Forests and Their Management
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Module – 04
Forest Mensuration
Lecture – 12
Measurement of Tree Attributes – II

[FL]. We move forward with our discussion on Forest Mensuration

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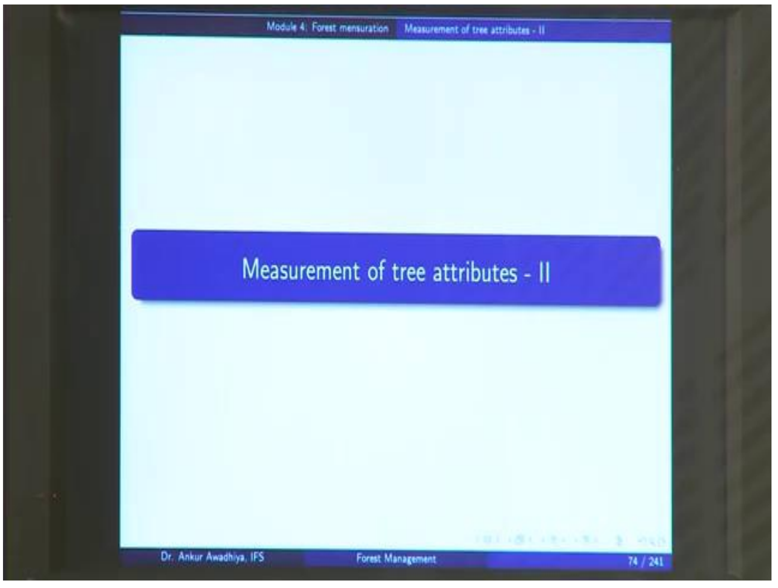

And, today we will have a look at the Measurement of some other Tree Attributes. So, in the last lecture, we saw how do we measure the diameter of a tree using either callipers or using a tape. But, then the most important parameter that we want to measure in a tree is the volume of timber that we can extract out of it.

Now, to find out the volume of timber that you can extract from a tree, you require two essentially three data – one is the diameter, the second is the height, and third is the form factor.

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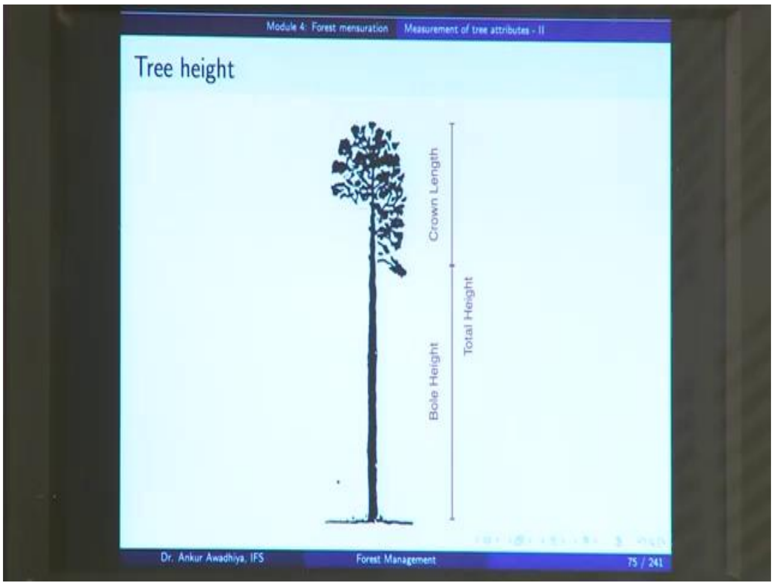

So, in this lecture, we will have a look at how do we measure the height of a tree. Now, in the case of height, we have three different measurements that can be taken. The first one is the bole height. Now, if you consider any tree, the lowest most branch that is a part of the crown; so, this is the lower most branch that makes the crown.

Now, the height of the tree till this lower most branch is known as the bole height, and above this height, we will be having logs that are having a large number of branches. So, they do not have a very large commercial value, but in the case of the bole you have a very good commercial value. And, the length from this point to the top of the tree is known as the crown length, and the total height of the tree is equal to bole height plus crown length.

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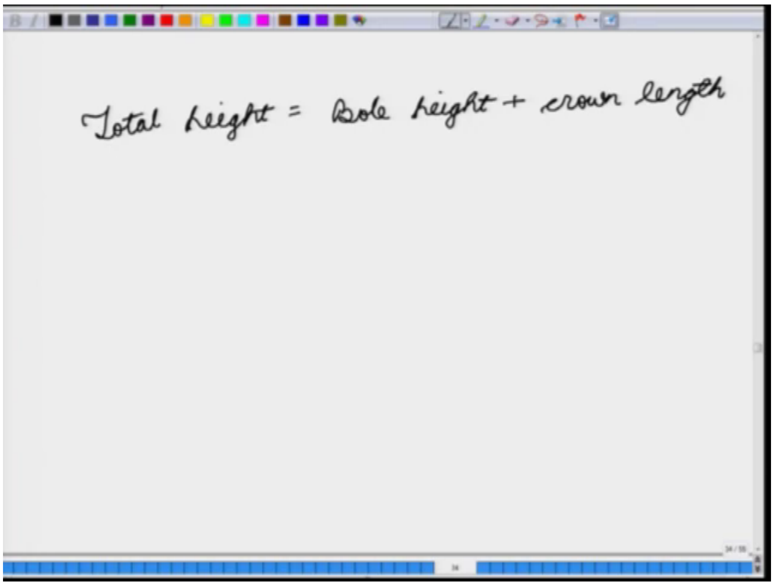

So, we can write that total height is equal to bole height plus the crown length.

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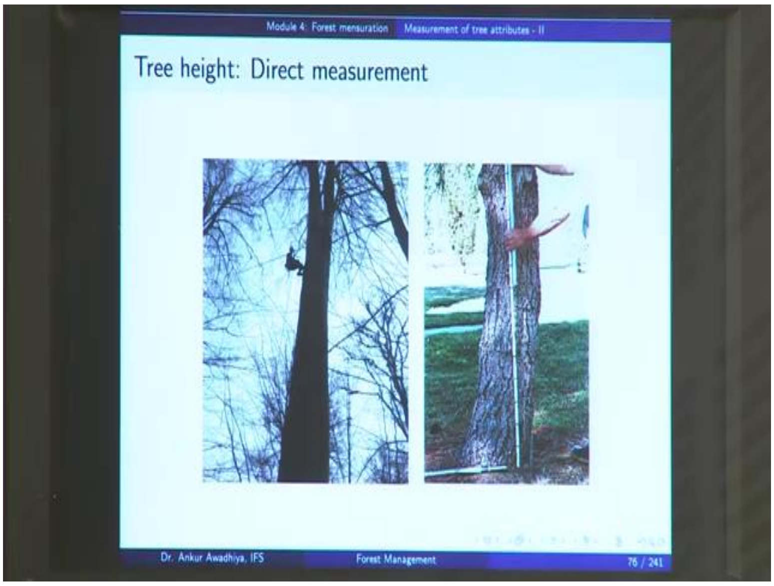

Now, in the measurement of the height of a tree, we have got two different options. The first option is known as a direct measurement. Now, in the case of a direct measurement, you place an instrument along the trunk of the tree, and you measure the length of the instrument till the height you want to measure.

So, essentially what we are seeing here is that, in the case of trees of short in height, we can just make use of poles, and this is a pole that can be extended, and once you have this pole you can stand near the tree, put your pole such that the bottom portion touches the ground, and the top portion is extended so that you can you are able to reach the height till which you want to measure. And, then you take this instrument out and you can measure the length of this rod, and this kind of a measurement will be known as a direct measurement, because you are directly measuring the height of the tree.

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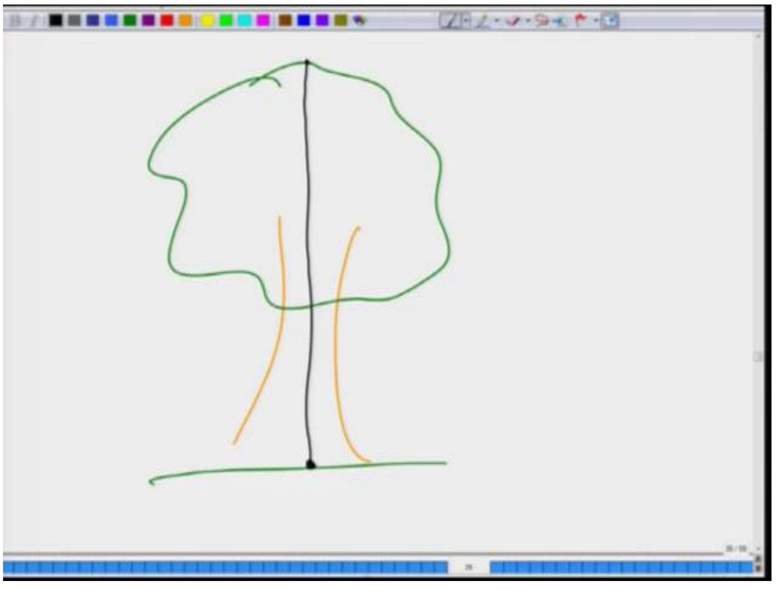

Another option is that if you have this tree and you want to measure the height, then you can ask somebody to climb this tree reach till this point and from this point you will drop a string with a weight attached to it. And, when this weight is touching the ground then the length of the string will give you the height of the tree.

So, these kinds of measurements in which you are using an apparatus or an instrument or a string to directly measure the height of a tree is known as a direct measurement.

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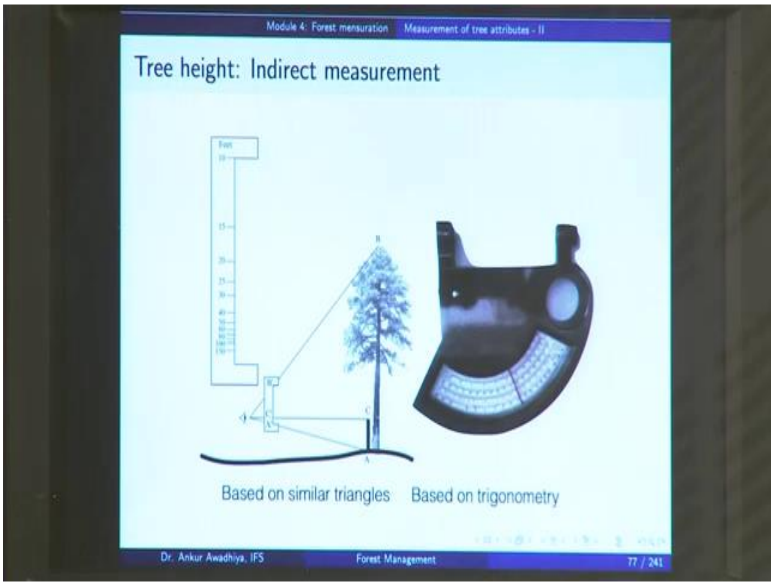

Now, of course, it is not a very good way of measuring because it is difficult to climb all different trees and it takes quite a lot of effort. So, another way of measuring the height is known as an indirect measurement.

Now, in the case of an indirect measurement, you can make use of two principles. You can do a measurement based on similar triangles, or you can do a measurement based on trigonometry. Now, in the case of an indirect measurement, you are not measuring the height directly; you are not putting an instrument to till the till you reach the top of the tree, but what you are doing is that you are standing at a distance from the tree, and you are making use of mathematical relations to get an idea of the height of the tree. So, the first such method is known as the method of similarity.

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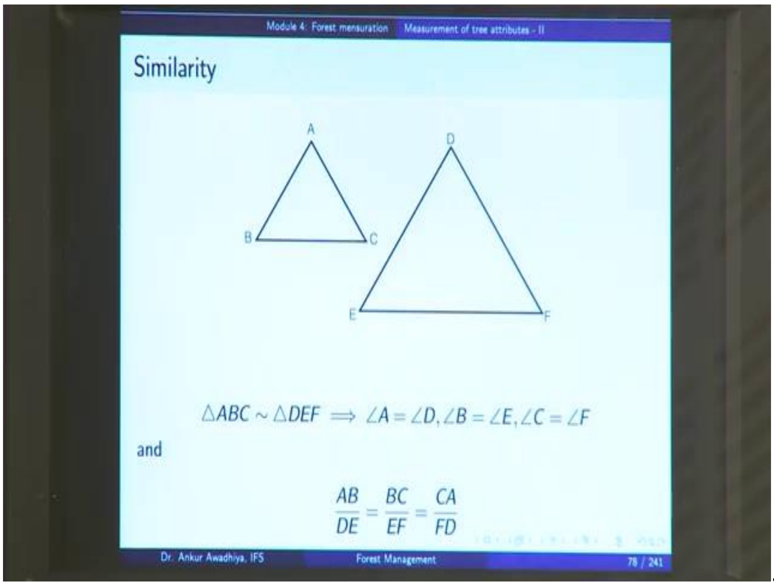

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Now, if you have two triangles.

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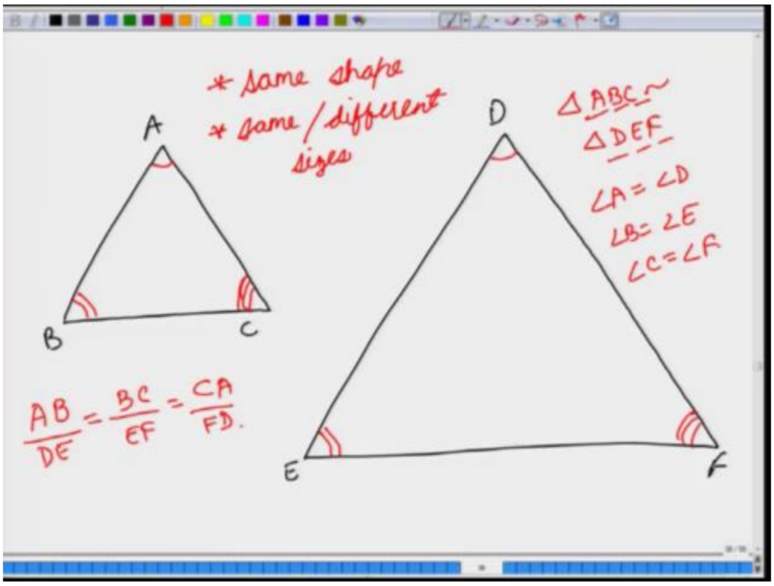

Now, you have these two triangles which are of the same shape, but different sizes. So, let us call this ABC and this one is DEF. Now, we call these triangles as similar triangles, if they have same shape and if they have same or different sizes. So, when we say that both of these triangles are similar triangles, they are having the same shape.

Now, what do you mean by the same shape? Now, in the case of these triangles, the same shape would mean that, if we say that triangle ABC is similar to triangle DEF, then angle A is equal to angle D, angle B is equal to angle E and angle C is equal to angle F. So, A is equal to D, B is equal to E and C is equal to F; angle A is equal to angle D, angle B is equal to angle E and angle C is equal to angle F.

At the same time, if both of these triangles are similar, then the equivalent sides would be in the same proportion which would mean that, if we take the ratio of AB, this will be the same as the ratio of BC divided by EF which is equal to CA divided by FD. So, in the case of similar triangles, you have the same shape - the angles the corresponding angles are equal and the sides are in the same ratio. Now, if we are able to get two triangles that are similar and we know at least one dimension of both of these triangles, then we can find out the other dimensions.

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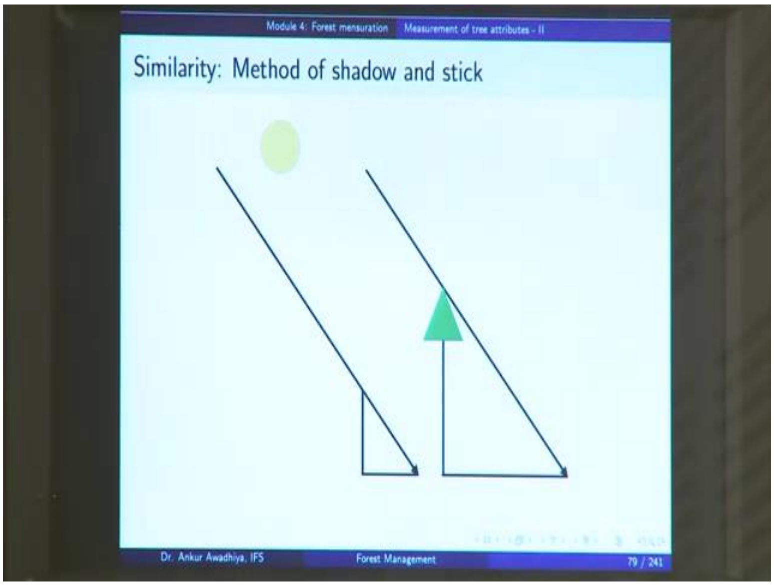

So, good example is the measurement of the height of a tree using the method of shadow and stick. Now, what we do in this case is that you have this tall tree, and you have the sun here.

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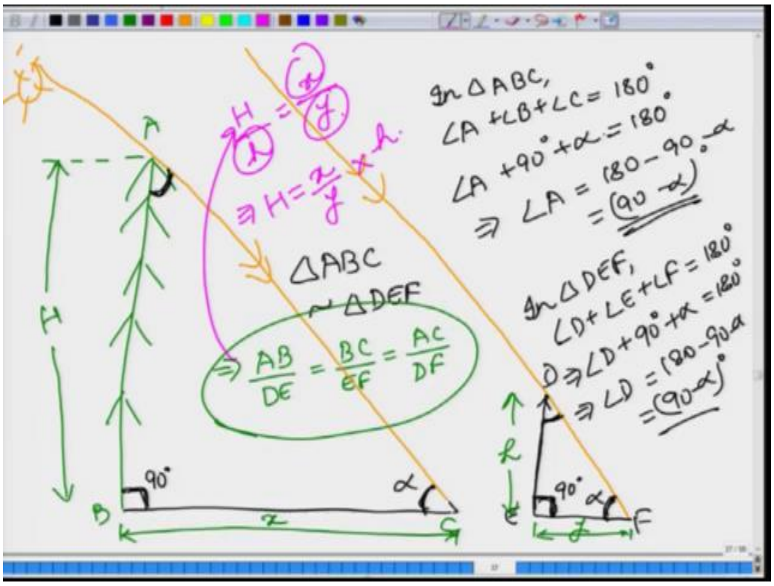

Now, the sun will cast a shadow of this tree. So, let us say that this is the shadow of this particular tree. Now, because sun is at a very great distance from the earth; so, in this case, the rays of the sun can be assumed to be parallel. So, if you take a rod and if you put it here, then if you look at another parallel ray of light, so, we are looking at another parallel ray of light so, it hits the rod. So, suppose this is your rod, and this is making the shadow. So, this is your rod and this is the shadow.

Now, because both of these rays of the sun are parallel to each other; so, let us call this triangle as ABC and the second triangle as DEF. Now, because both of these rays are parallel to each other, so they will be making the same angle. So, both of these angles are equal. Now, your tree is subtending an angle of 90 degrees with the ground, and this stick is also subtending an angle of 90 degrees to the ground. So, let us call this angle as alpha.

Now, in this triangle in triangle ABC, angle A plus angle B plus angle C is equal to 180 degrees. Now, angle B is 90 degrees, angle C is alpha plus angle A is 180 degrees. So, angle A is equal to 180 minus 90 minus alpha is 90 minus alpha degrees. Now, this is the value of angle A. Now, in triangle DEF, angle D plus angle E plus angle F is equal to 180 degrees. So, this would mean that angle D plus 90 degrees. This angle plus angle F is alpha is 180 degrees which would mean that angle D is equal to 180 minus 90 minus alpha is equal to 90 minus alpha degrees.

So, in both these triangles, what we are finding is that angle A which has this value is equal to angle D the same value, angle C is equal to angle F and angle B is equal to angle E. So, in that case, we can say that triangle ABC is similar to triangle DEF. Now, if we have two triangles that are similar, it means that AB by DE is equal to BC by EF is equal to AC by DF. Now, because you have this tree, you can measure this distance. Let us call this distance x; you can measure this distance. Let us call this y; you can measure this. Height of the rod - let us call it h, and you want to have the reading of capital H which is the height of the tree.

Now, if we make use of this equation, what we will get yes now AB is equal to capital H divided by DE, which is equal to small h is equal to BC, which is equal to x divided by EF which is equal to y. Now, we know the value of x, y and h. So, in that case capital H is equal to x divided by y into small h.

So, in this way we can find out the value of capital H which is the height of the tree, just by making use of similar triangles. So, in short, the method is that you have your tree and at some point, in the day the sun is casting a shadow of this tree. You measure the length of the shadow, during the same time period you put a rod of a known length near your tree, and you let the sun cast another shadow of the rod, and you measure the length of the second shadow.

So, once you have both these lengths and because you know the height of the rod, you can find out the height of the tree. So, this is one method of finding out the height using similar triangles.

Another method is using Christen’s hypsometer.

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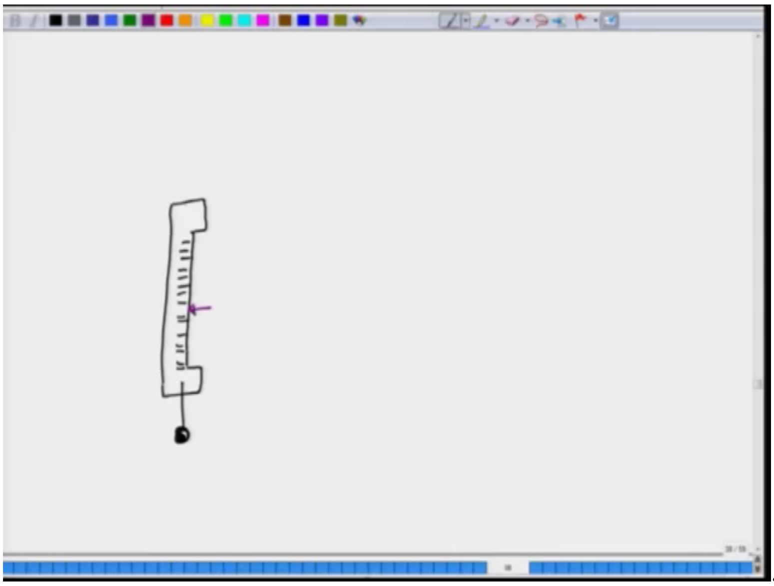

Now, Christen’s hypsometer is a device, it is typically made out of cardboard, and the device looks like this, and here you have the readings the readings of length. Now, to this piece of cardboard, you attach a weight so that whenever you are holding this device it should be vertical. So, which is why you are adding a weight here.

Now, if you want to find out the height of a tree, what you do here is that you take a rod of a known length - let us call it as small h. You place it near the bottom of the near the base of the tree. So, it is now right next to the base, and you keep your hypsometer in a vertical position. So, you will keep it like this, and you will place it in such a manner that the top of the hypsometer is.

So, you are seeing the this top of the hypsometer, and you are seeing the top of the tree and you are you align your hypsometer in such a manner that both these points come together. And, similarly you move in such a way that the bottom of this hypsometer, and the base of the tree are looking at the same point, looking at from your point of view from your perspective.

Now, what is happening in that case is that here is your eye level, the top of this hypsometer and the top of the tree are in the same line. The bottom of the hypsometer and the bottom and the base of the tree are in the same line. And, you look at the top of the rod and you try to figure out what is the reading that you are getting from the hypsometer. So, in this case, you will find out say the reading is this much. So, next you can make use of the principles of similar triangles.

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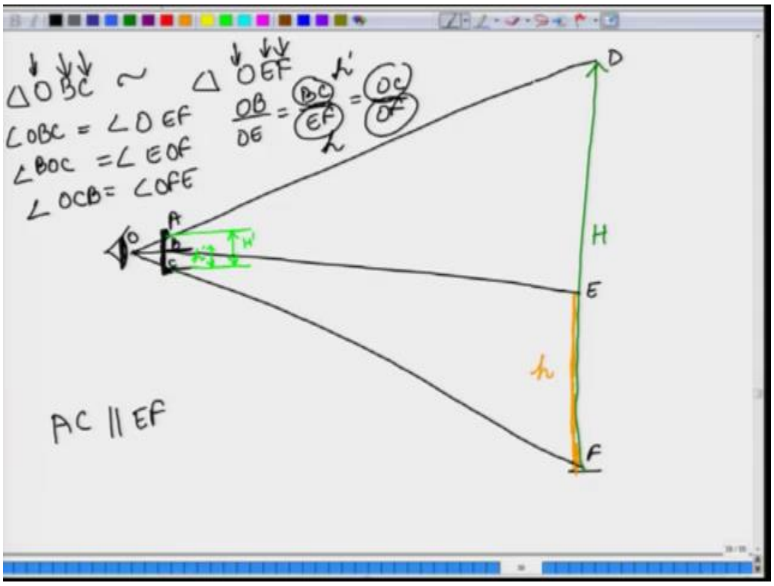

So, what we are having in this case is that this is your eye. So, this is your hypsometer. This green line - this is your tree, and this yellow line - this is the rod. Now, let us give a name to the vertices. So, let us call it O A B C D E and F. Now, in this case, you know the reading of BC, let us represent this as h prime (h'). So, this is your h prime; the length of the hypsometer which is this much let us represent it as H prime (H') with a capital H. The length of your rod is small h and the length of or the height of the tree is capital H.

Now, if we look at these two triangles - triangle OBC and triangle OEF, we find that because AC - AC is vertical and it is parallel to EF. Now, if that is the situation, you have these two parallel lines. So, in this case, angle OBC is equal to angle OEF; angle BOC is equal to angle EOF, and angle OCB is equal to angle OFE, which means that all the corresponding angles - angle O is the same in both of these, angle B is equal to angle E, and angle C is equal to angle F. So, both of these triangles are similar triangles.

Now, if both of these triangles are similar triangles, then we can write that OB by OE is equal to BC by EF, is equal to OC by OF. Now, in this case, you have BC. This is the value of BC and BC is equal to h prime with a small h, EF is equal to h - the small h, is equal to OC by OF

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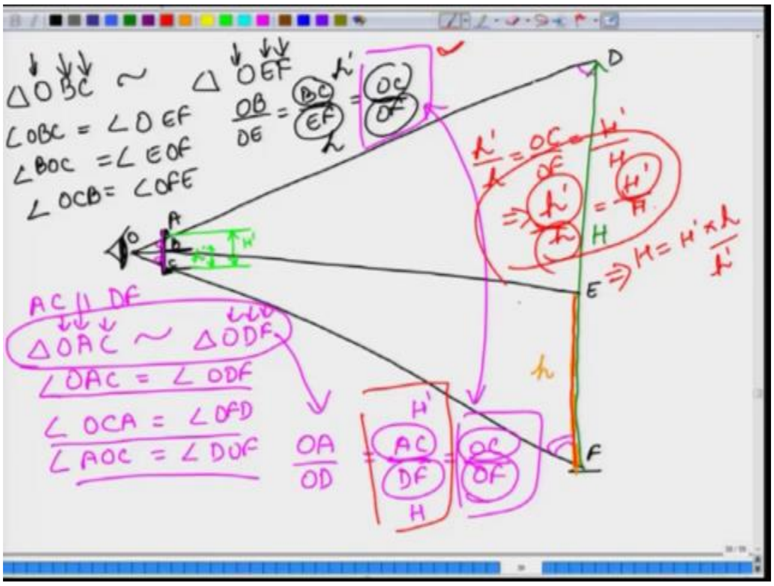

Now, let us look at to the at another pair of triangles. So, let us look at a triangle OAC and triangle ODF. Now, in both of these triangles, you have AC is parallel to DF. So, that would mean that in both of these angle OAC - this angle is equal to angle ODF. This angle; angle OCA this one is equal to angle OFD, this one. And, angle AOC is equal to angle DOF. So, basically what we are saying is that angle O is the same in both of these angle A is equal to angle D, A is equal to D, and angle C and angle F are equal. Angle C and angle F are equal which would mean that both of these triangles are also similar.

Now, if both of these triangles are similar that would mean that the corresponding sides are in the same ratio, which means that OA by OD is equal to AC by DF, is equal to OC by OF. Now, in this case, we know AC. So, AC is this much which is H prime with a capital H, DF is equal to capital H, is equal to OC divided by OF. Now, this figure of OC by OF we are seeing it in both the places. So, you have that, from this equation, you get that h prime by h is equal to OC by OF, and this OC by OF is also equal to capital H prime by capital H, which would give you the relation that h prime by h is equal to capital H prime by capital H.

Now, in the case of this hypsometer, you know the height of this rod, this one; you know the capital H prime, which is the length of the hypsometer, and you know the value of small h prime, which is the reading that you got from the hypsometer. So, if you rearrange this the equation, you get H is equal to H prime into h by h prime. So, this is how you can make use of a hypsometer, and the method of similar triangles to find out the height of a tree.

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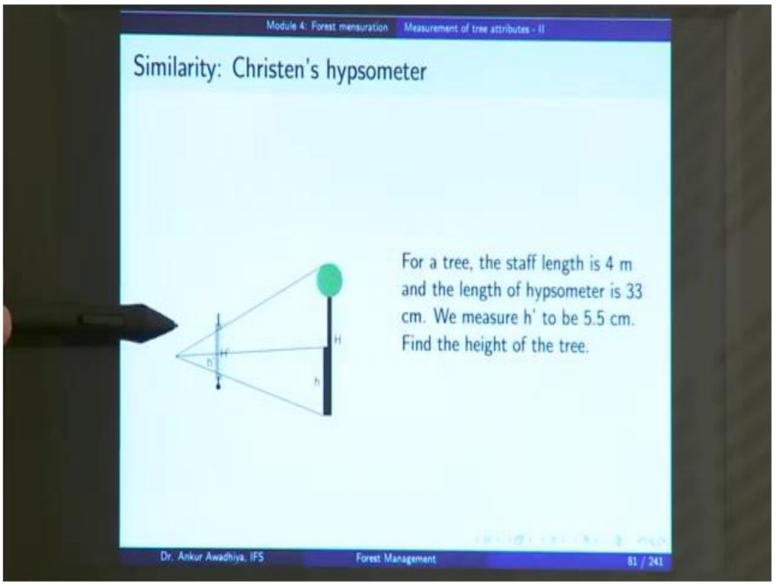

So, let us now look at an example. Now, in this case, the staff length this much or the small h is 4 metres; the length of the hypsometer is 33 centimetre which is your capital H prime, and we measure h prime to be 5.5 centimetres, find the height of the tree. So, we will we are going to make use of this equation.

So, you have h prime by h is equal to capital H prime by capital H, and in this case, what we know is that we want to find out capital H. So, capital H is question mark. We know the value of small h. So, small h is 4 metres, small h is 4 metres. We know the value of capital H prime, which is the length of the hypsometer which is 33 centimetre 33 centimetres and we have measured small h prime to be 5.5 centimetres small h prime is 5.5 centimetres.

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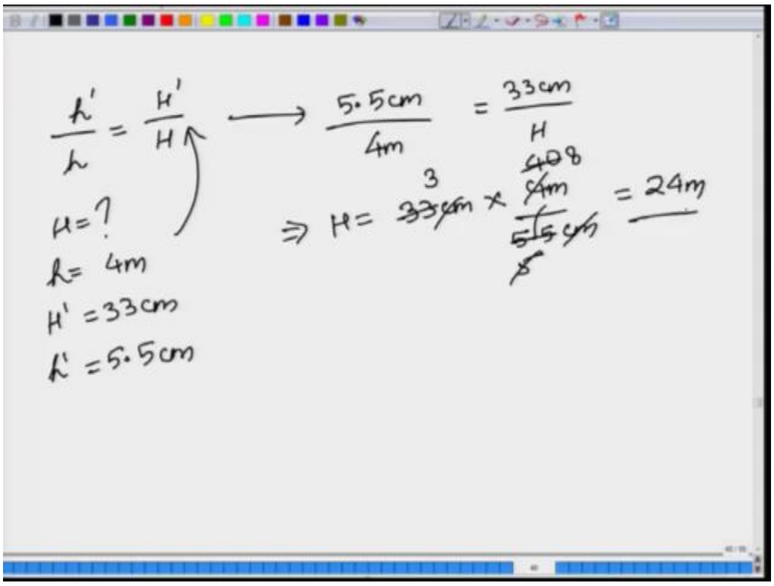

So, putting these values in this equation what we get is small h prime is 5.5centimetre, divided by small h is 4 metre, is equal to capital H prime which is 33 centimetre divided by capital H. So, you get that capital H is equal to 33 centimetre into 4 metres divided by 5.5 centimetre. Centimetre and centimetre get cancelled, 5.5. So, this becomes 40; 11 3s are 33; 11 5s are 55; 8 5s are 40 is 24 metres.

So, just by using a hypsometer, knowing the length of the hypsometer; the length of the rod or the staff length and the reading of small h prime, we are able to compute the height of the tree. So, this is a very simple instrument to measure the height of a tree.

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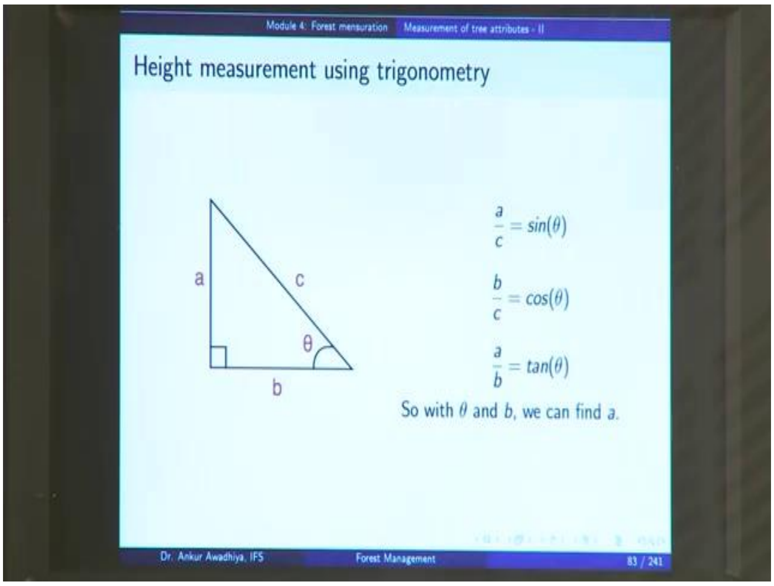

Now, another way in which we can measure the height of a tree is by using trigonometric relations. Now, trigonometry as the word tells 'tri' is 'three', 'gon' is the 'length', and 'metry' is 'to measure.' So, in this case we are measuring the three sides of a triangle.

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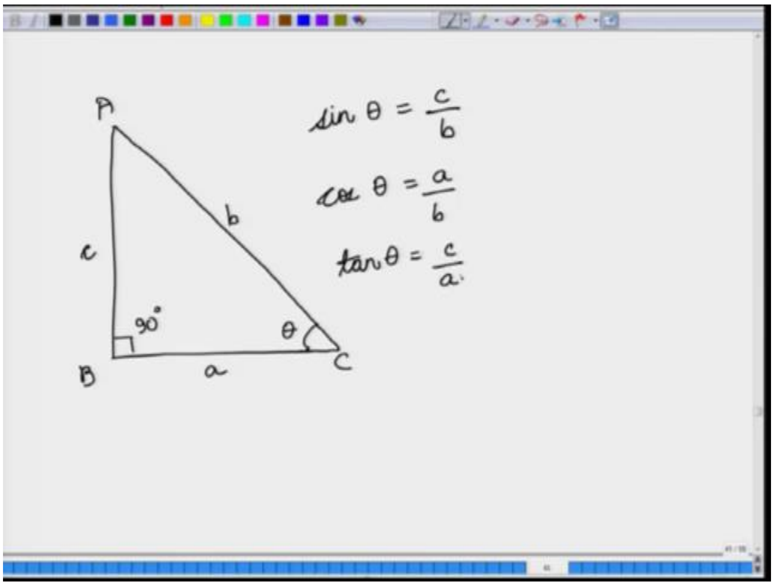

So, the relation goes like this. In the case of a right-angled triangle; so, this is 90 degrees. Let us call a triangle ABC. If we know the value of this theta, then the corresponding sides are represented as small letter variants of the angles. So, BC can be written as small a, AC can be written as small b, and AB can be written as small c. Now, for this triangle, for this right-angled triangle, we define sin theta is equal to c by b; cos theta is equal to a by b, and tan theta is equal to c by a.

Now, this is the relation that we can make use of in measuring the height of the trees. So, in this triangle, if we have these values a, b and c, then a by c that is the opposite side divided by the hypotenuse is sin theta. b by c which is in the case of this angle; this is the adjacent side divided by the hypotenuse is cos theta, and a by b is tan theta. So, if you can measure the value of this theta, and if you can measure the value of b, you can find out a by using a by b is equal to tan theta.

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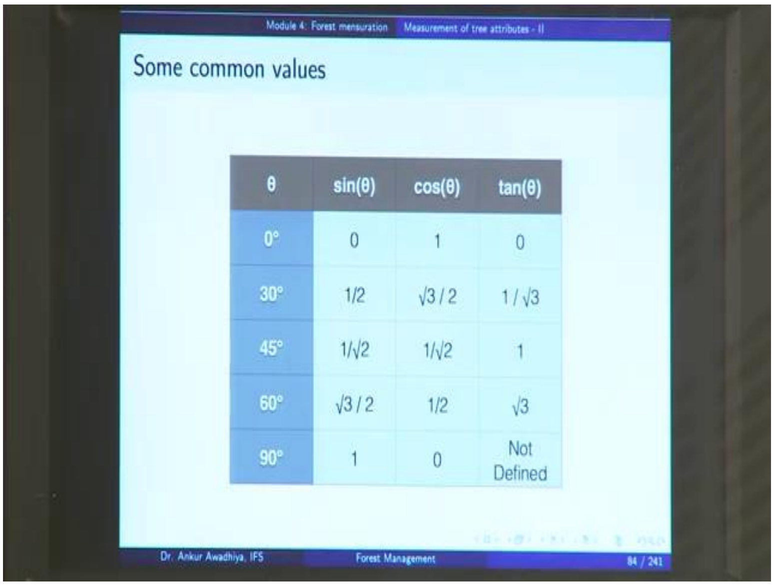

Now, the common values that you will generally use are these. In the case of sin theta, for 0 degrees it is 0. 0 half for 30 degrees, 1 by root 2 by for 45 degrees, root 3 by 2 for 60 degrees and the value of 1 for 90 degrees. So, sin 90 degrees is 1, sin 45 degrees is 1 by root 2 and so on.

In the case of cos theta, you move in the opposite direction 0, half, 1 by root 2, root 3 by 2 and 1. And, tan theta is given by sin theta divided by cos theta; so, 0 divided by 1 is 0, 1 by 2 divided by root 3 by 2 is 1 by root 3, 1 by root 2 divided by 1 by root 2 is 1, root 3 by 2 divided by 1 by 2 is root 3 and 1 divided by 0 is not defined. So, these are the common values of sin, cos and tan theta that you will be using.

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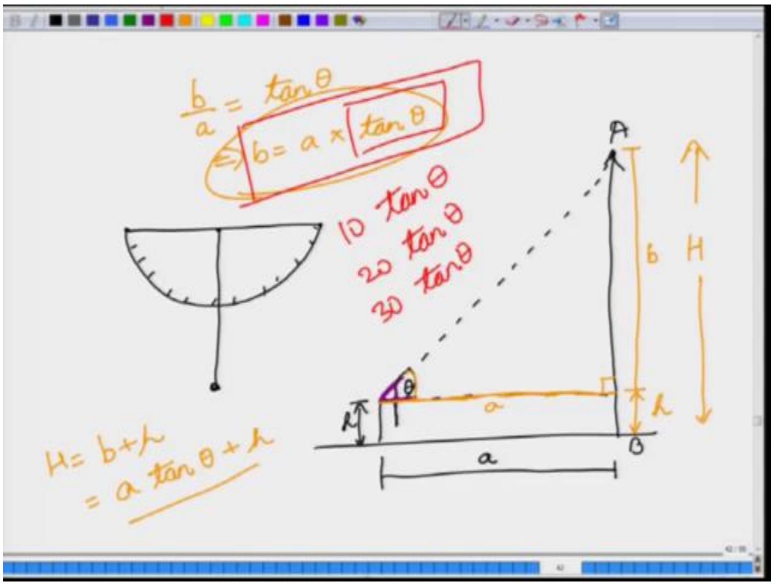

But then, the next question is how do you measure the height? Now, how it can be measured by making use of a protractor. In the easiest of circumstances, you can take a protractor and here you have the angular readings you make a hole here and you attach a weight. Now, if you do that suppose you are here, you have a tree and here you are standing. So, this is your eye level, you keep your protractor and you align this and this point with the top of the tree.

So, in that case, you will have a situation where your protractor. So, your protractor will look like this because you have a weight. So, this weight will always come down, and in this case, you can measure the angle that is subtended here. So, you can measure the angle, and once you know this angle, this is 90 degrees; you can also measure this angle. So, you can find out the angle that is subtended by the top of the tree, but in method he is making use of a Blume Leiss.

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Now, a Blume Leiss is an instrument in which here you have an eye piece, here you have the objective, you keep your thumb here, here you have a button, and on and here you have the scales. Now, what happens in the case of this instrument is that when you release the button, this counter it has a weight and it always comes down. So, it will look like this and whether you are and no matter howsoever you are tilting this instrument, this pointer will always be down.

Then, you look at the eye piece and you arrange this instrument in such a way that the eye piece, the objective and the top of the tree are in the same line, and so, your counter will be straight here, and you press this button which will fix the counter, and then you can take this instrument and have a reading.

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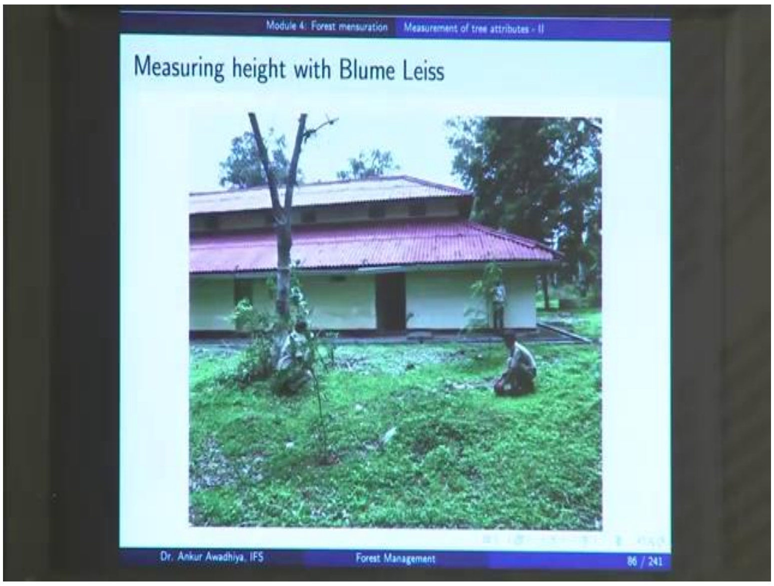

So, essentially what you are doing is that in the first day, you measure the distance from the base of the tree. So, here you are having two people you are measuring the height of this tree. So, we are using a tape to measure this distance, where this person will be standing.

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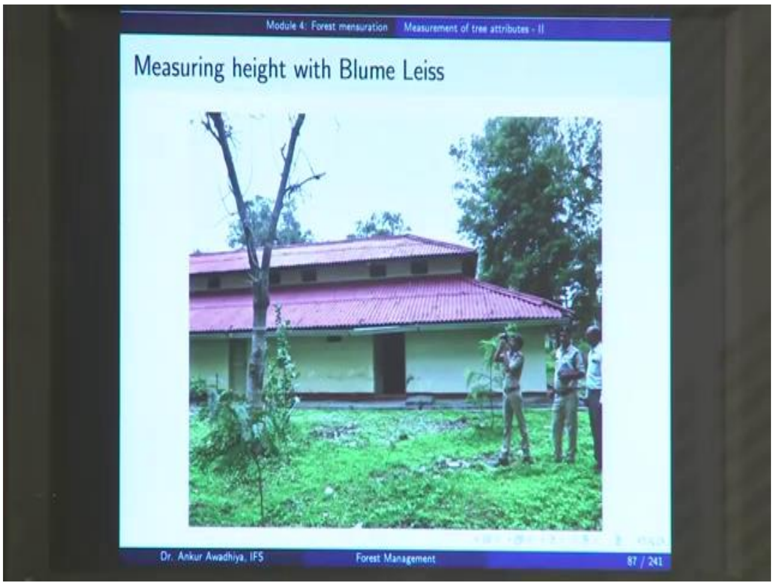

Next, this person take this Blume Leiss, and uses it in such a manner that his eye, the eye piece, the objective and the top of the tree all form a straight line.

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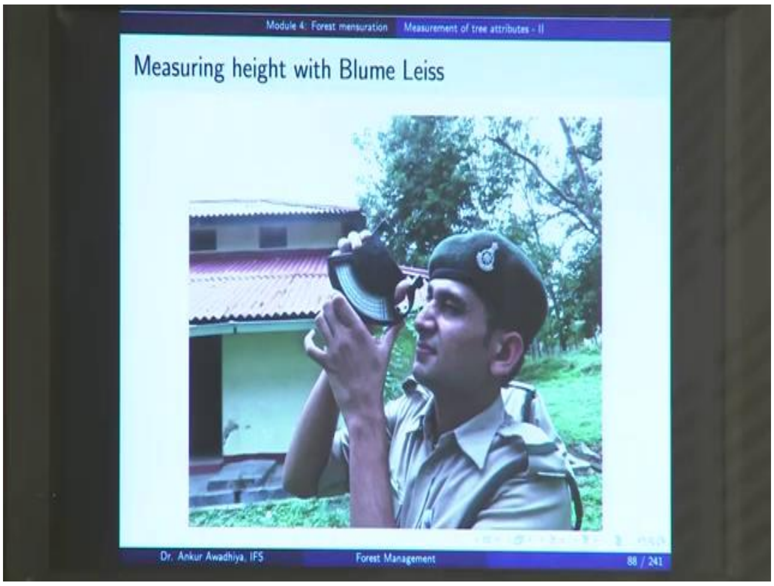

Next, when he does that; so, this is how it will look so - his eye and the top of the tree and the objective and the objective and the eye piece all are in the straight line, and you can see that this counter is downwards. And, in this position, he will press this button and so, this counter will become fixated.

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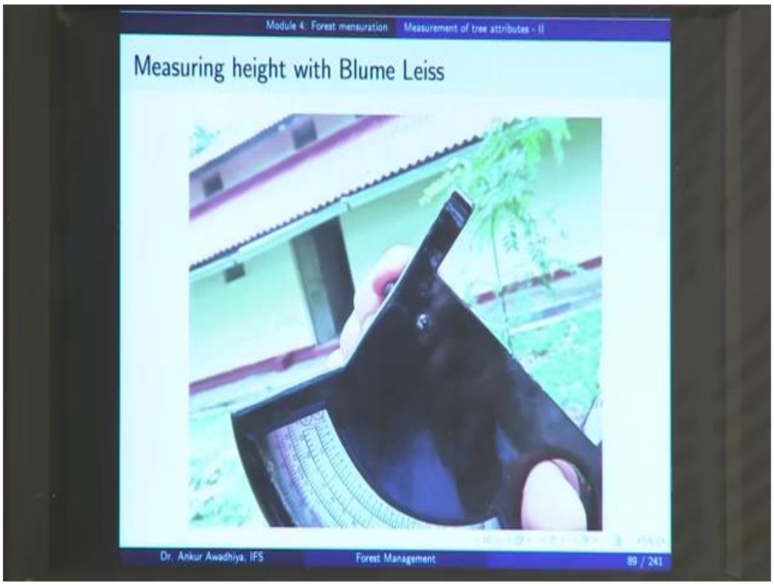

So, this is the button that is pressed and once you have it fixated, you can have a value of the angle that is being subtended, and it also gives you the values of tan theta, and it also gives you the value of the height of the tree, if you are standing at standard distances.

So, let us now; so, essentially what we are seeing that is that you are standing at a particular distance; let us say that this is a from the base of the tree, your height in this case is this small h, you know the value of theta. So, what is the height of the tree? Now, the height of the tree can be measured like this line and here you have an angle of 90 degrees. So, this line has a length of a small a let us say that this much is equal to b and this much is equal to small h.

Now, we because we know the values of theta; so, we can write that b by a is equal to tan theta or b is equal to a into tan theta. Now, the height of the tree capital H capital H is given by b plus small h. Now, b we can get from here. So, it is a tan theta plus small h, which is your height. So, we can use this instrument to get the height of the tree. Now, what this instrument also does is that not only does it give you the value of theta when you are using this instrument, but it also directly gives you the value of tan theta, and also the values of a tan theta for a specific distance.

So, for instance, you can have a value of ten times of tan theta, 20 times of tan theta and 30 times of tan theta. So, in this case, if you are standing at a distance of 10 metres then you will make use of that particular scale, and this is what we are seeing here. So, you have these different scales and all of these scales are giving you this one scale is giving you the value of theta; another scale is giving you the value of tan theta, and the other scales are giving you the values of a tan theta, with different a s that you can make use of. So, you stand at these standard distances, make use of the instrument and you directly get the value of a tan theta. you add your the height of your eye level to this reading and you get the height of the tree. So, it makes it for a very simplified measurement.

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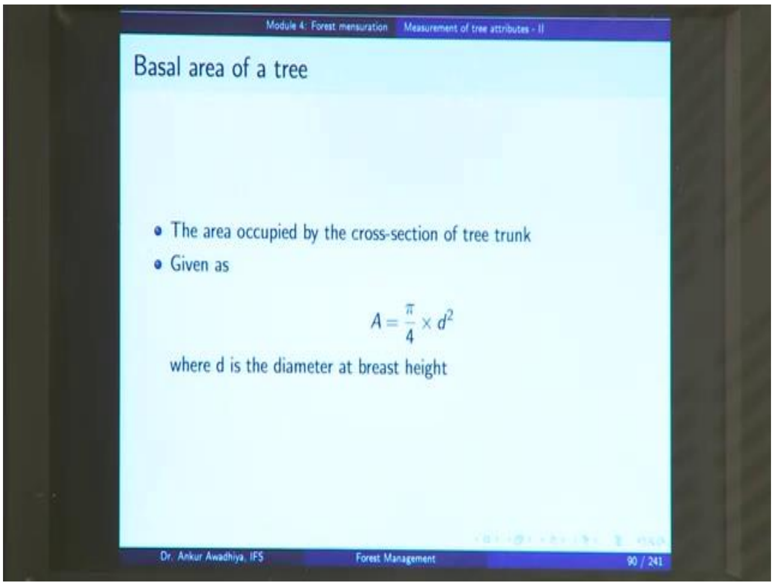

Now, let us have a look at what is the basal area of a tree. So, we now have we now know how to measure the diameter of a tree, how to measure the height of a tree. Now, the next thing that we require is the basal area.

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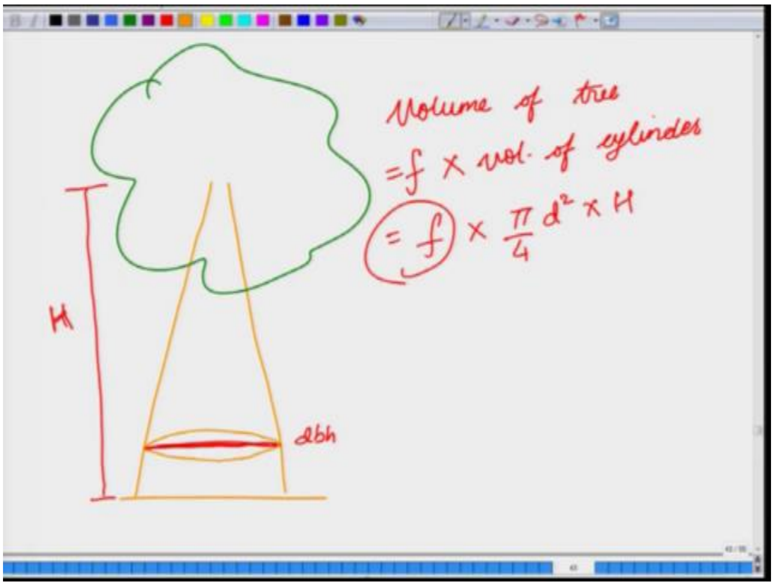

Now, why do we need the basal area? You have this tree. you know the value of the dbh, you know the height of the tree or the height of the bole that you are interested in. So, you know the value of capital H. So, the volume of the tree of tree is given by the form factor, let us call it as f into the volume of the cylinder. Now, as we saw, in the case of the false form factor, we take the volume of a cylinder that has the diameter of dbh, and that has the height of capital H. So, the volume of the tree is given by f, f into volume of the cylinder is pi by 4 d square into capital H.

Now, f would depend on as we saw in the previous lecture, it would depend on the species, it would depend on the site, it would depend on whether your tree is lying in the centre or is it lying towards the periphery. It would also depend on the genetic characteristics of the trees in your area. But, given an area, you can always chop down a few trees, get their volume divide it by the volume of the cylinder, and you will get a common value of small f or the form factor for your particular area.

But, then to find out the volume of any particular tree, you have to multiply that with pi by 4 d square into h. Now, this pi by 4 d square or the area of this cross section, goes by the name of the basal area of a tree. So, basal area of a tree is the area occupied by the cross section of the tree trunk given as pi by 4 d square, where d is the diameter at the breast height.

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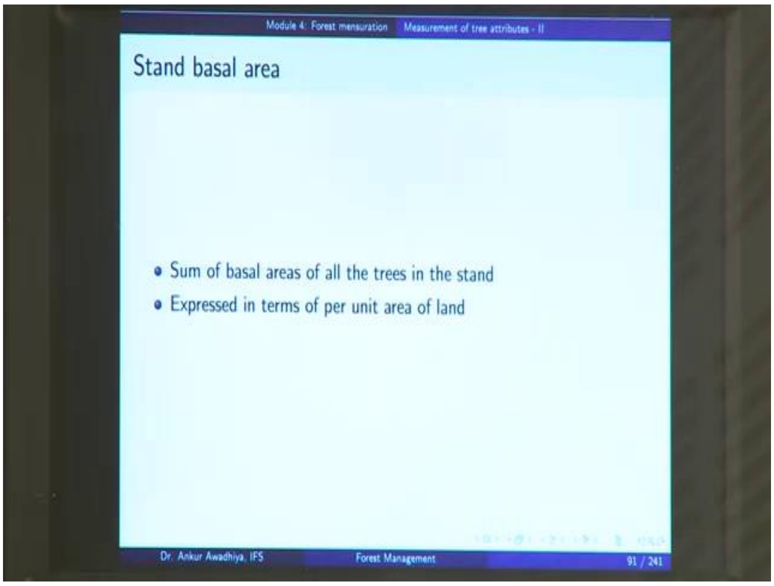

And, if we add up the basal areas of different trees in our stand, we will get the stand basal area, which is the sum of the basal areas of all the trees in the stand, and it is generally expressed in terms of per unit area of land. Now, the question is we can always measure small d, we can measure the diameter at breast height; why do we have this need to measure the stand basal area? Does it serve any other purpose other than to find out the volume of a tree? The answer is yes.

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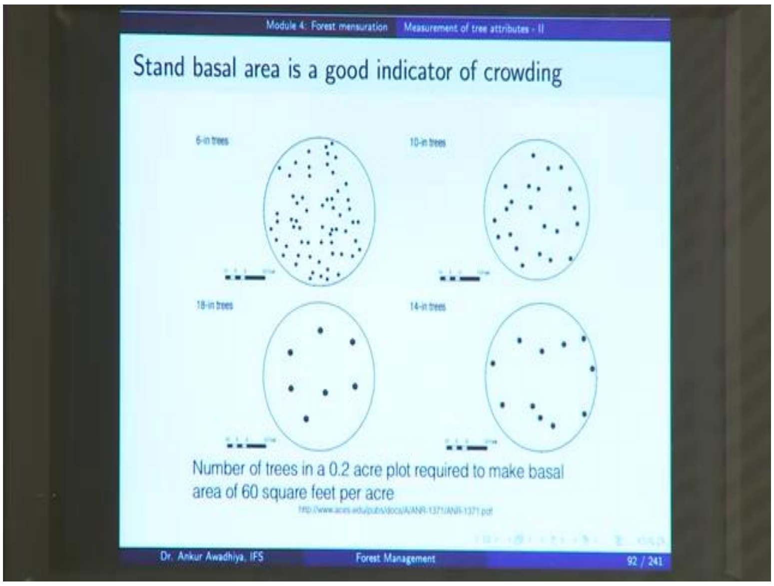

So, if we look at these four stands, we will find that this the stand basal area is a good indicator of the amount of crowding that you have in your stand. Now, these four stands are representing the number of trees in a 0.2 acre plot that are required to make the same basal area of 60 square feet per acre. So, what we are seeing here is that, if you have 6 inch trees, you will require so many trees to make up a basal area of 60 square feet per acre, but then, if the basal area increases, you require a fewer number of trees as compared to this one. If you increase it further to 14-inch trees, the number of trees reduces further. If you increase it to 18 inches trees, the number of trees reduces further.

Now, the amount of crowding that you have in your stand is dependent on the basal area of the stand. So, if you have a stand with a greater amount of basal area, you will say that there is a very huge amount of crowding because even though you have less number of trees, but the total amount of area that is being occupied by these trees is now so huge that your piece of land is no longer able to accommodate any more number of trees. So, stand basal area is a good indicator of the crowding your stand.

So, if you have if you want to have a look at the crowding whether you have a crowding or not in your stand, you do not go with the number of trees per unit are;, you go with the stand basal area and you compare it with a standard.

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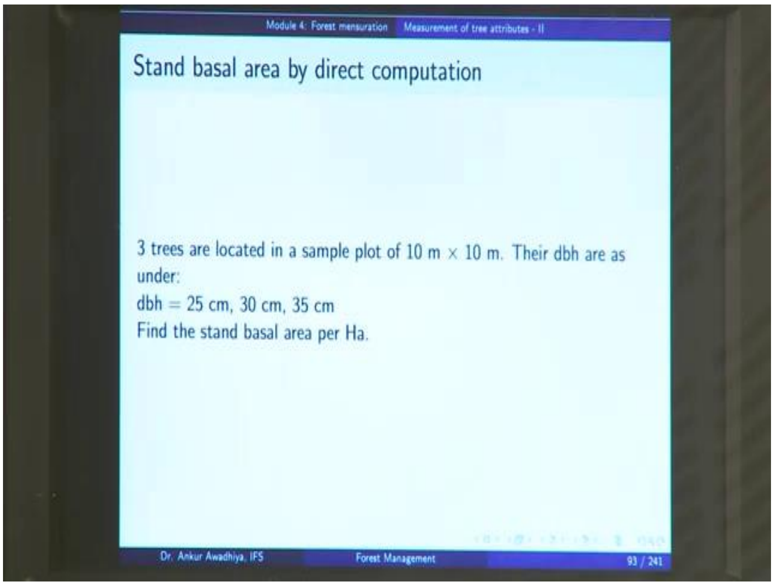

Now, how do you measure the stand basal area? So, you can measure the stand basal area by two or three different ways. The easiest one is to make is to do a direct computation. So, we will illustrate this method using this example.

So, you have three trees that are located in a sample plot of 10 by 10 metres that dbh are as under: 25-centimetre, 30 centimetre and 35 centimetre, and you have to find out the stand basal area per hectare.

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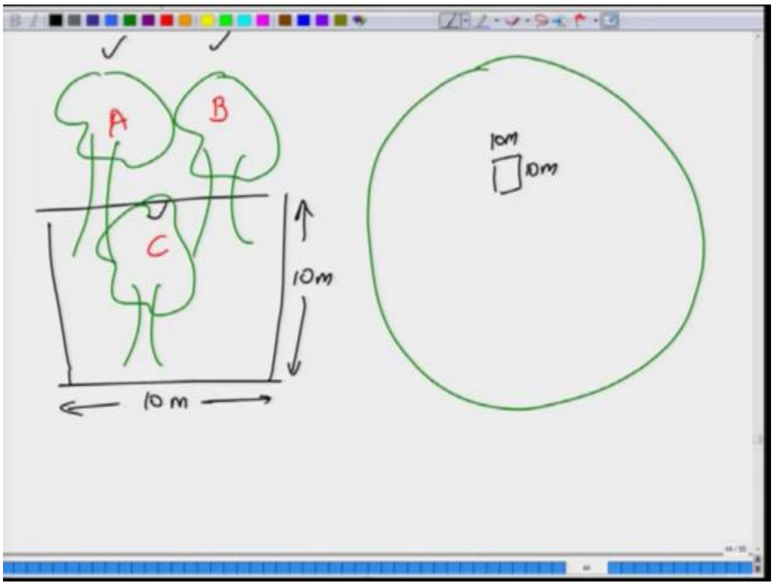

So, what this question says is that you have three trees in your stand. Let us call these three trees as A, B and C. And, the stand is having a - the sample plot is 10 metres by 10 metres. So, essentially what we are saying is that you have a big stand, and in this stand, you took a sample plot which is 10 metres by 10 metres, and in this sample plot, you have these three trees. So, using the data of the sample plot, you want to figure out what is the stand basal area per a unit hectare of your forest or of your stand.

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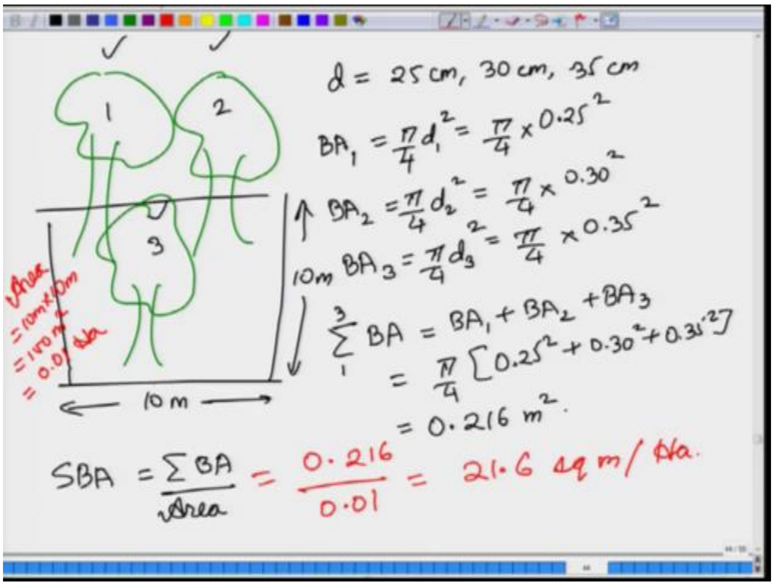

So, how do we do it? So, we are given that the diameters are 25-centimetre, 30 centimetre and 35 centimetre. So, the basal area of the first tree - let us just call it tree 1, 2 and 3.

The basal area of the first tree given by pi by 4 d 1 square is pi by 4 into 25 centimetre is 0.25 metre square.

The basal area of the second tree is given by pi by 4 d 2 square is pi by 4 into 0.30 square.

And, the basal area of the third tree is given by pi by 4 d 3 square is pi by 4 into 0.35 square.

Now, the total basal area; so, the sum of the basal area from tree 1 to 3 is given by BA 1 plus BA 2 plus BA 3.

So, you have pi by 4 into 0.25 square plus 0.30 square plus 0.35 square. So, this sum comes out to be 0.216 square metres. Now, the stand basal area is given by the sum of the basal areas of all the trees in your sample plot divided by the area of the sample plot. Now, the area of your sample plot is 10 metre by 10 metre, is 100 square metre, is 0.01 hectare, because 1 hectare is equal to 10,000 square metres. So, the stand basal area will be given by 0.216 divided by 0.01, is equal to 21.6 square meter per hectare. So, this is a way on which you can find out the basal area of a stand.

So, what are you doing here? In your stand, you take one or multiple sample plots. Now, those sample plots can be figured out by using the survey methods and by using sampling methods. Now, once you have a representative number of sample plots in your area, for each sample plot, and we generally prefer to have each sample plot of the same dimension. So, for each sample plot, you figure out how many trees do you have, and what is the dbh of each tree from. And, what using this dbh, you can find out the basal area of every tree in one sample plot. And, the stand basal area can be figured out by the sum of the basal areas divided by the sum by the area of the sample plot.

Now, suppose you took say five sample plots; so, you will you can even do that you will find out the basal area of each tree in each of these five sample plots, add up all these areas and divide it by the total area of your five sample plots, and this will give you an indication of the stand basal area of your stand.

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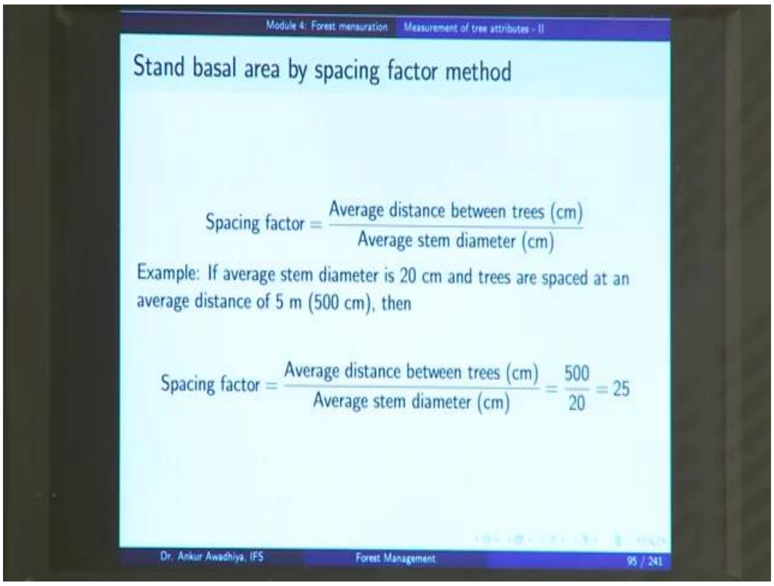

Now, another way to find out the stand basal area is using the spacing factor method. Now, as we saw before, if you have trees that are of a larger diameter, then the crowding comes up, even when you are having less number of trees.

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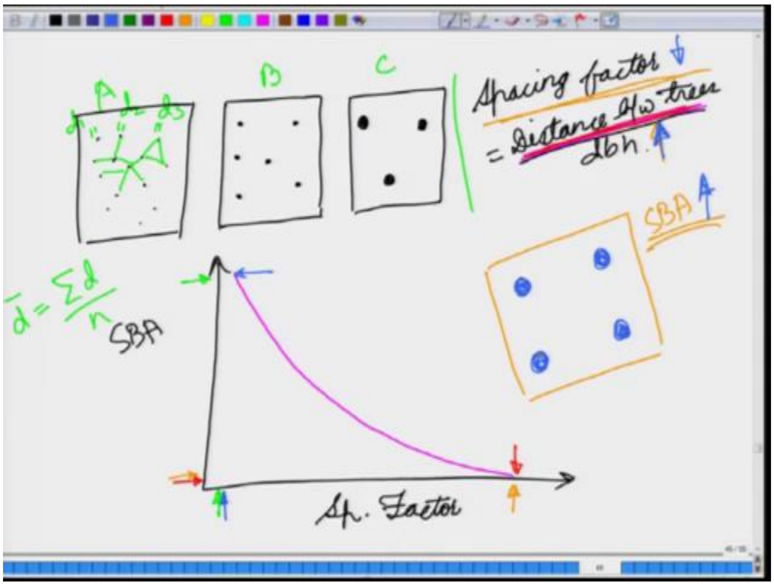

So, essentially, you will have a crowding at say this much density, if you have smaller or leaner trees, but if you have larger size trees then probably your stand is getting crowded now. And, if you have even larger cross section, then probably this stand is also equally crowded. So, what we mean to say is that the stand basal area is dependent, if you plot a relation between the stand basal area and the spacing factor.

Now, you define a spacing factor as distance divided by the dbh of these trees. Now, what we are seeing here is that in the case of the first- let us call it A, B and C. In the case of the first plot, you will find out this distance this distance this distance this distance and so on. So, you figure out the distances between various trees, and then you find out the average distance that you have between the trees and you divide that.

Next you figure out the dbh. So, you have d 1, d 2, d 3 of all these different trees, and you find out the average dbh, which is given as the sum of dbh of different trees divided by the number of the trees. So, you get this value. Now, spacing factor is the distance between the trees or the average distance between the trees, divided by the average dbh of trees in your stand. And, if you plot a curve between this and the between the stand basal area and the spacing factor, you get a curve like this.

So, what is this curve telling you? Or, how do you how do you disappear this curve intuitively? Now, in the case of your spacing factor, if the distance between the trees is more; so, we are keeping the dbh constant, if the distance between the trees is more, in that case, you will have a spacing factor that is more. And, if you are having a greater distance so, basically the amount of crowding in your plot is less, or essentially the stand basal area is less. So, this is what we are seeing here.

If you have a high spacing factor, because your trees are at a large distance. So, in this case, your stand basal area is less. Now, if your trees are close together; so, you are reducing this distance between the trees your trees are close together. So, in that case, you are having much more amount of crowding in your plot. Much more amount of crowding means that you will have a greater amount of the stand basal area. So, with reduced distance between the trees, the spacing factor is less, but the stand basal area is more, and this is what we are seeing here.

So, if your spacing factor is less, your stand basal area is more. Similarly, if you do not talk about the distance between the trees, we are keeping trees at the same distance. Now, if the dbh of these trees is less, that is you have trees that are say so, these are your trees with smaller diameters with smaller dbh. So, if dbh is less so, in that case, the spacing factor will be more. So, you have dbh is less so, the spacing factor is more. Now, if you have dbh which is very less, in that case, the amount of crowding in your plot is less, which means that the stand basal area is less. So, essentially if your spacing factor increases the stand basal area is less, which is what we are seeing here, the spacing factor is more and the stand basal area here is less.

On the other hand, if these trees are of a larger diameter; so, you have a greater dbh, let us use another colour. So, you have a larger amount of dbh with the same distance. So, essentially, in place of these small trees, now you are having large size trees, fatty trees. So, in this case, the dbh is more, which means that the spacing factor is less, but in this case, the stand basal area is more. So, this is what you are seeing that you the spacing factor is less, but the stand basal area is more. So, this is the kind of relationship that we see.

Now, let us look at an example. If the average stem diameter is 20 centimetre; so, you have this average dbh is 20 centimetre, and the trees are spaced at an average distance of

5 metre or 500 centimetres. This is the numerator, then the spacing factor is given as the average distance between the trees divided by the average stem diameter. This 500 divided by 20, is 25. So, if you are able to measure the dbh of a few trees in your of the trees in your sample plot, and if you are able to measure the average distance between the tree, you will get the spacing factor.

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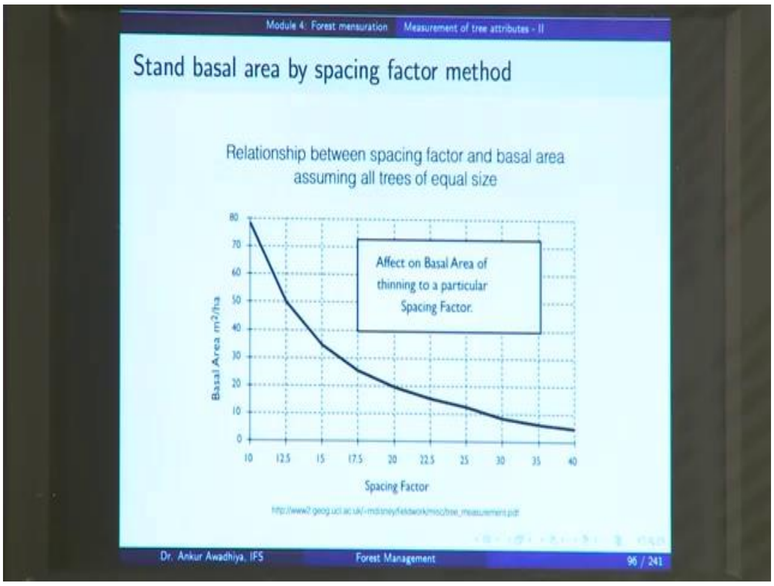

And, then once you know the spacing factor; so, in this case the spacing factor was 25. So, you can make use of this curve to find out the basal area per hectare. So, this is 25. So, this one will be roughly around 12 or 13. So, you can find out this the stand basal area using this spacing factor method.

So, in this lecture, we began by looking at how do we measure the height of a tree. So, the height of a tree can be measured either by using direct measurement, in which case you are directly placing an instrument on an apparatus next to this tree, and you are taking the direct measurement. Or else, you climb to the top of the tree, drop a string with a weight attached and the length of the string will be equal to the height of the tree. So, that is a direct method.

Another method is an indirect method, in which you make use of mathematical relations such as similar triangles, which we make use of in a hypsometer, or in the case of the stick and shadow method. Or else, you can make use of trigonometric relationships in which case, you have to measure an angle. And, if you know the distance to the tree and if you know the angle of elevation, you can find out the height of the tree.

And, we also saw that there is an instrument that is known as Blume Leiss; that can also be made use of to measure the height. And, it gives you the height directly for a few standard distances. So, you get the angle, you get tan theta, and you also get the height of the tree above your eye sight level for a few standard distances - typically 10, 20 and 30 metres.

Next, we had a look at the basal area of a tree which is given by pi by 4 into d square, where d is the dbh. And, measuring out the stand basal area is measuring of the basal area is important because you can add up these basal areas to get the stand basal area, which is typically expressed per unit hectare of the land. So, you have the stand basal area. Now, stand basal area is important because it is a very good measure of the amount of crowding that you have in your stand. So, if you have more number of trees or if you have less number of trees with a greater diameter, in that case, you will have a larger amount of stand basal area and that would also represent your crowding.

Now, we saw that stand basal area can very easily be measured using two methods - one of which is a direct measurement, in which you measure the dbh, find out the basal area of each tree, add up the basal areas, divide it by the area of area of the plot or the area of the sample plot, and you get the stand basal area.

And, another method is by using the spacing factor method. A spacing factor is equal to distance between the trees divided by the average dbh. And, if you know the spacing factor, and you have a relationship between the stand basal area and the spacing factor it comes to be an inverse S sort of a curve. in that case, if you know the value of the spacing factor, you can very easily figure out the stand basal area. So, these are some other tree attributes that we generally measure. So, that is all for today.

Thank you for your attention [FL].