Conservation Geography
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Module - 9
Human population and conservation
Lecture - 26
Population and population growth - II

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Namaste! We carry forward our discussion on human population and conservation, primarily, population and population growth. Now, in the last lecture, we saw, that the human population is different in different areas. There are a large number of areas where the population is very small, and there are a small number of areas where the population is very large. And we also looked at several population characteristics.

Things like sex ratio, things like median age, things like the growth rate of population, things like education rate, literacy rate, the socioeconomic factors such as the GDP per capita and so on. But, then, one question remains, what determines the rate of population growth? That is, if we know the current population can we make certain predictions about what is going to happen in the future.

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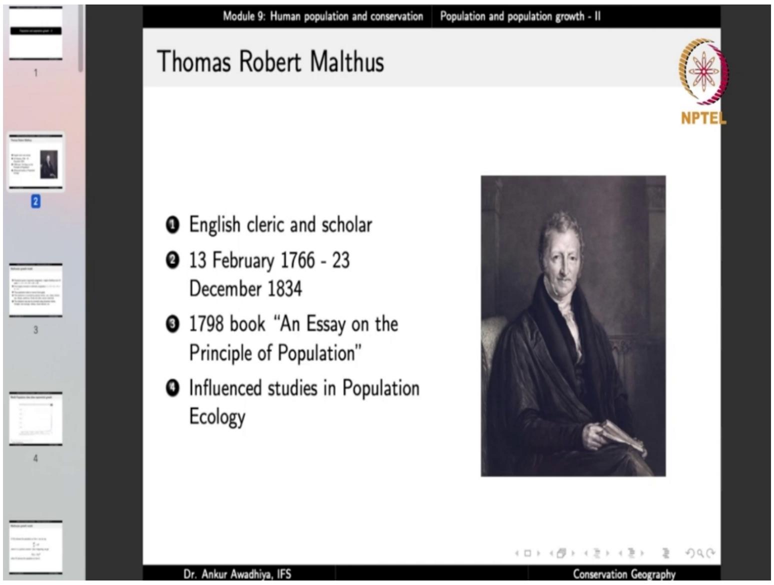

Now, different philosophers and different human geographers have looked at this problem. They have considered this issue and one of the most prominent ones amongst them is Thomas Robert Malthus. Malthus was an English cleric and a scholar who lived in the 18th and 19th centuries.

In 1798, he wrote a book An Essay on the Principle of Population in which he hypothesized his ideas about the growth rate of populations. And he has been a major influence on the studies in population ecology and studies in human geography. So, in this lecture, we are going to focus on his theory, try to understand what he tried to profess about the growth of human population. And we shall also look at the lacuna in his theories and what kinds of changes are we observing in the world today.

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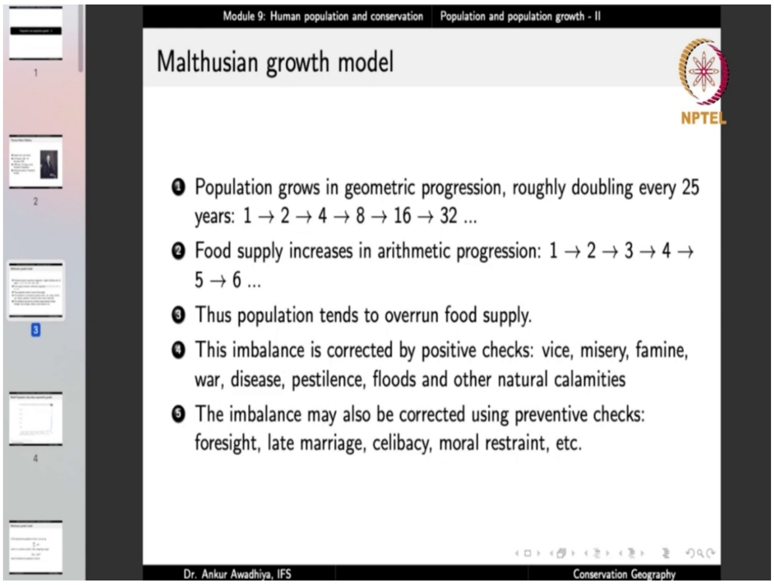

Now, Malthus proposed a growth model that is known as the Malthusian growth model in his honor. He stated that the population grows in geometric progression roughly doubling every 25 years.

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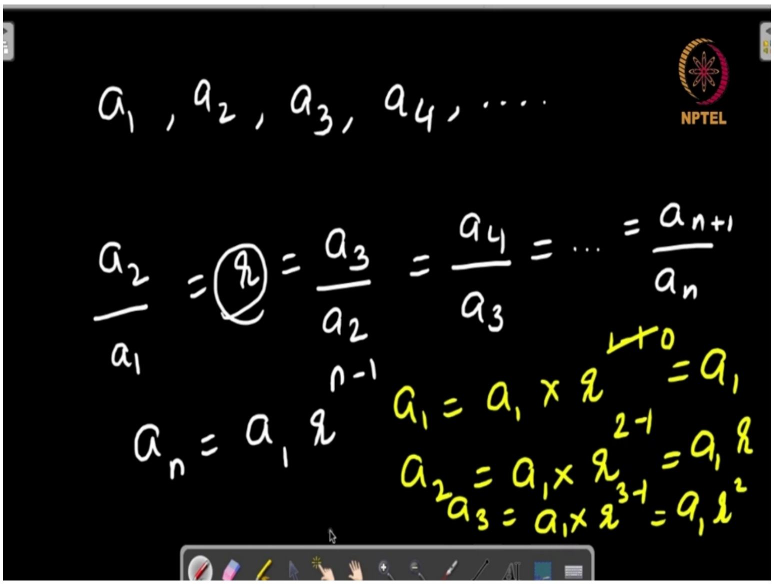

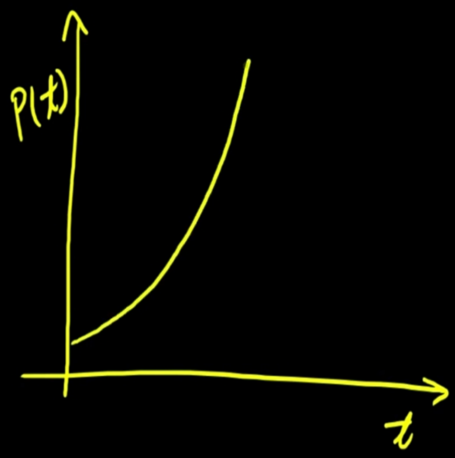

$a_1, a_2, a_3, a_4, \ldots$

$a_2 - a_1 = d = a_3 - a_2 = a_4 - a_3 = \ldots$

$$a_n = a_1 + d(n-1)$$

$$a_1 = a_1 + d\cancel{(1-1)}0 = a_1$$

$$a_2 = a_1 + d(2-1) = a_1 + d$$

$$a_3 = a_1 + d(3-1) = a_1 + 2d$$

Malthusian growth model

1. Population grows in geometric progression, roughly doubling every 25 years: $1 \to 2 \to 4 \to 8 \to 16 \to 32 \ldots$
2. Food supply increases in arithmetic progression: $1 \to 2 \to 3 \to 4 \to 5 \to 6 \ldots$
3. Thus population tends to overrun food supply.
4. This imbalance is corrected by positive checks: vice, misery, famine, war, disease, pestilence, floods and other natural calamities
5. The imbalance may also be corrected using preventive checks: foresight, late marriage, celibacy, moral restraint, etc.

Now, a geometric progression is a sequence of terms, so let us write it as a1, a2, a3, a4 and so on, such that, if we take the ratio of any two terms. so, a2 by a1, and if this ratio is r then this ratio is maintained everywhere. So, this r is equal to a3 by a2, this is also equal to a4 by a3 and so, on.

So, if we take any two terms say an and an plus 1 then this will be the common ratio or in other words we can write that the nth term is given by the first term into the r to the power n minus 1. So, for instance if you put n is equal to 1 in that case you will have a1 is equal to a1 into r to the power 1 minus 1, which becomes r to the power of 0 is 1, so this is a1, a2 is equal to a1 into r to the power 2 minus 1 is a1 into r, a3 is equal to a1 into r to the power 3 minus 1 is a1 into r2 and so on.

So, Malthus suggested, that the human population grows in geometric progression, which means that, there is a fixed ratio by which it would grow in every phase unit of time. And he suggested that the time period is 25 years and the ratios 2, that is, the population roughly doubles every 25 years. So, if we begin with say 100 million people, in 25 years it will become 200 million in the next 25 years it will become 400 million in the next 25 years it will become 800 million and so on.

And so, if you plot the human population growth so, if we plot here you have t and here you have the population at time t, then the population will grow like this, an exponential growth. But he suggested that the food supply does not increase as fast. The food supply increases in an arithmetic progression.

Now, an arithmetic progression is again a sequence of terms so, here we have a1, a2, a3, a4 and so, on such that, the difference between any two terms is constant, that is, a2 minus a1 if the value is d then the same value of d is a3 minus a2 is the same as a4 minus a3 and so, on. In such a case we can write an is equal to a1 plus d n minus 1.

So, let us now put some values a1 is equal to a1 plus d 1 minus 1 this becomes 0, so this is equal to a1. a2 is equal to a1 plus d 2 minus 1 is a1 plus d, a3 is equal to a1 plus d 3 minus 1 is a1 plus twice d and so on. So, this is the formula for an arithmetic progression.

Now, the important point about Malthusian growth model, is that, while the population is growing in a geometric progression, if everything works fine, if people have sufficient access to food, the food supply does not increase as fast. So, it increases in arithmetic progression. So, from 1 it becomes 2, then 2 to 3 then 3 to 4, 4 to 5, 5 to 6 and so on. So, in a very short period of time the population will overrun the food supply, that is, there will be a shortage of food because now there are so, many people and the food supply has not increased as fast, and this would create an imbalance, and this imbalance will be corrected by certain checks.

So, these are checks on the population things like vice, misery, famine, war, disease, pestilence, floods and other natural calamities. That is what Malthus is suggesting is that it is the inherent nature of human population growth to increase by geometric progression, whereas, agriculture increases only by arithmetic progression. So, after a while we will have a situation that the human population is too large and there is a shortage of food supply.

Now, this shortage will be overcome through certain mechanisms, which is referred to as checks. So, there can be a check such as a war. Now, if there is a war people get killed, and the population size reduces and when the population size reduces, now, it is at balance with the food supply or you can have natural calamities such as floods.

Now, in the case of a flood, a large section of the population will be killed, and again, you will have a balance that is again maintained or when the population size increases by too much there will be disease in the society. And this disease will take a toll on the population size. The population size will reduce and again we will have a balance.

Now, these kinds of checks he referred to as positive checks. Essentially, they are negative checks, but he said that the nature puts up a check and which is why he said that these are the positive checks that nature puts up to maintain a balance between the human population size and the food supply.

But then he suggested that there is also another way out something that he said are the preventive checks. Now, by preventive checks, he meant that humans themselves can do something to keep their population in check, so that, there is no imbalance and nature does not have to put up a positive check. Now what are these preventive chicks, they are things like foresight, things like late marriage, things like celibacy, things like moral restraint and so on.

So, if people marry late, if people produce less number of offspring. If a certain section of population becomes celibate and so, they just forego marriage, they do not produce any offspring. In that case by these actions of human beings, we can keep the population in check. And when the population is in check, when there is no imbalance between population size and food supply, in that case, the nature would not have to put up a positive check. So, essentially, there are two mechanisms by which the human population is kept in sales.

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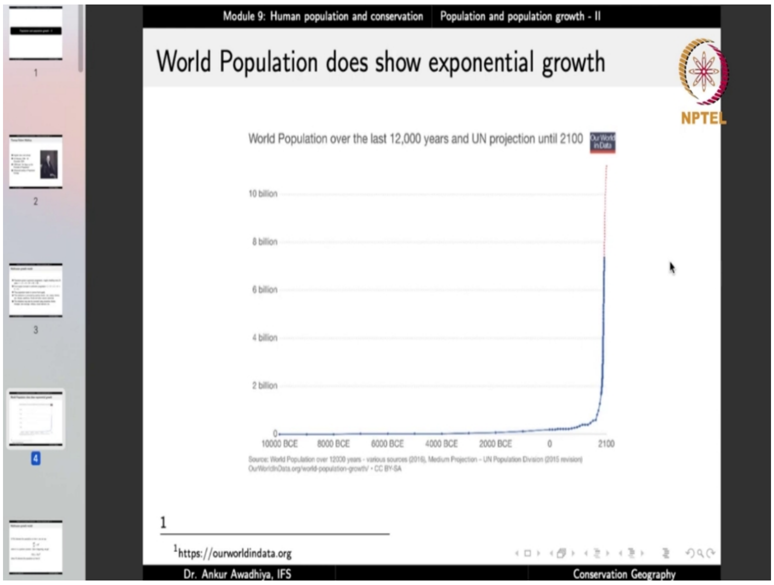

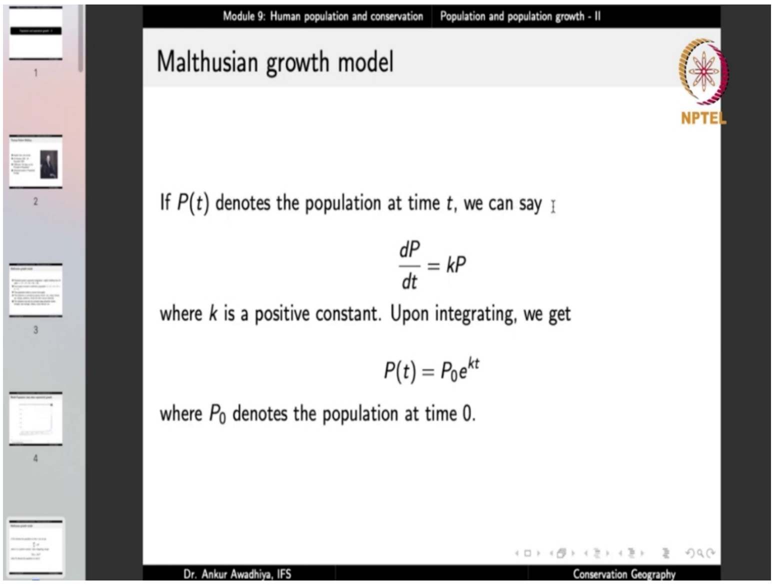

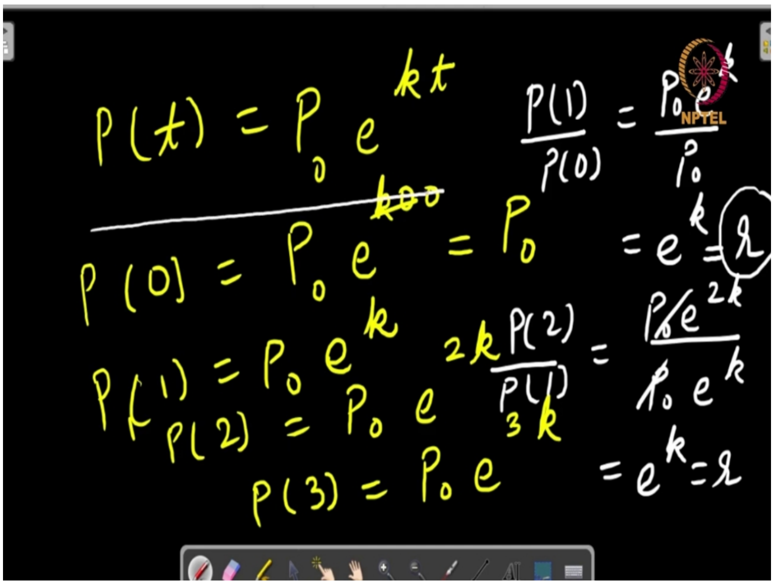

And if we look at this theory, the World Population does show exponential growth. So, for a large portion, we can see that, Malthus is correct in a large major, because if we plot the human population, so, on the x axis we have the time on the y axis we have the population, and this curve does look like an exponential increase. So, the world population does increase similar to a geometric progression.

And if we were to put it mathematically, if P, at time t denotes the population at time t, we can say that the rate of change in population that is dP by dt is a constant value multiplied by the population size at that point of time by which we are saying that the rate of increase is a constant and this constant multiplied by the size of the population will give you the actual increase in the population size per unit of time.

And here k is a positive constant, and if we integrate both the sides we get P, at time t is equal to P0 into e to the power kt where P0 denotes the population at time 0. That is what we are saying here, is that, P at time t is P0 that is population at time 0 into e to the power kt. So, if you put time is equal to 0, you get P0 into e to the power k times 0, so this becomes e to the power 0 is 1 so this is P0. At a time say P1 so P1 is equal to P0 into e to the power k.

P, at time 2 is P0 into e to the power 2k, P3 is P0 into e to the power 3k. And if we took a ratio then P1 divided by P0 becomes P0 into e to the power k divided by P0 is e to the power k, which is a constant. So, this is the constant r that we are talking about. P2 divided by P1 is equal to P naught into e to the power 2k divided by P naught into e to the power k. So, P naught and P naught get cancelled, so this is e to the power k is r. So, this is just another way of saying the same thing.

In the case of geometric progression, we said that the ratio of any two terms is a constant r, and we can represent the same geometric progression in this form as well. So, P at time t is P0 into e to the power kt. So, this is just another way of saying that the population is increasing in geometric progression.

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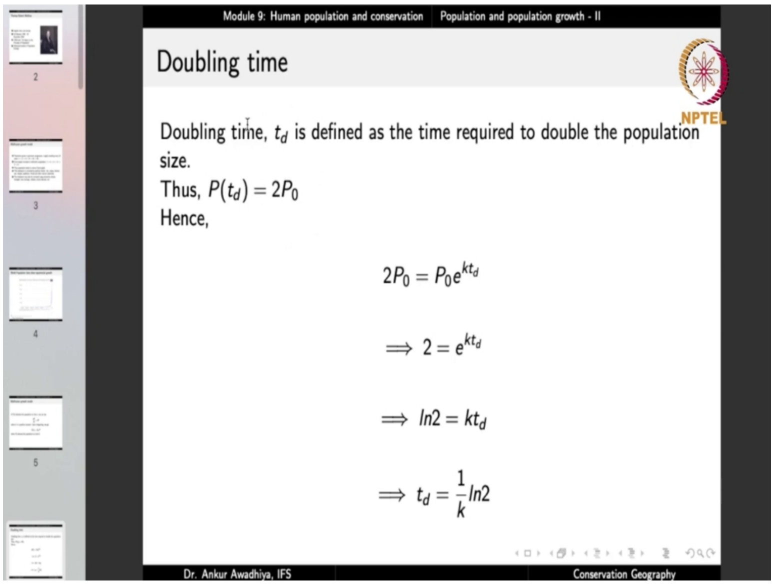

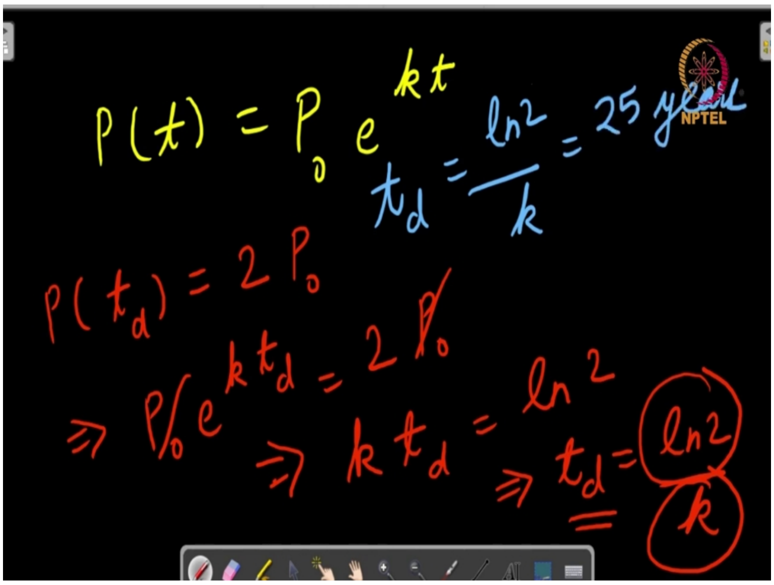

Now, the important thing is, we can calculate the doubling time with this. Doubling time is defined as the time required to double the population size. That is, P at time td, which is the doubling time is twice the initial population. So, in this case we can write that now we are trying to calculate the doubling time.

So, P at time td which is the doubling time is twice the initial population, which gives us that P0 into e to the power k into td is twice of P0. Now, P0 and P0 get cancelled. Now, taking natural logarithm on both the sides we get k into td is log of 2. So, we are taking log of both the sides and we get k into td is log of 2, which gives us that td is log 2 divided by k. Now, log 2 is a constant, k is a constant and so, td is a constant, which is what Malthus was also saying that we have a fixed doubling time and that is 25 years. So, if we go with Malthus, we can write that td which is log 2 by k is 25 years. So, this is the doubling time log 2 by k.

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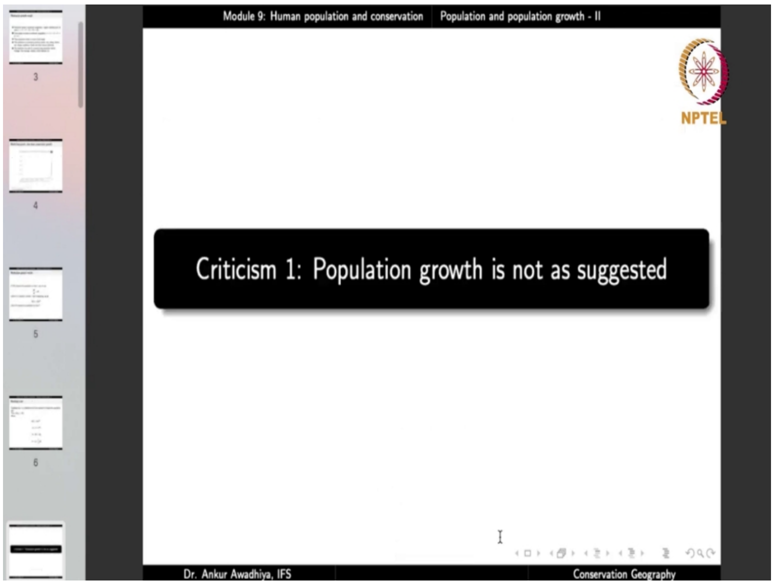

But now comes the criticism. The human population growth does not always follow the Malthusian law. So, more or less we saw that okay the human population is increasing exponentially, but not always. Because if the human population was actually increasing by a geometric progression, then we must be having a fixed td that is a doubling time. Malthus suggested that it was 25 years, but now, we are going to see if it actually is 25 years.

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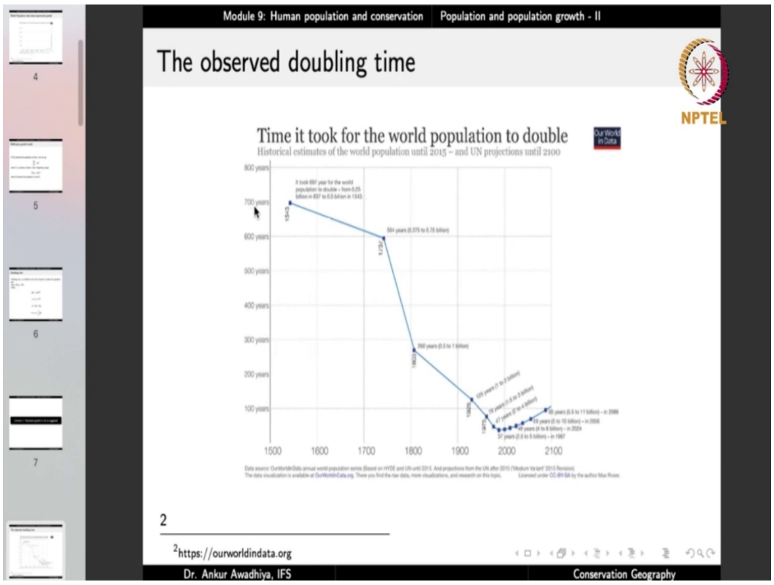

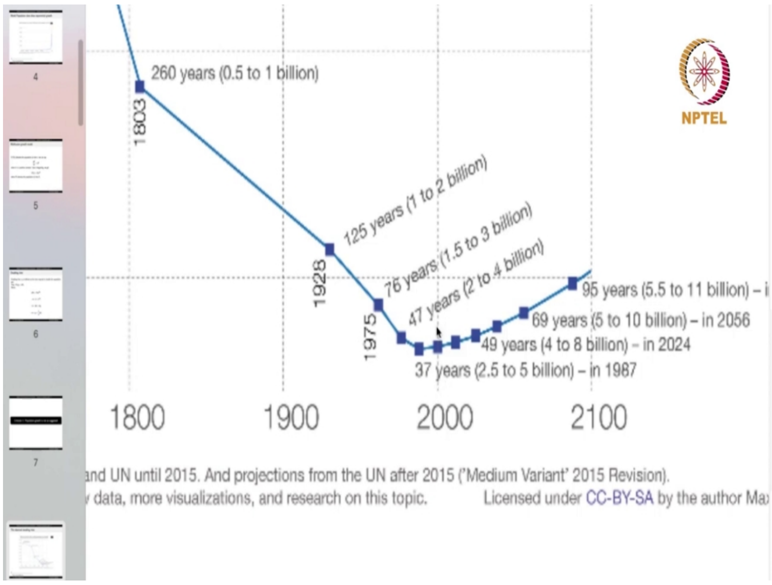

So, if we look at the observed doubling time, the doubling time has been changing. So, here on the x axis, we have the year. So, we begin with the year 1500, 1600, 1700 and so on, and we are plotting the doubling time on the y axis. Now, roughly around 1530 on this is 1543, so at 1543 the doubling time was around 700 years, then it kept on decreasing, such that, if we look at near the year 2000, we are seeing that the doubling time is as low as 37 years.

So, for instance in 1928, it took 125 years for the population to increase from 1 to 2 billion. In 1975, the population doubling time was roughly 76 years, because it had taken 76 years to increase from 1.5 to 3 billion, and the year 2000 it was roughly close to 38 years. And the population doubling time it has been decreasing and then it starts to increase. So, this is the actual doubling time, which tells us that Malthus was not exactly correct.

The human population does not exactly increase by a geometric progression, it more or less increases by a geometric progression, but the rate is not constant, the rate changes because of which the doubling time also changes.

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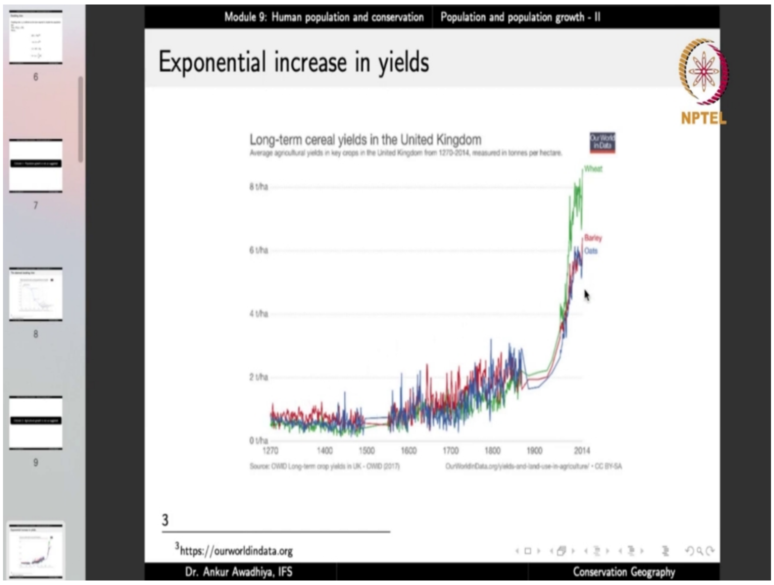

Second, when he talked about the agricultural growth, he said that it increases by an arithmetic progression. But that is again not exactly true. Because if we look at things like the cereals. We observe that there is an exponential increase in the yield. So, for example, in the year 1700, the yield of wheat was roughly 1 tonne per hectare in the United Kingdom. Currently, it is roughly 8 tonnes per hectare. So, it has become 8 times, and if you plot it, this also looks like an exponential curve. Whereas, if we went by Matthews, in theory, it should have been a straight line. So, there is an exponential increase in yields as well.

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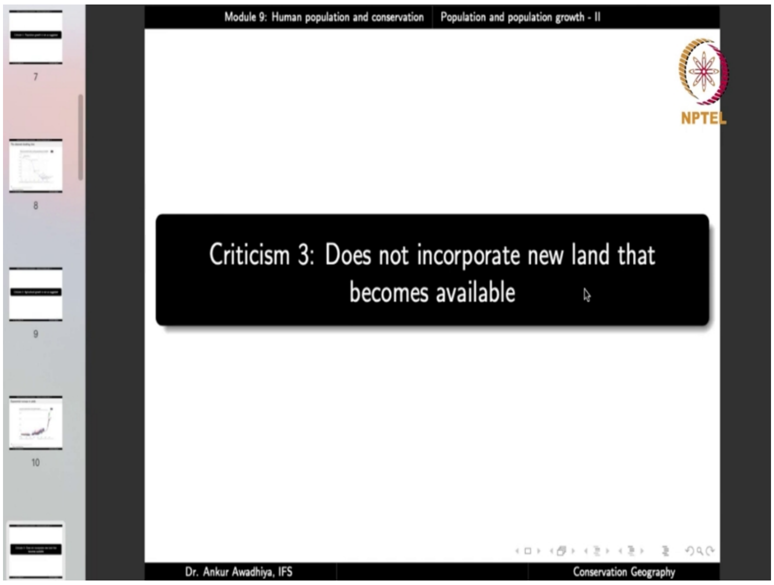

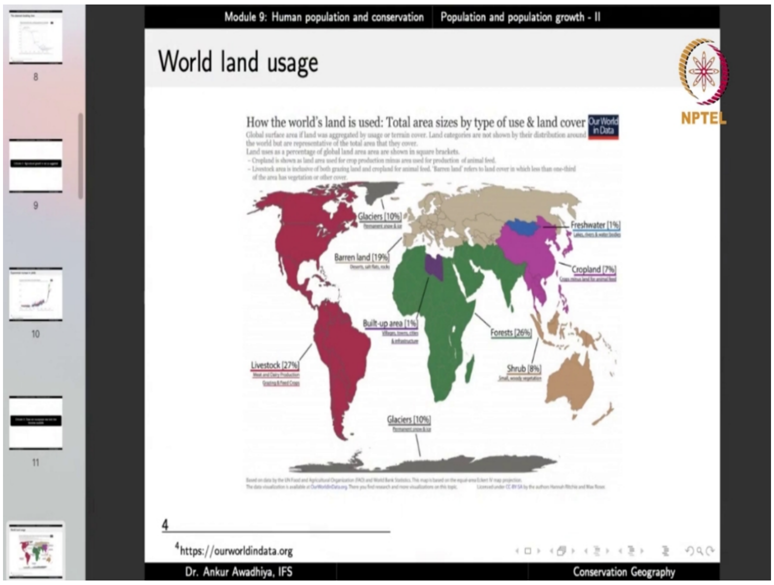

3, the Malthusian theory does not incorporate new land that has become available. Because over time, we have been deforesting a large amount of areas, and we are using that area to grow our crops or to raise our cattle. So, because the population size has been increasing, there is a greater requirement of food, and to meet this greater requirement of food what we can do is that we can bring more and more area under cultivation.

So, if you look at the current land use, we find that as much as 27 percent of the land area of Earth is being used for raising livestock. That is, if you took all the area of North America and all the area of South America combined, that is the area that we are using for livestock rearing today. Then crop lands are 7 percent of the area, meaning that if you took all of China, if you took all of Japan, that is roughly the size of our agricultural fields.

Forests currently are 26 percent of the land area that is most of Africa then certain parts of the Middle East and up to India. So, this much is the amount of land that is currently under forests. And this has been decreasing over time. The built-up area, which includes the villages, towns, cities, everything, that is roughly the size of the country Libya. Roughly 19 percent of the land is barren land 8 percent of land is shrubs, freshwater is just 1 percent of the land area, and glaciers are 10 percent of the land area.

So, what is happening over time, is that, we have brought 27 plus 7 is 34 percent of land under cultivation and agriculture. So, when the population size increases, we tend to bring more areas under agriculture, and agriculture includes both cultivating crops and rearing animals. And this is something that Malthus did not consider when he was making his theory. So, this is another criticism.

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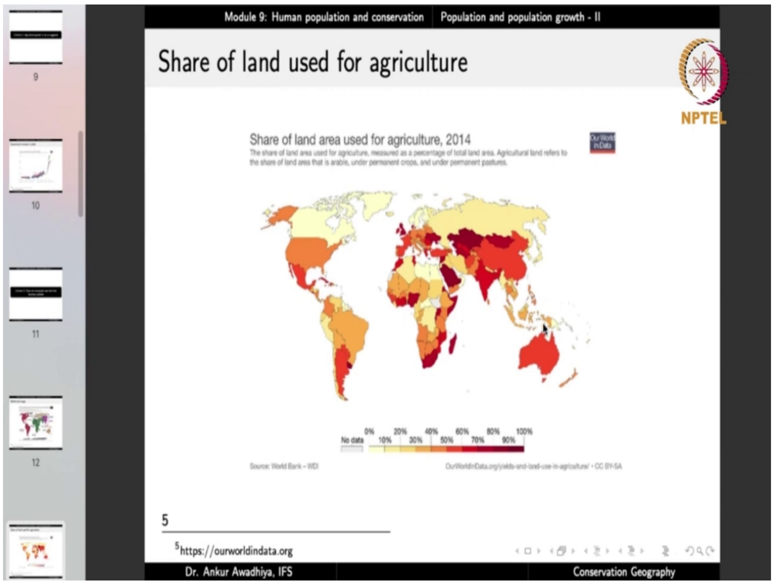

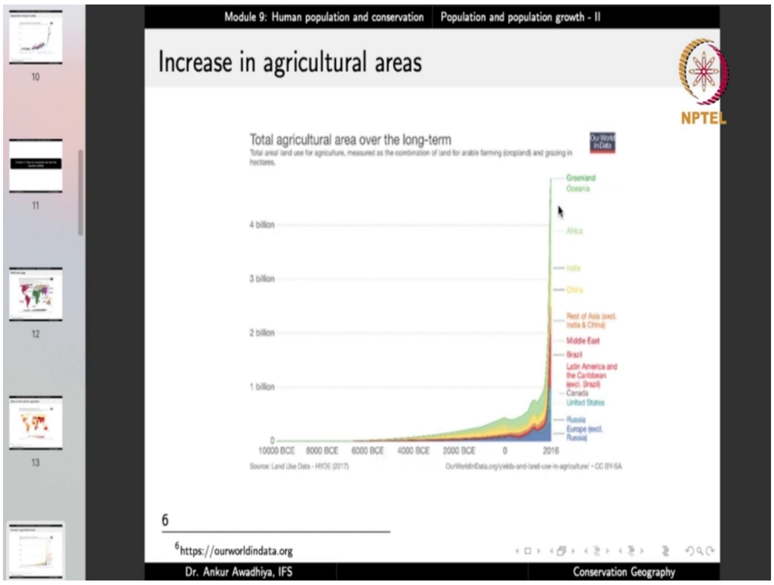

Currently, if you look at the share of land used for agriculture, in certain countries, it has increased to roughly 90 percent or even more. And so, the area that has been brought under agriculture it has been increasing. If you look at the areas that are under agriculture, over the long term, we see an exponential growth. There is an exponential increase in the areas under croplands, there is an exponential increase in the areas under grazing. So, this is also something that Malthus did not consider when he was propounding his theory.

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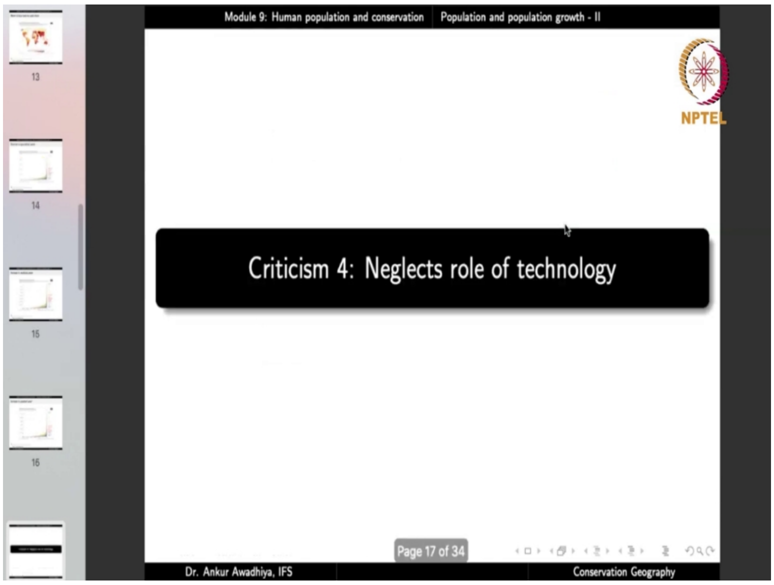
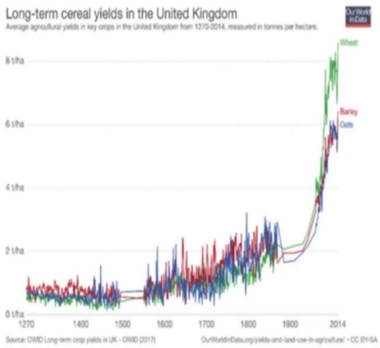


Exponential increase in yields



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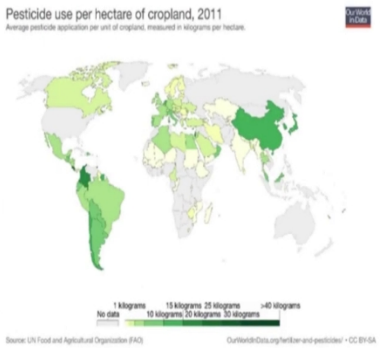
[9]https://ourworldindata.org

Technology to the rescue



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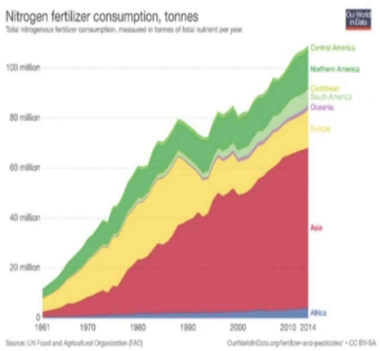
Technology to the rescue



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[11]https://ourworldindata.org

Another criticism is that not only can we bring more areas under cultivation, but at the same time we can also develop newer technologies, and technological growth is something that Malthus did not consider in his theory. So, the exponential increase in yields are one example of the use of technology. Today, we are using more and more amounts of fertilizers, more amounts of pesticides and these are resulting in a greater yield of several of our crops.

So, if we look at the pesticide use per hectare, we find that in a vast majority of countries, there is a substantial use of pesticides for growing of crops. The nitrogen fertilization consumption if you plot the amount of nitrogen fertilizers that are being used things like urea, then we will find that there has been a rapid increase in the amounts of urea or in other nitrogen fertilizers that we have been using. This is a technology.

Now, this nitrogen as we have seen before, this is coming from a large number of industrial processes. Things like Haber process or things like Ostwald process. When we were discussing about the biogeochemical cycles, we observed that there are very few avenues through which we can have nitrogen in the soil in a natural manner. So, we looked at the biological nitrogen fixation and things like lightning, but today the majority of nitrogen that we are putting on the land is being brought through industrial processes, such as, Haber process and Ostwald process. Now, these processes did not exist in the time of Malthus. So, this is something that he did not consider when he was making his theory.

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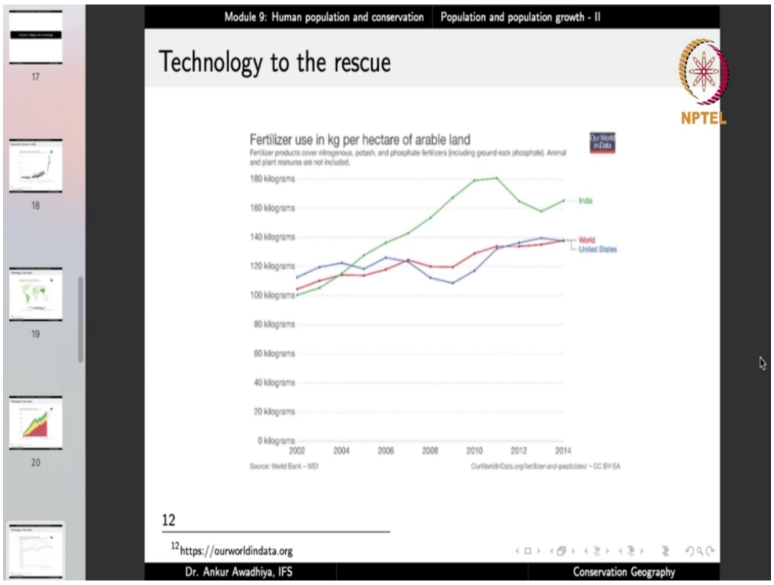

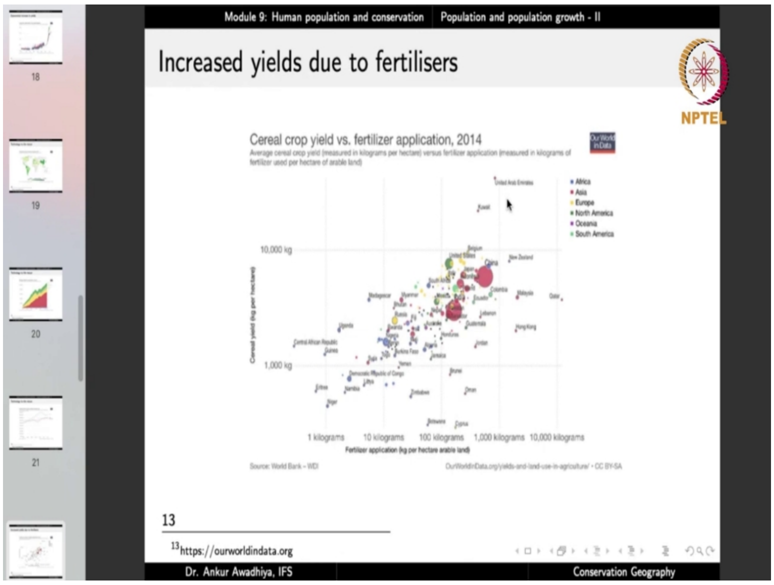

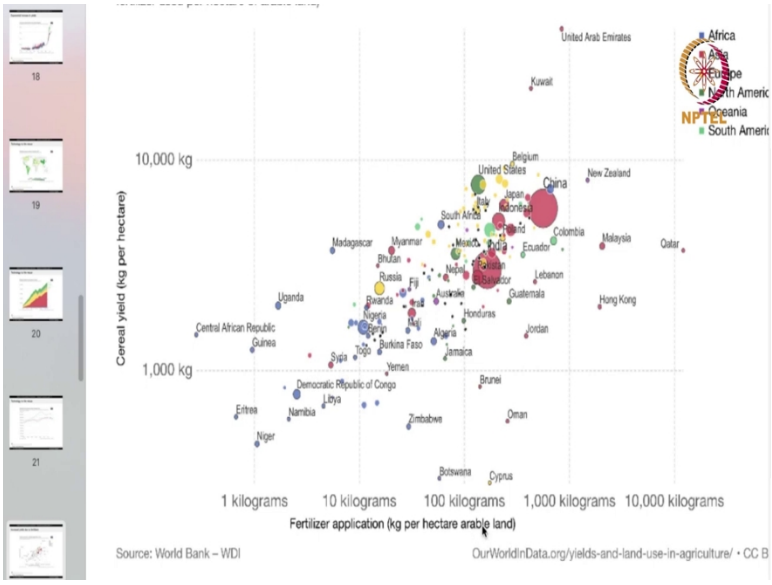

Similarly, if we look at the fertilizer use, we find that the fertilizer use also has been increasing. So, this is nitrogenous fertilizer, potash fertilizer and phosphate fertilizers, that is, the NP and K. And this is also showing an increasing trend, in India and in the world. And the increased use of fertilizer brings a vastly great increased yield.

So, if you plot the fertilizer application, that is, kg per hectare of arable land on the x axis and if you plot the cereal yield on the y axis, then we will find that for a large number of countries where we have more amount of fertilizer use, the yield is also very high. So, the yield increases with increase in fertilizer application. And so, this is another way in which we can bring a balance between the human population and the food supply. So, the positive checks and the preventive checks are not the only ways that we have with us, we can also increase the food supply. So, this is another point where Malthus has been proven wrong.

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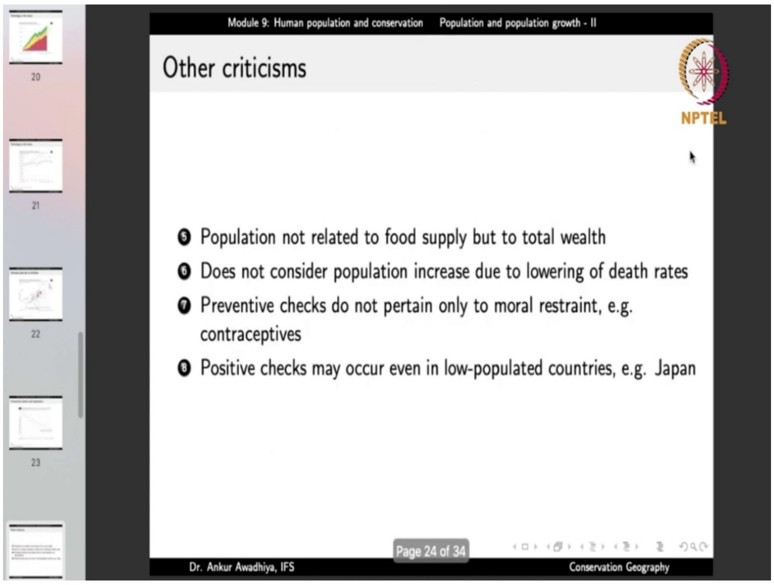

Now, with an increase in yield with an increase in productivity, we are observing that we actually require less and less amount of land to grow the same amount of food, that is, after 50 years the world uses 68 percent less land to produce the same amount of food. So, increase in productivity is also a way through which we can bring a balance.

Other criticisms include the fact that population is not related to food supply, but to total wealth. It has been observed that, as the wealth in a society increases, the population growth rate reduces and then it increases, that is, when people move away from poverty then they tend to have fewer children and this trend goes on till the society becomes extremely affluent where again we find a small increase in the number of children that are being born. So, in place of having a relationship with the food supply, actually there is a relationship with the amount of wealth that people have, the GDP per capita. So, this is another criticism. Population is not related to food supply, it is related to total wealth in the society.

Then, Malthus did not consider population increase due to lowering of death rates. Today, the vast majority of population increase has occurred because of advancements in medical science. So, earlier there used to be a large amount of infant mortality, child mortality such as under 5 mortality and all of that has been prevented because of advancements in medical science advancements in sanitation and availability of clean water.

Even things like washing hands with soap and water before eating food has brought a large amount of change. Now, this is something that Malthus did not consider. Malthus only considered that if there is more food, then the population will increase, if the population has moved past the amount of food that is available the population size will reduce. So, he considered that the food supply is probably the only thing that governs the population size. But in actuality, we find that the population size is changing because of advancements in sanitation, advancements in medical science and other things as well that Malthus did not consider

Then the preventive checks, do not pertain only to moral restraint. We again have new technologies of liberal. We have contraceptives, which can lead to a preventive check that is the humans can regulate their own population size without a moral restraint. So, this is also something that was not available in the times of Malthus. And another thing, is that, the positive checks also occur in the low populated countries like Japan.

So, Malthus had suggested that when there is an imbalance between the population size and the food supply, then either we can go with preventive checks in the form of moral restraints, so we can reduce our own population or we can keep our population size in check by having late marriages or by having celibacy, but we have technologies to reduce our population size without a moral restraint, and at the same time, the second option that Malthus had suggested was that if we do not go with preventive checks, nature will bring in positive checks in the form of things like floods or natural disasters or diseases.

But then it has been observed that we have these natural disasters or floods or diseases, even in those areas that have a low population size. So, there is no direct correspondence between the population size and the positive checks. So, this is another criticism of Malthus.

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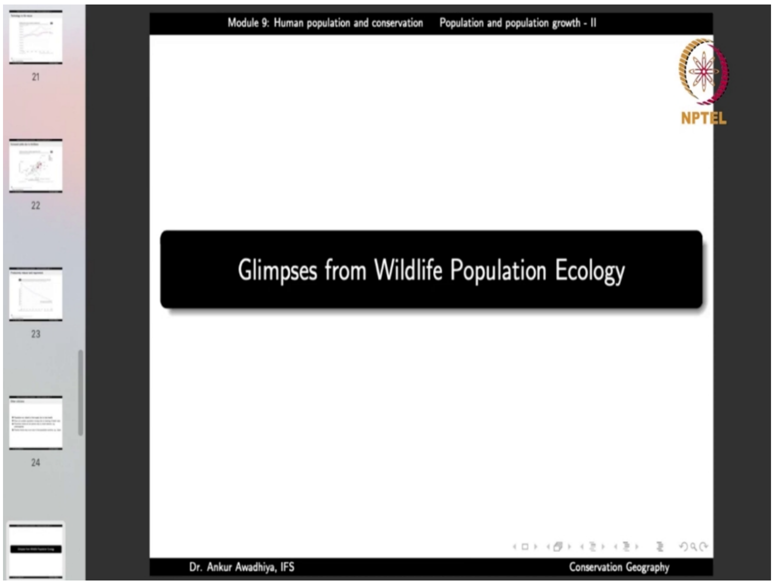

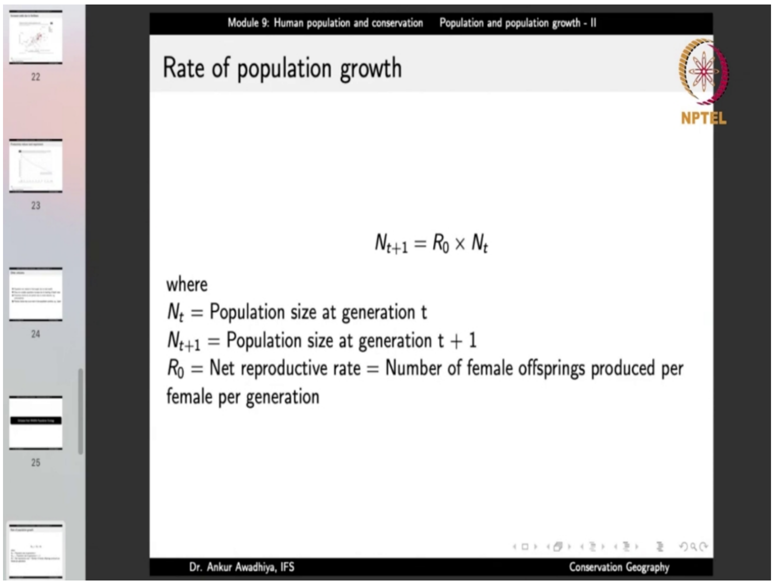

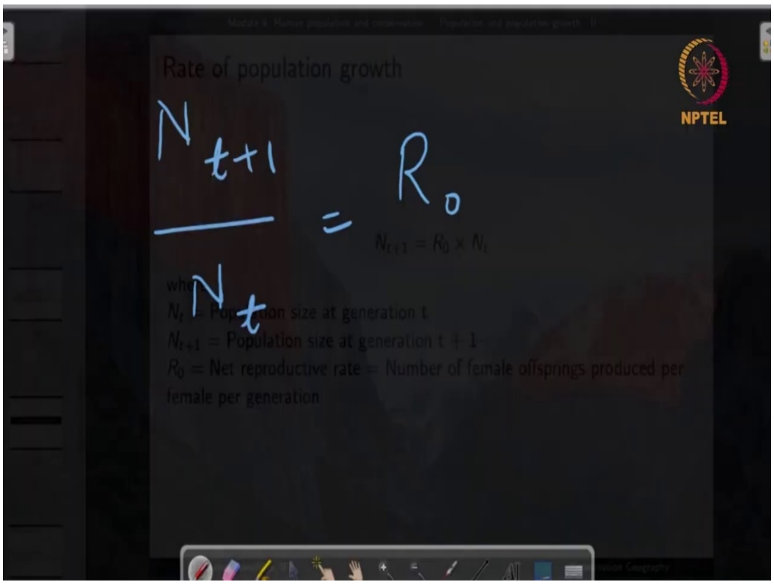

And in this context, we can have a look at our learnings from wildlife population ecology. Where did Malthus go wrong? What could be the changes that he could have incorporated to make his theory more worthwhile? So, if you look at wildlife populations, then if you begin with Malthusian theory. So, in the case of Malthusian theory, there is a geometric progression that is the population at time t plus 1 is equal to a constant multiplied by the population at time t.

That is, we are saying that the population at time t plus 1 divided by the population at time t is a constant which we are calling as R0. And this R0 is also known as the net reproductive rate or the number of female offspring that are produced per female per generation. So, we are using females only in this equation because females give rise to the young ones, and this is the rate of population growth that would be expected from Malthusian theory.

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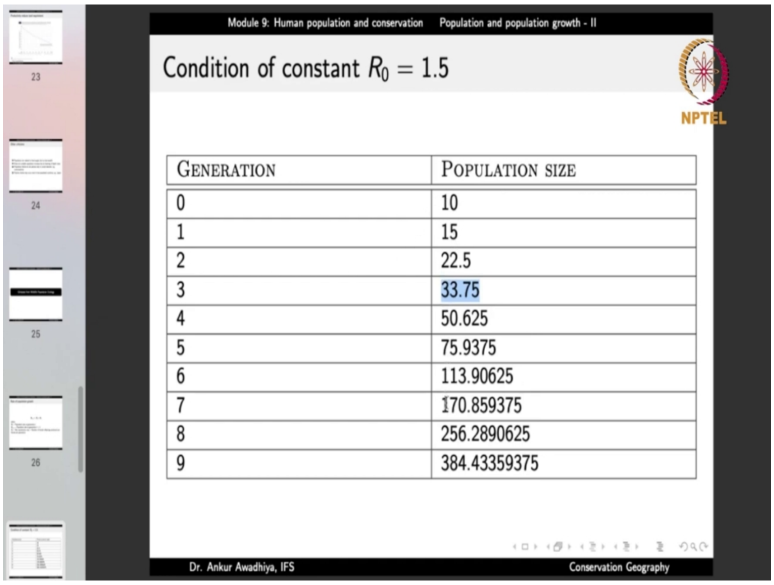

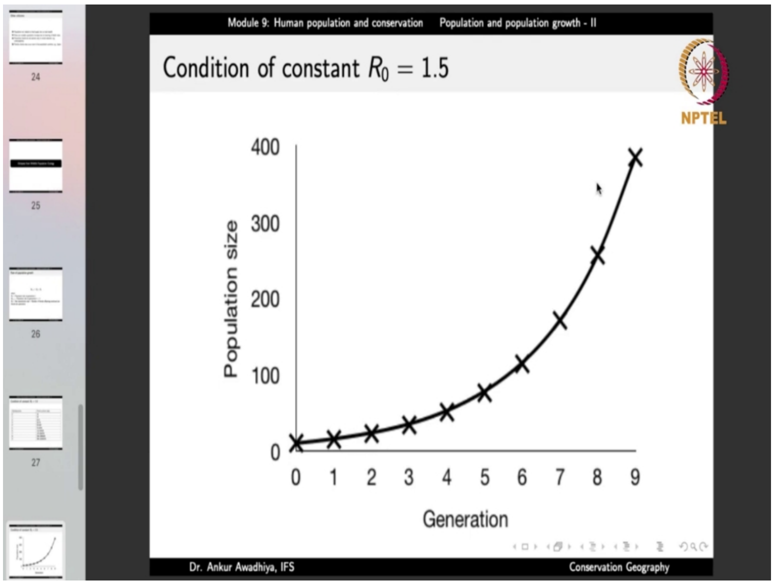

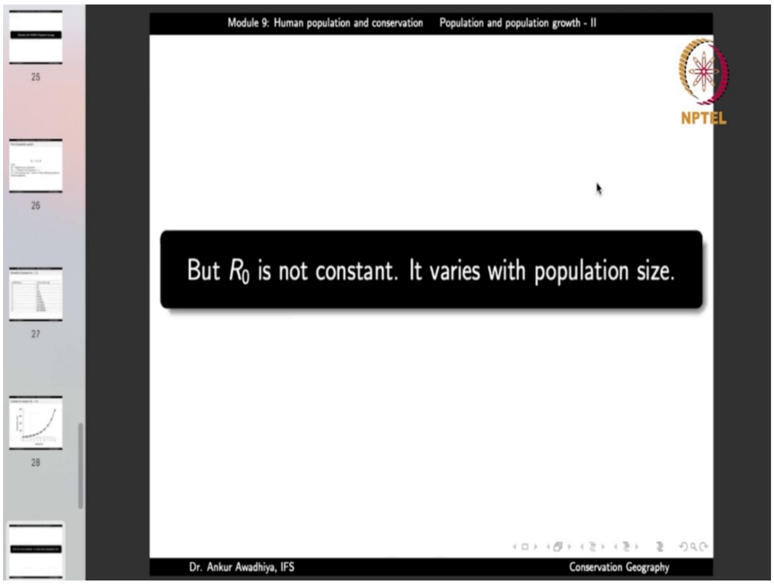

So, if we take a constant R0 say R0 is equal to 1.5 and we begin with a population size of 10. In that case, how will the population change with time. So, in the first generation, we will have the population is equal to R0 is 1.5 into 10. So, 10 into 1.5 is 15. In the next generation we will have 15 into 1.5 it will give 22.5. In the next generation we will have 22.5 into 1.5 which is 33.5 and so on. So, what we can see, is that, the population increases exponentially as is predicted by Malthus. So, 10, 15, 22, 33, 50, 75, 113, 170, 256, 384. If you plot this, this is the kind of curve that is expected, that is, the population size increases exponentially when you have the Malthusian theory.

But then do we actually see this in nature in the case of any wildlife population? The answer is no. And this is primarily because are not is not a constant and it varies with the population size. That is when we said that in the Malthusian theory, there is a geometric progression with a fixed doubling time that is not correct, because the doubling time or equivalently the rate of population growth is dependent on the population size.

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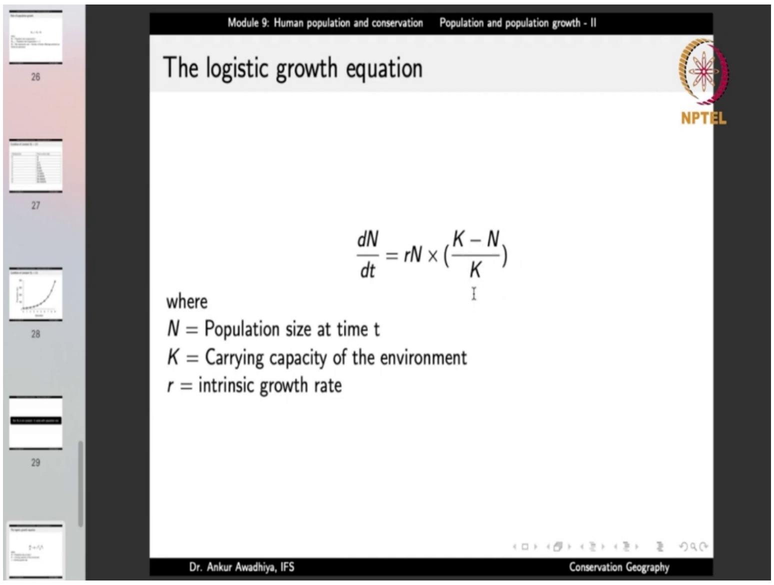

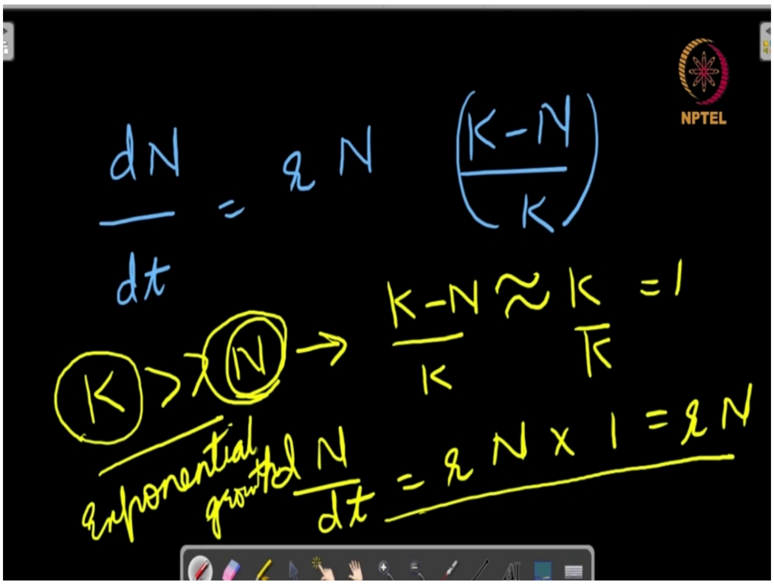

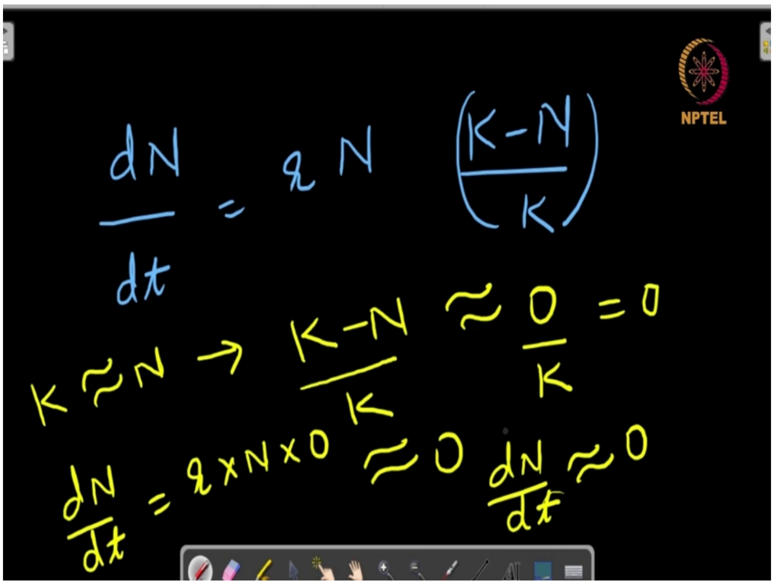

So, how does that work? Actually, we find that most of the wildlife populations can be explained through the logistic growth equation. That is, the rate of change with time that is dN by dt is r into N multiplied by this factor K minus N by K. Earlier, we were thinking that dN by dt is r into N, but then, actually there is this other factor that is working. This factor is K minus N where K is the carrying capacity of the environment N is the current population size divided by K.

Now, what is carrying capacity? Carrying capacity is the capacity or the ability of the environment to sustain a wildlife population. If you have an environment with lots of food, lots of water, lots of space, then it can sustain a large population size, but if you have an area where there is a shortage of food, then the size of population that this area will be able to sustain will be less, and this is what we refer to as the carrying capacity of the environment.

So, it depends on a large number of factors. And when the population increases and it reaches to the carrying capacity, then there has to be a mechanism to keep it in check, because the population cannot exceed the carrying capacity. And because of that we are having this factor. So, what we are saying here is that dN by dt is r into N into K minus N by K. dN by dt is rN into K minus N by K.

Now, let us consider a situation where K or the carrying capacity is very much greater than the current population size. That is, suppose, the carrying capacity is around 10,000 individuals. So, the environment can support 10,000 individuals, but currently we have only say 10 individuals so, K is very much greater than N.

In such a scenario, we will have K minus N is approximately equal to K because N is very small so, we can approximate that K minus N is approximately equal to K or K minus N by K is approximately equal to K by K, which is 1. And in that case we have dN by dt is r into N into 1 is r into N. That is, when the carrying capacity is very high population sizes very less than the carrying capacity we have this equation dN by dt is r into N which is the equation of exponential growth. So, in this situation we will have an exponential growth.

But what will happen if the population sizes already very high? So, the next scenario is when K is approximately equal to N. So, the environment can support 10,000 individuals and we already have say 9900 individuals. In that scenario we can write that K minus N is approximately equal to 0 because it is very small value because K is approximately equal to N So, K minus N is approximately equal to 0. So, K minus N by K is approximately equal to 0 by K which is 0.

So, in that case we can write that dN by dt is r into N into something that is approximately equal to 0. So, this is approximately equal to 0 itself or in this case dN by dt is approximately equal to 0 meaning that the with time there is no change in n, there is no change in the population size, which means, that the population size is now a constant it does not increase at all. So, this is what the logistic growth equation actually suggests.

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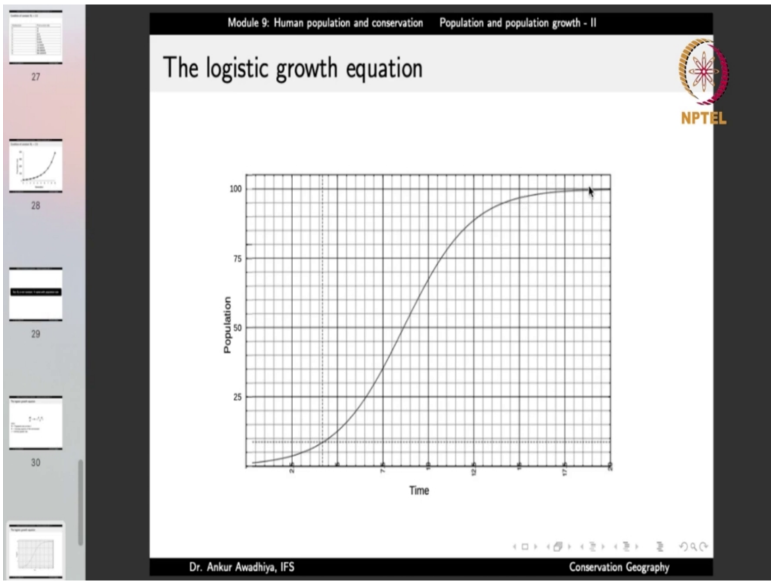

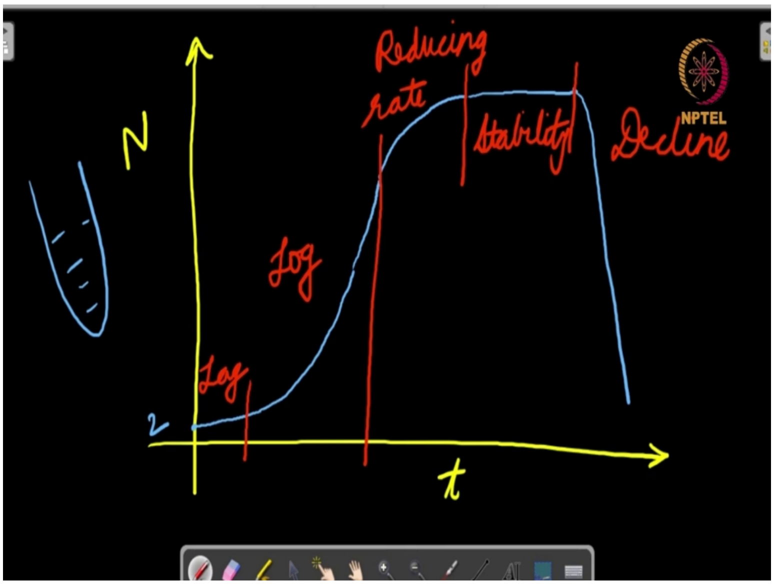

That is, if we plot the population versus time for any carrying capacity. So, suppose here the carrying capacities 100 and with time we will observe that in the beginning there is this exponential sort of a growth, but later on the population growth will become 0 and the population will become a fixed size population. Now, such sort of a curve is known as a sigmoidal curve.

We can understand this curve by taking the example of say rabbits on an island. So, on the y axis we are plotting the population size of rabbits. on the x axis we are plotting time t. Now, suppose there is an island it is a fairly large sized Island there no predictors, there are plants that are growing and so, the rabbits get their food and you release say a pair of rabbits.

Now, how would the population change with time? In the beginning, so, this is the pair of rabbits, so you have two rabbits here. So, the rabbits do not have any predator so they do not have to fear anybody and they have plenty of food, and there is plenty of space. So, the rabbit population would increase, but because you only have two rabbits, they can only produce a fixed number of children are offspring.

So, in the beginning the population increases, but it increases slowly, because there are less number of parents that are available. And as the number of parents increases, as the offspring become mature and they start reproducing themselves, we will start to see a rapid increase in the population, so this will pick up after a while. And so, now the population is increasing very fast.

But because now you have an exponential increase in population, so, after a while, what will happen is that the whole of the island will have rabbits everywhere. And now there are so many rabbits that they are now facing the crunch, there is a shortage of space, there is a shortage of food. And in such a scenario, we will say that the population is now reaching towards the carrying capacity. And when you have such a situation, there will be a shortage of food for quite a large number of rabbits.

And in that case, now, they will have to spend more time looking for food, they will have to spend more time fighting each other and the number of offspring that are produced every generation that will go down because more and more rabbits are now engaged in doing other activities.

And so, we will start to observe that the population now starts to have a reduced growth rate. And after a while, we will have a situation where the number of rabbits that are born is equal to the number of rabbits that are dying naturally because of old age. But when the island is completely covered with rabbits, it is also possible that there is a certain disease that erupts in the island, a majority of the rabbits get this disease because they are already poorly fed, they already are in a great amount of stress and so their immune system is not working that good and in such a scenario the population may actually crash.

So, this is what is normally observed. And we can observe these things even in the case of microorganisms. So, if you take a culture medium in a test tube, you add bacteria and you plot the number of bacteria that are there in the culture you will get the same curve. Now, this curve can be divided into several stages. The first one is known as the lag phase because here, the parents are less in number and so the population grows but it grows very slowly, because you do not have sufficient number of parents.

Then the second phase is known as the log phase where we actually find a logarithmic or an exponential growth, then we have a phase of reducing population growth, so we have a phase of reducing rate. Then we have a period of stability, where the population remains constant and this maybe followed by a phase of decline where the population size reduces, it declines. So, these are the various phases that are actually observed in various natural populations. So, it shows an S shaped curve so this is a sigmoidal curve.

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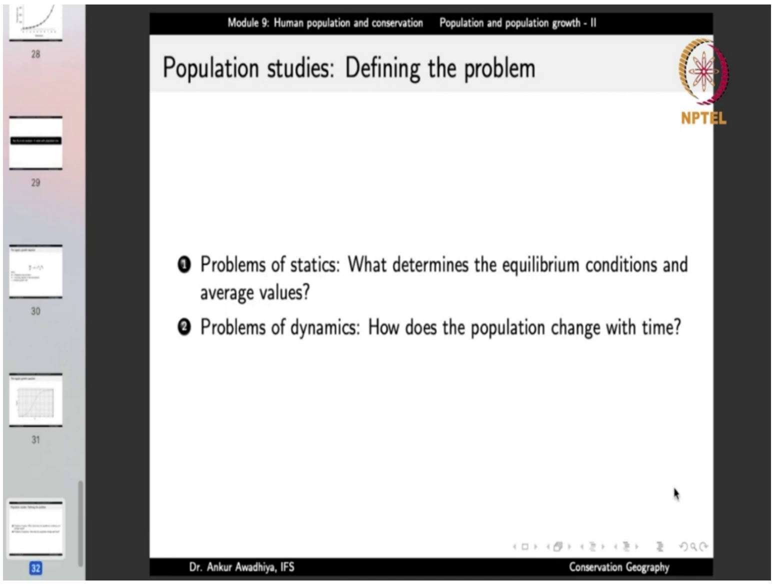

Now, when we do population studies, there are two kinds of problems or rather two viewpoints or perspectives that can be studied. So, we may be interested in problems of statics. Now, statics considers that, the population is fixed. Now, if we consider a fixed population what are the parameters and what are governing those parameters, that is, what determines the equilibrium conditions and the average values?

So, the problem of statics in the case of human geography may ask the question that, okay, Bangladesh has a high population density what determines this population density? How high can it go? Has it already reached the maximum point? On the other hand, because the population density in Greenland is less, what determines this value of population in that city. So, what are the equilibrium conditions and what determines those equilibrium conditions is what we ask in the case of statics. What determines the equilibrium conditions and their average values.

On the other hand we can have the problems of dynamics means changes. So, it asks the question, how does the population change with time. What are the factors that govern changes in the population? What are the factors that determine if a population will increase with time, it will decrease with time or it will remain constant, so these are the problems of dynamics. We study the problems of statics and dynamics both in the case of wildlife populations and in the case of human populations.

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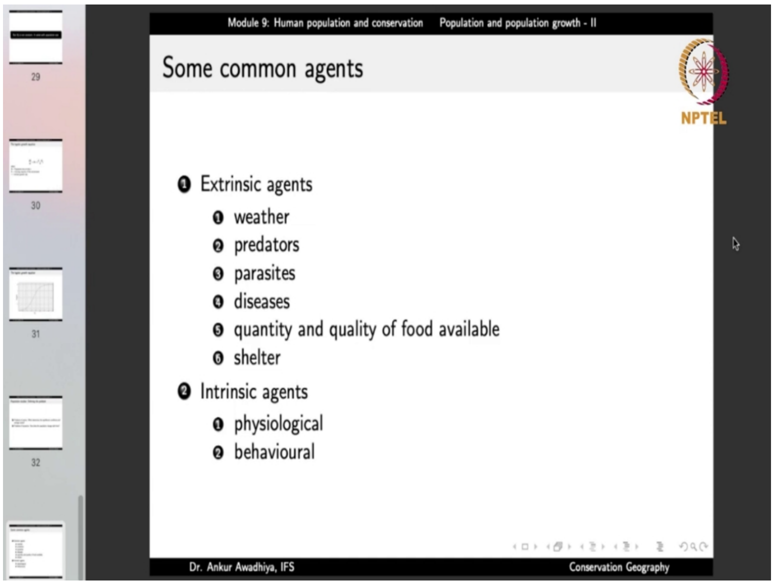

And in the case of wildlife populations there are certain agents that have been known. So, the size of the population and its growth rate is determined by several extrinsic agents that is outside agents and intrinsic agents. Extrinsic agents include things like weather, predators, parasites, diseases, quantity and quality of food that is available and shelter that is available.

So, for example, if there is a disease that wipes out a major chunk of the population the population size will decrease. If there is an area where the population is not getting sufficient food then the equilibrium population will be less. So, we can look at both the problems of dynamics and the problems of statics by looking at the extrinsic agents.

And there are also certain intrinsic agents, the physiological conditions of the animals, the behavioral conditions of the animals. So, these are various agents that determine the size of the wildlife populations. What about humans? In the case of humans, we now know that there is a process that is known as demographic transition.

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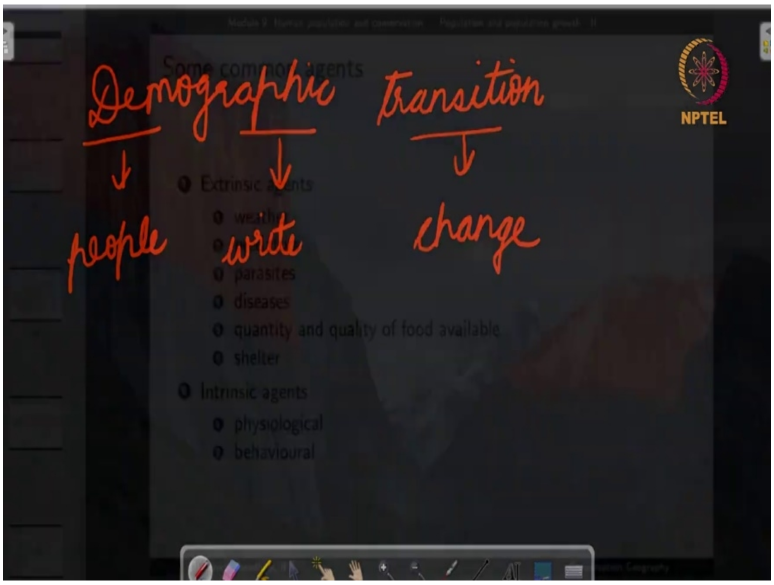

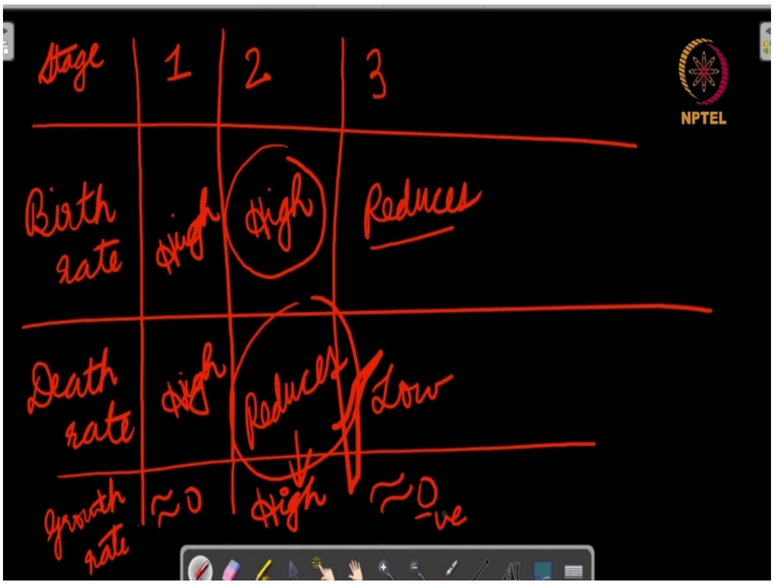

So, what is demographic transition? Demo refers to people, graphic is to write or to record, so demography is the process of writing or making a record of populations, people's populations, human population. And these demographic characteristics they undergo a transition which is a change. So, what kinds of changes can be foresee?

Now, in the case of primitive societies, we have conditions of high birth rate and high death rate. Now, the death rates are high because in the case of primitive societies there is no guarantee of food, there is widespread malnutrition, there is no sense of cleanliness and so there are a large number of diseases that occur in those societies, we have a very high infant mortality rate, we have a very high under 5 mortality rate. We also have a very high maternal mortality rate. So, during child birth a large number of women die. So, a primitive society is characterized by a high birth rate and a high death rate.

So, let us write birth rate and death rate. So, if we make a table, we can write that and this is the stage. So, in the first stage, you have a high birth rate and a high death rate. The death rate is high because you do not have sufficient nutritious food, you do not have medical facilities, and the birth rate has to be high in these conditions.

Because if you have a society that has a high death rate and a low birth rate in that case the population will collapse in a short period of time because the growth rate will be negative. And so, in these conditions, the society will just not exist, so only those societies are able to continue that have a high birth rate that is able to counter the high death rate.

So, this is in the case of a primitive a society without access to modern medicine or modern technologies. But then what happens? With the advancement of science, technology and our understanding about various diseases our understanding about things like malnutrition we make changes. So, we ensure that people get good food, nutritious food, they get access to medicines, there is universal healthcare.

Even small things like washing hands before eating food can make a big difference. People now understand the value of sanitation, so the sewage is dumped away from the society, the clean water that is used for drinking is way different from the sewage water. People do not dump their sewage in the same lake that they are taking their portable water from.

Now, with these changes we start to make differences in the death rates, because now, the diseases are not that prevalent. And if children are diseased they are getting medical attention they are getting the medicines. And so, in the second stage, we will have a situation where the death rate reduces, and so, now you have a low death rate. But there is nothing to change the behavior of people, they go on producing the same number of offspring that they have been producing, in the primitive society, so the birth rate remains high.

Now, if you have a society with a high birth rate and a low death rate, it would mean, that so if we write the growth rate in the first case it is roughly equal to 0, because the high birth are compensated by the high deaths, but in the second stage, you have a very high growth rate. Because you have a large number of births and low number of deaths, and so, the population increases, the population explodes like anything, and which is what we have observed in a large number of countries. With the advancements of science and technology, most of the countries move to a phase where they have an exploding population growth rate. But then, this cannot continue forever, and at the same time, there is no need to have a high birth rate. In the primitive we required a high birth rate to counter the high death rate, but now that people understand that okay, the death rate is so low they now start to feel concerned about the increase in their populations.

And so, the society makes change, the society goes for ways in which they can reduce the birth rate, both, at the level of the society and also at the level of the individuals. Because now, people come to the understanding that okay if I have more number of children my property will be divided in so many children that everybody will get a very small share of the property. And so, now people consciously try to use things like contraceptives.

And so, in the third stage we have a society where the birth rate also reduces, and the death rate is already low. And in this case, you again get to a phase where the growth rate is roughly equal to 0 or in certain cases, the birth rate reduces so much that it can even become negative. Because we already have so many people that now, an increase in the population is not required, we can actually reduce the population.

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And so, in a large number of societies if you plot the population growth. So, if you have population versus time, in the beginning you have very less growth of population or roughly the population remains stable because the high births and high deaths equalize each other, then we have a phase where the population increases exponentially, because the death rates are going down. Then it reaches a peak and then it starts to decrease. Now, once it starts to decrease you can have many scenarios. You can have a population that goes back to the original level of you can have a population that is maintained at this level or you can have a population that is maintained at some other level.

Now, that would depend on the society, it would depend on the culture of the society, and the conditions of the area. So, this is what is demographic transition. And demographic transition can help us answer the questions of statics and dynamics in the case of human populations. So, that is all for today. Thank you for your attention. Jai Hind!