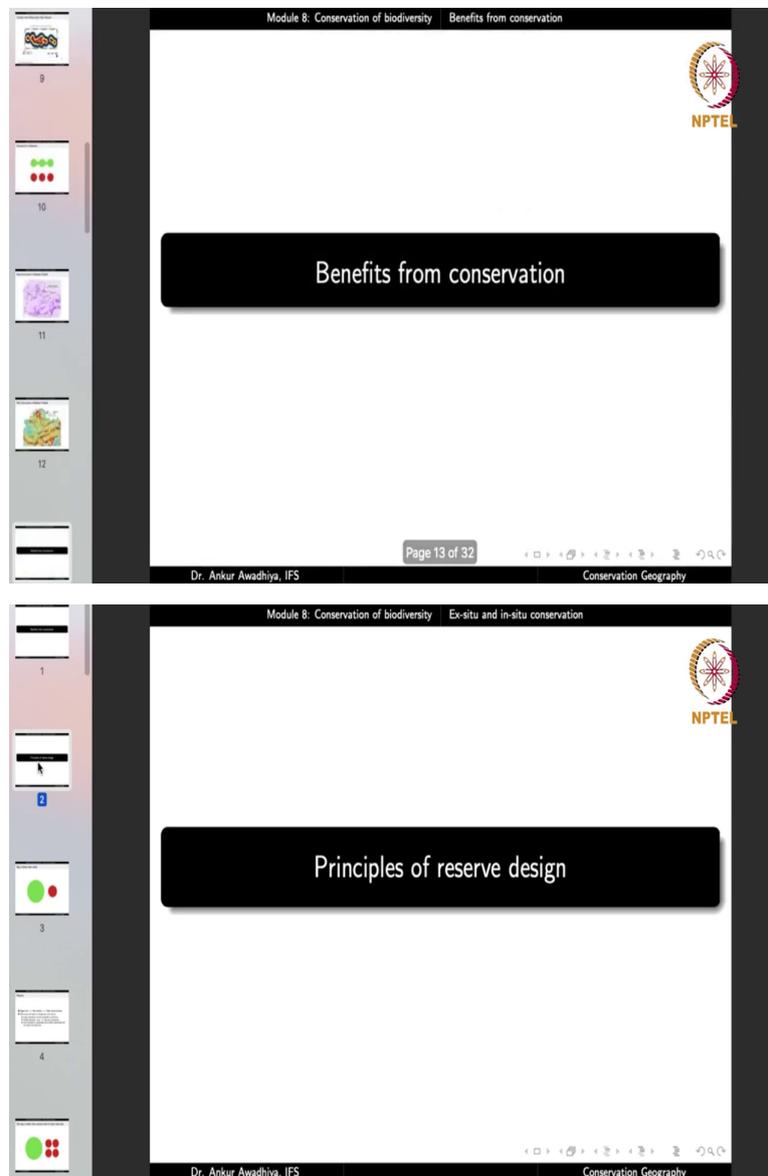


**Conservation Geography**  
**Dr. Ankur Awadhiya, IFS**  
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**Indian Institute of Technology Kanpur**  
**Module - 8**  
**Conservation of biodiversity**  
**Lecture - 24**  
**Benefits from Conservation**

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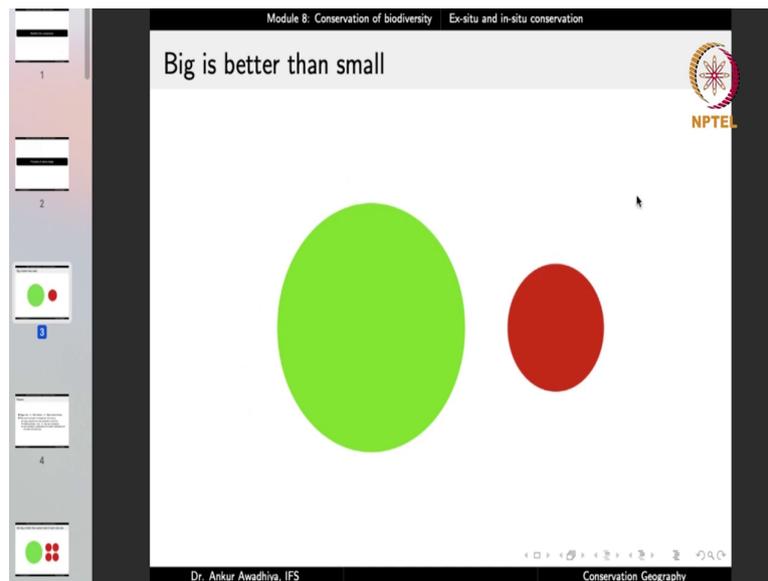


Namaste! We carry forward our discussion on the conservation of biodiversity and in this lecture we shall explore the benefits from conservation. But before let us look at the principles of reserve design that was left over from the last lecture.

Now, when we are designing a reserve there are certain principles to be kept in mind, and these principles exist for us to have the maximum bang for the buck, meaning that for a unit

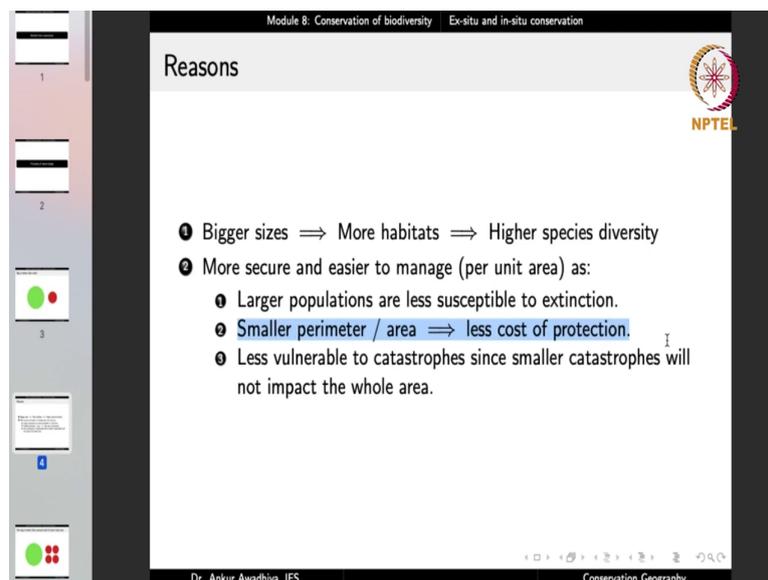
of effort for a unit of funding, we should be able to conserve the majority of species, that is our cost per unit species conservation should be the least possible. So, they make for the principles of the reserve design. So, what are these principles?

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One is big is better than small. So, if you have got two options you can make either a big reserve or you can make a small reserve, you should always go for making a bigger size reserve.

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And why? Because, if you have bigger sizes, it means that there are more number of habitats, more number of habitats means that there is a higher species diversity. And so, if you are trying to make a reserve, there will be certain inputs that you will have to make, you will have to go through a certain legal process in the country.

There could be things like public consultations, so if you have to do all these processes, you have to take the politicians into accord, you have to take the locals into accord, you have to

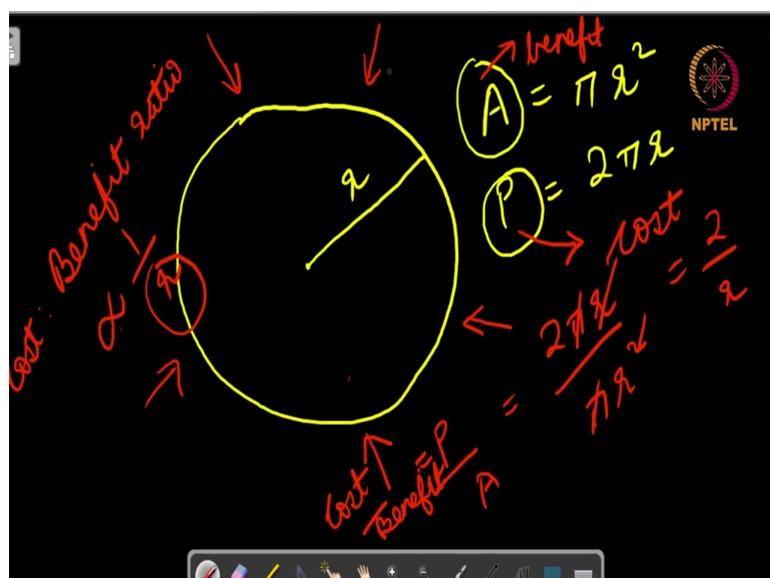
make plans, you have to make public consultations, you have to make a drafts, the drafts have to be ratified and finally it has to be published in the Gazette to be notified as a sanctuary or national park.

Now, when all of these have to be done, they will these processes will have to be done either for small reserve or the same processes will also have to be done for a larger size reserve. So, if you have to make a reserve, better go with a bigger size reserve, once you make a large size reserve, there will be a great amount of habitat diversity and so the reserve will be able to support a larger number of species, more amount of biodiversity will be conserved by making a larger size reserve.

But it also has another plus point, it is often more secure and easier to manage per unit area. So, there is more security and it is easier to manage, why? Because when you have large habitats, more habitats, then the larger size populations will be less susceptible to extinction. Why?

Because we will be having the diminishing population paradigm that will be acting here, but the small paradigm the small factor paradigm will not be acting because the population sizes will be sizable, they will be large, and so we will not have the small population dynamics acting in these populations. So, there is a greater amount of security. At the same time, if you have larger sized reserves, then you typically have a smaller perimeter per unit area. Now, this would make for a less cost of protection.

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Now, this is so because if we consider say a circular reserve with a radius of  $r$ , now in this case the area is given by  $\pi r^2$  and the perimeter is given by  $2 \pi r$ . Now, in the case of a reserve the species are getting a habitat in the form of area, whereas the cost of managing the reserve, the cost especially of protecting the reserve will depend on the perimeter. Why? Because the outside influences if poachers want to get inside they will come from outside, and so all of this perimeter needs to be protected.

So, perimeter is an indication of the cost and the area is an indication of the benefit of making this reserve. Now, if we do a ratio of cost is to benefit it will be given by  $P$  divided by  $A$ , which is  $2 \pi r$  divided by  $\pi r^2$ , so  $\pi$  and  $\pi$  get cancelled  $r$  and  $r$  get cancelled, so this is  $2$  by  $r$ . So, essentially the cost is to benefit ratio is proportional to  $1$  by  $r$ , or it is inversely proportional to  $r$ .

So, if  $r$  increases that is you are making a larger sized reserve, then the cost to benefit ratio reduces, and which is what we want, we want to have the maximum benefit for the minimum cost. So, the cost to benefit ratio should be as less as possible, which means that the radius should be as large as possible, if you make a larger size reserve, there are more benefits with lesser costs.

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Module 8: Conservation of biodiversity Ex-situ and in-situ conservation

## Reasons

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- 1 Bigger sizes  $\Rightarrow$  More habitats  $\Rightarrow$  Higher species diversity
- 2 More secure and easier to manage (per unit area) as:
  - 1 Larger populations are less susceptible to extinction.
  - 2 Smaller perimeter / area  $\Rightarrow$  less cost of protection.
  - 3 Less vulnerable to catastrophes since smaller catastrophes will not impact the whole area.

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Another benefit is that it is less vulnerable to catastrophes, since smaller catastrophes will not impact the whole area. Now, what does that mean? If you have a small size reserve, and suppose there is a forest fire, then there is a good chance that this reserve is completely destroyed.

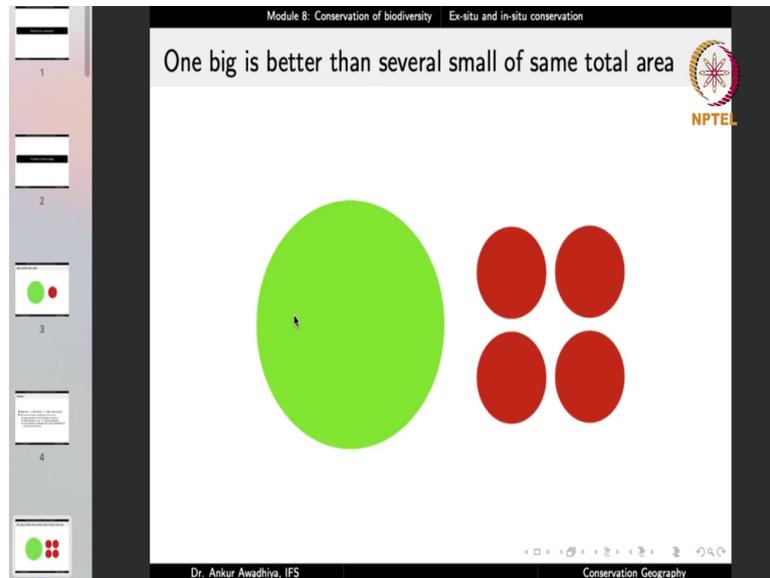
Whereas, if you have a large size reserve and then you have a forest fire say in a large area, but still you will have time to combat this fire. So, possibly you will be able to stop this fire in this zone, this area is destroyed, but this area remains. If that happens, the organisms that are there in this area after some time they will be able to repopulate these areas that have been destroyed.

So, in the case of catastrophes, if there are smaller catastrophic, they do not impact the whole area, and because they do not impact the whole area, so certain number of organisms do survive and these organisms will make it possible to repopulate the whole area. Whereas, in the case of a smaller size reserve, if you have a catastrophe such as a forest fire, then by the time you will be able to put up a substantial amount of action against the forest fire to douse it, probably the fire would have spread to the whole of the reserve.

Because in any case, the reserve is a very small reserve, and so all the organisms will be lost and then you will find it next to impossible to repopulate this reserve back to the original conditions. So, a larger size gives the populations more amount of resistance and more amount of resilience, more resistance because the smaller catastrophic do not impact the whole area, so some of the organisms will be left.

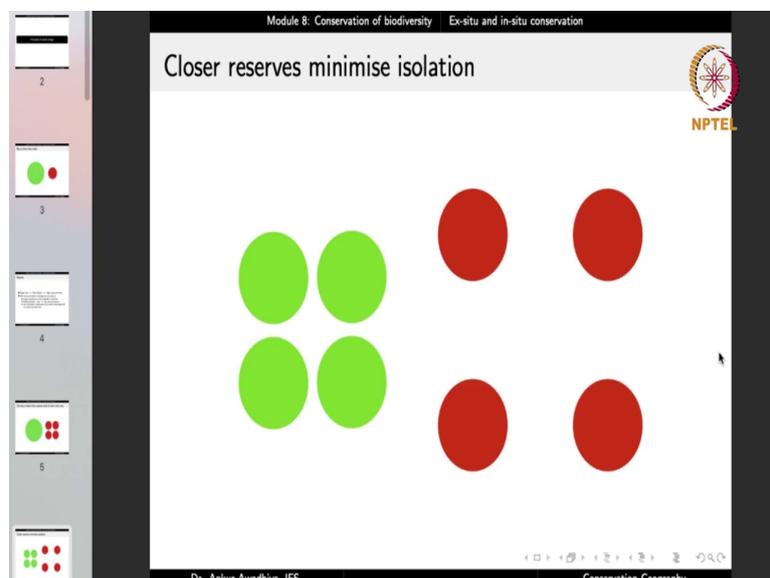
And more resilience, because these organisms that are saved from the catastrophe, they will be able to repopulate the whole of the reserve and bring it back to the original state. So, which is why it is always good to have larger size reserves.

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Another principle is that one big is better than several small of the same total area. So, here again if you have got two options and you are making the same size reserve, but you have two options one is to make it as one body and second is to make it as four or five different smaller bodies of the same total area, then you should always prefer making one large body. Because here again your cost is to benefit ratio will be less, so you will be able to reap more benefits with lesser costs of protection and the organisms will be much more secure.

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Next, if you do not have the option to make a large size reserve, at least try to make reserves that are close together. Now, why is that so? Because when you consider reserves that are close together, then the animals can move from one reserve to another reserve very easily. So, there is very little amount of human dominated landscape that these animals will have to traverse, and with frequent movements, these small populations will start to behave like a big population or a population of populations also known as a meta-population.

Meaning that if suppose here the this is small population begins to reduce in size, so there are some stochastic things that occur because of which this population is reducing in size. When that happens, individuals from here can migrate, individuals from here can migrate, individuals from here can migrate. And so, there will be certain source populations and they will be certain sync populations and continuous movement between these populations will happen in such a manner that the small population dynamics are more or less countered.

Now, this is only possible when you have these small populations that are close together, clustered together, but if these populations themselves are very far apart, in that case the animals will find it very difficult to move from one place to another place, because there is a huge amount of human dominated landscape in between.

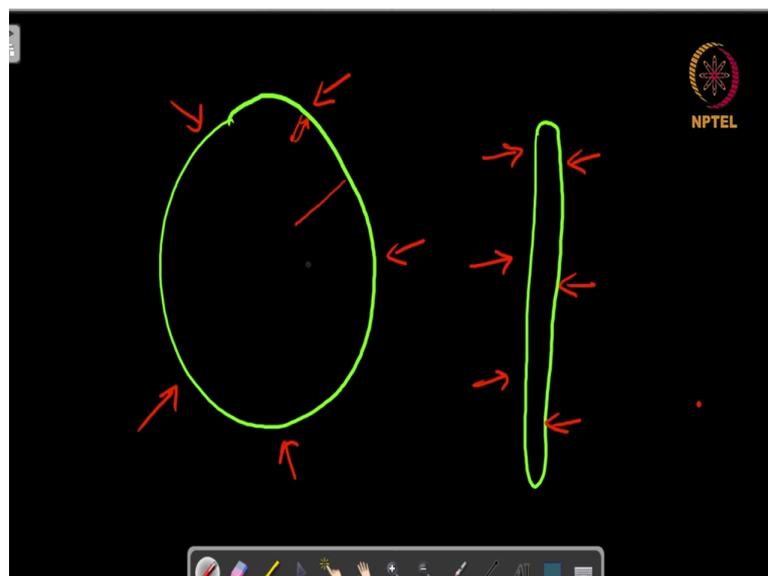
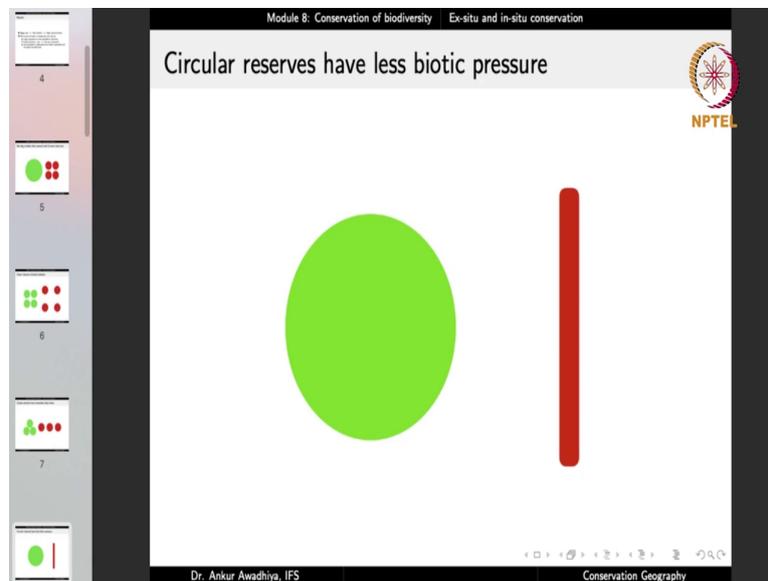
And in such cases, they will not behave as meta-populations, and so the small factor dynamics will play a role here, here, here and here. And in that case, all of these four populations will face a huge threat of extinction. So, given a chance always prefer to make close reserves, that minimize isolation.

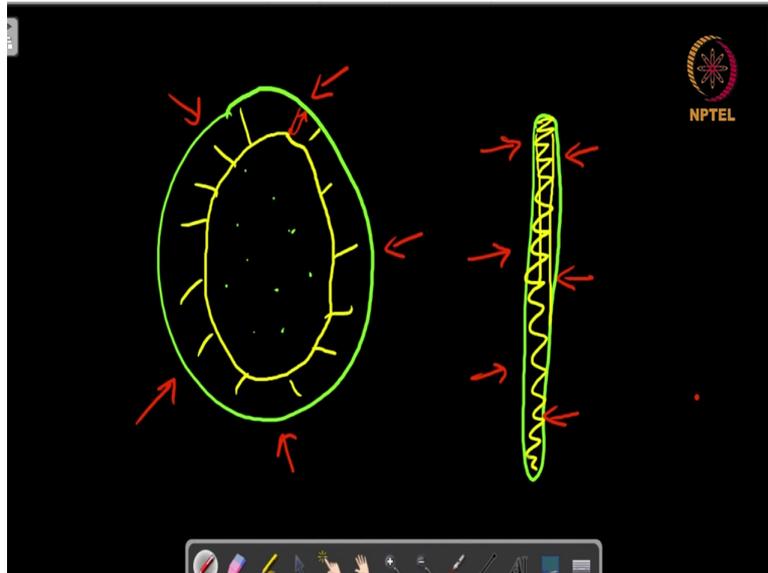
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The slide is titled "Cluster permits more movement than linear" and is part of "Module 8: Conservation of biodiversity" under "Ex-situ and in-situ conservation". It features the NPTEL logo in the top right corner. The main content shows two diagrams: on the left, three green circles are clustered together, and on the right, three red circles are arranged in a straight line. A mouse cursor is pointing at the top green circle. A vertical sidebar on the left shows a list of slide thumbnails, with the current slide (slide 3) highlighted. At the bottom, the text "Dr. Ankur Awadhya, IFS" and "Conservation Geography" is visible.

Not just close cluster them. A cluster permits much more moment than a linear arrangement of reserves. Now, in all of these cases, what we are trying to do is that we are trying to negate the effects of the small population dynamics by creating moments between different populations, so that they behave like a large population.

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Another thing is that we should always prefer to have circular reserves, because they have less biotic pressure. What does that mean? If we consider a reserve that is of this shape, versus a reserve that is say of a linear shape. Now, in both the cases, the threats are coming from outside, so when we talk about things like poaching, when we talk about things like cutting of trees, people are coming from outside. Similarly, when we consider competition due to grazing of animals, that competition pressure is also coming from outside.

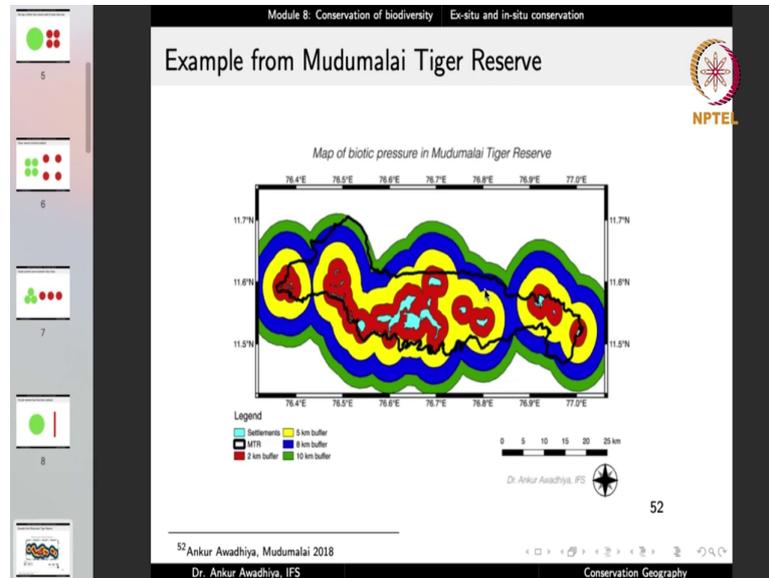
Now, these pressures will not probably reach towards the core of the large size reserves, because people tend to move for smaller distances. Because, if you think from the point of view of say a poacher or an illicit logger, then they would prefer to enter into the reserve perform their operation of tree cutting or killing animals and then they would try to move back outside, before being detected.

Now, if they try to move very much inside the jungle, in that case, their chances of being detected increase a lot. And so, in a vast number of cases, we can draw a line towards the center and from the boundary, which would be the zone of influence of outside pressures. So, this is the zone of influence. Now, in the case of a circular reserve, we will have a large area on the inside that will be free of any of these outside influences.

Whereas, in the case of reserves that are stretched like this, then the zone of influence from here it would cover something like this and from here it would cover something like this. And in that case, the whole of the reserve will be a zone of influence of the outside pressures. And in such case, there will be no area in the reserve that is free from biotic pressures or free from pressures of the surrounding human beings.

Now, we created a reserve to protect and conserve the wild animals from these influences. So, if these influences are able to reach every nook and corner of the reserve, then it does not make any sense to create a reserve in the first place. And so we always prefer to create circular reserves because they have less of these biotic pressures.

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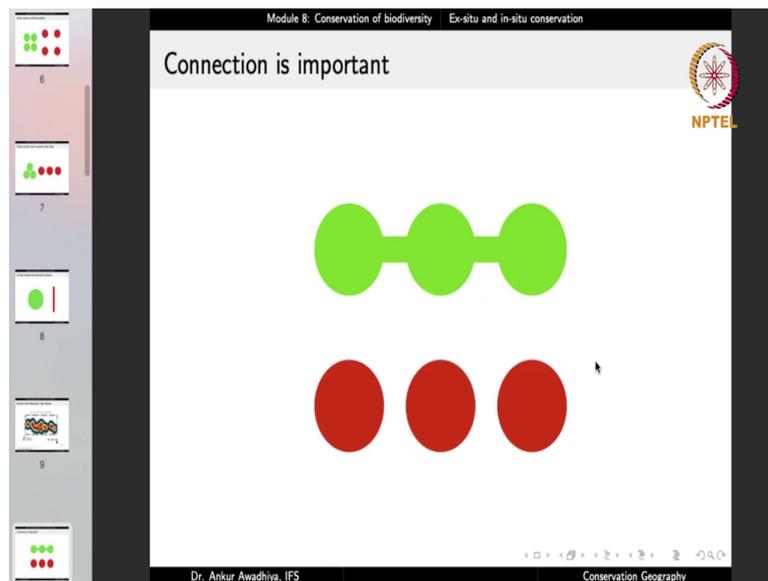
Now, this is an example from Mudumalai Tiger Reserve. Now, this black outline is the Mudumalai tiger reserve, these blue areas are the settlements inside. So, in many circumstances, we do not have reserves that are completely free of human influences, but we might be having certain things settlements inside.

So, people are living inside, people are doing cultivation, people are doing cattle rearing, and if we drew the biotic pressure zones or the zones of influence, then this red is showing us a 2 kilometer buffer, yellow is showing us a 5 kilometer buffer, blue is showing an 8 kilometer buffer and green is showing a 10 kilometer buffer.

Now, if humans and their cattle are able to move inside to say 10 kilometers, then there will be no zone that is left in this tiger reserve that would be free from the external influences. Even if humans are able to move only 5 kilometers, then to you will find that a majority of the tiger reserve will be within the zone of influence.

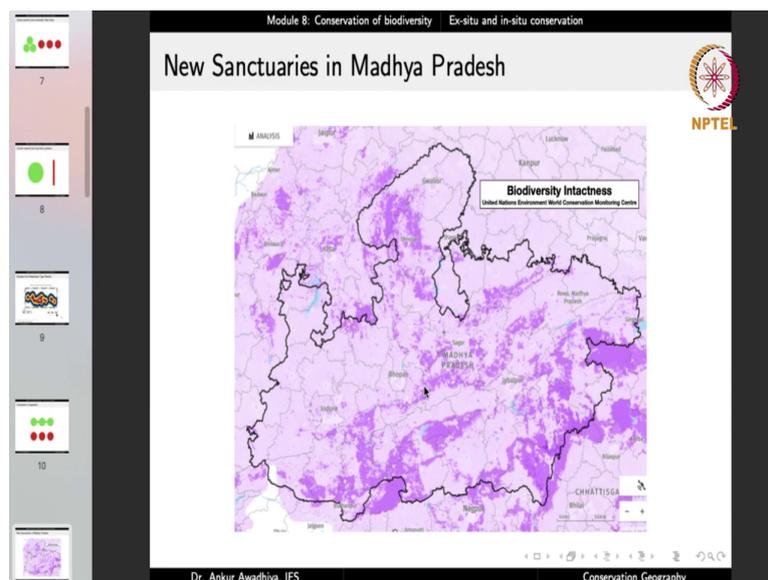
And so, we will not say that this is a very good design, and probably this gives us an idea that these settlements on the inside they can probably be relocated by giving certain amounts of compensation, so that more and more of the reserve becomes an invalid area for wildlife.

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Another principle is that connection is important. So, if nothing else works, at least try to maintain connectivity, because connections permit animals to move from one part to another part of from one small reserve to another small reserve creating them into a meta-population and negating the influences of this small factor paradigms.

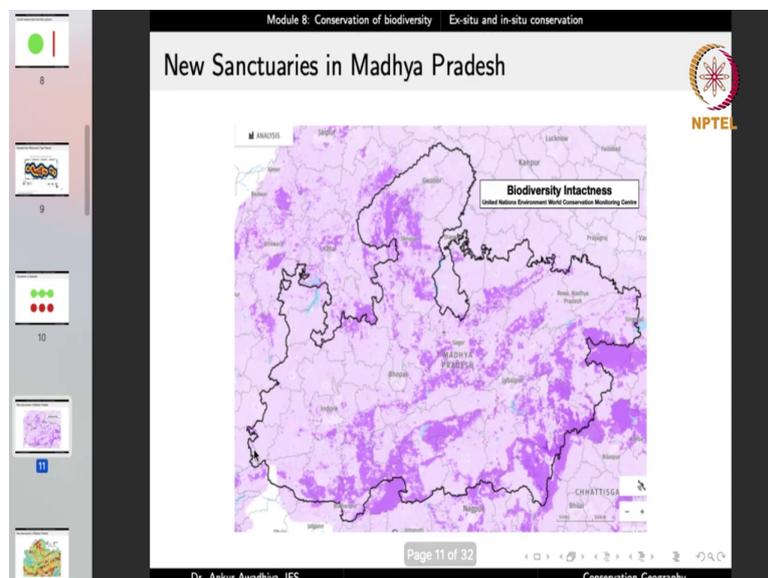
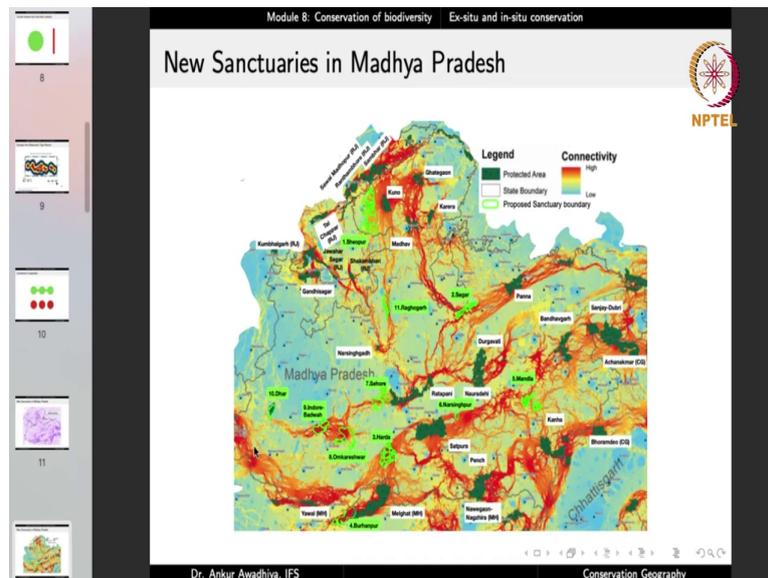
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So, how does it work in practicality? So, suppose in the state of Madhya Pradesh, we need to design new sanctuaries. And the question is, where should they be located? So, we can begin with things like biodiversity intactness index. Now, this is an index that gives an idea about which locations currently have a substantial amount of biodiversity, and in which locations

the biodiversity has already been more or less eliminated. So, in this map we can see that these dark colored patches are the ones where the biodiversity still remains.

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And when we next look at the areas where the reserves and the sanctuaries already exist, so here we have a map, which shows that here we have Kuno Palpur, here we have Ghatigaon Sanctuary, here we have Karera Sanctuary, so these dark colored areas are the ones where we already have the reserves.

Now, if we are trying to create new reserves, they should be in areas that are well connected, that should be having a substantial amount of biodiversity that can be protected, and that should be in areas that have a good amount of connectivity, that is we know that animals are already moving from one place to another place.

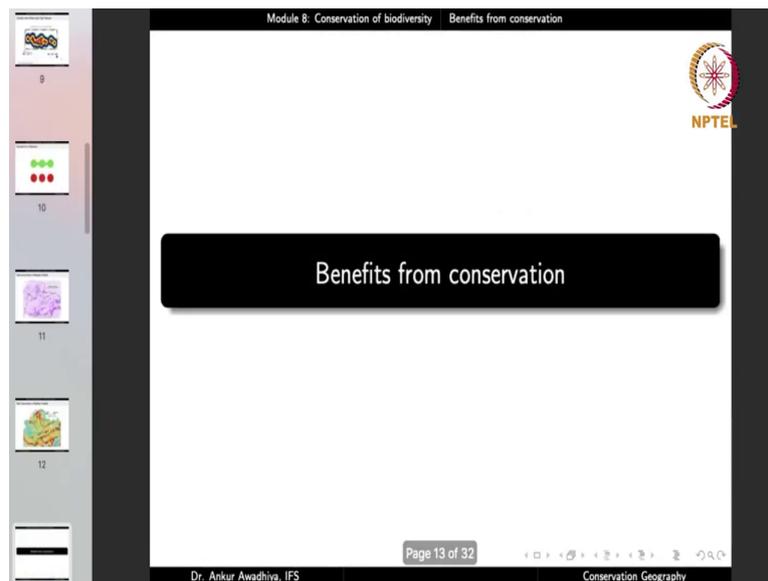
Now, Madhya Pradesh being the tiger state of the country, we can look at the tiger connectivity between all of these different areas. Now, this red color is showing us the tiger connectivity. So, these areas have a substantial amount of tiger connectivity, meaning that it is known that tigers move from one place to another place by taking these routes, these dark colored routes, so if we wanted to make new sanctuaries in Madhya Pradesh, we would prefer to make them in these locations.

So, now if we look at the biodiversity in intactness index. If you look at the existing sanctuaries, look at a gap analysis and also look at connectivity we can locate the areas where new sanctuaries can be constructed. So, this is how these principles play a role in actually making a decision about where to place the sanctuaries. And in all of these locations, we can then look at the principles of reserve design and try to create as largest a sanctuary as possible.

Now, in a large number of cases, when we try to create a large sanctuary, it might be having certain habitations inside. Now, if there is a habitation and if people are getting egged off, in those situations they may turn anti-animals or anti-conservation. So, for a large part we try to keep all the settlements out of the sanctuaries, so that people retain their rights and they become pro-conservation.

Because the sanctuaries will be providing them with certain benefits, the sanctuaries will be providing them with lots of employment, mostly through tourism, plus lots of ecosystem services, without having any negative influence on their rights. So, this is how the things play in the practical context.

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So, when we talk about these benefits, what are the benefits that we get from conservation?

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Now, we can classify the benefits in certain categories, but the umbrella term used for these benefits is ecosystem services, the benefits that people obtain from ecosystems. And typically well-functioning, resistant and resilient ecosystems. So, the benefits that people obtain from ecosystems are known as ecosystem services and these are primarily the benefits of conservation.

So, when we do conservation, we create an area or we protect an area in such a manner that it maintains its nature as a well-functioning ecosystem. And when it is a well-functioning

ecosystem, it provides certain benefits to people and these benefits are known as ecosystem services. So, these are the benefits from conservation.

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Module 8: Conservation of biodiversity Benefits from conservation

### Classification of Ecosystem Services I

**1 Provisioning services**

- 1 food: honey, spices, wild fruits, etc.
- 2 raw materials: timber, fuel wood, fodder, organic matter, etc.
- 3 genetic resources: crop improvement genes
- 4 purified water
- 5 medicinal resources: medicinal plants, assay organisms, etc.
- 6 energy: hydropower, biological fuels, etc.
- 7 ornamental resources: feathers, shells, flowers, fur, butterflies, etc.

**2 Regulating services**

- 1 carbon sequestration
- 2 climate regulation
- 3 biological control of pest population through predation
- 4 waste decomposition and detoxification

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So, what are these benefits? So, ecosystem services can be classified into several categories. The first is provisioning services. So, these are the services that provide something, they give something, and mostly material things. So, they provide certain materials and because of that we call them as provisioning services.

So, what are the provisioning services? Well-functioning ecosystems can provide people with food, food like honey, food, like spices, food like wild fruits. So, these are different things that are being provided by a well-functioning ecosystem. And so, these come under the category of provisioning services.

Then these ecosystems also provide several raw materials such as timber or fuel wood or fodder or organic matters. So, these are also the provisioning services, they provide genetic resources in the form of crop improvement genes. Now, these are very important especially because in modern agriculture we control the situations to such a large extent, that very little amount of variation is possible.

So, if you consider paddy cultivation, the paddy crop will be given a large amount of water, and irrigation is assured for these paddy crops because of which they have not developed any drought resistance for a very long time. Now, given that we are currently living in a context of climate change, given that there are a large number of diseases that are coming up and destroying our crops, especially crops such as coffee.

Now in these cases, if you wanted to give drought resistance or resistance against pathogens to our agricultural crops, where will we get the genes from? The answer is, we will get these genes from the wild relatives of the agricultural crops. This is because the wild relatives live in changing conditions, there is nobody in the forest to give them water, nobody to spray herbicides, or weedicides or fungicides on these plants.

So, these plants are able to survive in the wild conditions only because of their own inherent tendencies. And a large fraction of that is genetic traits. So, they have those genetic traits that give them drought resistance, flood resistance, resistance against diseases, resistance against insects, and so on. Now, if we wanted to give these resistances to our own agricultural crops, we can take these genes and move them into the agricultural crops through processes such as hybridization and selective breeding.

So, that is another provisioning service that the well-functioning equal system provides to us in the form of genetic resources. Then it provides us with purified water, because if you consider a water that is rich in sewage, rich in sludge, and if it if this water moves into a wetland, what happens? In the wetland there are so many organisms that feed on the organic matter that is there in the water.

And by that they reduce the amount of biological materials that are there in the water. They reduce the biological oxygen demand. In a large number of cases, the bacteria that are there in the sewage water will be eaten up by other microbes that are living in the water. So, wetlands provide a huge provisioning service in the form of purified water. So, they purify the water and provide the purified water that can be used by humans.

Another provisioning service is medicinal resources, medicinal plants, assay organisms and so on. Now, in a large number of cases the plants that live in wild conditions, they develop certain chemicals that are used against other organisms, especially insects and especially against diseases, these chemicals are byproducts of metabolism. And these metabolic byproducts also have medicinal properties.

So, if we talk about traditional drugs, things like quinine, so quinine was extracted from the bark of the cinchona tree. Now, in the cinchona tree quinine used to provide resistance against insects to the plant, resistance against herbivores to the plants, because it is such a bitter substance that organisms would not prefer to eat the cinchona tree or the cinchona plant.

Now, this quinine also turned out to have anti-malarial properties. So, this is another provisioning service that will functioning ecosystems provide, medicinal resources. They also provide us with energy, in the form of hydro power, biological fuels, and so on. So, we can also extract energy, which is again a provisioning service, we also get ornamental resources, feathers, shells, flowers, fur, butterflies, and so on.

So, these are several probating services that are being provided by well-functioning ecosystems. At the same time, they also provide a large number of regulating services, which means that they regulate something. Now, ecosystems regulate things like the concentration of carbon dioxide in the atmosphere, because they perform carbon sequestration.

And through carbon sequestration, they remove carbon dioxide from the atmosphere, and they add it in the form of biomass into their own bodies. In this way, they help reduce the impacts of global warming. They also play a big role in climate regulation, because areas that are near forests, they are typically cooler than the urban heat islands.

So, if in a city you have certain patches that have forests, then that would cool the surroundings. Now, similarly if we talk about large size forests, they are able to provide a climate regulation impact on a much greater surrounding. Next, they perform the regulating service of biological control of pest population especially through predation.

For instance, a large number of insectivorous birds that live in the forest, they feed on insects and they also reduce the insect population in the surroundings, which means that if you have a forest nearby, the agricultural farmlands in the vicinity they will not have to spread a very high dose of insecticides. Why? Because the birds are doing the job of removing the insects. So, that is another regulating service.

Waste decomposition and detoxification. Here again, we have the processes of degradation of organic materials and we also have the process of bio-remediation. So, in the process of bio-remediation, the plants take up the toxic materials, especially the heavy metals and they deposit them in into their own bodies, when they do that, the water that is passing through is made more purified because the heavy metals are removed from that water. So, this is another regulating service waste decomposition and detoxification.

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Module 8: Conservation of biodiversity Benefits from conservation

## Classification of Ecosystem Services II

- 1. bioremediation
  - 1. purification of air and water
  - 2. protection against floods
  - 3. groundwater recharge
  - 4. protection against disasters such as hurricanes and tsunamis
- 2. Supporting services
  - 1. soil formation and humus formation
  - 2. nutrient cycling
  - 3. primary production and oxygen generation
  - 4. provisioning of habitat for biodiversity
  - 5. biologically mediated habitats such as corals and mangroves
  - 6. pollination
- 3. Cultural services
  - 1. recreational (e.g. ecotourism, outdoor sports, etc.)

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Module 8: Conservation of biodiversity Benefits from conservation

## Classification of Ecosystem Services II

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So, we have bioremediation, then the plants also purify air and water, especially when you talk about the plants in those areas where we have lots of dust storms. So, the leaves of the plants, they act as barriers, they reduce the wind speed and they make dust fall and so they reduce the amount of dust that is there in the vicinity, this is another regulating service, they provide protection against floods.

This is done because the water that is falling on the ground is moved into the groundwater reservoir through groundwater recharge, and at the same time the speed of the water is reduced. And so, if we do not have a large quantity of water that comes into the water body at the same time, when water comes slowly then we do not have a flood like situation, whereas when all the water comes together, then there will be an inevitable flood.

So, this is another regulating service protection against flood, groundwater recharge. They also protect against disasters such as hurricanes and tsunamis, by acting as a physical barrier against the impacts of hurricanes and tsunamis. So, they act very much like a storm surge barrier, like a seawall and when there is a tsunami, then water cannot rush inside because the wall of trees can protect the coastal areas against these waters.

Then, ecosystems also provide a number of supporting services such as soil formation and humus formation. Now, we have seen this before in the context of weathering of rocks, that we have biological weathering, which is facilitated by biological organisms such as plants and animals. So, this is a supporting service in the form of provisioning of soil, which has a large number of uses, mostly in agriculture.

They also perform nutrient cycling, which is again a supporting service. They perform primary production and oxygen generation, meaning that they convert carbon dioxide into biomass. And this biomass sustains a large number of other organisms, because this acts as food for other organisms, and in this process, they also generate oxygen.

Now, we have observed before that the great oxygenation event that changed the composition of the atmosphere, it was brought about by plants, and plants are still doing the job of oxygen generation, which supports all different forms of life, so this is another supporting service. Provisioning of habitat for biodiversity, so where would tigers live if there were no forests? So, tigers reside in forest areas because the forests are home for tigers. And similarly, well-functioning ecosystems provide homes for a large variety of species. So, they conserve biodiversity, this is another supporting service.

Then, there are a large number of biologically mediated habitats such as corals and mangroves. Another supporting service is pollination. If it did not have the insects, the birds, the animals that are there in the forest, who would do the pollination, so this is another supporting service that well-functioning ecosystems provide.

Next we also have a large number of cultural services, such as recreational services, people go out into the forest which are ecotourism sites, they go out for outdoor sports. So, these are different cultural services.

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Module 8: Conservation of biodiversity Benefits from conservation

### Classification of Ecosystem Services III

- scientific and educational (e.g. for scientific studies and discovery, excursions)
- religious and spiritual
- cultural (e.g. use as a motif for books, films, paintings, etc.)
- therapeutic (e.g. ecotherapy)
- inspirational

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Scientific and educational services. For example, well-functioning ecosystems are good areas for scientific studies, for discoveries for excursions, if you had to teach people about botany, where would they find a large variety of plants to understand say differently forms or different types of growths of plants. So, well-functioning ecosystems also provide a role for scientific studies.

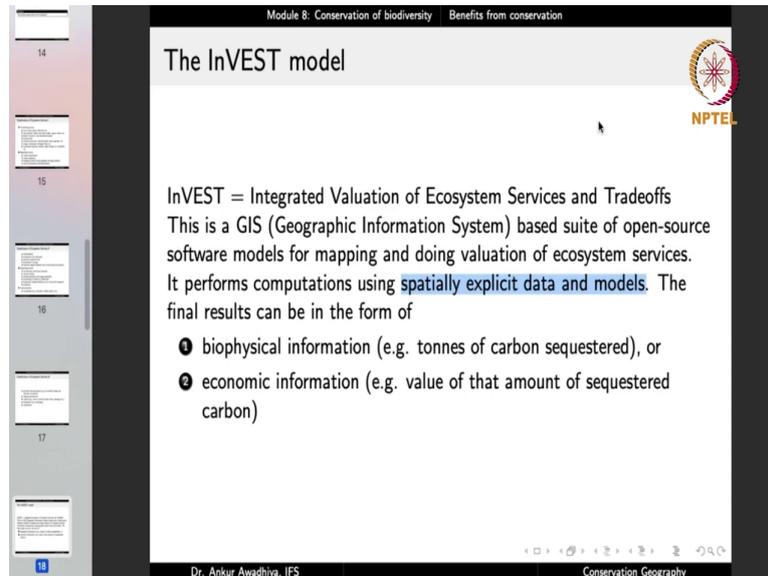
If you wanted to study the animal behaviors, the whole field of ethology is based on well-functioning ecosystems. Then, we also have a large number of religious and spiritual services that are being provided, because a large number of trees and animals they have religious significance, they have spiritual significance, people worship trees, people worship animals. And so they provide a service which is even a religious and spiritual service.

Then, there are certain cultural services, they are used as motives for books, firms, paintings and so on. They provide therapeutic services such as eco therapy, meaning that in certain countries, if there are people who are suffering from say anxiety or suffering from depression, then the psychologist would make a prescription that they should go out visit a forest area and when they go out when they see trees all around when they hear the chirping of birds, the minds are calmed.

So, this is another service, this is a therapeutic service that the forests provide. Then they also provide a lot of inspiration, inspiration to writers, inspiration to poets. And a large number of books and poems have been written in forest areas, taking inspiration from forest areas. So, there are N number of ecosystem services that well-functioning ecosystems provide. If we did not have lush green forests, if all the areas were just barren lands, probably we would not be

having large number of books or many poems or many films. So, there are several ecosystem services that are being provided by the forests.

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The screenshot shows a presentation slide titled "The InVEST model" from a course on "Conservation of biodiversity" and "Benefits from conservation". The slide defines InVEST as "Integrated Valuation of Ecosystem Services and Tradeoffs" and describes it as a GIS-based suite of open-source software models for mapping and valuing ecosystem services. It notes that the models use "spatially explicit data and models" and that results can be biophysical (e.g., tonnes of carbon sequestered) or economic (e.g., value of sequestered carbon). The slide includes the NPTEL logo and the name of the presenter, Dr. Ankur Awadhya, IFS, in the footer.

Now, how do we do a valuation of these services? For that we can make use of models such as the inVEST model, inVEST stands for integrated valuation of ecosystem services and trade-offs. This is a GIS based suite of open source software models for mapping and doing valuation of ecosystem services. Now, valuation of services becomes important for two reasons, one it allows us to have a greater understanding of what all ecosystems is a system providing.

Because when you want to do a valuation, you have to list down the various ecosystem services to do a valuation of each and every one of them. So, this makes us stop and think about the various ecosystem services that a well-functioning ecosystem is providing. And two, it allows us to take decisions.

If there is a forest that is being diverted to say create a mine and this mine would provide a total of say 100 crores of rupees to the economy in the form of jobs in the form of raw materials, but if the forest by itself is providing services worth 500 crores, so in that case you will probably not want to divert the forest into a mine.

But to have this decision, it is important to do a computation of the various ecosystem services that are being provided. So, models such as the inVEST model, permit us to make these computations and inVEST is a GIS based suite, so because this is a GIS based suite, we can compute things such as we can see that okay this 10 percent area of the forest is having

this density, it is doing this much amount of carbon sequestration, this other portion of the forest is having this density and is doing so much of carbon sequestration, so what is the total amount of carbon sequestration that this whole forest is doing?

To make these computations, we make use of GIS based systems, geographic information system based suites and it does a valuation of the ecosystem services. It performs computations using spatially explicit data and models. Because this is GIS based so the data, and the models are mostly spatially explicit, that is the main use of positional information.

And we can get final results in the form of biophysical information, such as tons of carbon sequestered or economic information, such as the value of that amount of sequestered carbon. So, with this background, let us now have a look at some ecosystem services and how do we do their valuations.

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Module 8: Conservation of biodiversity Benefits from conservation

### Some ecosystem services and their valuation I

NPTEL

- 1 employment generation, computed as  
$$\Sigma(\text{man days} \times \text{wage rate})$$
- 2 fishing benefits, computed as  
$$\Sigma(\text{production} \times \text{market prices})$$
- 3 fuelwood benefits, computed as  
$$\Sigma(\text{production} \times \text{market prices})$$
- 4 fodder benefits, computed as  
$$\Sigma(\text{production} \times \text{market prices})$$

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Module 8: Conservation of biodiversity Benefits from conservation

## Some ecosystem services and their valuation II

NPTEL

- 1 timber benefits, computed as
 
$$\Sigma(\text{production} \times \text{market prices})$$
- 2 bamboo benefits, computed as
 
$$\Sigma(\text{production} \times \text{market prices})$$
- 3 NTFP benefits, computed as
 
$$\Sigma(\text{production} \times \text{market prices})$$

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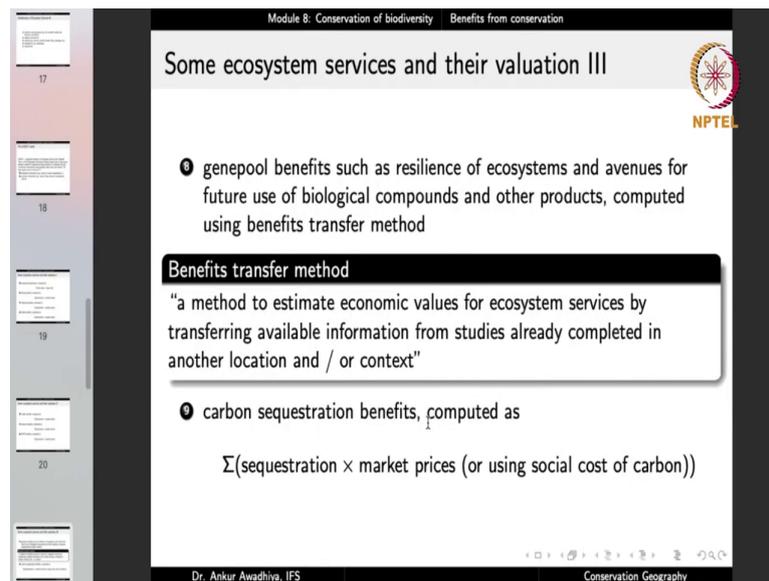
The first ecosystem services employment generation, and typically a large number of ecosystems in the form of protected areas give employment to people who act as guides, who act as Gypsy drivers, who act as people in the hospitality sector, because the tourists will be staying in some hotels, so there have to be people to cook food, to serve them food, to take care of their hotel rooms and so on.

So, there is a large amount of employment that gets generated nearly because there is a protected area that has been created. Now, this employment generation can be computed as the number of man days that are generated, multiplied by the wage rate. Now, different people would be paid at different wages, so we can do a summation of the number of man days for each person who is getting employment multiplied by his or her wage rate.

So, this gives us a valuation of the amount of employment that is getting generated because of the conservation reserve. Next we have fishing benefits, the fishing benefits can be computed as the amount of fish that gets produced multiplied by the market prices, and we do a summation because different species of fishes can be fetching different prices or probably different areas could be getting different prices.

Similarly, we can compute the fuelwood benefits as the sum over production into market prices, fodder again as a sum over production over market prices, so these are all different provisioning services that the well-functioning ecosystem is providing, fishes, fuelwood, fodder, timber, bamboo, NTFP and for all of these provisioning services, we can do a summation over production into market prices.

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Module 8: Conservation of biodiversity Benefits from conservation

### Some ecosystem services and their valuation III

NPTEL

- ④ genepool benefits such as resilience of ecosystems and avenues for future use of biological compounds and other products, computed using benefits transfer method

**Benefits transfer method**  
"a method to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and / or context"

- ④ carbon sequestration benefits, computed as

$$\Sigma(\text{sequestration} \times \text{market prices (or using social cost of carbon)})$$

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Now, to look at the genepool benefits, such as the resilience of ecosystems and avenue for future use of biological compounds and the products, they can be computed using benefits transfer method. Now, benefits transfer method is a method to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and our context.

So, basically because things such as genepool benefits are difficult to compute in each case, so what we do is that for one particular forest, we can compute the genepool benefits and use that particular value in the computation of ecosystem services of various different forests. So, essentially, if there is a forest that has been say largely used for its genepool benefits, such as the resilience of the ecosystem or for provisioning of genetic resources, so we can do a computation of how much amount of value has been added, because of the services that have been derived from this particular well-functioning ecosystem.

And for the other forests, we may probably not be using the gene pool, but they may be used, maybe sometime in the future. So, we can make a correlation and we can take values from one forest from which the genepool has been utilized and use the same values for other forests as well. We can do carbon sequestration benefits computed as sum of carbon that has been sequestered, multiplied by market prices.

Now, in this case those countries that are going to emit more carbon dioxide into the atmosphere, then is permissible under the quota can purchase carbon credits from other countries that are emitting less than their own quotas. And in this case, the carbon credits are traded on a world market. So, we can make use of the current trading price of carbon to

compute the carbon sequestration benefits, or else we can make use of the social cost of carbon.

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Module 8: Conservation of biodiversity Benefits from conservation

### Some ecosystem services and their valuation IV

NPTEL

⑩ carbon storage benefits, computed as

$$\Sigma(\text{total storage} \times \text{social cost of carbon})$$

**Social cost of carbon**  
"the cost of impacts caused by emission of carbon dioxide"

⑪ water provisioning benefits, computed as

$$\Sigma(\text{water provisioned} \times \text{market prices})$$

⑫ water purification benefits, computed as

$$\Sigma(\text{water purified} \times \text{average cost of treating water (replacement)})$$

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Social cost of carbon is the cost of impacts that are caused by the emission of carbon dioxide. So, if this carbon dioxide were to be emitted, if it were not sequestered, if it were not stored in the forest, then this carbon dioxide would have remained in the atmosphere. And that would have exacerbated the global warming and climate change. What would have been the negative consequences of that much amount of global warming or climate change, is what the social cost of carbon tries to figure out.

So, if there were more amount of global warming and climate change, then perhaps certain areas would be facing droughts, or certain areas would be facing more impacts of hurricanes, because hurricanes or cyclones they get their energy from the top layer of the sea, and if the temperatures go up, then more amount of energy is available, meaning that we will get more number of cyclones and more destructive cyclones.

Now, what will be the damage that these that they would have caused? Now, that amount of damage can be divided into several different categories. And one such category is the amount of carbon dioxide that is there in the atmosphere. So, we can compute the carbon sequestration and carbon storage benefits by doing the total amount of carbon that is sequestered and stored, multiplied by the social cost of carbon, which is the cost of impacts that are caused by the emission of carbon dioxide, but it not sequestered and stored.

Similarly, we can look at the water provisioning benefits by sum of water provision into market prices. So, total amount of water that the ecosystem is providing to people at different locations, multiplied by the market prices of water in those locations, will give us the valuation of the water provisioning benefits. Similarly, we can look at water purification benefits, the amount of water purified, multiplied by the average cost of treating water by doing a replacement.

So, if the water was not being purified by the forest or by the wetlands, then perhaps we would have needed to set up a water purification facility. What is the cost of setting up that facility, what is the cost of running and maintaining that facility is the amount of benefit that this particular forest or wetland is providing to us. So, we can make use of that cost, multiply that with the amount of water that has been provisioned, and we can get the water purification benefits.

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Module 8: Conservation of biodiversity Benefits from conservation

### Some ecosystem services and their valuation V

- 1) soil conservation and sediment retention benefits, computed as
$$\Sigma(\text{erosion avoided} \times \text{cost of damage avoided})$$
- 2) nutrient retention benefits, computed as
$$\Sigma(\text{nutrients retained} \times \text{cost of artificial fertilisers})$$
- 3) biological control of pests, computed using benefits transfer method
- 4) moderation of extreme events benefits, computed using benefits transfer method
- 5) pollination benefits, computed using benefits transfer method
- 6) nursery for various species benefits, computed using benefits transfer method

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We can look at the soil and, the soil conservation and sediment retention benefits, because the forests prevent soil erosion, this conserves soil and they retain the sediments. So, in this case, we can compute it as the sum of the amount of erosion that is avoided because of the presence of forest multiplied by the cost of damage that has been avoided.

Now, this cost of damage can be computed by say the reduced life of dams, if the dams gets silted, then their life reduces, or the cost of dredging of these dams and different water ways. These are all different costs that are being avoided by the presence of the forests and the wetlands. So, this is one way in which we can compute the soil conservation and sediment retention benefits.

Then nutrient retention benefits can be computed as sum of nutrients that are retained, multiplied by the cost of artificial fertilizers. So, together with the soil, the forests, and the wetlands are also conserving the nutrients, not just the macro nutrients like nitrogen, phosphorus, or potassium, but also a large number of micronutrients.

Now, if all of these nutrients were lost from the area, then we would need to supplement them by adding artificial fertilizers, what would be the cost of adding those fertilizers? The cost of procurement, the cost of transportation, the cost of spreading those fertilizers, now all of these things are being avoided just by the presence of the forests and the wetlands. So, this is the amount of value that they are providing.

Biological control of pests, which can be computed using benefits transfer method, in which case we do an intensive study in one location and use the same values in other locations, or by doing a computation of the cost of the pesticides that would have to be sprayed, the cost of transporting those pesticides and the cost of applying those pesticides, including the health costs of those pesticides, because whenever we release pesticides into the environment, they invariably make their way into the food chain and they reach us as well through our food.

So, what is the cost of the diseases that they are causing, if you add all of them together, we get the valuation of the pest control benefits that the forests and other ecosystems are providing. Similarly, we can use benefits transfer method for computation of things like moderation of extreme events or pollination benefits or the benefits because the forests are also acting as nursery for various species, especially those species that are rare and endangered.

So, probably sometime in the future, we may require these rare and endangered species say for the medicinal purposes. So, what is the benefit that the that the forests are providing, just by acting as a nursery for these plants can also be computed using benefits transfer method.

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Module 8: Conservation of biodiversity Benefits from conservation

### Some ecosystem services and their valuation VI

NPTEL

- 1) habitat for various species benefits, computed using benefits transfer method
- 2) cultural heritage benefits, computed using contingent valuation method
- 3) recreation benefits, computed using travel cost method
- 4) air quality benefits, computed as  
$$\Sigma(\text{air purified} \times \text{average cost of treating air (replacement)})$$
- 5) waste assimilation benefits, computed using benefits transfer method
- 6) climate regulation benefits, computed using benefits transfer method

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We can also use it for habitat for various species benefits. The cultural heritage benefits can be computed using contingent valuation method. So, for instance, if people pay a lot of respect to a particular tree, say a banyan tree, you can ask the people in the surroundings that okay if this banyan tree were to be cut down, what is the amount of compensation that you feel is a reasonable compensation for accepting the loss of this banyan tree.

So, if you ask the people who are the stakeholders of this banyan tree, the value that they put to this banyan tree, the cultural value, and then do a summation, then you can compute the cultural heritage benefits.

We can compute recreation benefits using travel costs method, meaning how many people are coming to visit a particular protected area, how much amount of money are they spending, because the people will have to spend money for travel, for accommodation, for food for getting entry into the protected area, they will have to pay a cost for transportation, say the cost of gypsies, they will have to pay cost of hiring a guide, hiring a driver and so on. So, what is the amount of money that people are spending?

Now, of course, the value that these people are getting out of the predicted areas is greater than this value that they are spending and only if the value that people get is more than the amount is spent, will they spend the amount. And so, we can make use of travel cost method to compute the recreation benefits.

Air quality benefits can be computed using amount of air that is purified multiplied by the average cost of treating air say by using air purifiers. Based assimilation benefits and climate regulation benefits can be computed using benefits transfer method.

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Module 8: Conservation of biodiversity | Benefits from conservation

Example: Panna Tiger Reserve<sup>53</sup> I

- 1 Flow benefits: ₹69.55 billion per year
  - Annual direct benefits: ₹0.78 billion
  - Annual indirect benefits: ₹53.11 billion
  - Option benefits: ₹15.65 billion
- 2 Stock benefits: ₹137.46 billion per year
- 3 Critical ecosystem services:
  - Water provisioning: ₹25.82 billion per year
  - Climate regulation: ₹20.21 billion per year
  - Waste assimilation: ₹1.66 billion per year
  - Benefits to human health: ₹144.55 billion per year
- 4 Kinds of services:
  - Provisioning services: ₹0.67 billion per year
  - Supporting services: ₹0.38 billion per year

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Now, what are these figures like? If we look at the valuations that were done for Panna Tiger Reserve, the flow benefits are around 70 billion rupees in a year, the stock benefits are 137 billion rupees, critical ecosystem services, water provisioning, climate regulation, waste assimilation to we can do all these kinds of valuations.

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Module 8: Conservation of biodiversity | Benefits from conservation

Example: Panna Tiger Reserve<sup>54</sup> II

- Regulating services: ₹68.48 billion per year
- Cultural services: ₹18.40 million per year
- Investment multiplier: 1939.36

<sup>53</sup>IIFM: Economic valuation of tiger reserves in India  
<sup>54</sup>IIFM: Economic valuation of tiger reserves in India

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And the final figure that we are getting is that the investment multiplier is 1939.36. Meaning that for every rupee that is getting invested for the protection and maintenance of Panna Tiger

Reserve, we are getting benefits as high as 2000 rupees. Because the people in the surroundings they are getting water, they are getting good soil, they are getting good health and so on. So, the kinds of benefits that we get from our well-functioning ecosystems are tremendous.

And when we talk about conservation of the ecosystems, we need to compute these values, only then we will be able to say that okay these areas should not be diverted for mining, because mining will not be providing us with these high amounts of profits, or in certain cases these areas should not be dammed, because then all of these benefits will be lost. So, only when we do such computations can we arrive at these decisions.

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Module 8: Conservation of biodiversity Benefits from conservation

### Often ecosystem services are about choices

NPTEL

- 1 tsunami protection wall or mangrove forests, e.g. Odisha
- 2 water purification plants or wetlands, e.g. Catskill mountains
- 3 artificial pollination or honeybees, e.g. Israel
- 4 sewage treatment facilities or forests, e.g. Kakreta

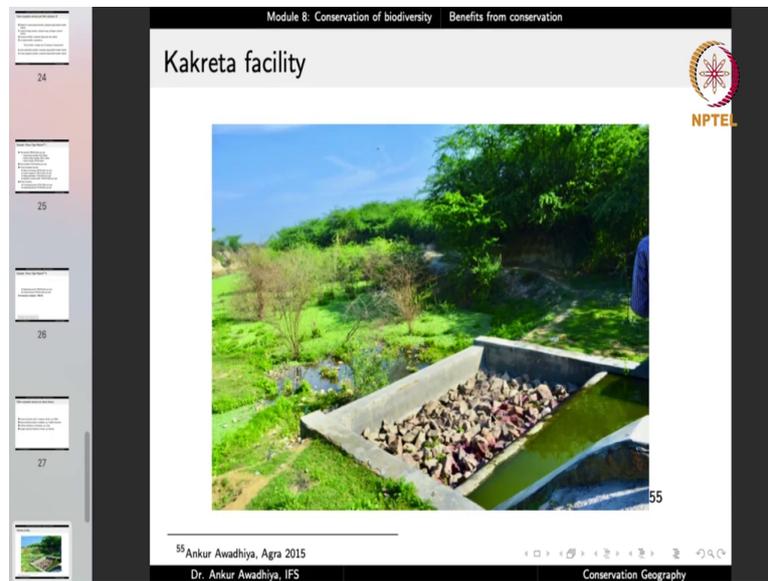
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Now, often the ecosystem services are about choices, because most of the benefits that the ecosystems are providing can be had from certain other ways. But then, what is the choice that we wish to make as a society? For example, mangrove forest protects us from tsunamis, the impact of tsunamis, but then as a society we can decide that no we do not want mangrove forests, let us build a tsunami prediction wall for an exorbitant amount of money and let us maintain it, this is his choice.

Similarly, in the case of water purification benefits, we can either make use of wetlands, as the city of New York is doing or we can make use of water purification plants. So, if a water purification plant is being set up in your locality, you can always ask the question, why do not we just conserve our wetlands, because the wetlands will provide us with the water purification benefits plus they will also provide other benefits such as tourism, recreation, jobs.

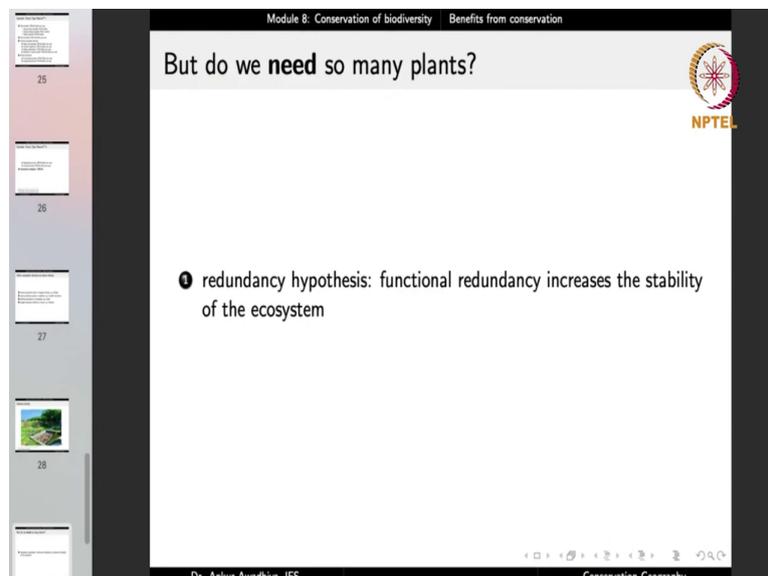
Similarly, we can either do artificial pollinators or we can make use of honeybees. Now, in the case of well-functioning ecosystems, we already get the pollinators for free. Whereas, in countries like Israel, now people are developing systems to rear these insects to rear honeybees and other bees to be used for pollination. Similarly, if we talk about sewage treatment facilities, we can make use of forest to treat our sewage.

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A very good example is Kakreta facility in the city of Agra. In this case, the sewage water is moved through an artificial wetland through these forests, and these forests not only treat this water, but also reduce the volume through the process of transpiration. And so ultimately, the effluent load into the river is reduced. So, these are all different choices.

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Now, the thing is if we wanted to have these ecosystem benefits, is it okay to just have a plantation forest in which case we only have a single species or do we actually need so many species? Because you will often hear the argument that okay we are cutting down this natural forest and we will raise a teak plantation, in which case we will be able to harvest timber which has a higher value and because timber teak is also a tree, so we will also get all the ecosystem benefits.

Well, it turns out that a single species can never replace the whole forest for two reasons, one is the redundancy hypothesis, the functional redundancy increases the stability of the ecosystem, one mechanism by which this happens is because the plants support each other.

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So, in a forest, there will be leguminous plants that provide nitrogen to all surrounding plants, there will be big sized trees that will support the shade loving plants, there will be tall plants that will be supporting climbers and so on. Now, different plants will support each other, and so this increases the stability of the forest all together. At the same time, it also acts as a backup against the diseases and other catastrophes.

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Module 8: Conservation of biodiversity Benefits from conservation

## But do we need so many plants?

NPTEL

- 1 redundancy hypothesis: functional redundancy increases the stability of the ecosystem
- 2 portfolio effect: diversification minimises the volatility of the investment

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So, this is known as the portfolio effect, diversification minimizes the volatility of the investment, meaning that if you wanted to invest your money, you do not invest it only in one mode, you do not just buy gold, or you do not just buy real estate, if you have a sum of money you will perhaps use some of it to buy gold some of it to buy real estate some of it you will keep in the bank and so on.

Because if one mode goes down, if one mode goes bust, if the price of gold reduces or if the real estate market is down, then at least you have some other ways through which you are keeping your investment safe. Now, similarly if you have a monoculture, if you only have teak plants, and if there is a disease of teak, then the whole forest is wiped off, you are left with only a bare piece of land, which will get eroded in no time.

But if you have a large diversity of plants, then even if there is a disease that completely wipes off many species, there will be other species to take its place. So, it keeps the whole investment safe. So, these two impacts help us understand why we need a well-diversified ecosystem to gain most of the ecosystem benefits in the long run. So, that is all for today. Thank you for your attention. Jai Hind!