Wildlife Ecology
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Lecture – 26
Human population growth and food requirements

[FL]. Today we move forward with our discussion on Human Ecology and in this lecture we will look at Human population growth and food requirements, especially the theory of Thomas Robert Malthus.

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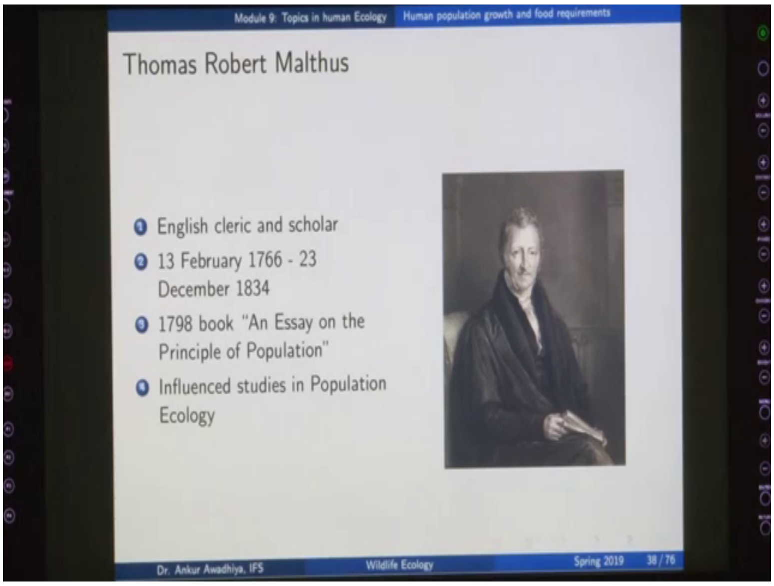

Now we had met Thomas Malthus in our first module and the lecture on the history of ecology. So, if you remember he was in English cleric and scholar who lived between 13th February 1766 and 23rd of December 1834. And in 1798 he wrote a book "An Essay on the Principle of Population" and this book has had a very deep impact on the study of population ecology. So, what did he write in this book?

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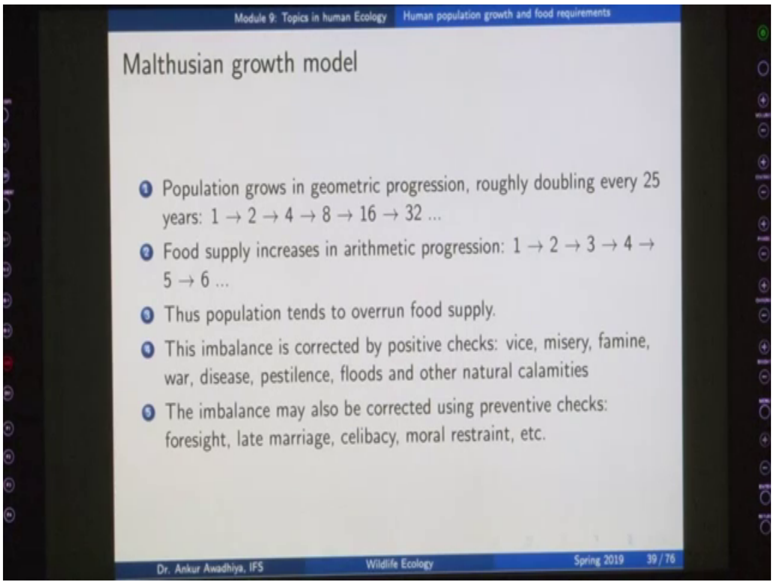

Basically the tenets of Malthusian growth models are these. The first point is that population grows in geometric progression roughly doubling every 25 years. Now this 25 years is a time frame that he noted from his particular times, but then later on we will see that this 25 years no longer holds valid.

But more or less what he said was that the population grows in geometric progression. So, if you have say 1 million people somewhere so, from 1 million in 25 years that will become 2 million, then in the next 25 years it will become 4 million then 8 million and then 16 million and 32 million and so on. So, if we see that this one is 25, 50, 75, 100, 125; so in 125 years it has moved from 1 to 32.

However, if we look at the food supplies they do not increase in geometric progression, but they increase in arithmetic progression. So, in this period; in 125 years it will go from 1 to 2, 2 to 3, 3 to 4, 5 and 6. So, suppose in the begging we had 1 million people and say 1 million kg of cereals so, at the end of 125 years we will be having 32 million people and only 6 million kgs of tons of cereal. So essentially it says that, the population tends to over and food supply.

Now, suppose you try to increase the food production for some particular point of time so, in that period because the population is dependent on the food. So, the population will increase very fast and even if you start with a larger amount of food in a very short time the population will overrun the food supply. So, this creates an imbalance so, you have more number of people and less number of resources.

Now, if you remember our talks on Darwinism that also said a very similar thing that every organism tends to over produce, but then the resources are limited and so, there is a struggle for existence. Now in the struggle for existence there are some organisms that die out.

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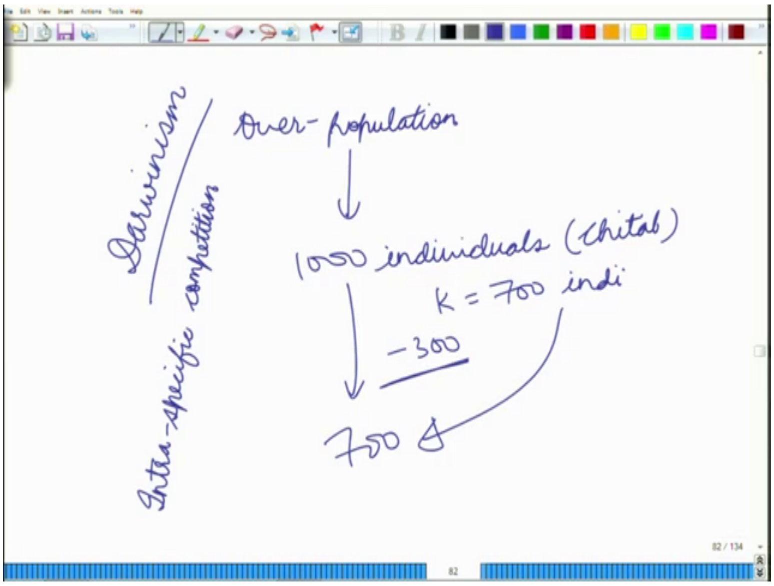

So, when you have overpopulation; so, suppose you have 10000 individuals of any particular species let us say that we are considering a Chital population. Now you have 1000 individuals, but the carrying capacity is say 700 individuals. So, in this case 300 individuals will die off, why would they die off? Because you have limited amount of resources, more number of individuals everybody is fighting and so in that case there would be some individuals who will be dominant and some individuals who will be not so dominant or a bit recessive.

So, the dominant individual is able to get more amount of food because it is able to drive every. So, for instance things that we talked about in the case of intra specific competition so, there will be competition and there will be some individuals in any population that will be able to drive of the other individuals. When you have this driving off of other individuals, so there will be some individuals in this population precisely 300 individuals who do not have access to sufficient amounts of food; so they will suffer from malnutrition, maybe they will suffer from some diseases and slowly and steadily they will die off. And ultimately we will come to a situation where you have only 700 individuals left which is equal to the carrying capacity. Now, these are the tenets of Darwinism.

And here what we are talking about is an intra-specific competition. Now in the case of Malthus what he says is that here also you have a population that grows very fast, you have a food supply that is growing not so fast, now in this case the food supply we can correlate it with the carrying capacity of the environment. In the case of Darwinism the carrying capacity was more or less fixed, but in this case Malthus saw that the food supply is increasing; so he stated that it goes on increasing in an arithmetic progression. But here is well you will have a situation in which the population tends to overrun the food supply and when that happens then nature would bring in some sorts of checks and balances.

And Malthus said that this imbalance is corrected by positive checks. So, these depths of people he is referred to as positive checks. And he said that these positive checks are vice, misery, famine, war, disease, pestilence, floods and other natural calamities. So, he said that in his theory, we are not talking about intra specific competition and some people who are able to drive of others, but then he says that the nature's way of solving this issue is to bring about some positive checks.

So, you will have some famine or maybe you will have some floods or you will have some diseases that are going to wipe out a major portion of the population. And once that happens the population which reduces to a level that is beings that can be sustained by the level of agricultural productivity. But then Malthus said that these positive checks are not a good way of checking the population because here we are talking about human beings and we do not want to have a situation of floods or families or diseases or pestilence.

So, then he said that as human beings there we have this other option that we can correct this imbalance, the imbalance between the number of people and the food supply using preventive checks. Now, preventive checks are foresight, late marriage, celibacy, moral restraint and so on. So, essentially he said that even though in natures plan is that we are going to increase our population in a geometric progression, but then we as human beings we can use our foresight or there could be some individuals who can let go of producing offspring. So, they are not producing any off springs, they are living a celibate life or there could be people would opt for a late marriage.

So, if you have a late marriage so, in that case the rate of population growth will come down because in place of having population that is doubling every 25 years maybe you will have a population that is doubling every say 30 years. So, he said that late marriage is also a way in which we can use a preventive check and things like moral restraint and so on.

So, this is in short the Malthusian growth model, the population increases in a geometric progression food increases in an arithmetic progression. So, that leads to an imbalance and there are positive checks and there are preventive checks; so this is in short the Malthusian model.

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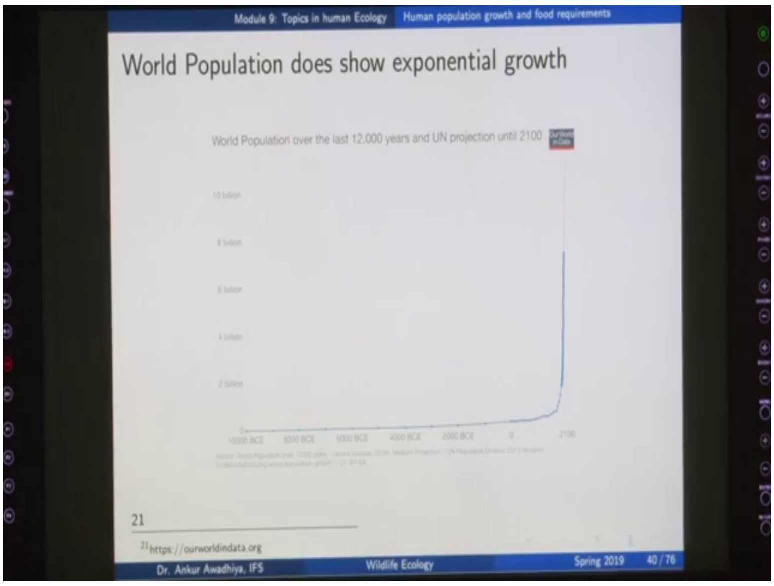

And if we look at the world population growth rate so, we can say that yes it does increase exponentially so, there is some amount of this geometric progression thing that is working. So, the population is increasing at a very fast rate.

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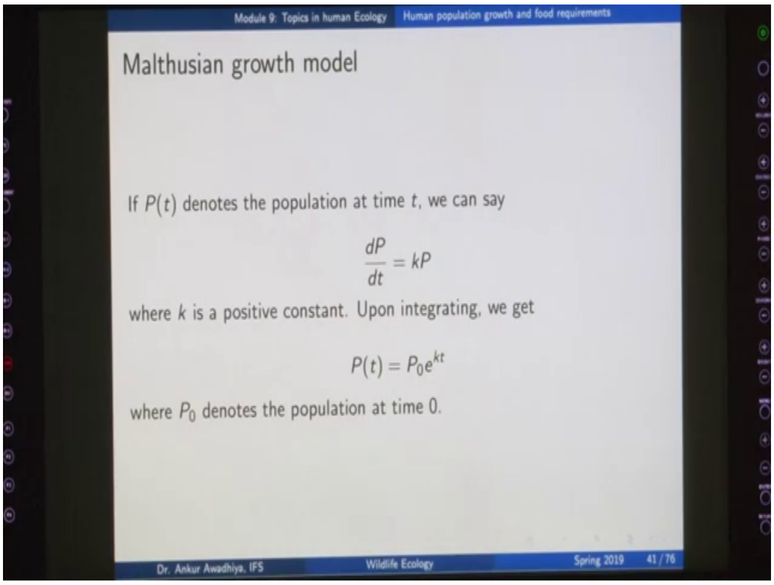

Now, if we put the Malthusian theory in terms of mathematics, we can say that if P t denotes the population at a time t, then we can say that dP by dt that is the rate of increase of the population is equal to k times P, where k is a constant and P is the population. Essentially what this thing is saying is that, you have a population that is increasing now; the rate of increase of the population will be proportional to the population that is present at that particular point of time.

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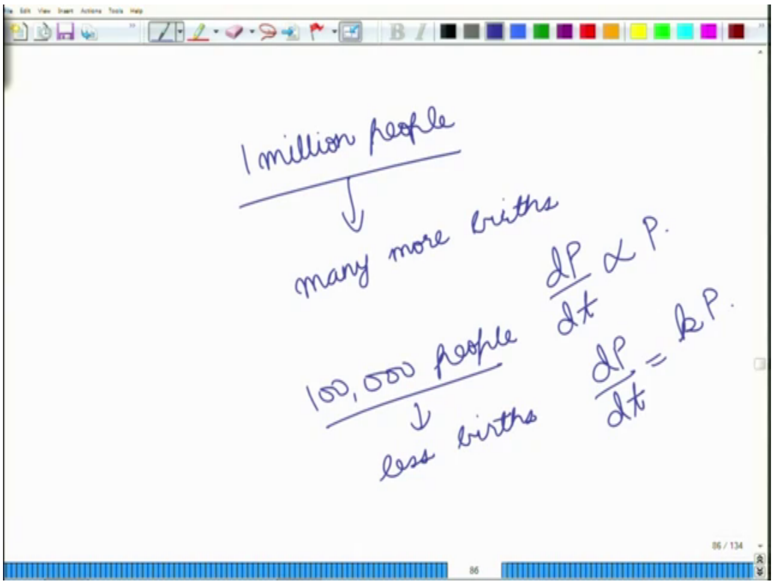

So, essentially if you have a situation and which you have 1 million people so, in that case you will have many more births as compared to a situation in which you only have say 100,000 people; so in this case you have less number of births. Because in the case of a smaller population, you have a lesser number of females that are pregnant at an important of time or are producing the off springs, because the females of any population that are very young or that a very old will not be producing the off springs, only those females that are in the reproductive age are going to produce the population or are going to produce the off springs.

Now in this case we are saying that dP by dt is proportional to the population at that particular time or we can say that dP by dt is equal to some constant k times P. Now, if that happens then we can integrate this equation and we will get to this result that P of t is equal to P naught into e to the power of k t, where P naught denotes the population at time 0.

So, here we are saying that the population at any time t is equal to some constant value which is the population at time point 0 multiplied by e to the power k into t where k is this constant that we had derived here and t is the time period. So, this would say that we have a population that is increasing exponentially.

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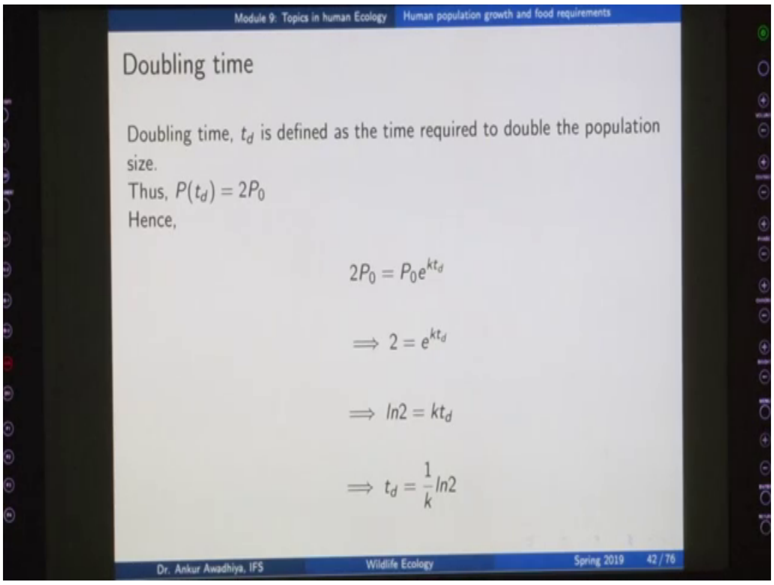

And from here we can define this term called as the doubling time. Now, doubling time or t d is defined as the time that is required to double the population size. So, suppose we started with 1 million people so, how much time does it take for the population to increase from 1 million to 2 million or from 2 million to 4 million or from 4 million to 8 million, that time t d is called the doubling time. So, here we can say that in time t d we have the population at time t d is twice the original population or the population as at time point 0.

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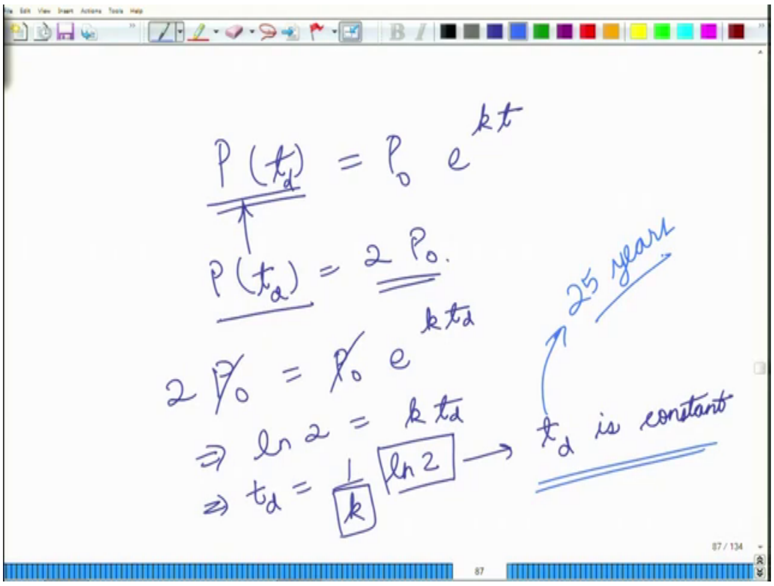

So, we had said that the population at any time t is equal to P naught into e to the power of kt and we are saying that the population at time t d is equal to twice the original population. So, if you put this value of t d here, we will get that you have twice of P 0. So, in place of P t you put P t d and in this case you have twice of P 0 is equal to P 0 into e to the power of kt. Now cancelling out the P 0 and taking natural logarithm on both the sides, you will have log of 2 is equal to k times t and in this case you have t d because this is the doubling time or we can say that t d is equal to 1 by k log 2.

Now, in this particular case because log 2 is a constant and k is also a constant so, we can say that your t d is constant or essentially when you are having an exponential increase, there will be a fixed time period t d which is known as the doubling time in which you will see that the population is increasing in a geometric progression so, this is what Malthus said. So, essentially this is a formula that we can remember that t d is equal to 1 by k log 2, but then is this theory correct is this what we actually see out there in nature?

Now it turns out that if you have a population that is increasing exponentially and you have the food supply that is increasing in an arithmetic manner, then we should have had a number of m means a number of floods, a number of pestilences, but then we are not seeing all of these today which brings us to the criticisms of this model. So, there are some things in this model that are not quite correct.

So, the first criticism is that the population growth is not as suggested, the population growth is not completely exponential. So, in our results we had seen that this term td is a constant which Malthus said that it would be 25 years.

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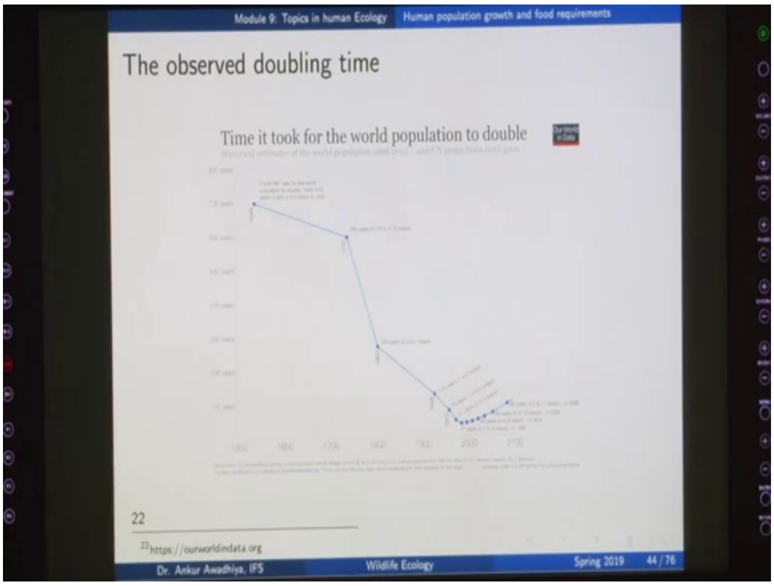

But then if we look at the actual doubling time so, on this x axis we have the years, on the y axis we have the number of years it takes to double the population. So, if we look at this point 1543 so, it took 697 years for the world population to double from 0.25 billion in 637 to 0.5 billion in 1543.

So, it took as many as 697 years or close to 700 years to move from 0.25 billion to 0.5 billion. And if we look at a time point later on so, if we look at this year 1928; in 1928, the world population had reached 2 billion and it had taken only 125 years to move from 1 billion to 2 billion. So, the t d is not constant, it can vary from as much as say around 700 years to as little as 37 years. So, if you look at this point so, in 1987 the world population was 5 billion and it had taken only 37 years to move from 2.5 billion to 5 billion. So, what we are saying here is that even though the Malthusian model says that your t d is a constant, but then in actuality we are saying that t d is not a constant.

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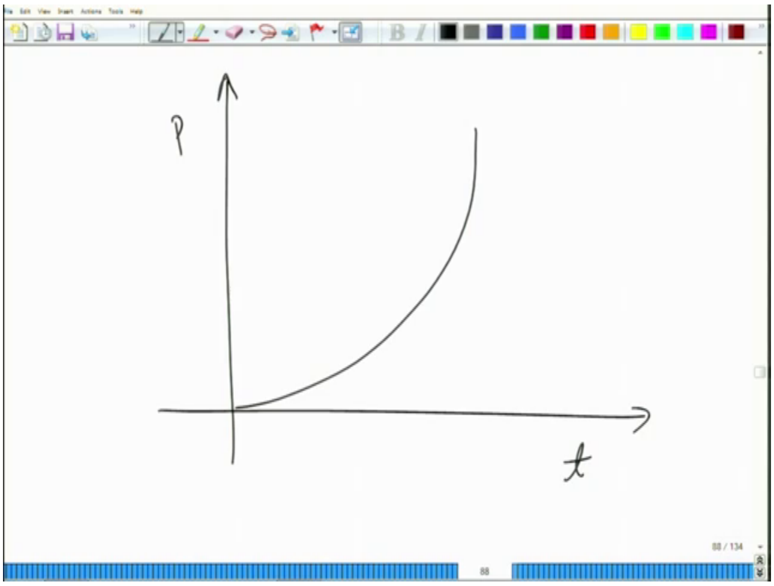

So, we cannot say that the population is actually growing exponentially, even though it looks like an exponential growth. Because when we are plotting the population versus time; it does look like we are increasing the population like this, but then if we look into the intricacies we find that t d is not a constant here.

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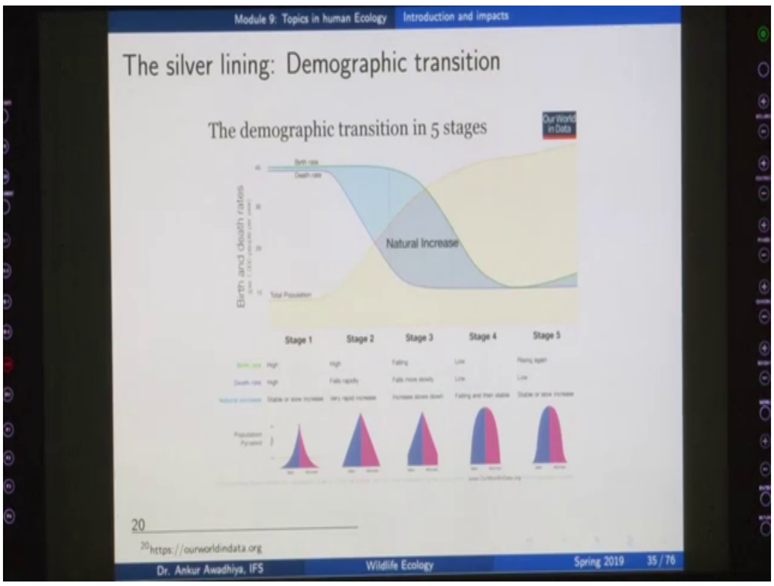

And it turns out that actually the population grows by this demographic transition.

Now what do we mean by a demographic transition?

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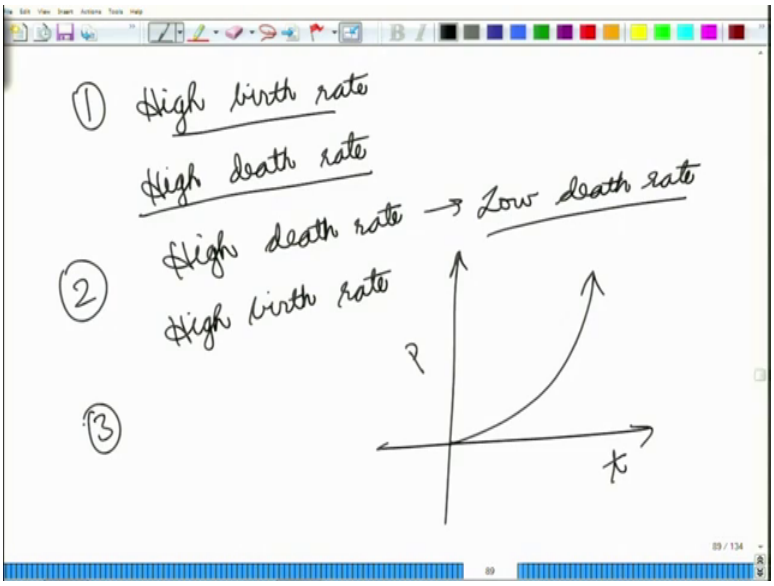

Now consider a society; now in the first case you have a society, that is a primitive society and in this primitive society you have a high birthrate and a high death rate. Now you have a high birthrate, because there are no methods of contraception that are available and because people are reproducing as much as possible. So, that because in this society you have a higher death rate. So, every parent wants that at least some of it is off springs are able to survive to it is own maturity.

So, remember we are ready in talking about fitness. Now fitness is the situation in which you are able to produce or your offspring and your off springs are such that they are also able to produce their own off springs. Now this primitive society has a high death rate. Now, why does it have a high death rate because you do not have modern medicine that is available?

So, if there is any communicable disease if you have, any infection there is a very huge possibility that you might die; also sanitation is not there so, people are suffering from diseases like cholera you do not have good houses, so you might have huge amounts of say plague or diseases that come up when you are not living in a sanitary environment and so on.

So, there is a huge death rate you do not have sufficient access to food, there is widespread malnutrition, the even your theories of nutrition have not been developed. So, you do not know if somebody is getting C scurvy or somebody is getting very very so, you do not know why are they getting these diseases or that you can prevent scurvy by giving some amount of lime or some amount of citrus fruits. So, you do not have all of these information and in the absence of the all these information you have a very high death rate.

Now, if you have a high death rate the society compensates by having a high birth rate. So, for instance if you know that out of every 6 children 5 children are going to die in their infancy so, you have say an infant mortality rate of 5 out of 6. So, if you as parents if you want to have at least one progeny that lives to its maturity; so, you would want to have at least say 6 children because you know that 5 out of 6 are going to die anyway. So, a high death rate leads to a high birth rate.

Now, in these societies with a very high birth rate or in a very high death rate, both the high birth rate and the high death rate cancel out each other. So, the rate of population growth is very less, because the number of individuals that are born into this society a number of them die off. So, this is the first stage in the transition in which you have a high birth rate and a high death rate.

Now, the second stage in demographic transition is where you are reducing the death rates so, you have shifted from a high death rate to a low death rate. Now, how are you able to reduce the death rate? By providing more amount of nutrition, by providing modern medical facilities, by having more amount of information about what somebody should eat, how to prevent diseases, how to treat diseases, if they are there.

So, in this level of society you have now a low death rate, but then a low death rate does not automatically transition into a low birth rate. Why? Because parents who were in the previous generation producing say 6 off springs, they will not shift from say of off springs to an off spring in an instant. So, you have the society in which you have a low death rate because of the medical facilities and because of the advances in science and technology, but you still have a high birthrate.

Now, if that is the situation you have a low death rate and a high birthrate so, in that case you have a number of individuals that have been born in this population, but because the death rate is low so, a number of them are also able to survive and reproduce further.

When that happens, you see the classical case of an exponential rate of population increase. So, this is population versus time and you have individuals that are being added into this population again and again and the more number of individuals that you have in this population the more number of off springs that are produced. So, this cycle supports itself and the population booms, that is the second stage.

Now, the third stage in this demographic transition is where, now because you have a very huge amount of population. So, now the society tries to reduce the birthrate as well.

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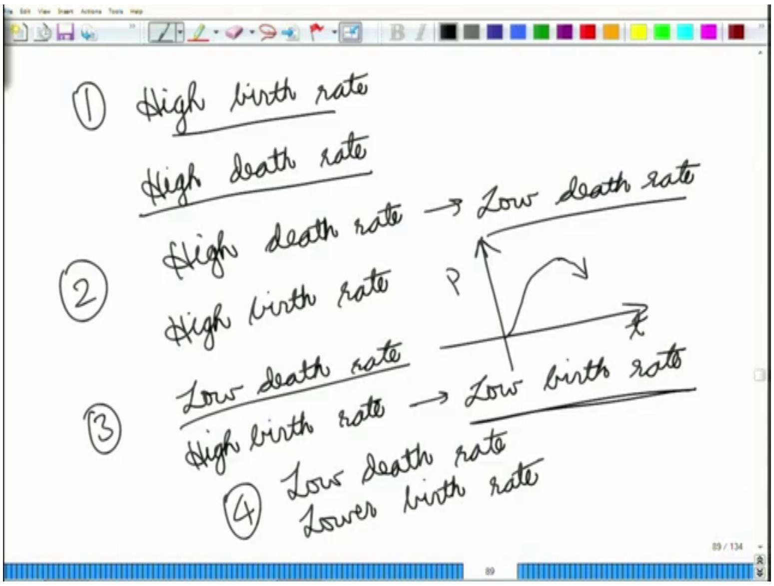

So, in this case you have a low death rate and you shift from a high birth rate to a low birth rate. Now, how can you have a low birth rate? By say having more access to contraception or say by having an increased age at which people want to have off springs or maybe in this society, now people just do not want to have any off springs or they just want to have only one off springs. So, in place of having a norm of say 6 or 7 babies now the norm is shifted to just 1 baby.

So, in this case you have a low death rate and a low birth rate. So, again the birth rate and the death rate are able to counter each other. So, the net increase in the population will be very small so, the population is now stabilized. So, in place of having your population that was increasing like this, now you have a population that is now moving towards stability. So, in this case the population will become stable in a very short period of time; because now, again you have a low birthrate that is being compensated by a low death rate.

Now, the fourth stage in the transition could be of a stage in which you continue to have a low death rate, but you have an even lower birth rate so, we had talked about the replacement level fertility. A replacement level fertility is a situation in which you have 2 people in the parental generation and they are able to replace themselves in the next generation. So, for instance you have a mother and a father so, 2 people in one generation and then in the next generation you also have 2 kids. So, that is the replacement level fertility. What if you have 2 individuals and the parental generation and less than 2 individuals in the next generation.

So, suppose on an average you have say 1.7 babies or say even just 1 baby. So, in that case the population will now go on decreasing itself. So, in place of having this population that was just stabilizing itself, now you can have a situation in which the population has started to decrease. So, that can be another mode in which the demographic transition occurs.

Now, in this slide what we are observing is that here you have the birth rates and the death rates, in the very first instance you have a high birth rate and a high death rate. So, the birth rate is this green colored curve and the death rate is this blue colored curve. Now, in this stage when you have a high birth rate and a high death rate, the population does not increase, the population remains more or less constant.

Then in the second stage when you have a falling death rate and the birth rate has remained stable so, in this case the population has started rising. In the third stage you have a falling death rate that continues and the birth rate has started to decrease, but here again we see that, we are increasing in the population, but then it is now becoming more and more stable and this is the stage where they actually are today. Now in a short while when we reach this stage in which your birth rate and the death rates both are low so, in this case we will observe flatness in the total population.

So, this yellow curve is the total population and then when you have reached this flatness, the fifth stage can be a stage in which your birth rate starts rising again or maybe the birth rate becomes even lower than the death rate and in both the cases you will have different results. So, if birth rates increase then you will see a further increase in the population or else you will start seeing a decrease in the population.

Now, these stages can also be represented in terms of the population pyramids. Now, in the case of a population pyramid what we are seeing here. So, a population pyramid looks like this.

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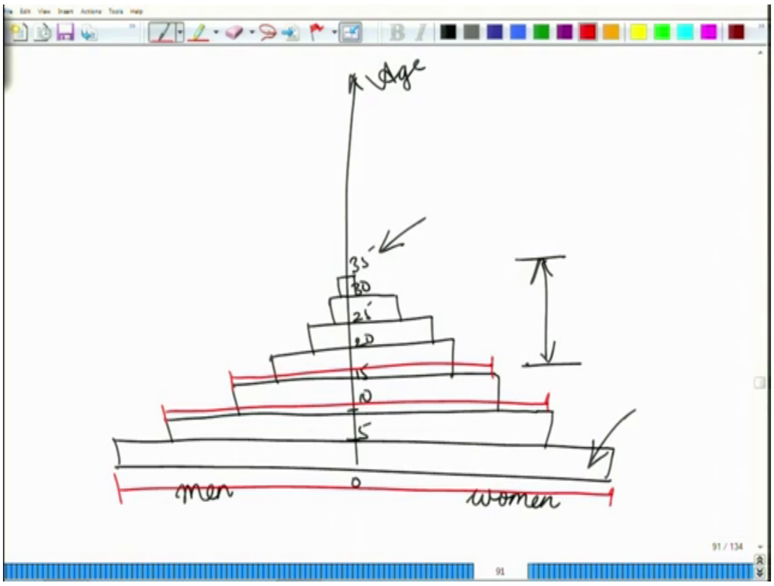

So, here you have the number of men in the population, here you have the number of women in the population and then this is the age of different cohorts. So, let us say that in the case of an age group between 0 to 5 years, you have a number of babies some of which are male babies, some of which are female babies.

Now in the case of 5 to 10 years you have a lesser number of individuals that are here then progressively it reduces 15, 20, 25, 30 and maybe 35. Now, this is a population where we are saying that you have a life expectancy of around 35 years plus you if we consider the population that is there in the reproductive age, let us say bit more than say 18 to 35 years. So, here we have less number of individuals that are there, but then the number of children that are being born are very large.

So, in this case this is representing a population with a high birth rate and a high death rate. Now, this has a high death rate because if you look at any particular rung; so, in this particular rung here we have so many children, but then out of these children only these many are able to reach to the next rung and then only these many are able to reach the next step of the ladder.

So, in this pyramid we are seeing a high birth rate and a high death rate and this is represented here. So, this is a population in which you have a high birth rate so, the bottom is very large, a high death rate so, it is tapering very fast and this is representative of the first stage a high birth rate and a high death rate.

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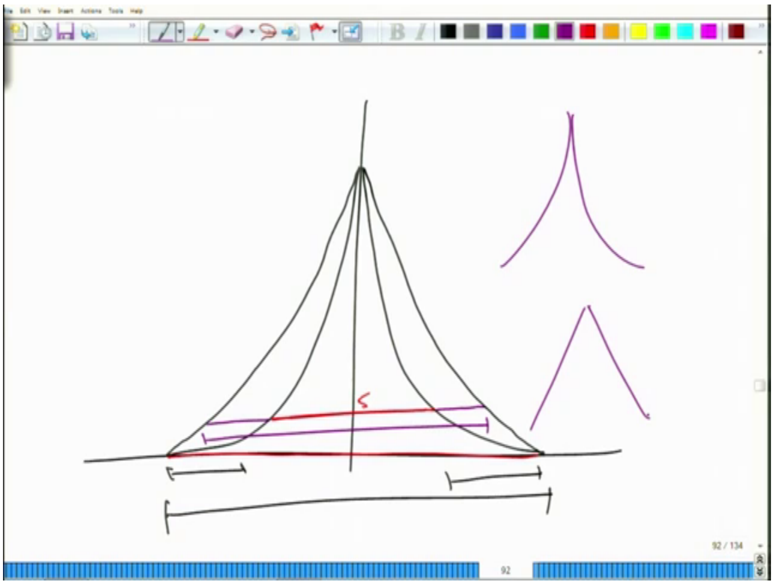

Now in the case of the second stage you have a reduction in the death rates. So, when you have more death rates so, suppose you have a population in which you have a very steep death rate. Now, if you reduce the death rates so, these many individuals that were dying off. So, now they will survive and maybe your death rate will reduce so, in this case the curve will become something like this.

So, it is now becoming more and more triangular in place of having a very it still has a very large sized base because you have a number of children that are being born, but then in place of having so, these are the number of children being born, but if you look at the number of children that are there in at the age of 5 years. So, earlier we had only these many children, but now, because you are able to reduce infant mortality and you are able to reduce under 5 child mortality. So, the number of children that are able to survive that has increased. So now, this curve increase of looking like this it now looks more like a triangle. So, this is the second population pyramid that we observe.

So, here you have a high birth rate, but death rate that is now lowering. Now, when you have a stage in which your birth rate also starts to slow down. So, in this case earlier we had this large taper; now the taper will start to reduce; so that is the third stage.

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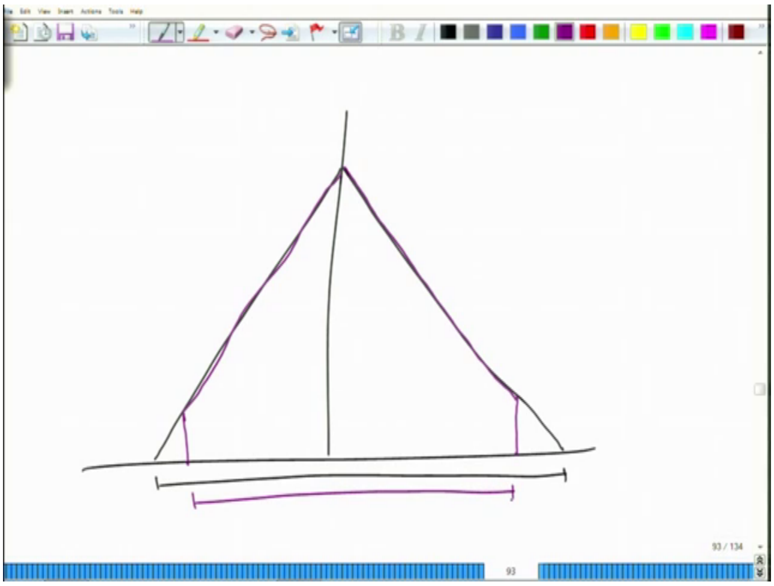

So, in the third stage what is happening is that in place of having the curve that was looking like this. Now, the society is trying to reduce the number of children that it is having. So, probably in place of having a steep stroke like this, probably it will look like this, because the individuals that have already have been born, but then the society can only reduce then the children that are being born now or in the future.

So, in this case in place of having these many children that were being born, now the society is trying to reduce this number to this much; which is why we are observing that this curve is now starting to lose out these two corners that were there in this triangle. Now in the fourth stage, when you have a low birthrate and a low death rate what is happening is that in after having this particular shape of the curve. Now, what the society is trying to do is, to convert it into a shape that looks like this.

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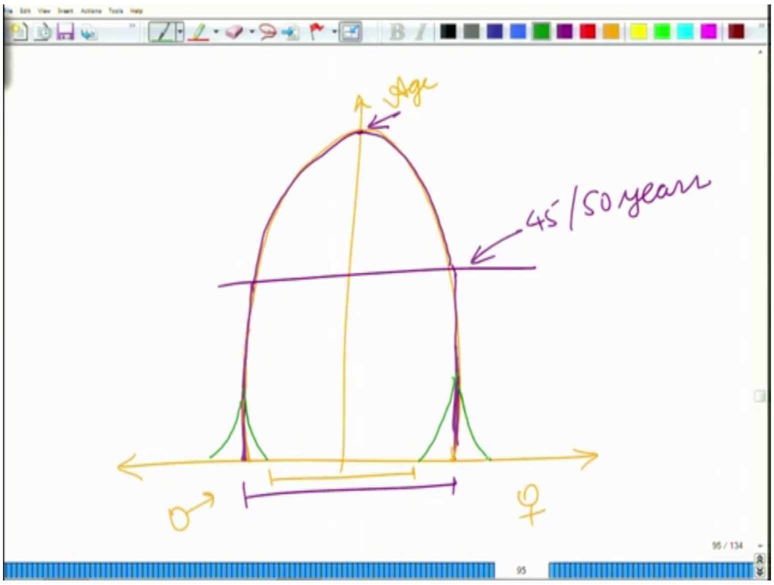

So, now you are trying to reduce your birth rates, but because the death rate is also low. So, any individual that is that has been born is going to survive for a very long period and then slowly you will start seeing the death at a very old age. So, here again you have the age and here you have the number of women and the number of men that up or the male and the female population that is there.

Now in this case what we are seeing is that, for till say a particular age; till the age of say 45 or 50, this is hardly any death that we are observing in this particular population. So, there is hardly any deaths that we are observing till this particular age let us say that this age is say 45 years or say 50 years. And even after this year this age because the society is having access to modern medical facilities. So, even the deaths after this age are very low in numbers and so it very slowly it becomes to the top and then this is the life expectancy of this particular population or this particular society. So, this is how we represent that society in the case of a population pyramid.

Now later on, it is possible that the society might try to reduce the birth rates even further and when that happens, you will see a society that will start looking like this. So, the number of children that have been born or the timing born that the society would try to reduce that even further. So, from having these many number of children probably the society will start to think about having these many number of children or it is also possible that the society might find that now the population has a number of old individuals and probably we need number of children to support ourselves. So, it is also possible that you might have a curve that will start to bulge out in the bottom.

So, this is what is represented here in the case of the fifth stage. So, this is the fifth stage of the society that has a low birthrate a low death rate, but then the birth rate is slightly more than the death rate. So, that was the first criticism of Malthus that what he had projected is not exactly correct because it also depends on the level of affluence of the society, it also depends on what stage of demographics stage you are there in the society.

The second criticism of Malthus is that agricultural growth is not as he had suggested. So, Malthus had suggested that agricultural growth was as an arithmetic progression 1 to 2, 2 to 3 and so on.

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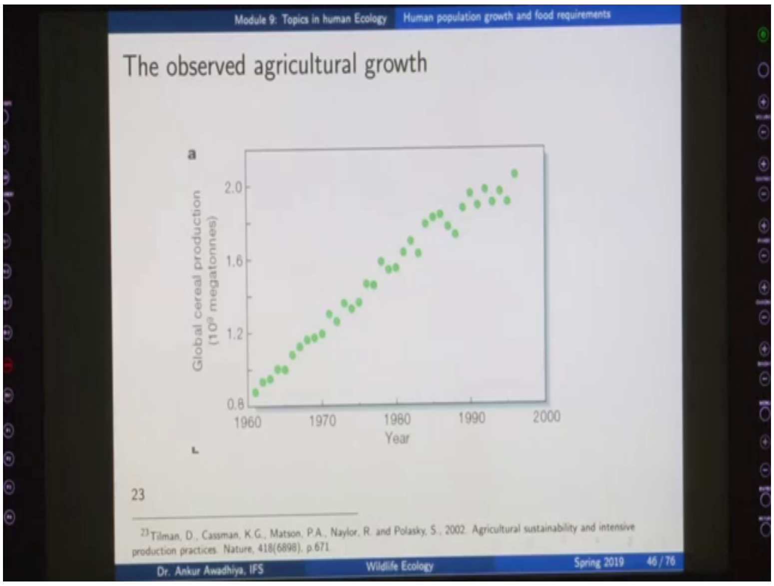

And that is possible when we are looking at a short period of time. So, for instance here we are seeing that the growth rate is increasing in an arithmetic progression.

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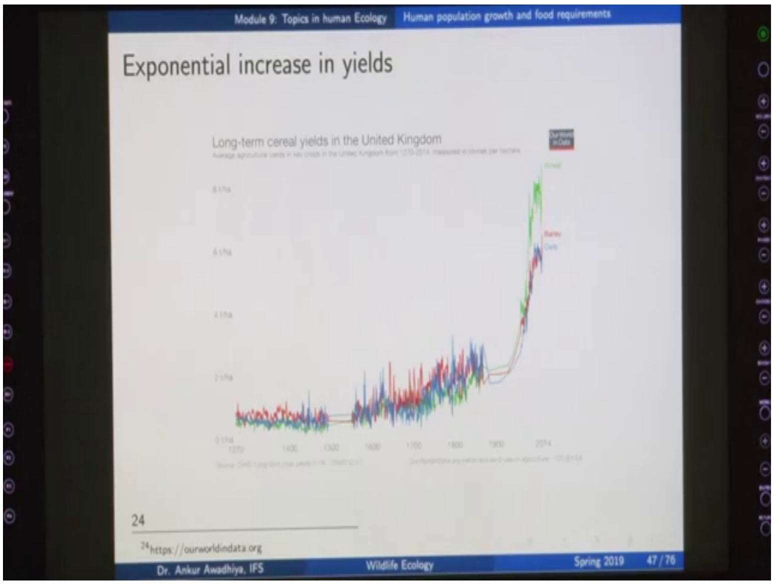

But then, if we look at longer time scales we find that here also we are observing an exponential increase in the yields of a number of crops. So, here we are saying the long term cereal yields in the case of United Kingdom, on the x axis we have the time so, it starts from 1270 and goes till 2014 and on the y axis we are seeing the yields how many tonnes per hectare of cereals are being produced.

And here we are looking at the red color is barley, the blue one is oats and the green one is wheat. Now, if you look at the very early stage productivity; we see that the productivity was close to say 0.5 tonnes per hectare, but now the productivity is as high as 8 tonnes per hectare in the case of wheat. So, from 0.5 tonnes per hectare to 8 tonnes per hectare, in this period we saw more or less in arithmetic progression, but then in this period what we are observing is a geometric progression or in exponential increase.

So, what Malthus had predicted in the case of agricultural productivity or agriculture will supply that is also not correct it might move as a geometric progression or it might even move as an exponential growth or a geometric progression. Malthus also did not consider that with time we can even incorporate more land into our agricultural sector.

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So, if we look at the amount of land that has been used for different sectors we will find; so, this is just a diagrammatic representation of the amount of land that is there in different sectors. So, here we can see that this pink area is the amount of land that we have diverted to the crops so, this is the cropland area. Then the red portion is the amount of area that has been diverted to livestock.

So, we can see that roughly around say between one forth and one third of the total area of the earth has been diverted to agriculture it is either a cropland or it is a land that is used for livestock or a land that is being used for grazing. What about the other lands? The green one is showing us the area that is under the forest, the blue one is showing roughly the amount of area that we have under built up area, the brown one is showing us the amount of area that is barren land and this dark brown area is showing us the amount of area that is a shrub land and this blue area is the total amount of fresh water.

So, if you add up all the fresh water that is there in the world, if you add up all the lakes, all the ponds on, all the rivers it would be roughly the size of Mongolia. And if you add up all the cropland it would be roughly the size of China plus Japan plus some other countries of Southeast Asia. And this proportion has not remained constant with time. We have tried to increase the amount of land that is there a label for croplands and for livestock and how do we do that? Well we through time, we have chopped up some of the areas of forest and we have diverted that land into our agriculture or maybe we have diverted some amount of shrub land into agriculture or we have diverted some amount of barren lands into agricultural sector. So, in this manner the amount of land that is being used for agriculture is increasing with time.

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And for a number of countries such as India, we can say that as much as around 80 percent of the land is currently being used for agriculture. And again, this chart is showing us, the share of land that is being used for agriculture in different countries. In some of the very goal countries like when we talk about Canada or when we talk about say Greenland. The total area that is under cultivation or under agriculture is say less than 10 percent, but then in some countries such as India it is as much as 80 percent and in some of the countries it is now even more.

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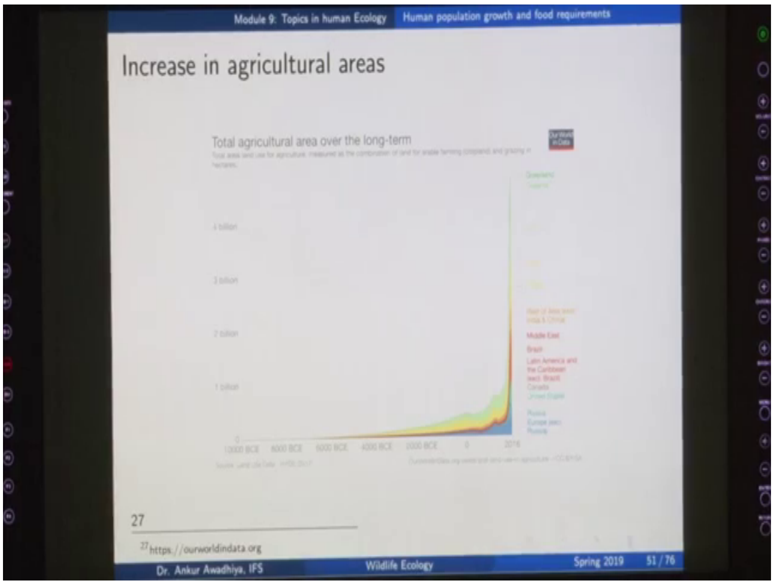

So, if you look at the rise of or the increase in the agricultural areas, here we can see that on the x axis we have the area that was there under agriculture and agriculture started around 10000 BC and we can see that the amount of area under agriculture that has also been increasing exponentially. So, we have been diverting a number of habitats, we have been diverting a number of other land uses and we are putting more and more land under agriculture.

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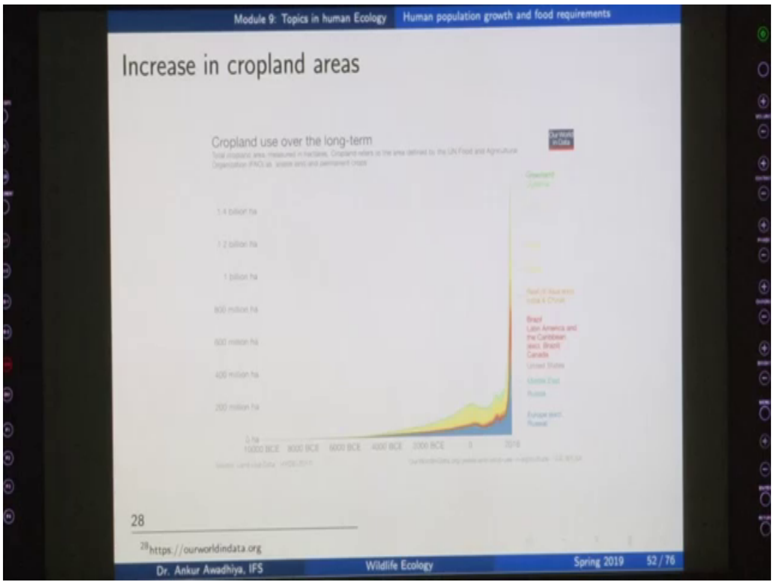

And this agriculture includes both the cropland. So, the crop lands have also been increasing exponentially and especially in the last 200 - 300 years we can see that the area has that the increase has been very rapid.

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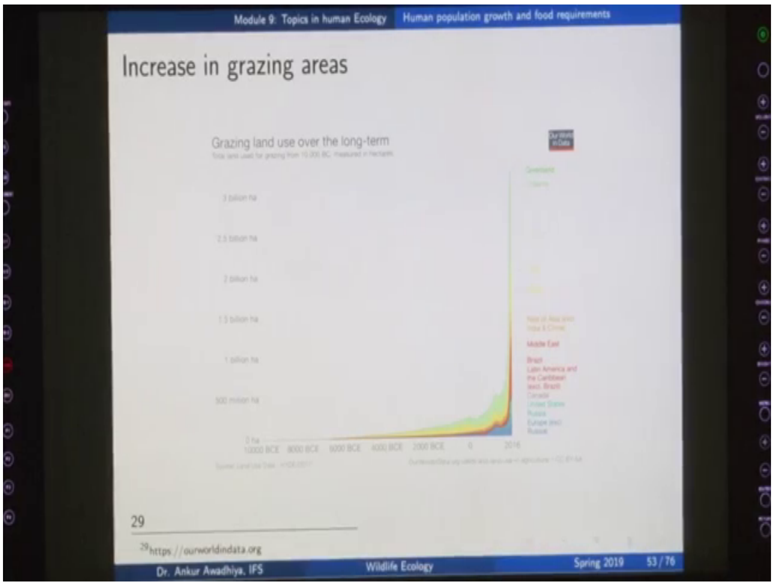

So, there has been more land in the case of cropland in Moreland in the case of grazing as well. And the fourth thing that Malthus did not consider was the rule of technology.

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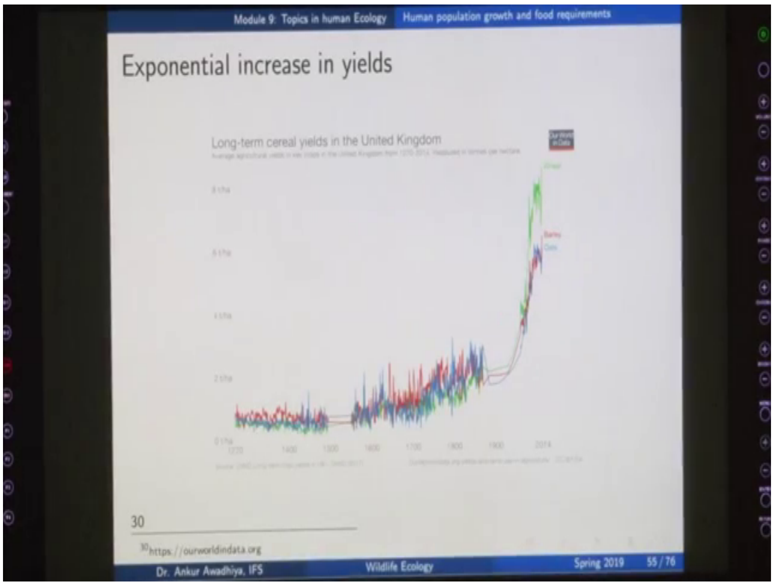

So, when we are talking about the exponential increase in yields. So, we saw this curve before wheat, barley and oats. So, here we are saying that the total amount of agricultural production that is there.

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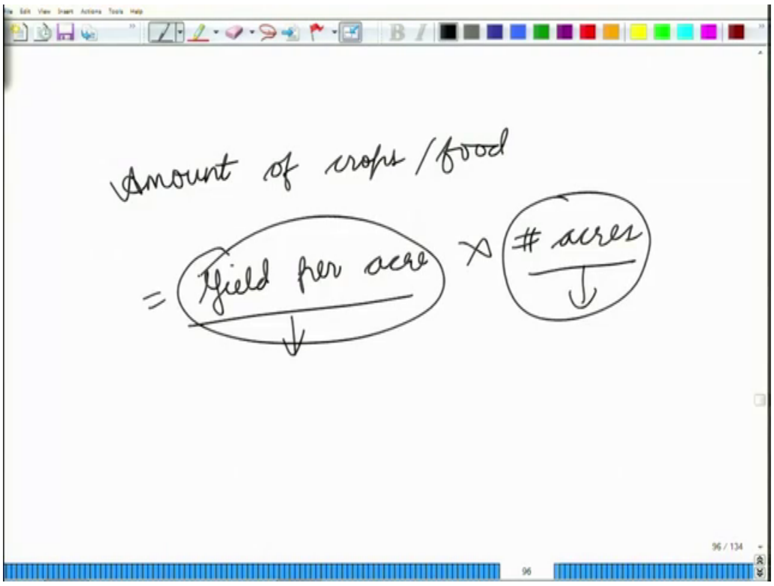

So, the total amount of crops or the amount of food it can be represented as the yield per acre multiplied by the number of acres. And we see that the yield per acre has been increasing with time, we see that the yield per unit piece of land has been increasing with time. And also we have seen that the number of acres that are put under cultivation the amount of area that is pretender agriculture that has also been increasing with time.

Now, why do we see an increase in the yield and increase in the area? Now increase in the area can be addressed or can be explained by the diversion of lands under different land uses into agriculture. So, from forest to agriculture, barren lands to agriculture, shrub lands to agriculture and so on, but then what about the yield per acre why is that increasing?

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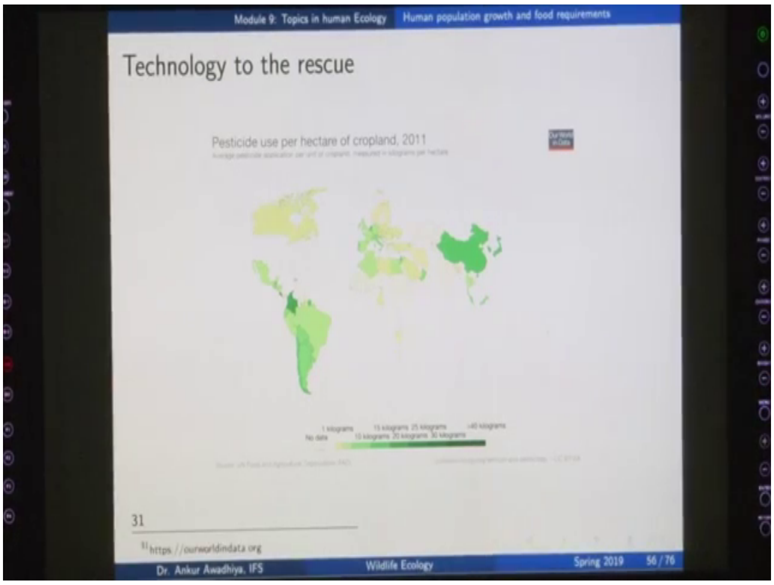

So now, in this chart we can see the pesticide use per hectare in the year 2011. Now remember that in the days of Malthus we did not have any chemical pesticides that were available. But now, if we look in the case of say countries like China we have as high as say 20 kilograms of pesticides that are being put per hectare of cropland so, it is a very high amount. So, these days we are using more and more amounts of pesticides.

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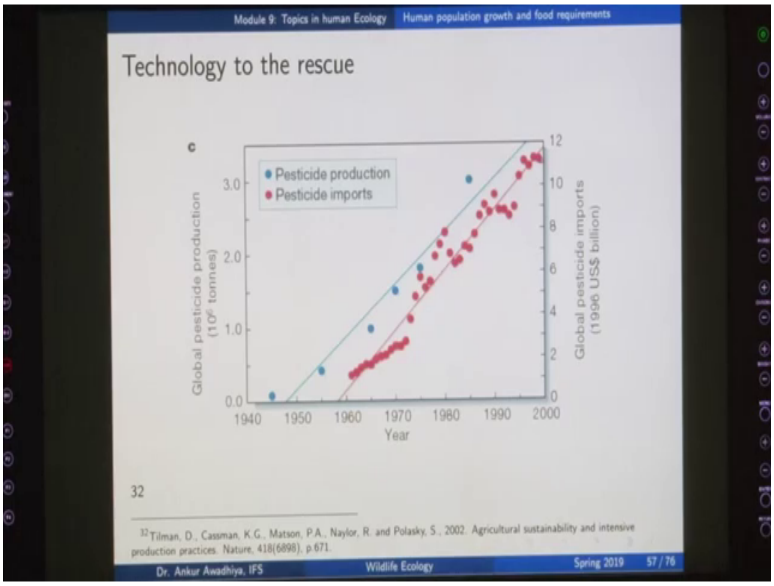

If you look at the pesticides that are being produced and are being imported in different countries, here also we can see that there has been a very drastic increase from 1960 onwards. Now this is the period in which using chemistry using, different chemical engineering processes we have not really discovered new and new pesticides, but we have also discovered ways in which these pesticides can be made in large scale plants.

So, we are producing newer and newer pesticides and we are producing these pesticides in a very large amount. And that is being shown here that the total amount of pesticides that are being produced it has been increasing and the pesticides that are being imported in different countries that is also increasing. So, there is a huge demand for pesticides.

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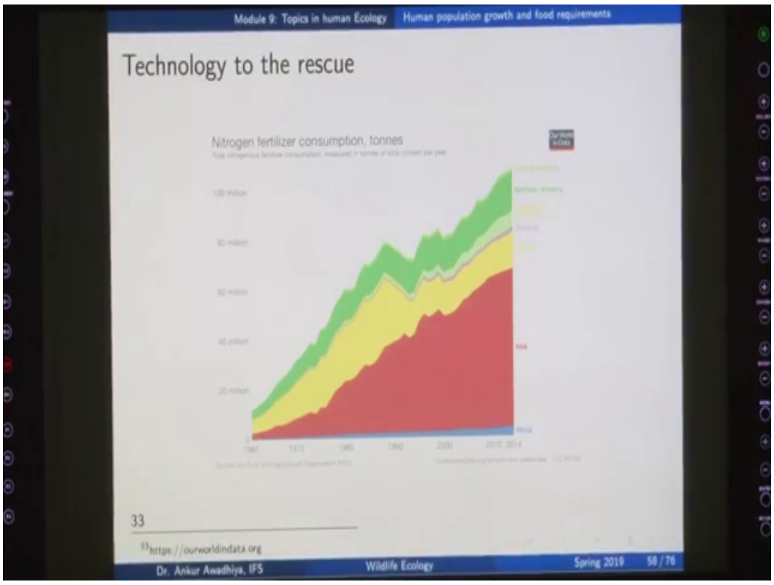

And similarly if we look at things like fertilizers now, this graph is showing us the nitrogen fertilizer that is being consumed in different areas. So, this red area is Asia and if we see that in the case of 1960s in early 1960s; we had a very small amount of nitrogenous fertilizer that was being used in Asia or maybe even in the total world. In the total world, we had say around 15 million tons of nitrogen fertilizers that was being used every year and from that 15 million tonnes now, we have even crossed 100 million tonnes.

And this increase can be seen in most of the areas. In the case of Asia this increase is very dramatic, in the case of North America it is very dramatic, in the case of Europe it increased and then people moved into organic agriculture and so it decrease, but then overall we can see that the increase throughout the world has been very rapid.

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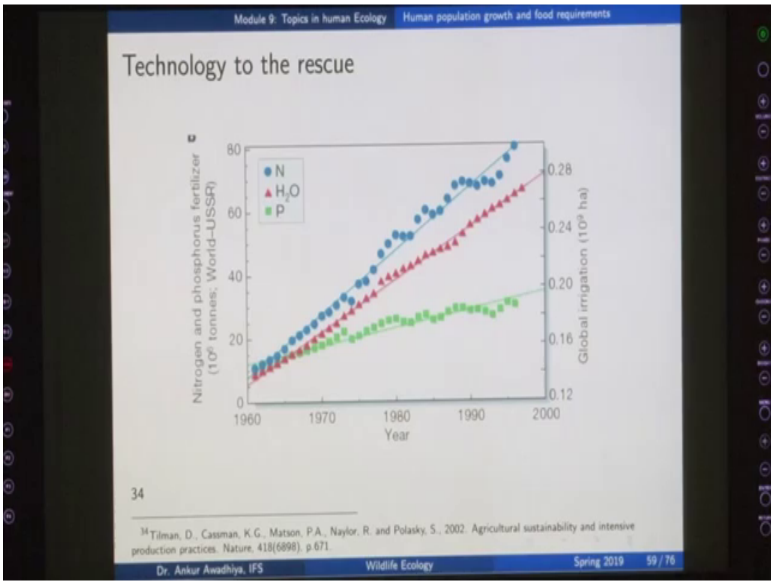

And that is true not just for nitrogenous fertilizers, but also for the other nutrients. So, here we are seeing the nitrogenous fertilizers and here we are seeing the phosphate fertilizers. Even the amount of water that we are using in agriculture it has been increasing. So, in essence we are developing newer and newer technology and we are deploying those technologies into the fields.

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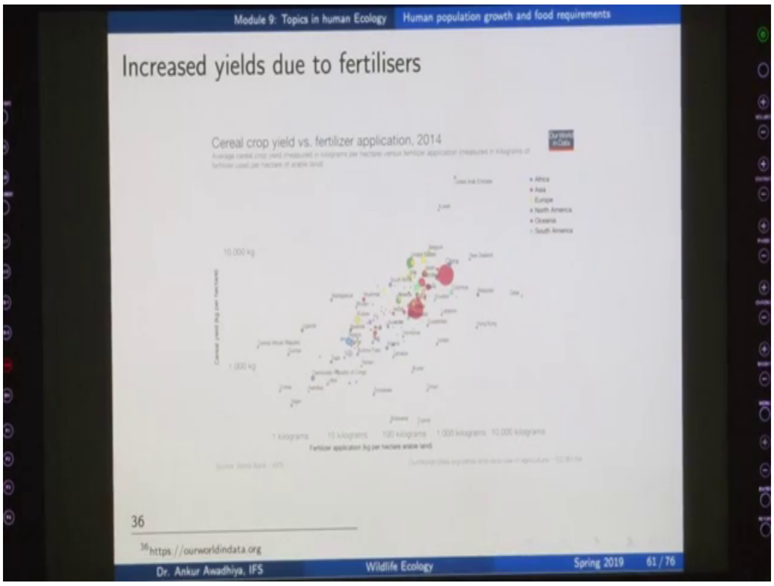

If you look at this curve here we are seeing on the x axis we have the fertilizer application that is kg per hectare of available land and this is a logarithmic curve. So, it moves from 1 kg to 10 kg to 100 to 1000 to 10000 and here on the y axis here again we have a logarithmic curve that is telling us the serial yield in kg per hectare. So, here we can see that roughly there is a correspondence.

So, the more amount of fertilizers that you use in any piece of land the more will be the yield. So, here we can say that there is roughly this line would denote the curve. So, with more amounts of fertilizer application the yields have been increasing.

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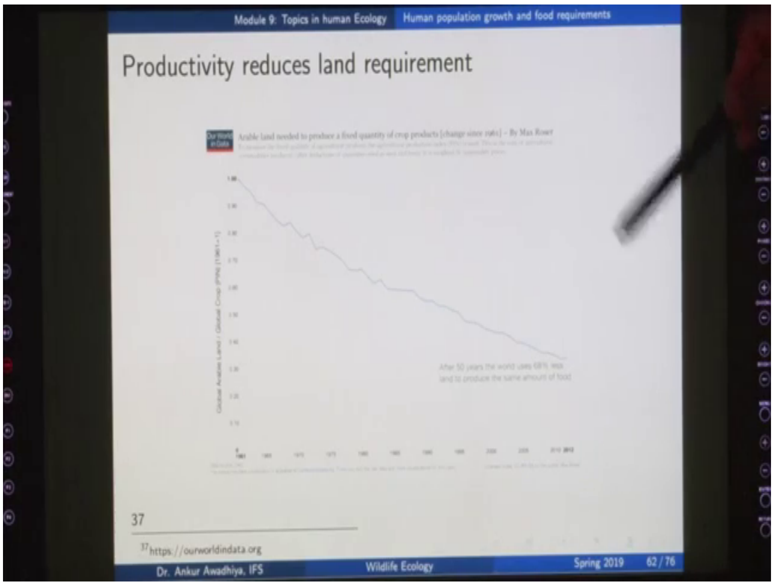

And the yields have been increasing so much, that now are requirement of land has now practically saturated, we do not need much more amount of land for producing more and more crops. Now, this curve is telling us that suppose on the x axis we have the years, it moves from 1961 up to 2012.

And if we say that in the case of 1961, we required say 1 hectare of land for producing the amounts of crops that were required then because of increase in productivity these days we require not 1 hectare of land, but as low as say around 0.3 hectare of land. So, after 50 years the world uses 68 percent less land to produce the same amount of food.

Now of course, through all these years our population has increased, so our demand for food has also increased. So, this curve will not represent completely that we are now using only 30 percent of the area for food production. The area for food production has also increased, but what this curve is telling us is that by having a very high increase in yields; we have been able to counter the amount of land that is required for cultivation of different crops. So, these are some criticisms of Malthus.

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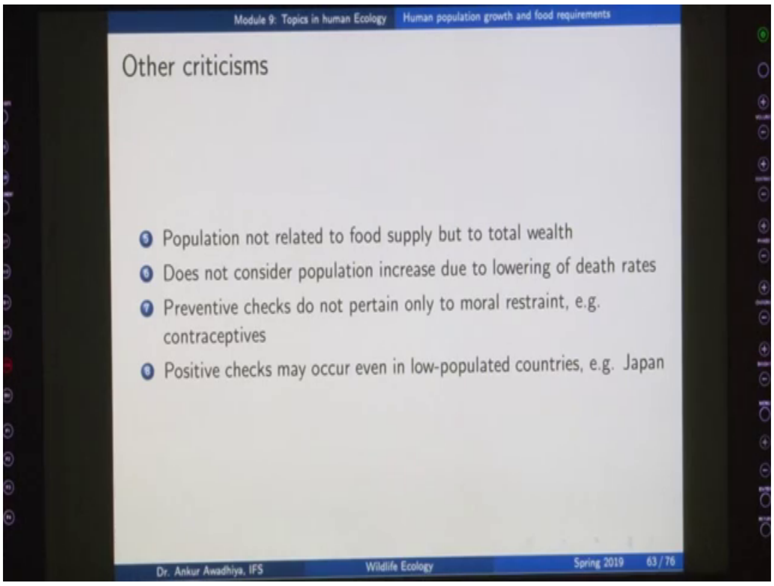

Some other criticisms are that, the population is not related to food supply, but to total wealth. So, essentially what this is saying is that in the case of Malthus he said that the population is limited by the food supply. So, if you are not able to supply enough amount of food to the population, the population will suffer an imbalance and that imbalance will be corrected by the positive and preventive checks.

But we know now, that the population is not limited by the food supply, but it is more or less related to the total wealth or the total affluence of the society at that particular point of time. Why? Because if a society is more affluent. So, in that case it would be able to afford modern medicine, it would be able to afford more amount of nutrition, it will be able to afford newer advances in science and technology.

And in that case we will see a lowering of the death rate and with a lowering of the death rate, after a while the society will also progress towards the lowering of the birthrate. So, these days we are talking about the demographic transitions of all these 5 different stages from a high birthrate and high death rate, to a low death rate and high birthrate, to a low death rate and a low birth rate, to a low death rate and an even lower birth rate and so on.

But then in the case of Malthus time we did not have this understanding and so, Malthus only related population growth to the food supply he was not able to relate it to wealth which we now know is the actual cause of population increase or decline.

Malthus also does not consider population increase due to lowering of death rates. That is with new technologies with modern medicine we were able to reduce the death rates even further and the Malthusian theory does not take this into account. Then preventive checks do not pertain only to model restraint. So in the times of Malthus we did not have a good technologies for contraception, but in these days because we have a number of contraceptives that are available in our society, beat in intrauterine devices, beat pills, beat condoms.

So, we have so many contraceptive devices that are available for us that these preventive checks are no longer just related to the model checks. So, model checks like abstinence or having a higher age at marriage and so on or celibacy. So, these are not the only model restraints that are currently applicable in the society, but contraceptives are playing a much bigger role.

And another criticism of Malthus is that the positive checks. He said that that there will be positive checks that are thrown out by the nature, if you have a high population in an area. If you have a population that is surpassed the amount of food that is available only then nature pursuit the positive checks like pestilence or diseases or floods and so on, but then we have seen that positive checks may occur even in the case of low populated countries such as Japan.

Now, in the case of Japan the country has been suffering from a number of earthquakes, the country has been suffering from tsunamis, from floods, and so on. And Japan is not a particularly very highly populated area. So, though and the understanding of Malthus that is there in his theory is probably a bit oversimplified and that is not how the societies or nature is actually functioning.

But that being said the theory of Malthus, does provide us a good food for thought because it does tell us some of the tenets that we have been thin in the case of population ecology that the population increases exponentially, but then the amount of resources that are available to that population do not increase in that faster manner.

And so there has to be some checks and balances, but we should stop ourselves only at that particular point, what should those checks and balances be or how does the population rate grow or how does the food supply grow that has been changing because of the advent of modern science and technology. So, that is something that needs to be remembered here. So, that is all for today.

Thank you for your attention [FL].