Conservation Economics
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Module 3
Modern impacts necessitating conservation
Lecture 1
Climate change

Namaste!

Today we begin a new module which is Modern Impacts Necessitating Conservation. In this module we will have a look at certain impacts of human activities because of which conservation has become more important these days. And we will focus our attention on three such impacts climate change, plastics and oil spills and mining.

Let us begin with Climate Change. What is Climate? 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. Climate is a broad composite - which means that, we are not looking at climate in terms of final quantities, we are looking at it as a broad composite of the average conditions of a region - which means that climate is different from weather. Weather changes every day with the changes in a few hours, but climate - because it is a broad composite, it is an average that is taken over several years.

Climate is more or less a constant quantity. It is a broad composite of average conditions of a region measured in terms of such things as temperature amount of rainfall or a snow fall, snow and ice cover and winds. These are different variables through which we describe the climate of a place. When we talk about the average conditions, the classical period for taking these averages is 30 years. It is a pretty long period of time in which we take the averages because of which the climate is fairly representative of the conditions of any region. Even though the conditions might change on an hourly basis or on a daily basis, but on an average the climate will be a very good representation.

How does climate act? There are five components of the climate system. We have the ocean or the hydrosphere, we have land or the lithosphere, we have the winds or the atmosphere, we have the biotic components or the biosphere and we have the ice or the snow cover which is the cryosphere. So, there are these five different components from the climatic system and all five of these interact with each other continuously. For instance if there is a change in the wind condition, then there might also be certain changes in the biotic composition of the area or when

the winds blow over the mountains, then there are changes such as reduction in the debris or snow fall of the area. So, these five components continuously interact with each other.

If climate is an average condition, why do we talk about climate change? When we talk about climate change because even these averages are changing.

How do we define climate change? Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability which is persisting for an extended period of time which is typically decades or even longer. Climate change may be due to natural internal processes or because of external forcings or due to persistent anthropogenic changes in the composition of the atmosphere or in land use.

How can the climate change? The climate change may be due to natural internal processes or because of external forces. What does that mean? Remember that when we said that when we were talking about climate there are these five different components of climate and there are some natural processes that are changing these components. For instance, there might be changes in the tectonic layers of the Earth. The Earth is divided into a number of plates and these plates are in constant movement. When the land surface changes because of the natural processes, then that might change the climate. So, the climate change may occur because of the natural internal processes.

Or it may occur because of external forcings. Now what are external forcings? You have the climate system and there is something that is acting from outside which is resulting in a response to this climate change. We will explore what are these somethings - what are these forcings?

It can be due to natural internal processes or external forcings or also due to persistent anthropogenic changes. Anthropogenic changes means man made changes in the composition of atmosphere or in the land use. Humans are changing the composition of the atmosphere, humans are changing the land use and because of this also we will we can have changes in the climate. So, the next question is, what are these forcings and what are the kinds of responses that we can have?

These are some common forcings: Changes in the plate tectonics. These are changes in the land and sea distribution of the earth because of movements of different plates or changes in the Earth's orbit. Even the orbit of the Earth changes - and these changes occur over thousands of years. Because of changes in the Earth's orbit, if the Earth comes closer to the Sun then the Earth will warm up, if the Earth moves away from the Sun then the Earth will cool down. Or changes in the strength of the Sun. The Sun gives out energy which is regulating the climate on the planet - and this energy is not fixed - it changes. Now, if it so happens that the Sun starts to give out more energy, more amount of heat to the Earth then that would result in a change in the climate - the Earth will warm up, and there will be changes in the wind patterns. If the Sun starts to give

out less amount of energy the Earth will cool down - that will also bring out changes in the wind patterns, changes in the biosphere, changes in the hydrosphere.

So these are also forcings. But the most important forcing these days is the anthropogenic forcing. Anthropos means human and genesis is formation or production. So, anthropogenic forcing is a forcing that has been produced by human beings. What can they be?

The most important anthropogenic forcings or modes of anthropogenic forcings include things such as the release of greenhouse gases such as carbon dioxide. Now greenhouse gases are those gases in the atmosphere that act as a green house by trapping the heat of the Sun in the atmosphere. While they permit the short wavelength radiations of the Sun to enter through the atmosphere and reach to the land surface, once the land surface is heated and it re-radiates the radiation in the form of longer wavelength radiations, then these gases trap them - they do not permit them to move outside to the outer space.

These greenhouse gases such as carbon dioxide or methane are being produced at a at a much larger level by humans and that is an important anthropogenic forcing. Now how do humans produce a heavy amount of carbon dioxide? By burning fossil fuels such as petroleum, natural gas or coal. How do humans aid in the release of methane? By having more and more number of livestock. Not only do humans release these gases, but they also are acting upon in reducing those modes that would have reduced these gases in the atmosphere.

Plants for instance capture this carbon dioxide and convert them into biomass. And when they do that in the process of photosynthesis, they reduce the concentration of carbon dioxide from the atmosphere. But in our quest for having more food, in our quest for having more land for construction, what we are doing is that we are cutting off the trees. When the trees are cut then less and less amount of carbon dioxide is brought back from the atmosphere into the lithosphere. Also things such as burning of the trees - forest fires - a majority of them are anthropogenic - they are manmade. And why would man want to burn forests? For they want to clear off the land.

If somebody wants to encroach upon a forest land and convert it into an agricultural field, it is very easy to burn the forest. And once the land is cleared then the land can be brought up for cultivation. Or the production of things such as concrete. Concrete production releases a huge amount of carbon dioxide when the calcium carbonate is heated. These are all different modes through which humans are ah aiding in changing of climate by providing a forcing.

Now, when there is a forcing on the climate system, it results in a response. And what are those responses? Responses could be changes in the atmosphere, changes in the wind pattern or changes in the ocean, etc. Now this may result in changes in say the flow of the ocean currents or changes in vegetation or changes in land surface or changes in ice. If the Earth heats up then

more and more of ice will melt and the water will get into the ocean. You will have a larger volume of water that is there in the ocean and even this water - when it gets heated up - it will expand. This is a response that we will see because of the forcing of increasing the temperature.

And these responses manifest in the form of heat waves, they manifest in the form of changes in the ice pattern, they manifest in the form of droughts or floods or increased temperatures in a number of areas or in the form of forest fires. So, these are several responses that we are observing because of changes in the climate and these also result in biological responses.

So, the climate change results in changes in the temperature. There is a change in the mean temperature, there is a change in the extreme temperature, there is a change in the amount of variability that we see in temperature, there is a change in the seasonality of temperature, there are changes in rainfall, there are changes in extreme events. We find more and more number of floods, more droughts, more storms, more fires - not only in a greater duration, but also in a greater intensity, or changes in carbon dioxide concentration in the atmosphere or in the oceans.

In the oceans when carbon dioxide gets dissolved it also results in changes in the pH - the water becomes more acidic.

There are changes in the ocean dynamics because of changes in the sea level. Why do we have a a change in the sea level? Because more and more amount of ice is getting melted and this ice is adding to the water in the seas. And when the water is being heated up because of global warming it expands and so, we are seeing changes in the sea level. We are seeing changes in the marine currents.

So, all of these climate change components result in changes in the biological system - at the organismic level, population level, species level, community level, ecosystem level and even at the biome level. For instance we will start seeing changes in the natural selection and we will look at changes in natural selection and allelic diversity in a short while.

There are changes in mutation rates in different organisms because the mechanisms that are there to correct for mutations - they are hindered because of an increased temperature and because the animal is not that fit. There is change in the heterozygosis richness, there are changes in physiology, changes in fecundity. So, organisms will be having less or more number of offsprings. Organisms are changing their activity rates and rhythms - those organisms that earlier used to move in the known period - they are now avoiding the known period because its too hot.

There are changes in the species sex ratios, changes in disease susceptibility - especially because of a changed climate, now the organism is not that fit and when the immune system is down - when the organism is not that fit - it can very easily fall prey to diseases which is resulting in changes in the survival of organisms. We are also seeing changes in the phenology. Now

phenology refers to the timing of different processes. So, we are seeing changes in the arrival and departure times of different migrating species because the summers are coming earlier, they are lasting longer - the winters are coming late, and they end faster. There are changes in migration patterns. Because of changes in temperature we are seeing changes in budding and flowering of different organisms - different plants. If there are changes in the budding or flowering period, there are changes in migration, then it is also possible that there will be certain species that will not be getting sufficient food. Because in a number of cases the migration patterns are correlated with the presence of food in the other location.

Now if there is a species of bird for instance that is dependent on these flowers and if the birds have reached into the area, but the flowers have not bloomed - in that case the birds will not have sufficient food. So, changes in phenology are also leading to a large amount of extinctions.

There are changes in the growing season length. Those plants that grow in the summer season - they are now getting more time to grow; those plants that use the winter season - they now have a shorter growing period. There are changes in dispersals of hatchlings and fledglings; there are changes in hibernation. Now because of these we are also seeing changes in the population dynamics, the number of individuals that are recruited which means the number of offsprings that have been born and that are able to survive. Because of that if less number of individuals are getting recruited, less number of young ones are getting recruited - that changes the age structure, because now the population will be older population because you have less number of young ones. There are changes in sex ratio - especially in the case of reptiles because in a number of reptiles such as crocodiles - or in the case of tortoises, the sex selection is temperature dependent. So, if the temperature changes you will have a changed ratio of the number of males and females that are born.

We are seeing changes in abundance, we are seeing changes in distribution. Why changes in distribution? Because the habitat is changing. And why is the habitat changing? Because of changes in the growing season, changes in budding and flowering time, changes in hibernation. That is changing different habitats.

We are seeing changes in the range size, range localization, and we are seeing changes in the interspecific relationships. There is an uncoupling of a number of relationships such as those between the flowers and the insects. So, in the case of a number of flowers the pollination is done by, say, insects. Now if the flowers are blooming at a period when the insects have not yet arrived on the scene - because probably the insects have not come out of their eggs - in such a scenario there will be a decoupling because earlier the insects were getting food from the flowers and the flowers were getting pollinated by the insects. Now because there is a change in the timing the insects will not get sufficient food, the flowers will not be pollinated and so, this will result in a decimation of both of these species.

We are seeing new interactions that are coming - because whenever you have a change in timing then those species that are already present - there they will start to form a new relationship. Now that may have a positive consequence, but that can also have a negative consequence. So, for instance the invasive species are able to come up into newer areas much more easily because they are forming newer relationships and these invasive species are then decimating the local indigenous flora and fauna and they are establishing themselves - the local biodiversity is gone and it gets replaced by the invasive species. This is another change that we are observing.

There are changes in the community productivity - the amount of biomass that is being produced. We are seeing changes in the ecosystem services because the ecosystem composition is changing, the production is changing, the function is changing. And we are seeing changes in biodiversity.

Because we are seeing catastrophes at a much greater frequency, at a much greater intensity, there are changes in the resilience of different communities - there are changes in the eco types, we are seeing shifts in the distribution patterns, we are seeing more and more amount of desertification. So, there are a number of biological responses that we are also observing because of climate change.

And we have a pretty solid evidence that these anomalies are occurring because of changes in the climate or changes in the temperature. In the case of a number of species we have observed that the more is the temperature anomaly, the more is the phenological anomaly. And this is also manifesting in terms of say the amount of phytoplanktons that are there in water. With increased temperature the amount of phytoplankton in water is going down which will have an impact on the amount of productivity, that is there in this aquatic ecosystem.

We are seeing that the total biomass is going down as temperature increases. Certain species of zooplanktons - they increase in number or increase in concentration when the temperatures go up. Certain microorganisms increase in number. Now some of these microorganisms may even be pathogenic. So, we will start observing more and more number of diseases.

We are observing bleaching of corals. Corals are very important species in a number of ecosystems because they provide shelter to a number of other species. They are the keystone species - their importance is much greater than the numerical abundance. Now because of changing climate, because of acidification of water, because of increased temperatures and because of certain pathogens the corals are dying out. And this dying of corals is manifested in the form of lack of color. So, we are observing more and more amounts of coral bleaching.

We are observing that the ice cover near the poles is going down which is putting species like the polar bear in a much perilous state. Species of mangroves are dying out, species of kelps are dying out. All of these - the corals, the kelps, the mangroves and the ice - they are habitats that

provide a living space to a number of organisms and when we are seeing these habitat level destructions, it means that a number of species are now under threat because of climate change.

We are seeing an increase in the invasion - and rise - of exotic species. In this curve you can see that over the years the number of frost days has gone down which means that the temperatures are rising up, at the same time the number of exotic species is going up. So, there could be a correlation between both of these.

We are observing rigorous responses in plants in the forest - we are seeing changes in the stand volume, changes in the annual increment that the forest is putting down, changes in the gross primary productivity, changes in carbon sequestration that has been done by the forest, and we are also seeing changes in a number of animals in terms of their health. Things such as climate change result in extremes of temperature which increases the chance of an animal getting the heat stroke. Climate change is leading to weather disasters. An increased frequency and an increased intensity of extreme weather events such as floods and fires increases the chances of animals drowning or animals suffering from dehydration or from gastrointestinal illnesses. Because in the case of a flood-like situation, the animals are forced to have dirty water which is resulting in a lot of trouble to animals. Climate change is also leading to ecological changes because of changes in the phenology, because of decoupling of pollination relationships between plants and animals - which is leading to changes in food availability.

If an animal gets less amount of food it will suffer from malnutrition - we will have cases of growth retardation, developmental delays. Similarly, because of changes in the phenology and because of changes in the range of different plants, we are seeing changes in allergen and mycotoxin exposure that the animals are suffering from. We are seeing more cases of allergies, cancers and birth defects - these ecological changes also increase the chances of exposure to infectious diseases - and a number of infectious diseases are also emerging anew.

We are also observing other changes. Every organism has a particular level of temperature that it can tolerate. There is a best temperature that the animal prefers - there is a tolerable temperature and if we go beyond the tolerable temperatures, the animals suffer from discomfort and may even perish.

Now, because of changing temperatures what is happening is that, we are observing a large number of local extinctions. If the temperature increases beyond the tolerable limit, then we will start seeing animals that are dying. So, there are local extinctions in the warm edge. And these extinctions have been predicted to increase with more and more amount of global warming. We are also observing changes in the spatial distribution of organisms - because suppose this is the equator and this is the north direction. As temperatures go up, more and more of these colder areas are now becoming warmer. These organisms that were living here, they will be able to occupy these areas that were so far not being occupied because they were beyond the tolerable

limits of these organisms. So, on the one hand the organisms will be dying in the warm end, on the other hand there will be an expansion in the cold edge. So, we are seeing changes in the spatial distributions, changes in the ranges of different organisms. A good example is the spread of insects in the mountains as the temperatures are going up.

As we move up the temperature goes down. There are a number of species of insects that are only able to tolerate the warmer conditions; they cannot tolerate the colder conditions. Because of that a number of species of insects are only localized in the lower height of the boundaries. Now as the temperatures are rising what is happening is that these cooler areas are also now becoming warmer. As temperatures rise, these insects - which were earlier only in the lower altitudes - they are now able to reach into the higher altitudes. So, we are observing changes in the spatial distribution of insects.

Also with increased amounts of climatic extremes, increased amounts of rains in certain areas, increased amount of flooding, we are also observing that insects are making use of these pools of water to increase their numbers - because they lay eggs in these waters. We are seeing changes in the vectorial capacity of mosquitoes or the ability of mosquitoes to transfer diseases - and we are seeing changes in the allele frequencies at the genetic level. A very good example here is the story of the Tawny owl.

The Tawny owl is a species of bird - its an owl that is found in Europe. This bird is available in two colors - there is a lighter version which is grayish in color and there is a darker version which is brownish in color. In the areas where this bird lives the trees are generally covered with snow. When the trees are covered with snow - and snow is white in color, so the gray colored birds are able to hide in the snow. If there is say a rat here that one of these birds wants to catch and eat. In that case if it is a brown colored bird, then it will be very easily seen by the rat and this rat may try to hide whereas, if it is a gray colored bird then it camouflages so well that the prey is unable to observe this bird and it increases the the chance of the bird getting a prey.

Because of this reason a majority of the birds are gray in color. Now the color of the bird is determined by the genes that the bird has - the allele frequencies that are there in the bird population. A majority of the birds are light in color and there are very few birds that are dark in color. Now, because of global warming what has happened is that, the snow is melting. So now, if we look at these birds that were gray in color now they are very easily seen in the backdrop of these trees and so, the advantage that they had in terms of color is now gone. Now if it is a light colored bird then the prey will very easily spot the bird, if it is a dark colored bird then it will be difficult for the prey to spot the bird. And so, how has nature responded? Or how has this species responded? Because these light colored birds are now less able to get to the food so, they have lost their fitness or they have greatly reduced their fitness whereas, the fitness of these birds has gone up and slowly we are seeing that more and more number of these birds are now in darker shades - there are changes in the allele frequencies. So, we are seeing changes at the genetic level

because of climate change. So, this is another thing that we are observing.

When we have such a huge amount of climate change what can we do about it? The kinds of responses that we can put up for conservation and to tackle climate change are divided into two categories: we can have mitigation or we can have adaptation.

Mitigation is defined as a human intervention to reduce the sources or enhance the sinks of greenhouse gases. The other way out is adaptation. Adaptation in a natural organic system is response to actual or expected climate stimuli or their effects which moderates harms or exploits the beneficial opportunities. It is an adjustment in the system - you are trying to adjust your lifestyle, you are trying to adjust your profession, you are trying to adjust the industry you are working in or you are trying to make adjustments in the ecosystems. So, it can be an adjustment in either the natural systems or in the human systems. And why are you doing these adjustments? In response to actual or expected climate stimuli or their effects.

You are making these adjustments so that you can respond to the climate change that is either actually happening or which is predicted. Adaptation is in response to actual climatic stimuli or expected climatic stimuli or their effects. The aim of adaptation is to moderate the harm. So, you are trying to reduce the harm or you are trying to exploit the beneficial opportunities that climate change may offer.

So, for instance, if you are living in an area that is extremely cold and you think that because of climate change - because of some amount of warming, now the climate will become a bit more pleasant in your area. That might result in the development of a new opportunity - probably tourists will now start coming to your area. And if you are making changes - if you are say developing infrastructure or if you are doing advertisement so that you can attract these tourists to make use of the beneficial opportunities - then you are doing adaptation.

So, the two responses to climate change that you normally make are either mitigation or adaptation. In the case of mitigation what happens is that, we ask what can we do to avoid climate change or to reduce the climate change. If the earth was going to raise its temperature by say 1.5 degrees can we bring it down to 1 degree, then we bring it down to 0.5 degrees? If we are doing that by either reducing the amount of greenhouse gases that will be emitted into the atmosphere or by trying to bring down the gases that have already been emitted, then we are doing mitigation. The other response is adaptation where you say that ok climate change is going to happen, and I cannot do anything about it, but is there anything that I can do to reduce my harm or to make use of the beneficial opportunities? If you have such a response then what you are doing is adaptation.

Often both of these strategies are needed together and they are used together. So, how do you decide? What needs to be done? So, there is climate change - if you foresee that the impact is

minimum or if you find that the impact is minimal then probably you do not need need to do anything in that area.

But if the climate change is too much and you find or you predict that the limits are going to be exceeded then you have two options - you can either figure out if there is a way to mitigate the emissions or you can figure out that there is no way that mitigation is possible. If there is an option of mitigation that is available and you deploy it, then you may have a success or you may have a failure. If you are expecting that climate change will exceed the limits, will bring you too much of a harm, you try to mitigate the emissions and you get a success because of which the impact is now minimal. When that happens you do not need to do any other thing - you can sit back and relax, but if you get a failure - so you tried to mitigate the emissions, you tried to bring the levels of greenhouse gases down, but they resulted in a failure - you could not do anything - then you will decide that mitigation is now not possible which means that the only option that you have now is adaptation.

In the case of adaptation, we can adapt to a particular capacity. There is always an adaptive capacity of any system whether we talk about a natural system or whether we talk about manmade system, whether we talk about an industry or whether we talk about a profession, we can only adapt to a particular extent - adaptation is not infinite.

So, when you cannot mitigate the only option that is left is adaptation. Now, if you have an adaptive capacity that is sufficient to adapt - which means that suppose there is a society that has ample amount of resources and say can come up with an air conditioner in every home. Now air conditioner in this case will be an adaptation because it is not doing anything to reduce global warming, but it is helping people to live in this area which has heated up too much. So there could be certain societies that can do adaptation - there will be certain other societies that are probably the poor societies and they will not be able to bring about adaptation. If the adaptive capacity is sufficient then adaptation is possible. If the adaptive capacity is not sufficient then adaptation is not possible.

If the adaptation is not possible here again you have two options, you can either build up the capacity - so you build your adaptive capacity, you find out ways in which you can have more sources of energy, you can have more number of air conditioners, you try to increase your capacity of adaptation as a society and if you are able to do that then adaptation becomes possible.

So we reached to this point where mitigation was not possible. So, the first step is that if we can mitigate we will try to mitigate, but if we are not able to mitigate - if mitigation is not possible, then we will try to adapt, but then it is also possible that the adaptation is not possible - and it is not possible to build the capacity. Now that becomes an issue because you are neither able to mitigate , nor are you able to adapt.

In that case the only options are either to perish as a society or to look for some other ways of mitigation. So, what we find from this flowchart is that at all points of time we as a society need to think. If we can mitigate the emissions, we should try to act in that line; if mitigation is not possible or if we as a society fail to mitigate climate change then we could adapt, but it is also possible that if adaptation is not possible because we have a limited adaptive capacity as a society, then it is also possible that we will perish. So, these are the options that are there. Mitigation and adaptation both need to be tried. The first option is of course, mitigation. You try to ameliorate the climate change, but if that is not possible then as a society adaptation might be our only option.

So, what are the mitigation options that we have in the society? To reduce emissions we can come up with laws. For instance, the government might say that any vehicle that has a fuel efficiency less than a prescribed limit will no longer be permitted to be manufactured. In this case we are using a law to mitigate climate change by not allowing the production of those vehicles that are fuel inefficient or we may come up with a law that says that any person who is using electricity above a a certain threshold will have to pay a a a penal rent. Here again we are talking about a law to incentivize people to cut down on their electricity consumption.

You will remember that incentives are what induce people to act in a certain way and law is a very powerful tool to induce activities that need to be promoted or to dis-induce those activities that need to be suppressed. So, the government may use laws to promote those mechanisms that reduce the emissions or the government may make use of laws to penalize those mechanisms that are leading to a large amount of emissions other options with us are use of green energy. Green energy - such as solar cells - they take off our dependence on the fossil fuels. If in place of using a thermal based power plant we have shifted to say solar power plants - in that case the emissions because of the burning of coal they will be gone.

So, we will be acting in a way to reduce the emission or REDD. REDD stands for Reducing Emissions from Deforestation and Forest Degradation which means that whenever there is deforestation that is a forest is getting cut and is getting destroyed or there is a degradation of forest which means that we are shifting from a dense forest to a moderately dense forest to an open forest probably to a no forest or a scrub forest. Now, when such a thing happens we say that there is a forest degradation. Now whenever there is deforestation or forest degradation there is emission of greenhouse gases because the carbon that was stored in the plant biomass that has now been released because when people cut these trees they will either burn them or they will convert them into furniture which will slowly and steadily again emit out the carbon.

Now when we have deforestation or forest degradation all of this carbon is getting released out. There is also another chunk of carbon which is there in the soil. So, the soil carbon gets released when you remove the tree cover and the carbon that is released is of a very significant quantity.

So, whenever there is deforestation or forest degradation there is an addition of greenhouse gases. If you prohibit or if you can prevent deforestation and forest degradation then you are reducing the amount of emissions that would have happened if there was a deforestation or forest degradation. So, REDD is another mitigation option - you are trying to reduce emissions from deforestation and forest degradation.

Other option that we have is to create sinks which are the mechanisms that are going to take greenhouse gases away from the atmosphere - things such as having more amount of afforestation. Planting more trees or going for artificial trees - artificial tree is nothing but a device that can mimic photosynthesis and try to capture carbon from the atmosphere. Now it is still in an experimental phase, but yes if the technology gets developed that can also be used as a mechanism. To create a space for carbon - we can try to do carbon sequestration in geological sites. Now, what is that? You make use of machines to capture the carbon from the atmosphere; we compress this carbon dioxide - probably react it with certain chemicals so that it gets fixed and then we store it in a geological site - probably you make use of an old mine and you put these chemicals or these this carbon dioxide in that area and we shut it off, so that the carbon dioxide that was there in the atmosphere is now no longer in the atmosphere - it has been kept closed in a geological facility. So, this is another way of creating a sink - carbon sequestration in a geological site. Or we can look at REDD plus. So, here REDD is reducing emissions from deforestation and forest degradation. When we say REDD plus what we do is we do conservation, sustainable management of forest, and enhancement of forest carbon stocks.

In the case of REDD plus what we are saying is that we are going to conserve the forest that we already have and at the same time we are going to perform a sustainable management of forest. In a sustainable management of forest the wood is removed from the forest, but it is removed in such a fashion that you always have trees that are absorbing carbon from the atmosphere. What it means is that if you have a forest and the forest only has those trees that have become very old - so they are no longer putting up any further growth in them. In that case they are not collecting or fixing the carbon dioxide that is there in the atmosphere - because if they were fixing the carbon dioxide then there would have been certain growth in their bodies, but they are so old that they are no longer putting up any increment.

So, in the case of REDD plus what we do is that we do a sustainable management of forest in which case we remove those trees - that is we cut down those trees - that are very old and plant a new tree in its place or plant several new trees in its place and the wood that has been removed from this old tree is processed in such a manner that the carbon will not be released back into the atmosphere for a very long period of time. So you process it and you use it to make certain goods that are long lasting that is you are not going to use this wood say for fuel wood or for the manufacturing of paper that has a short life, but you will probably use it to make certain furnitures that will last for several decades and in the place of this tree that was removed you plant several new trees so that you always have a young generation that is fixing the carbon

dioxide that is there in the atmosphere.

That is the sustainable management of forest. Through sustainable management of forest we are converting an old forest that was no longer putting up an increment, that was no longer doing carbon sequestration and perhaps was even emitting carbon - because the old trees were dying naturally and they were being acted upon by other organisms that were eating up those wood and were releasing the carbon back into the atmosphere. Here we are avoiding that and we are converting it into a sustainably managed forest where wood is extracted for a long term use and the old trees are replaced by younger crop that can do the carbon sequestration. So, that is sustainable management of forest.

Or we can look at opportunities where we can enhance the forest carbon stocks which means that if you already have a forest is there a way to increase the density of plants, so that you can have more amount of carbon that gets sequestered? Is there a possibility that apart from having trees you can also have certain undergrowth or say certain climbers - climbers and undergrowths are also plants - they will also been be fixing carbon dioxide that is there in the atmosphere and and storing them as biomass. So, is there a way in which we can enhance the amount of carbon that is there in the forest? Can we do something about the amount of carbon that is stored in the soils - it gets increased? When we look at these opportunities - conservation, sustainable management and enhancement of forest carbon stocks - we are talking about creation of sinks through REDD plus. So, this is also another mitigation option that we have.

In the case of adaptation, these are the elements of adaptation: You begin by observing the climatic variables such as temperature or the amount of rainfall that you have in your area - you look start to look at non climatic variables such as if there is an invasive alien species of plant or animal that is coming into your area and through these observations you make an assessment. What will be the impact of climate in your area? How vulnerable is your country or your society or your community to the impacts of these climate changes? And once you make this assessment that yes the community is vulnerable you make a plan. You could make a plan such that you are trying to remove the invasive alien species of plants that are coming into your area and will have an impact on agriculture. So, you say that we are going to cut out all of these plants that are coming into our area then we implement the plan, you actually take help of people and you actually cut the plants and then you do a checking - did you achieve the objectives? Were you able to control these plants?

Now it is possible that you were able to control the invasive alien species or it is also possible that the roots that got left behind - they sprang up new shoots in the rainy season. In that case you will have to make certain adjustment, which means that we are going to uproot the roots - you are going to uproot the plant completely and for that you make the new plan and you do the cycle again and again. This is the Deming cycle: plan do check act, and in between you make use of observations; you make a continuous assessment.

Now adaptation is of three different kinds. It can be anticipatory that is proactive or it can be reactive. Anticipatory adaptation is an adaptation that is done before the negative consequences are being felt by your community. A reactive adaptation is done once the negative impacts are already being seen. For instance, if you anticipate that you are going to have droughts in your area and you start to come up with new irrigation mechanisms - you are doing an anticipatory adaptation. On the other hand, once you are already seeing a drought and you install more pumps you are doing the reactive adaptation.

Adaptations can be spontaneous or they can be planned. A spontaneous adaptation is say increasing the speed of your fan because you are feeling warmer. A planned adaptation could be a plan - to say remove the invasive alien species or to set up new hospitals because you are seeing a rise in the number of diseases.

Or the adaptation can be private or public that is done at the individual or community level or at the government level.

And in adaptation we generally do three things: we try to create a resistance to change. So, if we expect that there will be more number of forest fires, we try to reduce the effect of fires. In the case of insects and diseases you try to have a better protection against them - you remove the invasives, you do a resistance breeding so that the plants or animals in your area are more capable of tolerating the drought or flood situations or increase temperatures. So, that is creating a resistance to change.

Another option is promoting a resilience to change. The resilience means that if there is a climate change and there is a negative influence if later on you are able to bring back the effects of the climate change you should have a capacity to bring your system back to normal - things such as surplus seed banking. So, in this case what we are doing is that we are creating a seed bank so that we have the seeds ready whenever the temperatures come back to normal - whenever the climate comes back to normal, we can make use of these seeds and recreate the whole ecosystem. Or intensive management during establishment - here establishment means establishment of trees or promotion of biodiversity rich ecosystems because biodiversity rich ecosystems are more capable to come back to normal whenever the situations are brought back or the third adaptation option is to enable a response to change. Now, how do you enable response to change? You assist natural adaptations and transitions - assisted migration to newer areas. So, what we are saying here is that because of changing climate we expected that this that we will have a range expansion in this area and we will have an extinction in this area. So, in the case of assisted migration what you do is that, it is possible that the dispersion in this area will be very slow - so you actually take a few individuals and you bring them to this area. So, that is an assisted migration in which case you are trying to enable the forest or the ecosystem to respond to change. We try to increase redundancy; you manage for asynchrony. So, when you are

expecting that your flowers will not be pollinated because there is a change in the timing of flowers and the insects. Can you manage for that? And you bring in say an insect species from some other area that will be able to pollinate your plants in this particular point of time or you can try to look at the past spread of different forest. And you can try to establish them now. Or you can try to promote connected landscapes so that the animals are able to move to the other areas. In this case we are enabling the forest or the ecosystem to respond to changes. So, these are the the three main adaptation options: you create a resistance to change, you promote resilience to change and you enable the forest to respond to changes.

Now whenever we are doing adaptation it is important to note that there is an adaptive capacity: the ability of a system to adjust to climate change including variability and extremes to moderate potential damages, to take advantage of opportunities or to talk to the consequences. There is a capacity whether we talk about the forest, whether we talk about the nation, whether we talk about the community - there is a capacity to adapt. If you try to do an adaptation that is greater than the capacity, then probably you will bring harm to the system and in that case we will say that we have gone through a maladaptation - any change in the natural or human systems that inadvertently increases the vulnerability to climatic stimuli, an adaptation that does not succeed in reducing vulnerability, but increases it instead.

So, for instance, a good example is that you tried to do an adaptation by installing an air conditioner into every home in your country and in running of those air conditioners you you release so, much amount of carbon dioxide - because of burning coal or say natural gas - that the climate change increased even further and because of which there is a catastrophic collapse of the community - everybody perishes out then we will say that this is a maladaptation. So maladaptation is any changes in natural or human systems that inadvertently increase the vulnerability to climatic stimuli or an adaptation that does not succeed in reducing the vulnerability, but increases the vulnerability - that is maladaptation.

Now, as before we can relate climate change and the responses to the ten principles of economics. People and society face tradeoffs. Here the tradeoff is whether you want to have more and more resources now or whether you want to survive in the future, whether you want to have more and more electricity now by burning fossil fuels or do you want to forgo the impacts of climate change. So, there are always tradeoffs - these tradeoffs lead to cost - what you give up to get something. So, if you want your children and your grandchildren to live in a on a planet that is still safe to live - that is not seeing very extreme climatic events, then probably you will have to give up on certain amounts of comforts.

So, tradeoffs lead to cost. People respond to incentives which means that if we can incentivize the use of green technology or if we can disincentivize, the generation or emission of greenhouse gases, then probably people will respond to them and these incentives could mean things as simple as taxes and subsidies. So, if the airline tickets cost more because of an added tax say

because of of greenhouse gas emissions, then probably less people will be interested to use the airline and more people will, say, shift to other modes of transportation. And when we talk about incentives, the governments can sometimes improve market outcomes because the government has a legitimized power to make changes.

So climate change is something that is happening today, climate change is something that is because of the misguided actions of humans. We have the option to mitigate, we have the options of adaptation, but then if we want to actually perform significant and successful mitigation and adaptation, we will have to make use of the principles of economics to incentivize people towards the right path. So, that is all for today.

Thank you for your attention. Jai Hind!