Forests and Their Management
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Module – 09
Logging and Yield
Lecture – 26
Growing Stock and Increment

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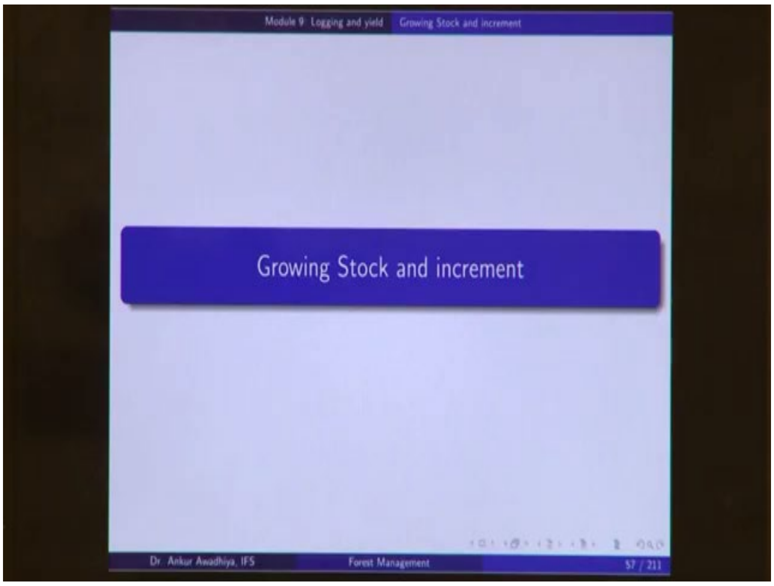

[FL]. We carry forward our discussion on Logging and Yield, and today we will have a look at Growing Stock and Increment. Now, a major purpose of classical forestry is to have the maximum growth of timber, so that we can extract the maximum quantity of timber from a particular stand. And, the computation of the volume of the stand, the changes in the volume of the stand is what we are going to have a look at in this lecture.

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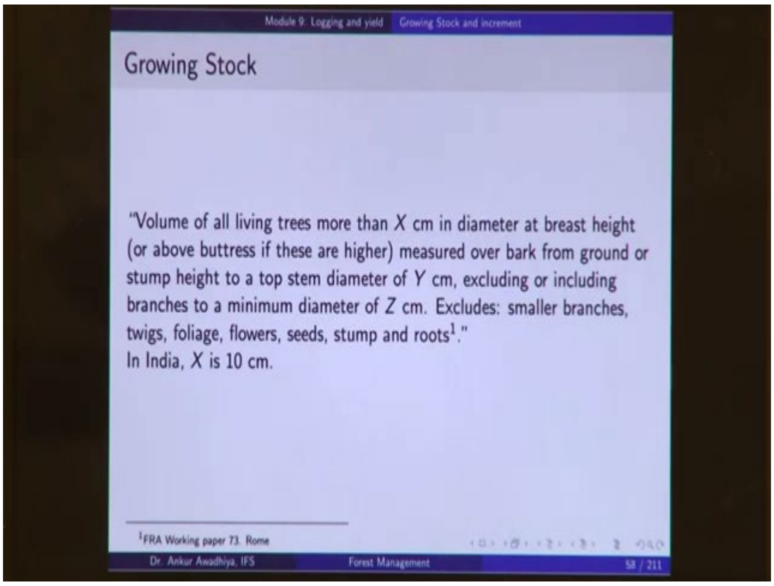

So, we begin with growing stock. Now, growing stock is defined as, "volume of all living trees more than X centimeter in diameter at the breast height." So, you are adding up the volume of all the living trees. So, you do not count the dead trees and you are only counting those trees that are more than X centimeter in diameter at the breast height.

Now, more than X centimeter means that very small trees or the saplings will not be counted in this definition. Now, why is that so? For two or three reasons. One is that in the case of very thin plants, it is difficult to take an accurate measurement of their girth or their diameters and so it is better to leave them, and two is that, if you look at any stand, the density of the stand will go down.

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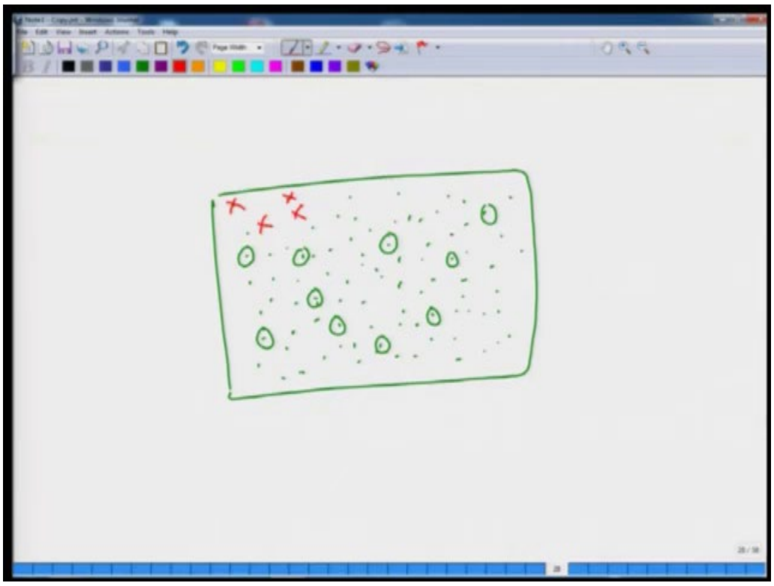

Because, let us consider, a forest in which we were having a very large number of plants; now, with time these plants would grow their diameters would increase and they will start competing with each other. So, after a while when their diameters have increased, then the level of competition becomes so large that this side is unable to fit these many plants and so what will happen is a number of these young plants will die out.

So, essentially the mortality of the young plants is very large and so we do not take their measurements because we are unsure whether we are going to retain them in the stand or not.

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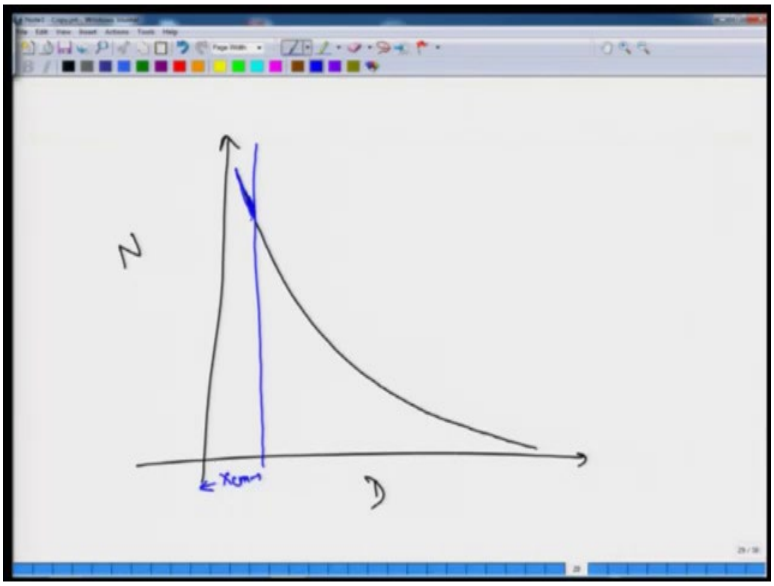

At the same time, we have seen in the case of a natural forest that, if you plot the ND curve the number versus diameter, we get a curve like this. Now, what this means is that, in the case of plants with very less diameter; so, this is X centimeter, the number of plants is very large. Now, these are those plants that are not putting an appreciable influence on the total volume of the growing stock, but then their number is very large.

So, these are very thin plants in a very large number and because they do not put an appreciable influence in the total growing stock. So, as an engineering approximation, we can leave out these plants. So, it is difficult to measure them; it is to measure their girths, it is difficult to measure each and every plant, because they are in such a large number, it is very possible that a number of these plants would die out very soon.

And, also these plants are not putting an appreciable influence on the growing stock and so, we leave out these plants whenever we are computing or measuring the growing stock. So, coming back to the definition volume of all living trees more than X centimeter in diameter at the breast height or above buttress, if these are higher measured over bark.

So, the measurements of the diameter are being done over bark, because just to measure the growing stock, we are not going to remove the bark and do the measurements. So, the diameters are taken over the bark from the ground or stump height.

So, in different countries, the measurements are either done from the ground or they are done from the stump height. Now, in this case, we are measuring it from the stump height we are not measuring it from the breast height.

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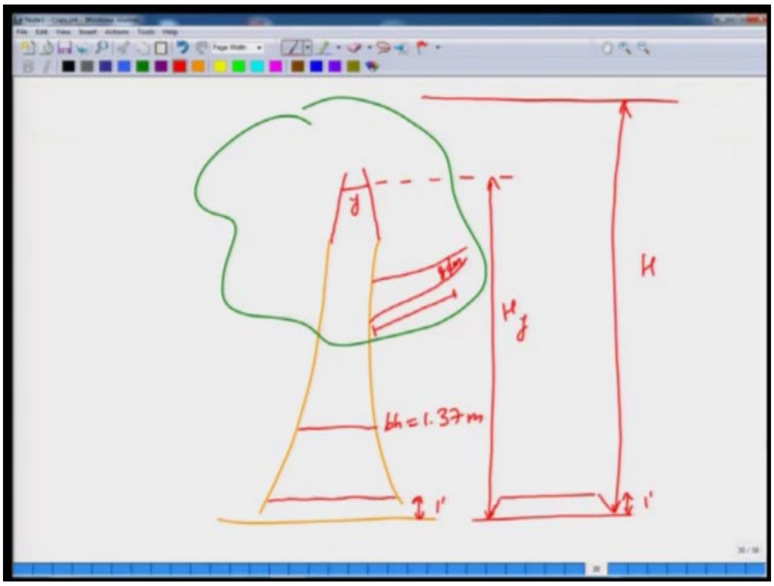

Now, what is stump height? If we consider a tree and let us say that this is the breast height, which is 1.37 meters. this stump height is the height at which we are going to cut in this tree when we are harvesting, this tree this typically is around 1 foot. Now, the stump height; we want to keep it as low as possible because, if you increase the height of the stump, you are losing away that would that could have been used otherwise.

But then, the stump height has to be a finite value you cannot cut at 0 height because as you go down there are pebbles, there are rocks, there is undergrowth. And, there is a good chance that your equipment, while you are cutting this tree, might strike one of these pebbles or rocks and it might get damaged.

So, to avoid the damage and also for the sake of convenience, you cut the tree at a certain height and this height is known as the stump height. And why is this the stump height? Because, once you have cut this tree, then you will have a stump that is left on the ground. And, the height of the stump is this one foot where you cut this tree. So, this is at the stump height. Now and when we are measuring the growing stock, the measurements are taken from either the ground or the stump height, depending on the country, to a top stem diameter of Y centimeter.

So, what we are saying here is that we are not going to measure it - measure the height till the height of the tree, but we are going to measure it till the point where the diameter of the main trunk reaches a diameter of y. So, we are going to take measurement of height such that above this height, the diameter of the main stem is less than y centimeter. Now, why is that so? Because remember that we are doing this growing stock measurement, for the case of commercial extraction of timber from this stand, and those stems that are less than y centimeter in diameter they do not have appreciable commercial value.

And so, we do not take those measurements. Excluding or including branches to a minimum diameter of Z centimeter. What is it saying? It is saying that, if you have a branch and if this diameter of this branch is; so, let us say that here it is Z centimeter. So, you are going to take this measurement as well. So, you will include the branches till of a diameter of Z centimeter. Any branches that are less than Z centimeter in diameter will be excluded. Now, why is that so? Because the branches also can be used as timber and they also have a merchantable value.

So, volume of all living trees more than X centimeter in diameter at the breast height, so removing the smaller stems measured over bark from the ground or stump height to a top stem diameter of Y centimeter, excluding or including branches to a minimum diameter of Z centimeter. So, it excludes the smaller branches, twigs, foliage, flowers, seeds, stump and roots. So, whatever biomass remains is a part of the growing stock.

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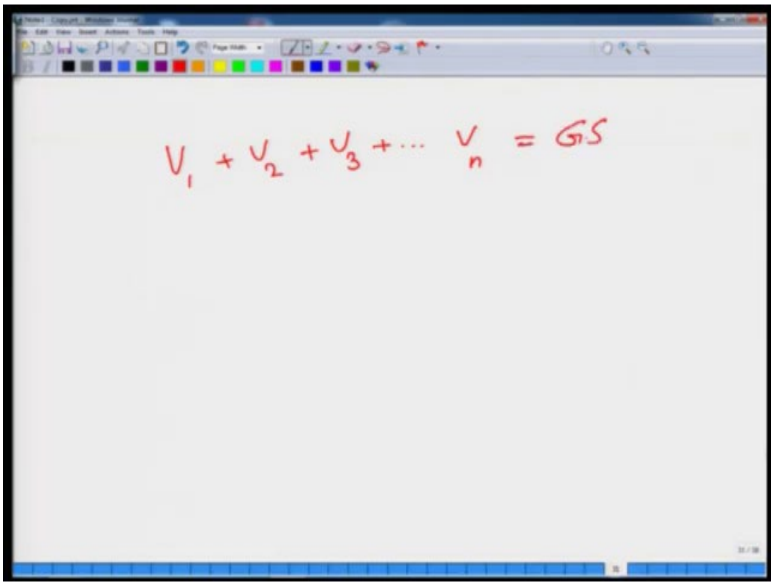

So, you do these measurements for the first tree, and let us say that the volume of the first tree is 1, for the second trees V 2, for the third three tree is V 3 and so on till the end tree and you sum these up and this is the growing stock.

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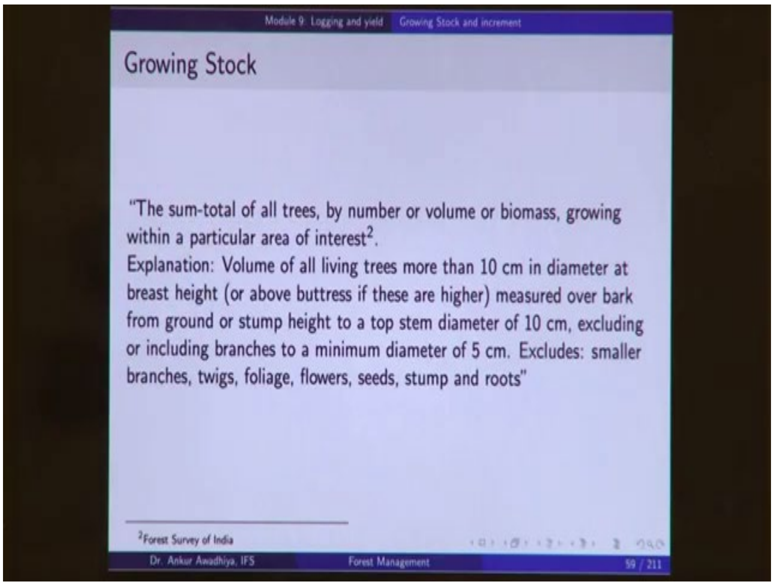

Under the definition is, “the sum total of all the trees by number or volume or biomass, growing within a particular area of interest.” So, it is a sum total of all the trees growing within a particular area of interest, that is typically a forest stand, and this sum total is by in terms of number. So, you can say that the growing stock is having say 1500 trees, or you can do this computation in terms of volume by saying that the growing stock is say 100 cubic meters in volume, or you can do it in terms of biomass, in which case, you will say that this growing stock is say 75 k tons of carbon.

So, you can do the growing stock computations in any of these formats and here again the explanation is volume of all living trees more than 10 centimeter in diameter at the breast height or above the buttress measured, over bark from the ground or stump height to a top stem diameter of 10 centimeters, excluding or including branches to a minimum diameter of 5 centimeters. Now, this is specific to India.

So, in our country, we take the value of this in the previous definition we had taken it as X centimeter, Y centimeter and Z centimeter. So, here we are having that X and Y are 10 centimeters, and Z is 5 centimeters.

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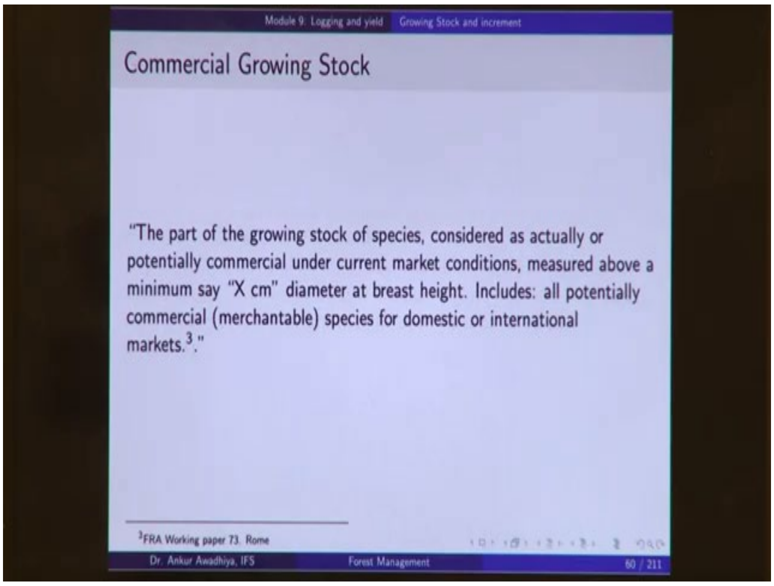

And we also define a commercial growing stock. So, a commercial growing stock is a subset of the growing stock which is comprised of commercially important trees. So, the part of the growing stock of species considered as actually or potentially commercial under current market conditions.

So, if the market conditions change, the commercial growing stock will change, measured above a minimum say X centimeter diameter at breast height. It includes all potentially commercial or merchantable species for domestic or international markets.

So, essentially, the growing stock is to say simply - it is the total volume or total biomass of a forest, typically by computed, by removing very small plants, very thin plants and those parts of the plant or the trees that are not of a commercial value.

Now, if you want to manage a forest for timber, you would want to manage it in such a manner that this growing stock is large. So, you would want to make to manage a forest such that the growing stock is large and at the same time it is putting up increment.

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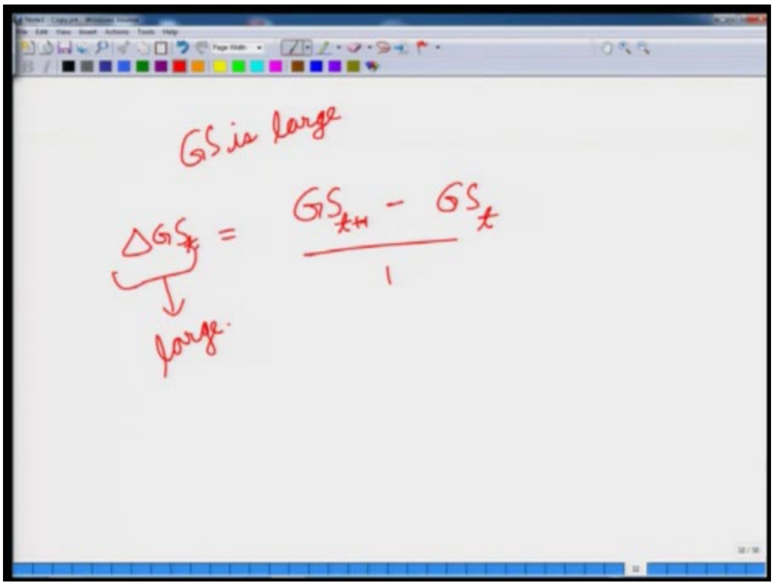

So, if we say that the growing stock at time t and say t plus 1; so, we want to manage the forest in such a manner that it has a large growing stock and this large growing stock is increasing still.

So, any increase is something that we will be able to harvest, if you want to do this harvest in a sustainable manner. So, we would want to manage it in such a manner that GS is large and the delta GS per unit time let us say at time t this is also large. Now, what are the factors that determine this GS and delta GS? So, let us have a look at that.

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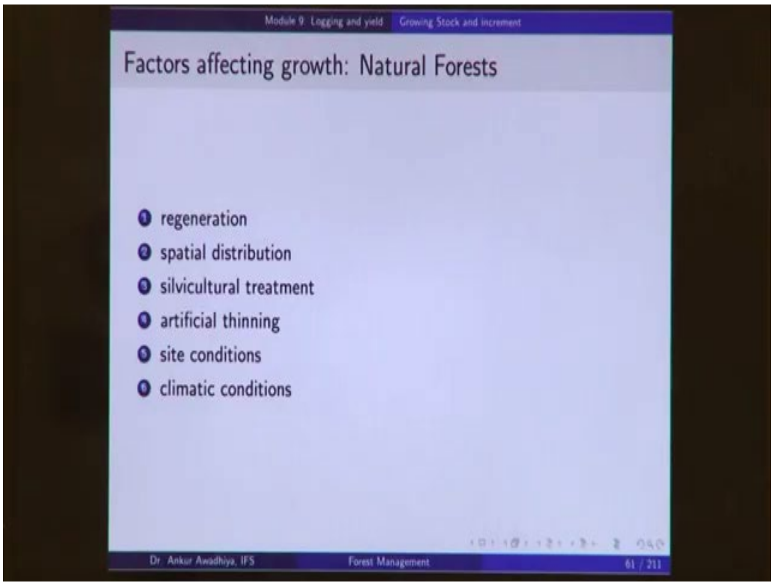

Now, factors affecting growth in natural forest. One – regeneration. If you are having a forest in which the regeneration is less; so, in that case, the young generation are not coming up properly. And, in that case, the growing stock will either be stagnant or it will decrease as the whole trees start to die off. So, regeneration is very important in the maintenance of growing stock.

Secondly, the spatial distribution of plants. Now, the if the spatial distribution is such that the plants are evenly distributed, and all of them are able to have enough access to the resources; so, in that case, they will be able to put up a larger increment a larger growth and so, your growing stock will increase at a faster rate and it will reach larger values. On the other hand, if you have a spatial distribution, such that your plants are a very close together and they are out competing each other, in that case, the growing stock increments will not be large.

Silvicultural treatment. If you are managing your forests properly, you will get a larger increment in growing stock. If you do not manage it properly, then probably your growing stock will not be optimum.

Artificial thinning. So, if whenever we are doing thinning, the growing stock goes down; but then the artificial is thinning is done, so that the plants that remain are able to put up the maximum increment that they are capable of.

The growing stock also depends on the site conditions and the climatic conditions, because, if you have a site that is fertile and is having adequate amounts of sunshine and moisture, then it will be able to support a larger number of trees. And, it will be able to support a larger and faster growth of these trees.

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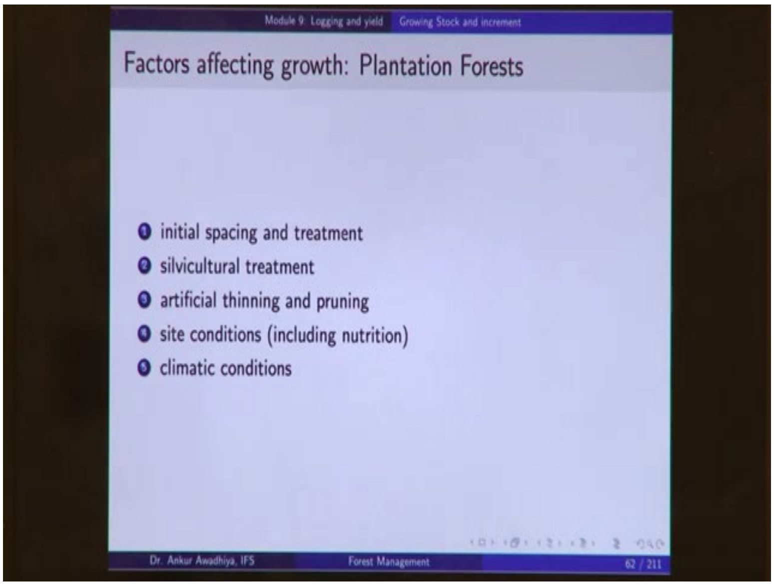

Now, similarly, in the plantation forest, the growth is dependent upon the initial spacing and treatment. The silvicultural treatments that are applied artificial thinning and pruning site conditions and the climatic conditions. So, here, we can see that the growth is dependent on a number of factors both in natural forests as well as plantations.

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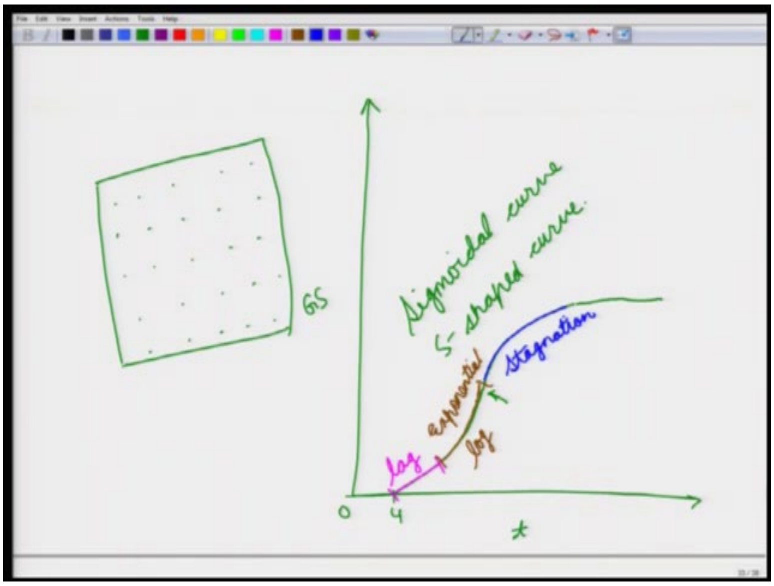

Now, if you consider any piece of land, and let us say that we have planted this land with some particular species, and we are trying to do a computation of the growing stock versus time.

Now, at time 0 when you are doing this planting probably the growing stock is 0, because your plants are so thin that they do not come into the definition of growing stock. And, probably your plants remain thin till say 4 years. So, from 0 to 4 years your growing stock is 0 this is time, this is the growing stock. Now, what happens after that? After this point, the growing stock; now, your plants have come to a stage where their volumes will be calculated or computed in the growing stock computations.

Now, these are the young plants and these young plants are growing up at a very fast rate but, probably, they have not reached to that stage where their growth rate is the highest. So, in this case, the sort of curve that we will see is that the volume or the growing stock will increase and it will go on increasing at a faster and faster rate. So, now, this is probably a point where the plants have reached to such an extent that their canopy is now covering the whole of the land.

So, now, they are able to extract the maximum amount of sunlight as a total as a whole. So, once this canopy closure has happened, then the growth rate will start to reduce, because, now, the plants even though they are growing, but they are suffering a dearth of the nutrients; they are suffering a dearth of sunlight. And, they are probably also competing against each other, because of it they will not every plant will be able to get the maximum quantity of water or nutrients from the soil.

So, after a while the competition is increasing and increasing and so, the rate of growth will be slowing and slowing, till a point where will see that the growth rate is now either 0 or very close to 0. So, now, you are having a forest, in which there are trees, but then the trees have reached to such a stage they are mature trees. But they are in such large number, that now they are not able to access anymore nutrients, there is not any growing space left for them. And, because of that, now, this strand is not showing up any growth.

Now, this kind of a curve is known as a sigmoidal curve or an S shaped curve.

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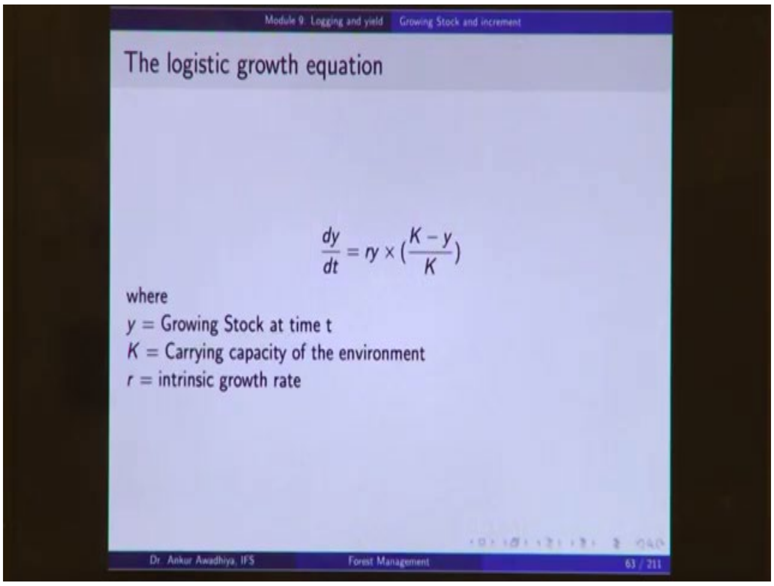

And, if we wanted to represent it mathematically, we can represent it as a logistic growth equation. Now, a logistic growth equation is written as dy by dt where, y is the growing stock at any time t. So, the change in growing stock is equal to r, which is an intrinsic growth rate multiplied by y which is the growing stock at time t into K minus y divided by K, where K is the carrying capacity of the environment.

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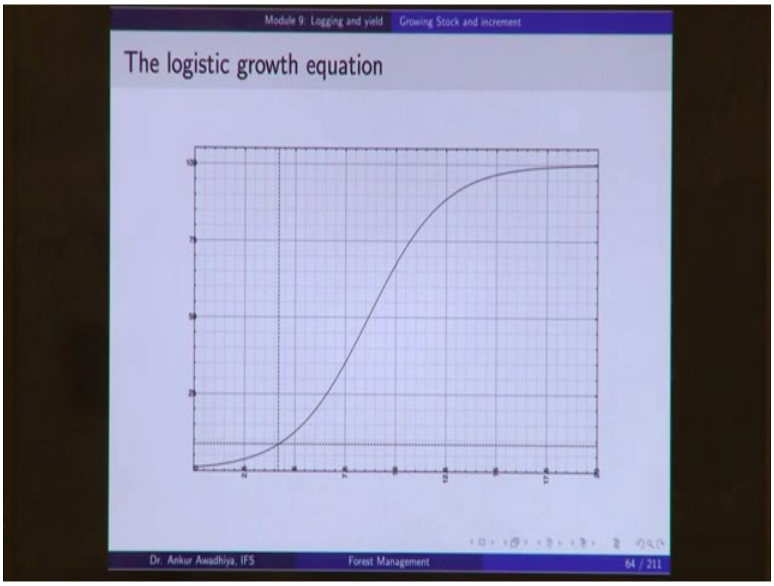

And, this is how this curve will look like when we plot it. So, essentially the logistic growth equation is the equation of a sigmoidal curve, and a sigmoidal curve represents the changes in the growing stock of the stand.

So, we can represent a growing stock by the logistic growth equation. Now, in this curve, we can discern three phases; the first phase is known as a lag phase. So, in the lag phase, the growing stock is increasing, but it is increasing at a slow pace. So, it is increasing very slowly.

Next, we will have an exponential phase. So, this is an exponential phase also refer to as a log phase. And, after this log phase, next, we will reach a phase of stagnation because now the growth is increasing, but it is, but the rate of growth is now moving towards 0. So, that the total amount of growing stock will become constant.

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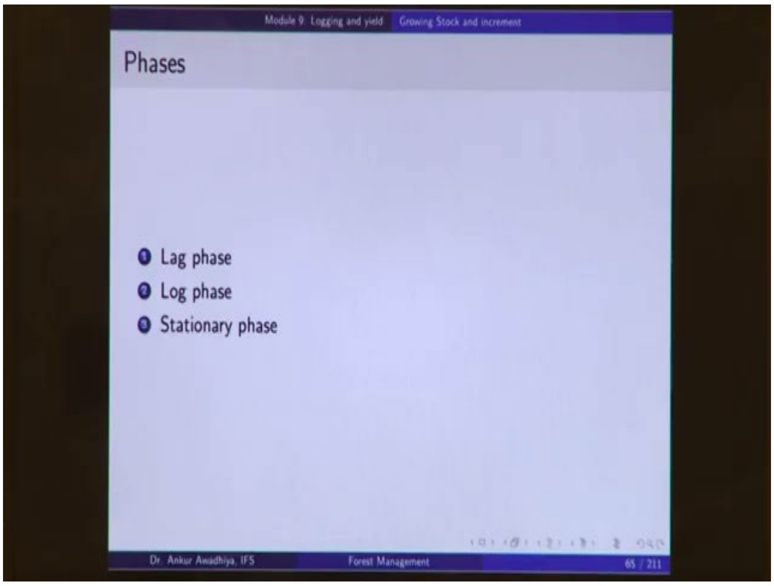

So, we can define these three phases lag phase, log phase and stationary phase. Now, why do we need to understand this growth curve? It is important because we want to understand the rate at which the growing stock is increasing.

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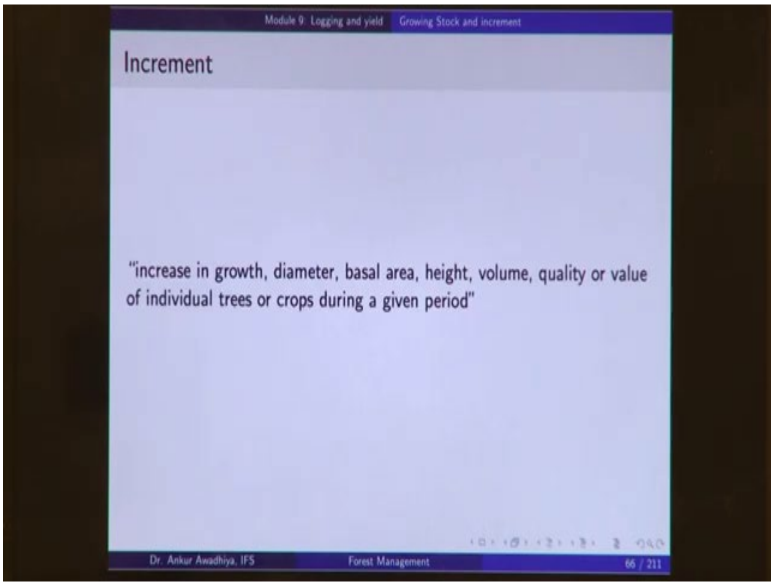

And, that rate of increase is known as the increment. So, increment is defined as, "an increase in growth, diameter, basal area, height, volume, quality or value of individual trees or crops during a given period."

So, when we say that a tree is putting up increment, we mean to say that it is increasing in volume; or it is increasing in height; or it is increasing in diameter; or it is increasing in some other quality or value with time. So, these changes are known as increments and we can measure increment in terms of a single tree or in terms of a forest stand.

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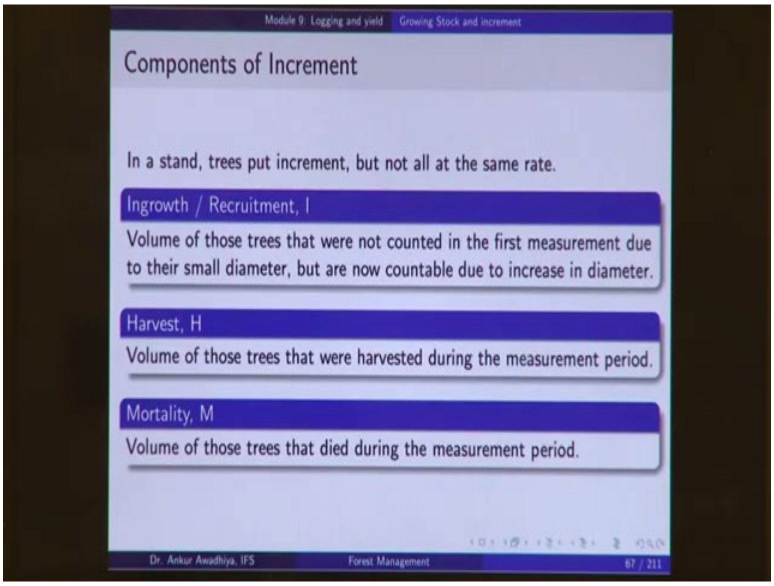

Now, this increment is comprised of a number of variables. Now, different trees are putting up increment, but not all at the same rate and not all at the same time. So, when we look at the increment of a stand, we have to consider different phenomena that are happening.

The first phenomenon that is happening is in growth or recruitment which we represent as I. And, growth is defined as the volume of those trees that were not counted in the first measurement due to their small diameter, but are now countable due to increase in diameter.

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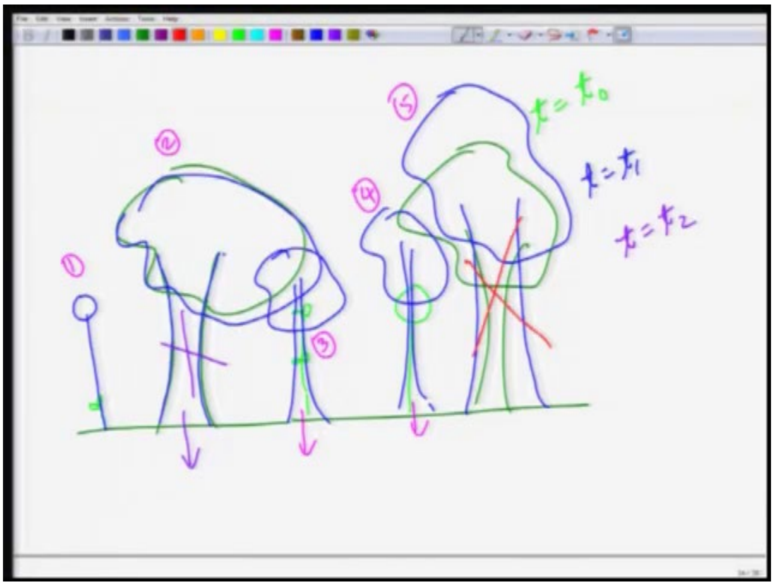

So, what we are saying here is that, suppose in the first stage, we were having some large trees and some small trees. Now, this is at time t is equal to t 0. Now, if you look at time t is equal to t1, in that time, this plant has reached to this height; this plant has become something like this; this plant has become something like this; this tree has increased in size, but probably this tree does not show any changes.

Now, between time t is equal to t0 and time t is equal to t1, there are some plants that have now entered into the calculation. So, like this plant number 1, it was neither counted during time t is equal to t0, but and nor in time t is equal to t1.

This plant was counted in both is that the time periods, this third plant it was not counted in the first computation, but during the time of the second computation say after 5 years, it has now reached to two that diameter that it is now countable. The 4th plant it was not counted in the 1st instance, but it is now counted in the 2nd instance. The 5th plant was counted in the 1st instance and also in the 2nd instance.

So, in this case, these two plants 3 and 4 which were not counted which were not countable in the first instance, but are now comfortable in the second instance. We will call their volumes - the addition of their volumes into the growing stock as the in growth. So, in growth or recruitment is the volume of those trees that were not counted in the first measurement due to their small diameter, but are now countable due to the increase in diameter. Second component is harvest, volume of those trees that were harvested during the measurement period.

Now, it is possible that during your time let us say yeah the next time is t is equal to t 2. Now, from time t is equal to t 1 to t is equal to t 2, you have harvested this tree. So, this tree at time t is equal to t 2 it is not being counted. So, it was counted earlier during time t is equal to t 1, but at time t is equal to t 2, it does not counted, because it no longer exists in that side, because it has been harvested. So, this harvest should also be computed in the growing stock computations, volume of those trees that were harvested during the measurement period.

Now, similarly we also have mortality represented by M, volume of those trees that died during the measurement period. Now, remember that, in the case of the growing stock, definition we only count in the living trees. So, those trees that die off are not counted. So, let us say at time t is equal to t 2 by this time this tree has died off probably because it was old or probably because it got infested with some diseases or probably it got burnt during the forest fire.

So, this tree which has died off it will be represented in terms of mortality M.

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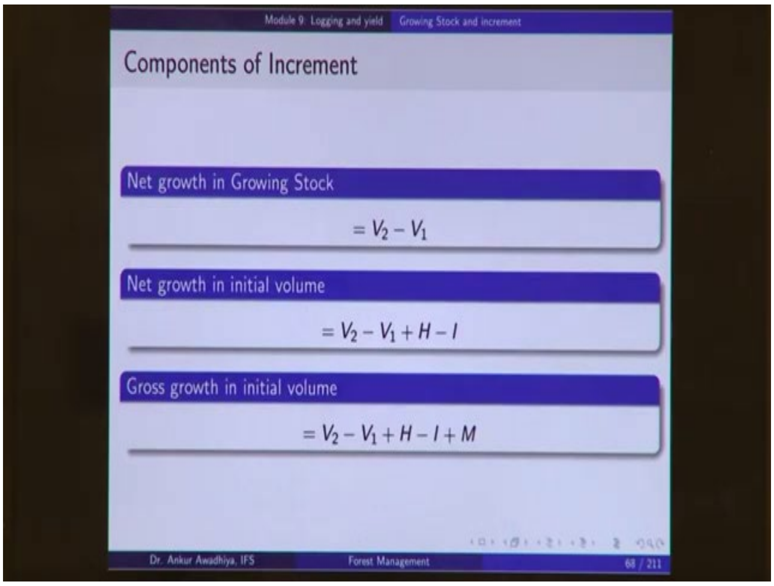

So, now if we look at the components of increment, we can define three things. Net growth in the growing stock will be represented as V 2 minus V 1 where, V 2 is the growing stock at time t 2 which is the volume of all the living trees above a certain diameter at time t 2 minus V 1 which is the volume at time b at time t 1.

So, this is the net growth in growing stock. If we want to compute the net growth in the initial volume, in that case, we will have to add H and subtract I. Because we are talking about the initial volume, during initial volume this I was not there; I is a component that we are getting from the in growth. So, because in growth is a new addition to the growing stock, we were not counting it before.

So, if we are only talking about the net growth in the initial volume, we will have to remove I and we also add H. We add H, because H is something that we have extracted. So, that particular tree was there on the site during time t 1 it put up some certain growth and we removed it. So, the inner, so this H will be counted in the net growth in the initial volume. And, we also define a cross growth in the initial volume which is net growth plus mortality.

Because, in the case of mortality, we have not removed this tree it died on the spot, but if we look at a gross change in the initial volume we will have to add this.

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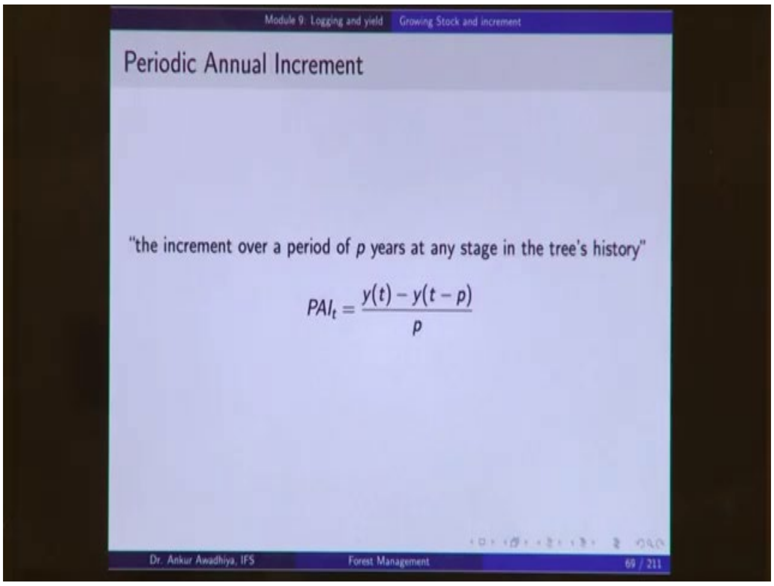

Now, this increment is typically measured in terms of periodic annual increment or current annual increment or mean annual increment. Now, these are defined as the periodic annual increment is the increment over a period of p years, at any stage in the tree's history.

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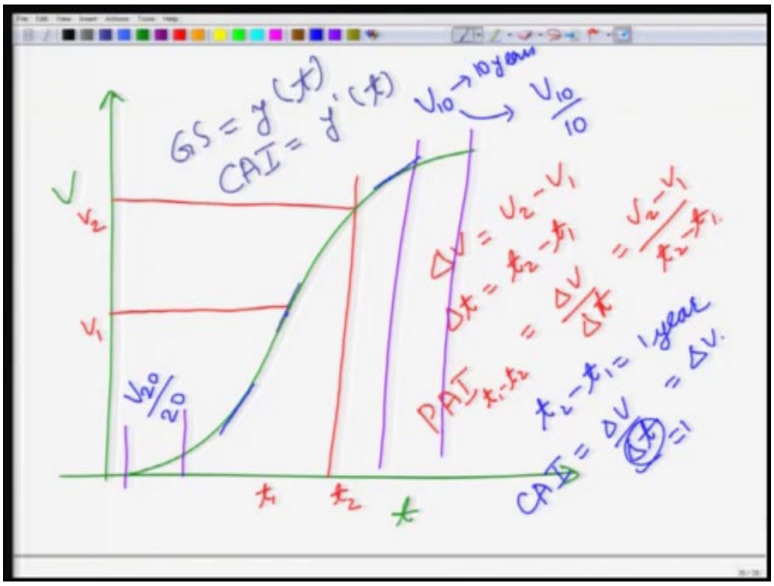

So, what we are saying here is that let us plot. So, this is V versus t and we are asking the question, how much was the increment between time t is equal to t 1 and t is equal to t 2? The volume at this time t is equal to t 1 was V 1 and here it was V 2. So, we will say that the total increment that is delta V is equal to V 2 minus V 1. Now, this increment happened in a time of delta t which is t 2 minus t 1 and so, we will say that the periodic annual increment for this period t 1 - t 2 is equal to delta V divided by delta t, is equal to V 2 minus V 1 divided by t 2 minus t 1.

So, this is the volume of the stand at time t 2 minus volume of the stand at time t 1 divided by the number of years between t 2 and t 1. So, this is periodic annual increment we are measuring annual increment. So, we are dividing everything by the number of years in between. So, what was the average annual increment, in this period?

Now, this PAI will be different depending on the t 1 and t 2, if you took these 2 years in the beginning versus in the middle versus at the end, we will find that the PAI is very little in the beginning, it is very little in the end, and it is more in the center.

Now, if in the place of this period of t 2 minus t 1, if we say that t 2 minus t 1 is equal to 1 year. So, we are doing these computations in such a manner that t 2 minus t 1 is 1 year, then we will say that the PAI is the current annual increment.

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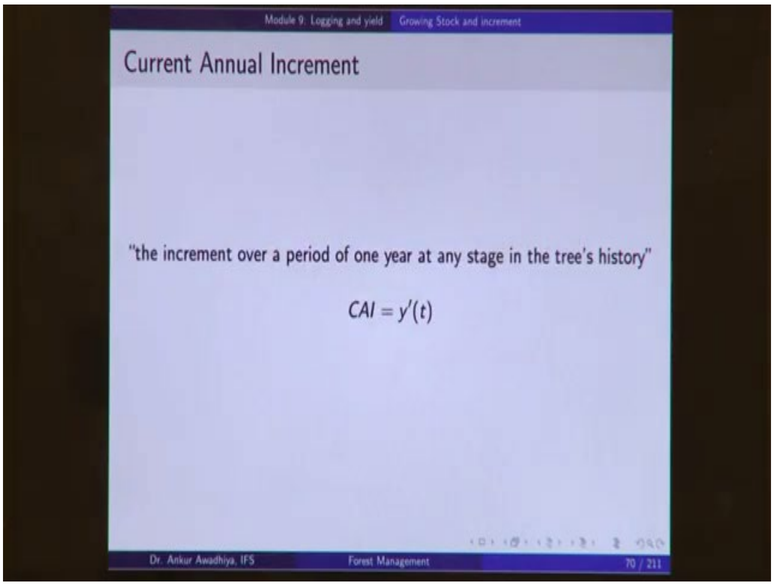

So, current annual increment is "the increment over a period of one year at any stage in the tree's history." What is the change in the volume per year? So, in this case, you will have CAI is equal to delta V by delta t and delta t is equal to 1. So, this is equal to delta V or if you want to represent it mathematically the CAI is represented as the slope of the curve at any point.

So, the CAI is the slope of the curve. Now, if we represented the growing stock curve as V as y. So, we said that the growing stock is y, which is a function of t, then CAI is equal to y prime t or the differential of the growing stock curve with respect to time. The third thing that we; so, this is how it will look like.

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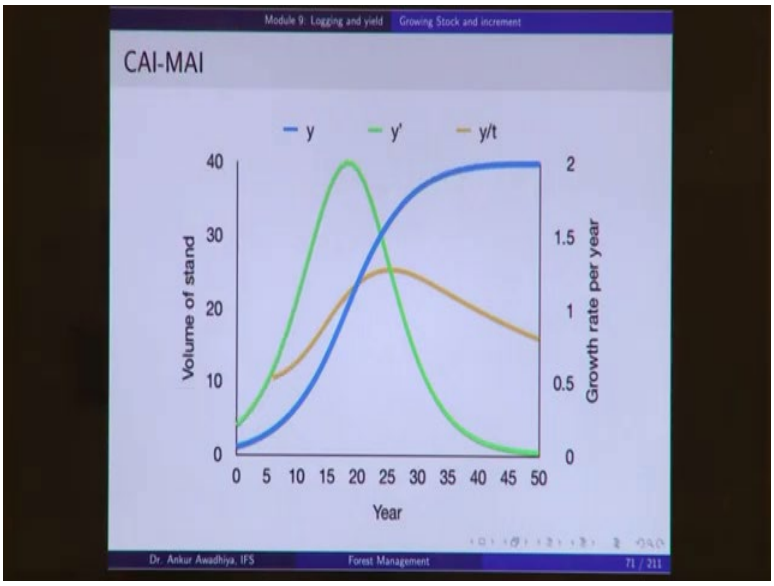

So, this is our curve y which is the sigmoidal curve represented here in blue. Now, if we look at the CAI or the differential of this curve, so the CAI at this point is very less because the slope of the curve is very less, then the CAI will go on increasing and it will reach a maximum somewhere here at the inflection point.

So, inflection point is the point at which the shape of the curve is changing; the direction is changing. So, on this side, it is concave; on this side, it is becoming convex, if you look at it from the top. So, this point will be called as the inflection point. So, the CAI will go on increasing till the inflection point, and then it will start to reduce and become 0 after a while, and this is what we are seeing in this y primed curve.

So, y prime is increasing; it reaches a maximum at the inflection point, then it is starts to reduce, and then, after a while it comes close to 0. So, this is CAI or the Current Annual Increment.

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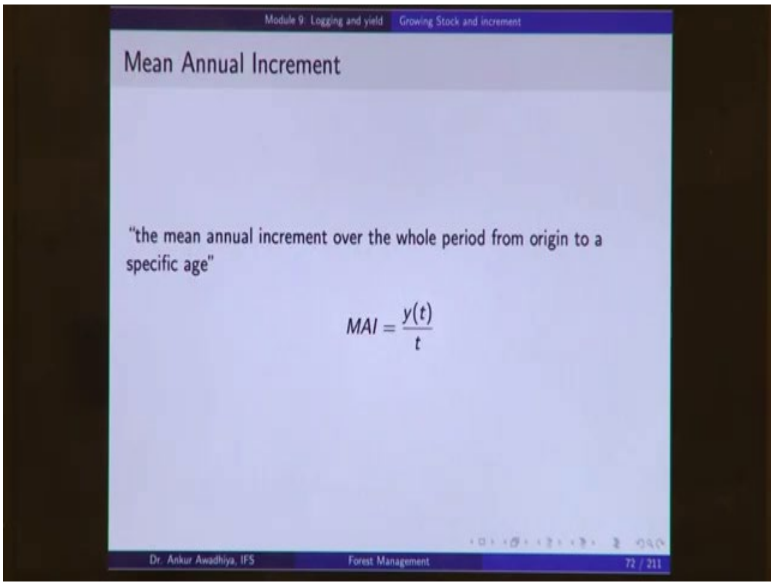

We also define MAI or the Mean Annual Increment. Now, the mean annual increment is asking the question, what is the average growth of the stand at any stage of its life? So, suppose the volume of the stand is V10 at the end of 10 years. So, every year on average this tree was putting up V10 divided by 10 cubic meters of growth. If you consider a volume say V20, so in 20 years it reached a volume of V20, if you want to find out the mean annual increment it will be V 20 divided by 20.

So, essentially MAI is for any time t is equal to y of t that is that the growing stock at time t divided by t, which is the number of years that it has taken to reach that value of the growing stock. So, the mean annual increment is the mean annual increment over the whole period from origin to a specific age, and here, we are representing it with the yellow curve. So, the yellow curve is telling us that at this point we have a particular value of mean annual increment.

Now, the mean annual increment is increasing with time, then it reaches a maximum and then it starts to decrease. Now, why is that so? So, let us see let us consider the CAI, at this point this CAI is very large the MAI is less. Now, the CAI is increasing. So, CAI is telling you the change in the volume every year. So, when CAI is increasing it tells us that the total growing stock is increasing at a faster rate.

So, the total growing stock is increasing increasing, then it reaches a maximum rate of growth at the inflection point, and after that the CAI is reducing, which means that the rate of growth is reducing, and after a while the rate of growth even comes to 0. But consider this point where both these curves are cutting each other. Now, after this point the current annual increment is less than the annual increment till the till this age.

So, what we are seeing here is that after this age of say around 27 years, the rate of increase every year is less than what was the average till 27 years. So, with every passing year, you are adding less to the growing stock as compared to what you were adding up earlier, but the denominator which is the number of years is going on increasing.

So, what we will see is that the MAI will reach to a maximum, and after this point, it will start to decrease. So, the points where the CAI and the MAI curve cut each other is the point where you are having the maximum MAI. So, the crucial thing to remember is CAI is maximum at the inflection point where the rate of growth is maximum, and MAI is maximum where the CAI and MAI curves cut each other.

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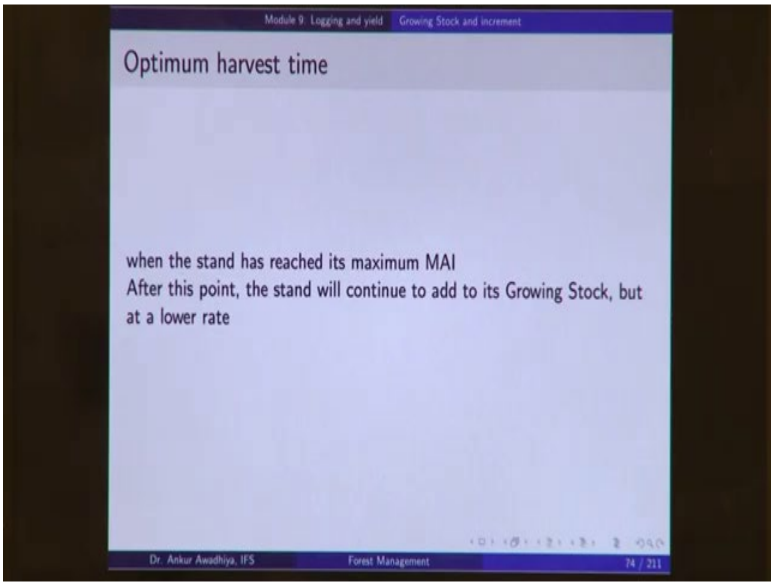

And, this cutting is important because it tells us the optimum harvest time. So, the optimum harvest time is the time when the stand has reached the maximum MAI or the point where the CAI and MAI cut each other. Now why is that so? Because after this point, the stand will be putting up more growth, but at a slower pace; the rate has reduced. Now, remember we needed two things in the stand. We want to have a stand with a very large value of growing stock and also a large value of increment.

Now, before this time, before the maximum value of MAI, the growing stock was increasing and the increment was also pretty substantial and so, we said that we should not be cutting the stand or harvesting the stand before this point. But after this point, even though the growing stock is substantial, but now the rate of increase is decreasing and so it will be much more profitable to harvest this stand, and probably regenerate the forest.

So, the points where; the point where the MAI and the CAI cut each other is a good indication of what should be the rotation age for this particular species at this particular site.

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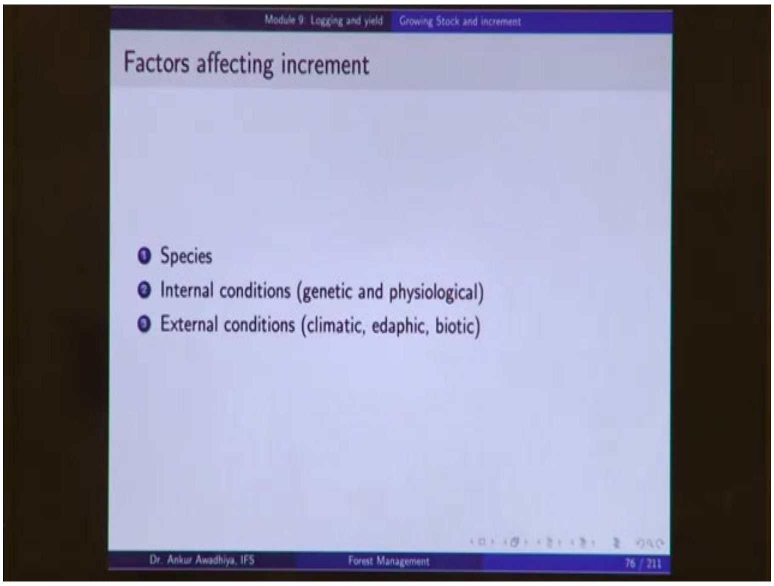

Now, the increment is not the same for every species; it is not the same for every site; it depends on the species; there are certain species that we call as fast-growing species. So, species like eucalyptus or species like poplar, these are the species that grow very fast.

On the other hand, we have certain species like teak which have a medium rate of growth, and there are certain other species such as sterculia that grow at a very slow rate. So, the increment that is being put up by a stand, will depend on the species, or the species composition of the stand. If it has those species that grow very fast, then we will be having a larger increment.

If it has those species that grow slowly, then we will have a smaller increment. Increment also depends on the internal conditions that is genetic and physiological conditions. So, essentially, if you have those plants whose parents were showing very fast growth; so, their genetic constitution as such that they are showing up a faster growth. So, there is a genetic composition involved also there is a physiological composition that is involved.

So, it will depend on the age of the plants. If the plants are young, or in amateurs, or in a growing phase, then they will show up a faster increment. If the plants are old, then their physiological state determines that the rate of increment will be lesser. Increment also depends on the external conditions climatic, edaphic and biotic conditions.

So, why climatic? Suppose, it is a draught year; the plants are not getting sufficient amount of water; they are suffering from stress. So, the rate of growth will be lesser. The edaphic factors. If you have a site which does not have sufficient amount of nutrients, the rate of growth will be less.

Biotic factors; Suppose, you have a stand which is now infested with the disease. So, also the plants are now diseased and so, they are not able to put up a large amount of growth. So, it dip; so, the increment depends on species, depends on internal factors, it also depends on external factors. It also, at times, depends on those factors that are out of our control. So, suppose you have a site which recently suffered from a forest fire, the plants are gone. So, now, the increment will be 0, because you do not have any trees on that piece of land. So, it also depends on catastrophic events.

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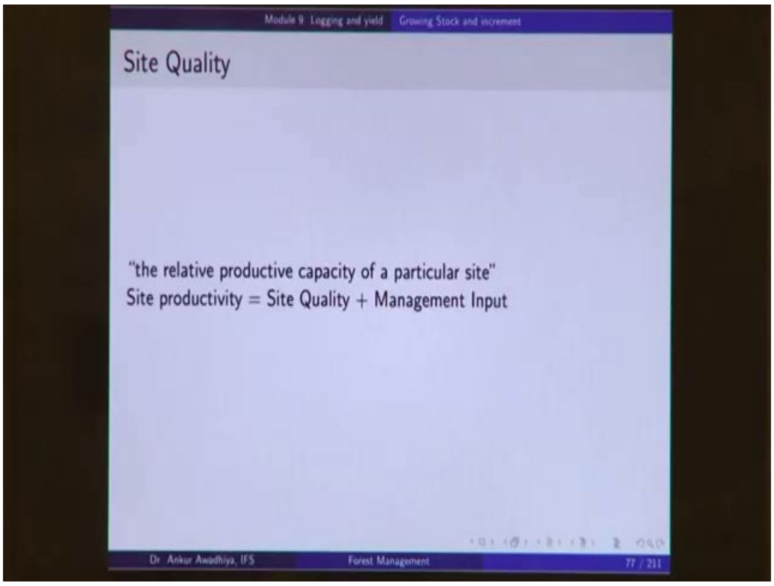

Now, the thing that is within our control is the sight quality. Sight quality is defined as, "the relative productive capacity of a particular site."

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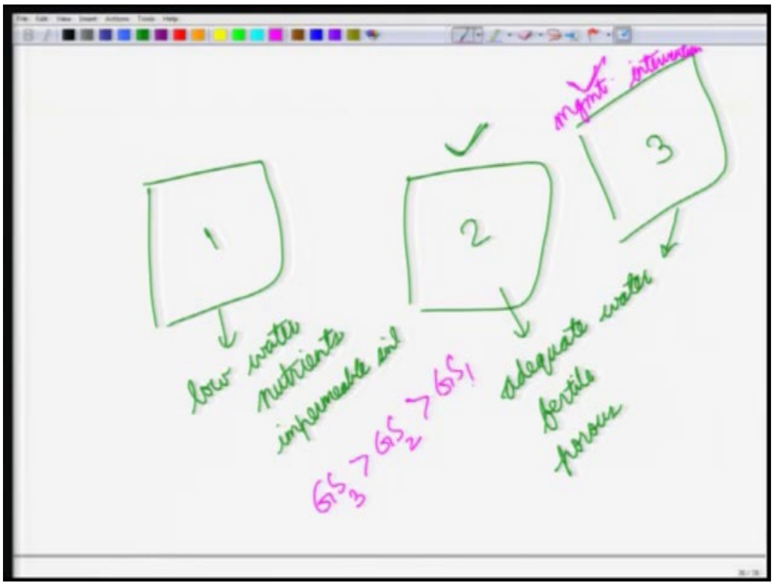

What we are saying here is that suppose, we have two pieces of forest, two pieces of land and we are growing forests on these pieces. The first one has low water availability; it has low amount of nutrients; it has say soil that is impermeable. On the other hand, the second site has adequate water; it is fertile. So, it has sufficient amount of nutrients and the soil is porous or and a well drained soil, so it is easily able to accommodate the roots.

Now, which of these two sites do you think will be better to raise the crop? So, obviously, the site 2 will be a better site. But then, let us consider a 3rd site which is also having all these three things, it is also having adequate water; it is fertile; it is porous; and probably both these sites are right next to each other. But then inside 2, you do not do any silvicultural operation, in the case of site 3, you are doing a scientific management.

Now, which of these sites will have the highest production? So, in that cas,e we will say that this site 3 which had a good intrinsic condition. It had good water fertility; good soil plus we also gave it good management interventions. So, this side will be showing the largest amount of growth. So, the growing stock in 3 will be greater than the growing stock in 2 which will be greater than the growing stock in 1 because site one is having the least intrinsic productivity.

So, when we talk about a site productivity, it depends on the site quality and the management input. But, if we only talk about the site quality; if we do not do any management input, we are not increasing the fertility of the soil. We are not going with any plantations; we are not doing scientific thinning.

If you only consider the intrinsic quality, so that will determine the relative productive capacity of the of any site; we are not talking about absolute productive capacity. The absolute productive capacity will also be dependent on the management input, but if we just talk about the intrinsic qualities, we will be talking about the site quality.

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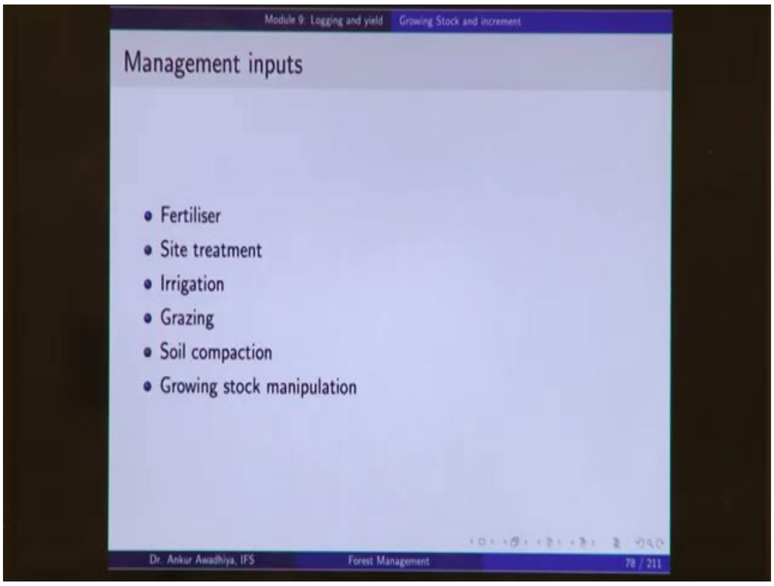

Now, when we talk about management inputs these could be application of fertilizer, treatment of site - say by plowing, irrigation of the site, control over grazing, control over soil compaction, manipulation of the growing stock. If we are doing all of these, we are changing the absolute production capability of the particular site; but, if we do none of these, then we are only talking about the site quality.

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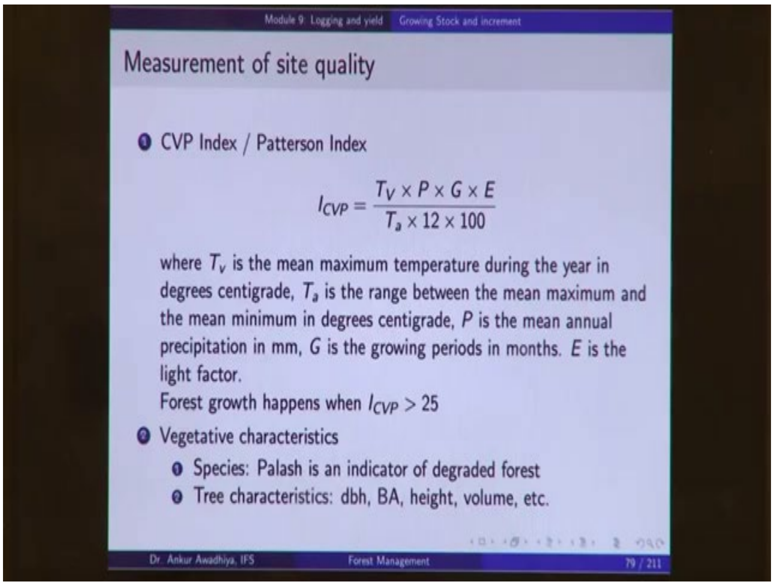

So, how do we measure the site quality? There are typically two ways of measuring the site quality; the first one is the CVP index. So, CVP talks about the climate, the vegetation and the precipitation of the area. CVP is also written as the Patterson index, it is given by T v by T a where T v is the mean maximum temperature during the year, T a is the range between the mean maximum and the mean minimum temperature.

So, the greater their the ratio, the greater will be the CVP index multiplied by P which is the mean annual precipitation and in millimeters multiplied by G by 12. So, G is the growing period in months. So, how much is the growing period? Do you have a growing period that is say only 2 months or do you have a growing period that is say 10 months? So, more the growing period more the CVP index multiplied by E divided by 100 which is the light factor what is the availability of light in the site?

So, it is talking about what is the temperature. Higher the temperature, higher the CVP index. It talks about the precipitation of the site; more the amount of water, more is the CVP index. It talks about the growing season; more is the growing season, more is the CVP index. It talks about the availability of light; so, more is the availability of light, more is the CVP index.

And, it also talks about the range of temperature. So, if the range of temperature is less, then the CVP index will be high. So, essentially, if a site is having temperatures such that in every month you are having roughly the same temperature, then the CVP index will be high as against a site that is showing a very great amount of variation. Now, forest growth is possible, only when the CVP index is greater than 25.

Now, when we talk about the site quality, we can make use of the climatic data of the site by looking at the temperature data, the precipitation data, the growing season, and the availability of light in that area, to determine what will be the site quality of the area. So, this is one easy way or one mathematical way of finding out the site quality. Another is through the use of vegetative characteristics.

So, if you go to a forest area and if you see, that this forest area is full of Palash trees. So, in that case, you can make a conclusion that because Palash is an indicator of a degraded forest. So, in that case, this forest is not having a good site quality, because if it had a good site quality, then probably it would have been able to support other species other than Palash. So, where nothing grows, we generally see Palash growing.

So, if you only see Palash it means that the site is not capable enough of supporting other vegetation. So, by looking at this species that are present in a forest, you can have an idea of the site quality of that site or you can look at that the tree characteristics. So, you visit two forest areas and in one forest area you have very tall trees.

So, you have trees that are very high, you have trees that have a very large amount of girth. So, this is the first site; site 1 then you go to site 2. And, in site 2, you have plants that are stunted. Even its an old growth forest, but the plants are stunted and they have lesser girths. So, in that cas,e you will get an idea that site 1, because every other thing being constant the first site was able to support trees to a larger size, to a larger height, to a larger value a girth or volume as compared to the second site.

So, probably the site quality of the first site is better than that of the second site. So, you can make an estimate of the site quality by either looking at the CVP index of the site, or by looking at the species that are present in the site, or by looking at the tree characteristics of that particular site.

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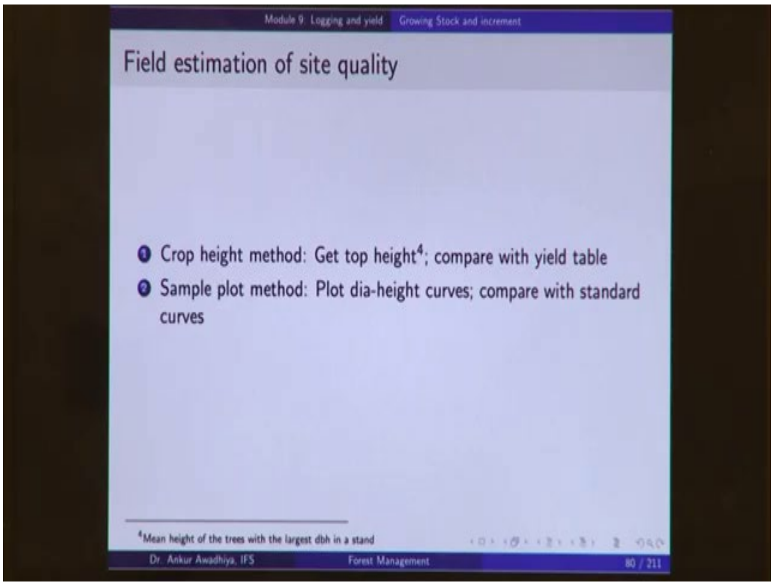

And, when we talk about tree characteristic there are two methods; the first one is a crop height method. So, in the case of the crop height method you get the top height and compare it with the yield table. What is top height? Top height is defined as the main height of the trees with the largest deviation is stand.

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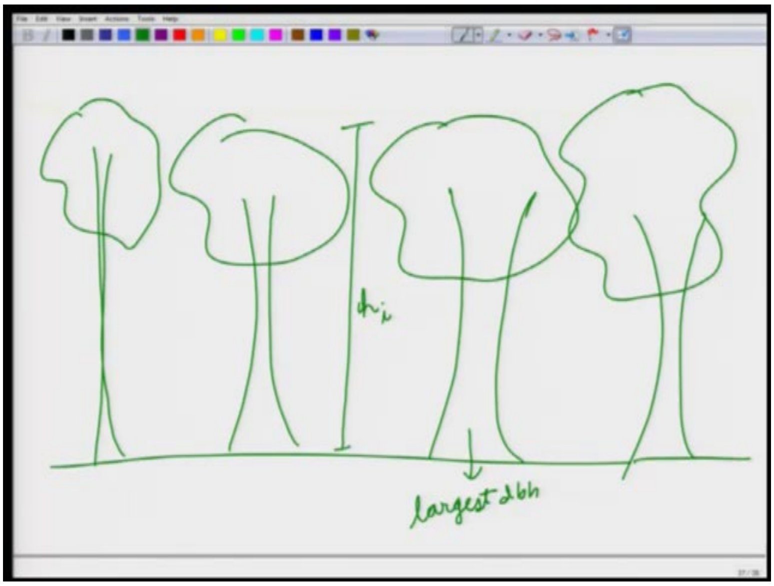

So, when we say top height, we are not saying that we are measuring the height of the tallest trees, probably you have this tree which is at the tallest tree, but if you look at the trees in this stand. So, if you look at those trees with the highest dbh or the largest dbh, and you find out their heights and you do an averaging of the heights of those trees that belong to highest dbh class. When we say class, we are saying; let us say 0 to 10 centimeters, 10 to 20, 20 to 30 and so on. So, those trees that belong to the largest diameter class; you measure the heights take an average, and that is the top height and when you do that you can compare the crop height with the yield table.

So, yield table is a compilation of the growth stat of the growth statistics of different stands at different points of time. And so, in a yield table, it will give you an idea that in the case of the best sight quality is a sight quality I, the top height is say 30 meters.

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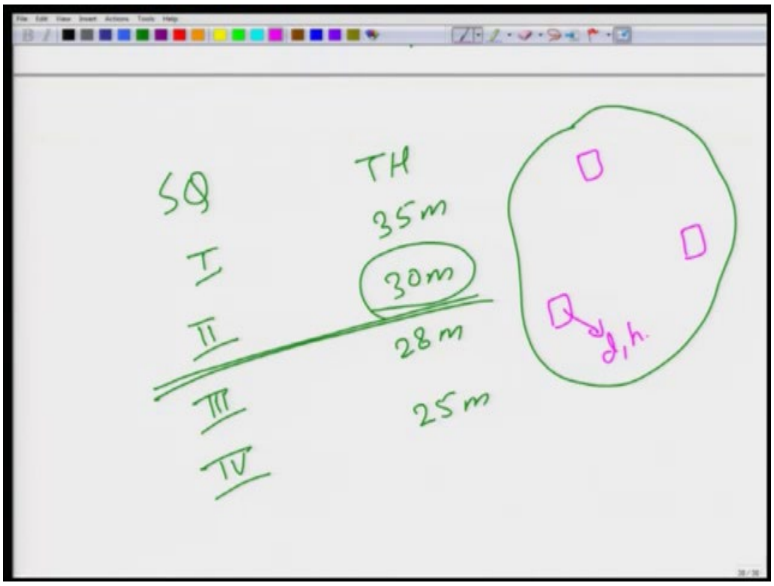

Sight quality and top height. For sight quality I the highest it goes is say, let us say 35 meters; sight quality II, you reach 30 meters; sight quality III, you reach say 28 meters; sight quality IV, you are only able to reach 25 meters.

Now, you go to a site and you measure the top height, and you find that the top height is 30 meters. So, then you can say that this site belongs to a sight quality II. So, this is one way of looking at the tree characteristics. So, we find out the top height, compare it with the yield table and we get the site quality. Another method is the sample plot method.

So, in the sample plot method, you take a sample plot in your forest. So, in this large forest, you took a few sample plots. And, in these sample plots, you do a measurement of the diameter and the height of different trees, and then you plot the diameter and height curves for different for different individuals in the sample plots.

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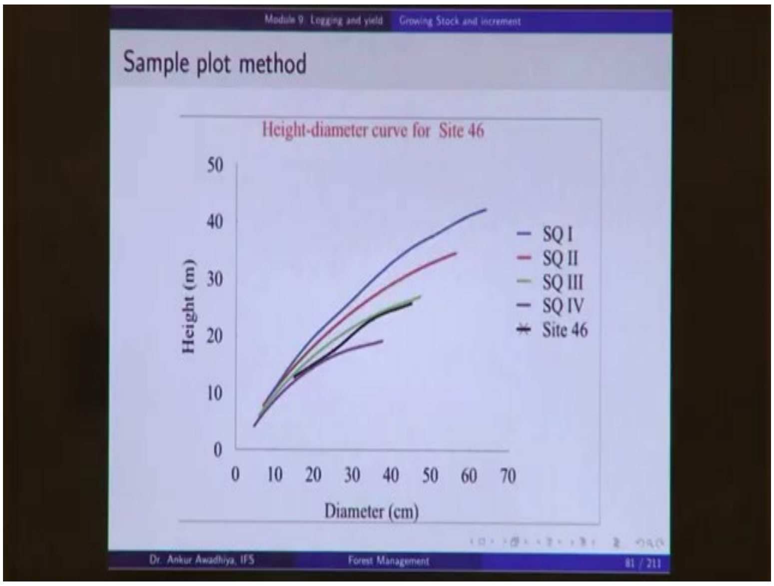

And, then you compare it with the standards. So, in this case here, we are seeing that the height versus diameter curve of Sal trees in a forest stand. So, this was (Refer Time: 54:42) forest stand and so, here we see that this black one is the one that we are getting from the field data. So, we saw that we have trees of different diameters and these are the different heights. So, you plot this and you also plot the site qualities that the diameter and height data of different site qualities that you get from the yield table.

Now, if we look at this curve, we can very easily see that this black line is close to the green one; green one is site quality III. So, in this case, we will say that the site quality of the of the forest stand in Tim lee is site quality III. So, this is also another method of finding out the site quality.

So, in this lecture, we had a look at the growing stock. Now, growing stock is defined as the total volume of all the trees in a stand and we when we say total volume it is volume only of the living trees, and not including the volume of those trees that are less than a particular diameter at breast height. And, it also does not include very thin branches; it also does not include things such as the root or the stump or the leaves or the fruits and so on. So, you can do it in terms of volume; you can do it in terms of weight, and so on.

So, when we are; when we are managing a forest for timber, we would want to have a forest that has the largest amount of growing stock, and also a forest that is showing a large amount of increment. Now, increment is defined as the change in the growing stock per unit time. So, we can define periodic annual increment which is change in growing stock divided by the number of years that have passed in between.

Or, we can define the current annual increment which is equal to the differential of the curve that represents the and the growth of the stand, which is typically a sigmoidal curve showing a logistic growth equation. So, if you take the slope of the curve, it will give you the current annual increment. The third thing is the mean annual increment; mean annual increment is the is a growing stock at year n divided by n number of years.

So, what is the average amount of increment that your stand has been putting up since the time it was grown? So, that is the MAI. Now, typically in the case of forest stand, the CAI increases reaches to a maximum at the inflection point of the growth curve, and then it starts to reduce. The MAI also increases, and it also starts to reduce. Now, MAI is maximum, where the CAI and MAI curves cut each other.

And, that is the point where the stand has reached an appreciable value of growing stock. And, it has also reached the maximum amount of rate of increment that it could achieve, because after this point the rate of increment is going to go down. So, this gives a very good indication of the rotation age for that particular species at that particular site.

Now, the rate of increment depends on a number of factors. It depends on the species; it depends on the site conditions, both intrinsic conditions as well as extrinsic conditions. So, there we can make an estimate of the site quality which is defined as that as the relative productive capacity of a site. If you are not giving any management inputs to the site, what will what is the product, what is the relative productive capacity of this site as compared to a standard site.

So, this comparison can be done in a number of ways. You can either go with CVP indexes, in which case, you look at the at the temperature data, the precipitation data, the growing period data as well as the availability of light to compute the value of I for different sites. Or, you can do a field measurement by looking at the species that are growing in a site.

So, if a site only has those species that grow in degraded areas and does not have any species that grows in rich soils, then probably this that particular site is not having a good site quality. Or, you can make use of tree characteristics. Tree characteristics include measurement of the top height. So, in the case of top height, you take the average height of those trees that belong to the highest diameter classes. And, you compare that with the yield table and you get an idea of the site quality.

Or, the second method is to take sample plots, and then plot the height versus diameter curve and compare it with the standards. So, by looking at the site quality, you can make an estimate of the rate of growth or the rate of increment as well as the maximum amount of growing stock that your site will be able to support.

And, if you want to increase the site quality, probably you will have to go with some amount of amelioration in the site, or some amount of management inputs to the site. So, that the fertility goes up or what it is available for a longer period of time or probably you could even construct a greenhouse. So, by doing all of these, you can ensure that the growing stock is very large and it is also growing at a very fast rate. So, that is all for today.

Thank you for your attention [FL].