Conservation Geography
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Module - 4
Atmosphere
Lecture - 12
Climate and Climate Change

Namaste! We carry forward our discussion on the atmosphere. And in this lecture we shall explore climate and climate change.

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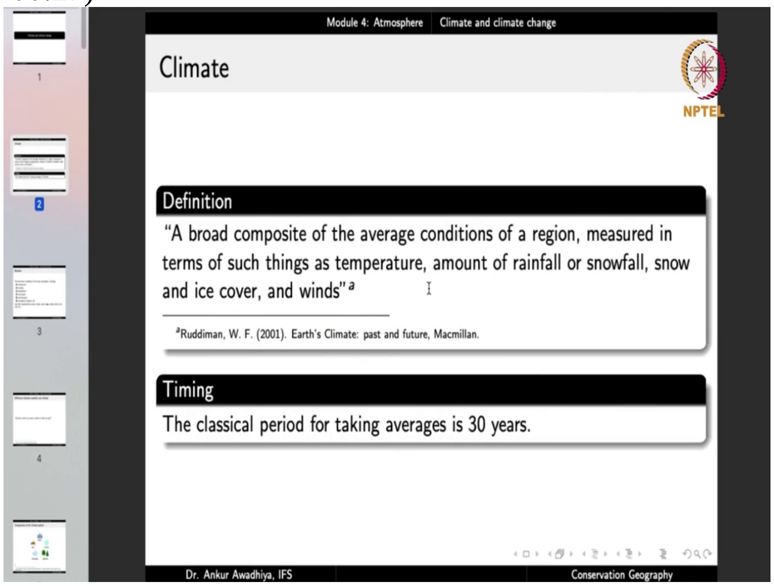

Climate is defined as a broad composite of the average conditions of a region, measured in terms of such things as temperature, amount of rainfall or snowfall, snow and ice cover and winds. And when we talk about average conditions, that classical period of taking the averages is, is 30 years. So, what do we mean by this? We observed in the last lecture that different places on the Earth are having different temperatures.

Different places have different air masses, different movements of these air masses, which result in vents. And when these air masses interact with each other, whenever the warm and moist air rises up, it would cool down resulting in precipitation, resulting in cloud formation, resulting in snow fall, hail storms, thunder, lightning and a number of things, even cyclones. Now, when we talk about climate, we are asking the question what is the average condition of a particular place in a particular time?

And when we talk about average conditions, we are taking long term averages, averages over 30 years. So, we ask the question, on an average in this, in any particular region, what is the temperature? Is it a high temperature area or a low temperature area? What is the average amount of snowfall or rainfall? That is, is this area a dry area or is this area a moist area? Snow and ice cover if they are applicable and the winds. Is this area a windy area or is this area to calm area? So, we are taking long term averages and we are asking the question what are the average conditions in the particular area.

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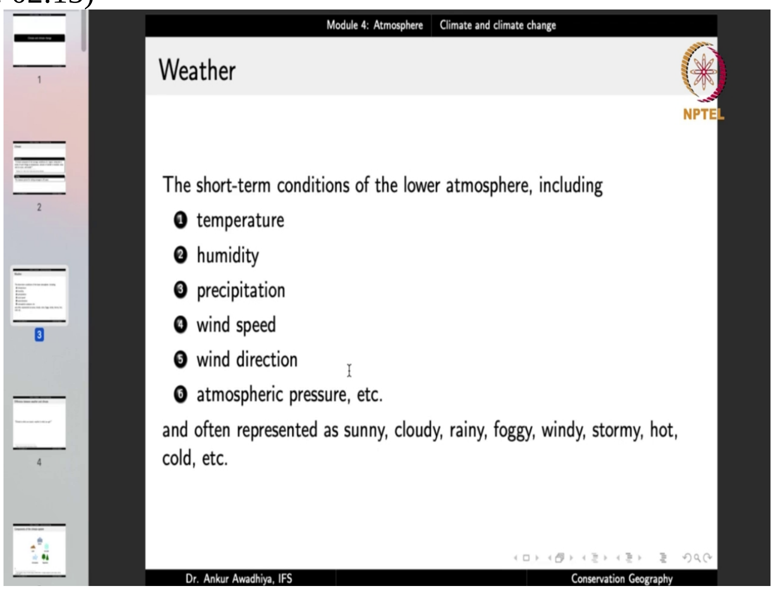

Now, this is different from weather. Weather is the short-term conditions of the lower atmosphere. Here also we are talking about the same things, temperature, humidity, precipitation, wind speed, wind direction, atmospheric pressure and so on, but in the short run. So, essentially, in the month of December, most parts of North India have a winter season. So, the climate is cold. But it is possible, that on a certain day in the winter season, you may even get a small burst of rainfall.

Or probably, you can have ample amount of cloud cover. Whereas on the next day, it is possible that you get sunshine. So, when we talk about climate, we will say that in the month of December, the area is cold. But when we talk about weather, we will say that today it is a sunny weather or today it is a rainy weather or today it is a cloudy weather or it is a windy weather and so on. So, climate is over a long term, weather is over a short term. And weather is often represented as sunny, cloudy, rainy, foggy, windy, stormy, hot, cold and so on.

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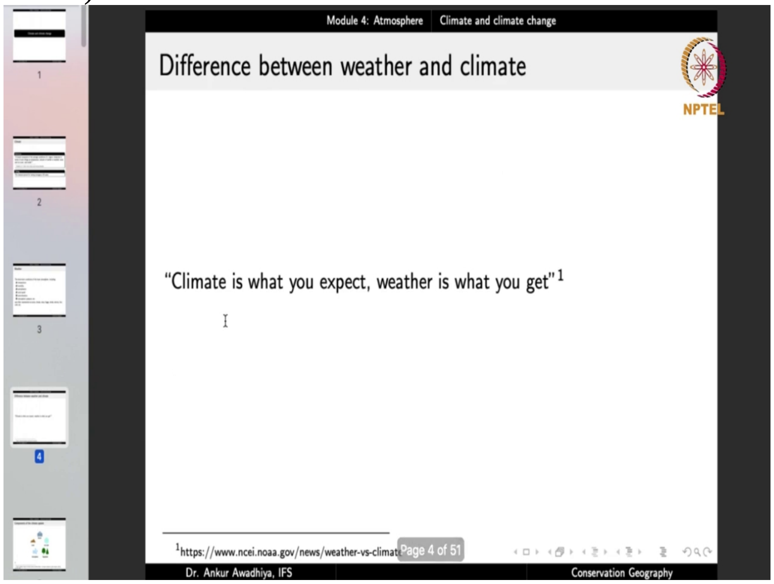

So, essentially we can say that climate is what you expect, and weather is what you get. So, you will expect that a place in North India in the month of December, you will get a cold climate. But when you actually go to that place, it is possible that you get a rainy weather, or probably you get a sunny weather or a windy weather. Because on that particular day, at that particular time it is, when we talk about whether we are talking about the conditions that are prevalent at that point of time.

Now, climate is what we generally talk about, when we are talking about changes. Because climate is over a long term, climate is what we expect in an area. It is a long-term average. And so if the climate changes, then it is something to be worried about. If the weather changes, okay, weather can change at any point of time. Today, it is sunny, on the next day it can be cloudy, nothing to worry about.

But on an average, on a long-term average, if it turns out that in the month of December, the temperatures of say a place like New Delhi, they rise, then we will be concerned about it. Because on an average, the conditions should not change a lot. But if they change, we will say that okay, there is something going on. That is climate change. So, how does climate come into being?

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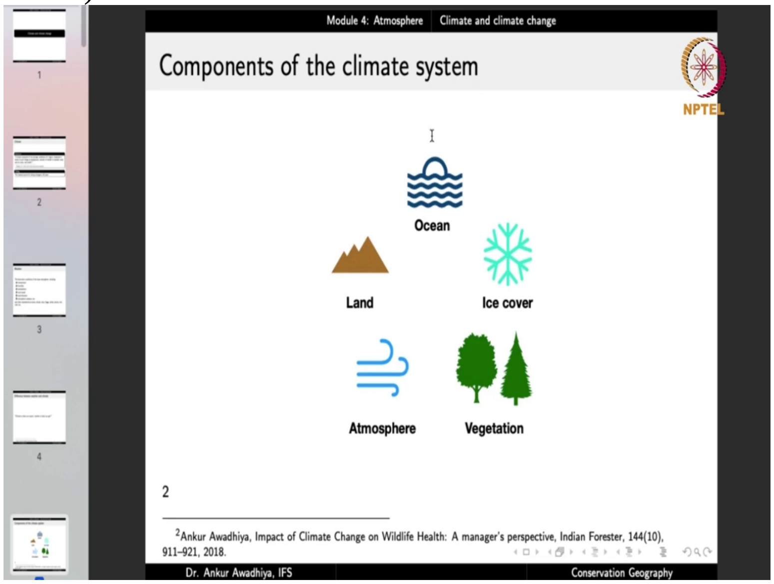

Climate can be understood in terms of five different components. So, you have water or the hydrosphere, you have land which is the lithosphere, you have the air in the atmosphere, then we also have the biosphere, in terms of vegetation. And we also have ice cover or the cryosphere. So, these are the five different components in a climate system.

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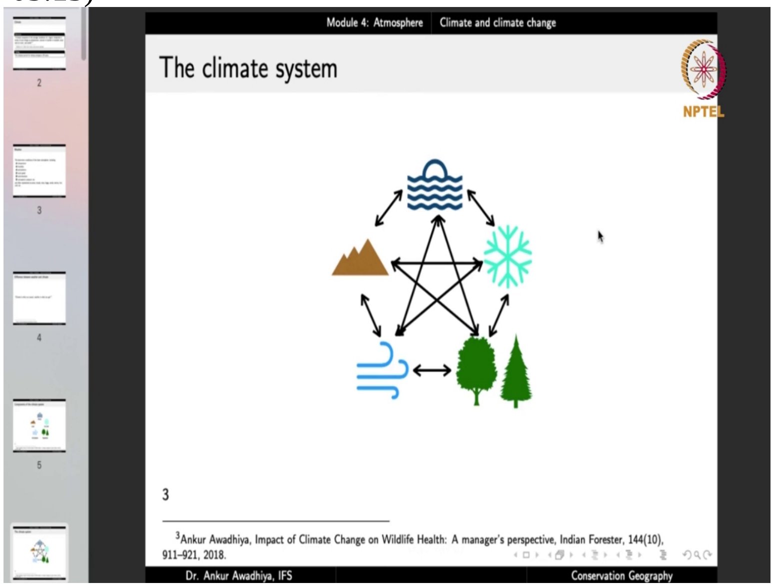

And these components continuously interact with each other. So, for instance, if an area is very windy, then it is possible that the plants will be of a shorter height. So, we will get those plants that are adapted to those conditions. We have observed before, that when the plants came into being on this planet, then they took up carbon dioxide from the atmosphere and released oxygen.

Now, carbon dioxide being a greenhouse gas, when its concentration reduced, the Earth cooled down.

So, the plants have a lot of bearing on the cryosphere. Water has a lot of bearing on plants, water has a lot of bearing on the land, because of things like erosion. Water also has a lot of bearing on the winds that get developed, we have looked at air masses. And air masses develop over large sized areas, such as oceans and seas. So, if the oceans change, if the ocean temperature increases, then the air masses would change. We have also looked at the interaction of the atmosphere with the hydrosphere. Because of the prevailing winds, we get ocean currents. So, all of these components continuously interact with each other. And this is the climate system, an interaction of all these five components.

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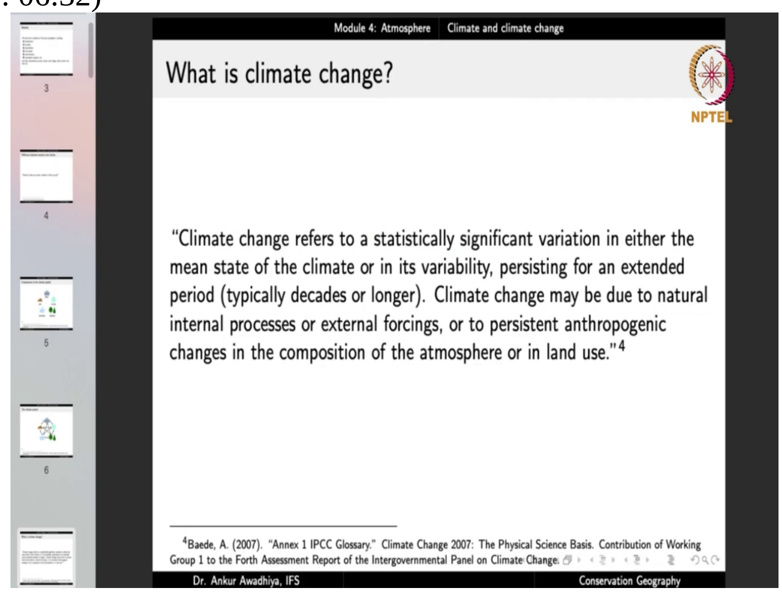

Now in this system, we can now define climate change. Climate change refers to a statistically significant variation, in either the mean state of the climate, or in its variability. Persisting for an extended period, typically decades or longer. So, we are talking about those changes that are statistically significant. So, if the climate changes a bit, but it is not statistically significant, we will not call it a climate change, we will consider it a normal variation.

But if there is a statistically significant change, we will say that, there is a climate change. And variation in what? Either the mean state of the climate or in its variability. So, when we say the mean state, we are talking about, if the temperatures in December go up. So, on an average, the

December temperatures in India are pretty low, but if they increase, then there is a change in the mean estate.

On the other hand, we can also have a change in the variability of the conditions. So, for instance, you have a place where you get say rainfall in 100 days out of 356 days. Now, if it turns out that in one year, you get rain only in 50 days, and in the next year you get rain in 200 days. That is, in one year you are getting a drought like situation, in another year you are getting a flood like situation.

So, here we are not talking about changes in the mean, we are talking about changes in the variability. Because on an average, when we say that a place gets 100 days of rainfall, then probably it would be say 95 to 105 days or 90 days to 110 days, that is the normal amount of variability that can be expected.

Now, if this variability increases from 50 days to 200 days, then we say that, there is something going wrong, there is a climate change. Because we are observing a change in not the mean in this case, but the variability of the system. And these changes, should persist for an extended period of time. So, if for instance, in one year you get a drought, you will not say that, this is a climate change, no.

If you get a drought over an extended period of time, so, year after year, you are getting a drought or year after year you are getting a flood or year after year you are getting a large amount of variation, in temperature or rainfall, then you will see that, this is a climate change. Because climate is a long-term average. So, climate change will also have to be looked at on a long-term scale.

Climate change may be due to natural internal processes or external forcings. And they can also be because of persistent anthropogenic changes, in the composition of the atmosphere or in the land use. So, what causes climate change? We can have climate change due to natural internal processes. So, for instance, it is a natural process that you can have volcanic activity.

Now, if in a natural way, there is so much amount of volcanic activity that a large amount of dust is spewed out into the atmosphere, which increases the opacity of the atmosphere and reduces its transparency, so that less amount of sunlight is able to reach into the Earth, the Earth would begin into cool down. Now, this occurred because of a natural change. But we can also have climate change because of certain external forcings, including anthropogenic changes.

So, when we talk about the great oxygenation event, we said that earlier the atmosphere was rich in carbon dioxide. And so, carbon dioxide being a greenhouse gas, it was trapping up the heat, on the planet. And so, the planet was very hot. Then when the plants came, they took up carbon dioxide, released oxygen, the concentration of carbon dioxide reduced and, in that way, the plants helped to cool down the planet.

Now, when we talk about anthropogenic changes, we are talking about the rampant use or let us say, overuse of resources such as coal, petroleum and natural gas. So, in this way, we are taking up the carbon that has been stored for thousands of years or millions of years, we are taking it, we are digging it out of the Earth. We are burning it and we are releasing carbon dioxide back, back into the atmosphere.

So, this is an anthropogenic change, something that is caused by human beings. So, climate can change either because of natural processes or it can change even because of artificial processes, which we call as anthropogenic climate change. And these changes can be in the composition of the atmosphere or in the land use. And when we talk about changes in the land use, we are talking about the human beings, that are clearing away the forests.

Now, forests act as a natural storehouse of carbon. So, when you clear up the land, when you burn up the trees, you are again releasing carbon back into the atmosphere. And at the same time, we are also removing a sink of carbon. So, forests if they persisted, they would have absorbed more and more carbon dioxide. But once you have cut down the forest to make way for say, agriculture or for cattle ranching, or say for a habitation project. In that case, you are removing a sink of carbon. So, changes in the land use can also result in long term changes in the climate.

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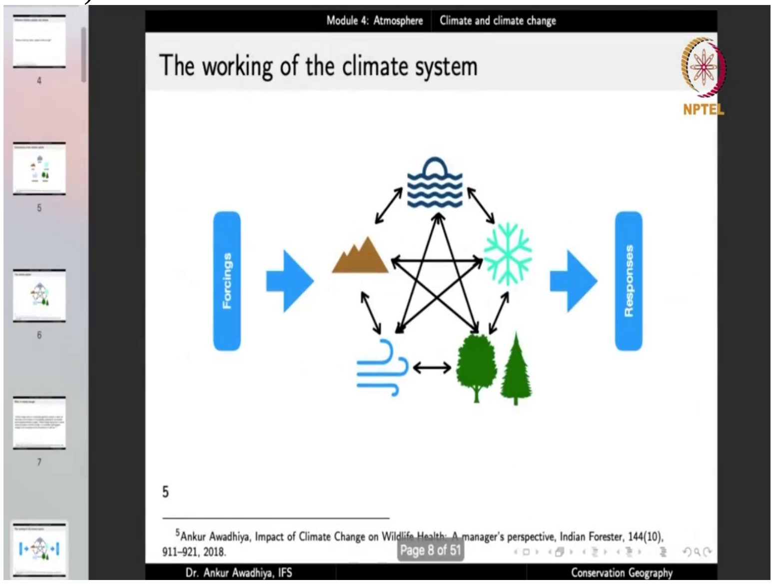

And in this case, we can talk about the working of the climate system. So, we talked about the five components, if there is a forcing, if there is something that forces the system to change, there will be certain changes, that are known as responses.

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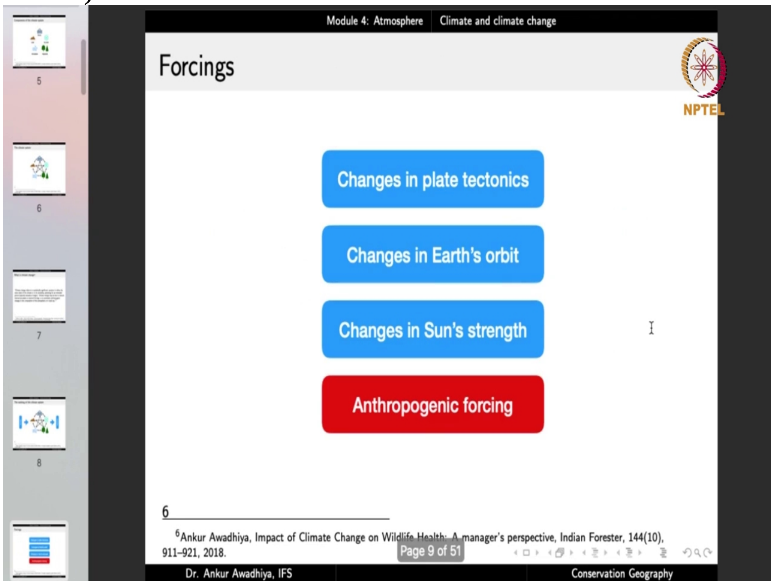

And these forces can be things like changes in the plate tectonics. So, when we were talking about plate tectonics, we said that when plates collide with each other, they can result in orogenic changes, that is the creation of a new mountain or even epeirogenic changes, that is creation of a new continent, or we can have subduction. In which case, the crust gets destroyed. And we said that, when the thrust gets destroyed, the materials that are there in the crust, they also move down below the crust, into the mantle, towards the mantle.

And in that way, we are have… we get changes such as the conversion of carbonate rocks into their constituents. So, you will get an oxide and you will get carbon dioxide that gets released in a volcanic eruption. So, changes in the lithosphere can lead to changes in the climate.

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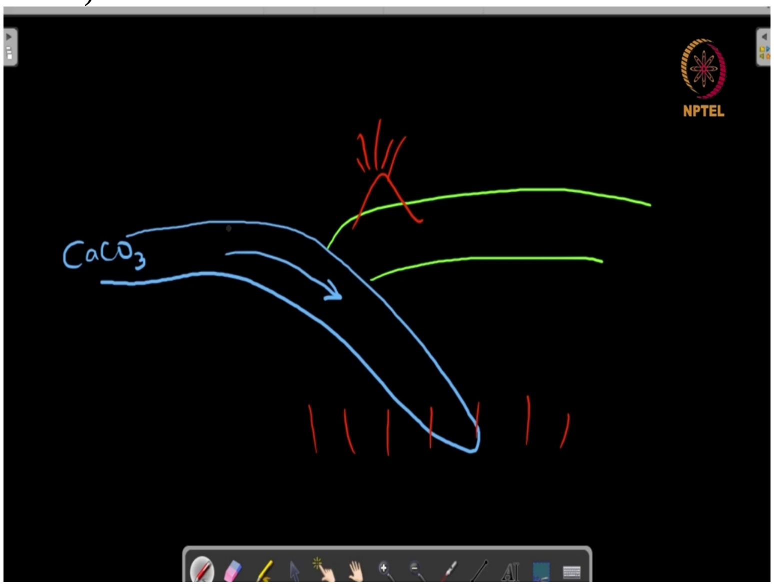

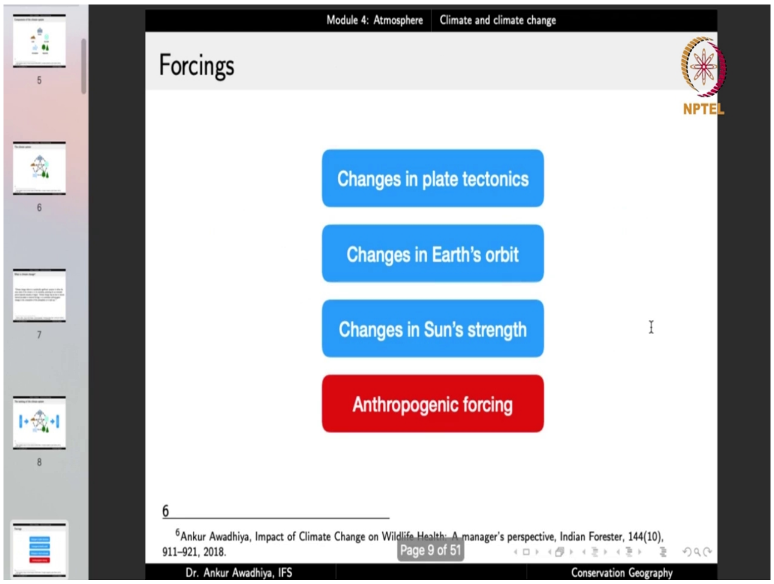

So, what we are talking here is that, you have two plates. So, the first plate is going down like this and here you have another plate. Now, when this blue plate is going down, what is happening is that all the calcium carbonate or other carbonates, they are also going down. And here in the bottom, the amount of heat is too large. And so, the carbon dioxide gets released and it comes out through the volcanic eruptions.

So, changes in the lithosphere, changes in the crust are leading to a release of carbon dioxide into the atmosphere. So, this is what we are talking about. So, one of these forcings is changes in the plate tectonics. Similarly, another forcing is changes in the Earth's orbit. Now, when we talk about the orbit of the Earth, we have three different things. We have eccentricity, we have precession, and we have the tilt, which are known as the EPT cycles or the Milankovitch cycles.

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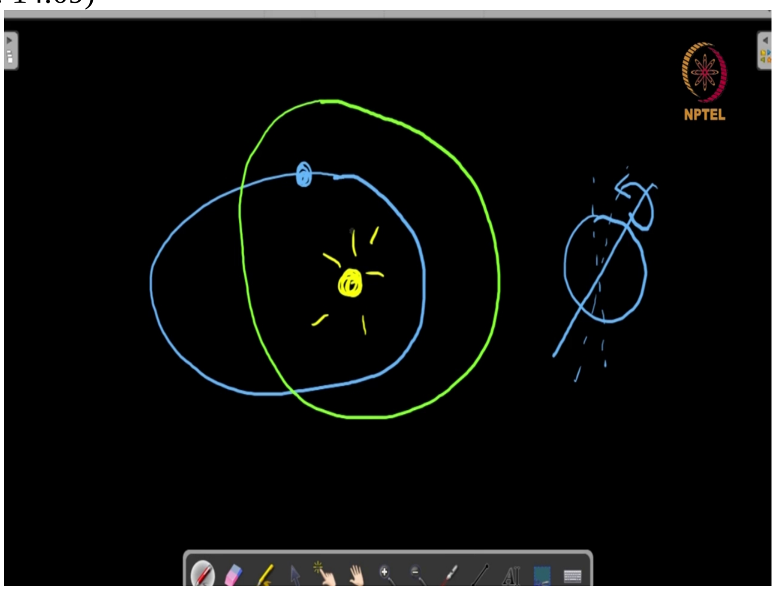

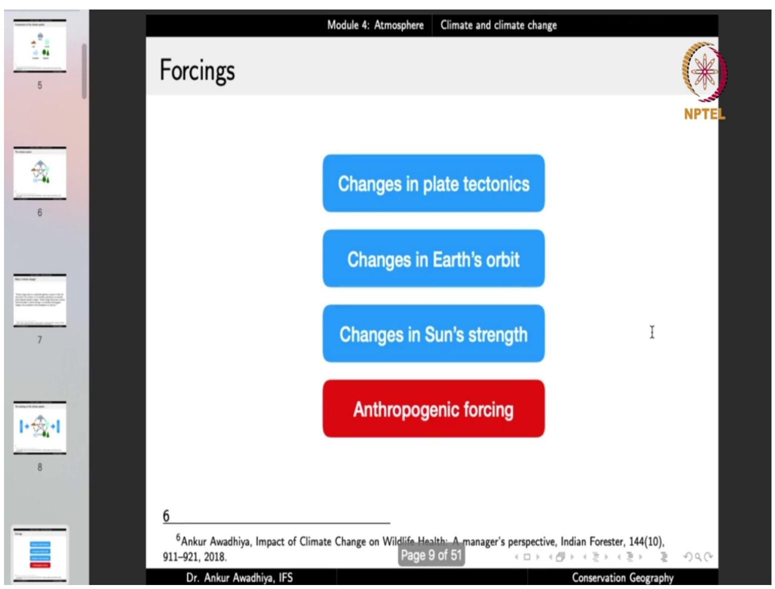

Now, in this case, what happens is, when we talk about the Sun and the Earth going around the Sun. Now, in this case, the orbit of the Earth may change with time and it does change with time. So, from an orbit like this, we can perhaps have a more circular orbit. So, when there are changes like this, or when there is a change in the tilt of the Earth, so today we know that, the Earth is tilted it is going around like this.

And in this case, the Earth is tilted at an angle of 23 and a half degrees. But this angle can change. So, from this angle, it can say become this angle or it can become this angle and so on. So, we can have changes in the Earth's orbit, which can result in changes to the climate or we can have changes in the Sun strength. The whole of the climate system is being given energy by the Sun. Now, if the Sun gives out more amount of energy, the whole system will get heated up.

So, that is another forcing. But these forcings are few and far in between, they are not that important today. The most important force in today is the anthropogenic forcing or the anthropogenic climate change. Primarily, because of two things. One is the release of carbon dioxide by rampant burning of fossil fuels. And second is changes in the land use, because of which we are destroying the sinks of carbon.

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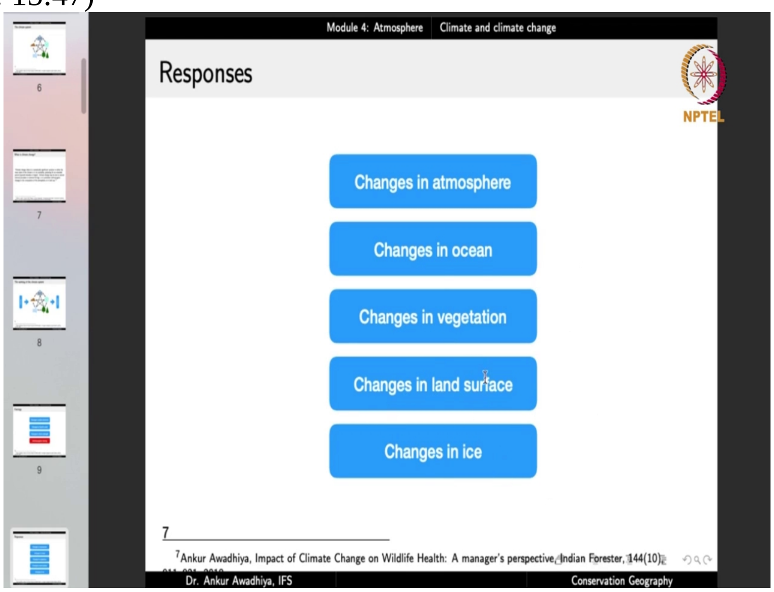

And in this case, there can be several responses, in terms of changes in any of these five components. So, you can have changes in the atmosphere, changes in the ocean, changes in the vegetation, changes in the land surface and changes in ice. What sort of changes? Because of, say, a heating of the planet, it is possible that the atmosphere will expand. We had observed in an earlier lecture, that the atmosphere exists only on those celestial bodies that have an appreciable gravity and a low temperature.

Because when the temperature increases, you get large quantities of large sized convective cells. Because of which, the atmosphere expands and the gases get lost into the deep space. So, you can have changes in the atmosphere when the Earth warms, the atmosphere expands. You will have changes in the wind patterns, you will have changes in the air masses, you can also have changes in the ocean.

The oceans will also start to warm up and the oceans may also start to capture the carbon dioxide dissolved the carbon dioxide into them and in that way, the acidity of the oceans will go up. Because, what, water when it dissolves carbon dioxide will get carbonic acid. And with an increase in acid, the pH of the oceans will go down. We can also have changes such as, increase in the sea surface level.

Because when the oceans get heated, they also expand water expands when it is heated. Also, when the temperatures increase, the ice caps melt. And all that is that has been stored in the icecaps for millions of years, that all comes rushing down into the oceans, because of which the oceans also get more amount of water and the sea level rises. So, we can have different sorts of changes in the oceans, different sorts of changes in the hydrosphere.

We will also have changes in the vegetation. Because certain plants, that are adapted to cold conditions, when the temperatures rise, those plants will die off. On the other hand, those plants that are more adapted to living in higher temperatures, they will probably survive better. With more amount of carbon dioxide in the atmosphere, carbon dioxide acts as a fertilizer for plants. Because plants use a carbon dioxide during photosynthesis.

So, more amount of carbon dioxide would also mean more amount of photosynthesis. Similarly, with changes in the wind patterns changes in the atmosphere, we will have certain areas that will have more amount of droughts or more amount of floods. So, the vegetation will change. We will also have changes in the land surface. Why?

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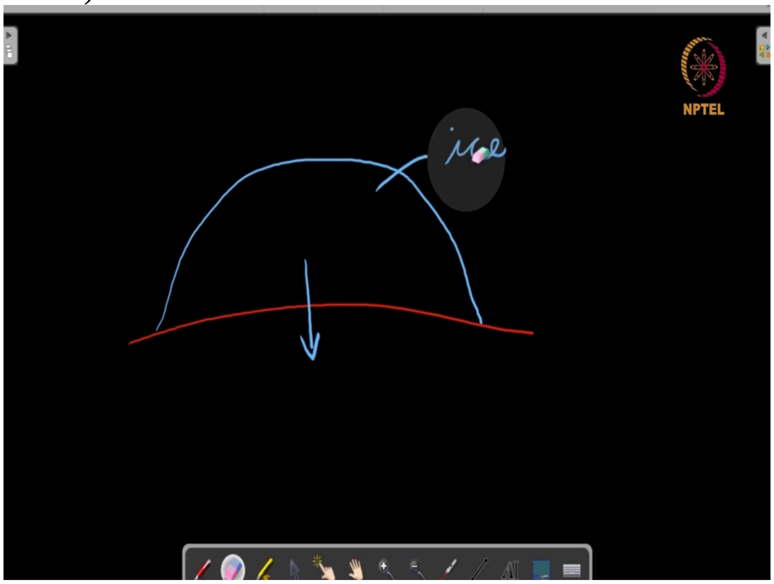

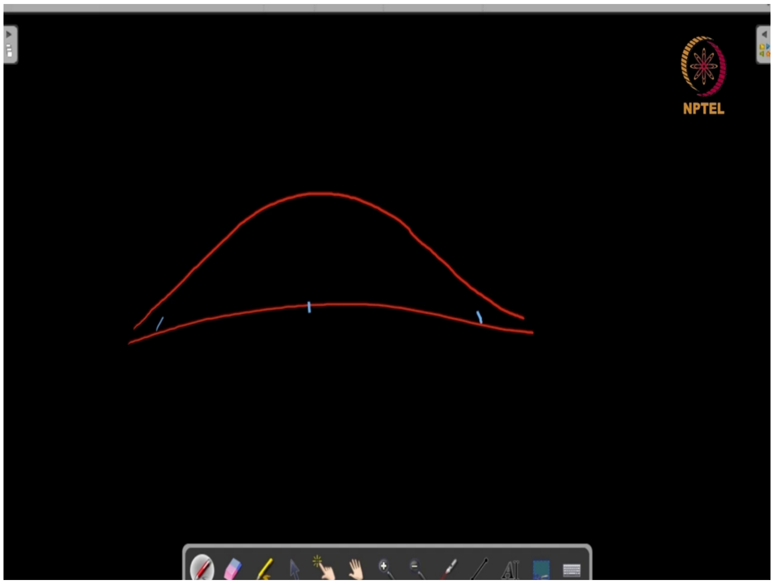

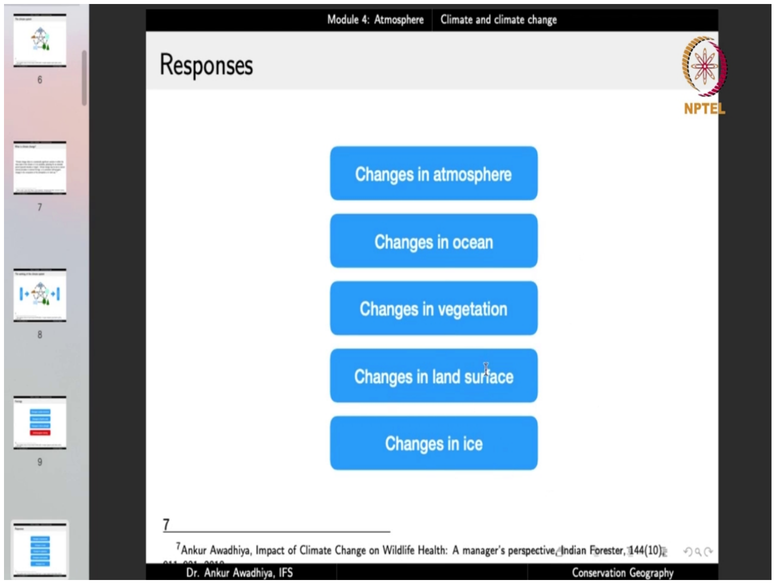

Because, let us consider a piece of land that is covered with a lot of ice. So, we are talking about a snow-capped area. Now, this ice puts a tremendous amount of weight down on this Earth. And we know that, the mantle is semi solid, it is a viscous sort of a substance over geological timescales. And so, this Earth has been pushed down. Now, when you have a climate change, and when all of this ice is gone, what will happen is that this force that was pushing the Earth down will now no longer be here. And so, the Earth will rise.

So, this is a change in the land surface. Similarly, when you have more amount of torrential rains, then probably the agents of erosion in terms of flowing water, they will start to have more amount of activity. In those areas, that become drier, the water will start to have less amount of activity. The glaciers would change, and large number of glaciers may melt away. When that happens, their agent as a, as a change agent of geomorphology that would end. And we will also have changes in ice, as we have already seen. So, responses changes in one or more components of the climate system.

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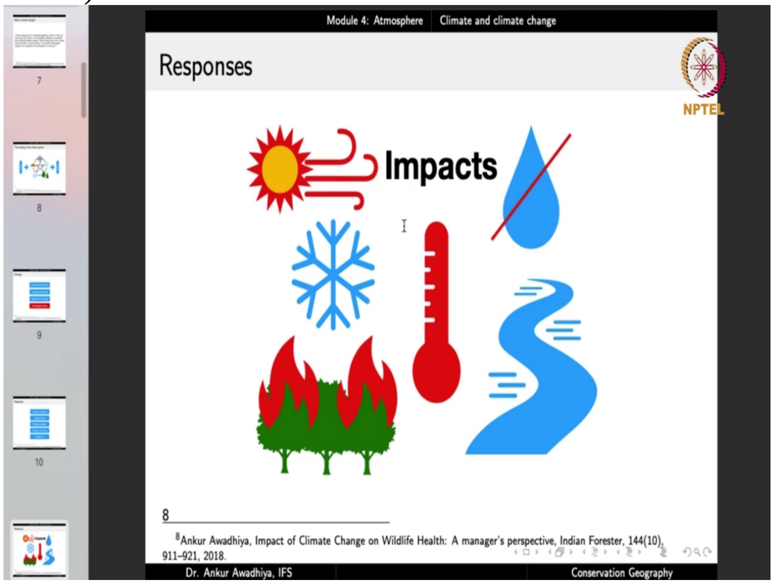

And these responses will have a large number of impacts. So, we will have situations in which people die of heatstroke, for instance. Because the temperatures have gone up and the winds are very dry and hot, or we will have changes in the snow cover. Because of which, a large number of cultures and large number of societies that are dependent on that snow cover, that will be impacted.

There would be changes in the temperature, there would be changes, such that some areas will get drought, some areas will get floods will have more and more number of forest fires. So, these are all different kinds of responses and impact that we will observe because of the climate change. Now, in a large number of these responses, we are already observing them. So, when we talk about things like wildfire, say the Californian wildfire or the Australian wildfires.

We are observing that the forest fires have gone up in frequency, they have become more and more dangerous. Because they are such widespread fires, that there is nothing to protect us and the animals from these fires. Then, in certain areas, we are already getting a scarcity of water. The city of Cape Town, suffered from a severe water shortage such that. it was predicted that they will go out of water one day. Certain areas are getting more and more amount of floods. The floods in China they have been increasing year after year. We are observing certain places that are becoming warmer, certain places that are becoming colder. So, we are observing changes in all of these factors.

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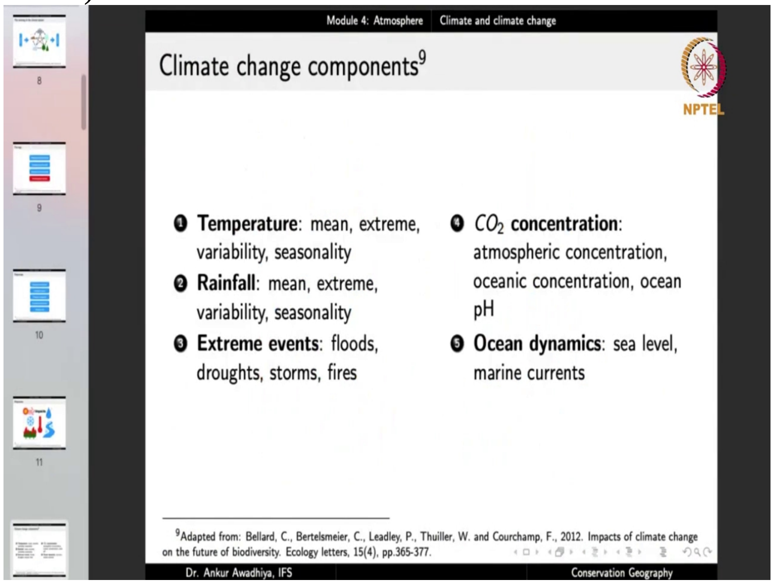

Now, in this context, we can talk about the climate change components. Now, when we talk about changes in temperature, we can have changes in the mean temperature, we can have changes in the extreme temperature. That is the maximum or minimum temperature that exists in an area. It can become hotter or it can become colder, not just in the average sense, but also in terms of the extremes.

So, when we talk about the maximum temperature on Earth that was recorded, this is what we are talking about. Or changes in the variability and, and seasonality of the temperature. Similarly, in the case of rainfall, we can talk about mean rainfall, extreme rainfall, variability of rainfall and seasonality of rainfall. So, for instance, in India, we get monsoons say from the month of end of May to something around end of September.

Now, this months change, we will be talking about a change in the seasonality of rainfall. Extreme events, such as floods, droughts, storms and fires. Carbon dioxide concentration in the atmosphere or in the ocean, resulting in changes in the oceanic pH. And we will also find changes in ocean dynamics, such as sea level and the marine currents.

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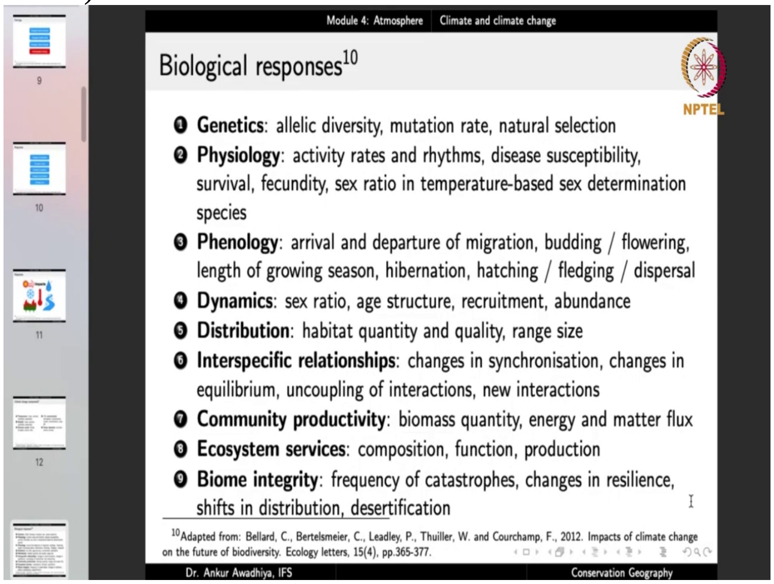

And these changes are now impacting the biosphere. We are observing a large number of biological responses. We are observing changes at the genetic level. The allelic diversity of different organisms is changing. There is a change in the mutation rate, there is a change in natural selection. So, we will look at this in a short while. There are changes in physiology of organisms, the activity rates and rhythms are changing.

The organisms are becoming more and more susceptible to diseases. Because of living in more extreme states, which is changing the survival of organisms. It is changing the number of children or the, the number of young ones that these organisms have. It is changing the sex ratio in temperature-based, sex determinations species. Such as reptiles, like the crocodile, or the turtles. So, when the temperatures increase, in that case, we will find more number of males or more number of females.

Depending on the species we are talking about. Now, if in a population, you only have all the young ones, that are males or all the young ones that are females, in that case, the, the survival of this population will come at stake. Because, you will not be having a good sex ratio in the next generation. We are observing changes in phenology, such as the arrival and departure of migration, budding, flowering, length of growing season hibernation, hedging, fading and dispersal times.

So, essentially, what is happening is that, the birds that migrate by looking at changes in the weather, they are not, now not getting those cues. The flowers they bloom in a particular temperature in a particular humidity, but with changes in the climate, it is happening that certain flowers just do not bloom at all. The plants just do not bloom. Certain flowers do not convert themselves into fruits.

So, these are changes because of changes in the climate, which result in a change in the timing of different activities of the organisms. We are observing changes in dynamics, changes in sex ratio, ages structure, recruitment and abundance of organisms. And a large number of species are going down in number because of these responses. We are observing changes in distribution of organisms. Changes in habitat, quantity and quality and the range sizes.

So, we will explore this in more detail in a short while, but what is happening is that, those species that are more adapted to living in warmer conditions, they are now shifting towards the north, they are shifting towards higher altitudes. Whereas those species that are more adapted to living in cold conditions, they are now finding that they have nowhere else to go. So, for instance, when we talk about a species such as the polar bear.

If the poles get devoid of ice, what will happen to them? How are they going to fish? How are they going to hunt for food? Because they make use of these ice to walk, they make use of these eyes to stand and look around. They also need rest after they have swam a lot. And so, these act as resting spaces. Now, when the ice is gone, the polar bear will not have a way to venture deep into the ocean and get its food.

So, the polar bear will get to the brink of extinction. We are observing changes in interspecific relationships. Changes in synchronization. Now, what is changes in, in synchronization? There are certain birds that, that lay eggs which hatch in a particular season, so that they can match their timings with the fruiting of certain trees.

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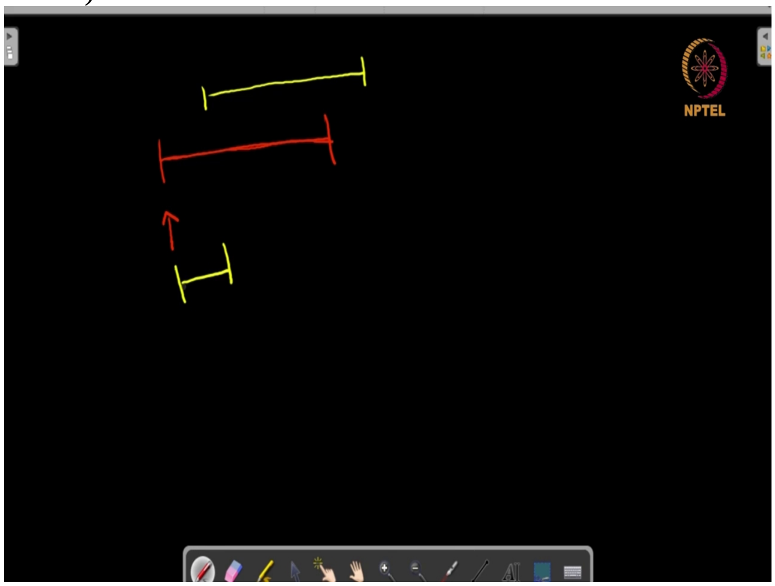

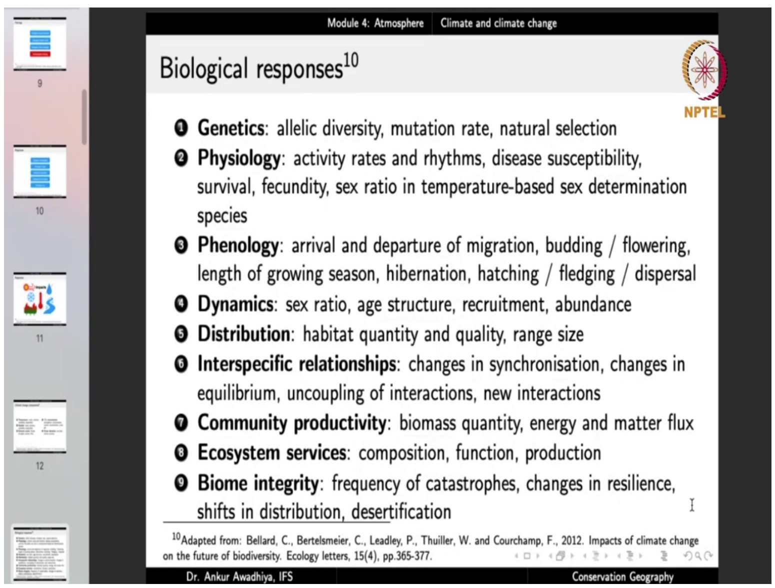

So, for instance, in that case, what will happen is, if the tree fruits in this time point, the bird's eggs will hatch such that they hatch somewhere around this point. So, that the young ones can make use of this whole complete fruiting season, so that they have some sufficient amount of food. Now, if the eggs hatch here, but because of changes in phenology, the fruiting happens like this. So, for this much period, the young ones will not be having any food.

And in that case, the young ones will simply die. So, we are getting changes in the synchronization of species, which is impacting the interspecific relationships between species. We are getting pollinators at time when we do not have flowers. And when we have flowers, we do not have the pollinators. So, with time, both the flowering plant and the pollinators, they are getting decimated.

We are observing changes in the equilibrium, uncoupling of interactions and new interactions that are coming up. So, for instance, with changing climate, we are now observing more and more number of invasive species, exotic species that are not natural to that area. Now, if such a species are able to expand their range, then the existing relationships between the organisms will be collapsed and new relationships will be formed.

So, these are changes that we are observing. There are changes in community productivity, the amount of biomass that has been produced, the energy and the matter flux in the communities. So, the efficiency of communities is going down, we are observing changes in ecosystem services, composition, function and production. So, with changing climate, we are not having such good relationships between different species, that we will be able to get the optimal level of ecosystem services.

So, now with a change in climate, the species that are living in the forest, they are probably not able to clean water to that good of extent as they were doing beforehand. We are observing changes in the biome integrity. So, we are observing changes from the genetic level right up to the biome level. The frequency of catastrophe is increasing, the biomes are becoming less and less resilient, there are shifts in distribution, we are observing an increase in desertification.

So, these are all different biological responses. And these biological responses become extremely important, because these responses are given out by certain species, which may already be threatened species. So, if you have a species that has already been pushed towards extinction, because of say rapid hunting, and so, now, very few number of individuals remain.

Now, because of climate change, if it so happens that the food source of this species also gets dwindled. Because the native species die out and exotic comes and occupies the area and the, this threatened species is not able to eat this exotic species. What will happen then? Then this threatened species, will have no option but to get extinct. And so, these changes become very important from the point of view of conservation.

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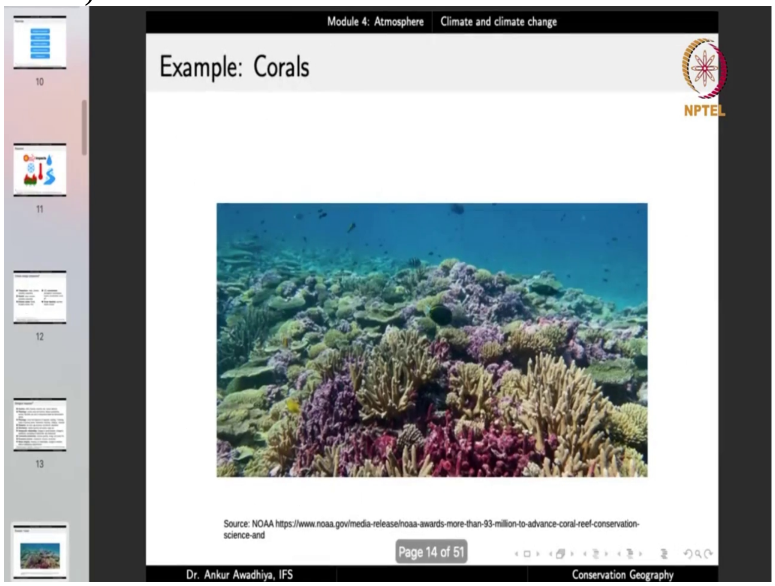

So, what are the kinds of changes that we are actually observing? In the oceans we have a large number of corals. Now, corals are organisms, that exist as a symbiotic community. And they play a very important role as keystone species. So, when you have corals, quite a large number of species can use them as their home, they can use them as shelter, they can use them for laying eggs and so on. So, corals are very important for species such as fishes.

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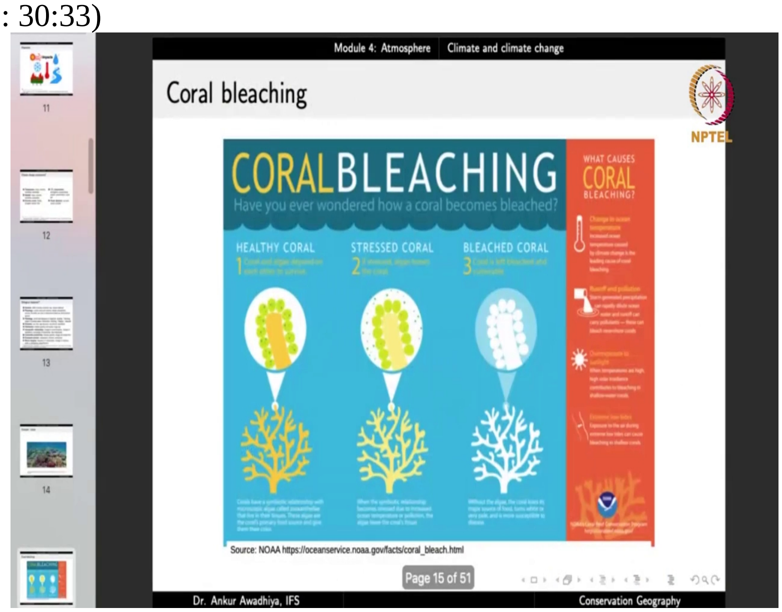

Now, what is happening is that with an increase in temperature, and with an increase in acidity of the oceans, the corals are now dying off. So, we have this phenomenon that is known as coral bleaching. So, in a healthy coral, the coral and algae live together. When the coral faces a stress, especially in terms of increased temperature, increased acidity or pollution. So, in that case, the algae goes out, and this becomes a bleached coral. Now, earlier the algae was supporting the coral, the coral was supporting the algae. Now, with the algae gone, the coral is less supported. It is less able to maintain itself. And so now, it is more susceptible to diseases, it is more susceptible to death.

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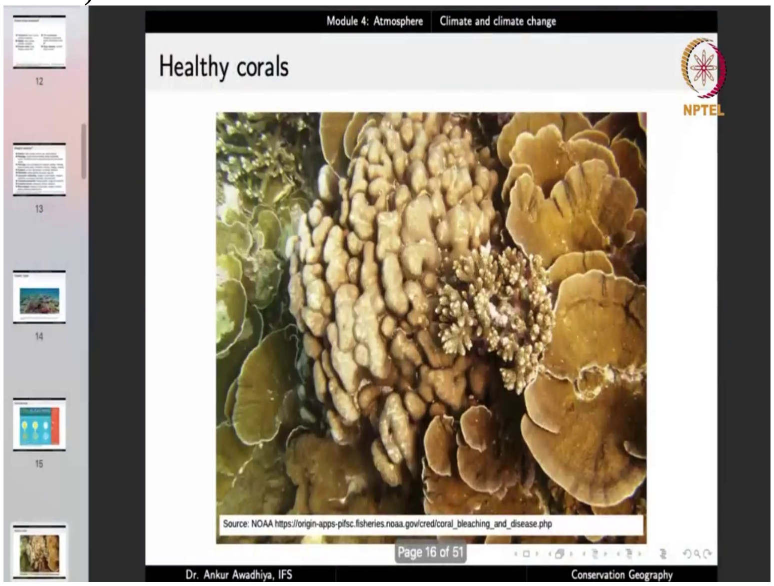

And this is what we are actually observing. So, this is an example of a healthy coral. So, you can observe that it is a colored thing.

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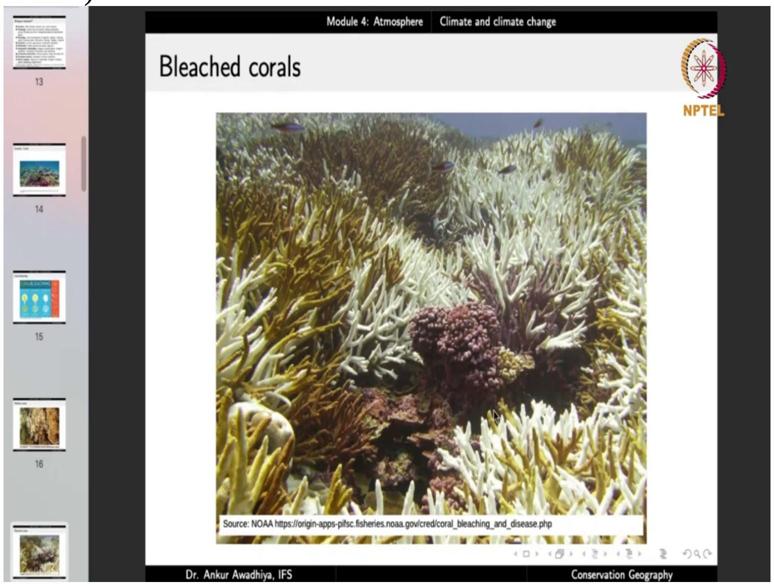

And this is an example of bleaching. So, all these corals, they have now turned from these yellow green structures. So, we are observing certain healthy corals here and these are all bleached corals. Now, they do not have the algae living with them.

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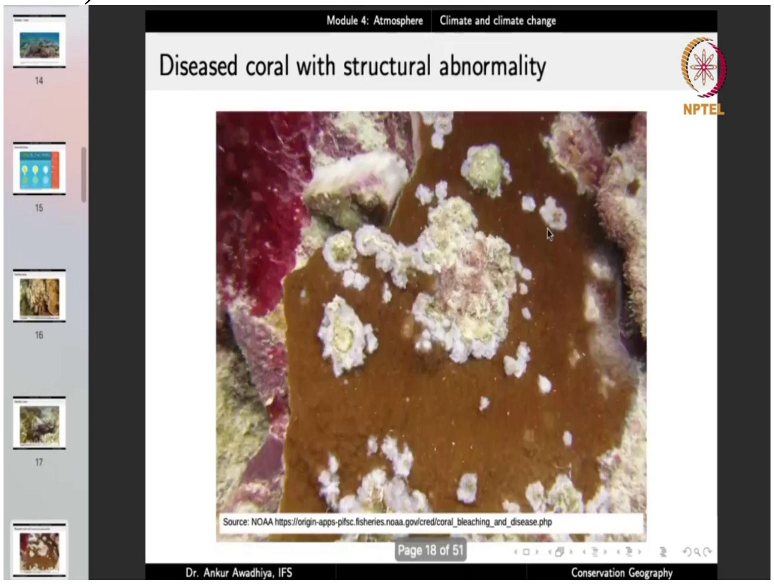

And with bleaching, we also observe different other impacts. We are observing diseases more frequently in these corals.

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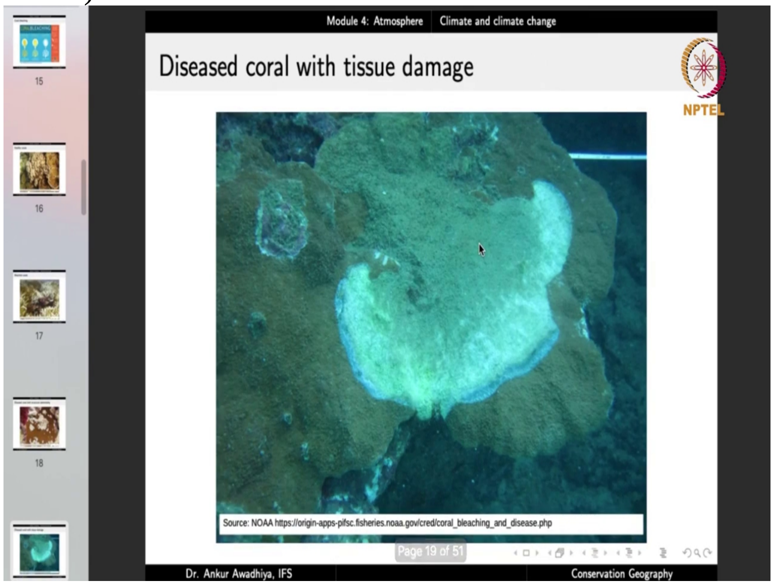

Structural abnormalities, tissue damage and even death of the corals.

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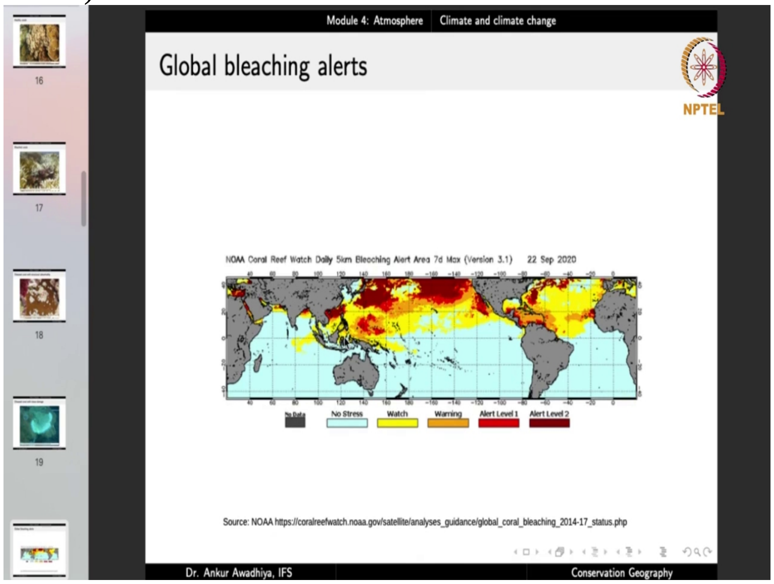

And these days, if we look at where we are getting these threats, we will find that we are getting them in a majority of area. So, there are very less areas that are left, that are having low stress. But most of the areas we are getting warnings or alerts for coral bleaching. Now, in this context, it is also important to know that, the corals are not found in very hot areas or in very cold areas. So essentially, we are only talking about these areas that are getting, that have corals and most of them are now facing a threat of bleaching.

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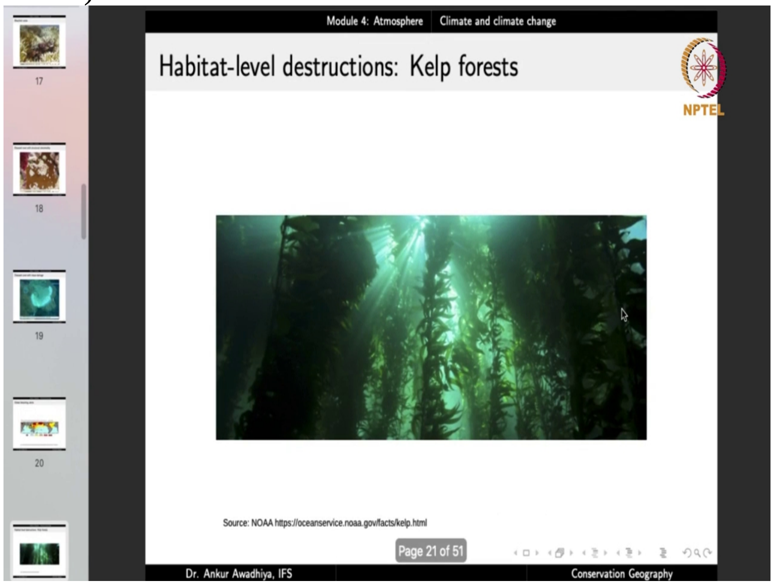

Another habitat level destruction is in the kelp forests. The kelp forests, again, are keystone species, and they act as shelter for a large number of organisms. Now, we are observing that these kelps are dying off.

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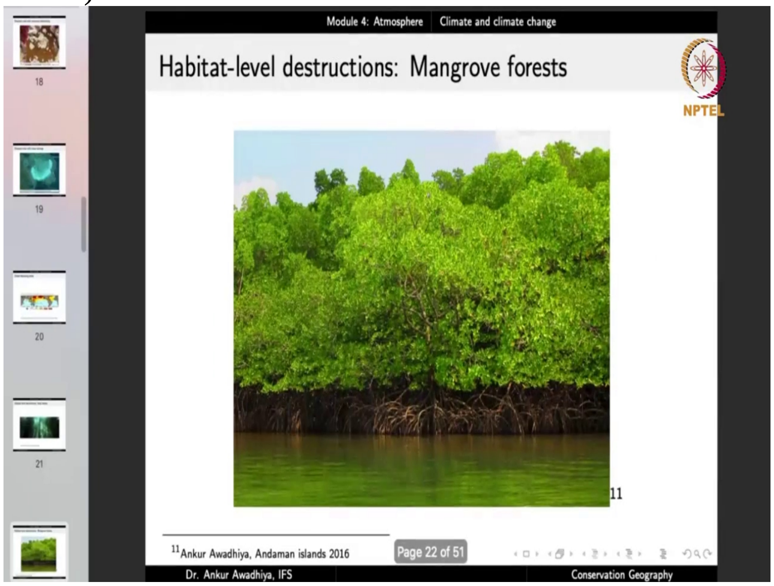

Another change is in mangrove forests, mangroves are dying.

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We are observing changes in the polar ice. So, if the polar ice reduces, the polar bear has nowhere else to go.

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We are observing more and more number of exotic species, that are flaring in different areas.

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Even in our country, we are observing a spread of *Lantana camara*, which is an exotic species. It is an invasive species.

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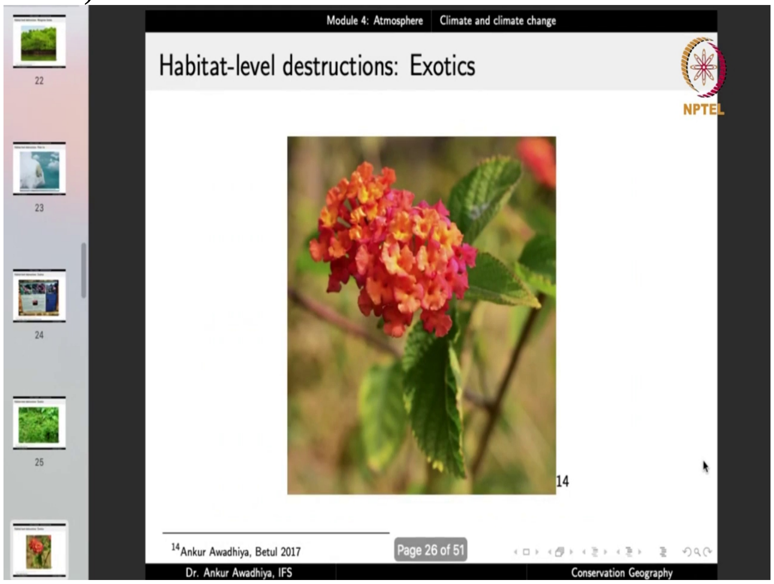

It, so this is what the flower looks like.

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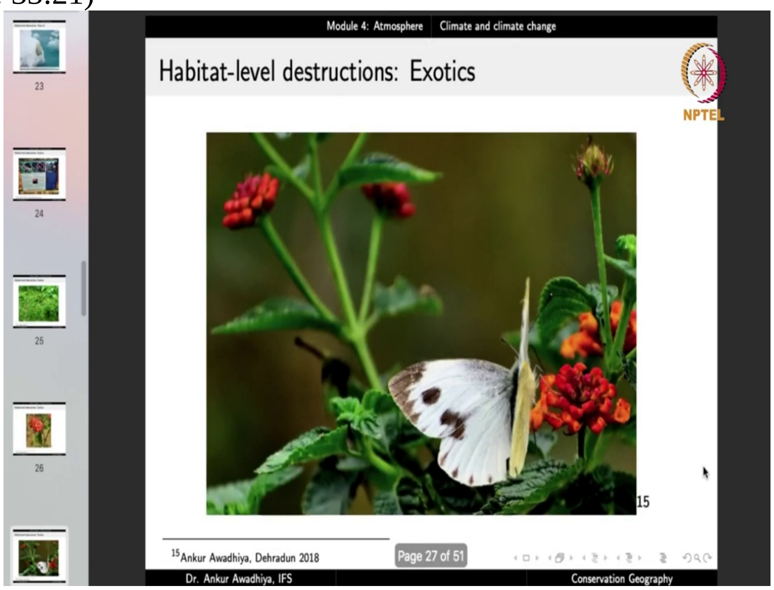

And it is now developing new interactions, displacing the old ones.

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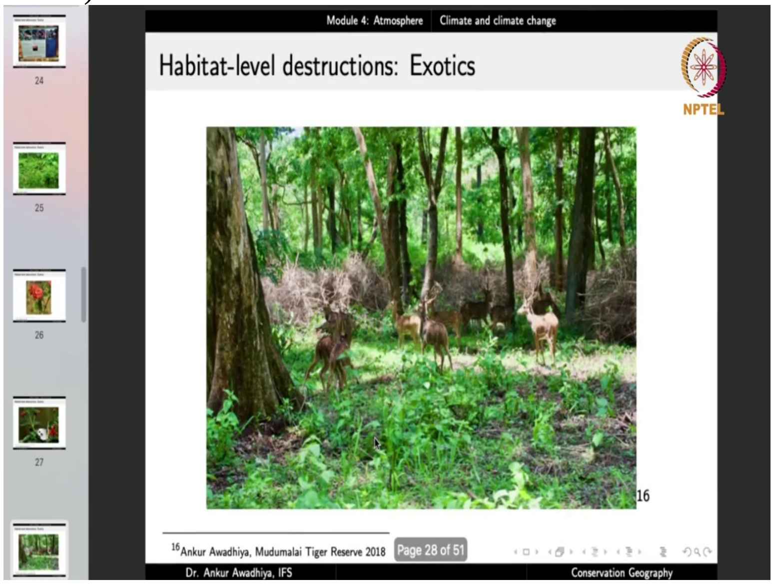

And in a number of areas, we find that this *Lantana camara* has now spread so thickly, that it is now displacing a large number of native species from their habitats. And now it has become important to manually uproot all of these species, all of these individual plants to make way for our native wildlife. So, this is a change that we are actually observing today.

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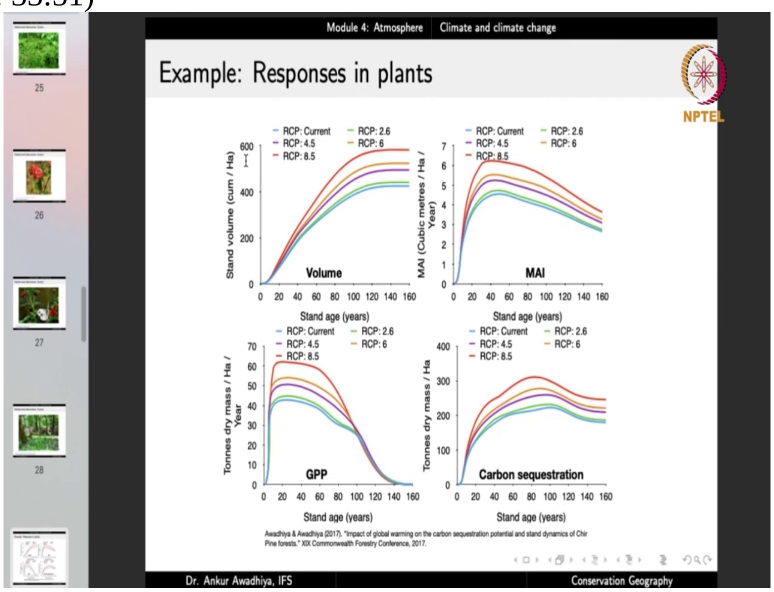

We are finding responses in plants. So, when the temperatures go up, when the carbon dioxide goes up, we find changes in volume mean annual increment, gross primary productivity and carbon sequestration potential of different plant species.

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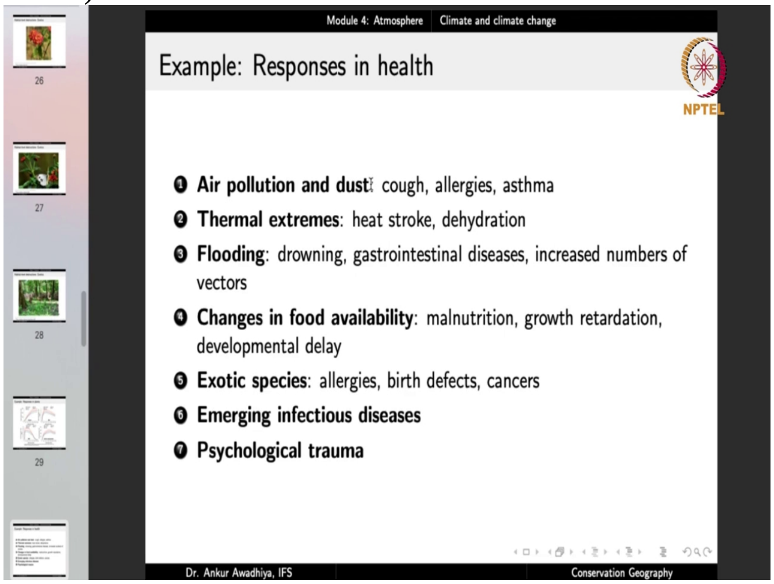

We are observing changes in the health of different animals. Air pollution and dust that is being generated, because the areas are getting more and more drier are leading to things like cough, allergies and asthma in different organisms. Thermal extremes, that is in excess of temperature is leading to heatstroke and dehydration, even in wildlife. So, these are again pushing our wild species towards extinction.

They are stressing these species. When there is flooding, we are observing animals that are drowning, that are suffering from gastrointestinal diseases, there is an increase in the number of vectors such as mosquitoes. Whenever there is a flooding incident. Now, in the case of climate change, both the mean is changing and the extremes are changing. So, certain areas are getting more broad certain areas, getting more floods.

It is not that every area will become dry or every area will become warm, we are observing changes that are happening. We are finding changes in food availability to different organisms. Because of which a large number of our wildlife are now suffering from malnutrition, growth retardation, developmental delays. Exotic species are leading to allergies, birth defects and cancers. We are finding new infectious diseases that are emerging. And a large number of animals also suffer from psychological trauma. Because of a large amount of malnutrition, diseases and deaths. So, climate change is actually showing itself in its effects on its, on the wildlife. So, it is impacting us and it is also impacting the wildlife.

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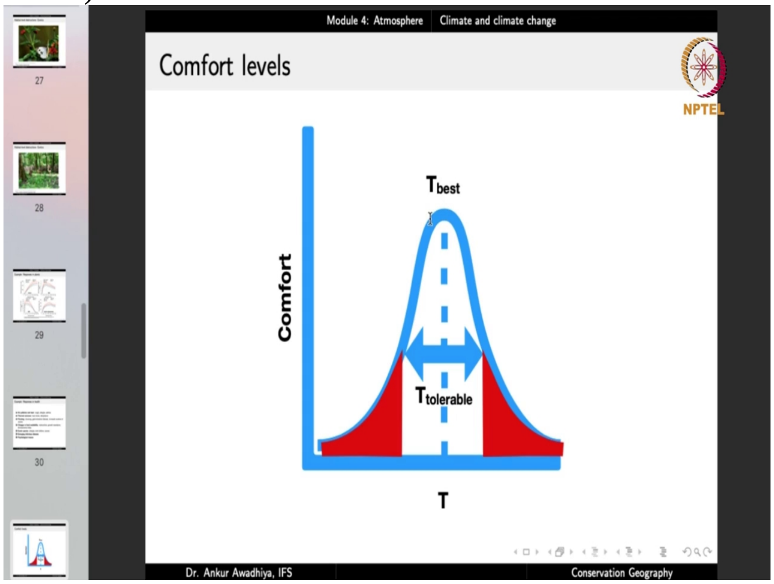

Another big change is, it occurs because the organisms have different comfort levels. So, there is a best suited temperature for any species. But there is also a tolerable range of temperature. So, for instance, we find it to be very comfortable when the temperature is around 25 degrees. But even if the temperature increases, say to 40 degrees, we are able to survive or even if it reduces to say as low as 15 degrees we are able to survive.

But what happens if the temperatures increase even further? If the temperature becomes 60 degrees? We probably will not be able to survive. if the temperature goes down to say minus 20 degrees, probably we will not be able to survive. We will only be able to survive, if we are, if we get certain other supports, in the form of climate-controlled environments. But the wildlife do not have this option. We cannot install air conditioners, we cannot install heaters in the forest. And so, in the case of a large number of wildlife, they do not have any option and they just die off.

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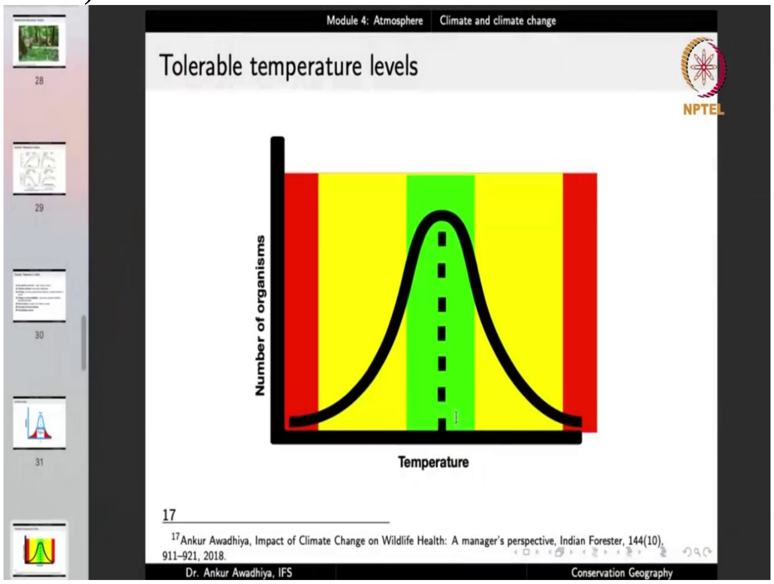

If we make a plot between the temperature and the number of organisms that can be sustained in those temperatures, in this green zone will find a large number of species. But when the temperatures become more and more extreme, the habitat will be able to support a lesser number of species. And because of this as well, our threatened species are becoming even more threatened.

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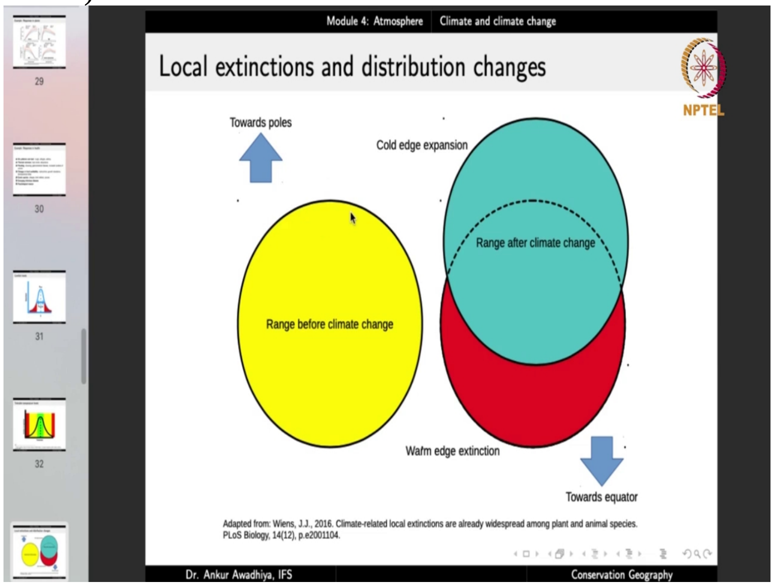

We are observing local extinctions and changes in the distribution. So, for instance, if before climate change, this was the range of a particular species. So, this is towards the poles and this is towards the equator. Now, when the climate changes, when it becomes hotter, what happens is that these areas, that are towards the equator, so these are the warmer areas in the range, these are the colder areas in the range.

And this range represents the, the variation in temperatures that are tolerable. Now, these hotter areas when the temperature increases, they become a bit too hot for these species. So, the species will die off in these areas. So, this is known as a warm edge extinction. On the other hand, these areas that were earlier too cold, for the organisms to live in, they have now become warm enough and so the organisms can be found in these locations. So, the range changes, and this is known as the cold edge expansion. So, whenever the temperatures increase, we find extinctions and deaths in the warmer areas of the range, and we find an extension in the colder areas of the range. But then, this process cannot go on forever.

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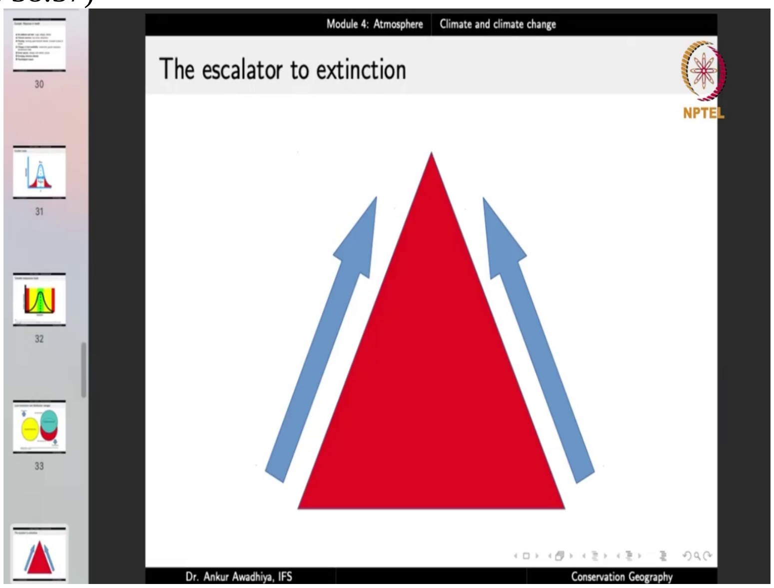

What about those species that are living on the mountains? Now, in this case, what happens is that, when the temperatures increase, the organisms start to shift to higher and higher altitudes. Because we have seen before, that there is a lapse rate and as we move to higher elevations the temperatures are lower, in the troposphere. Now, with an increase in, in the general temperature, the organisms will shift towards higher and higher locations.

But then what will happen to those individuals, or those species that are already living in the peak of the mountains? Well, they will have nowhere else to go, they will get extinct. So, the process of the escalator to extinction states that, with increasing temperature, organisms move higher and higher. Ultimately, they reach to the top and after that they become extinct. So, they rise to become extinct. This is the escalator to extinction.

And this is something that we are actually observing in a large number of species. They are changing their ranges, they are moving towards the poles or they are moving to higher altitudes. But then, this movement can only occur till a limit. After which, the organisms are getting extinct.

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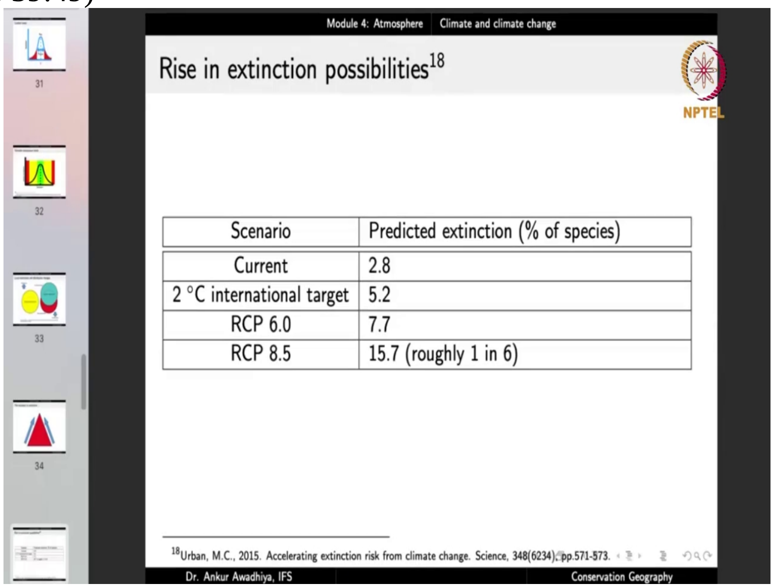

This is resulting in an increase in the extinction possibilities. So, the predicted extinction currently is 2.8 percent of species are predicted to go extinct soon. But, if we do not take hold of the climate change, if we do nothing, then roughly one in six species will become extinct.

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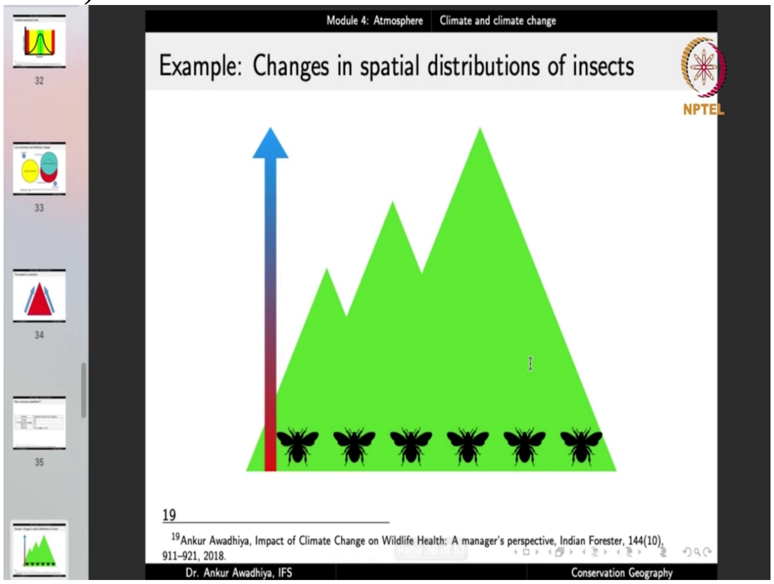

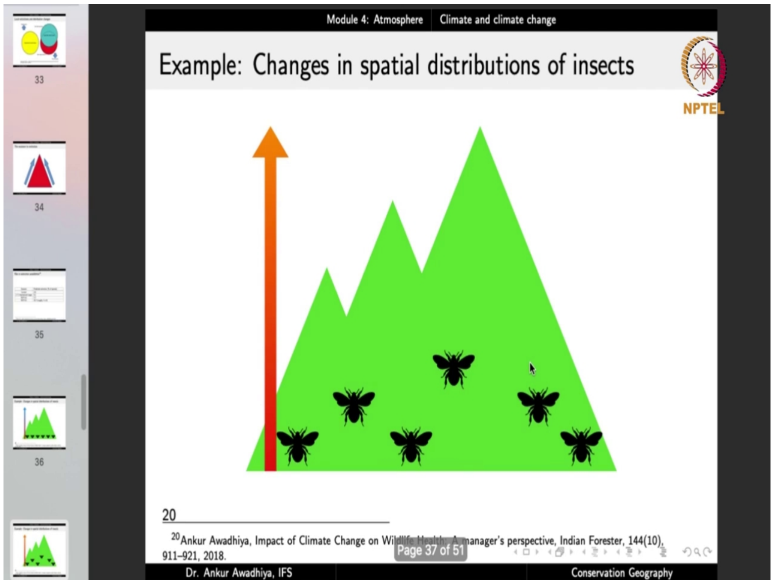

We are also observing changes in the spatial distribution of things like insects. So, now, this is very similar to what we are observing in the case of escalator to extinction. With an increase in temperature, insects are moving higher up the mountains.

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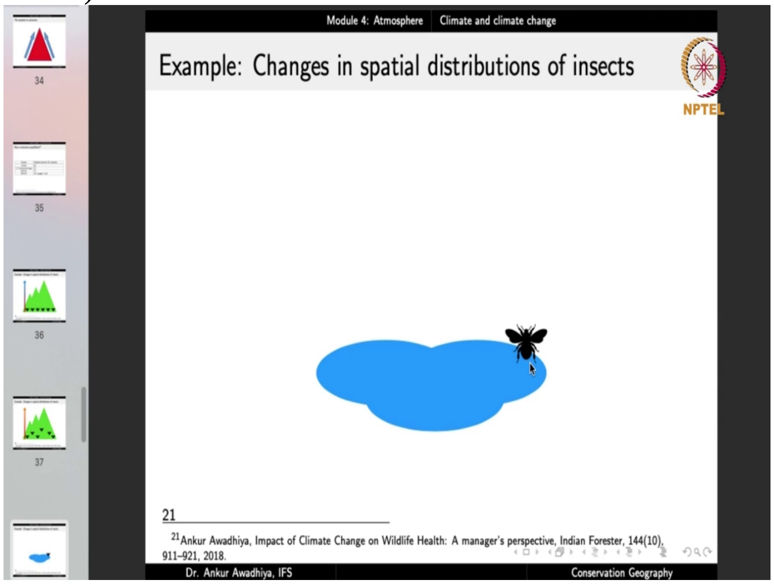

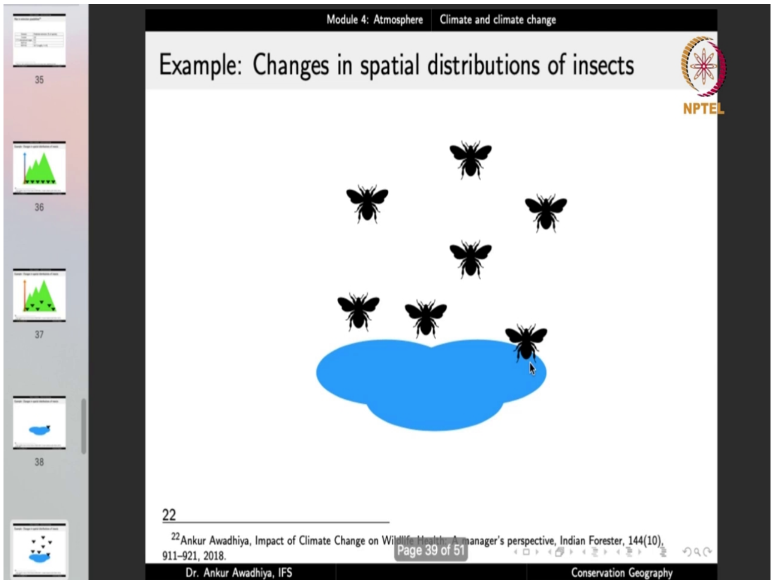

Not only that, what is happening is that with an, with a change in the climate, we are getting more amount of puddles that are getting formed, in a large number of areas where the rainfall is increasing. With puddles, the insect population is also increasing, because they are able to breed more. Now, more number of vectors, more number of insects also means more number of diseases.

Now, humans can save themselves by using things like insecticides or by using say, mosquito nets or other equipment. But what about our wildlife? When the mosquito population increases, the wildlife do not have another line of defense against them. So, when the vector populations increase diseases spread, threatening the wildlife even further.

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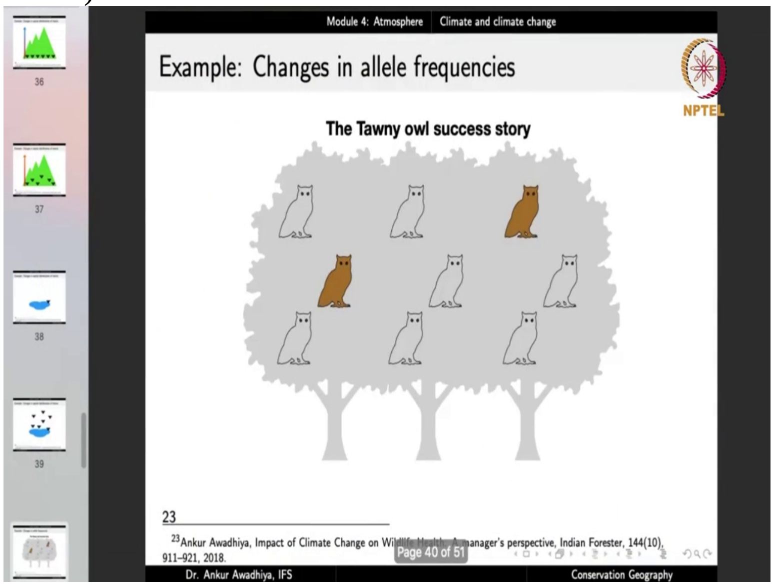

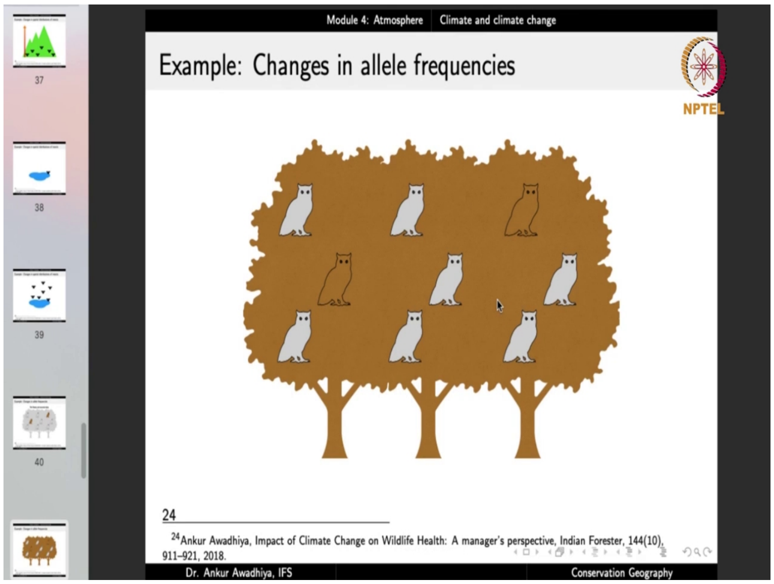

We are finding changes in the allele frequency. As in the case of this Tawny owl. Now, Tawny owl is found in areas in Europe, in certain areas of Asia. This owl is found in two colors, one is a brown colored variant and the other is a gray colored variant. Now, in the normal circumstances, when the trees get covered by with snow, the gray colored owl is very difficult to spot. Whereas the brown colored owl becomes very conspicuous.

Now, what happens is, this owl is a predatory bird. So, it hunts for animals such as rats and mice and rabbits. Now, if this owl can be easily spotted by the prey, the prey will, will become more alert, and the owl will have to go hungry. So, in the normal circumstance, the gray colored version is better able to catch the prey. Because it has a very good camouflage. It mixes well with the snow clad trees, whereas the brown version is easily spotted.

And so, in most cases, it has to go hungry and it is not as fit. But with changes in the climate, what is happening is that, now the trees do not get that much amount of snow. The winter season has reduced. Now with a reduction in the winter season, we get trees that are now no longer covered with snow for a majority of time. When that happens, once you have a dark colored tree, now these gray colored owls are very easily spotted by the prey.

And now they have to go hungry. Whereas the dark colored owls are now, better camouflaged. And what we are observing is that with time, we are finding a majority of owls that are now of a dark colored variant. So, we are observing changes in the genetic level, in the organisms. Those alleles, that make the organism more fit to the environment, they are found in majority. But with the changes in climate, these allelic frequencies themselves are changing.

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So, what can we do about this? If you do nothing, the all, then our wildlife is in a very precarious state. And with the wildlife, we ourselves in a very precarious state. Because without wildlife, we will not be getting the ecosystem services. We require wildlife, we require things like tigers.

If we did not have tigers in our forests, the herbivore populations such as the deers, they would increase so much that they would eat up all the plants all the young ones.

And after a while when the old trees die, there will be nothing to replace them. And so, the whole forest will be gone. Once the forest is gone, the soil will get eroded. And that will have tragic ecological consequences, even economic consequences. Because this eroded soil will not only reduce the fertility of the area, but it will also choke up our dams, our waterways. And so, we need the forest to maintain our soil, we need the forest to keep our rivers flowing.

We need the forests to keep our waters clean. And so, we need the forests to maintain our soil we need the forest to keep our rivers flowing, we need the forests to keep our waters clean. And to keep these forests, we require the carnivores such as Tigers to keep a check on the herbivore population. Now, if we removed all the herbivores, that again will not be a good situation. Because these herbivores are also playing a role, in the ecosystem.

A large number of these herbivores are actually seed dispersal organisms. So, if you remove all the herbivores, probably the seeds will not be disposed and that again would lead to a loss of the forest. So, if you want to maintain the forest for the human kinds benefit itself, you require all of these different species. And these species are now getting threatened because of climate change. Not only are the species getting threatened, we ourselves are getting threatened.

We are, the human population now is facing more extreme events. We are getting more number of droughts, more number of floods, forest fires are consuming our societies, we are getting more number of heat waves, people are dying out of heat stroke, agriculture is getting impacted because we are not, now not getting enough amount of water, with changes in the temperatures, a large number of our crops are failing.

So, we ourselves are also facing the consequences. So, we need to do something about climate change. So, what can be done? The ways to tackle climate change are divided into two categories. We call them mitigation and adaptation. Mitigation, is a human intervention to reduce the sources or enhance the sinks of greenhouse gases. So, what is happening is that today, the majority of the climate change is because of human activities.

Primarily, because we are burning of fossil fuels, releasing carbon dioxide into the atmosphere. And at the same time, we are removing our forests to make way for agriculture or ranching or habitations. So, on the one hand, we are increasing the sources of carbon, we are putting more and more carbon dioxide into the atmosphere. On the other hand, we are reducing the sinks of carbon. That is, those things, that could have taken this carbon dioxide out of the atmosphere.

And with more amount of carbon dioxide, we are getting the climate change, we are getting global warming. So, how can we reverse the process? Well, by reducing the sources of carbon, and by increasing the sinks of carbon. So, we just have to do the reverse of what we have been doing. Have more areas under forest, plant more number of trees, and emit less amount of carbon dioxide into the atmosphere.

Say, by using things like bitter cars, more efficient cars. Shifting to say a renewable source of energy, shifting to solar electricity in place of coal-based power plants. So, in that way, we will be spewing out less amount of carbon dioxide into the atmosphere. And we will be taking out more carbon dioxide from the atmosphere. And ultimately, the concentration of carbon dioxide will go down. And so, the global warming will be reversed.

When we take steps in this direction, to reduce the sources of carbon and to increase the sinks of carbon, then we say that we are working at mitigation of climate change. So, mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Greenhouse gases include, not just carbon dioxide, but also gases such as methane. Now, we also have another option. So, we have mitigation, the other option is adaptation.

In mitigation, we were saying that, the climate change is happening, what can we do to reduce this climate change? To reverse the climate change itself? So, if there is global warming that is happening, can we do something to reduce the temperature? In the second option, which is adaptation, we say that, the global warming is bound to happen, we cannot do anything about it, climate change is going to happen, we cannot do anything about it.

What can we do to reduce the impacts? So, for instance, if you expect that your community is living in an area that is, that is going to face a lot more heat, a lot more temperatures, a lot more heat strokes, can you do something about that? What about installing more number of air conditioners in every home? Can we do something to subsidize the air conditioners? Or can we say install more number of shades in this, in this area?

Or if there is an, if you are having agricultural fields in an area that is going to suffer from droughts, can you shift to drought resistant species. Now, when we do a thought process like this, when we do actions in this direction, we are doing adaptation. So, adaptation is defined as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects. So, it can be on the basis of actual effects or expected effects.

Actual effects means that, your city is already suffering from a shortage of water. And so, now you are bringing in water from another area into your city, this is a response to an actual effect. Response to an expected effect means that, you expect that you will face a water scarcity and so, you have already started to bring in water or take steps in that direction. So, that is a response to an expected effect.

Which moderates harm or exploits the beneficial opportunities. So, we are trying to reduce the harm or even to make use of the beneficial opportunities. So, as an industrialist, if I think that more and more number of air conditioners will be installed. So, let me make profit out of it, let me have one more unit, that makes air conditioners. So, that I can have more profits, I can exploit this opportunity which is a beneficial opportunity in my eyes. So, that is adaptation.

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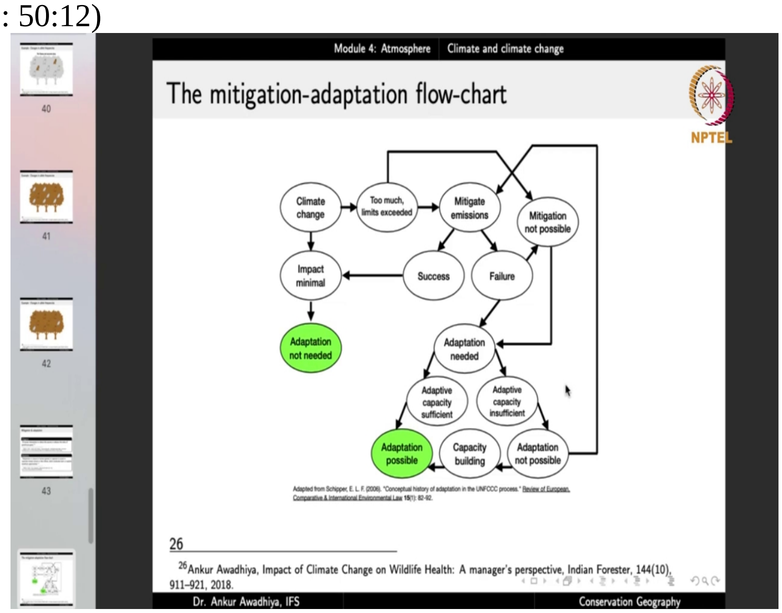

And in most of the situations, this mitigation and adaptation, they go hand in hand. So, if there is climate change, we make an assessment. If we believe that the impact is minimal, nothing needs to be done. But if the impact is too much, then we can try to mitigate the emissions. That is, we try to reduce the sources of greenhouse gases and increase the sinks. If we are successful here, then again, the impact is reduced and so no adaptation is needed.

On the other hand, it is possible that the climate change has become so large, that mitigation is not possible at all. So, we did not do anything, when we had the time, now the time is gone. In that case mitigation can no longer be done. Now, if mitigation can no longer be done, then adaptation is the only thing that can be done. Similarly, if we tried to mitigate the emissions, but we failed, in that case too, adaptation will be the only option left with us.

Now, in this case, if our adaptive capacity is sufficient and adaptation is possible, there is still some hope. Whereas if the adaptive capacity is insufficient and adaptation also is not possible, we can try to increase the capacity building, by and if we are able to increase our adaptive capacity, adaptation is possible, then too some hope is left. But if we fail in that, then there is nothing else but doom for all of us.

So, for instance, if we go on increasing the number of air conditioners that are installed, there will be a time because these air conditioners will also require electricity, and if we go on emitting fossil fuels to run them, so after a while, we will not be having any more capacity to run these air conditioners. What will happen to us then, if we do not have our equipments, we will be in the same league as the animals, the animals are themselves suffering even today. And when we also are left out of our, our adaptive capacity options, in that case, we will also reach in the same league and we will also be doomed.

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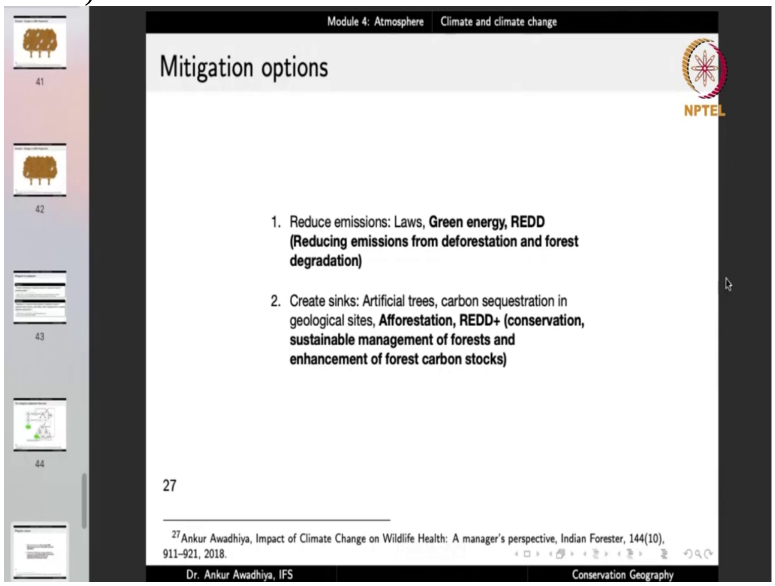

Now, mitigation options can be divided into two parts, reducing emissions and creation of sinks. Reducing emissions, includes things like laws, green energy, that is renewable energy and reducing emissions from deforestation and forest degradation. And the second option is the creation of sinks. Now, these things can be in the form of artificial trees or certain devices that do carbon sequestration.

Carbon sequestration in the geological sites, that is after carbon capture, this carbon can be stored in certain geological sites. So essentially, we are reversing the process. We, earlier we took out coal from and petroleum and natural gas from geological sites, we burned them. So, the mitigation option is to capture this carbon, convert it into a more purified form of carbon, that is concentrate the carbon and then store them in the geological sites, essentially reversing the process. Or afforestation, that is planting of trees and REDD plus. So, REDD plus includes, REDD together with conservation, sustainable management of forests and enhancement of forest carbon stocks.

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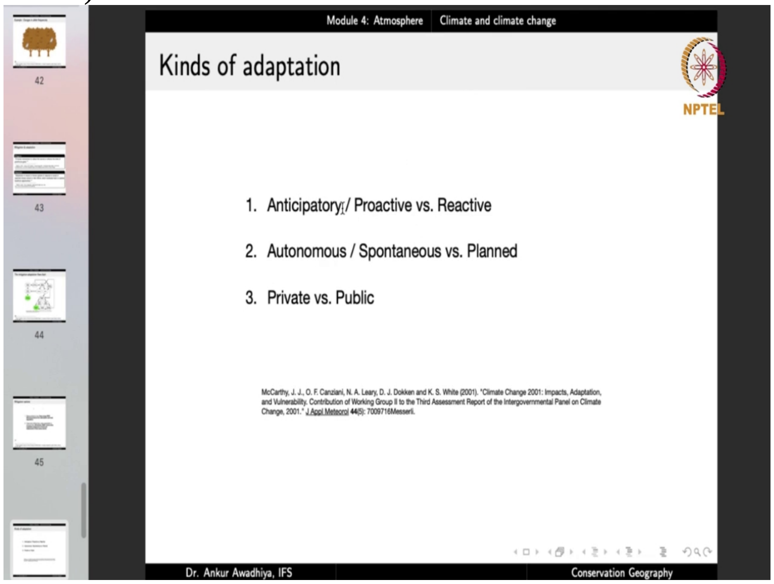

In the case of adaptation, we can have anticipatory of proactive adaptation in response to expected changes, or reactive adaptation in response to already existing changes or already visible changes. We can have autonomous or spontaneous adaptation or this adaptation can be planned through certain planning authorities. We can have private adaptation or product, or adaptation can be done at the level of the government, which is public adaptation.

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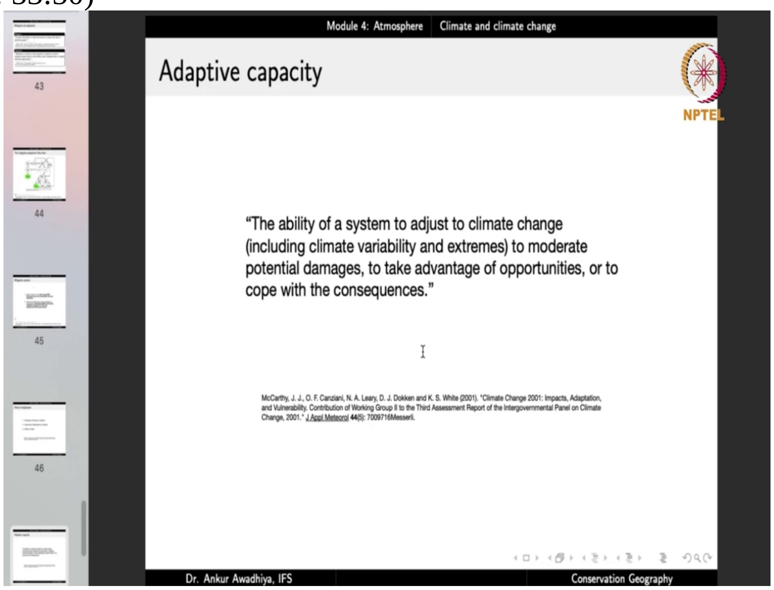

And in this context, we can talk about the adaptive capacity. Which is, the ability of a system to adjust to climate change, including climate variability and extremes. To moderate the potential damages or to take advantage of opportunities or to cope with the consequences. That is, it is the capacity of a system to adapt. And a system may not always be having the capacity to adapt, you can have a system that is so near the threshold, that there is no more adaptation that is possible.

So, for instance, today we can talk about doing mitigation and doing adaptation, because the levels of carbon dioxide still are manageable. But in a few more years, we would be at a stage where adaptation and mitigation will probably no longer be possible, which would be a situation of doom.

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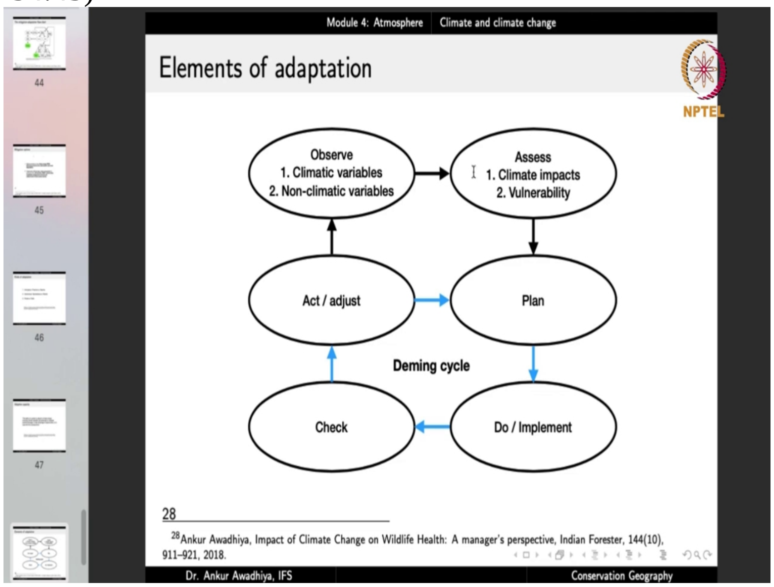

Now, elements of adaptation include observation. So, we look at climatic variables and non-climate variables, make an assessment of the levels of impact and the vulnerability of various societies. Plan and adaptation, implement the plan, check if the plan is working or not, and then adjust the plan, so that the cycle can go on and on. So, this portion is known as the Deming cycle or the PDCA cycle, plan, do, check and act, PDCA. And this portion goes on and on. And this portion is substantiated through observations and assessments, that are done time and again.

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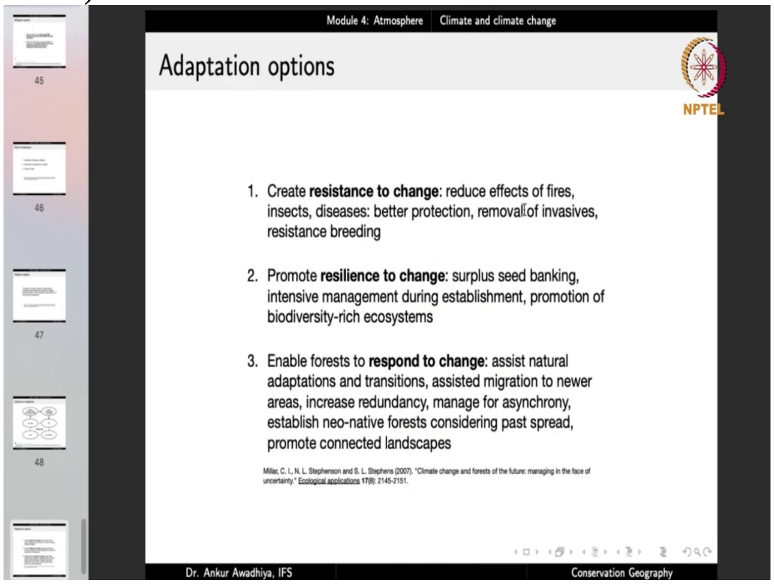

So, what are the adaptation options with us? We have three different adaptation options, one increase, creates a resistance to change. So, that the systems are able to resist the changes, such as reduce the effects of fires, insects, diseases, through better prediction, removal of invasive and resistance breeding. So, in this case, we are trying to have a system that is able to resist the change.

So, for instance, if we expect that there will be a drought, we resist, we generate those plants through breeding operations, that are able to resist the drought. The second option is promote resilience to change. Now, resilience to change, means that when the changes occur, the system collapses. But it maintains a level of resilience, so that when the situations come back to normal, the system is able to thrive back to the original state.

And how is that done? That is done by surplus seed banking. So, for instance, if we expect that a particular species is going to completely be wiped off from this planet, because of climatic changes, what we can do is, we can at least start to collect and protect the seeds. So, that later on, when we are actually able to perform mitigation of climate change, when the situations come back to normal, we will be able to make use of those seeds to bring this species back from extinct.

Or intensive management during establishment promotion of biodiversity rich ecosystems. Because, if the amount of biodiversity is more than the systems are typically more resistant to changes. Because even if certain species get extinct, there will be other species to take, take their place. So, for instance, if one pollinator becomes extinct because of climate change, there will be another pollinator to take its place.

So, that increases the resilience of the system. And enable the forest to respond to changes, not just forest, but also the communities. In the case of forests, we talk about assistance of natural adaptations and transitions, assisted migration to newer areas, increasing of redundancy, management of asynchrony, establishment of new native forest considering the past spread and promotion of connected landscapes.

So, essentially, what we are saying is, if the species are going to change their ranges, because of climate change, what we can do is we can at least help those species move to the newer areas. We can at least pick up certain individuals and bring them to the newer areas. Because the species may not be able to move that fast. So, for instance, in the case of trees, it is possible that the seeds are not able to reach into the newer ranges. So, we can collect the seeds and we can bring the seeds to the newer ranges, where the species can still thrive. So, these are the three different adaptation options, resistance, resilience, and response.

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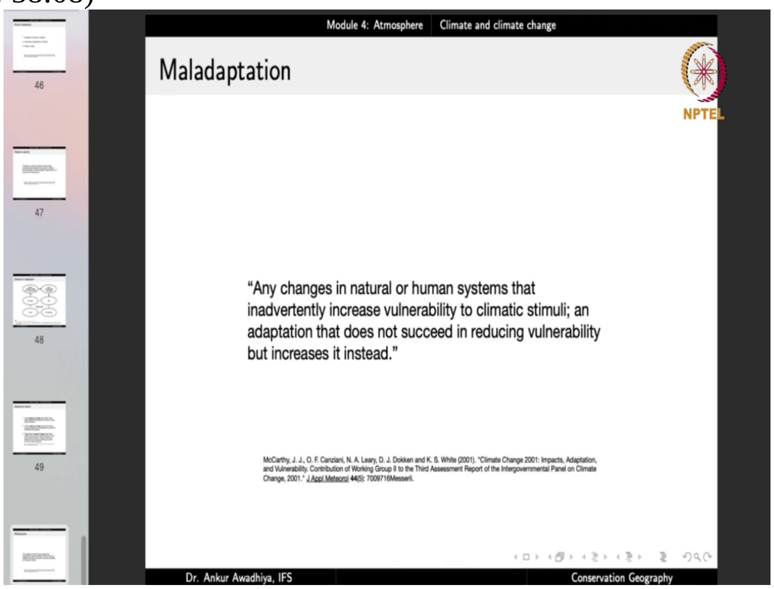

And in this context, we should always, always talk about maladaptation. Maladaptation is any changes in natural or human systems, that inadvertently increase the vulnerability to climate stimuli. So, we were trying to reduce the vulnerability. But if we do something that inadvertently increases the vulnerability, to climatic stimuli. A very good example is our example of use of air conditioners.

So, to help the community to adapt, suppose a decision is taken that we will install air conditioners everywhere. But it can also turn out that, that we get more and more electricity to run these air conditioners. We spew out so much amount of carbon dioxide into the atmosphere, that ultimately our vulnerability to climate change actually increases. Because this adaptation option is such that it makes us even more precarious in the face of climate change. So, this will be a maladaptation, or an adaptation that does not succeed in reducing vulnerability but increases it instead. So, that is all for today. Thank you for your attention. Jai Hind!