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NPTEL ONLINE COURSE
Ecology
Ecological footprint
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One of the objectives of this few lectures is to introduce ecology for people who are non-ecology background or non-biology background. So, I would look at why do we need to study ecology and environment.

So, I am showing some pictures which are just happening in our backyard most of the time, and we may not be observing it because we may not see it happening. But at the same time, this is all over the place, and we need to pay attention to this, so I am initially showing some of the impacts of our activities on the environment, our immediate environment and we will go from there to the need for studying in ecology as a background.

So, for example, this picture shows, you know, for example, we throw plastics and other non-biodegradable waste into the environment, this is the backyard picture of famous monument or some historical structure. So every place that we visit we can see that there is a you know due to human mismanagement of waste, waste is thrown around everywhere, especially plastics and non-biodegradable waste.

So, this example, is sometimes wildlife gets affected, the picture showing a deer dead which has consumed plastic because we package food and other things in plastic and we throw it outside, and we do not know who will be consuming that waste which we have thrown out. For us it is

waste, for the other animal it becomes sometimes unknown accidental you know consumption of that food item, and it becomes, it causes death or lethality in the animal.

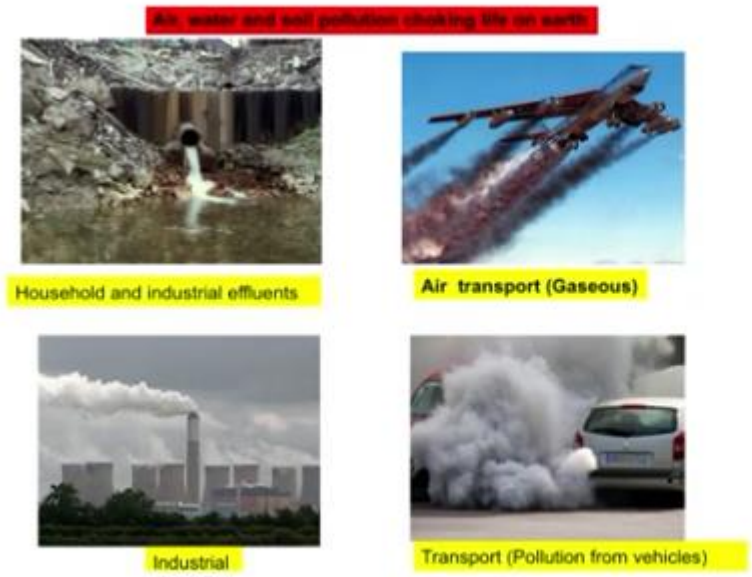
Pollutants discharged into water bodies (liquid)

The next slide shows how we, that is about how we throw around solid level of waste, the waste that is in the solid state.

The next picture shows most of our you know urban areas if you look at if there is any water body, let us say if you take Chennai city there are two rivers flowing through the city. So, if you look at any of this water bodies and if you go closer to any human settlements, there you will see that there is a lot of household and other waste; that is basically when we take water in, which is potable in nature and when we flush the water comes out. We do not know where it is going and the water is ending up in. This most of the time in freshwater bodies like either lakes or rivers or a oceans, not fresh water essentially ocean also, so we do not see again this pollution that is happening because it is happening at the backyard of our households, so this is an example of a pollution which is in the liquid state.

And so soil pollution, for example, is another cause of worry, which again we do not see it is invisible, but it because soil is also very live entity with a lot of living organisms there, but it threatens whole lot of life on earth, for example, if you put you know some soap solution or a detergent solution into soil you can see that how earthworms die and you know come up immediately.

So similarly, there are so many you know chemicals and other invisible you know agents that we are throwing out into the environment which is causing damage to living systems around us.



And then look around for the, you know, gaseous form of pollution that is all around us in the form of, you know, either transportation, industrial, or you know transportation of various means which are all causing gaseous form of pollution. So, we have all kinds of pollutions that is around us, so why do we need to worry about this?

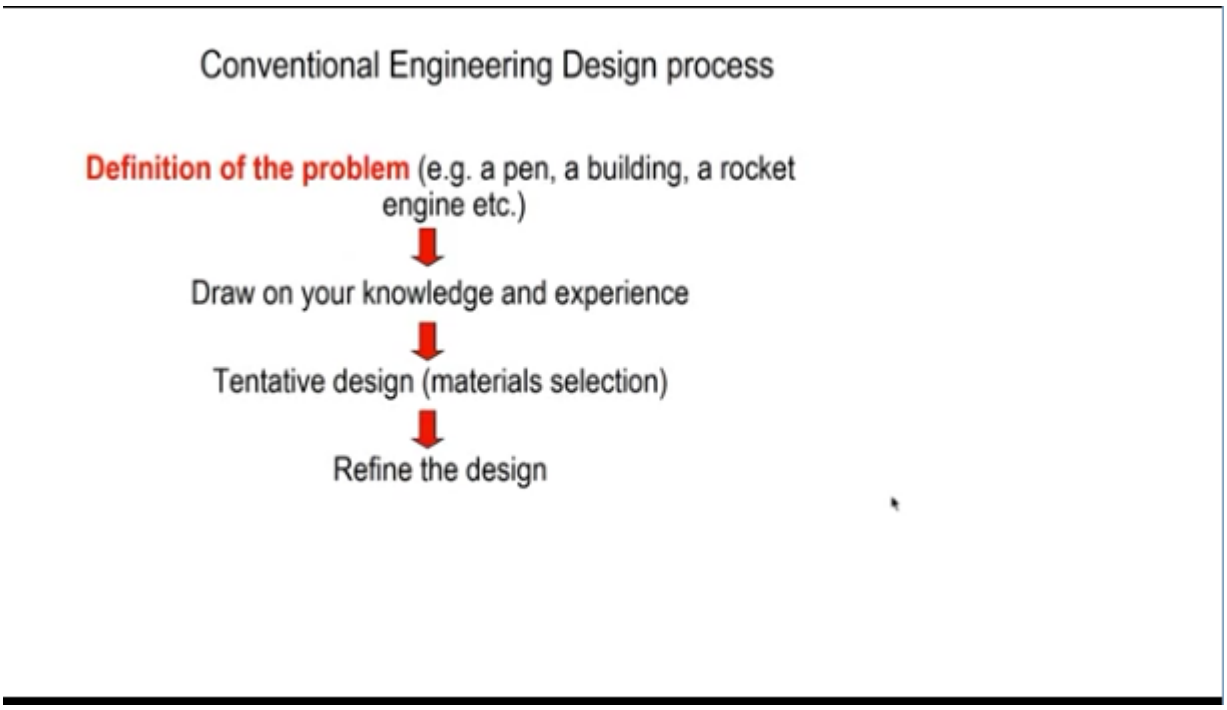
- Human life is intricately connected to other forms of life on Earth and its environment
- Hence life and its interactions with the environment in any form are important in engineering decision making by humans.
- Human activities should not engage in destruction of life forms.

So that life, especially, I mean all forms of life and because we are talking about why we need to as human beings, why we need to study ecology. We cannot disengage ourselves and say that ecology is something else which I do not need to know, I need to know because human life is

intricately connected to other forms of life on earth and its environment. As I said in the, you know, we will be discussing this because of the system concept that comes in ecology and ecology, you need to know that you know our life is not something that we can separate out, it is like the human body. If I take it has different systems which are working, for example, if we have you know blood circulation that is controlled by circulatory system, or digestive system which takes care of our food, how it is digested and you know the nutrients are absorbed in our body or if I look at you know the nervous system, for example it controls all our muscle activities, all other activities of our body, but at the same time we cannot take out each of the system and say that live human being can work independent of let us say nervous system or let us say you know the other different systems that are called muscular system or any other system that is contributing to the whole well-being of that system.

Similarly, the life on earth is actually is intervened with many other factors that is you know, that is making life possible on earth, so hence life and it is interactions with the environment in any form are important for engineers, especially this course is delivered to engineers and scientists and so are others who are not studying ecology per say. So, it is very important in our day to day decision making, and that decision making can affect the environment and the ecology, and in turn, the ecosystem services that is rendered to us by the ecosystems.

So, human activities should not engage in destruction of life form should be one of the principles that need to be followed here. So, now as an example, I am taking a conventional engineering design process in which how do we look at a problem, for example, so an engineer is given a problem of designing let us say, pen or a building or a rocket or engine or let us say mobile phone or you know a television, or a radio or whatever.



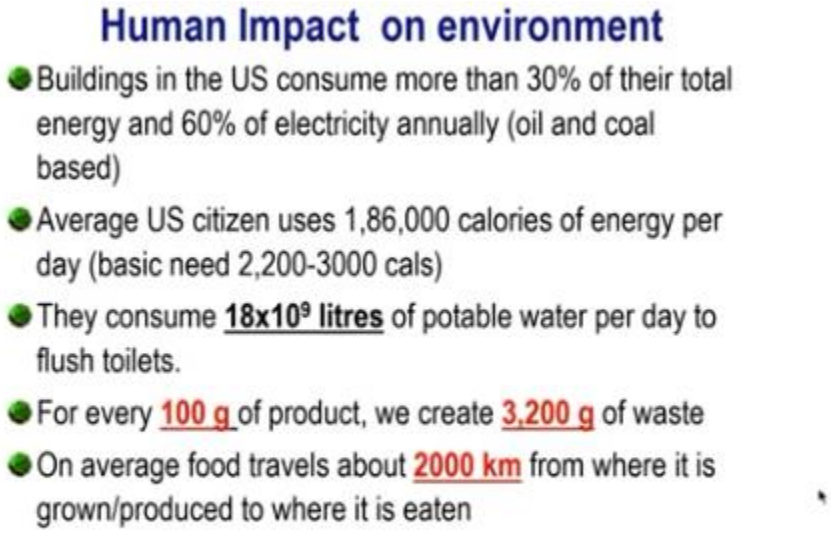
So that product when you are designing, you do certain steps which are iterative in nature, which is like drawing on your four years of engineering education or whatever.
And then drop on that knowledge and the experience to come up with a tentative design, at that stage, we, you know to select materials or whatever that we want to use and how is it going to perform, how is it function, how is its cost etcetera. So many parameters we optimize at that level, and then if there is anything that is not refined that level we will further refine that design and then get to the final design of the item that we are thinking.

But then in the conventional engineering design process, for example, we consider three constraints, these are cost, safety, and level of performance. So, these are the questions normally asked to any engineer who is designing let us say you know product let us say you know a pen or a mobile phone or whatever, what is the cost? Is it safety use? What is its functionality? Level of performance is it in a compliable with a 3G or 4G or whatever. The question we always or normally forget to ask is, are there enough resources on earth to design this product or process? Are we impinging upon earth resources to live? What is meant by this earth's resources? So, if an engineer is using a material you may be thinking it is just availability of that material, let us say you are designing a car, one of the resource material that is required for the functioning of the car would be the energy requirement which could be coming from let us say non-renewable source like petroleum or diesel. So, the question is like it is a resource that is coming from earth, whether it will be sustained throughout or whether it can be sustained throughout or not.
Then next question that could ask I mean that when you are taking up this energy does it affect other ecosystems and compromise the functionality of the other life forms that are sustaining there.

Let us say we need energy again for lighting up a particular place or lights and usage of electricity, so the question is where does the energy come from? So, it is again could be from various sources, it could be from hydroelectric power, it could be from nuclear power, it could be from solar power, it could be from various sources. Let us say there is a hydroelectric power that is coming, so does it compromise? Let us say on any resources that is required, so it is taken from water, and you turn turbines to generate electricity.

But at the same time you also will know that hydroelectric dam, if you have to construct, mostly it is constructed in catchment areas where rain falls and that could submerge large areas of forest land which could be compromising on earth resources for rejuvenating the functionality. For example the source of water that is produced from the forest are compromised by doing that the operation of designing a dam in that particular locality.

So, there are invisible damages on the resources sometimes, sometimes it is direct damages or direct taking up of resources and nonreplenishability of the resource could be a problem. Second could be damaging the functionality of the resources, third could be you know polluting the resources. So this could be happening during the lifetime of that product, it could be from, if I look at the life cycle of a particular product it could be from the raw material you know availability to the end of the product when it is thrown out into the environment or when you want to dispose it, how is it disposed? Through this lifecycle of a particular product, you will be compromising on, or we will be compromising on many of earth's resources that will be used during its lifetime.



So, the human impact if we want to then on environment, there are many examples we can indirect or direct impacts. For example if we take buildings they look like you know dead systems where there is no you know particular thing that we can assign as on environment, but at

the same time buildings require for example sometimes heating or sometimes if it is an hot country you require cooling. So, these buildings, for example, consume whole lot of energy, an example is in the US, for example, many buildings consume more than 30% of their total energy is consumed by buildings itself, and 60% of electricity annually which is oil and coal-based. So, it shows the indirect impact on the environment or the earth's resources in terms of buildings.

Secondly average, this is citing US citizens but that is the case down today you can average it to any developed countries including India, China, any other country, the citizens who can really afford luxury life or even life which is middle class would be called as could be using this kind of energies that I have written in this PowerPoint. So average US citizen uses about 1,86,000 calories of energy per day.

So human need, for example, us if you take as an animal let us say every animal we can classify saying that it requires certain amount of energy. And human beings we can say that we require something like 2000 to 3000 calories, so instead of that we use a something like 1,86,000 of something of the order of you know, so if you look at the requirement it is a huge you know multiplication that is required to arrive at this number that is given here which is indirect use of various forms of energy that is required.

So, we will come to this when we are looking at the ecological systems and energy flow in ecological systems, we will realize that the human beings if you want to fix us into the food web, where do we stand? So, if we were taking only 2000, 3000 calories it means that we are just eating the food and then sustaining ourselves, but that is not the case, we require energy for not just food alone, we require for housing, we require for transportation, we require for material needs, we will see how this translates into our energy requirements.

So, then we are also consuming a whole lot of fresh water which is potable in nature, especially for applications like you know flushing toilets, so the water becomes completely non-usable or non-potable at the instant that we use for purposes like you know washing, cleaning or flushing toilets etcetera. So, the water becomes unusable which is just equivalent to the water pollution or the pollution, the pollution that effluent that comes out of you know household itself.

Similarly, for every 100 gram of product today we create about 3.2 kilograms of waste, so that is the story everywhere, any product that we take, everything is packaged, that packaging means we are creating more and more waste elsewhere.

On an average, similarly food is also traveling a whole lot of distance today, so from where it is produced or grown or produced which is also causing to where it is eaten. For example, if you look at the rice, or the wheat or the fruits or whatever that we are eating today, where is it originating and where is it cultivated, and how is it transported across to different continent sometimes. Different you know large distances, before it is reaching our table, so this also means lot of energy consumption and also pollution during the transportation of this materials.

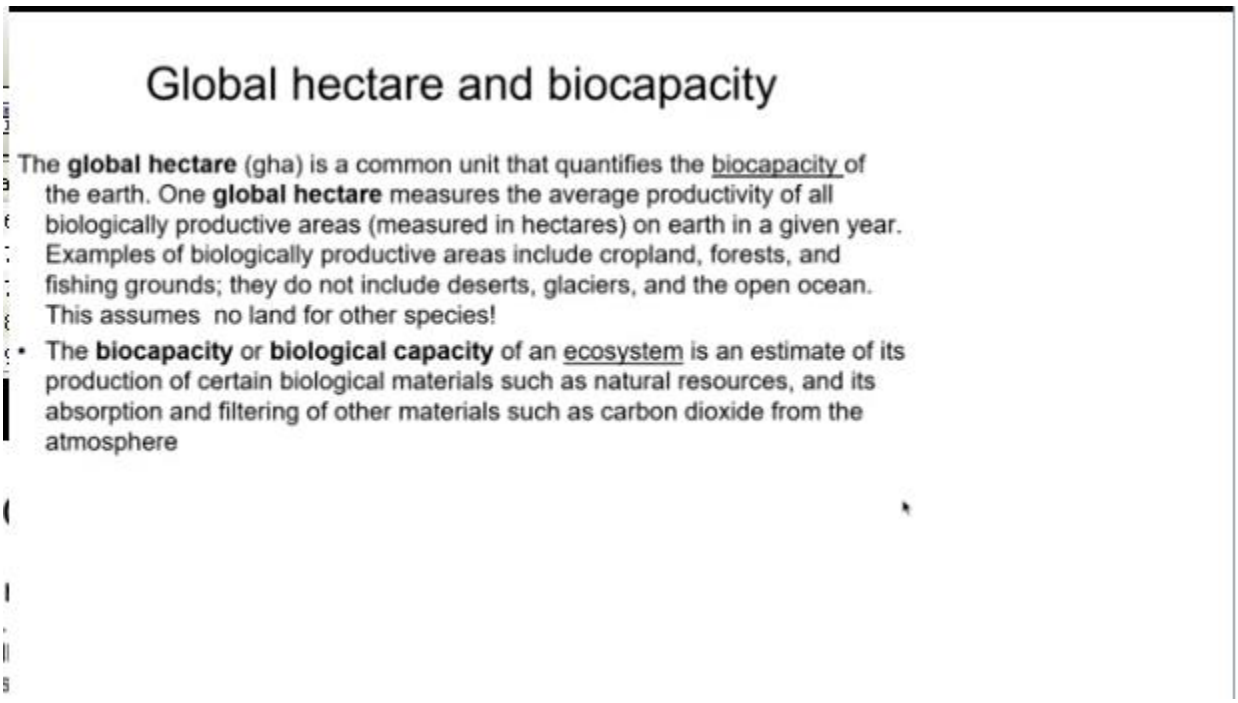
So, the level of environmental destruction rises with the volume of stuff consumed and with the distance it traveled. So how do we know what is its impact? All these things that we are consuming, the amount of materials that we consumed and the distance that it travels it has an impact, is it possible to measure it? So, this measurement, what is the impact of us on the environment? Is given in terms of a quantity called ecological footprint, many of us would have heard a term called carbon footprint, but it is very important for us to know not just carbon footprint, the ecological footprint is more important for us to define why, how life can be sustained on earth if we need to do that.

So, ecological footprint, for example, for it is given for any, I mean North American, it is about 5 hectares of arable land or a cultivable land per person per year; So, but the world has only 1.2 hectares of usable land per person. Which means if we can, on an average if every person gets only 1 hectare of land, if we are very affluent society, and having a lifestyle which is equivalent to the upward middle-class lifestyle, we will be requiring something like 5 earth instead of 1 earth, that is the meaning of this.

So, this ecological footprint is nothing but it is a measure of the land, so we can translate all our requirements into some form of land usage. So this is a land requirement for growing our food, processing our organic waste, we are not at all talking about even you know non-biodegradable waste and other things, we are talking about only processing our organic waste even that require some land area, sequester our carbon-dioxide and provide our material needs.

So, if we include all this we will get something called ecological footprint. There are different kinds of ecological footprint calculators on the web, one can go and use those calculators and put in the numbers that you use, for example, if you are traveling by car, or by scooter or by bus or by cycle or walk, you can see what is your footprint. Ecological footprint, which is actually sum of various things that is you know put together as shown in this slide, the ecological footprint has carbon footprint, food footprint, housing footprint, and goods and services footprint.

The average per capita footprint is given in quantity known as global hectares by consumption category, so each of this is given us, for example, the total footprint which is given here is can be divided into four categories, one is carbon footprint, food footprint, housing footprint, goods, and services footprint.



So, this footprint, the quantity is given in global hectares, and this global hectare is a common unit that quantifies the biocapacity of the earth, so we are going towards why ecology is important, and where all these our material requirements, where our food requirements, all our

needs for energy, where are all these things getting translated into, and how we are affecting ecosystems, how we are affecting the environment, how we are affecting the ecosystem services that biosphere is providing us.

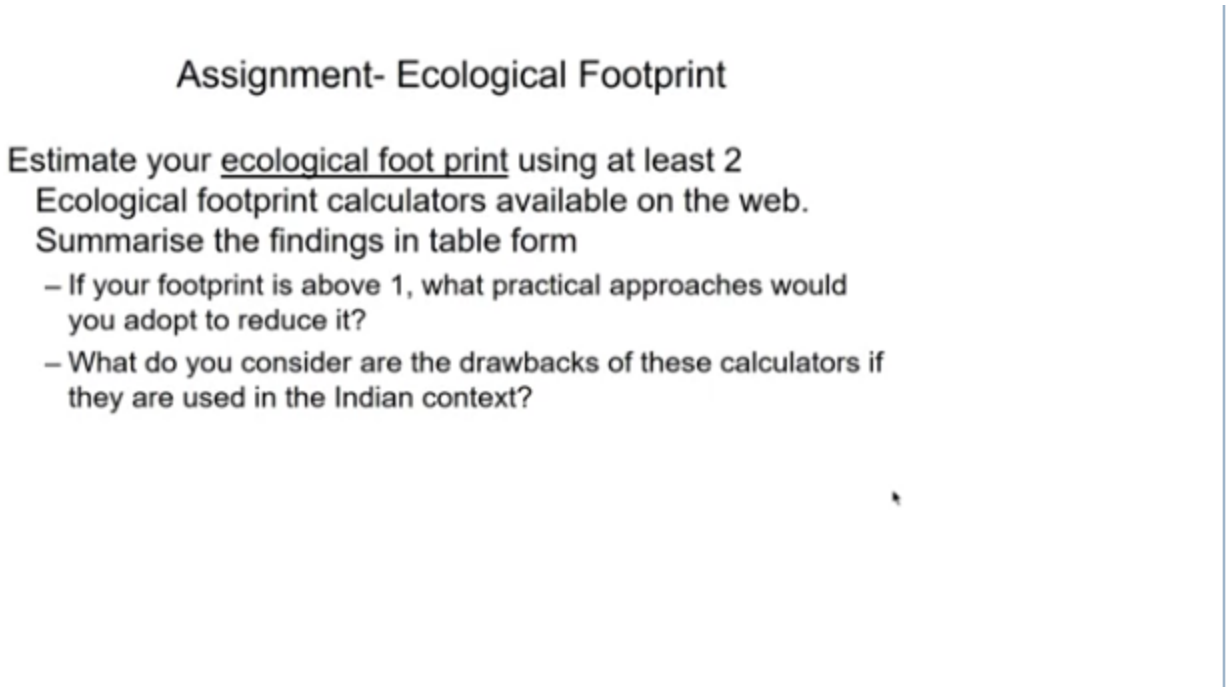
So, the global hectare is a common unit that quantifies the biocapacity of the earth. What is the biocapacity? It is the biological capacity of an ecosystem which is an estimate of its production of certain biological materials such as natural resources, and its absorption and filtering of other materials such as carbon dioxide from the atmosphere. So, it is essentially the biological capacity of an ecosystem.

So, one global hectare measures the average productivity of all biologically productive areas which means, for example, if I look at you know carbon-dioxide absorption on earth, it is exclusively carried out by living organisms such as plants or you know the systems which can absorb and convert them into useful matter.

One global hectare measures the average productivity of all biologically productive areas measured in hectares on earth in a given year. So, examples of biologically productive areas include, it could be a farmland or it could be forest, or it could be some fishing ground, but they do not include this, the calculation of biocapacity does not include non-biologically though they are also biologically active in a very limited fashion, limited way. Deserts are not included, glaciers and the open ocean are not included in the calculation of this global hectare. So the remaining available land that is producing, that is having plant mass, and other life forms which can absorb the carbon dioxide and also can provide some natural resources is only considered in the calculation of this global hectare.

So, this is also assuming that no other species is existing. This global hectare calculation assuming that there is no other species, we are the only consumers for all the resources that earth is producing which is not a correct estimation, so if we adjust for all the other species also the availability of that global hectare that per capita footprint that is available to us will shrink further.

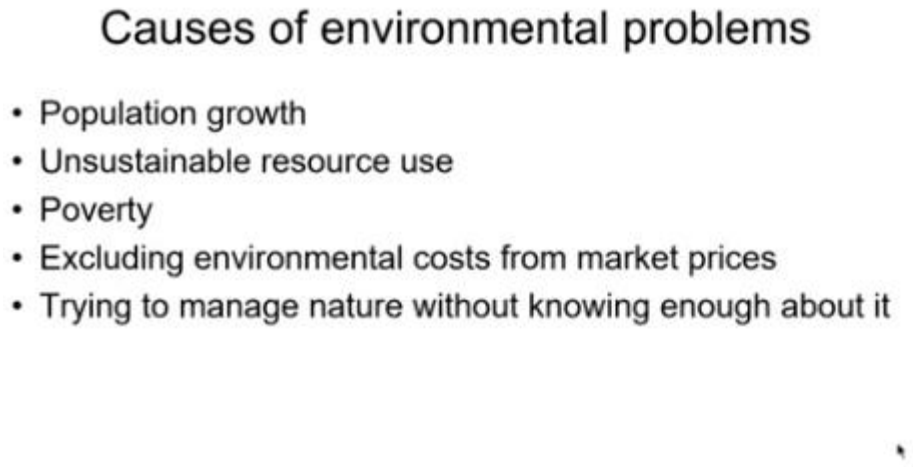
So, now we are exploiting the earth with the assumption that there is no other species requiring any more, any land area, any natural resources, they do not need to process carbon-dioxide, all these assumptions are taken into account to get this number here which is not accurate.



So, you can also do an assignment of calculating your own footprint and using two different calculators and see, if you see that your footprint is above one. The global footprint if equal to ecological footprint being equal to one means, you are able to meet your requirement using the current earth that we have, that is one earth is only required. But if it is above one, let us say if it is two it means that two earths are required to meet our requirements or if somebody is getting let us say 5 physiological footprint, it means you require 5 earths to meet your requirements. So, the question is if your footprint is above 1, what practical approaches would you adapt to reduce it? There are various means that when you are doing the calculator, using the calculator available on the web you can see that there are various ways in which you can reduce a footprint.

For example, your footprint using a means of transport, currently let us say you are using car to go to office or you know motorbike to come to the class. So is it possible for you to switch to a public transport system like a bus or you could walk to the office or it to the school, is it possible to reduce your footprint? Or for example, the food that you are consuming today, is it possible to change the kind of food that you're consuming to something which has lower footprint or the kind of lifestyle that we may have, we may using you know energy, more energy consuming devices like you know air-conditioners or other devices when it is not required also at certain times of the year, is it possible to reduce the footprint by reducing the energy, so these are the changes that is expected here.

Similarly, what you consider or the drawbacks of this calculators if they are used in the Indian context, this many of this ecological footprint calculators are developed elsewhere, but are there any drawbacks if you adapt it to an Indian context?



So, now if you look at all this, all the causes of environmental problems there are multiple causes to it, one is like population growth, so there are multiple reasons being cited in literature, I am just citing few of them. So one is population growth. So as human population is growing, the demand for us you can see with the ecological footprint that you are calculating, the demand for the resources of earth is increasing and also the waste under the pollution that we are creating is increasing.

Similarly, unsustainable resource use, what is meant by unsustainable resource use is again? The rate at which resources can be produced, for example, if you take certain resources we call as non-renewable resources, an example is you know petroleum or diesel. So, if you take they have forms available on earth or let us say, they call, these are all deposits which are energy sources which are available on earth, but that has transformed into that energy or usable material form over millions of years of transformation that has happened to renewable source like plant materials which have died long time ago. But currently if you want to convert any of the plants to let us say gasoline or diesel, it is not possible you know unless you put a lot of energy to convert them back into energy of diesel of petrol.

So, if we consume the let us say the non-renewable energy sources like diesel or petrol at very high rates, and then we will not be able to replenish them at the rate at which we are consuming it, or let us say we are cutting a tree to make furniture. So, for the conversion of that to a product of our use it took maybe only one week's time, but at the same time to grow that tree back to that level it may take 30 or 40 years. So, it is an unsustainable resource use in some sense because the rate at which you are consuming is not the rate at which you are replenishing it.

Similarly, poverty also can be causing environmental problems excluding environmental cause from market prices which is also an environmental problem. And trying to manage nature without knowing enough about it, this is one of the biggest you know mistakes that most of us

are making and because we are part of this whole complex system and we do not know what we are doing is, how is it affecting the earth's functioning and the ecosystems functioning.

So, are there solutions to such problems? So the current emphasis on environmental problem is if there is a pollution clean it up using environmental technologies. So, if you look at to the future what we call as sustainable solution, if you want to look at we have to think about preventing, producing the waste itself, which are known as clean technologies or it could be waste disposal. So current practice is to bury or burn it, so is it possible to prevent the disposal or the pollution prevention itself.

So current again emphasis on environmental problems protecting species, for example, we here always protecting a particular species or the other, let us say we talk about lions of Gir in India, they need to be protected so, or for example, we will hear about tigers, so these are all species-wise protection. Are there other species existing in this let us say if you take Gir sanctuary, are there any other species there? Or if you take a tiger sanctuary, we hear about lot of tigers and their protection, but do we hear about other species that exist in those upon this sanctuaries which are their habitats. So, our focus should shift from just species to protecting the habitat because that is very important, the species are vanishing because the habitat is not protected, not because species required a special protection against poaching or you know special protection against only one aspect of it, it is multiple aspects of protecting the habitat, is important for protecting the species.

Environmental degradation, so the current emphasis is to reduce the environmental degradation, but the future sustainable solution should be towards restoring the environment to its original clean state. Similarly, increasing resource use is one of the emphasis today of our human needs, we require more and more resources that is available on earth. So is it, so reduce the less

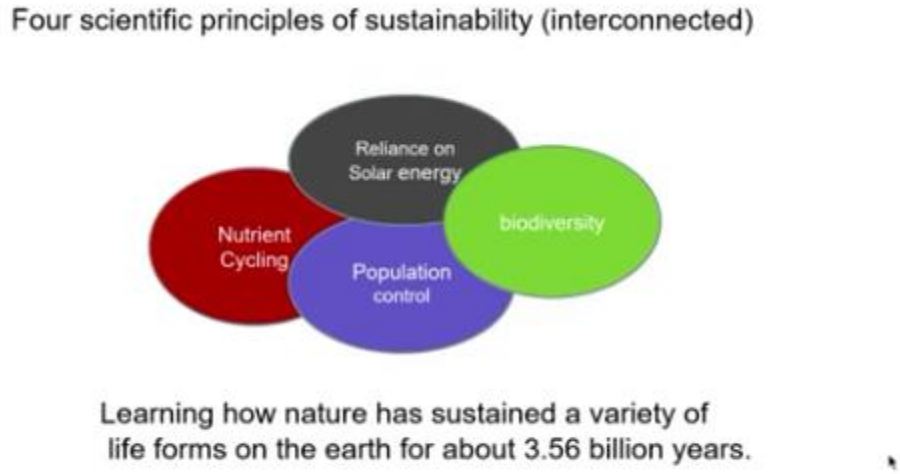
resource wastage, so we can shift to, so most of this resource that we are gathering today for various uses need not be utilized more effectively, so is it possible to reduce the resource waste? An example is in engineering you can think of reducing the material usage in design or reduce the usage of energy.

So, if you come up with energy efficient devices or material efficient devices let us say a mobile phone, does it have to be a very large device, can I design with less material and less energy consumption, so that is actually a pro method towards reducing the demand on resources. So basically you can avoid the resource wastage in those circumstances. So as engineers you can do many things or scientist or others who are looking at you know lifestyles, or you know usage or designing systems, you can think of alternatives which will reduce and then focus on sustainable solutions.

Similarly, population growth, we are you know currently focusing on, so, for example, many times we hear that you know certain countries of population is declining, certain countries population is growing exponentially, this is altogether human impact if you take it is a global impact rather than if we subdivide into different categories or different countries or different nations. The human impact is global, so whether it is climate change or whether it is you know causing compromising the quality of environment. So, it is important to stabilize human population, so when we come to ecology, we can try to understand every species as you know certain number, in the population that it can reach for a sustainable long-term survival.

So, is there an upper limit that we can set for human population? Is it required to go to that the level at which it can, or should it go on increasing? So, if any species when it is increasing in number, the number, the population dynamics will shift towards more problems. Depleting and degrading natural capital is the current emphasis, so it is not only that we are taking away the natural capital which is in terms of various resources that is available to us. So we have to see the earth's ecosystems and the services that provide, that we are getting as natural capital, so the emphasis should be shifting to protecting natural capital, it should not be you know designing or looking for, for example exploiting what is the maximum possible way of exploiting that is, what is available in nature.

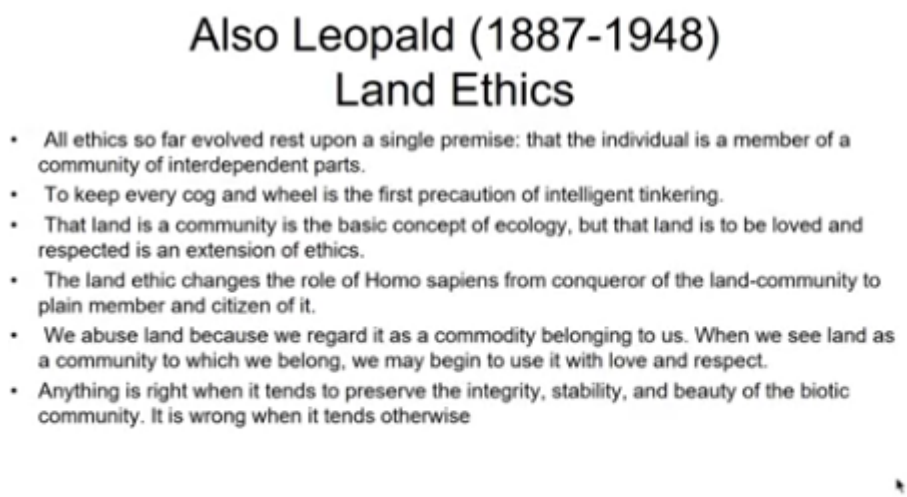
So, the four scientific principles of sustainability which are interconnected are, so that is what we learned from nature that earth has been you know living with this different life forms for about 3.56 billion years, it is not that we have come only like few seconds ago if you put it on across on a clock which is having 24 hours.



Human beings have appeared just before this 24-hour clock if I take it will be just you know the last few seconds of the clock.

So, if we are in this 3.5 billion, 5, 6 billion years of earth's existence. There were many many life forms which have come and gone and many times earth has undergone different periods of box of mass extinctions of species. All this has happened, so we learn few lessons from this, we should learn few lessons from this for to live harmoniously on earth and which includes this sustainability principles. So, this sustainability principles involve this four circle shown here, so that shows that these are interconnected. So, for example, all earth's living systems are dependent on solar energy, so similarly this leads to the biodiversity on earth and this solar energy. How it is used for biodiversity and then that biodiversity is again linked to population, so how each species and its population is controlled within this biosystems, and the diversity is dictated by the interactions between this energy that is flowing into the system and the kind of population that is interacting with each other.

And similarly, the non-interactive part is, I mean the non-living part of it is the nutrients which are cycling through the system, which is also very essential for the existence of life on earth. So this four circles dictate or interconnected circles dictate how life is sustained on earth and how we should look into the future to sustain life on, in a sustainable fashion we can live.



So, the pioneer in environment Aldo Leopald, he has talked about the ethics of you know how to live on earth and how we can reduce our damage. So all ethics so far evolved rest upon a single premise, that the individual is a member of a community of interdependent parts. So it is a very important principle here that we have to remember that each of us are a part of the community of interdependent part. We do not have an independent existence, so whether it is non-living nutrients or whether it is the community that we live in, or we are you know interacting with the other relevant of earth.

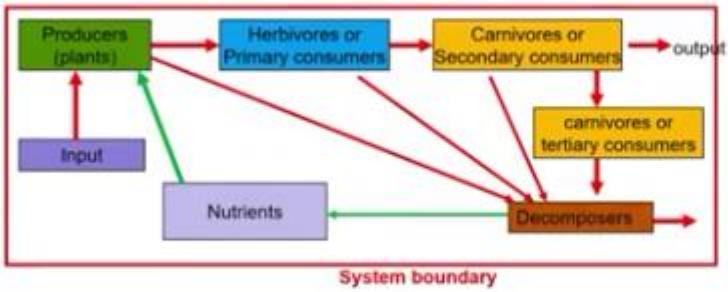
So to keep every cog and wheel is the first precaution of intelligent tinkering. So we have to think, if we are thinking animals which are part of this system, we have to think about keeping every cog and wheel in its place, and that land is the community is the basic concept of ecology, but that land is to be loved and respected in an extension of others. The land ethic changes the role of homo sapiens from conqueror of the land-community to plain member and citizen of it. So we should not be as individual species which are existing here, human beings are homo sapiens should not look at land or someplace to conqueror and own up and do whatever we feel like, instead we should be living as a member of this community which is contributing towards its well-being. So, we abuse land because we regard it as a commodity belonging to us, we sell and buy land, and we do various things once we so-called own the land, we do various things, so this should not be done in a way that will affect the existence of life on the land.

When we see land as a community to which we belong, we may begin to use it with love and respect. Anything is right when it tends to preserve the integrity, stability, and beauty of the biotic community, that means the living system should be allowed to leave and be, it is wrong when it tends otherwise that means when we try to destroy the integrity, stability, and beauty of the living systems we are doing the wrong. And that is what is causing problems to the environment and the ecology.

So, now when it comes to ecology we ask many questions here. So ecology is the, so first question is what is ecology, we have defined it, or you have studied it in school as well, it is a study of how organisms interact with one another, and with their physical environment of matter and energy.

- What is ecology?
  - Ecology is the study of how organisms interact with one another and with their physical environment of matter and energy.
- What keeps us and other organisms alive?
  - Life is sustained by the flow of energy from the sun through the biosphere, the cycling of nutrients within the biosphere, and gravity.
- What are the major components of an ecosystem?
  - Ecosystems contain living (biotic) and non-living (abiotic) components.
  - Some organisms produce the nutrients they need, others get their nutrients by consuming other organisms, and some recycle nutrients back to producers by decomposing the wastes and remains of organisms.

The living organisms (biotic community) of a habitat and their non-living environment function together as one unit called the ecological system or ecosystem



What is ecology?

That is in a nutshell if you look at it, it is a, ecology is nothing but living organisms or biotic community that is interacting with the nonliving environment or which is the surrounding system, that is the input, that is nutrients and other things that is going into the system and then

the living community which is inclusive of your the food web that is producers, herbivores, carnivores, decomposers, all this are the biotic community.

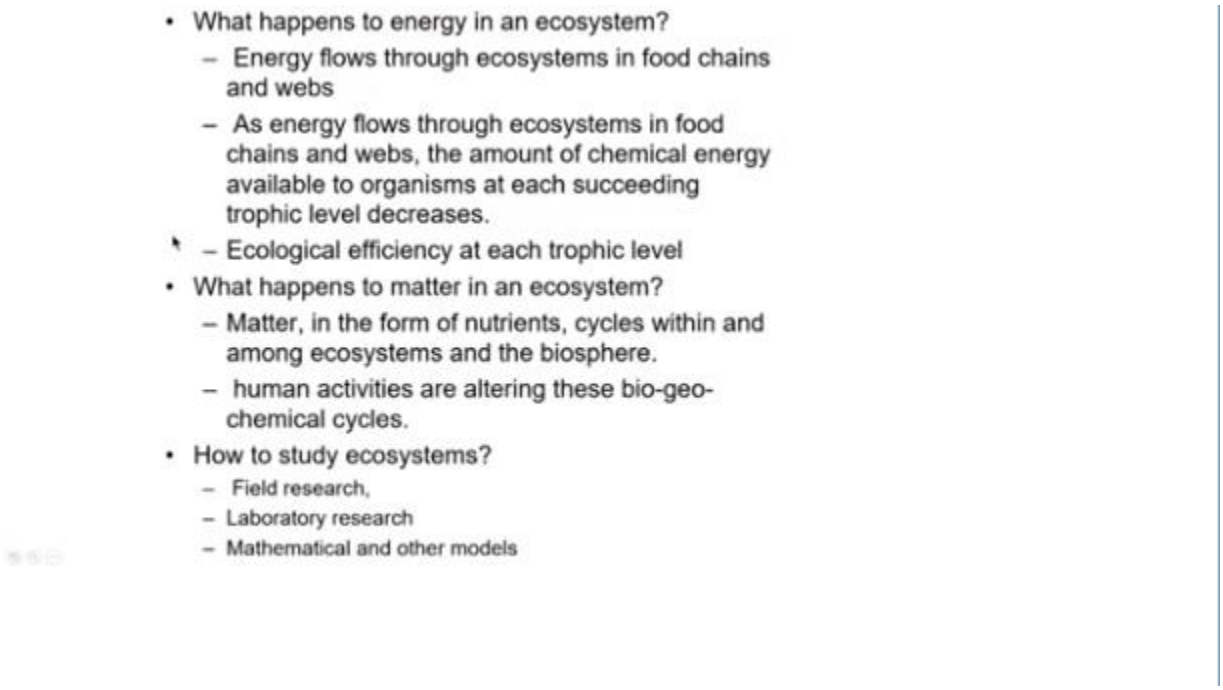
So, the living organisms of a habitat and their nonliving environment function together as one unit called ecological system or ecosystem. So this is the definition of, so this system has, every system has a kind of boundary which is the little loose definition, so this is not the boundary which is, so it can be also defined because it is a system, it may have a boundary which may be defined in various ways thermodynamically.

So, the next question is what keeps us and other organisms alive? So, life is sustained by the flow of energy from the sun through the biosphere, the cycling of nutrients within the biosphere and gravity, so the earth with its natural resources that is generated by the flow of energy from sun sustains life on earth.

Next question is, what are the major components of an ecosystem? So as we have defined ecosystems are living that is biotic and nonliving abiotic components and some organisms reducing nutrients they need, others get their nutrients by consuming other organisms or in some other recycle nutrients back to producers. So you could see that the system that we have seen has all the components that is some of them are using the nutrients, and it is flowing from one level like producers to herbivores to carnivores. Or it could also be directly producers may get decomposed, herbivores will get decomposed or carnivores will get decomposed. All this decomposition again brings back the nutrients in a cyclic manner into the system. So the important concept that we have suggest nutrients cycling in the, is one of the important component that maintains life on earth.

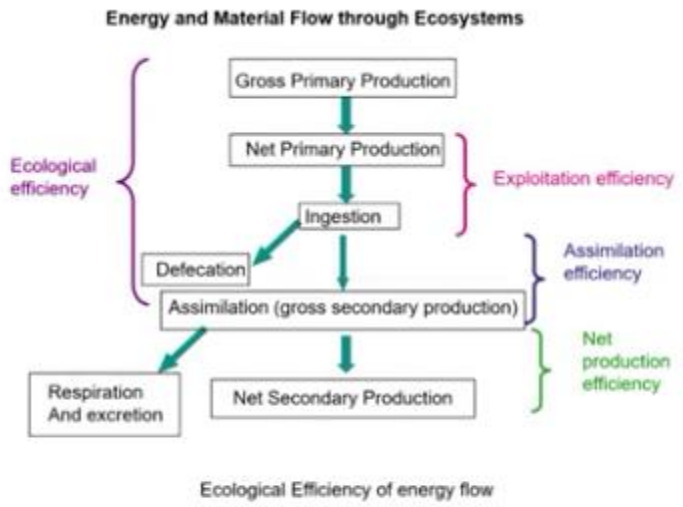
So, if you break this components by doing various things, so now if you look at this cycle that is shown here in the system, you can see the human intervention at various levels, humans can disturb, many aspects of this cycle by interfering at each stage. So we could, so you can think and list what are the interferences that humans do at various stages in this ecosystem that we have shown as a food web or as a energy flow diagram or as a nutrient flow diagram. All this ways you can represent a food web in this or we can show an ecosystem, so basically how, for example, as though we are a part of this ecosystem, how for example we may be interfering in each of this stage and disrupting the energy flow and the material flow in this systems. So that is one of the negative contributions of human beings to the system.

So, all other living systems if you look at whether we want to look at producers, herbivores, carnivores, or any other animal, what do they use? They use only the input, that is the material that is flowing into the, so the only energy harvesting system that is available here is the producers or the plants and then from their energy is flowing into the next level through the food that is consumed by herbivore that is they eat plants. And then they get the energy for their sustenance, and then from there the energy is flowing into carnivores, so if you look at that the only energy, direct energy harvesting, solar energy harvesting agent here is the plants which are producing it.



So, the next question that arises here is what happens to the energy that is in ecosystem? So the energy that is flowing through the ecosystems and as we know energy is flowing through the ecosystems in food chains, and webs. So as energy flows through ecosystems in food chains, and webs, the amount of chemical energy available to organisms at each succeeding tropic level decreases. So you can see that in the previous diagram, so when from producers to herbivores there is some efficiency with which energy is flowing.

Similarly, from each of this stage if you take there is an efficiency that we can look up, and that is very important, so that is why it is known as ecological efficiency at each tropic level.



Ecological Efficiency of energy flow

So, how does energy and material flow through these ecosystems is an important thing that we need to understand when we are looking at ecology. So, when we understand this as I said there is a definition of ecological efficiency here. So the ecological efficiency can be defined in various ways, so one is that a net primary production or NPP that is the net primary productivity of plants, so the gross primary production is the first stage which is like taking energy from sun. Plants convert that energy into useful glucose or you know matter and that glucose is transferred from the plants. That is the, so the gross primary production is nothing but the total energy that is produced by the plants, and from there they use some energy for their respiration and other purposes so that gross primary productivity minus respiration will give us the net primary production.

And from the net primary production that is what is the plant mass that we see growing on earth, okay. So the herbivores let us say take up the plants, so that is the next level of energy flow. So this is the second level, this is for the plants how the energy is flowing, and then the next level is how the energy is flowing in the next level that is the herbivores. So, it is defined as the exploitation efficiency, how efficiently a herbivore is exploiting the available food sources that is present there. So basically they will ingest the food and some amount will be defecated and lost from the system and remaining things will be assimilated which will be used for their growth.

So, this growth is considered as the gross secondary production here. So the efficiency is calculated as assimilation efficiency at this stage so what is remaining as after defecation is the assimilation efficiency. So then from the herbivores so basically they also have respiration and excretion which happens and depending upon the amount of energy that they are using. So the remaining amount that is the net secondary production, so basically net primary productivity or primary production happens at the plants level, net secondary production will happen at the herbivore level.

So, you can calculate what is known as the net production efficiency from this, so you can see the ecological efficiencies defined as the sum of this or the processes that goes on from gross primary production till assimilation of the nutrients in a herbivore. So that is the ecological efficiency of the system.

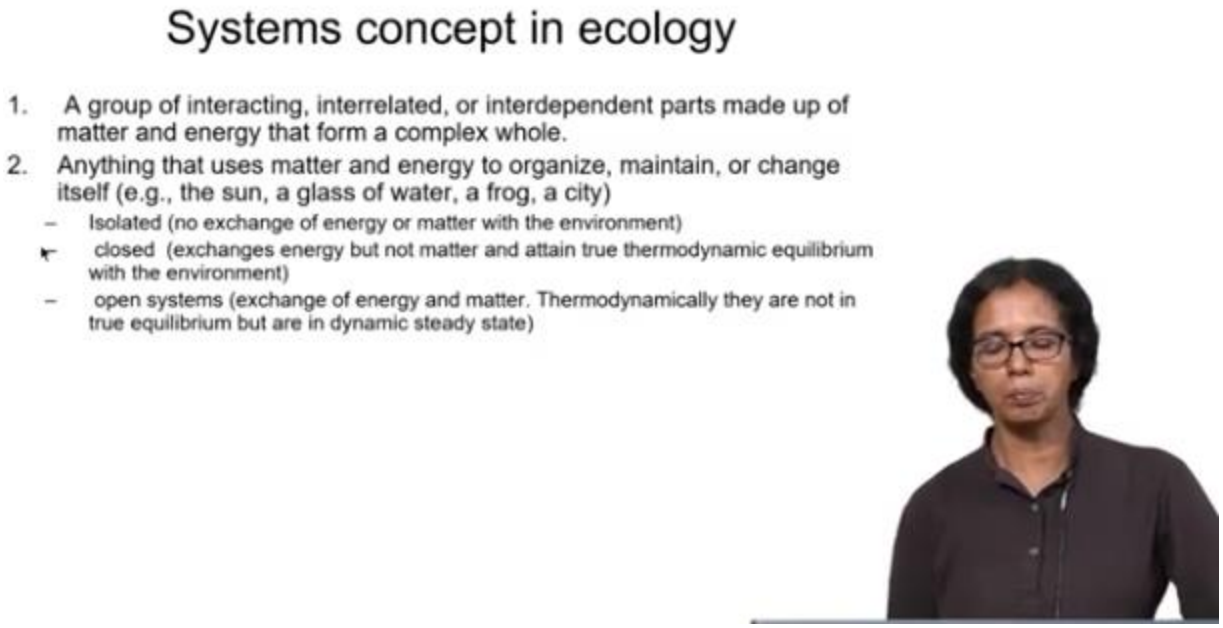
So, the question is what happens to matter in an ecosystem? Matter in the form of nutrients, cycles within and among ecosystems and the biosphere, so this is very important that you know, the nutrients have to, if we break the cycle in various ways that we interfere then the question of you know the nutrient availability and the flow in the ecosystem and among the ecosystems will get affected.

Human activities are altering this, so these are known as the biogeochemical cycles. Thus you know the water cycle, the nitrogen cycle, the phosphorus cycle, the carbon cycle, all this are examples of the nutrient and the biogeochemical cycles which is very important for the sustenance of life. For example, if a cycle is broken and let us say particular nutrient is not available to the ecosystems, so the ecosystem will get deprived of the nutrient and they will you know start dying out or you know declining in its existence.

How do we study ecosystems? That is one of the questions that come up there are various ways in which ecologist or trained people who are studying ecosystems. So they do field research, examples are like you hear about the census of wild animals, so or to find out you know how the population of a particular animal is changing or a particular species is increasing or decreasing or how the population dynamics of it is over a period of time. Or it could be the behavior of a particular animal. One needs to know for example what are the food habits of a particular species, let us say bird or let us say particular insect, what does it eat? How does it you know behave in a particular environment? All these are studies which ecologist may do, so it could be at a system level, it could be at ecosystem level, it could be at individual species level, it could be at community level, it could be at behavior level. So there are various ways in which one can study by going to the field and directly observing the individuals or the communities.

So then you can also do laboratory research to understand ecosystems. So sometimes there are various experiments that are conducted in inside laboratories, for example, population studies, you can do using small organisms like single-cell organisms or paramecium or some algae growth or you know other or bacteria, yeast, all these organisms can be used for studying. Let us say population or behavior, how they respond to environment, all these parameters can be varied and then looked upon in a laboratory itself to get insights about how species behave, but it could be different from what exactly could be happening in the field for different organisms.

Similarly, we also, it is not that the ecology is a subject which is only descriptive in nature, it uses a whole lot of quantitative data which is involving mathematics and statistics. For example, if one wants to understand the ecology of a place, you need to study the population dynamics which is involving lot of mathematical models and statistical estimations. And sometimes it is a physical models and other chemical models are required also to study ecosystems and the flow of energy and matter in the ecosystems as well as the behavioral study, other aspects of ecosystems.



So, the system concept in ecology is very important, so why do we emphasize this? A group of interacting, interrelated or interdependent parts made up of matter and energy that forms a complex whole. So anything that uses matter and energy to organize maintain or change itself. So these are considered you know, brought in to elaborate on the systems concept in ecology, so that anything that uses matter and energy to organize or maintain or change itself, it could be you know a glass of water, it could be a frog or a city. These are all systems which will be either organizing or maintaining or changing itself at every given point using matter and energy.

So based on the systems concept, ecosystems also can be considered as either isolated systems which means there is no exchange of energy or matter with the environment, it could be a closed system. For example, if, you know, enclose some organism inside a completely closed container, which does not have any exchange of matter or energy with its surroundings, it could be considered as an isolated system and how it behaves could be studied.

Closed system, exchanges energy but not matter and attain true thermodynamic equilibrium with the environment, so these are all based on the assumptions of ecosystems are also thermodynamics systems which are either isolated closed or open systems. So open systems exchange both energy and matter, thermodynamically they are not in true equilibrium but are in dynamics steady states, so this is mostly the case of, most of the ecosystems they are in dynamic steady state and they are not in the true thermodynamic equilibrium.

So, there are examples of natural ecosystems which could be any wetland or marsh or a swamp, a pond, lake, grasslands, forest, ocean all this could be examples of natural ecosystems which could be either terrestrial or it could be aquatic.

- Some examples of natural ecosystems are: Wetlands,ponds, lakes, grasslands, forests etc.
- The non-living (abiotic) : air, water, soil and the basic elements and compounds of the environment
  - The climate regime and physical factors like temperature, R.H, etc.
  - Inorganic substances such as water, C, N, S etc.
  - Organic substances like proteins, lipids etc.

And the nonliving part of it includes air, water, and soil, and the basic elements and compounds of the environment, which could be the climate regime and physical factors like temperature, relative humidity, all this affects the ecosystems.

Similarly, inorganic substances that also flows through the ecosystem, so they can also affect the state and the condition of an ecosystem, like water, carbon, nitrogen, sulphur, etcetera, all these materials flow through the ecosystems.

Organic substances which is also present in the, these are nonliving, but well required for the existence of ecosystems in the total this thing.

Thank you