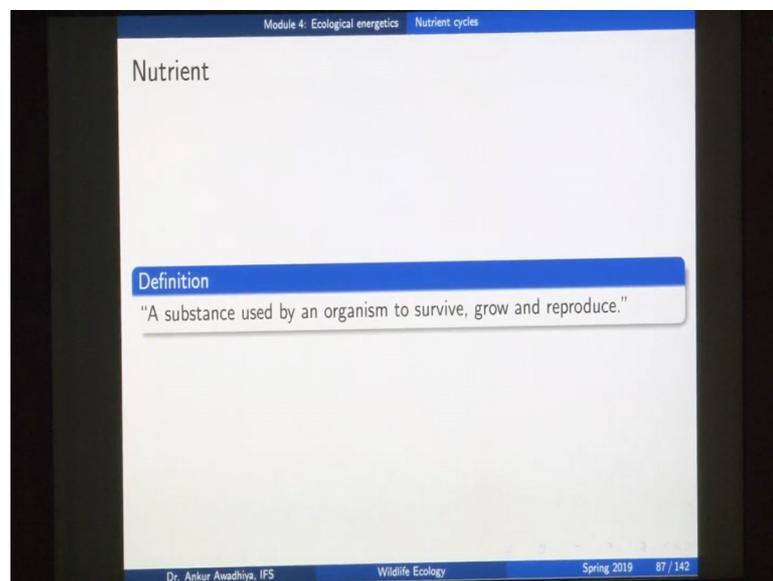


**Wildlife Ecology**  
**Dr. Ankur Awadhiya**  
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**Lecture – 12**  
**Nutrient Cycles**

[FL] Today, we move forward with our discussion on ecological energetics and look at some Nutrient Cycles.

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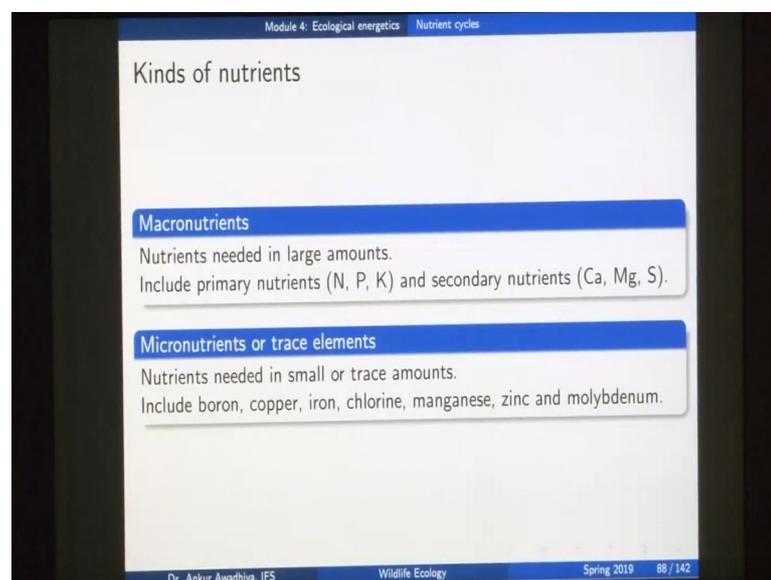
So, as always we begin with a definition what is a nutrient? A substance used by an organism to survive to grow and reproduce. So, essentially when any organism is having food it is getting a number of nutrients, those nutrients in our parlance we say that we are getting proteins, carbohydrates, fats minerals and so on. But, then if we look at these minerals more fundamentally so, we are getting some elements out of these nutrients.

So, when are talking about say carbohydrates or fats we are getting carbon, hydrogen and oxygen; when are talking about proteins we are getting nitrogen; when are talking about other mineral salts we are getting say iron or we are getting copper or we are getting selenium and all of these are different minerals or all of these are different nutrients when we talk about in the parlance of ecology as well.

So, when we talk about say plant nutrition a plant is not getting carbohydrates or fats or proteins from somewhere else because a plant is a producer; it is producing its own food. But even when it is producing its own food it will require some nutrients those nutrients will be say carbon dioxide or water or some mineral salts that will use to make out of these different food items. So, all of those substances will be called as nutrients.

So, a nutrient is a substance that is used by an organism to survive grow and reproduce that is to carry on its life functions, survival growth and reproduction.

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Now, if we talk about nutrients there are certain nutrients that an organism requires in larger concentrations or larger amounts and there are some nutrients that are required by the organisms in the smaller amounts. So, for instance, if we talk about ourselves we require much more amount of carbohydrates, proteins and fats then say we a requirement of say sodium in the form of sodium chloride which is our common salt. So, for us we will that carbohydrates, proteins and fats are the nutrients that we require in larger quantities and substances such as sodium chloride or may be some amount of selenium or some amount of say magnesium is something that will require in very smaller quantities.

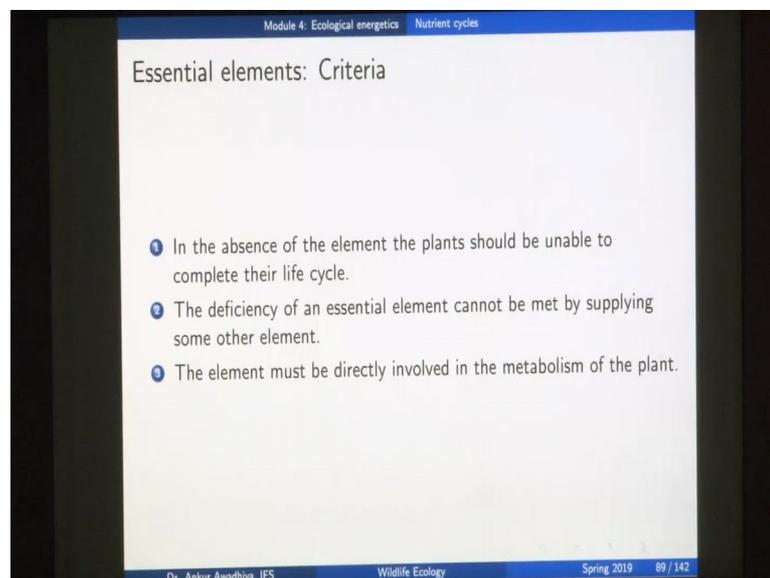
Now, in similarly when we talk about the nutrition of plants and in this particular lecture will be mostly concentrating ourselves with the nutrition of plants because once the

plants have made their food products, then those products get moved on with the different food chains and food webs.

So, in the case of plants, when we talk about macro nutrients or nutrients that are required in larger amounts we can talk about primary nutrients that is nitrogen phosphorus and potassium N, P, K. So, for instance whenever we are talking about fertilizers, we always talk about the N, P, K fertilizer; the fertilizers that provide you nitrogen, phosphorus and potassium. So, these are the primary nutrients. Or they can include the secondary nutrients so, just calcium, magnesium or sulphur. So, these are the nutrients that the plant require in larger amounts.

Now, micro nutrients or trace elements are the nutrient that are needed in small or trace amounts and in the case of plants it could include things like boron, copper, iron, chlorine, manganese, zinc, molybdenum and so on and when we are talking about nutrients one definition is about macro and micro nutrients. The second one is the about essential and non essential nutrients.

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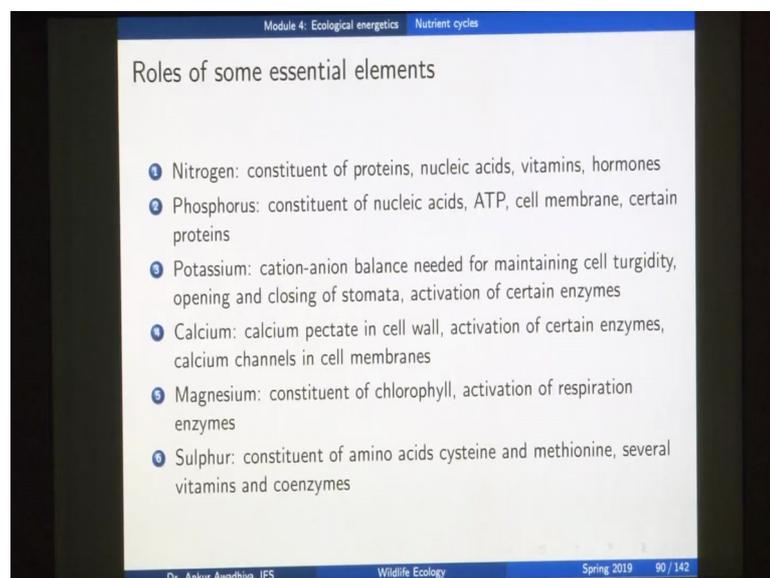
Now, essential nutrients are those nutrients that are required by the plant and that cannot be substituted by anything else. So, there are three criteria for data mining whether an element or is essential or not. The first one is that in the absence of the element the plant should be unable to complete their life cycle.

So, if you say that suppose carbon is an essential element so, in the absence of carbon the plant will be unable to complete its life cycle because all of its parts are made of carbon. The second criteria is that the deficiency of an essential element cannot be met by supplying some other element. So, suppose in place of providing a plant with carbon dioxide we try to provide it with say sulphur dioxide or maybe you try to provide it with say ammonia so, anything that does not have carbon.

Now, if we if you provide a plant with anything does not have carbon the deficiency of carbon cannot be met by supplying some other element. So, it is a sign (Refer Time: 05:18) for the growth of plants. It is an extremely essential thing and the plant cannot live without it. And, the third one is that the element must be directly involved in the metabolism of the plant. So, these are the three criteria to determine whether an element is an essential element or not.

Now, let us look at some essential elements and their rules.

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Let us begin with nitrogen. The nitrogen is a essential element because if you do not give nitrogen to a plant it would be able to complete its life cycle. Nitrogen cannot be replaced by other element and the nitrogen is essential for the metabolism of the plant. Now, why? Because nitrogen is a constituent of proteins so, different amino acids; so, when we say the amino the amino growth is the nitrogen growth. So, it is the constituent of different proteins, it is there in the nucleic acids; so, when we talk about DNA or RNA

that also contains nitrogen. It is a constituent of several vitamins and hormones in the case of plants and also in the case of animals as well.

So, nitrogen is an essential element because it is a constituent of and it is a constituent of proteins, nucleic acids, vitamins, hormones and so on. Another essential element is phosphorus. Now, phosphorus is a constituent of nucleic acid again in the case of DNA or RNA we have phosphorus. It is a constituent of ATP; ATP stands for adenosine triphosphate which is the energy currency in a cell. So, when a cell needs to move energy from one place to another or when a cell needs to use energy for some particular purpose it will be using the energy that is stored in the ATP molecules. So, the ATP will get converted to ADP and it will breath out some chemical reactions. And, phosphorus is essential part of ATP.

Phosphorus is also a constituent of the cell membrane of a cell. So, cell membrane is the outer layer that contains all the constituents of the cell inside the cell. So, it separates what is inside the cell and what is outside the cell and phosphorus is a constituent of the cell membrane and it is also a constituent of certain proteins. Now, here again phosphorus is an essential element because the plant cannot live without it. You cannot place it or substitute it with anything else and it is involved in the metabolism in the plants because of its role in nucleic acids and ATP, cell membrane, proteins and so on.

Another essential element is potassium. So, when we talk about N, P, K this is n this p this is k the potassium is called kalium and we look at it is deep roots and kalium is presented by K. Now, potassium is a part of cation-anion balance that is needed for maintaining cell turgidity, opening and closing of stomata, activation of certain enzymes and so on. So, when we say turgidity it is an expression of the pressure that is being contain inside a cell. So, for instance if you have a cell and you take out the water that is inside so, the cell will become placid. So, it will look like a balloon that is now not inflated. So, and turgidity when you take up balloon and you inflate it then we say that balloon is turgid. In the case of plants, in the case of a number of cells this turgidity is not governed by the movement of air, but by the movement of water.

And, for that case the amount of hospilarity in the cell is essential. So, if you more amount of salt in inside a cell. So, this so, the salt will attract more amount of water from outside and will result in the increase in the turgidity of the cell and potassium plays a

key role there because it is involved in the cation anion balance. And, the cell turgidity in turn regulates the opening and closing of the stomata and stomata are the pores in the leaves through which the gaseous exchange occurs in the case of plants and potassium is also involved in the activation of certain enzymes.

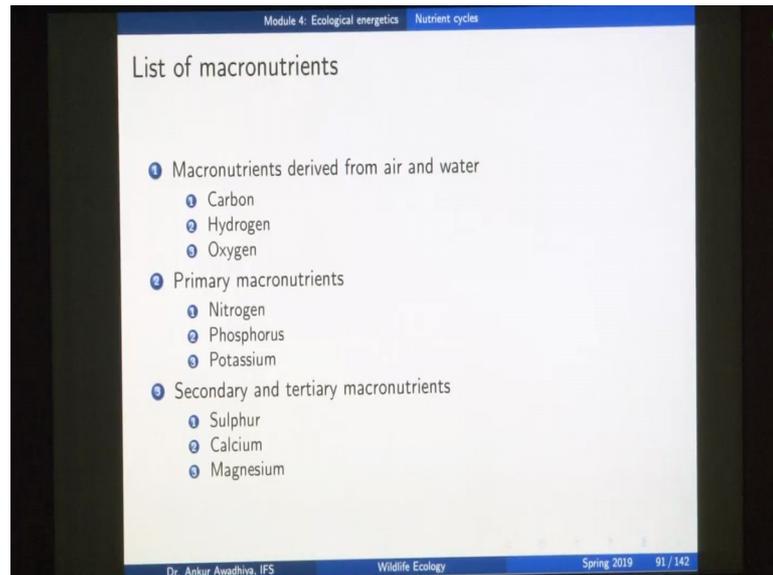
Another essential nutrient is calcium; and calcium is used in the formation of calcium pectate in the cell wall. And, calcium pectate specially plays a role in the cell division. So, when you have a plant cell that is dividing into two cells. So, calcium pectate will form a layer that will separate the two cells or the two daughter cells. So, it is a part of the calcium pectate in the cell wall it is also involved in the activation of the certain enzymes and it also plays a role in the calcium channels in the cell membranes.

Next, we have magnesium; magnesium is a constituent of chlorophyll. So, just like our hemoglobin contains iron inside it similarly chlorophyll contains a magnesium iron inside it. So, magnesium is important because it is involved in a formation of chlorophyll it is a constituent of chlorophyll plus it is required in the activation of certain respiration enzymes. So, if you remove magnesium from the cell you would not have any chlorophyll and the plant will and the cell will not be able to respire.

Next is sulphur; sulphur is a constituent of amino acids cysteine and methionine and it is also constitute of several vitamins and coenzymes. So, here our all here are some of the essential elements that the plant requires and this is not an exhaustive list, there are also a number of other essential elements that are required by the plant.

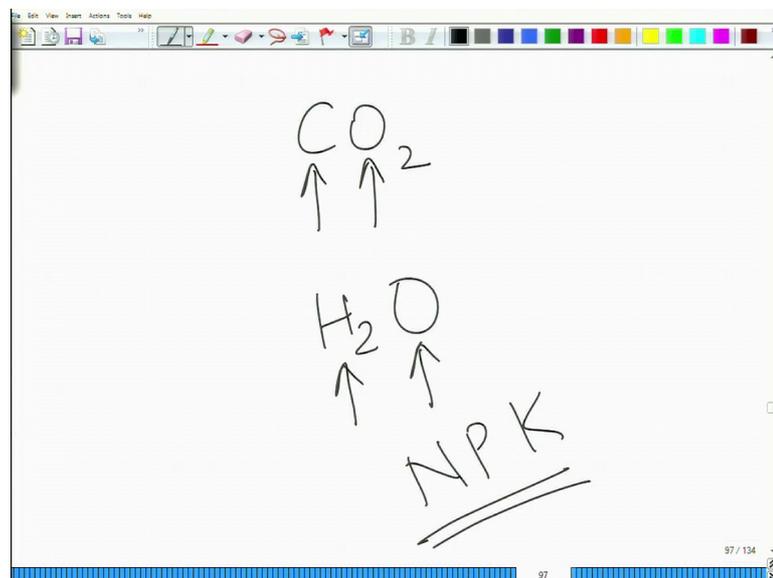
So, we looked at essential and non-essential elements we looked at macro nutrients and micro nutrient. Macro nutrients is something that you require in large amounts, micro nutrients is something that you require in smaller amounts. So, let us now have a look at what are things that a plant need.

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So, we will divide this list into two parts one is the macro nutrient and the second one is the micro nutrients. In the case of macro nutrients we can divide it into again three sub categories the first is the macro nutrients that are derive from air and water and this includes carbon, hydrogen and oxygen.

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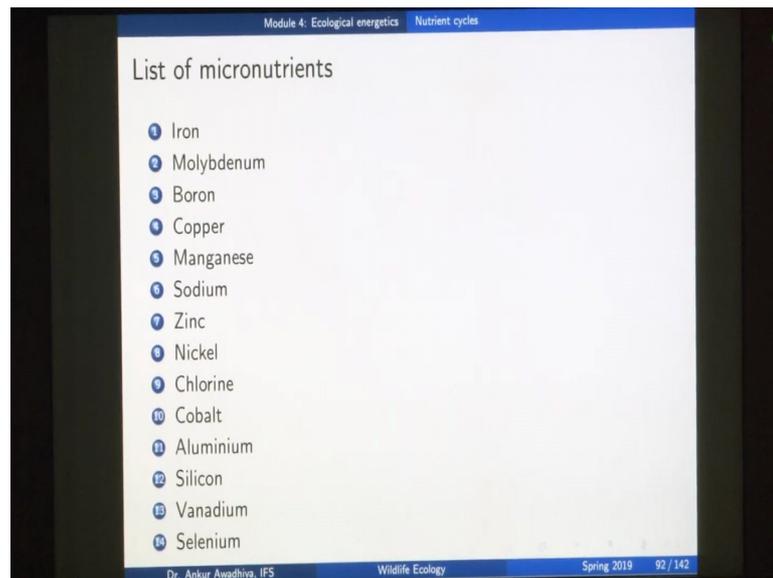
Now, carbon is derived from the air in the form of carbon dioxide. So, here you have carbon and you have oxygen and hydrogen is derived from the water  $H_2O$ . So, here you have hydrogen and oxygen. So, essentially the requirements of carbon, hydrogen and

oxygen these are the three macro nutrients that the plant needs in very large amounts and these are met from the air and water.

The second is primary macro nutrients and primary macro nutrients are nitrogen, phosphorus and potassium N, P, K. So, we can remember it by N, P, K and these N, P, K, they come from the soil. So, they come from mineral salts that are there in the soil or are added to the soil in the form of fertilizers and the plant takes these macro nutrients along with the water that gets absorbed by the roots. So, these are the primary macro nutrients.

Then, we have secondary and tertiary macro nutrients which includes sulphur calcium and magnesium. So, now, here again sulphur and magnesium are required in large quantities, but not as large as N, P, K or as large as CHO. So, these are the macro nutrients that a plant needs.

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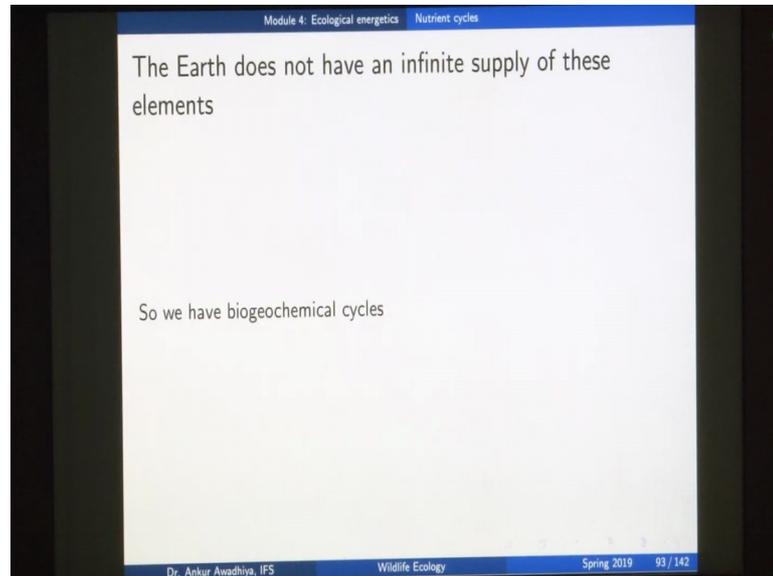


Next we have a list of the micro nutrients. Now, remember again micro nutrients are required in smaller quantities. So, in the case of plants it includes iron, molybdenum, boron, copper, manganese, sodium, zinc, nickel, chlorine, cobalt, aluminium, silicon, vanadium, selenium.

Now, all of these micro nutrients they play an important role in the activation of certain enzymes, in the functioning of certain proteins as coenzymes in certain cases or in the case of things like sodium and chlorine this also plays an important role in the water

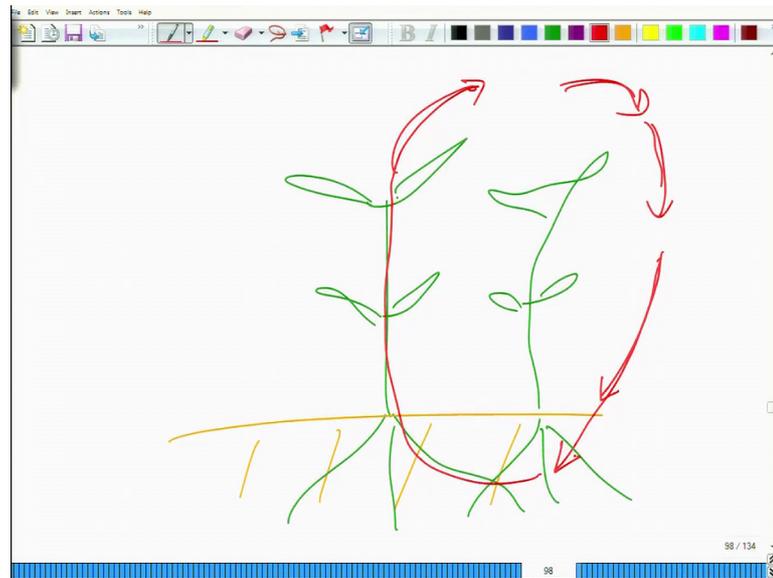
balance inside the cell. So, in the case of water balance we are talking about the turgidity. So, if we have more amount of sodium chloride or say potassium chloride inside the cell, so, it will absorb more amount of water and so, it will become more and more turgid.

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But, then you have the situation that all the plants require all of these nutrients, but then these nutrients are not present in an infinite quantity on earth. So, there is a certain depository of these nutrients, but then the plants have been growing for ages. So, in that case how do they get these nutrients if you have a certain nutrient stock? It is through the biogeochemical cycles.

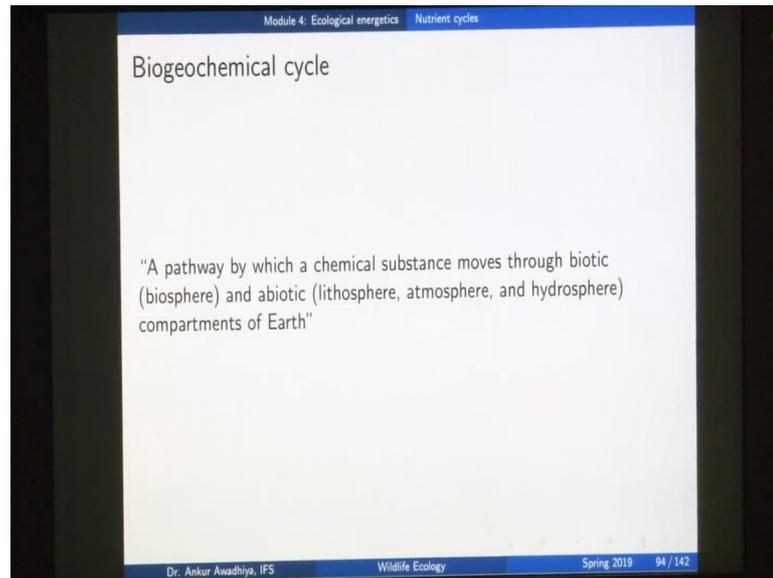
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So, what we are saying here is that if you have a plant and this plant is growing in the soil and the soil has certain amount of nutrients and then these plants get eaten up by animals they get eaten up by other carnivores animals and so on. So, ultimately these nutrients that are taken up by the roots of the plant we should ultimately come back to the earth. So, that if there is another plant that is growing then it should have access to these nutrients.

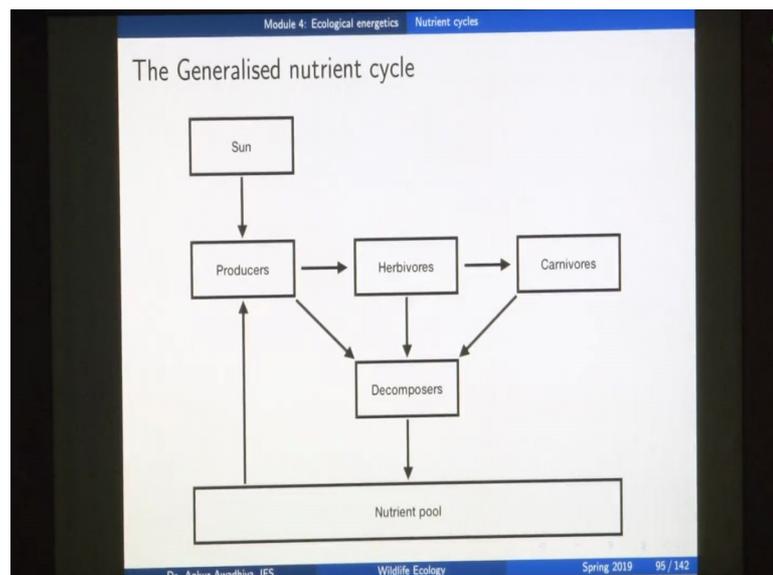
So, the movement of the nutrients will occur in a cyclical manner. So, it moves from the soil through the plants into the animals and then through the animals and the decomposers it will move back to the soil. So, this forms a cycle and we call these cycles as biogeochemical cycles. So, because these involve biological process, they these involve geological process and these also involve chemical processes. So, these are biogeochemical cycles.

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They can be defined as a pathway by which a chemical substance moves through biotic and abiotic compartments of the earth. So, it is a pathway it is a root through which chemical substances are moving through biosphere and abiotic components that is lithosphere which is the rocky portion of the earth, atmosphere that is the airy portion of the earth and hydrosphere which is the watery portion of the earth compartments of the earth. So, this is essentially a biogeochemical cycle.

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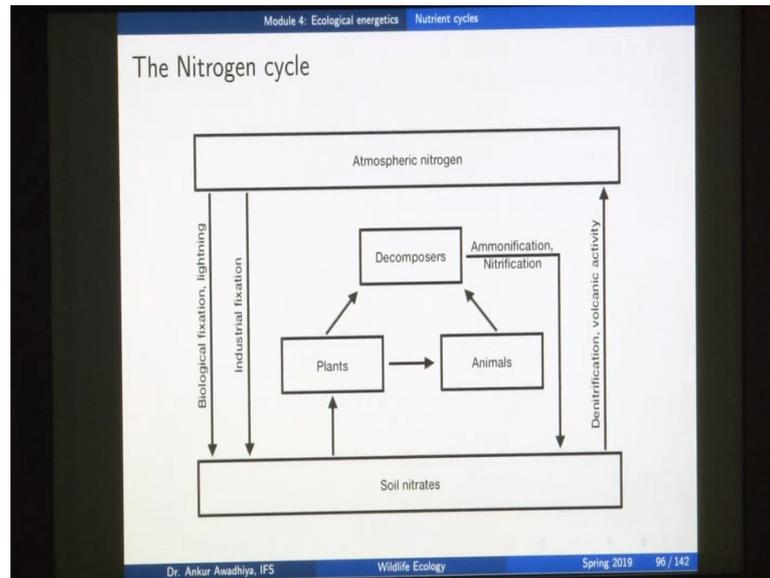
And, in general we can represent a biogeochemical cycle like this. So, you have a nutrient pool. When we say a nutrient pool, it is a repository of the nutrients you can have this repository either in the soil or maybe in the water or maybe in the air. So, one instance, if we are talking about carbon, so, the pool of carbon is there in the air in the form of carbon dioxide and then this pool is then utilized by the producers or the plants which also gained energy from the sun to use these nutrients from the nutrient pool and then they make food or they make certain biological molecules.

Now, from these plants it goes to the herbivores and then it goes to the carnivores and from all three of these it moves through the decomposers back into the nutrient cycle. So, for instance you have a dead leaf. So, this dead leaf will be eaten up by say earthworms and after the earthworm has eaten it they have increase the surface area. So, number of bacteria and enzyme will act on it and ultimately they will all converted back into carbon dioxide.

Now, whether it is a dead leaf or may be a dung of an animal or may be the carpus of an animal. So, all of these will be decomposed back into carbon dioxide or if we are talking about a pool that is present in the soil let us talk about say calcium that has been derived from the soil. So, this calcium is taken up by the plants through their roots then it gets into some biological molecules from there it goes to the herbivores to the carnivores and then when the decomposes are decomposing that dead and decayed parts of these animals or the dungs and excreta of these animals. So, after that all that calcium will be then release back into the nutrient pool which in this case will be the soil.

Now, in this lecture we have a look at certain biogeochemical cycles in more detail.

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Let us begin with the nitrogen cycle. Now, in the case of nitrogen cycle we do not have one pool, but we have two pools. The first pool is the atmospheric nitrogen. So, what then 70 percent of our air that is surrounding us that is nitrogen and the second pool is that of the soil nitrates which are present in the soil.

Now, a plant is unable to use the atmospheric nitrogen directly, so it has to take up the nitrogen in the form of nitrates which should come into the soil. So, how does this atmospheric nitrogen reach the soil? It is through the same biological fixation. So, we had talked about a mutualistic relationship between these by bacteria by the name of rhizobium which live in the root nodules of certain leguminous plants. So, these bacteria are able to fix this atmospheric nitrogen. So, they convert the atmospheric nitrogen into a form that the plants are able to use. So, biological fixation is one way in which nitrogen moves from the atmospheric pool to the soil pool.

The second one is lightning. So, when you have lightning there is an intense amount of heat and electrical discharge and in that case nitrogen and oxygen both the gases that are present in the atmosphere they can react together and they can form nitrates and nitrites which then come down to the soil through rain. So, that is the second way.

And, the third process is industrial fixation. So, these days because we want to put more amount of nitrates into the soil. So, that the plants can use them, especially for agricultural production so, we are artificially converting the nitrogen that is there in the

air into the nitrates. So, that is the other way in which the atmospheric nitrogen can move, get converted into the soil nitrates. So, here we are seeing that this pool is the nitrogen this pool is moving into the, this pool.

But, then again because we are talking about cycles, so, nitrogen can move from the first pool to the second pool. It also be able to move from the second pool to the first pool. So, if you have soil nitrates. So, there can be denitrification and volcanic activities that can convert the nitrates that are there in the soil or that are there in the rock that into nitrogen and through both of these processes denitrification and volcanic activity nitrogen can move from the this pool of the soil into the atmospheric pool.

Now, that is the movement of the nitrogen between both of these pools, but then how does it move through the biological system? So, these soil nitrates can be taken up by the plants and then these nitrates can be used to form different components such as the proteins.

Now, when the plant has formed certain proteins the plant gets eaten up by the animals and then plants and animals when they are dead and decaying they are decomposed further by the decomposers and then the ah. So, nitrogen has pool from the soil nitrates to the plants, plants to animals and plants and animals to the decomposers. Now, these decomposers can further break down these proteins and convert them either into ammonia or they can convert into nitrates and in this process which is known as ammonification or nitrification it can then come back to the soil nitrates pool.

So, here we are talking about the two things one is the pools. So, these are the two pools that we have and the second is fluxes; the fluxes that rate at which the nutrient is moving from one pool to another or from one pool into some other organic substance. So, if we talk about the rate at which soil nitrates are taken up by all the plants rate on the earth then we are talking about both the flux of nitrogen that is pooling from the soil pool into the plants. So, that is the generalised nitrogen cycle and we look at the sub processes in more detail now.

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Module 4: Ecological energetics Nutrient cycles

## Nitrogen fixation

The conversion of atmospheric nitrogen into ammonia is called nitrogen fixation.

Occurs by

- 1 biological fixation
- 2 lightning
- 3 industrial fixation

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So, when we talk about nitrogen fixation it is the conversion of atmospheric nitrogen into ammonia and this occurs through biological fixation or lightning or industrial fixation. So, it can be converted into either ammonia or it can be converted into nitrites and nitrates, but mostly we say that the first stage is the conversion into ammonia. So, this is the conversion of atmospheric nitrogen into ammonia which occurs through these three processes.

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Module 4: Ecological energetics Nutrient cycles

## Biological nitrogen fixation

The conversion of atmospheric nitrogen into ammonia is called nitrogen fixation.

$$N \equiv N \xrightarrow{\text{Nitrogenase}} NH_3$$

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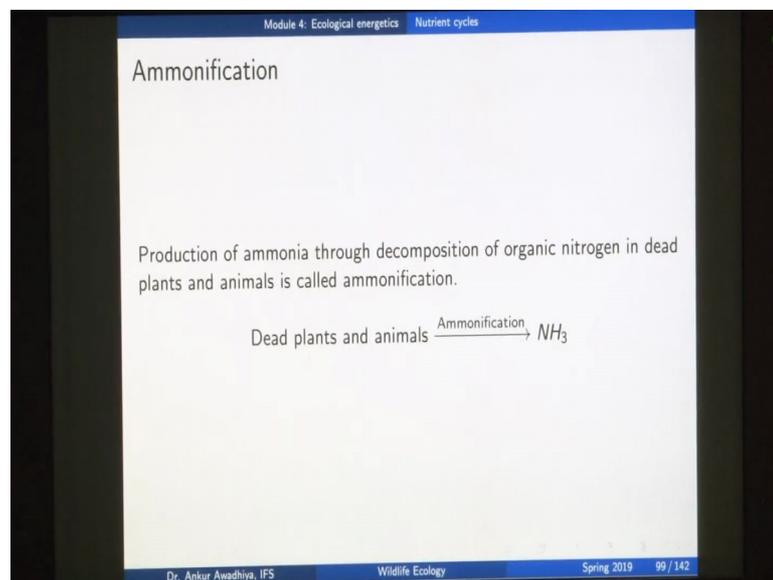
- 1 *Rhizobium*: symbiotic bacteria
- 2 *Azotobacter*: free-living bacteria
- 3 *Nostoc*: cyanobacteria
- 4 *Anabaena*: cyanobacteria

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So, the first one is called is biological nitrogen fixation. Now, biological nitrogen fixation is the conversion of atmospheric nitrogen into ammonia and it occurs in the biological organisms. So, in this case you have this nitrogen which is acted upon in the presence of this enzyme called nitrogenase and it converts it into ammonia and it is done by rhizobium.

So, rhizobium is a bacteria that lives in the root nodules in the leguminous plants or it can be done by certain free living bacteria which is azotobacter or it can be done using some cyanobacteria. So, cyanobacteria is cyano refers to blue. So, these include some like nostoc and anabaena. So, these can also perform biological nitrogen fixation.

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We can also get ammonia by the decomposition of organic nitrogen in the dead plants and animals in through the process of ammonification when the process of ammonification you have the organic molecules that are rich in nitrogen and they are in this process of ammonification they are converted into ammonia.

Now, ammonification generally happens because of the action of decomposers. So, if you have say piece of egg that is lying around you will have some bacterial growth and then it will convert proteins specially the albumen that is there in the egg and that will convert it into ammonia and it will release it back. So, this is the process of ammonification.

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Module 4: Ecological energetics    Nutrient cycles

## Nitrification

Biological oxidation of ammonia to nitrites and nitrates is called nitrification.

$$2\text{NH}_3 + 3\text{O}_2 \xrightarrow{\text{Nitrosomonas or Nitrococcus}} 2\text{NO}_2^- + 2\text{H}^+ + 2\text{H}_2\text{O}$$
$$2\text{NO}_2^- + \text{O}_2 \xrightarrow{\text{Nitrobacter}} 2\text{NO}_3^-$$

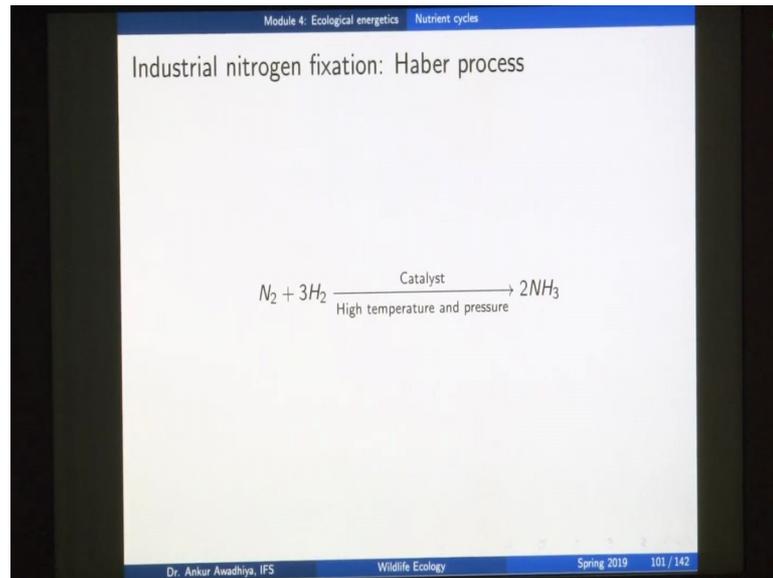
These nitrifying bacteria are chemoautotrophs.

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Next, we have the process of nitrification. Now, in the process of nitrification the ammonia that has been produced; now, ammonia is typically a toxic substance from most of the organisms. So, it needs to be converted to something else. So, that it is gotten rid off. So, nitrification is a process in which there is a biological oxidation of ammonia into nitrites and nitrates.

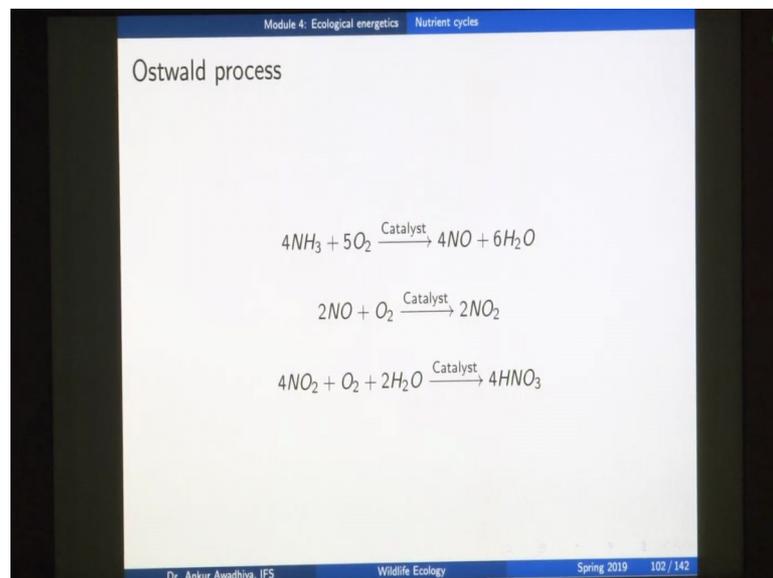
So, in this case we have ammonia that is reacting with oxygen and it can be done through organisms like nitrosomonas and nitrococcus and they will convert this ammonia into nitrites. And, then this nitrites can be further oxidized using nitrobacters and converted into nitrates this should be 3, NO 3 minus. So, you have nitrites that are converted into nitrates and these nitrifying bacteria those that are converting ammonia into nitrites and nitrates they are chemoautotrophs. So, they are autotrophs, they are making their own food using chemical reactions with their chemoautotrophs.

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Now, in the industrial process we have the Haber process. In the Haber process we have nitrogen and hydrogen that are reacted together. So, these two gases are reacted at high temperature and pressure in the presence of catalyst to form ammonia and once we have ammonia and then further convert it into the nitrates using the Oswald process.

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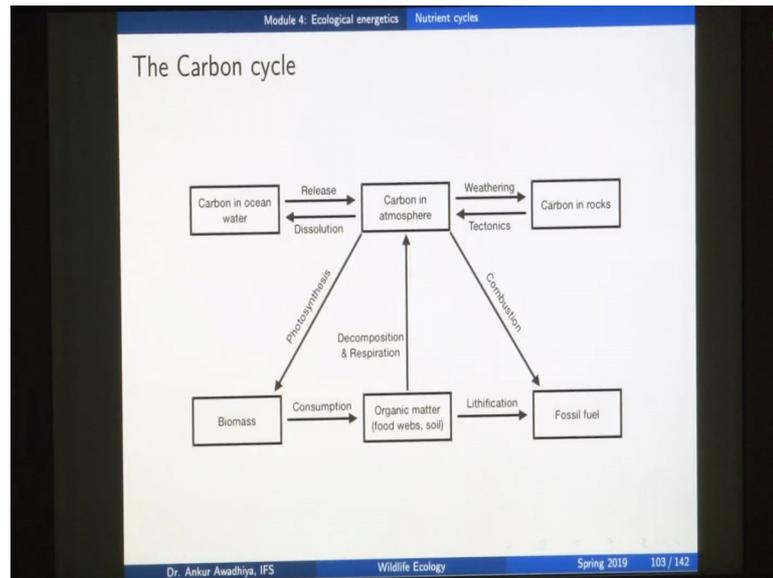


Now, in the case of Oswald process we have ammonia that reacts with the oxygen in the presence of catalyst to form NO and NO is further oxidized in the presence of catalyst to form NO<sub>2</sub> and then NO<sub>2</sub> is in further oxidized in the presence of catalyst to form NO<sub>3</sub>

and it is also reacted with water. So, it gives you  $\text{HNO}_3$ . So, that is the nitric acid. Once you have the nitric acid you can combine it with any this to get nitrate salt. So, if you add  $\text{HNO}_3$  with  $\text{NaOH}$  you get  $\text{NaNO}_3$  which is sodium nitrate.

So, that is all about the nitrogen cycle.

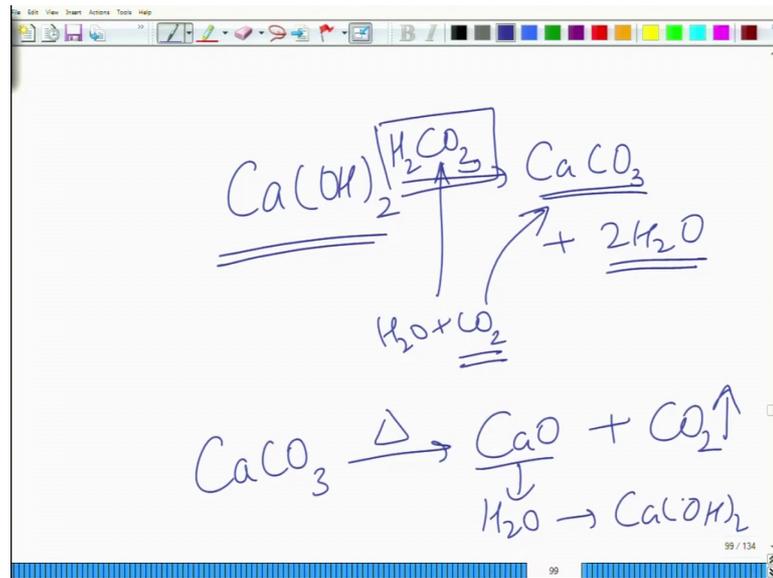
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Let us have a look at the carbon cycle. Now, in the case of carbon cycle the main pool is the carbon in the atmosphere, but then carbon is also stored in other pools especially like pools like oceans or pools like soil carbon or pools like the biological carbon in the form of forest. But, in this case when we are talking about the carbon cycle will mostly focus on the atmospheric pool because that is the largest pool.

Now, here you have carbon in the atmosphere and then this carbon can be utilized in the process of weathering and it can form carbon in the rocks.

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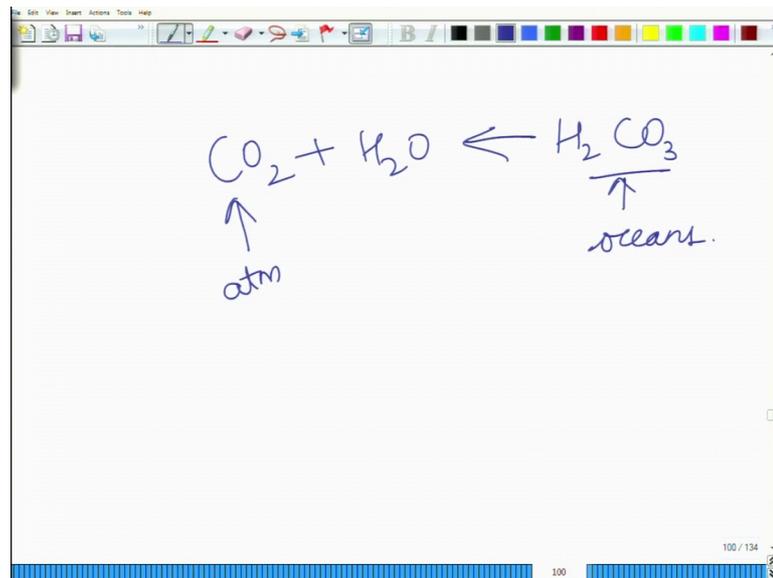
Now, what we are saying here is that if you say have a rock that is calcium hydroxide it can react with carbon dioxide or carbon dioxide plus water because carbon dioxide normally comes down with rain in the form of  $\text{H}_2\text{CO}_3$  and in this case it will form  $\text{CaCO}_3$  plus  $2\text{H}_2\text{O}$ . Now, in this process what is happening is that the calcium hydroxide that is present in the rocks, it is been acted upon by carbon dioxide and water to form calcium carbonate and with the release of water.

So, the this thing was coming from  $\text{H}_2\text{O}$  plus  $\text{CO}_2$ . So, here we have  $\text{CO}_2$  in the atmosphere that is been converted into  $\text{CO}_2$  in the rocks and in this process which is known as weathering. So, in the process of weathering when the reaction is having this rock will also break down. Once it breaks down then further internal minerals will give more and more available for weathering. So, in the process of weathering you can have carbon in the atmosphere that becomes logged into rocks in the form of calcium carbonate.

And, then in a number of tectonics process which is the process in which the plates of the earth collide against each other move past move into the mantle or may be give rise to over mechanical activities you can have the release of these carbon. So, if you say have the  $\text{CaCO}_3$  and then it is heated up. So, it will form calcium oxide plus  $\text{CO}_2$ . So, this  $\text{CO}_2$  gets released into the atmosphere and this calcium oxide in the presence of water it can act with water then it can form  $\text{CaOH}$  twice once again.

So, what we are saying here is that carbon can very easily move from this one pool which is carbon in that atmosphere to carbon in the lithosphere. So, that is the second pool. Another pool is carbon that is present in the ocean water. Now, in this case we have that carbon in the atmosphere can get dissolved in the water to form carbon in the ocean.

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So, what we are saying here is that you have  $\text{CO}_2$  that is reacting with  $\text{H}_2\text{O}$  to form  $\text{H}_2\text{CO}_3$ . So, in this case this carbon that was there in the atmosphere has now reached into the oceans. So, this is the process in which through dissolution the carbon can reach into the third pool of carbon which is the ocean water and then from the ocean water it can come back to the carbon pool through the release of carbon. So, in this process it is nothing, but you have the reverse process. So, we have  $\text{H}_2\text{CO}_3$  give average to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ .

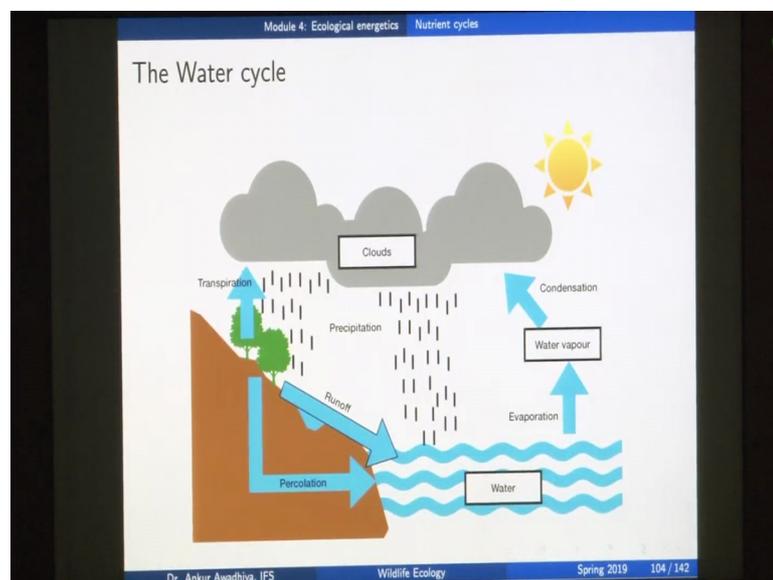
Now, once you have carbon in this pool and carbon in the atmosphere it can be taken up by the by the producers through the process of photosynthesis and converted into biomass. Now, once you have this carbon in the form of biomass in the form of say cellulous or different carbohydrates or say protein molecules or fat molecules once you have it in the biomass; so, this biomass can get consumed by the other organisms the herbivores and then from herbivores into the carnivores and predators and so on and so, this biomass is converted into different kinds of organic matter like food webs or it can be into the soil and in all of these processes this biomass can also be used by the plants

themselves. During respiration it can be released back into the atmosphere or once it is reached in to the animals from there it goes into the decomposers, it can then again release back into the atmosphere or when the animals are respiring there also they are releasing carbon dioxide back into the atmosphere. So, this is the process in which the carbon will move through the different food chain and food webs.

But, then we can also convert this organic matter or rather they can also see the conversion of this organic matter into one another pool which is the fossil fuels. And, in this case this process is known as lithification in which you have these plants and animals that get buried inside the earth and slowly and steadily they get converted into things like petroleum or coal.

So, this is the process in which carbon will reach this pool which is the pool of the fossil fuels and then these fossil fuels when they are burnt they release carbon back into the atmosphere. So, this arrow at should not be here it should on this side. So, in that case this fossil fuel will release carbon back into the atmosphere through the process of combustion. So, that is the carbon cycle.

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Another cycle is the water cycle because water cycle is also an essential nutrient that is providing two essential elements that is hydrogen and oxygen. Now, water cycle is something that we all know. There is water in different water bodies, it gets evaporated and forms water vapour because of the heat that is given out by the sun and when then

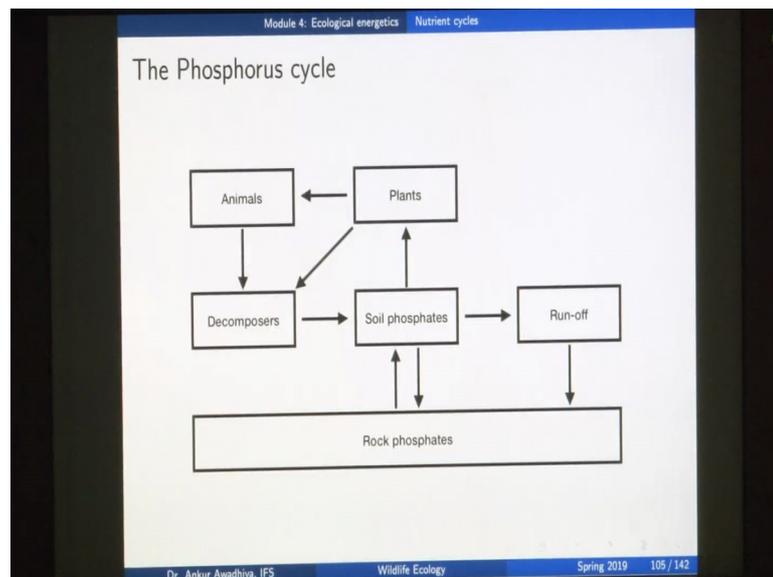
this water vapour condenses it forms clouds; when these clouds are then further cool down, so, all these water forms a droplet us it falls down in the form of rain which you called as precipitation.

Now, this rain can fall either into these big water bodies or it can fall into the land. Now, on the land this water will be absorbed into the soil, it should percolate down or it will move through run off. In the process of runoff, it is getting into the streams and rivers and then ultimately reaching into the big water bodies and then like oceans and seas so, that is runoff or it can get accumulated in some terrestrial water bodies such as ponds or lakes.

And, here again you can have the process of evaporation and this happening or you can have these plants that are absorbing the ground from water and then in the process of transpiration they are releasing it back into the atmosphere or you can have the situation in which the percolated water it moves below the ground and then it also reaches into the oceans.

So, here again we see a cyclical process. The water is you can start from any process it will move a complete cycle. So, this is the water cycle.

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Another cycle is the phosphorus cycle. Now, in the case of the phosphorous cycle the main pool is the rock phosphates. Now, the rock phosphates that is the phosphorus that is

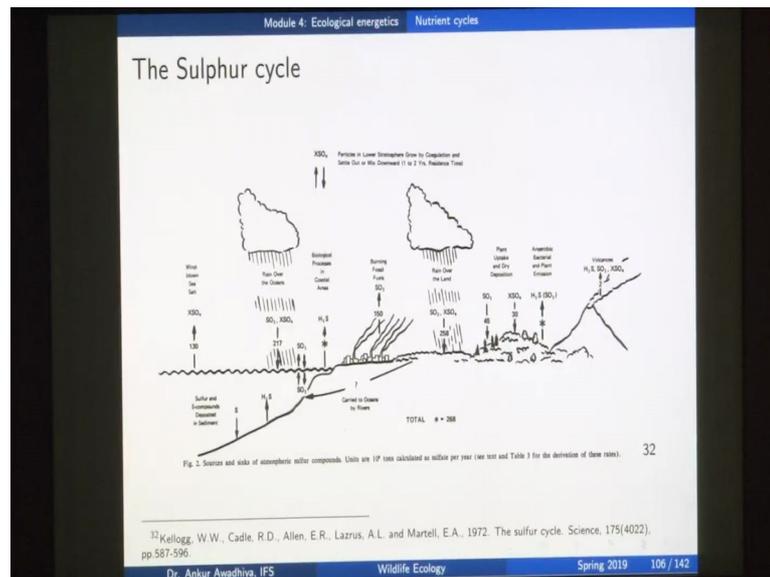
present in the rocks. Now, when these rocks undergo some amount of weathering when these rocks go through some amount of weathering. So, these phosphates these phosphates will be converted into the soil phosphates. So, these are more or less soluble forms of phosphates that are there in the soil. And, this is a two way process. So, the rock phosphate can convert into the soil phosphates and these soil phosphates can precipitate down and then they can become incorporated into the rock phosphates.

Now, once the phosphorus has reached into the soil it can be taken up by the plants from the plants it moves to animals and from plants and animals it moves to the decomposers and from there it comes back into the soil. So, this is a small cycle that is happening here.

Now, the other cycle that is happening is that when you have these soil phosphates and there is rain fall. So, some amount of phosphate can get dissolved in the water move along with this streams and rivers move in a runoff and with this runoff it can go into the oceans and in the oceans it might get it might get start precipitating out. When it starts precipitating out it gets to the bottoms of the oceans and then through tectonic forces tectonic processes it might again get converted into some rocks, so that it forms a rock phosphate again.

And, this rock phosphate later on become this exposed again through the tectonic processes like earthquakes. So, in this in these processes these rocks are exposed into the air and in that case they will again start weathering and the process will start continue. So, that is phosphorus cycle.

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Another cycle is the sulphur cycle. Now, in the case of the sulphur cycle you have a number of sulphur compounds that are there in the air and then when there is rain fall. So, these sulphates can get these SO<sub>2</sub> SO<sub>3</sub> molecules, they can react with the water and then they will come down into the earth once they have come down into the earth in the form of sulphate they can taken up by the plants from plants to animals from plants and animals into the decomposers from there back into the soil plus they can be these processes like release of H<sub>2</sub>S or release of SO<sub>2</sub> that is happening you know then the oceans or may be through the action of the decomposers.

And, also the these days a very important portion is they release of sulphur through the fossil fuels combustion. So, in this case we have these industries that are spearing out our sulphur and if the sulphur is very high these sulphur dioxides are very high in concentration so, nearby you can have acid rain which will then further come down into the soil. And, in this process increase the acidity of the soil may be lead to the deaths of a number of plants and so on. Thus sulphur is also released in huge amounts through the volcanoes.

So, the large releases are this industrial release and the volcano release then when sulphur is there in the air. So, it might react with oxygen and converted into sulphur oxide or sulphur trioxide, then it will come down with water again in the form of acid rain from there it will get absorbed by the plants, it will move through the bio biosphere

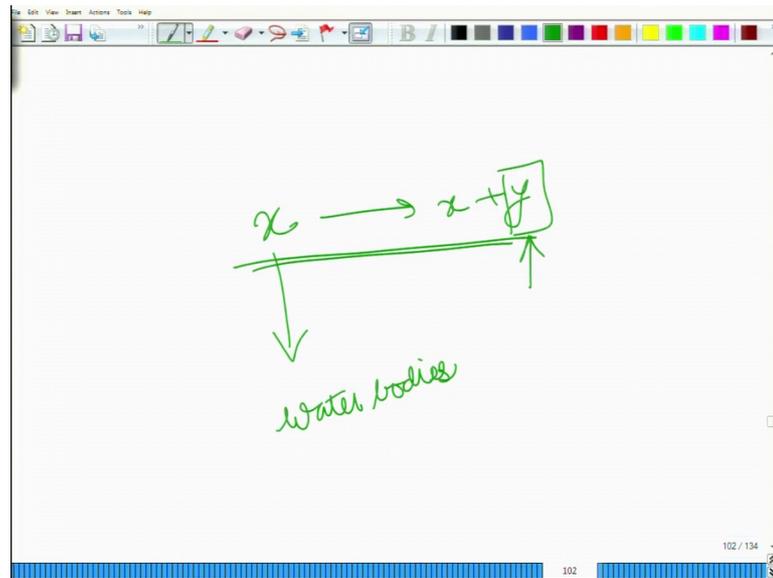
and then again come back to the soil and then get released back into the atmosphere. So, that is the sulphur cycle.

So, once we have looked at all of these different cycles the next question is, so, what? If all these cycles just work as they should in that case they would be hardly any need to understand this cycles. But, then these days they are also saying a number of impacts of human interventions on all of these different cycles. Now, what kinds of impacts are facing say in the case of the carbon cycle we are spearing out of huge quantity of carbon dioxide in into the atmosphere by the burning on the fossil fuels. So, because of that the concentration of carbon dioxide in the atmosphere has been raising.

Now, if that happens it might lead to global warming or it is already leading to climate change and things like that that is one aspect. The second aspect is that in the case of sulphur cycle we are seeing a huge amount of release of sulphur dioxide into the atmosphere because of different industries that are again using up the fossil fuels or that are involved in the processing of different materials. So, in the processing of or conversion of ores into metals it takes huge amount of sulphur dioxide is also released if the ore is a sulphur rich compound.

Or in the case of nitrogen cycle we are seeing a huge change because of the industrial nitrogen fixation. Now, when we are using the Haber process when we are using the Oswald process we are we are making these fertilizers, but in the same process we are tinkering with the fluxes rates that should be there in the environment or that should be a part of the ecology. So, suppose in the normal biological cycles you have a  $x$  amount of nitrogen that is present in the form of nitrites in the soil because you are adding more nitrites in the form of industrial nitrogen fixation it converts from  $x$  to say  $x$  plus  $y$ .

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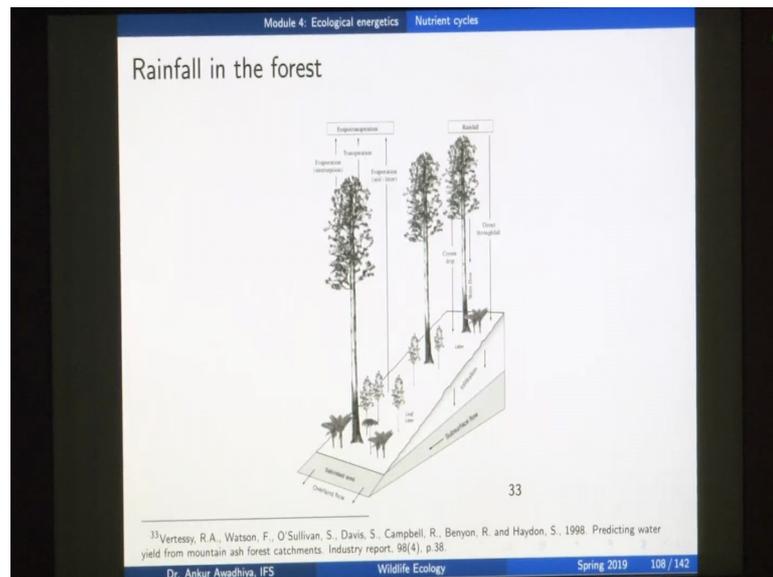
So, what we are saying is that earlier we had this  $x$  amount of nitrogen that was there in the soil and from there we have converted it into  $x + y$ . Now, this extra portion of  $y$  might lead to a number of consequences in the whole of the ecosystem. So, it will increase the growth of plants; it will increase the number of say plankton, planktons, or algae that are there in the water bodies, but then it can also lead to two situations such as eutrophication.

Now, similarly when you have this nitrogen in the soil so, with water it also gets into the water bodies. Now, the water bodies are not only home to the plants, but then these water bodies also provide a source of water to different animals. Now, if there is an animal that is getting a huge amount of nitrites from its water, it might also lead to severe health consequences such as methemoglobinemia.

Now, when we are looking at these aspects, any change that is brought about by the human beings can lead to a plethora of changes in the ecosystems.

So, now let us look at some impacts of human interventions.

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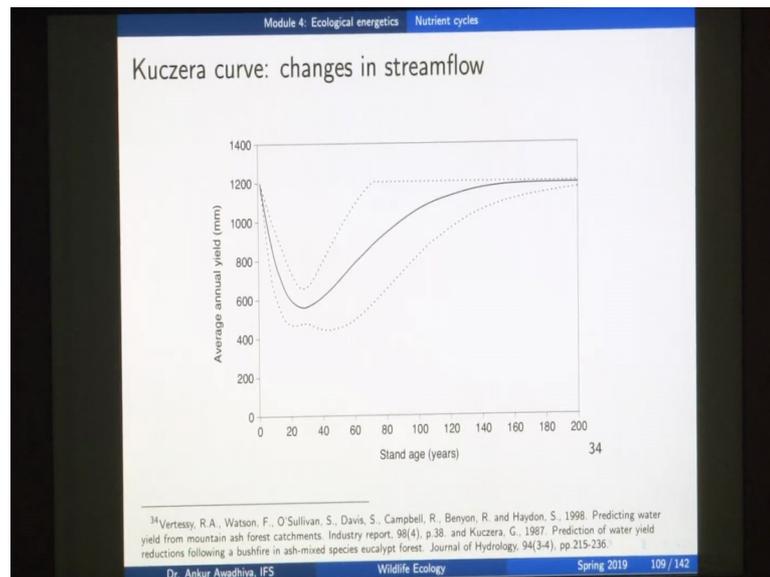
And, let us begin with the water cycle. Now, if you have a rain fall in the forest what happens to this rain? So, some of this rain, it directly gets to the soil and from there it might either run off or it might infiltrate into the soil and become a part of the ground water or start a surface flow. So, that is one portion.

The second position is that it gets intercepted by the trees and from these trees, it will start dripping of in the form of the ground dip or in the form of stem flow and again come back and in the in this direct through fall it was coming at a very high speed, in this case it is coming down at more of a trickling speed because it has been intercepted here. And, then you also have quit a lot of litter certain number of small plants that are there and so, the water also gets percolated and it also gets absorbed by these later.

Now, that is about the water that is coming down. What about the water that can go up? Now, when you have these plants that are intercepting the rain water, so, there can be some amount of evaporation interception; there can be some amount of transpiration in which the plants are taking water from the soil and then releasing back into the atmosphere or you can have some amount of evaporation that is directly coming because of the latter or because of the soil. So, this is basically what happens when it rains in the forest.

Now, what happens when you cut a forest?

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Now, the changes in the stream flows are given by the Kuczera curve. Now, in the case of Kuczera curve there are some forest in Australia that got burnt and once you have a forest that does not have any more trees what are the impacts into the stream flows that you will observe.

So, the first thing is that you will see that on the y-axis here you have the annual in the average annual yield in the in terms of millimetre in the streams and you will find that the stream flow will reduce drastically; within say 20 years you will see a peak decline. Now, it appears a bit counter ended because if you have trees in a forest so, those trees are taking out water from the soil and they are releasing in back into the atmosphere. So, that much amount of water will not be able to reach back into the streams.

Whereas, if you remove those trees all the water that is falling down it will become a part of the either the runoff or it will get percolated into the water table. But, then here we are observing that when you cut the trees the amount of water that is available in the streams it also reduces and we will look the reasons in the short while.

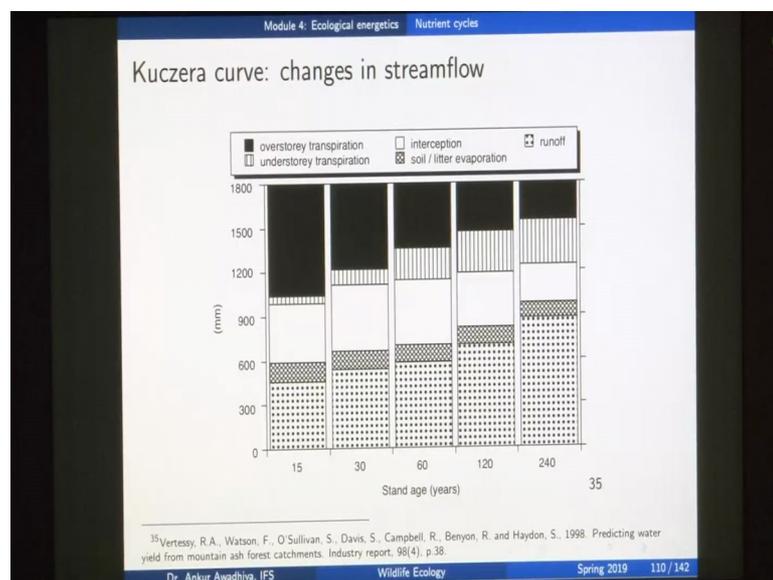
So, in a period like 20 years you will see that the amount of water that is available in the streams it moves from 1200 millimetre a rate up to 600 millimetre. So, it has roughly halved. So, a number of streams that were being provided water because of those forest they would dry off. Then they would be this process of recovery that will recover a long

period of time even say around 150 years. So, in this long period the forests are gradually growing up and after a while you will see that the stream flow comes back to the normal value of 1200 millimetres.

But, then the question is what is happening in between why do see a dip in the stream flow? Now, if you have a forest that has been cleared. So, in that area you have nutrients that are available in the soil, you have water that is coming in the form of precipitation. So, there will be some growth of plants. Now, let us see what happens because those plants are growing because remember that when a plant is growing so, it is converting a lot of nutrients into its body parts. So, it is making a lots of cellulous.

When it is making of those cellulous where is it getting the hydrogen from because cellulous is also a carbohydrates. So, it has carbon hydrogen and oxygen. So, where does this hydrogen coming from? And then when there is a plant that is growing up what is the amount of water that it is going to give out or through transpiration.

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So, if you look at these forest and these and the amounts of water that were been used up by different components of the ecosystem then they were studied we see that in the case of this stand age. So, if you have a forest that has plants that are roughly 15 years of age. So, in that case this the overstorey transpiration is very large. Now, overstorey transpiration is the amount of water that is being released because of these plants and the

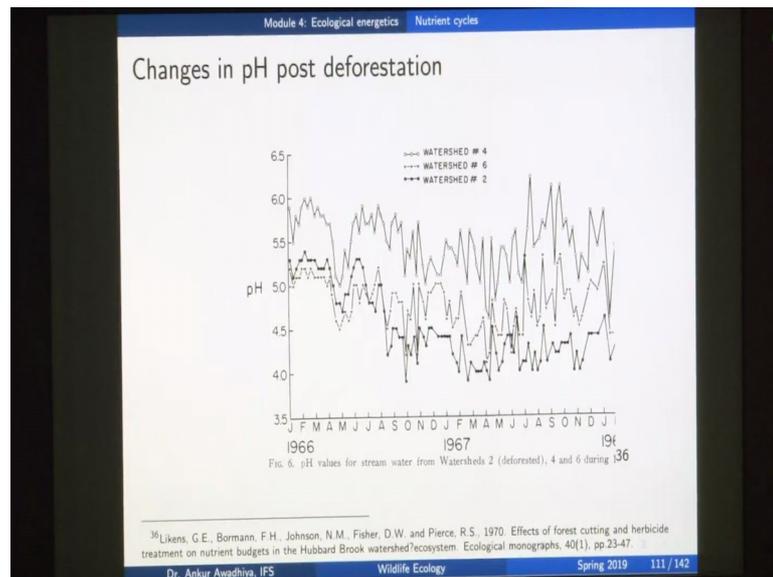
second portion the runoff is very less. Now, runoff is the amount of water that will get into the streams.

So, the runoff is more and more amount of water has been lost because of overstorey transpiration; some amount because of understorey transpiration, then there is a huge amount that gets intercepted, then there is some amount that is released because of the soil and its evaporation and you can see that roughly the amount that is released in the soil and its evaporation it will remain the same with the age of the stand. But, as the forest matures you see that the amount of overstorey transpiration gets reduced significantly.

So, because your plants are already grown very large they do not have to make more amount of cellulose they only have to make cellulose to maintain themselves. So, the amount of water that is required or the amount of water that is being lost because of transpiration it reduces.

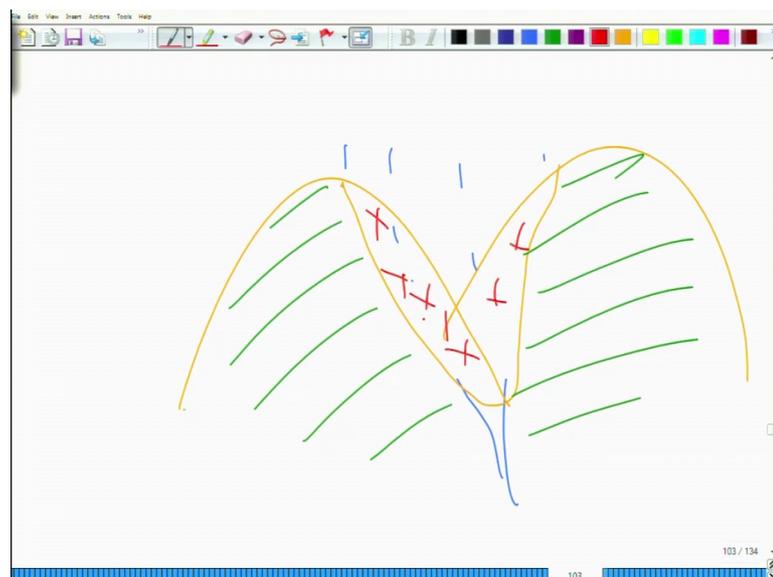
Now, at the same time the understorey transpiration increases a bit because now, you have plants that are very tall and you have plants that are there in the bottom canopy or in the groundcover and these plants are now using up more and more amount of water to sustain themselves. And because you have these losses that are reducing, so, the amount of runoff, it increases. So, once you have a mature forest you will have this much amount of water that is coming out into the streams if you have another forest that is a very young forest you will have a very less amount of water that is coming out into the streams.

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Other changes that happen are things like changes in the pH because of deforestation. So, once you have a forest that is matured and if you look at the stream water, so, you have this pH value of say around 5.5 to 6. So, here we have two watersheds that have good number of trees and then here we have this third watershed that is down here and this is the watershed that was deforested.

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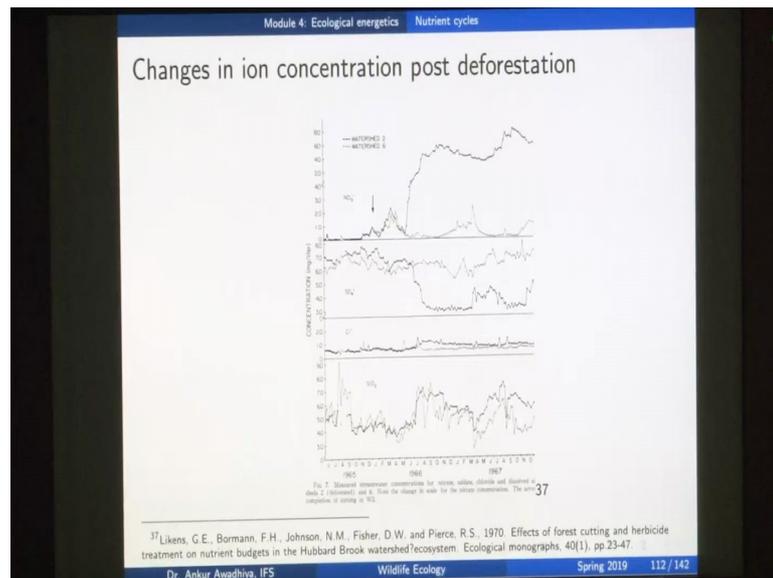
So, in this case you had these hills and in these hills also there were two patches that were created. So, something like this because the water that is falling here so, when it

rains, so all these water gets into this particular stream. So, all these area was deforested the area that was raining this was deforested and the rest of the area was left as such.

So, if you perform this deforestation in a watershed so, you are clearing of all the trees that were there in this area. Once that happens you can observe that the pH of the water lowers and it lowers significantly. So, you have a pH that is close to 6 that are more or less a normal water or a neutral water a completely neutral water will have a pH of 7, a pH 6 is slightly acidic water, but if you have a pH that is close to 4 that is highly acidic water. Now, if you have a water that is highly acidic then probably a number of organisms will not be able to survive in it.

So, deforestation not only changes the amount of water that is available in this streams it also changes the pH of water that is coming into the streams.

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Now, let us look at the changes in other ionic concentrations. So, the most important is the nitrate concentration. So, if you have a forest in which you do not have in which you have not cutting out your trees. So, the amount of nitrates that is available in terms of milligrams per litre is say close to around 2 milligrams per litre; now, which is shown in this bottom curve, which is presenting watershed that was not deforested.

Now, in the case of this second watershed that was deforested you see that the nitrate concentration; so, this is the point that deforested was complete and in a short while it

increased as much as 60 milligrams of nitrates per litre of water. Now, if you have a water that is containing a say 2 milligrams of nitrates per litre. So, that is a water that is that is a very good water it is a potable water, it can be had for drinking by not only the animals, but also the human beings.

But, if you have a water that is having as high as 60 milligrams of litre of nitrates, so, that is a very high concentration of the nitrates. If you drink that water you will suffer from a number of diseases, such as methaemoglobinaemia. Not only that, if you have such huge concentration of nitrates in water then it might also results in some amount of algal bloom. So, as we had seen in the case of Potomac river in which we had in one of the lecture we have had seen that this whole river was covered with algae.

Now, we are seeing the change in the nitrate concentration of as much as 30 times from 2 milligram to 60 milligram. So, there is a 30 fold increase in the amount of nitrates that is now available in the water. Similarly, if you look at the amount of sulphates; the amount of sulphates reduces drastically. So, from around seventh it becomes halved ; so, it becomes around 3 milligrams per litre.

In the case of chloride there is a slight increase, in the case of silicates there is a slight increase, but then what we are seeing here is that once you are cutting of your trees once you are deforesting an area so, that is changing not only the plants that are there in that particular area, but then because it is changing the concentration of different nutrients that are there in the water. So, that will have an impact throughout the ecosystem because even this even the areas which are very downstream, but because they are getting water from this areas. So, they will also start suffering some impacts.

Now, other impacts are these. So, here we are looking at the concentration of calcium in the water. So, in the normal conditions you have a calcium concentration of around 10 milligrams per litre once you have cut your forest it increases from 10 milligrams per litre to as high as 110 milligrams per litre.

Now, all of these it is not coming for all of these calcium is not coming from the biological entities, but what is happening here is that the plants were able to hold to the soil and the soil also as a huge amount of calcium inside. So, because the plants root are able to hold to the soil, so, this calcium just remain there in the system. But, once you have cut these plants, so, once these once the soil is not exposed now, it is now getting

advantage into an unbound form, so all of these calcium have now started to leak into the water streams and all of these calcium then will start flowing downstream.

If we look at the magnesium concentration; magnesium concentrations also increases more than doubles. In the case of potassium consideration, the potassium concentration becomes as well as four times; the sodium consideration, it usually doubles; the aluminium concentration, it also increase up to around say three times. So, if we look at just one process that is deforestation that is been done by the human beings it is leading source so many changes in the water quality in the amount of nutrient that is available in the water. Now, that changes not only the water quality for drinking by the animals, but that also changes this the changes of growth of plants down the stream which because those plants are getting well nutrients from this water source as well.

Now, this is just one process. Now, let us consider another process the incorporation of nitrates in the form of fertilizer or the or the use of fertilizers that have all these N, P and K into the farm lands. Now, when that water gets leached out when along with the runoff, when all those nutrients are able to reach into the streams and into the water bodies that will lead to an immense amount of algal bloom because of that immense amount of algal bloom in a very short period of time the water quality will deteriorate so much that will have very less amount of oxygen and our and your water body will not be able to support any further life form.

So, just because the activities of human beings are changing these nutrient cycles, so it becomes very important these days to understand what are the impacts of our activities into different nutrient cycles, so that we are able to reduce our impact on the eco system specially the negative impacts.

So, in this lecture we started by looking at what are nutrients; then we classify the nutrients into macro nutrients and micro nutrients; we looked at different nutrients what are their roles; we looked at the essential elements, the conditions or the criteria essentiality; then we looked at a generalized nutrient cycle, how nutrients move from one pool to another pool or from one pool into the biosphere and then back again and then we looked at different nutrient cycles in more detail.

And, finally, we looked at the consequences of some human activities such as deforestation and these activities can have a large impact on a number of nutrient cycles

because the amount of nutrients that are present in different pools it changes a lot. And, similar is the impact when they are we are using industrial nitrogen fixation or when we are using fertilizers or when we are spearing out sulphur dioxide because of our activities in the mining sector or when the ore sector or maybe because of or maybe when we are releasing out carbon dioxide and sulphur dioxide when we are burning out the fossil fuels.

So, that is all for today. Thank you for your attention, [FL].