Soil Fertility and Fertilizers
Professor Somsubhra Chakraborty
Department of Agriculture and Food Engineering
Indian Institute of Technology, Kharagpur
Lecture 60
Agricultural Productivity and Environmental Quality (Contd.)

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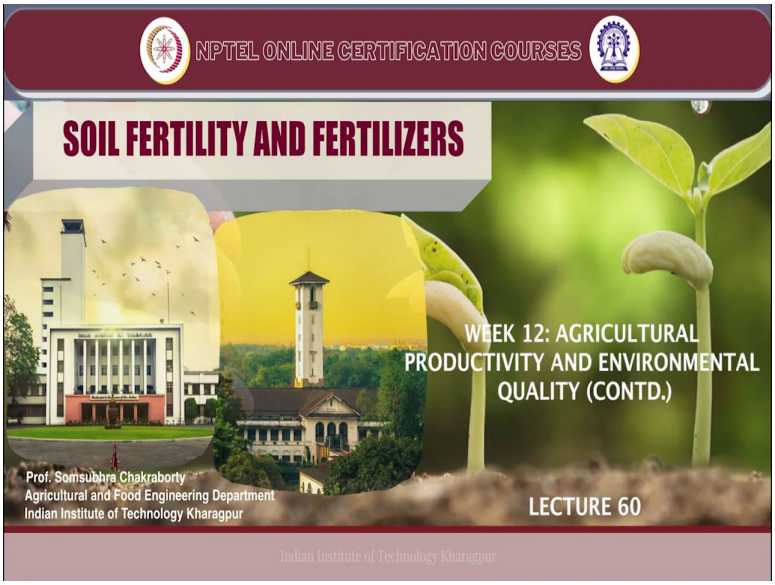

Welcome friends to this last lecture of this NPTEL Online Certification Course of Soil Fertility and Fertilizers. Today, we are going to focus on sustainable development goals and different types of ecosystem services. Now, in our previous four lectures of this week, we have discussed some important concepts. The topic of this week obviously, the agricultural productivity and environmental quality.

So, in the first lecture of this week, we have discussed about the carbon sequestration and how agriculture impacts carbon sequestration, how soil plays an important role for carbon sequestration. And in the second lecture, we have discussed about the fertilizer related pollution problems and how to mitigate those pollution problems using alternative sources like bio-fertilizer like manure we have discussed.

In the third lecture, we have discussed about the stubble burning which is one of the major cause of environmental problems in India, particularly in Indian condition. And in the fourth lecture, we have discussed about the advantages of conservation agriculture over conventional agriculture and how the conservation agricultural practices can impact the different types of soil physical and hydraulic properties, we have discussed in details.

Now, in this lecture, we are going to see what are different types of sustainable development goals and specifically we are going to discuss several ecosystem services and how they impact our surrounding.

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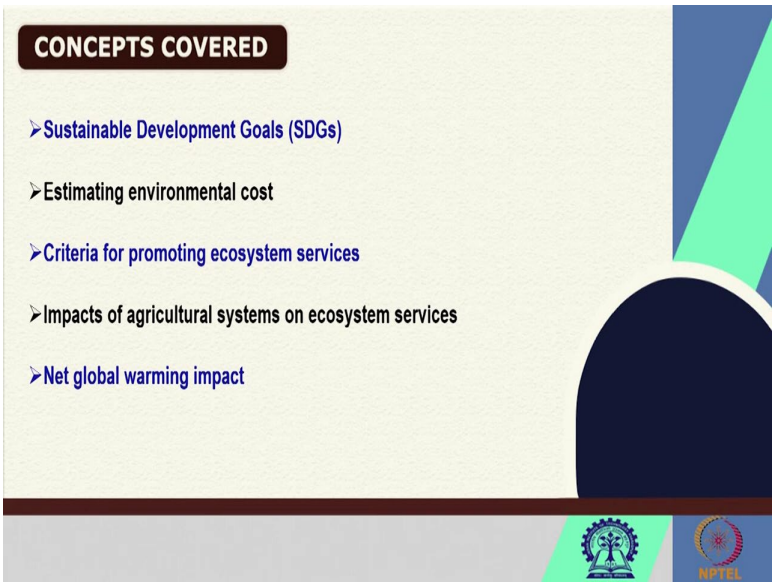

So, let us see what are the concepts which we are going to discuss. First of all, we are going to discuss the sustainable development goals or SDGs, then we are going to discuss about how to estimate the environmental cost. And also, we are going to discuss the criteria for promoting ecosystem services. And then we are going to see the impacts of agricultural systems on ecosystem services. And finally, we are going to see net global warming impact. So, these are the concepts which we are going to cover in this lecture.

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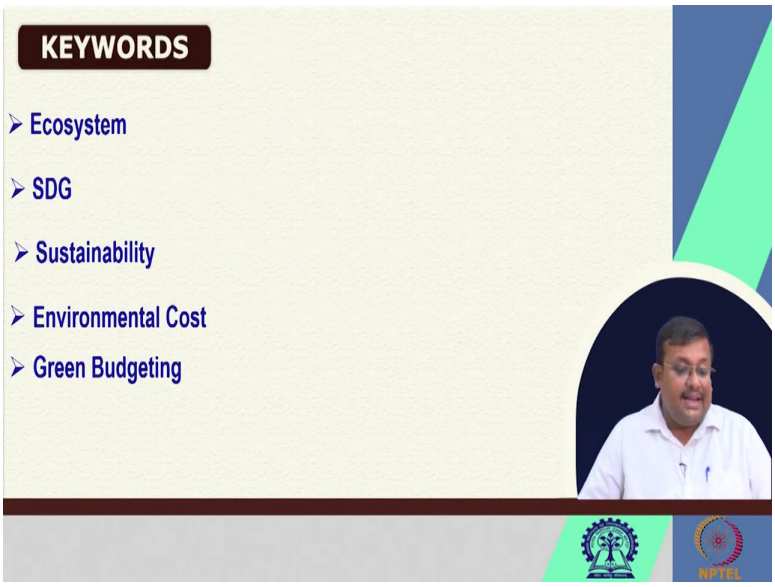

And these are some of the keywords like ecosystem, SDG, sustainability, environmental cost and green budgeting, which we are going to discuss in this lecture.

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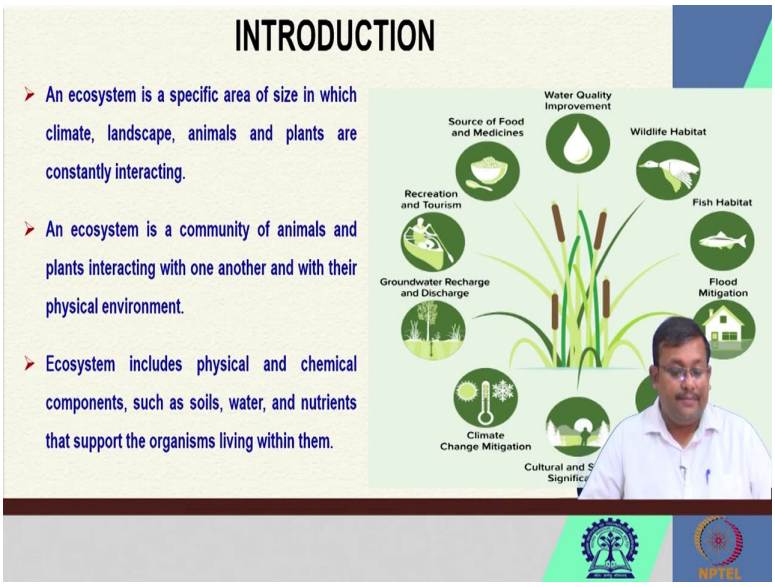

Now, we all know about ecosystem. However, I would like to recap or recall the definition of ecosystem, which is a specific area of size in which climate, landscape, animals and plants are constantly interacting. And remember that an ecosystem is a community of animals and plants interacting with one another and with their physical environment. Now, what includes an ecosystem?

So, ecosystem includes physical and chemical components such as soil, water, nutrients, that support the organism living within them. So, we can see that soil is an important component of the ecosystem and soil is constantly interacting with their surrounding living organisms to maintain this ecological balance.

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Now, we already have developed briefly about the sustainable development goal, but let us discuss more about these sustainable development goals or SDGs. Now, we know that these sustainable development goals or SDGs also known as the global goals were adopted by United Nation in 2015 as an universal call to action to end the poverty and protect the planet and ensure that by 2030 all people enjoy peace and prosperity.

Now, to enjoy the peace and prosperity it is very important to achieve these all 17 goals. First of all, no poverty, then zero Hunger, then good health and wellbeing, then quality education, then gender equality, then clean water and sanitation, then affordable and clean energy, then a decent work and economic growth, and then industry motivation and infrastructure, reduced inequalities, then sustainable cities and communities, then responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions and partnerships for the goals.

Now, these are the 17 sustainable development goals adopted by United Nations to ensure that people enjoy peace and prosperity worldwide. Now, you can see that the 13th goal that is climate action is a very important goal. And this goal is adapted to reduce the impact of

climate change. Climate change is one of the major issues of contemporary world and several research as well as several policies were implemented for reducing the climate change.

So, that is why the climate action is an important goal. And while we talk about climate action, of course, soil plays an important part as you know, because soil act as a storehouse of the carbon and thereby it can reduce the negative impact of the greenhouse gases by carbon sequestration. So, that is why we should focus, we should always try to adopt the best management practices for soil. Now, the next question comes to our mind, what are the major obstacles for achieving these goals.

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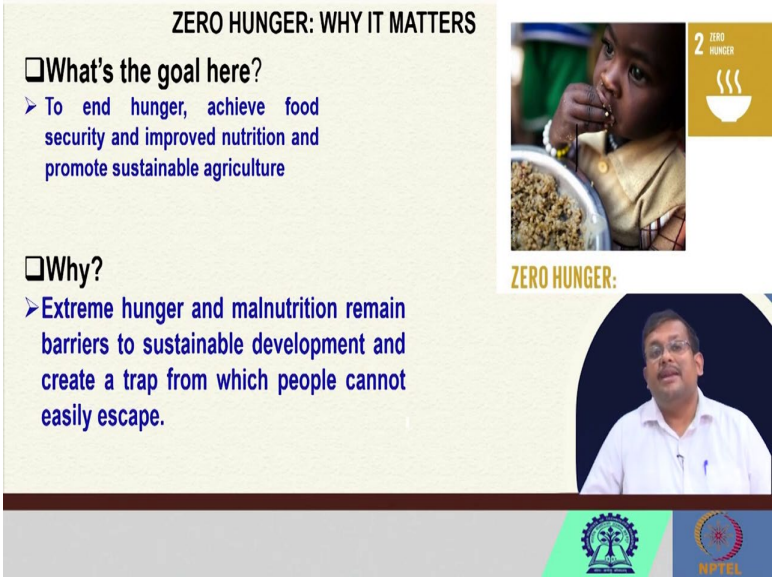

The major obstacles for achieving goals are hunger. Now, so, what should be our goal, so, to end the hunger achieve food security and improve nutrition and promote sustainable agriculture. Why? Because we know that extreme hunger and malnutrition remain barriers to sustainable development and create a trap from which people cannot easily escape.

Because you cannot expect 100 hungry-farmer to follow the environmental friendly steps, if he has a more economic action irrespective of whether that can create or that can bring negative impacts to the environment. So, first of all, we have to reduce this hunger and malnutrition so, that these sustainable agricultural practices can be performed by the farming community.

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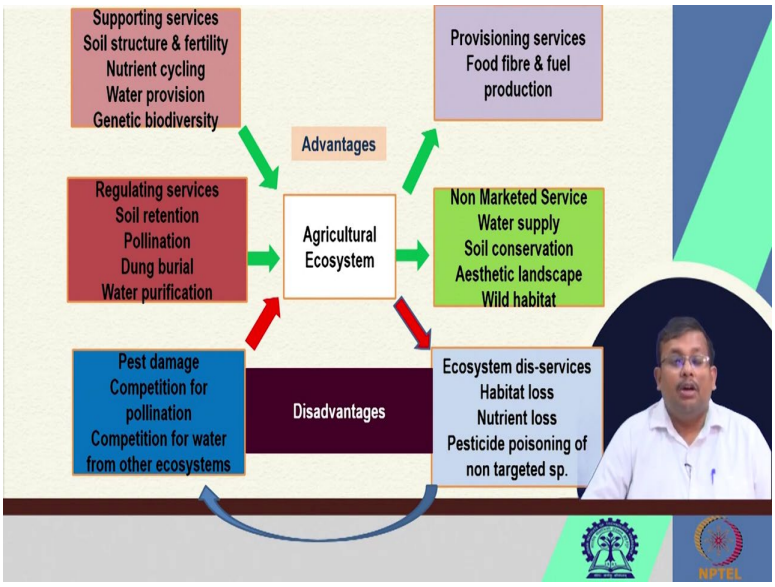

Now, if we see the agricultural ecosystem. Of course, agriculture ecosystem plays a very important role for producing several types of services we call it ecosystem services. Now, we can broadly categorize these services into four categories. One is supporting services. Another is provisioning services. Third one is regulating services and fourth one is non-marketed services.

Now, if you see the supporting services, under the supporting services we can see soil structure and fertility, then nutrient recycling, then water provision, genetic biodiversity comes under these supporting services. Under the provisioning services, food, fiber and fuel production. And then regulating services include soil retention, pollination, dung burial, water purification.

Nonmarketed services include water supply, soil conservation, aesthetic landscape, wild habitat. However, there are several ecosystems disservices also like habitat loss, nutrient loss, pesticide poisoning of non-targeted species, which ultimates lead to the pest damage competition for pollination and competition for water from other ecosystems. So, these are some of the disadvantages, which we can see from different types of ecosystem services.

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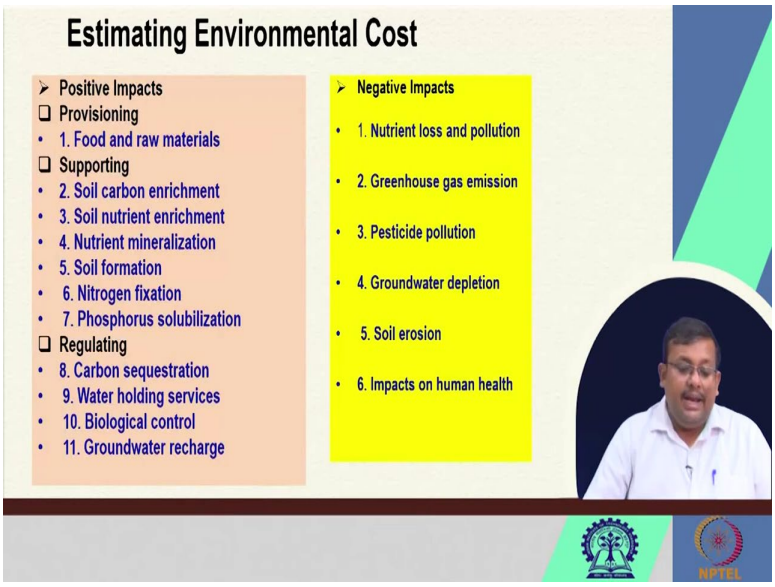

Now, the next question comes to our mind how we can estimate the environmental cost. Now, if we see broadly two category, one is positive impacts by different ecosystems services another is negative impacts. So, we can see but provisioning, the positive impacts are food and raw materials and the supporting services we know soil carbon enrichment, soil nutrient enrichment, then nutrient mineralization, soil formation, nitrogen fixation and phosphorus solubilization.

These come under the supporting services. In case of regulating services we know carbon sequestration, water holding services, biological control, then groundwater recharge, all these are having positive impact. But at the same time, there are several negative impacts also. Like we can see we call them ecosystem disservices like nutrient loss and pollution, greenhouse gas emission, pesticide pollution, groundwater depletion, soil erosion, and ultimately impacts on human health.

So, these are the negative impacts. So, we need to maintain a balance, we need to maintain always a positive balance which basically is calculated by subtracting the negative impacts from the positive impact. So, the environmental cost for ecosystem services is always calculated by subtracting the negative impacts from the positive impacts.

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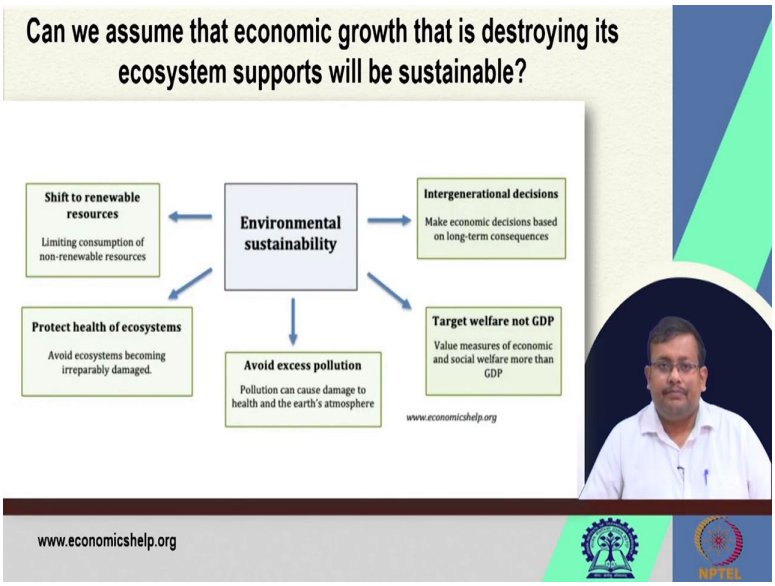

Now, then next question comes to our mind. Can we assume that economic growth that is destroying its ecosystem supports will be sustainable? Now, environmental sustainability is dependent on several factors. First of all, we need to shift to renewable resources. And we need to limit consumption of nonrenewable resources. We need to protect the health of the ecosystem and we need to avoid ecosystem becoming irreparably damaged, we need to avoid excess pollution.

And because pollution can cause damage to health and earth atmosphere. We need to maintain the target welfare not GDP because value measures of economic and social welfare more than GDP. And also, we need to maintain the intergenerational decision and make economic decision based on long term consequences. So, all these are needed to get the environmental sustainability goals.

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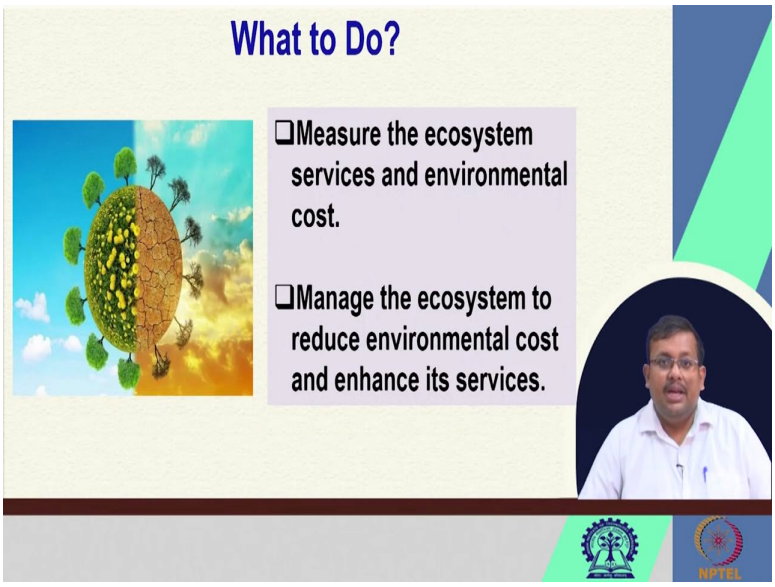

Now, what to do? First of all, we need to measure the ecosystem services and associated environmental cost. And then secondly, we need to manage the ecosystem to reduce the environmental cost and enhance its services.

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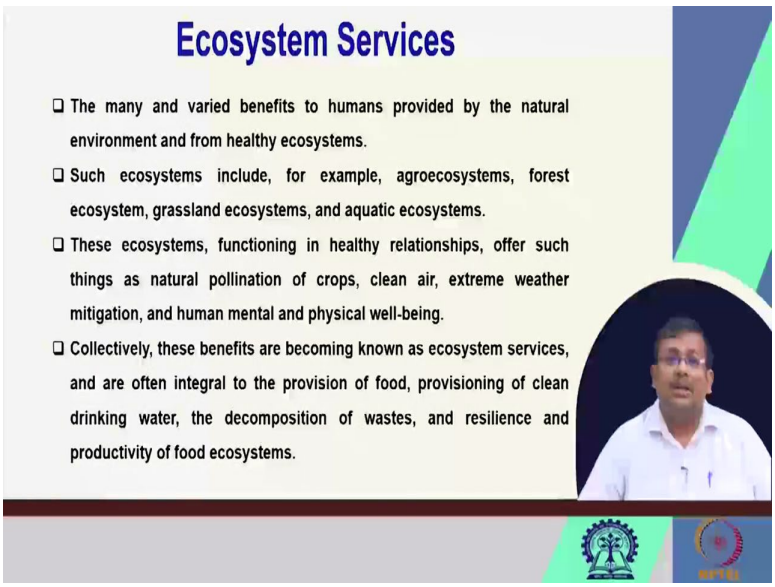

Now, let us see the definition of ecosystem services. Now, ecosystem services can be defined as the many and varied benefits to humans provided by the natural environment and from healthy ecosystems. And such ecosystem includes for example, agro-ecosystems, forest ecosystem, grassland ecosystem and aquatic ecosystems. These ecosystems functioning in healthy relationship offers such things as natural pollination of crops, clean air, extreme weather mitigation, and human mental and physical wellbeing.

Collectively, these benefits are becoming known as ecosystem services and are often integral to the provision of food, provision of clean drinking water, the decomposition of wastes and resilience and productivity of foods ecosystem. So, these are mainly different types of ecosystem services.

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Now, if we see pictorially the ecosystem services you can see that nature can give us a different type of components free like clean water, fish, food, pollination, cool temperature, control flooding, and then pollination. And we have to regulate these by controlling the flooding, then purifying the water, then storing the carbon and cleaning the air. And also, in case of cultural management, we should provide education, we should provide maintain the recreation, we should maintain the aesthetic beauty, and then stewardship.

And finally, supporting the support services we need to give buy food and then soil formation, photosynthesis, biodiversity, and habitat. So, these supporting services are given by these ecosystems like they give us food, they give us soil formation, they give us photosynthesis, biodiversity, habitat and stewardship. However, from our point of view, we should maintain the stewardship aesthetic recreation education.

And also, we should regulate this air quality, carbon storing, water purification, control flooding. So, these are different types of ecosystem services in four different categories like provisioning, regulating, culture and supporting.

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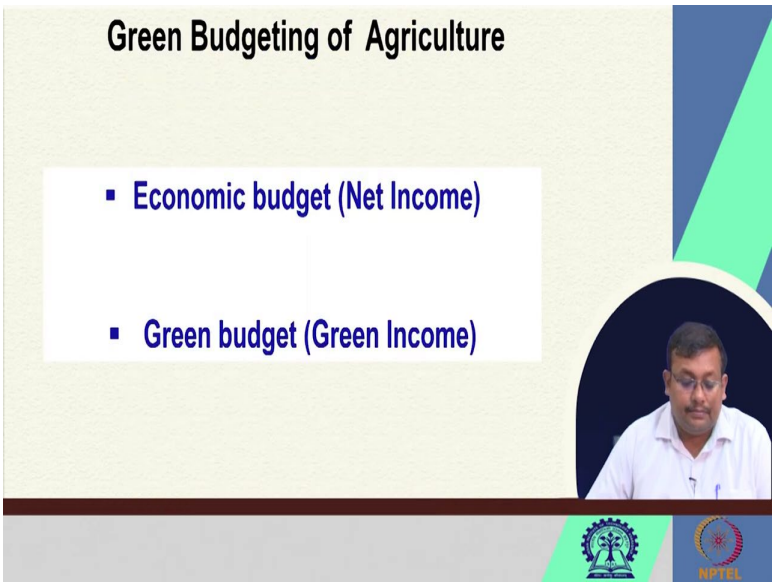

Now, the next important concept is green budgeting of agriculture. Now, here there are two terms, one is economic budget, which is basically synonymous to net income, another is green budget, which is also known as green income.

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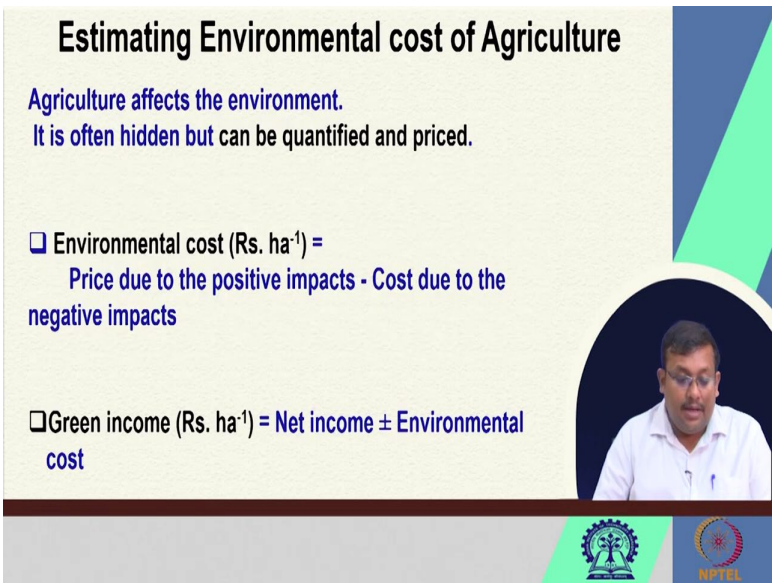

Now how to estimate the environmental cost of agriculture. So, agriculture, we know affects the environment and if it, it is often hidden, but can be quantified and priced. So, the environmental cost can be expressed in terms of rupees per hectare and price due to the positive impacts minus costs due to the negative impacts. So, if you subtract the cost due to the negative impact from the price due to the positive impacts, we will get the environmental cost.

However, the green income, which is also rupees per hectare is basically the summation of net income plus environmental cost, it could be positive or negative also, because plus minus environmental cost. So, we know now that what is environmental cost and what is green income.

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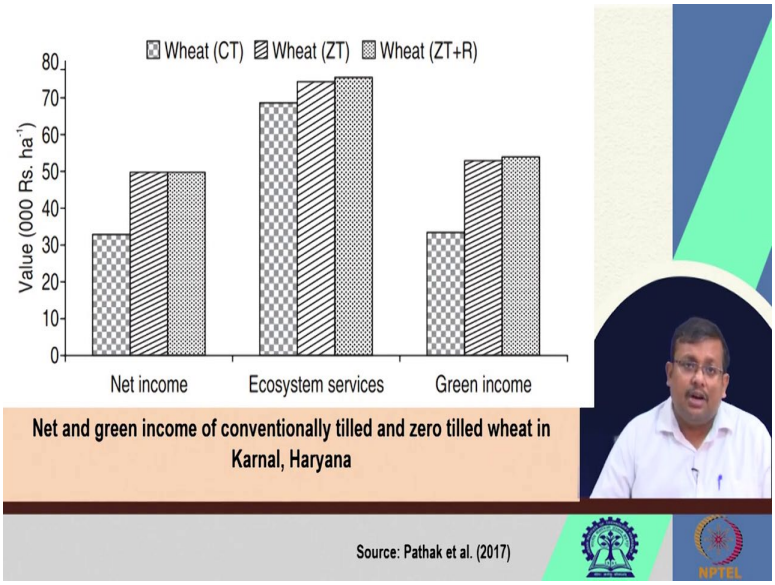

Now, let us see the comparison of net and green income of conventionally tilled and zero tilled wheat in Karnal, Haryana. So, here you can see this is conventional tillage, this is from zero tillage, and this is for zero tillage plus residue. So, you can see all the net income and then ecosystem services and green income are showing the similar pattern where the conventional tillage showed the lowest net income, lowest ecosystem services and lowest green income.

However, we can see that the zero tillage and zero tillage with residue shows almost similar net income ecosystem services and green income and they are always higher than that of the conventional tillage. So, that implies the benefits of using the different types of conservation agricultural practices as compared to the conventional agricultural practices.

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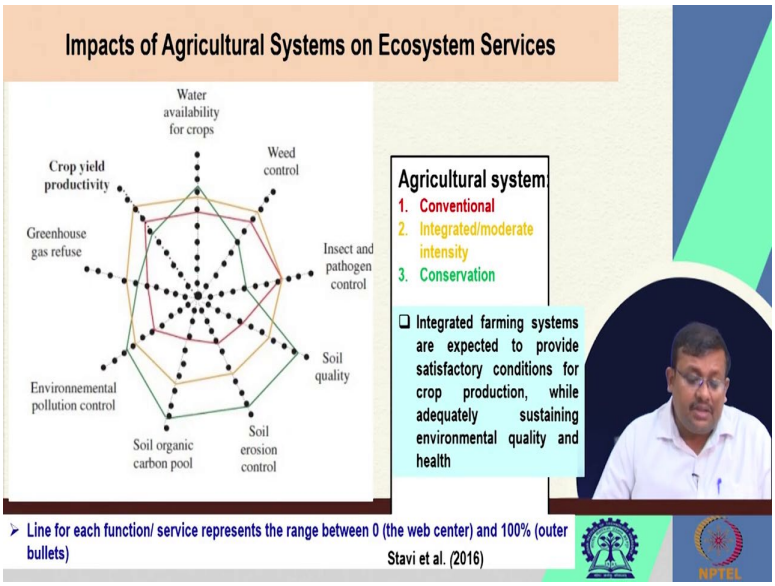

Also, we can see impacts of agriculture system on ecosystem services. Here, you can see how these different things are varying. So, you can see the conservation, when you follow the conservation agriculture, soil quality, then soil erosion control, soil organic carbon pool, and also the environmental pollution control and water availability for crops are higher than conventional and integrated or moderate intensity agriculture.

So, that shows the, and also if you see the integrated or moderate integrated farming system, you can see in case of integrated farming system, they can choose the higher crop yield productivity and higher weed control and then insect and pathogen control, and also, they also offered the soil erosion control also. However, conservation agriculture is most suitable for soil quality maintenance and soil erosion control.

However, conservation agriculture is not as good as other practices for weed control. So, integrated farming systems are expected to provide the satisfactory condition for crop production while adequately sustaining environmental quality and health.

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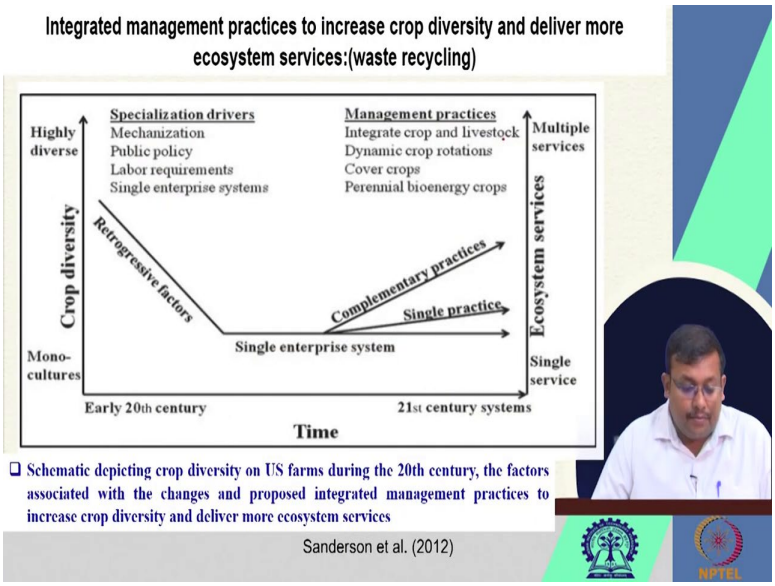

Now, also if we see the integrated management practices, how they can increase the crop diversity and deliver more ecosystem services. Here, you can see schematic depiction of crop diversity on US farm during the 20th century. And we can see here in the x axis, this is the temporal variation early 20th century to 21st century. And then you can see the crop diversity in the x axis and then ecosystem services.

So, when there is a high diversity there is high ecosystem services. However, you can see that as time progresses there were several retrogressive factors like mechanizations, then public policy, labor requirements, single enterprise system. So, those impacted the reducing the crop diversity and once they reduce the crop diversity ecosystem services also will reduced. And then you can see single enterprise system.

However, the adoption of different types of complementary practices like integrated crop and livestock, dynamic crop rotation, cover crops, perennial bioenergy crops have improved the ecosystem services in the 21st century systems. So, we can see here it is schematically depicting crop diversity on US farm. The factors which are associated with the changes and proposed integrated management practices to increase the crop diversity and deliver more ecosystem services.

So, you can see that different types of complementary practices like integrated crop and livestock and these dynamic crop rotation, cover crops specifically these conservation agricultural practices can help in attaining higher ecosystem services than what was previously achieved.

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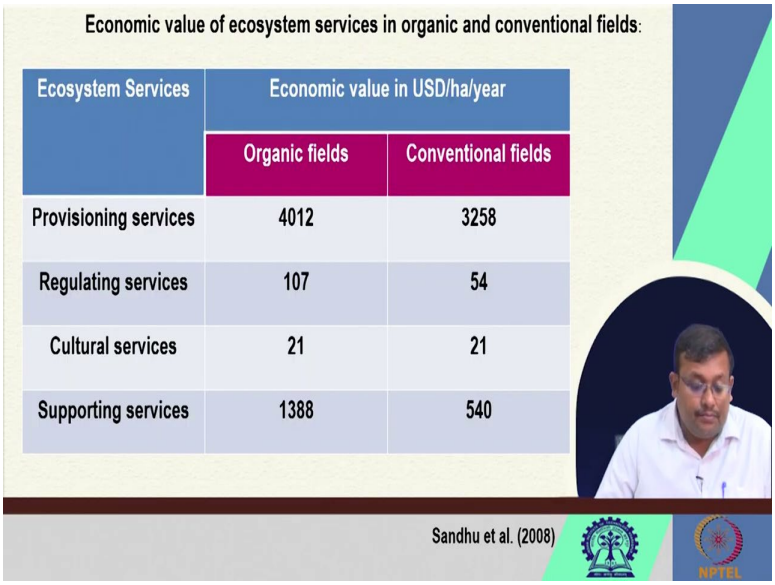

Also, if you compare the economic value of ecosystem services in organic and conventional fields, you can see all in four ecosystem services like provisioning services, regulating services, cultural services and supporting services, organic fields are giving us better economic value in US dollar per hectare per year as compared to the conventional field, we can see here, we can see regulating services also producing higher economic value in case of organic field. Cultural services produces almost similar. However, supporting services also produce higher economic value in organic fields than the conventional fields.

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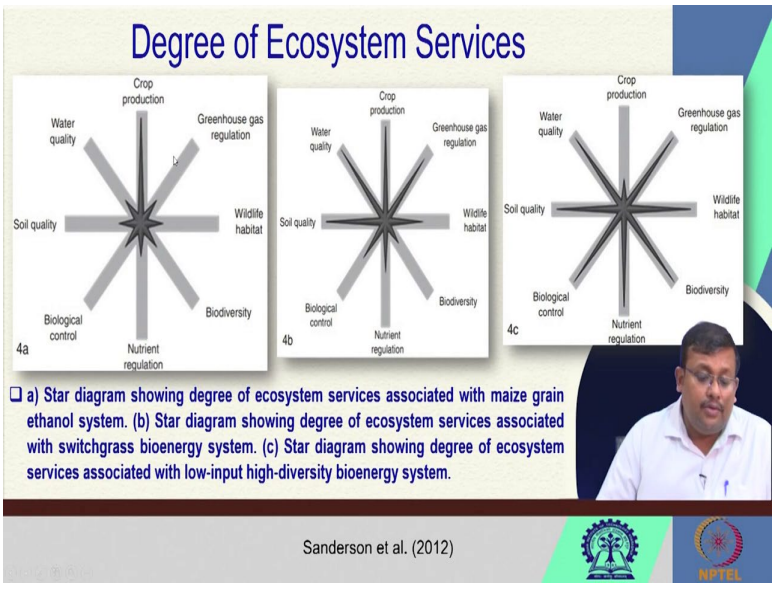

Also, you can compare the degree of ecosystem services from different types of ecosystem, like here we can see this is the start diagram showing the degree of ecosystem services

associated with maize grain ethanol system. So, we can see crop production may be higher. However, the other ecosystem services are somewhat not that much. However, in case of this one, which shows the star diagram showing the degree of ecosystem services associated with switchgrass bioenergy system.

We can see crop production not only crop production, but also water quality, soil quality and greenhouse gas regulation, these ecosystem services are greater than biological control, nutrient regulation, biodiversity and wildlife habitat. However, if we consider the third one which shows the ecosystem services associated with low input and high diversity bio-energy system.

You can see most of the ecosystem services are producing at the optimum quantity, nutrient regulation, biological control, soil quality, water quality, greenhouse gas regulation, wildlife habitat and biodiversity. So, you can see that when we are following these low input high diversity bioenergy system that can help us to get better ecosystem services.

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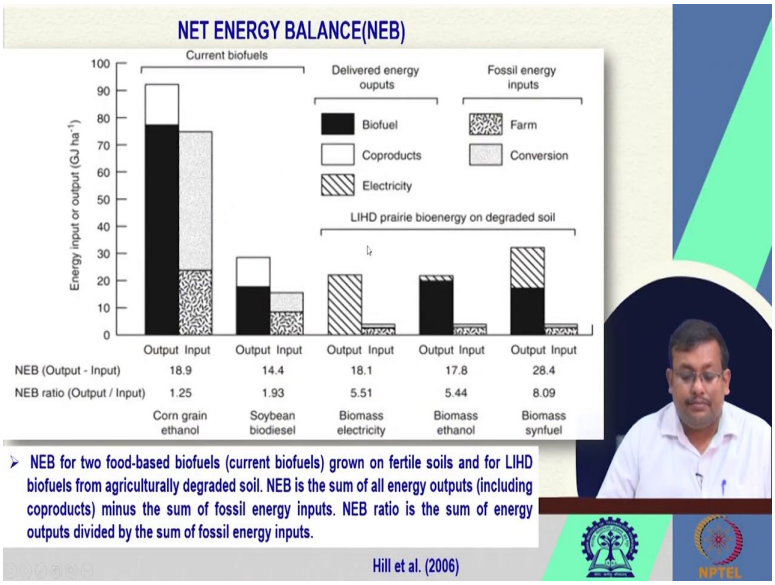

Also, we can see here the net energy balance for current biofuels and different types of prairie bioenergy on degraded soil. So, in the current biofuels, you can see here there are outputs and these are the inputs. In the outputs, we can see these black color bar showing the biofuel, however, this patch is the crop products. And these are basically the fossil energy inputs for maintaining the farm and then conversion.

So, you can see here, so, this is output and this is input. So, net energy balance will be output minus input. Similarly, for different types so this for corn gain ethanol, which we can see here, this is for soybean biodiesel. So, these are for the current biofuels. However, these are for bioenergy on degraded soil. So, we can see the output minus input and then output minus input, output minus input, so net energy balance.

And also, you can see net energy balance ratio, which is basically output by input. So, you can see here the net energy balance in case of these bioenergy on degraded soil, so you can see here 5.51 and output by input is 5.44. And then here you can see 8.09. So, here we are getting higher NEB ratio than these current biofuels.

So, here we can see that these are the NEB or net energy balance for two food-based biofuels, these are the current biofuels going on fertile soils, and these are biofuels which are grown in agriculturally degraded soils. So, this gives us a comparison between the different types of practices and how we can gather more net energy balance from different crop system or cropping system.

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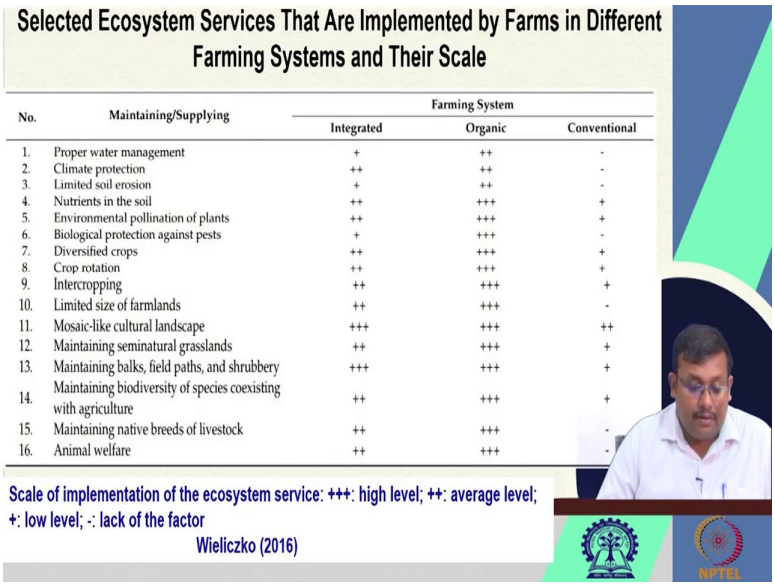

Now, if you see the selected ecosystem services that are implemented by farms in different farming system and their scale, you can see that for maintaining and supply proper water management integrated farming system gives us the low level of services ecosystem services. However, organic farming system gives us the high level. However, conventional system does not give us proper water management.

So, you can see for different practices like climate protection, we can see higher level of ecosystem services from integrated and organic system. However, conventional system does not give that benefit. Limited soil erosion, we can see for organic farming system we are getting higher soil conservation and limited soil erosion. However, in case of conventional tillage, there is your lack of that ecosystem service. So, you can compare for different types of ecosystem services and which farming systems are beneficial for which ecosystem service we can see from this chart.

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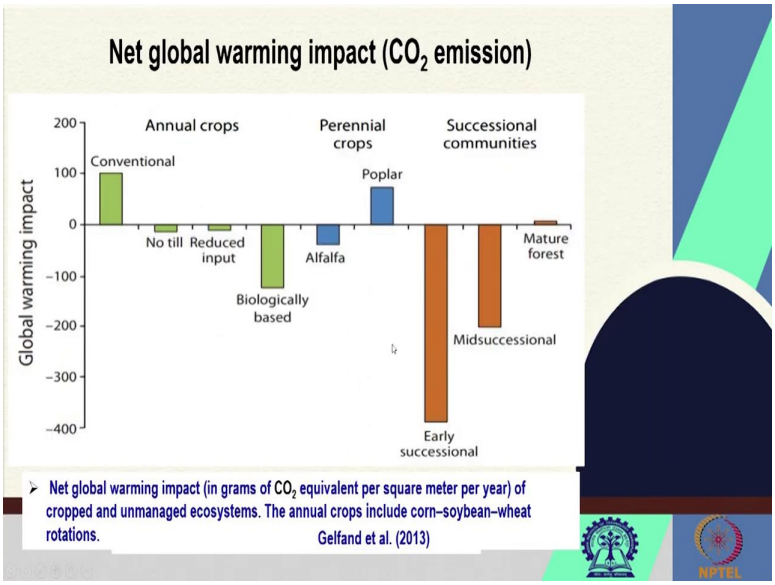

Now, if we see the net global warming impact. The net global warming impact we can see in case of, so global warming impact we can see conventional agricultural practices gives us the positive or higher global warming impact. However, in case of no till, reduce input and biologically based system, alfalfa-based system, then different types of forest systems, they can help us to reduce the global warming impact.

The successional communities means those communities which are grown in shade, but later they become dominant species. So, these are known as a successional communities. However, mature forests can show some positive global warming impact, and that means, they are actually producing the global warming. So, we can see conventional agriculture then popular based perennial crops and mature forest produce some global warming impact.

However, the no till, reduced impact, biologically based, alfalfa, early successional and mid successional communities can produce the beneficial effects on global warming impact. So, that means they can reduce the global warming impact.

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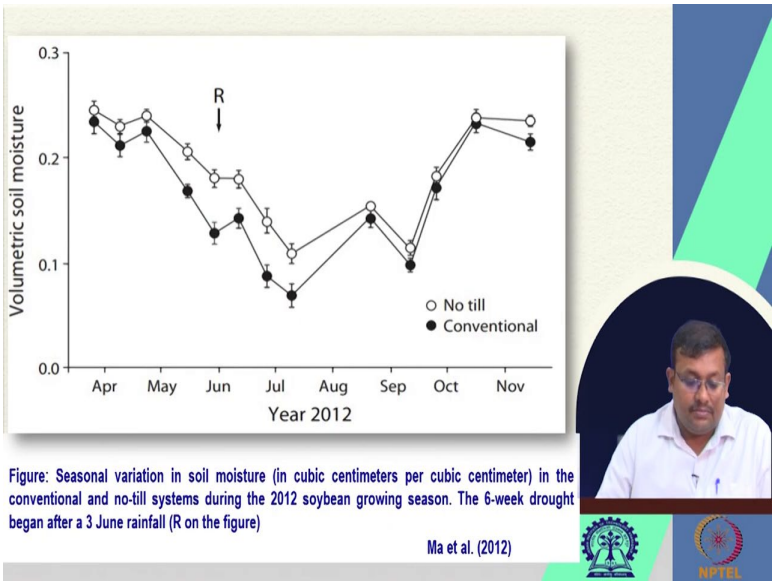

Now, also if we can see the seasonal variation in soil moisture. So, these are seasonal variation of soil moisture in two different conventional and no till system. So, this is the no till system and this is the conventional system. You can see that any at any given point of time in the no till system they have more moisture content than the conventional system. So, this is the 6 weeks drought begin after.

So, here this R stands for the rainfall, which occurred at 3rd June. So, this is regarding this research. And then the 6-week drought began after 3 June rainfall. So, after that there was a 6-week rain drought. And we can see a different time we are having higher moisture content in no till system than conventional system. So, that shows the beneficial effects or beneficial ecosystem services provided by the conservation agriculture as compared to the conventional agricultural practices.

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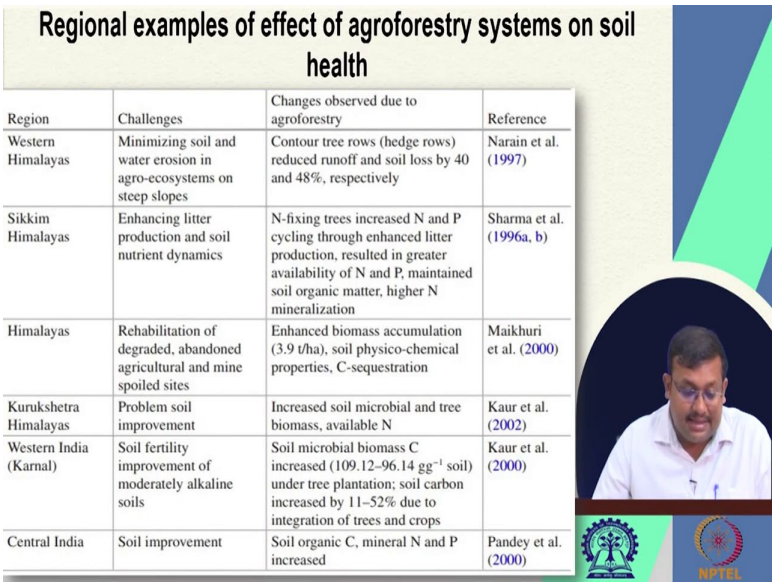

Also, if you see some regional examples of effect of agroforestry systems on soil health, you can see in western Himalayas the major challenge is minimizing soil and water reduction in agroecosystem on steep slopes. And what type of management practices has helped for reducing the challenges or overcoming those challenges like contour tree crops, reduced runoff and soil loss by because contour tree crops can help to reduce this runoff and soil loss by 40 and 48 percent respectively.

Then similarly, in Himalayas rehabilitation of degraded abandoned and agricultural mines spoiled sites are the major challenges which has been addressed by enhanced biomass accumulation and soil physiochemical properties and carbon sequestration. Similarly, in case of central India soil improvement was the major challenge. So however, different types of practices has been achieved.

So, all these changes have been brought by the agroforestry system. So, agroforestry has played a tremendous impact on improving the soil health. Because we can see in western Himalayas these agroforestry has helped to reduce the soil erosion and also in case of Himalayas they can help in improving the soil physiochemical properties and carbon sequestration, in case of central India they helped him soil organic carbon improvement and then mineral nitrogen and phosphorus increment.

And also, you can see in case of Kurukshetra Himalayas, this agroforestry has helped in increasing the soil microbial and tree biomass and increasing the available nitrogen. So, you can see that agroforestry has helped tremendously for generating the positive ecosystem

services for the betterment of the environment. And also, thereby they have solved those challenges which were considered as daunting for better management of better ecosystem management in these regions.

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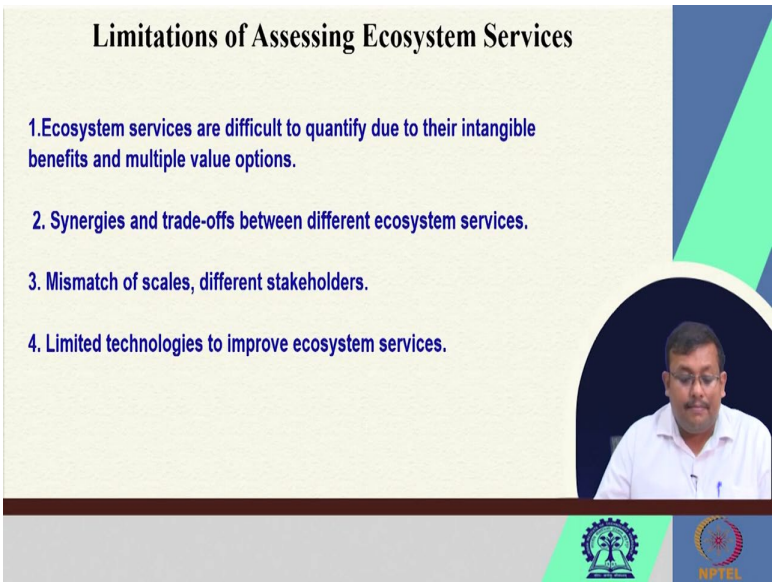

And also, however, there are several limitations of accessing the ecosystem services. First of all, the ecosystem services are difficult to quantify due to their intangible benefits and multiple value options. So, also there are synergies and tradeoffs between different ecosystem services. There are mismatching of scales and different stakeholders and limited technologies are there to improve the ecosystem services.

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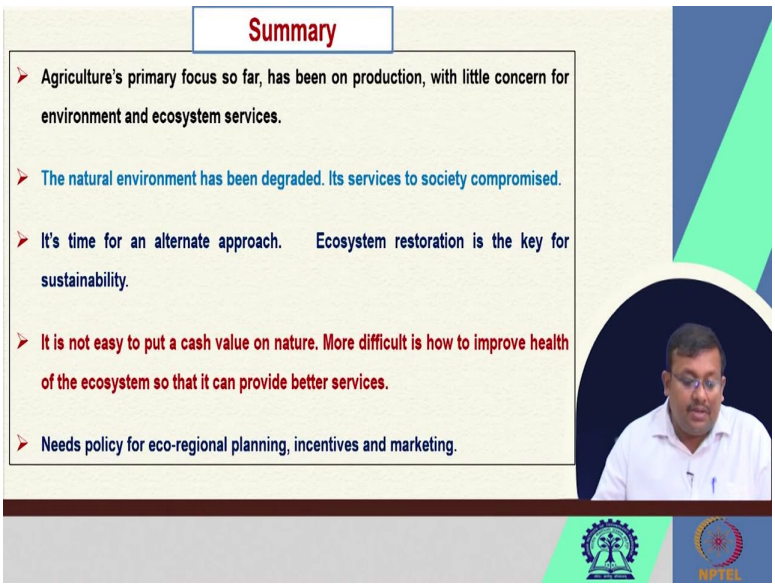

So, summarily we know that agriculture's primary focus so far has been on production with little concern for environment and ecosystem services and the natural environment has been degraded and its service to society was compromised so far. Now, it is time for an alternative approach and ecosystem restoration is the key for sustainability. And it is not easy to put a cash value on the nature more difficult is how to improve health of an ecosystem so that it can provide better services. So, ultimately, we need better policy for eco-regional planning and incentives and marketing.

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Okay guys, so we have come to the end of this lecture. So, I would like to end this lecture by discussing this line. So, that is you should always remember that nature is beautiful, and we should always protect it and we should always restore the ecosystem. So, guys, that makes the end of this course of Soil Fertility and Fertilizer.

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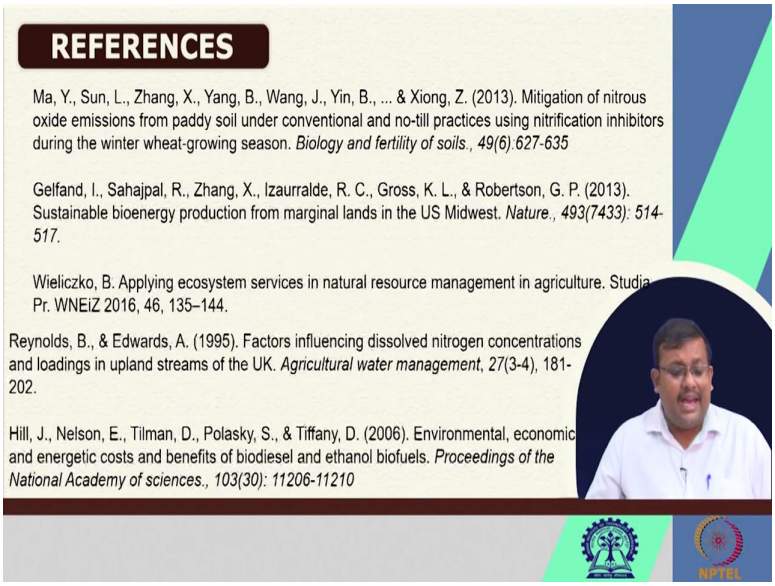

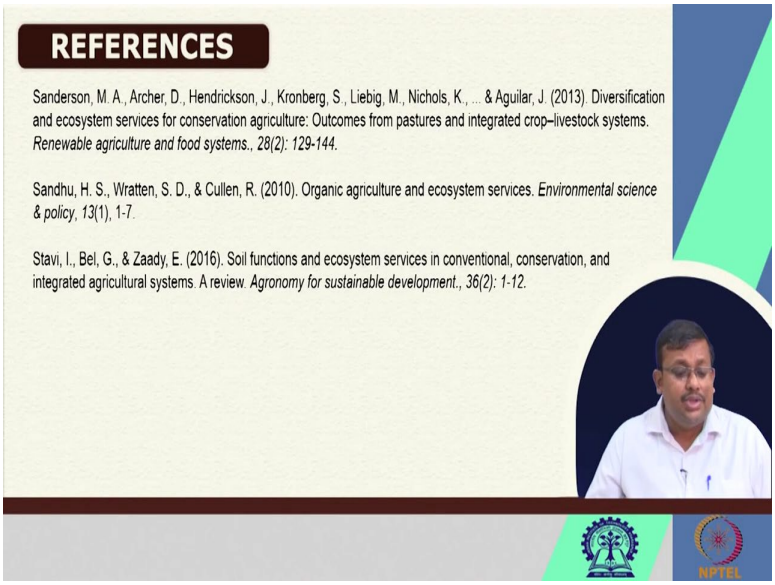

These are some of the references, which I have used for this lecture, you can go ahead and see these references.

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With this, guys let us wrap up this course, I hope that you have gathered some good knowledges about soil fertility, and then soil nutrient and their interactions and how they are useful for plant nutrition, what are the beneficial practices or management practices you should follow for ensuring better soil health so that our future generation can reap all the benefits and how we can maintain the soil for better climate and reduce the climate change impact.

So, we have discussed all these things. If you have any difficulties, please feel free to email me and I will be happy to answer your queries. I wish you all the best for the final exam. And, again, if you are having any difficulties, please let me know and I will be happy to answer your queries. I would also like to thank my TAs, my students who have helped me for developing this course and delivering this course. Thank you, guys. I wish you all the best.