting blocked by this algal bloom.

So, this is called algal bloom. And when there is an algal bloom photosynthesis and growth of plants under the water will be weakened or potentially stopped. Next, the algae bloom dies and falls to the bottom of the water body, then bacteria begin to decompose and break down the remains and use up all the oxygen in the process.

So, whatever oxygen were dissolved in the water, the bacteria will eat up all these oxygen. So, the decomposition process caused the water to have reduced oxygen leading to dead zone. So, this is the eutrophication process. And when there is dead zone, all the organisms which are present in the water will be negatively impacted because of loss of dissolved oxygen.

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Factors with their degree of influence on different loss mechanism of N

Factors	Denitrification	Volatilization	Leaching
SOIL			
pH	LOW	HIGH	---
Salinity	---	HIGH	---
Texture	HIGH	MEDIUM	HIGH
Temperature	MEDIUM	HIGH	LOW
Organic C	HIGH	---	LOW
Topography	---	---	---
WEATHER			
Temperature	MEDIUM	HIGH	LOW
Wind Speed	---	HIGH	---
Rainfall	HIGH	MEDIUM	HIGH

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So, here you can see these are the factors with the degree of influence on different loss mechanism of nitrogen. So, pH has high impact on volatilization. Salinity has high impact on volatilization. Texture has high impact on denitrification and leaching. Temperature has high impact on volatilization, of course, higher temperature higher volatilization.

Organic carbon has higher importance on denitrification and among the weather parameters temperature has high impact on volatilization. Wind speed has high impact on volatilization. Rainfall has high impact on denitrification as well as leaching.

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FACTORS	Denitrification	Volatilization	Leaching
FERTILIZER			
Type	MEDIUM	HIGH	HIGH
Amount	HIGH	HIGH	HIGH
Placement	MEDIUM	HIGH	LOW
Timing	MEDIUM	MEDIUM	MEDIUM
Manure	HIGH	LOW	MEDIUM
CROP MANAGEMENT			
Tillage	MEDIUM	LOW	MEDIUM
Cultivar	LOW	MEDIUM	HIGH
Irrigation	HIGH	MEDIUM	HIGH
Drainage	HIGH	LOW	HIGH
Ground Cover	HIGH	MEDIUM	LOW

Fertilizer type has high impact on volatilization leaching. Amount of fertilizer will have high impact on denitrification, volatilization and leaching. Placement has high impact on volatilization and then timing has medium impact on everything. Manure application has high impact on denitrification and crop management has almost low to medium impact.

Cultivar has high impact on leaching. Irrigation has high impact on denitrification as well as leaching. Drainage has high impact on denitrification as well as leaching and ground cover has high impact on denitrification as well as only for denitrification.

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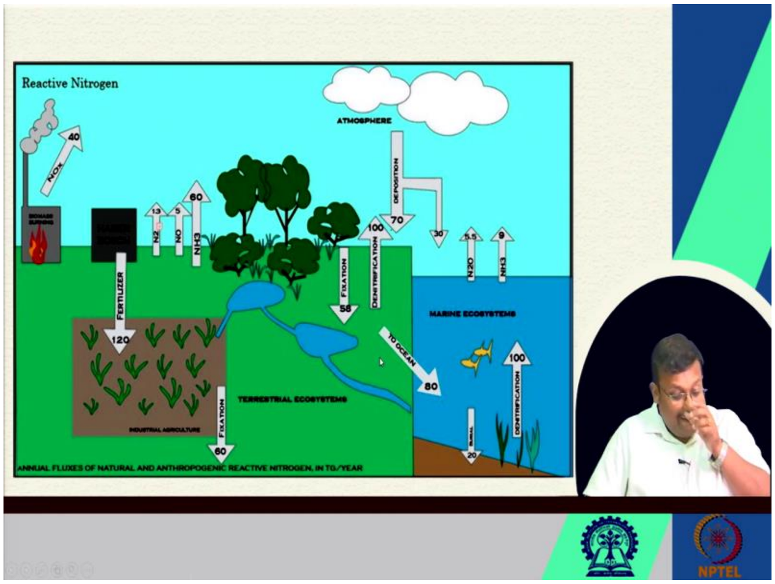

So, if we want to see the annual fluxes of natural and anthropogenic reactive nitrogen in teragram per year we will see this picture. So, here we can see that these nitrogen, nitrogen oxides are releasing at 40 teragram per year. So, due to biomass burning, and then due to the Haber-Bosch synthesis, through fertilizer we are adding 120 teragram of nitrogen per year and different losses of nitrogen, nitrous oxide and ammonia accounts for 13, 5 and 60 teragrams.

And fixation of the nitrogen accounts for 60 teragrams and then also here fixation 58 teragrams and denitrification 100 teragrams and then atmospheric deposition 70 teragrams and ocean deposition 30 teragrams. From ocean surface the release of nitrous oxide and ammonia 5.5 and 9 teragram. Denitrification from the ocean is 100 teragrams. So, and then the movement to the ocean from land surface is movement of nitrogen from land surface to ocean is 80 teragrams. So, you can see that how the fluxes of nitrogen can be distributed in different parts of the ecosystem.

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Environmental problems associated with N fertilizer use.

Environmental problem	Causative mechanism	Mitigation strategies
Ground water contamination	Nitrate leaching	Judicious use of fertilizers, increasing efficiencies, nitrification inhibitors, coated fertilizer use
Eutrophication	Erosion, surface run-off or ground water discharge	Reduce run-off, water harvesting, controlled irrigation, control erosion
Methaemoglobinemia	Consumption of high nitrate through drinking water and food	Reduce leaching loss of N
Acid rain and ammonia re-deposition	Nitric acid originating from reaction of N oxides with moisture in atmosphere, ammonia volatilization	Reduce ammonia volatilization loss, decrease the *p*H of soil, increase CEC, use fertilizer formulations and inhibitors
Stratospheric ozone depletion and	Nitrous oxide emission from soil global warming	Use of nitrification inhibitor, urease inhibitor, increase N use efficiency

(Pathak et al., 2003)

Now, environmental problems associated with nitrogen fertilizer use. We can see groundwater contamination and basically this is due to the nitrate leaching. So, what are the mitigation strategies? Judicious use of fertilizer, increasing efficiencies, nitrification inhibitors, we have discussed about the nitrification inhibitors in our previous lecture, coated fertilizer use, similarly eutrophication causes due to erosion and surface runoff of groundwater discharge.

So, how to mitigate that reduce runoff, water harvesting, control irrigation, control erosion? Then methaemoglobinemia is basically consumption of due to the consumption of high nitrate through drinking water and food. So, if you reduce the leaching loss of nitrogen that will help to reduce this methaemoglobinemia.

And then acid rain and ammonia deposition is basically the responsible mechanisms are nitric acid originating from reaction of nitrogen oxides with moisture in atmosphere and ammonia volatilization. So, mitigation strategies reduce ammonium volatilization loss, decrease the pH of the soil, increase CEC, use fertilizer formulation and inhibitors.

And then stratospheric ozone depletion is basically caused by nitrous oxide emission from soil global warming and the mitigation strategies are used of nitrification inhibitor, urease inhibitor and we also if we can increase the nitrogen use efficiency that will also reduce the stratospheric ozone depletion effect.

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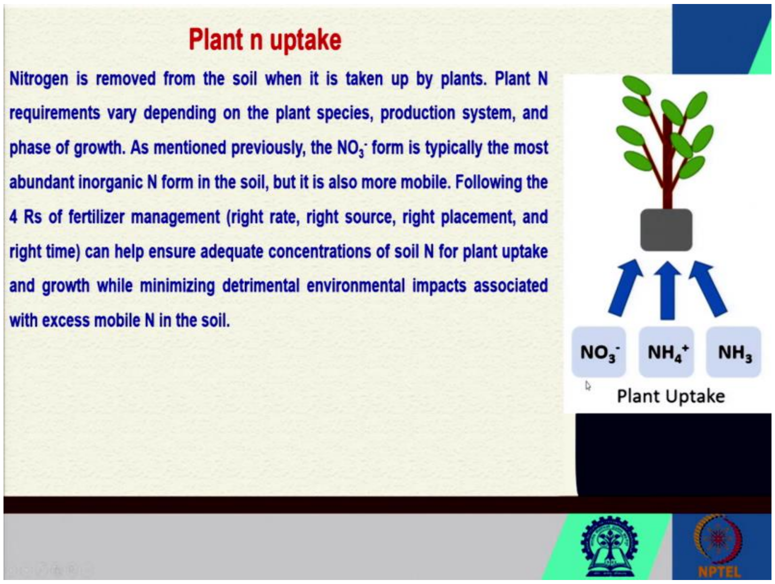

Now, plant nitrogen uptake. So, nitrogen is basically removed from the soil when it is taken up by the plant. So, plant nitrogen requirements vary depending on the plant species production system and phases of growth. So, as mentioned previously the nitrate form is typically the most abundant inorganic nitrogen form in the soil, but it is also more mobile. So, following the, so, there is a concept of plant nutrition.

So, the concept of plant nutrition says there is a four R concept. Four R means, right rate, right source, right replacement and right time. So, if we maintain the right rate of fertilizer, if we maintain right source of fertilizer, if we do the right placement of the fertilizer and we apply the fertilizer right time that will take care of holistically the plant nutrition.

So, following these four R's of fertilizer management, it can help ensure adequate concentration of soil nitrogen for plant uptake and growth while minimizing detrimental environmental impacts associated with excess mobile nitrogen in the soil. So, plant basically can pick up this nitrate and ammonium in some cases anhydrous ammonia is also being used.

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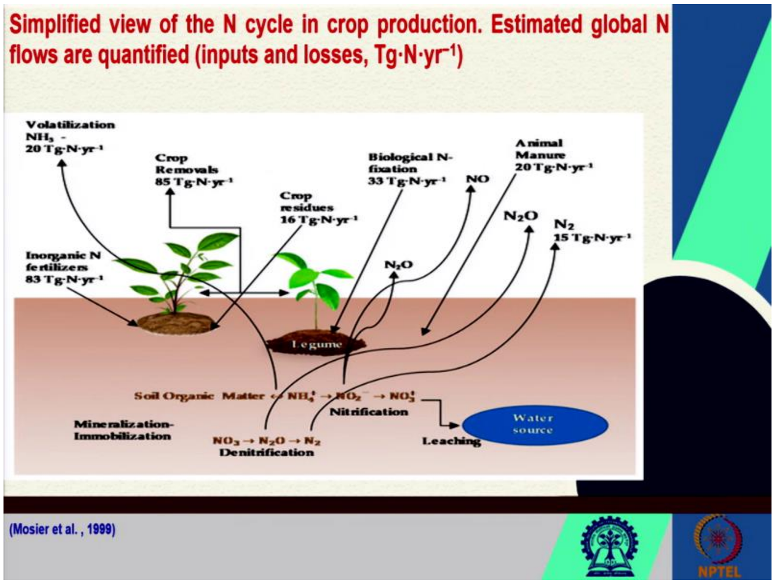

So, this is a simplified view of nitrogen cycle in crop production and here from here you can have an idea about the amount of nitrogen either is different inputs and outputs and fluxes or I would say how different soil nitrogen process are impacting the loss or gain of nitrogen we can have a very good idea you can see here volatilization loss.

Ammonia is basically accounts for 20 teragram nitrogen per year. Crop removal 85 teragram nitrogen per year. Inorganic nitrogen through fertilizer 83 teragrams nitrogen per year. So, these will give you an overview of how this nitrogen cycle is affecting the crop production and also estimated global nitrogen flows are mentioned here in each and every process.

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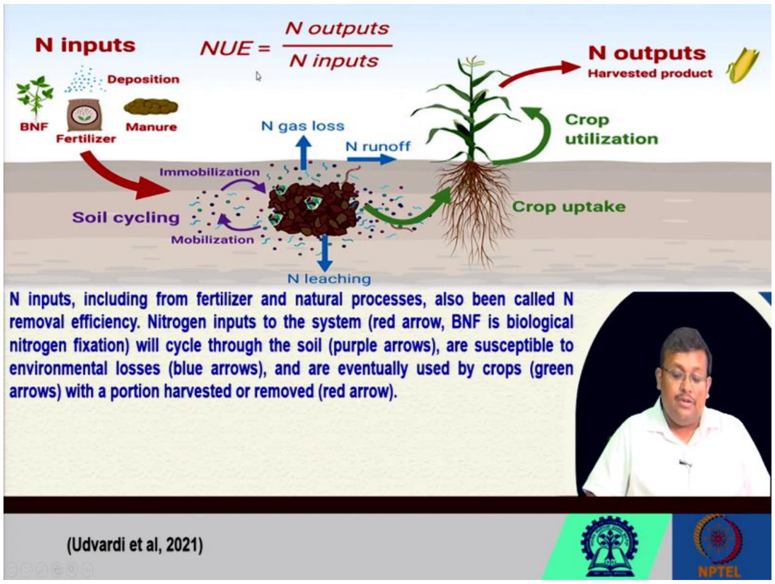

So, nitrogen inputs including from fertilizer and natural process also been called nitrogen removal efficiency and nitrogen inputs to the system are basically denoted here by red arrow. Now, for example, and also biological nitrogen fixation is biological, BNF is biological nitrogen fixation we have discussed. This nitrogen will cycle through the soil and these purple arrows are showing the immobilization and mobilization or mineralization.

And also susceptible to environmental losses, so these are the environmental losses like ammonia volatilization, nitrate runoff and nitrate leaching and are eventually used by the crops which are indicated by this green arrow with a portion harvested or removed. So, this is crop uptake crop utilization finally, through crop removal, there is a loss of nitrogen from the soil. So, this shows nitrogen use efficiency basically we can calculate by nitrogen outputs by nitrogen inputs, we are going to discuss these incoming slides in incoming lectures in details.

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So, these are the references which I have used for this lecture. I hope you have got some good information in this lecture. Let us wrap up our lecture here and let us meet in our next lecture to discuss more about soil nitrogen process and plant nutrition. Thanks.