Conservation Geography
Dr. Ankur Awadhiya, IFS
Indian Forest Service
Indian Institute of Technology Kanpur
Module - 7
Biosphere
Lecture - 20
Life on Earth

(Refer Slide Time: 00:13)

Namaste! We carry forward our discussion on the biosphere. And in this lecture, we shall explore life on Earth, primarily, the ecological succession, and the biogeochemical cycles. So let us now begin with life on Earth.

(Refer Slide Time: 00:35)

So what is ecological succession? Ecological succession is a phenomenon that occurs when you have any piece of land that is available for plants and animals or biotic organisms to colonize. So for instance, if we begin with a newly formed rock. So suppose there is a volcanic eruption. And because of that volcanic eruption, certain amounts of lava have come out, and that lava is now available on the surface. It has cooled down. And so it is now a rock.

Now, this rock, does not have any living organisms because it was so hot that all the living things, they would have died. So essentially, when we have volcanic eruptions, there is a huge amount of death of organisms, and perhaps the organisms, or their dead bodies are now under several feet of the newly created rocks. Now, what will happen?

After some time, we will start to observe that there are certain life forms that have arrived on these rocks. They have colonized these rocks. And once they have colonized these rocks, they will start to perform certain actions. So for instance we had observed that in the case of weathering, the plants and animals also are involved in doing weathering, which is known as the biological weathering.

Now in this process, the roots of the plants that have come up into this area will go on cracking the rocks. They will go on reducing the rocks into smaller particles, so that after a while, there will be a layer of soil that has come up. Now, this layer of soil will provide a very different habitat from the bare rock surface that was existing there before. And once you have the soil surface, probably certain more number of plants can be supported or certain other species of plants can be supported that could not have been supported before.

Now in all of these processes, once we are moving from a bare rock into a rock with certain amount of organisms, moving to a layer of soil with certain amount of organisms and perhaps moving into more and more levels of complexity, what is happening is that the organisms are coming into this area from some other place.

Now organisms, especially plants, can come into this area through a number of means. If the seeds are small, they can be carried into this area through wind. Perhaps the seeds can also come into an area through water. Or, if say, there are birds that are coming to these areas, and these birds have eaten up certain fruits, then the seeds can come to these areas through the bird droppings.

So there are n number of ways in which the plants can come into this area. And similarly for animals, animals by nature are mobile and so they can also come into this area. And slowly and steadily, we will observe that there will be a gradual transition from a bare piece of rock into a full fledged forest.

Now, this is how all the forest on the planet have come up. So this is the process which is known as ecological succession. It is a succession because something replaces the previous thing. So essentially, whenever we have a biotic community in an area, it makes use of the resources of that area. It thrives in the area, and in the process, it converts the area into something else.

For example, a rock into a rock with a layer of soil into a rock with a greater depth of soil into a rock with a very fertile layer of soil and so on. And whenever such processes happen, whenever there are changes, then these changes lead to a situation where the existing biotic community becomes less efficient in making use of the resources than another community that can come into this place and replace the original community.

Why? Primarily because if we consider rocks, then perhaps only very primitive plants will be able to survive on these rocks because the conditions are very extreme. In the days, it would become very hot. In the nights, it would become very cold. There is no soil.

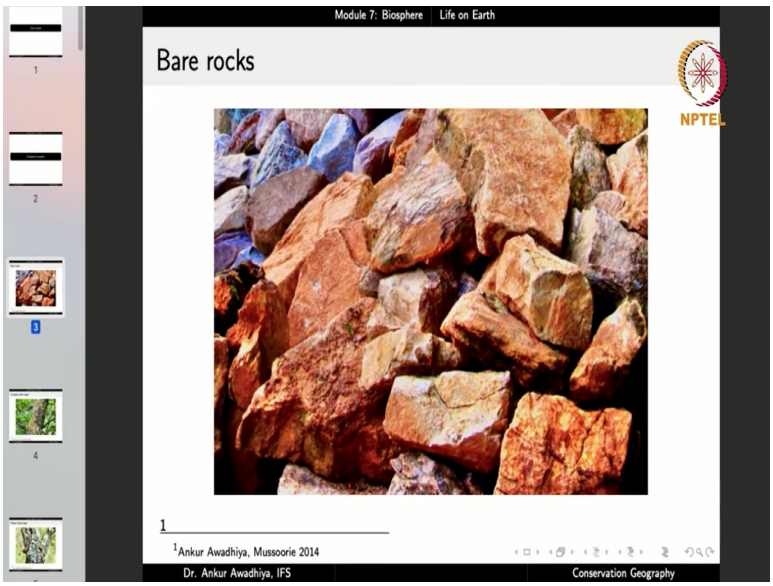
There is a very less amount of mineral nutrients that are available because the rocks have not yet weathered. The amount of water is perhaps also very less because any water that falls it just flows off. It drains off.

So in this process, only very primitive plants can be supported. But once these plants have acted on these rocks, once they have weathered these rocks, created a layer of soil, and at the same time they have deposited their bodies as well into this soil, creating some amount of humus.

So now, with the humus being there, certain other plants can come into these areas, and these plants will be more efficient in thriving in these areas because they are more easily amenable to make use of the soil conditions that are now prevailing in this area. So this is a succession. Something replaces another. And this is an ecological succession. It happens in an ecosystem.

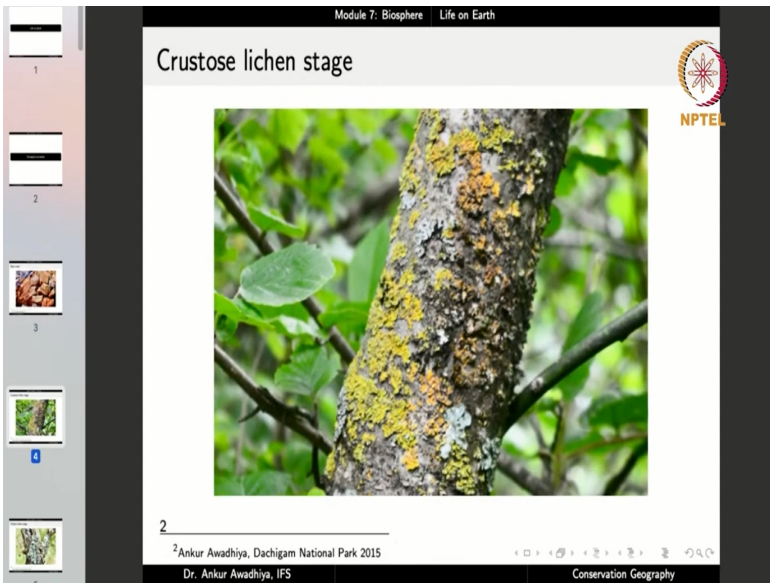
It creates an ecosystem which gradually moves from a simple stage to a more complex stage. So let us know explore this ecological succession in more detail.

(Refer Slide Time: 06:39)



So when we have bare rocks, then there is no living organism that is living on it.

(Refer Slide Time: 06:48)

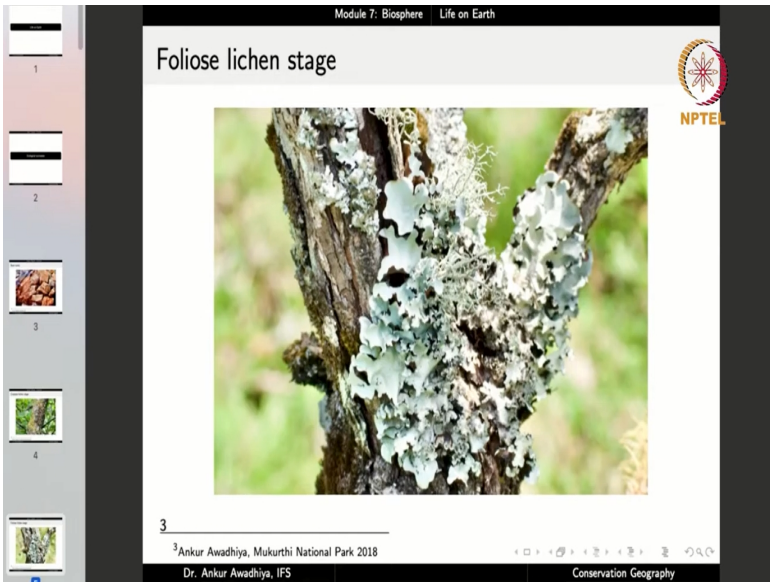


But after some time, the primitive plants will come up, and the first primitive plants that come up are the lichens. Now, lichens are a symbiotic complex that is comprised of plants

and fungi. So essentially, these are these two species that are living together, are supporting each other, and in this way, they are able to thrive on some of the most extreme habitats. And the first lichens that come up are the crustose lichens. So these look like crust.

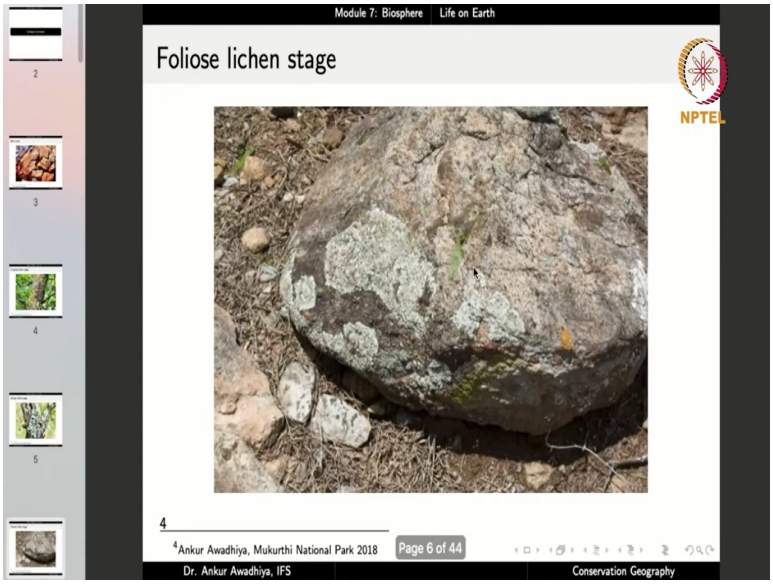
So if you look at a piece of iron that is rusting, this is the sort of crust that would be coming up in the form of rust. So these look like a crust that has come up on the surface. And in this case, we are looking at crustose lichens on the bark of a tree, but they can also come up on the rocks. And once they have come up on the rocks, they will start the process of biological weathering and they will also start to create humus into this area.

(Refer Slide Time: 08:01)



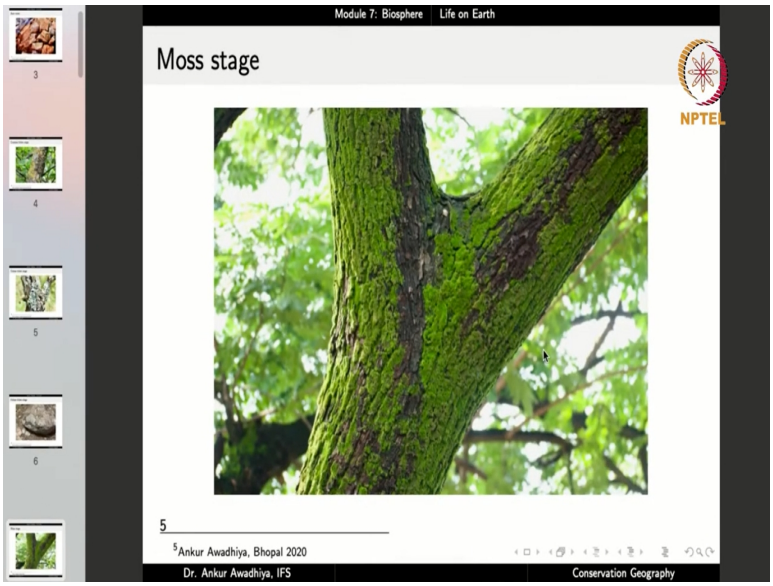
And after a while, the crustose lichens will be replaced by foliose lichens. Now foliose means leaf. So these are the lichens, again, they are a symbiotic community, but they appear to be like leaves. So this is the next stage that would come up. So first you had the rocks, bare rocks, then crustose lichens, then foliose lichens.

(Refer Slide Time: 08:24)



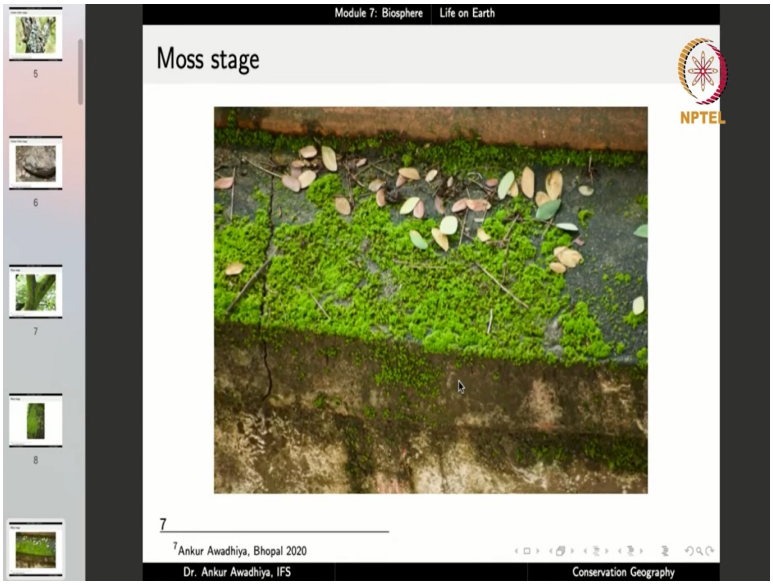
And you can have a stage in which these folioses lichens are now replacing the crustose lichens. So on this piece of rock, you can observe that there are certain foliose lichens and there are also certain crustose lichens. So this is now in a process of being replaced.

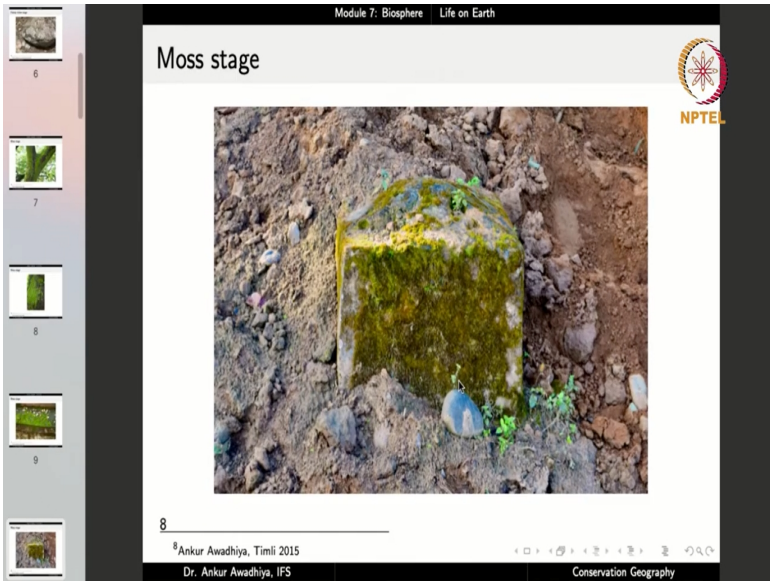
(Refer Slide Time: 08:44)

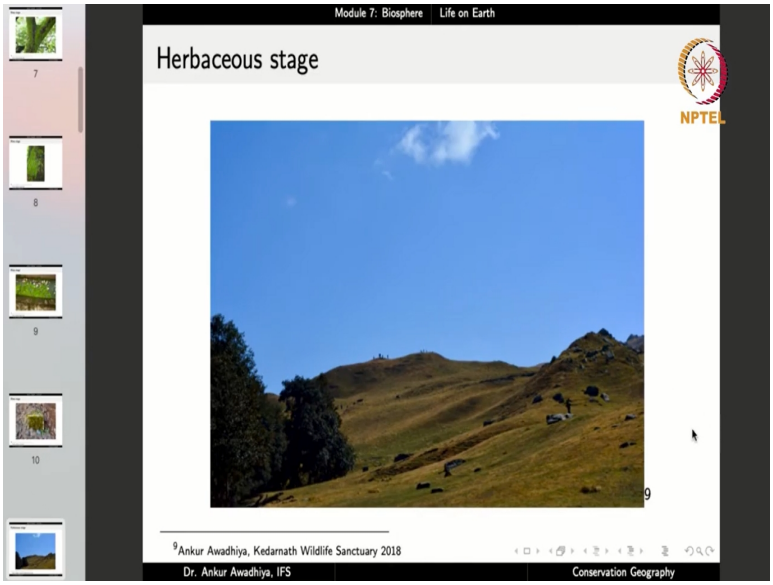


Once you have the lichens, the foliose lichens, now, the next stage will be that of mosses. Now, mosses again are very primitive plants you can normally observe mosses on the barks of trees during the rainy season. So this is what almost looks like.

(Refer Slide Time: 09:04)







Now, a moss can come up on the bark of a tree, or it can even come up on stone pavements, or it can come up even on the rocks. So this is the next stage, a moss stage. And we can find moss in a large number of very extreme habitats. Once you have the mosses, the next stage will be the herbaceous stage.

Now, in herbaceous stage, you have the herbs, meaning that you have things like grasses. Now, grasses require soil. So grasses could not have come up when you had the bare rocks or grasses even could not have come up once you were only in the crustose lichen or foliose lichen or the mosses stage.

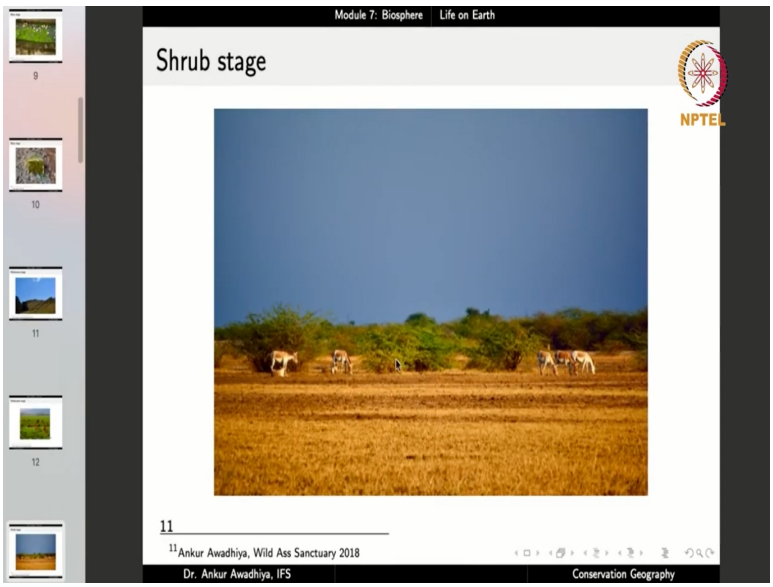
It takes a bit of time for the soil to develop for the soil to be fertile enough for grasses to thrive in this area. Now, this is primarily because the grasses have roots, and these roots

require a certain depth of soil. So after the moss stage, the next stage will be the herbaceous stage, which will be dominated by grasses.

(Refer Slide Time: 10:18)

So this is an example. All of these areas are dominated by grasses. Now, grasses play a very important role in a large number of ecosystems because they provide a large and abundant source of food. So there are a number of grazing organisms that can make use of grasses.

(Refer Slide Time: 10:32)

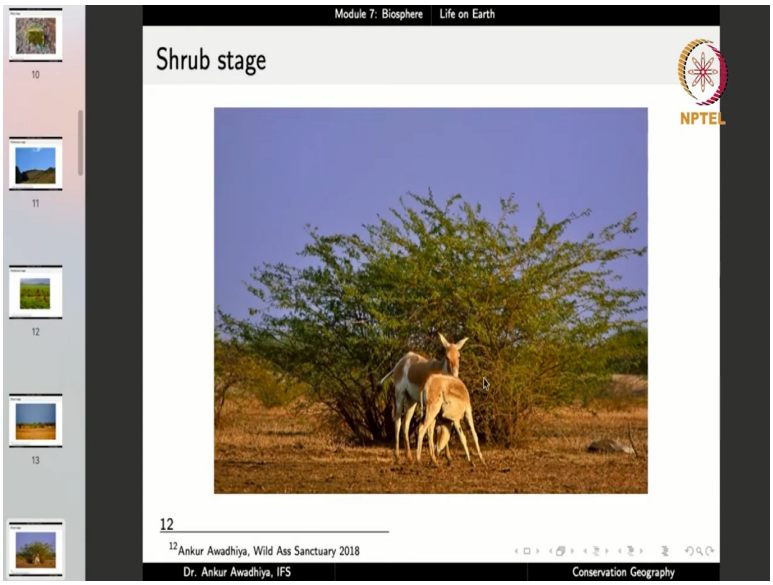


After the grass stage, next will be this shrub stage where we will have plants, typically woody plants, but they are of a short height. And they also do not have a main trunk and the branches, and essentially, all the branches just start from the ground level.

So after the herbs, next will be the shrub stage. Now, you can observe here that in this picture, we have the shrubs and we also have the grasses. So when we talk about ecological succession, we are not talking about something that is replacing the previous layer or the previous stage completely. We can always exist in a state of interdependence. And you can always have two or more stages that are formed together.

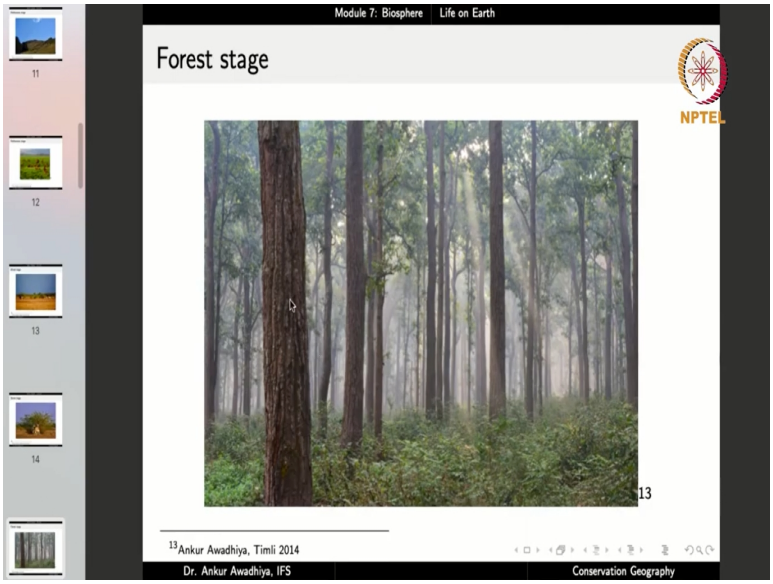
So this is an example. Here, you have grasses and you also have the shrubs. So it's the herb and the shrub stage together. Now, shrubs are vastly more complex than grasses. A large number of shrubs also have berries, and these berries can very easily support a large number of small animals, birds, reptiles and so on.

(Refer Slide Time: 11:53)



So, this is the next stage. After herbs, we have the shrubs. In this picture you can observe a shrub and you can observe that all of these branches are just coming out from the soil level. You do not have a main trunk followed by the branches. That will be found in the forest stage.

(Refer Slide Time: 12:06)



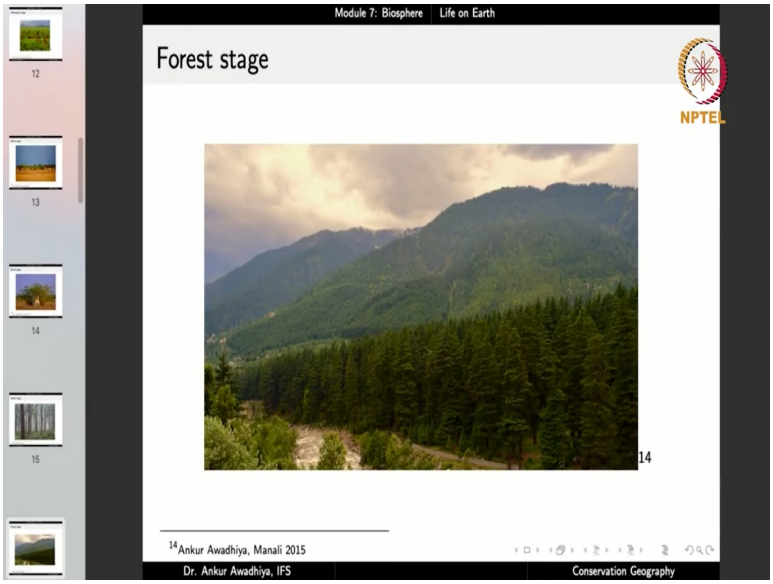
So here you have a main trunk. You get trees, and these trees have different branches. So after the shrub stage, the next stage is a forest stage. Now, forests are very more complex ecosystems, or communities, as compared to a shrub land, or a grassland. So forests will typically support a very large number of organisms because you are now having a growth in the three dimensions.

So a vast more amount of surface area is now made available. And plus you also observe a large amount of niche differentiation. So in a forest you can have certain organisms that make use of canopies, certain other organisms that make use of branches, certain other organisms that make use of the main stems, certain other organisms that live on the ground. And at the same time, a large number of forests also have patches of shrubs and herbs and other stages.

Now, typically a forest will be a climax community. That is a community that has reached the peak of succession. Now, no more amount of succession is needed, or no amount of succession will happen. Now, this is because the plants are now in such a large number that they are now making use of the maximum amount of sunshine that is possible to be used in that area. They have a large amount of biodiversity.

So these communities are automatically very much resilient. They are very much resistant to changes, and whenever there are changes, then these communities are able to spring back to the original state wherever the conditions come back to normal. That is resilience.

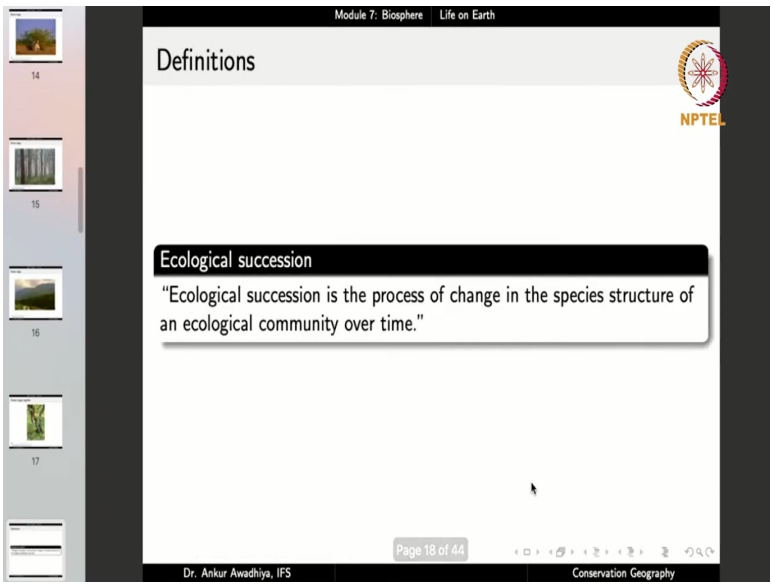
(Refer Slide Time: 14:14)



Now, once we have a climax community, which is resistant, which is resilient, after that, no more amount of ecological succession will happen in this area. So this in brief, is the ecological succession from a bare rock into a climax community, which is typically forest. And in a large number of cases, we find that in the more complex stages or in the more later stages of succession, we also have the other organisms or the other stages that are also represented to a certain extent.

So for instance, in this image from Mukurthi National Park, we can observe that we have tree, we have grasses, we have the lichens, both the crustose and the foliose lichens. And so we are observing different stages together in this image. We have the crustose lichens, the foliose lichens, and up to the trees. So various stages can be found together.

(Refer Slide Time: 15:03)

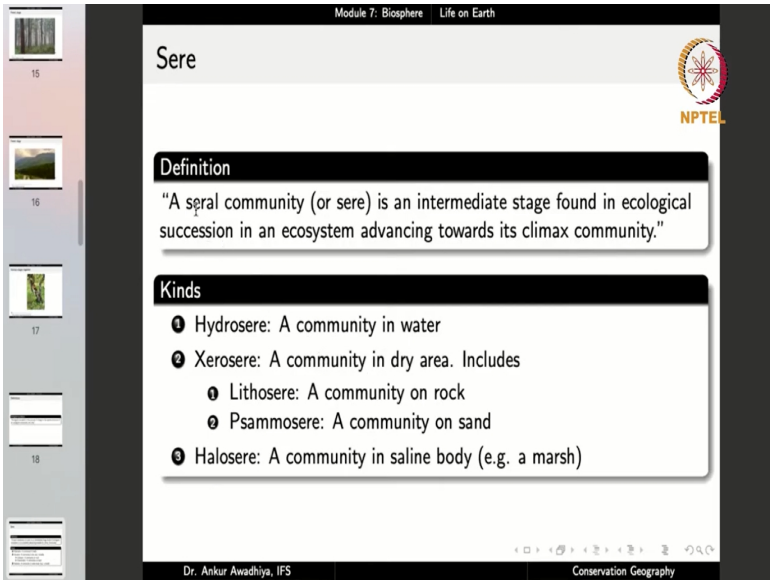


So we define ecological succession as the process of change in the species structure of an ecological community over time. Ecological succession is a process. It is not a snapshot. It is a process. It goes on from a beginning stage to an ending stage. And it is a process of change. So things are changing and what is changing? Changes in this species structure, meaning what species are present in what ratios, where are the present, and so on. And species structure of an ecological community over time. An ecological community is a group of several species.

So when we are talking about, say, the herbaceous stage, we're not just talking about a single species of grass. Perhaps there will be n number of species of grasses in this area, which will also be supporting certain other organisms. They will be supporting things like micro organisms, things like insects, things like birds, things like rodents, things like other animals. And so this is an ecological community because we have a large number of species that are living together, and they are interacting with each other. They are dependent on each other.

So ecological succession is the process of change in the specie's structure of an ecological community over time. So it takes time, and primarily because whenever we have a particular stage then it will take certain time to act on its surroundings, to act on its environment to change the environment. And once the environment changes, then now, the existing ecological community is not that efficient as compared to another ecological community that can come up in this area.

(Refer Slide Time: 17:13)



So this is ecological succession, a process of change in the specie's structure of an ecological community over time. And when we talk about these stages, they are known as the seres, a seral community or a sere is an intermediate stage, found in the ecological succession in an ecosystem advancing towards its climax community.

So when we say that in the process of ecological succession, we had the herbaceous stage, then the herbaceous stage is referring to the sere or the seral stage because it is an intermediate stage in the ecological succession in a community moving from the primitive community up to the climax community.

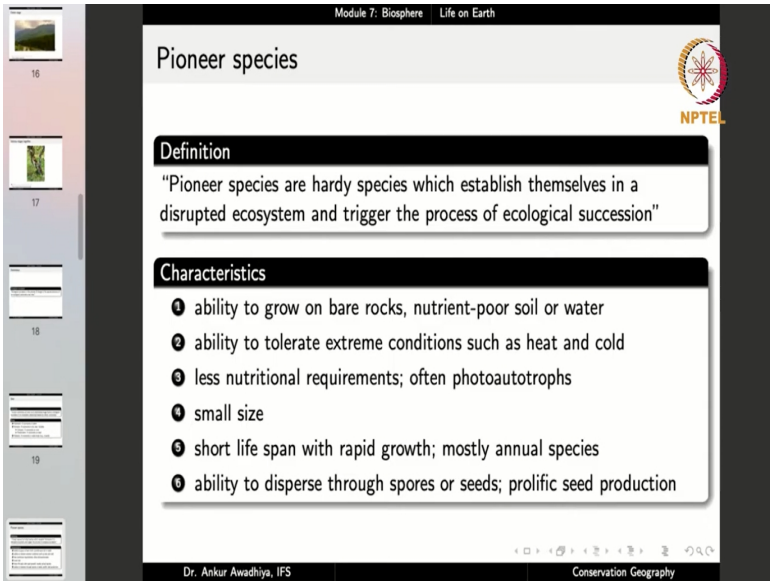
So any intermediate stage found in ecological succession is also known as the sere or the seral community. And in this context, we have different kinds of seres. We can have hydrosere. Now, hydro refers to water. So hydrosere is a water sere or a sere in water. Sere is a community. So a community in water. Typically, one which is in intermediate stage in ecological succession will be a hydrosere. Zerosere, zero is dry, so zerosere is a community that is getting formed in a dry area.

What can this dry area be? It can be a lithosere. Litho is rock. So we observed this term in the case of lithosphere, which is rock sphere. Now, lithosere is rocksere, a community on the rock.

Psammosere, psammo refers to sand. So a psammosere is a community on sand. Or we can have a halosere. Halo refers to salt. So halosere is a community in a saline body such as a marsh.

So we can have different kinds of seres in different environments. We can have seres in a dry environment, in a wet environment, in a saline environment, and so on. Now, the important thing to remember here is that when we say sere, sere is an intermediate stage in the process of ecological succession.

(Refer Slide Time: 19:27)



Now, when we talk about ecological succession, it has a beginning and perhaps also an end. We say perhaps because at times, a single climax is not possible. So we can say that okay this forest has been existing for say 400 years, so it should be the climax community. But it is possible that in future, this might undergo certain other forms of evolution, certain other forms of succession.

And so we say that we have a beginning and perhaps an end. The end is not very certain because things may change. But in any case, you will have a beginning, and in the beginning you will have a community that is a pioneer community. In a number of cases, this community is formed just to have a single species, which is the pioneer species.

Now, pioneer species are hardy species, which establish themselves in a disrupted ecosystem and triggered the process of ecological succession. They are hardy species. They are very mature tolerant of extreme conditions. So they can tolerate on conditions such as very hot

conditions or very cold conditions, or very dry conditions, or very nutrient sparse conditions. And because they are able to tolerate such conditions, we call them a hardy species.

Now, if you think about the beginning, if you think about a bare piece of rock, in that case, the rock will not be providing a very good surrounding for a large number of organisms, because it just does not have any soil, it does not have large quantities of water, and the conditions are very extreme.

So the organisms that are able to survive and thrive on this bare piece of rock have to be very much tolerant of these extreme conditions. Or in other words, they have to be very hardy species. So pioneer species, because they have to come up on these beginning stages, they are hardy species, which established themselves in a disrupted ecosystem.

Now, this is not a well formed ecosystem, it's a very disrupted ecosystem because the community that was earlier in this area that has been completely destroyed. For instance, you can begin with a process where you have very lush green forests in the area, but then there is a volcanic eruption, and when lava comes out it burns everything down, and now you just have a bare piece of rock in this area.

So it shifts from a well formed ecosystem to a disrupted system. So pioneer species are hardy species which establish themselves in a disrupted ecosystem and triggered the process of ecological succession. Their characteristics are the ability to grow and bare rocks, nutrient poor soil, or water, again, because the conditions are very extreme, ability to tolerate extreme conditions, such as heat and cold.

In the daytime, it will become very hot because there is nothing to shade the rock. In the nighttime, it will be very cold when the heat gets convicted or edited out. So the species have to be able to tolerate these conditions. They should have less nutritional requirements because, again, you have very less amount of nutrients that are available on the bare piece of rock.

So if the nutrients are not available, then the organisms that are able to survive in such conditions should be able to make do with very little amounts of nutrients and typically, these are photoautotrophs. Photo is light. Auto is self. Troph is nutrition.

So these are organisms that are able to get their nutritions by themselves, meaning that they are able to make their own food using light. So in this case, we are talking about green plants that are able to perform the process of photosynthesis.

So when we talk about the pioneer species, they are typically in green in color, and they are plant species. Why not an animal species? Because the animal species would require that something else should be there beforehand to provide it with food. And so it cannot be the pioneer species, it cannot be the first one in the area.

Pioneer species is the first species. So it should be able to prepare its own food. And typically it does so by making use of sunlight. They are typically small in size, again, because the amount of nutrients that are available in the area are so less that they cannot support large size organisms.

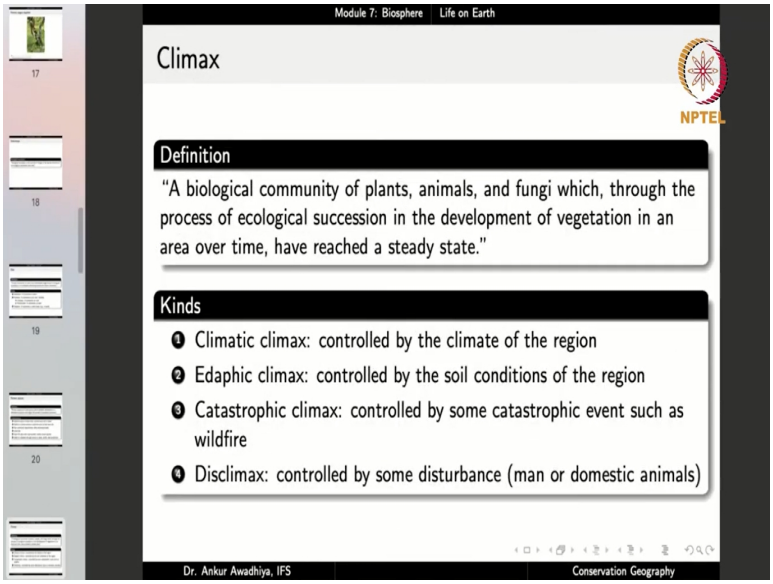
They typically have short life span with rapid growth. And mostly, we find annual species that is species that live only for one year. And they should have the ability to disperse through spores and seeds, and should be prolific seed producers.

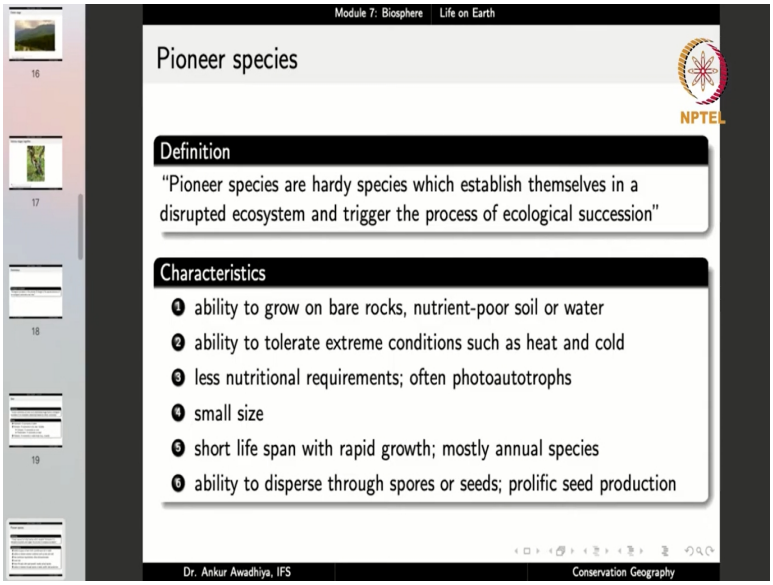
Now, why should they have this ability to disperse through spores or seeds? Because otherwise how would they be the first ones to come into the area. Plants are immobile organisms. They are sedentary. They are fixed in one location. So for these species to come to these bare rocks, there should be a mechanism of movement. And typically, this mechanism of movement is through the moment of this spores or the seeds. And mostly, this movement is through wind or water.

So when you have winds that bring these spores or seeds, and they come to this, to a bare rock and they're able to establish themselves, they are able to grow on these bare rocks, then they become the pioneer species. And a large number of these spore producing small sized organisms are those that are annual, which means that they live only for one year. They produce a large number of seeds, and then they die. And these seeds will, in the next year, they will again make more plants.

These plants will again grow, and then they will again make large quantities of seeds and then they will die. So this is the process.

(Refer Slide Time: 26:09)





On the other extreme, we have the climax community defined as a biological community of plants, animals and fungi, which, through the process of ecological succession in the development of vegetation in an area over time, have reached a steady state. Steady state means that now there is no more change that is needed, or no more change that will happen.

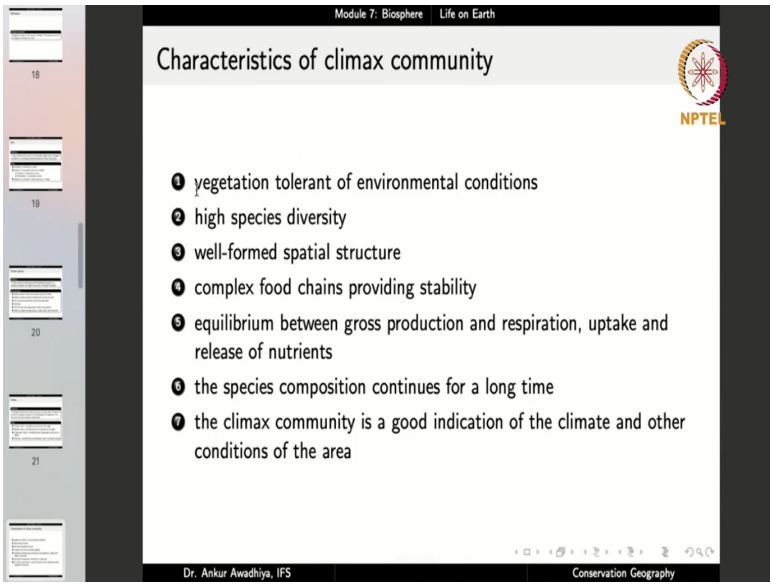
So it is a biological community of plants, animals and fungi. In the case of pioneer species, we were only talking about a single species, but in the case of climates, we are talking about a community of large number of plants, animals, and fungi. And this community has formed through the process of ecological succession in the development of vegetation in an area over time. And it has reached a steady state, meaning that now no more changes are happening.

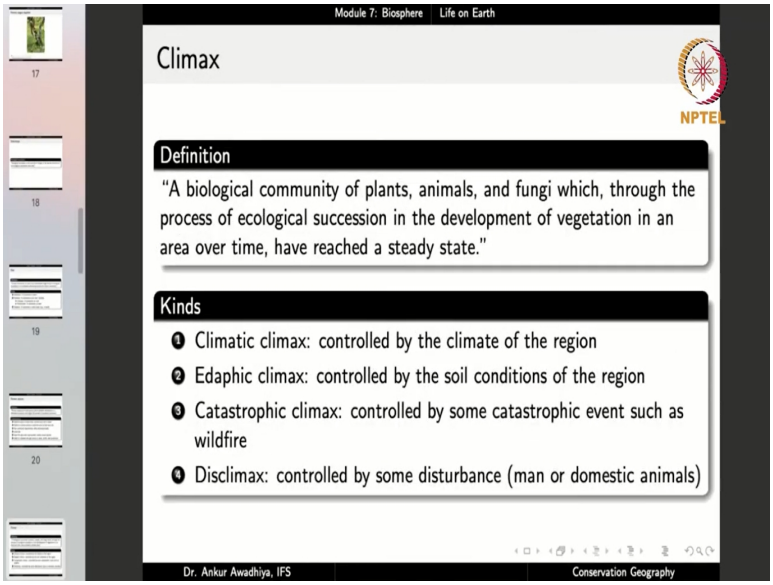
In that case, we will call it a climax community. And we have different kinds of climaxes. We can have climatic climax, which is controlled by the climate of the region. So when we say that dry areas will have such and such climax communities, wet areas will have such and such climax communities, we are talking about the climatic climaxes, which are determined by the climate of the area.

But the climaxes can also be determined by, say, the soil of the area. So if we say that such and such community will be the climax community in black cotton soil, then we are talking about edaphic climaxes controlled by the soil conditions of the region. Not that much dependent on the climate, but more dependent on the soil conditions.

We also have catastrophic climaxes, which are controlled by some catastrophic events such as wildfires. And we also have disc climaxes which are controlled by disturbances such as men, or domestic animals. So what are the characteristics of these climates communities?

(Refer Slide Time: 28:10)





One, the vegetation is tolerant of the environmental conditions, meaning that when we are talking about climaxes, the vegetation is one that can make the maximal use of those environmental conditions as are prevalent in that area. So that is the first characteristic. Two, there should be a high species diversity for two reasons, one, because the succession has happened over a long period of time. And in that long period, more and more number of organisms would have come into the area. And two, because when we say that this is a steady state condition, it means that there should not be large changes that are occurring in this area, which means that the community has to be resistant to changes, and resilient to changes.

The community should be able to resist any changes that are happening. Any small changes, they will just be thrown out. And the community should have a large amount of resilience, meaning that if there are changes, then the community will come back to the original steady state condition once the changes are reversed.

Now, this typically requires that we have a large amount of biodiversity in the area. Why? Because suppose you only have two organisms. One is a predator and the second is a prey. Now, if the prey dies off because of certain changes, then the predator will also die off and the community would collapse.

But if you have large number of organisms in the area, large species diversity in the area, then probably the predator would be able to make use of certain other preys that are available. So alternatives are available.

Now, these alternatives ensure that whatever happens, they will be a certain number of predators and preys that will always survive so that if because of certain changes, one species is affected, say, if there is a disease in the area, and say, the population of Cheetahs goes down. Now in that case, the Tigers would not die because the Tigers have also other prey that are available to feed them in such conditions. And once the conditions come back to normal, once the disease phase has gone away, then the Cheetah population will be able to come back to the normal stage.

Now, this would not have been possible if we only had a single prey species which is Cheetah because even when its population was going down because of the disease, that Tigers would have finished off the remaining individuals and the community would have collapsed. Now, because we have more number of prey organisms, so the community is able to survive the changes. It gains resilience. And so typically in the case of climax communities, we will find a large number of species. They will have a large amount of biodiversity. They have a well formed spatial structure, comprising of trees, shrubs, herbs, undergrowth, and so on.

They will have complex food chains that provide stability. There will be equilibrium between gross production and respiration, uptake and release of nutrients, again, because this is a steady state condition. Nothing is changing. If production was greater than respiration, in that case, there will be changes. More and more amount of biomass would get accumulated. And so we cannot have that condition in the case of a steady state. And so there has to be a balance between production and respiration.

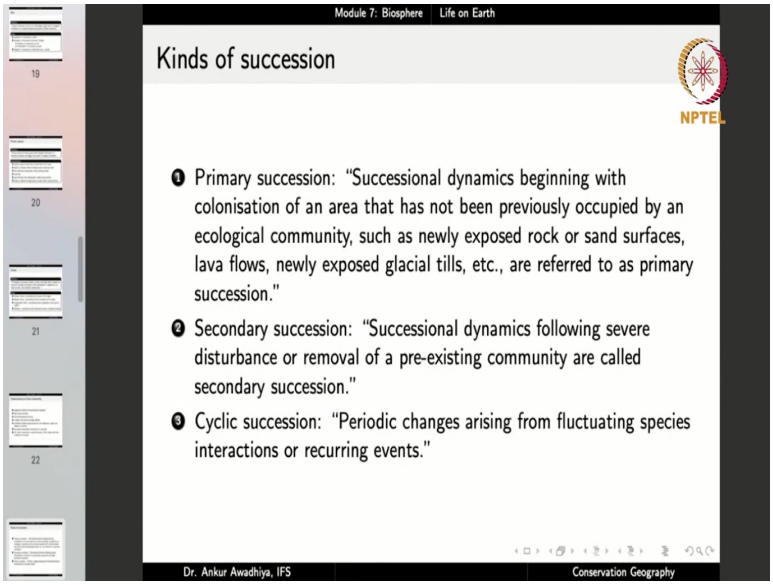
Similarly, there has to be a balance between uptake and release of nutrients. Because if uptake is more and release is less then you will have a change in the biomass. If uptake is less and releases more, again you will have a change in biomass, which would not be conducive to a steady state condition. So there has to be a balance.

So there is an equilibrium between gross production and respiration, and also an equilibrium between uptake and release of nutrients. Because of all of these, the species composition continues for a long time, which is the steady state, and the climax community becomes a good indicator of the climate and other conditions of the area.

For example, if we look at a climates community that is comprised of evergreen forests, then you can say in one go that okay, this area should be having abundant sunshine and abundant amount of rainfall because only in these conditions will we get the rain forests. And so the

climax community becomes a very good indicator of the climatic conditions of the area. So these are the characteristics of the climax community.

(Refer Slide Time: 33:10)



Now, when we talk about succession, there are three different kinds of succession- primary, secondary and cyclic succession. Primary succession is successional dynamics, beginning with colonization of an area that has not been previously occupied by an ecological community, such as newly exposed rock or sand surfaces, lava flows, newly exposed glacial tills, etc. These are referred to as primary succession. So in the case of primary succession, the succession begins from a stage where you do not have any organisms whatsoever.

In the case of a secondary succession, it is the successional dynamics following severe disturbance or removal of a pre existing community, such as the case of a forest fire. So in the case of primary succession, you have an area that has never been previously occupied. So it is a completely new area, but in the case of a secondary succession, this area was already previously occupied, but then something happened because of which all the plants and animals died.

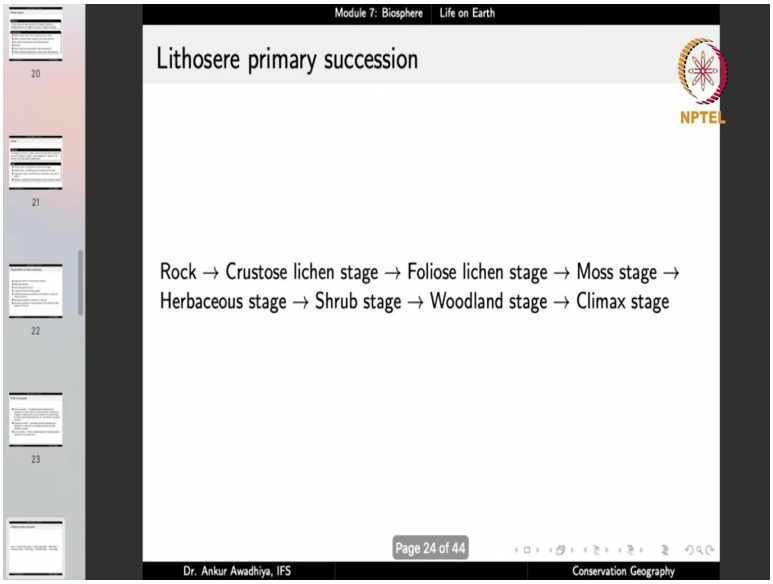
Perhaps there was a fire, or there was a flood. And because of that, everything died. And so now, it has to begin afresh. If that happens, we will say that there is a secondary succession that is going on. In the case of primary succession, we have an area that was never previously occupied. But in the case of secondary succession, it is an area that was previously occupied. Then we also have cyclic succession, which is periodic changes arising from fluctuating species interactions or recurring events.

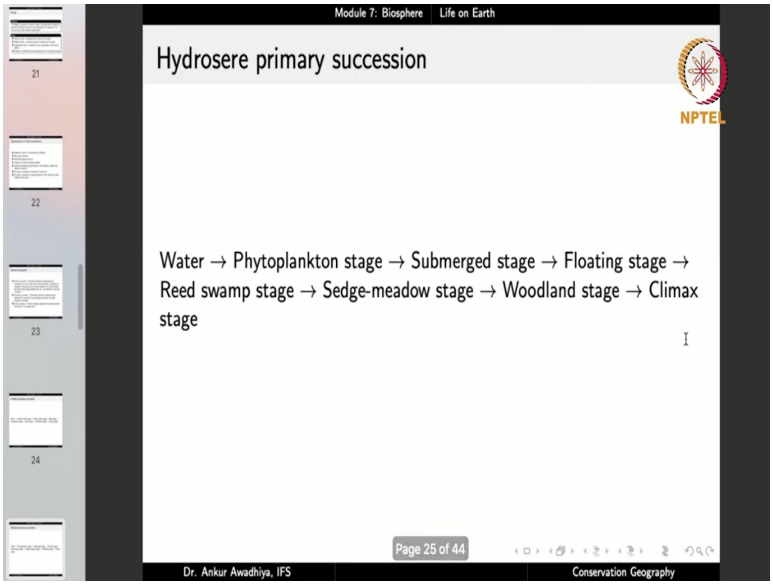
So cyclical succession means that something is going on in a cyclical manner. When we talk about areas such as the Kaziranga National Park, Kaziranga National Park has the river Brahmaputra, which floods every year. So every year, when there is a flood the area will get inundated underwater. And in that condition, the plants will die off because their supply to air has been cut off.

Now, once the plants have died off, and when the flood receeds, then you again have a fresh area that is now available. Earlier, this area used to have certain plants, but now everything has been killed. And so now succession will begin afresh. And in the case of Kaziranga, it begins with the grasses because a large number of seeds and spores are brought into this area with the floods. But because this process happens again and again every year, year after year, we call it a cyclical succession.

So these are the three different kinds of succession- primary, secondary, and cyclic. Primary happens in an area that was never previously occupied. Secondary happens in an area that was previously occupied but then something disturbed or removed everything. And cyclic succession is something that happens year after year because of fluctuating species interactions or recurring events.

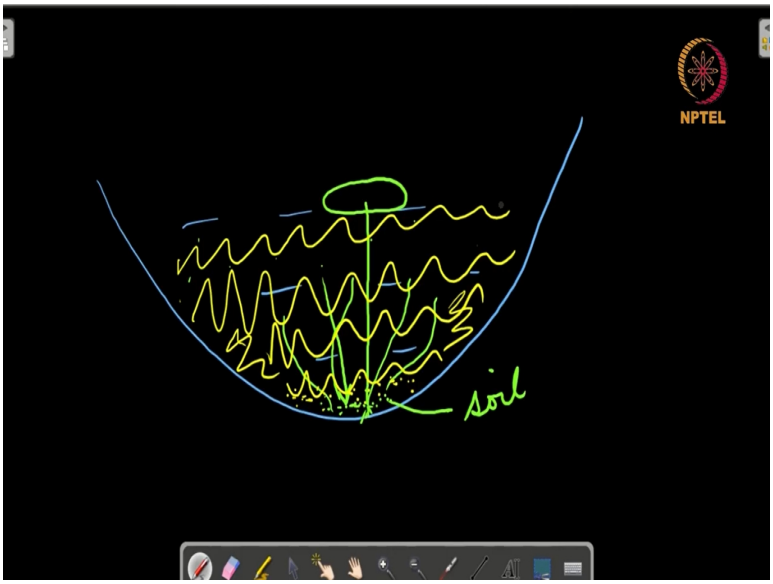
(Refer Slide Time: 36:27)





So let us now look at certain examples. We have looked at lithosere primary succession. Beginning with rock, we have the crustose lichen, foliose lichens, moss, herbs, shrubs, trees, and the climax stage. In the case of Hydrosere primary succession, in this case, we are talking about a succession that is happening in water. So what will happen in the case of water?

(Refer Slide Time: 36:57)



In the case of water, we will begin with, say, a pond. Now, what will be the first species that can come up in a pond? Now, there are no species, but the first species that will come up will probably planktons, which are microscopic organisms. So this is what we are seeing here that in the case of water, it will move from water to a phytoplankton stage. So these are plant planktons, microscopic organisms which are plants, they are again photo autotrophs. They make their own food using sunlight.

And these planktons will grow in this water, and once they die, they will fall off. And so they will form a layer of sediments in the bottom. Now this layer of sediments is now rich in organic matter, because it is comprised of the bodies of all the dead planktons. And once you have this layer that has come up, this is very similar to soil. And so now this can support a large number of plant growth.

So from the phytoplankton stage, we will come to submerged state. Submerged state means that now we will have certain plants that are coming up in this area. Typically, they are ribbon like because they are able to withstand any water movements, and they are completely submerged. They do not come to the surface.

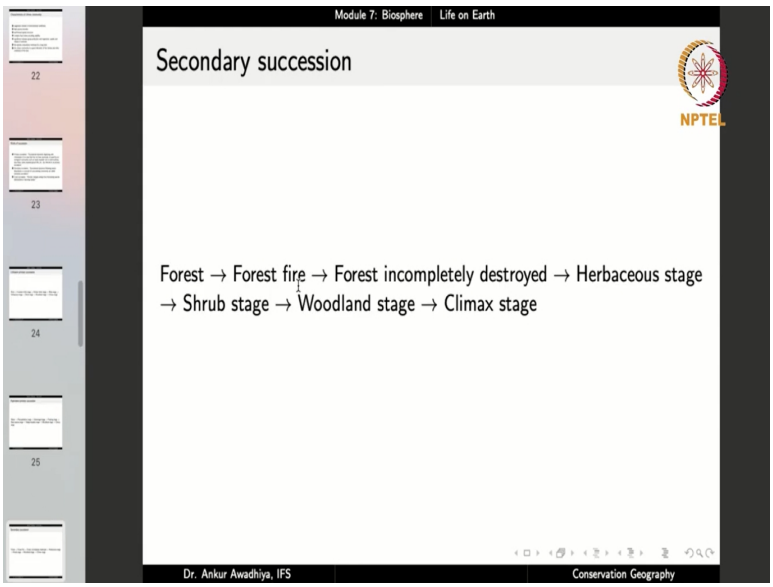
And then once you have this stage, these plants are again dying and they're increasing the soil cover at the bottom. So now we have a much more thicker layer of soil. Once you have that, now we will have certain plants that we'll be able to come to the surface. Plants like lotus.

So they will be coming to the surface. They will have their roots that is there in the soil, but the leaves will be able to come up. So from the submerged stage, we will come to a floating stage. Now, floating plants are large size plants. So when they die, they will leave a large amount of biomass in the water, and with that, all of this area will become full of soil.

Now, once you have all of this area that is now soil, now, only a very little amount of water is left on the top. And we are slowly now observing a change from a pond into a swamp. And in this swamp stage, we will get reeds, which are again plants that grow in the swampy areas.

From reeds, again, you are increasing the amount of soil, and after a while, no more water will be left in this area. So this will comprise of damp soil. And in the case of damp soil, now we will get the grasses. So from a reed swamp stage, we will get sedges and meadows. Meadows of grasses.

(Refer Slide Time: 40:14)

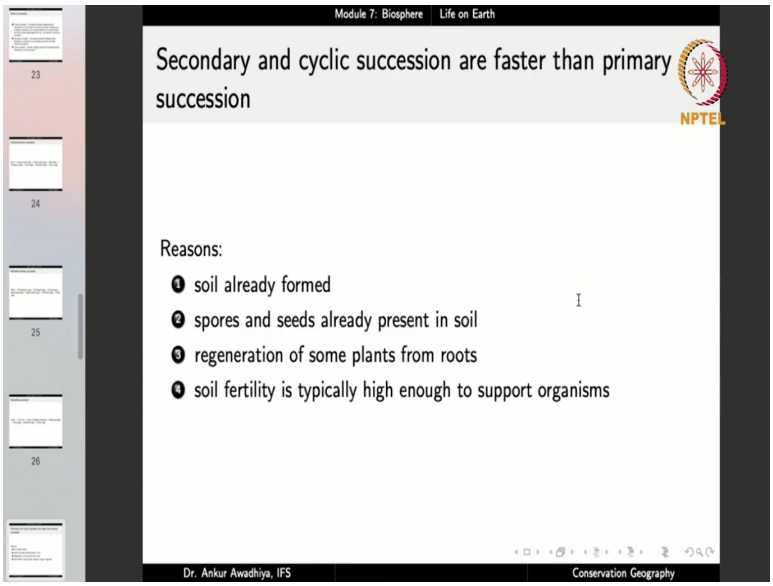


And from there, we will slowly move into a woodland stage, which is the forest, followed by the climax stage. So this is the hydrosere primary succession. In the case of a secondary succession, we can have a thing like forest, followed by forest fire, which kills all the organisms. So the forest become destroyed, perhaps completely, perhaps incompletely.

Now, if the forests are completely destroyed, then again, the spores and seeds will have to be brought from elsewhere. If the forests are incompletely destroyed, in that case, certain plants may remain in the area to provide with the spores and seeds, or in certain cases, we can also have vegetative propagation. And so after a while, we will start to get the grasses, followed

by the shrubs followed by the forest, and followed by the climax forest. So this is the secondary succession, a succession in an area that was previously occupied, but then it got disturbed.

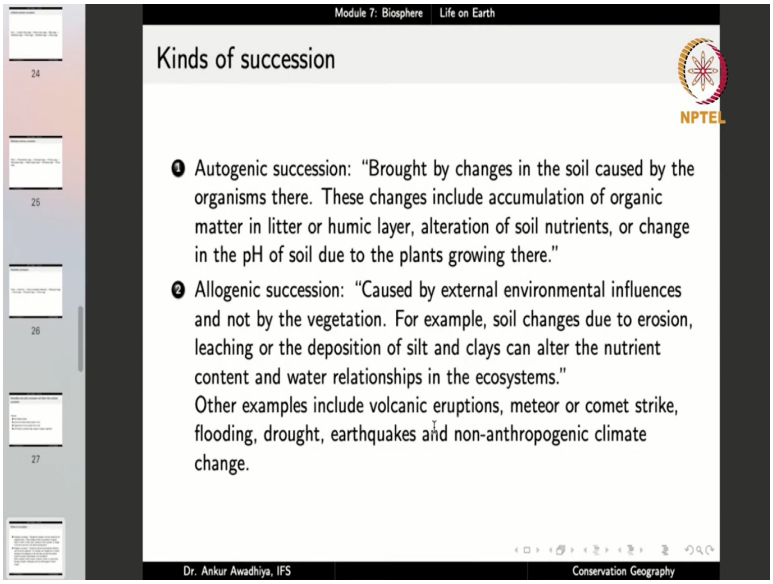
(Refer Slide Time: 41:07)



Now, typically, the secondary and cyclic successions are faster than primary succession. Why? Because in secondary and cyclic successions, the soil is already there. So soil formation does not need to happen afresh. When there was the forest fire, the plants were killed, the animals were killed, but the soil remained in the area.

And so because we do not have to have a new formation of soil, so secondary and cyclic successions will be typically much faster. In a number of cases, spores and seeds are already present in the soil. There can be regeneration of some plants from roots, which is the vegetative propagation, and the soil fertility is typically high enough to support organisms from the very beginning. So for these reasons, the secondary and cyclic successions are faster than primary succession.

(Refer Slide Time: 42:01)



Now in this case, we can differentiate between autogenic and allogenic succession. Auto is self. Genesis is production. Self production, a succession which is produced by itself. So it is brought by changes in the soil caused by the organisms that are present in the area. These include, these changes include accumulation of organic matter in the litter or humic layer, alteration of soil nutrients, changing in the pH of soil due to the plants growing there.

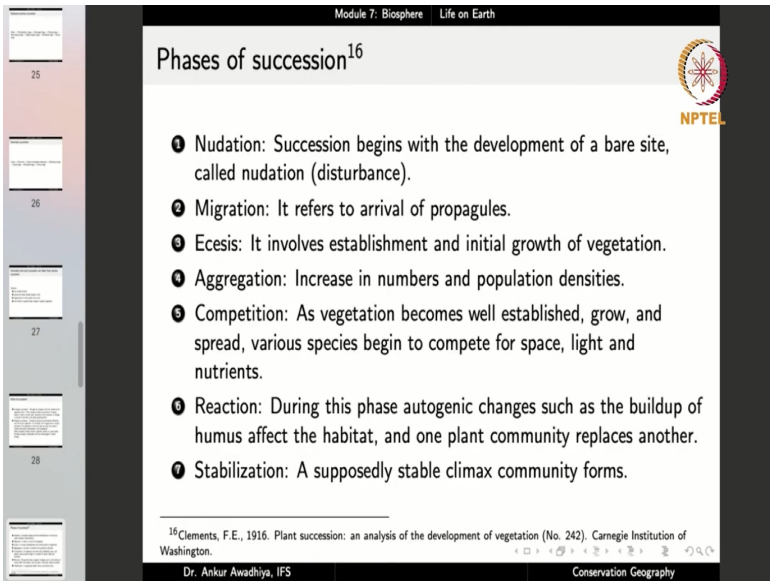
So when we were talking about this lake, and these changes were being brought about by the organisms that were already living there, we are talking about an autogenic succession. Allogenic, allo is other. Genesis is production. So it is a succession that is produced by

others, not by the plants and animals that are living in the area. Caused by external environmental influences, and not by the vegetation.

For example, soil changes due to erosion, leaching, deposition of silt and clays can alter the nutrient content and water relationships in the ecosystems, but these changes are not being brought by the vegetation and so we will say that this is an allogenic succession. Other examples include volcanic eruptions, meteor or comet strike, flooding, draught, earthquakes, and non anthropogenic climate change.

So these will produce changes which are not because of the vegetation that are found in the area. And so we will call them as allogenic successions, successions that are brought about or produced by something else, not by something that is living there.

(Refer Slide Time: 43:52)



Now, we recognize seven different phases of succession. Succession begins with a nudation. So an area is made nude or bare. So succession begins with the development of a bare site, and this is known as nudation, typically caused because of certain disturbance. So when there is a forest fire, or when there is a flood, or when there is a volcanic eruption, all these result in a surface that is now bare. It does not have any plants and organisms that are living in the area. And so this will be known as nudation. It is making this area nude or bare.

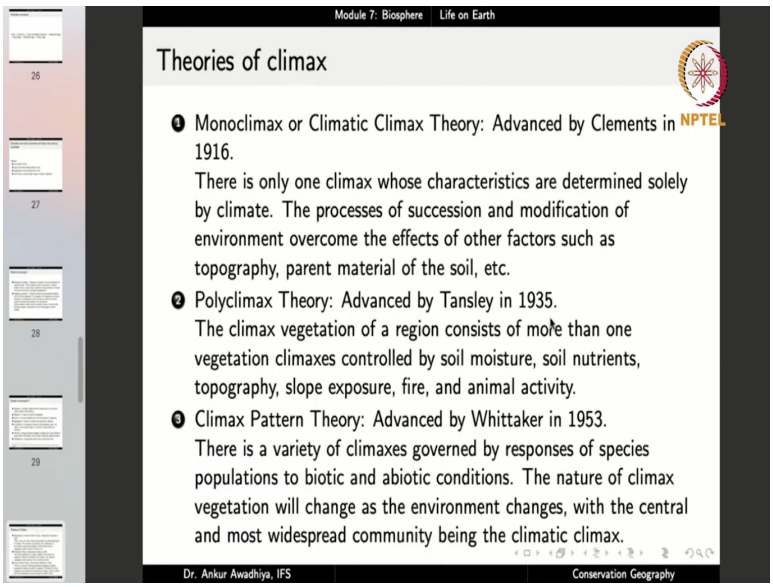
This is followed by migration, which is the arrival of propagules, which is the seeds and the spores. Then these seeds and spores will become established. They will grow. And this process is known as ecesis.

Once they have become established, once they have started to grow, their numbers will increase, the population density will increase, and this will be known as aggregation. Followed by competition, because now you have so many large number of organisms that are living that the site cannot support everyone. And so there will be competitions as vegetation becomes well established to grow and spreads, various species will begin to compete for the space light and nutrients.

Once you have competition, this will be followed by a reaction. During this phase, autogenic changes such as buildup of humus affect the habitat, and one plant community replaces another. Now, it replaces another because due to competition the older community is less efficient than the newer community.

Now, the newer community which is more efficient, it will displace the older community. And this process is known as reaction. And this will continue until the process of stabilization, which is the formation of stable climax community.

(Refer Slide Time: 45:57)



Now, when we talk about climax, there are several theories of climax. We had observed before that we can have a climax that is controlled by the climate, by the soil, or by catastrophes or other disturbances. So which of these will dominate? In this context, we have the monoclimax theory, the polyclimax theory and the climax pattern theory. A monoclimax theory or the climatic climax theory was advanced by Clements in 1916. It says that there is only one climax, whose characteristics are determined solely by the climate. So depending on the climate you will have only one sort of climax that is possible.

The processes of succession and modification of environment overcome the effects of other factors such as topography, parent material of the soil, etc. So whatever happens, you will have only one climax for one particular climate.

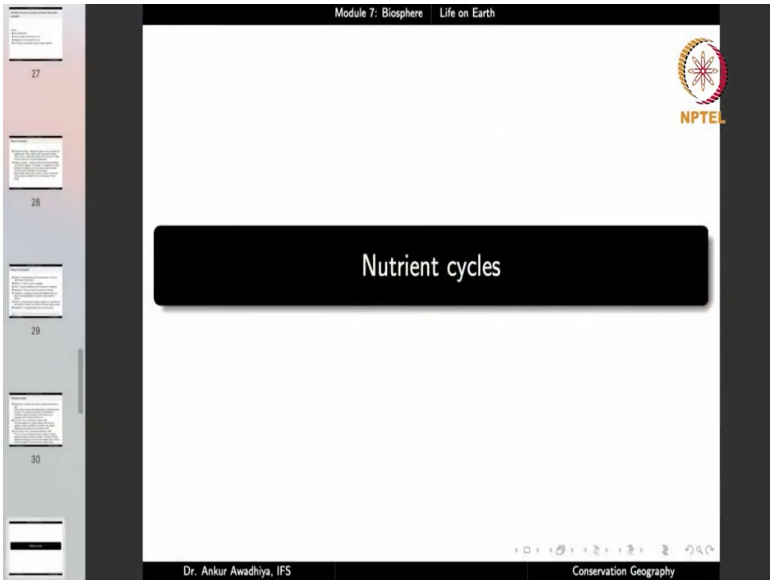
Second is the polyclimax theory which was advanced by Tansley in 1935. It says that the climax vegetation consists of more than one vegetation climaxes controlled by soil moisture, soil nutrients, topography, slope exposure, fire, and animal activity. So it says that there is not just one climax, but there are a large number of climaxes in any area, which are governed by soil moisture, so there will be different areas with different moistures, different amount of nutrients, topography, soil exposure, fire and animal activity, and they will result in several climaxes in the area.

The third one is climax pattern theory which was advanced by Whitaker in 1953. And it says that while there is a variety of climaxes governed by the responses of species populations to biotic and abiotic conditions, the nature of the climax vegetation changes with the environmental changes, but the central and the most widespread community will be the climatic climax.

So Whitaker's theory says that we will have the climatic climax that dominates, but within its umbrella, we can have the polyclimaxes. So it basically mixes both of these theories, the monoclimax theory and the polyclimax theory. Monoclimax theory said that there is only one climax, which is governed by the climate. Polyclimax theory says that there are n number of climaxes because there are very large number of variables, but the climax pattern theory says that the climatic climax dominates, but you can have certain amount of variations that are governed by the other conditions.

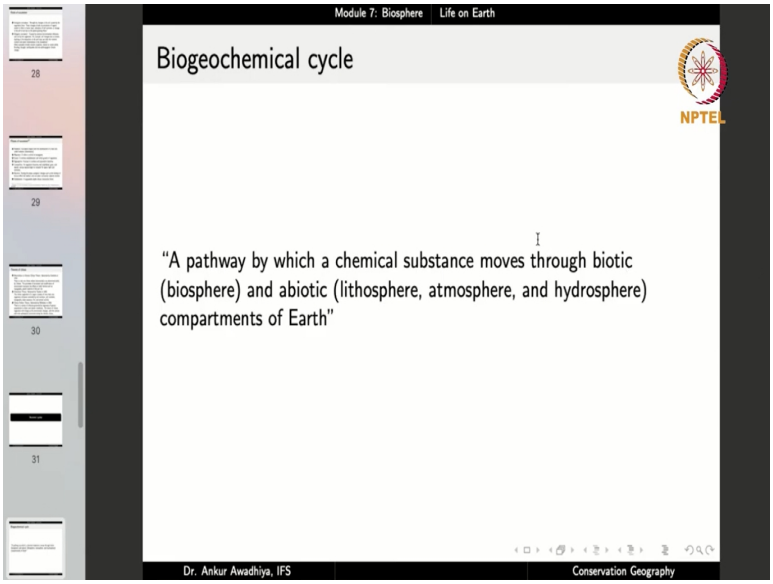
Next, let us have a look at nutrient cycles. So when we were talking about the ecological succession, the most important point was the availability of the nutrients. In the case of the bare rock, there are no nutrients available because there is no soil. And other communities were able to come into the area when the soil got formed through the process of weathering and through the process of deposition of humus.

(Refer Slide Time: 49:42)



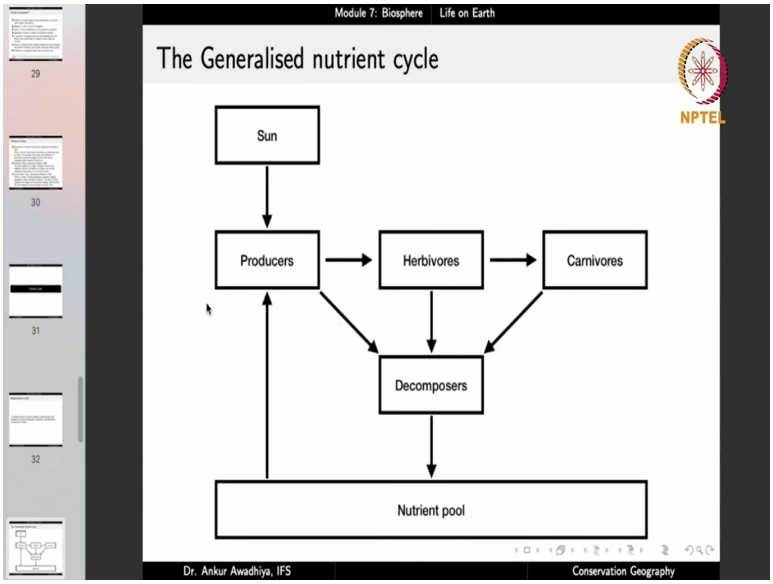
Now, when we talk about the availability of nutrients, the planet has only a fixed amount of nutrients that are available. But then, the communities have been existing for such a long period of time. So where do all these organisms get their nutrients from? Now, they get the nutrients from the nutrient cycles, also known as the biogeochemical cycles.

(Refer Slide Time: 49:46)



So this is a very important part of the life on Earth. Biogeochemical cycles are defined as a pathway by which a chemical substance moves through biosphere, lithosphere, atmosphere, and hydrosphere, that is different compartments of Earth. Now, how does the nutrient move is what the nutrient cycle looks at.

(Refer Slide Time: 50:04)



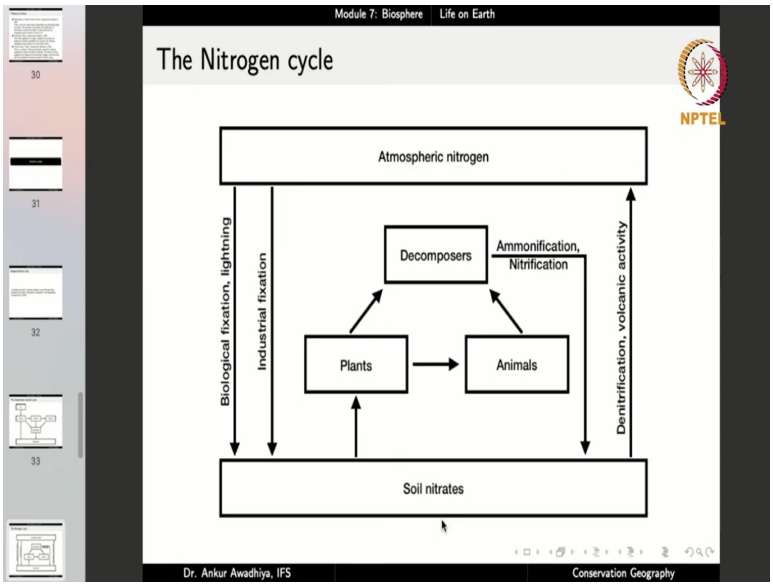
This is the generalized nutrient cycle. We have the producers, which is the plants. They take energy from the Sun, and they take nutrients from the nutrient pool. Typically, these nutrient pools are the soil, the water, and the air. So the plants will make food by using water that they are getting from their roots.

They will make use of certain chemical nutrients that will be required for the activity of various enzymes, and they will take carbon dioxide from the atmosphere. So they are taking all these different nutrients from different nutrient pools, and they are using the energy of the Sun to make food.

Now once you've made this food, this food is now available for various other organisms such as the herbivores. So where does the deer get its food from? It gets it from the grasses. So in this way, the energy and the nutrients move from the plants to the animals. And from these animals, they move to even higher animals that is the carnivores.

So the tiger also gets its food in the same process. And when the plants, the herbivores, and the carnivores die, their bodies are acted upon by the decomposers and the nutrients are moved back into the nutrient pool. So this is the generalized nutrient cycle. So let us now look at certain specific nutrient cycles.

(Refer Slide Time: 51:28)

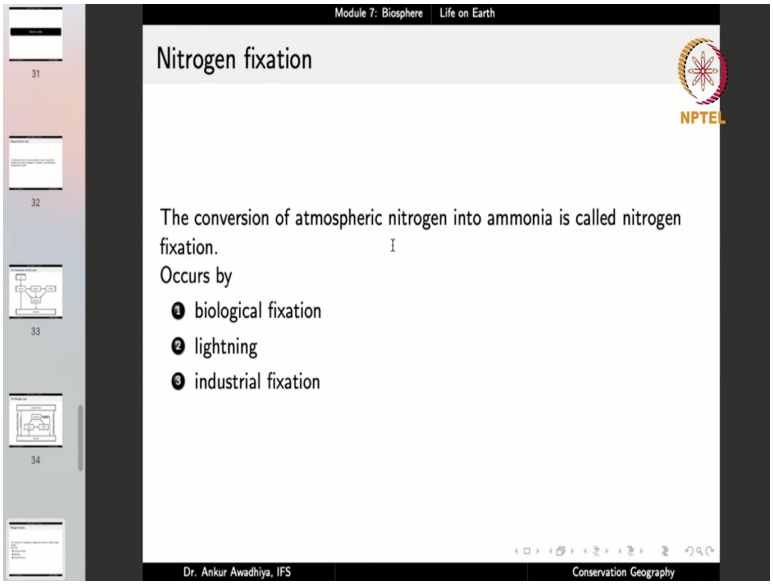


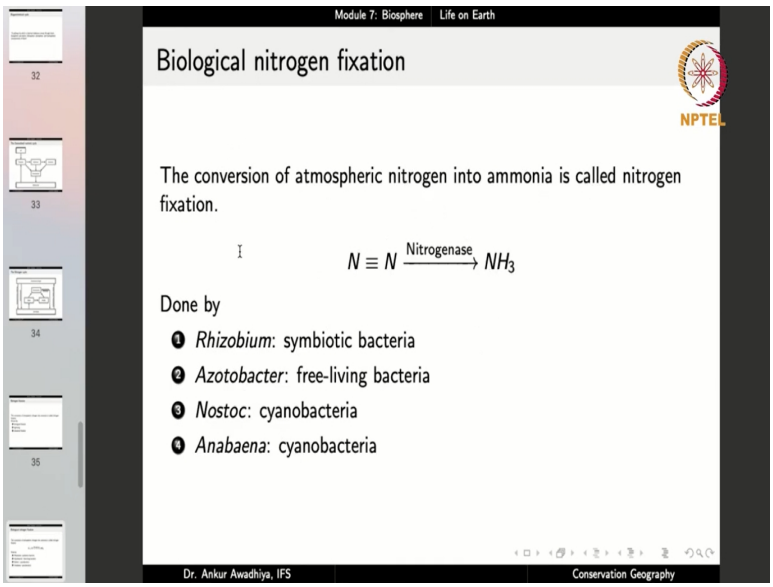
So here, we have the nitrogen cycle. We have two major pools, the atmospheric nitrogen, and the soil nitrates. The atmospheric nitrogen can be moved into the soil nitrates pool through biological fixation or lightning or through industrial fixation. So by these activities, it moves into the soil nitrates component. Soil nitrates can be converted into atmospheric nitrogen, through the processes of denitrification, and volcanic activity.

Now once you have the soil nitrates, these can be taken up by plants, and from there they will move to animals, or to decomposers and through the processes of ammonification and

nitrification, they will again come back into the soil nitrates pool. Now let us have a look at these processes.

(Refer Slide Time: 52:19)

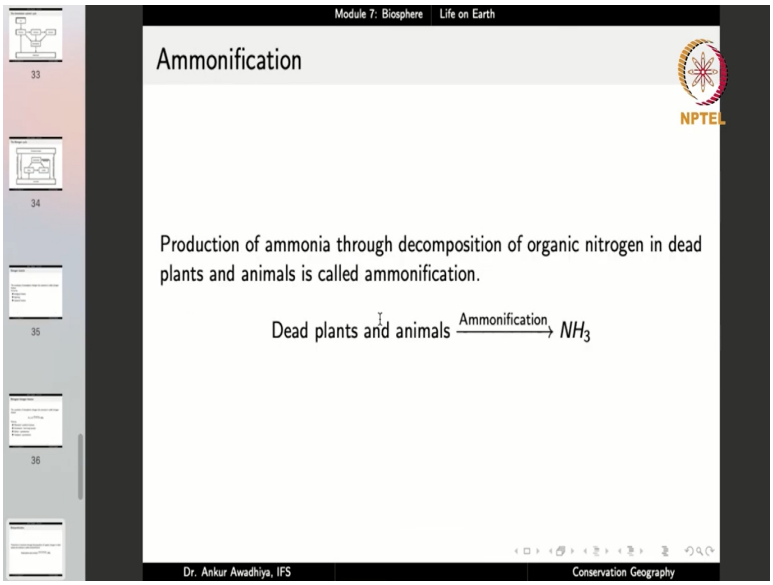


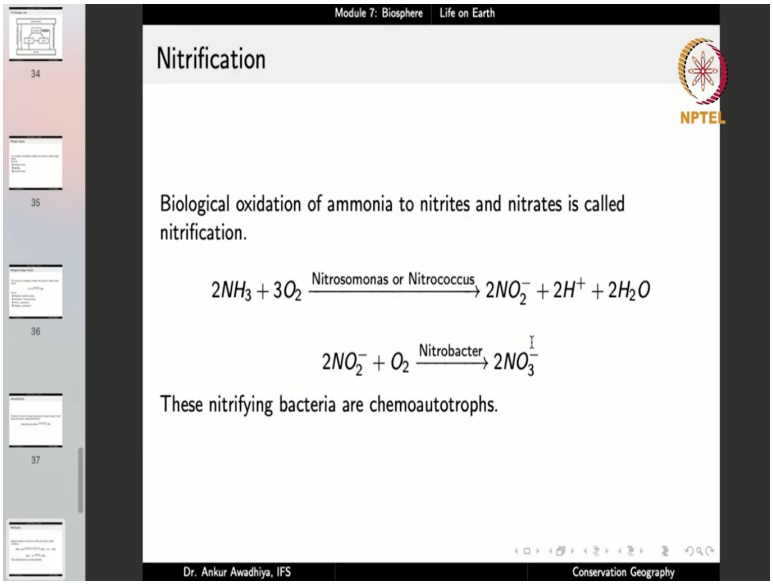


So nitrogen fixation is the conversion of atmospheric nitrogen into ammonia, which occurs by biological fixation, lightning, or industrial fixation. Biological fixation is the conversion of atmospheric nitrogen into ammonia through the action of biological organisms. So typically, you will have N_2, which is nitrogen, and it will be acted upon by certain enzymes such as nitrogen is to form ammonia. And this is done by organisms such as rhizobium, which is a symbiotic bacteria, which means that it is a bacteria that lives in a mutualistic relationship with certain plants, typically the leguminous plants that have root nodules.

So these include all our pulses species, such as daal, or chana. Next, we have Azotobacter, which are free living bacteria. We have Nostoc and Anabaena, which are cyanobacteria. So these are various organisms that perform biological nitrogen fixation, which is conversion of atmospheric nitrogen into ammonia through biological processes aided by enzymes.

(Refer Slide Time: 53:32)

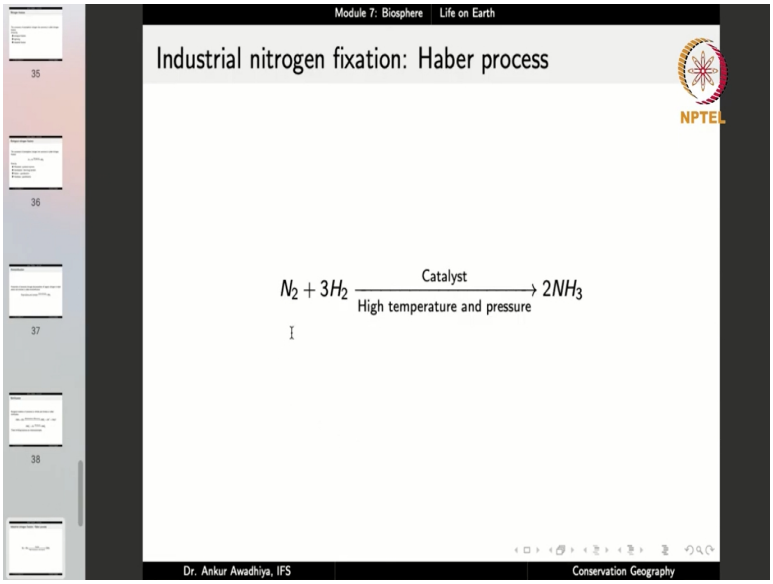


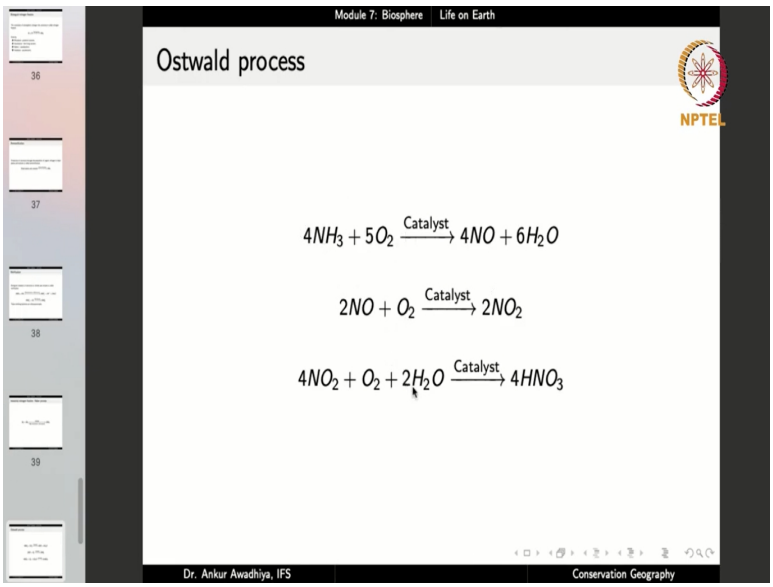


Then we have ammonification, which is the production of ammonia through decomposition of organic nitrogen in the dead plants and animals. So dead plants and animals through the process of ammonification, they will make ammonia. Nitrification is the biological oxidation of ammonia into nitrites and nitrates, which is done by Nitrosomonas, Nitrosococcus or Nitrobacter.

So in this process, Ammonia is oxidized to make nitrites and nitrates. And these nitrifying bacteria are chemoautotrophs, that is, they are getting their food in this process. So they are autotrophs, that is, they make their own food but they are chemoautotrophs, they are not photo autotrophs. They are not doing photosynthesis, but they are getting their energy through these chemical reactions.

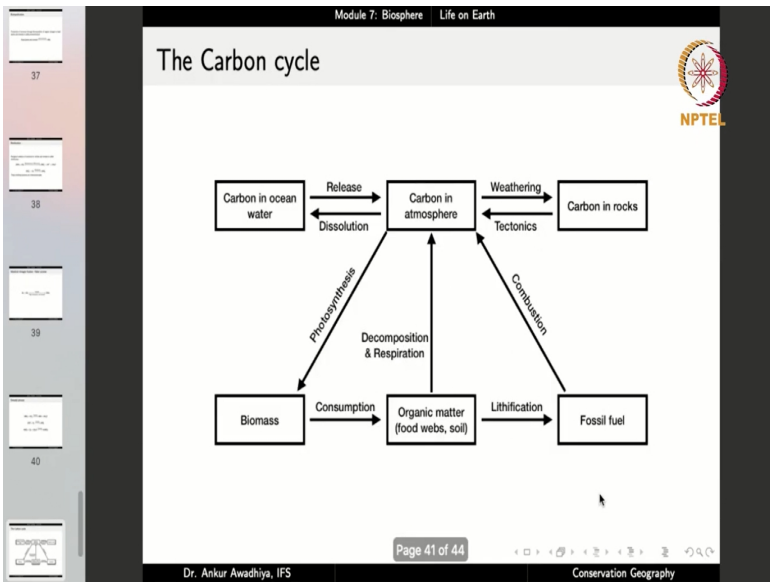
(Refer Slide Time: 54:25)





Next, we have industrial nitrogen fixation, such as the Haber's process where nitrogen and hydrogen are reacted together in the presence of catalyst, high temperature and pressure, directly to get ammonia. We also have the Ostwald process. In this process, ammonia is oxidized, reacted with water to get nitric acid.

(Refer Slide Time: 54:51)



Now, apart from nitrogen cycle, we also have several other cycles for different nutrients. So we have things like the carbon cycle. In the case of carbon cycle, we have several pools. We have carbon in ocean water, carbon in atmosphere, carbon in rocks, carbon in the organic pool, and the fossil fuels. So carbon in the atmosphere can get dissolved to form carbon in the ocean water, which, upon getting heated will get released back into carbon in the atmosphere.

Carbon in the atmosphere can aid the process of weathering. So we had looked at carbonic acid that was acting to weather rocks, especially, the rocks that were rich in calcium carbonate. So the atmospheric carbon aids in the process of chemical weathering of rocks. So through the process of weathering, it gets locked into carbon in the rocks, and through tectonic processes, especially heating, the carbon can be released back into the atmosphere in the form of carbon dioxide.

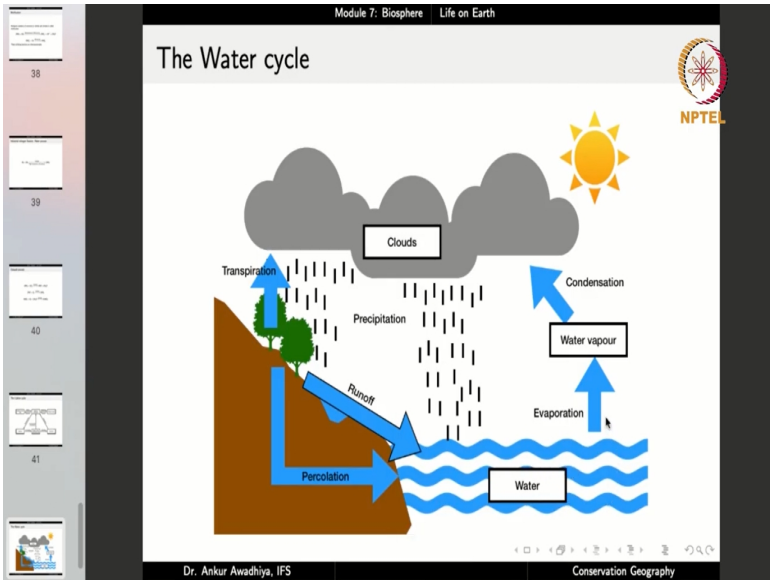
Now, this is the most important pool. Carbon in the atmosphere can be taken up through plants by the process of photosynthesis to create biomass, which will then be consumed by different organisms, become part of organic matter in different food webs and soil. And upon decomposition and respiration, it will be released back into the atmosphere. Or this organic matters can become a part of fossil fuels, through the process of lithification.

Now we have looked at lithification before. Lithi is rocks and lithification is the process of making rocks. So we had observed in one of the earlier lectures that in the case of water bodies, when the sediments are deposited at the bottom of the water body, a number of plants, the parts and animals and their dead bodies they can also become a part. They will get

covered by sediments. They will be acted upon by the pressure that is acting, and through the great amount of pressure, they will be converted into rocks.

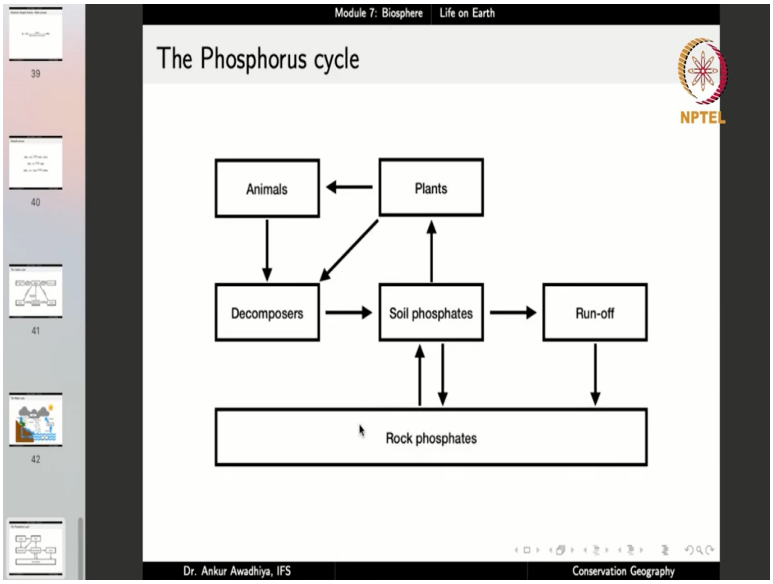
And in the case of organic matter, they will form fossil fuel that is carbon in the form of coal, or natural gas or petroleum. And this upon being burned, becomes a part of the carbon in the atmosphere. So this is the carbon cycle.

(Refer Slide Time: 57:14)



We've also looked at the water cycle in which case, water upon evaporation becomes water vapor. Upon condensation, it forms clouds. Upon precipitation, it comes down to the Earth, and the plants can take up this water, perform transpiration to add water for the atmosphere. The water that has come down through rains, it can move through runoff, or it can move through percolation. So this is the water cycle.

(Refer Slide Time: 57:41)



Another cycle we have is the phosphorus cycle, in which case, the biggest pool is the rock phosphates, that is phosphorus that is bound up in different rocks. Now, these rock phosphates can become a part of soil phosphates through the process of weathering, or these soil phosphates can get precipitated and form part of rock phosphates.

Once in the soil, it can be taken up by plants, move to animals and decomposers, come back to soil phosphates and these soil phosphates can also be lost through runoff, and after a while, they will get precipitated somewhere else and become a part of the rock phosphates. So this is the phosphorus cycle.

So essentially, when we talk about the nutrient cycles or the biogeochemical cycles, the important thing to remember is that nutrients do not stay put at one place. They move through the biosphere, lithosphere, hydrosphere, and atmosphere in a process that is known as the nutrient cycle. And this ensures the availability of several nutrients to all the different organisms.

So in this lecture, we had a look at the process of ecological succession, through which we move from pioneer species, up to a climax community stage. And in all these communities, we require nutrients for the functioning which is provided by the several nutrient cycles or the biogeochemical cycles. So that is all for today. Thank you for your attention. Jai Hind!

(Refer Slide Time: 59:19)