**Soil and Water Conservation Engineering**
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# Lecture - 49
# Design Of Wind Breaks

So, hello friends so, I welcome you all to this second lecture of module of week 11 of Soil and Water Conservation Engineering. And, in the last class we have seen about the wind erosion, its definition and what are the different control measures are there to reduce the erosion due to wind. So, let us see the so, this is a second lecture of this week 11. So, in the first lecture we have seen the process of wind erosion, the definition of wind erosion, different movement of the soil particle.

Or initiate whether it is like detachment of the soil particle from the surface in the process of initiation. Then, we have talked about transportation, deposition, we have talked about the soil particle transport through various and transport of soil particle, soil particle movement through like saltation, suspension and surface stream; depending on the size of the particle and the grade of the soil particle ok.

So, in the we also see we also seen the various ways or various factors that influence, the various ways which influence the erosiveness of the wind, different factors that controls the wind erosions ok. And we have identified the parameters which can be used, which can be modified to in order to which we have to modified in order to reduce the effect of wind erosion. So, such as by reducing the wind speed and by making the soil surface cover more resistant to the wind erosion ok. So, in the present task in today's class we will be understanding the windbreaks which are mostly used to reduce the effect of to reduce the wind speed ok. So, let us start this class.

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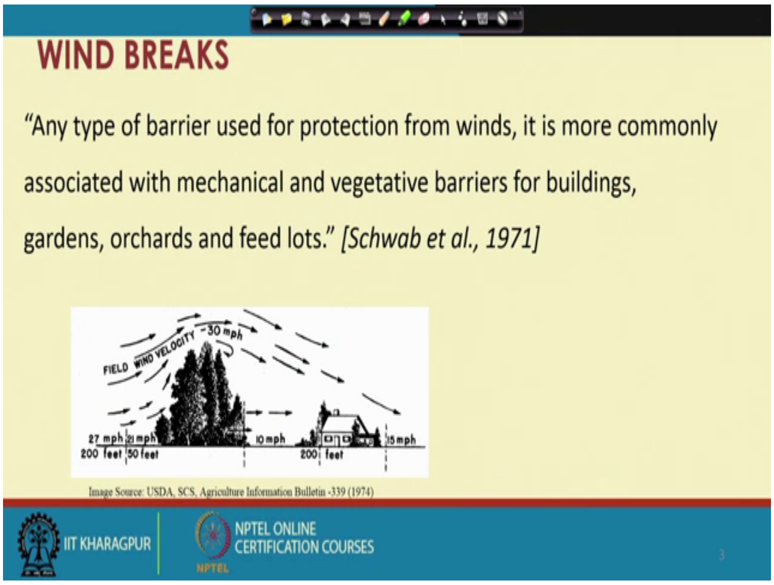


So, windbreak it is a can be defined as any barrier that can be used to protect the to any type of barrier which can be used, for protection from the wind ok. So, it is any type of barrier, which can be used for protection from wind and it is more commonly associated with the mechanical or vegetative barriers for buildings, gardens, orchards and feedlots ok. So, what does they do? So, this we will see that in the next slide.

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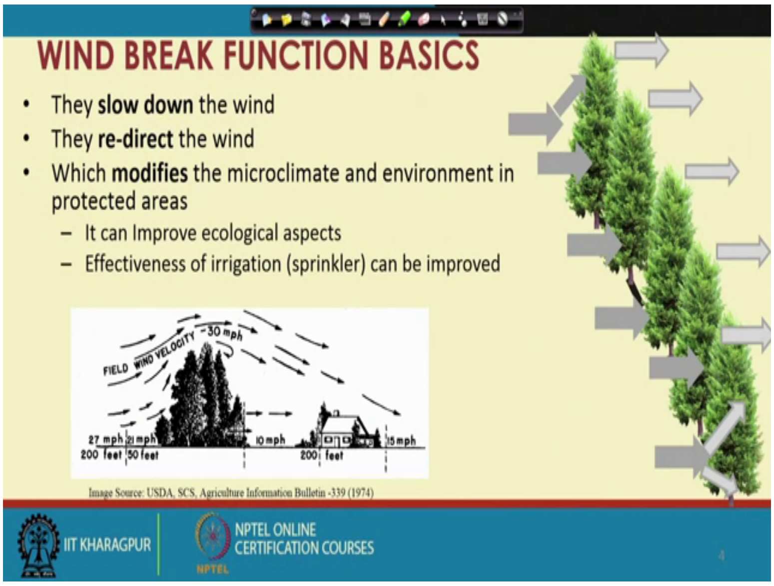


So this is of, this slide shows the function of windbreaks ok. So, the wind break they reduce the surface wind, they slow down the wind and they absorb the higher magnitude of wind velocity and deflect the higher erosive winds to another direction. So, we can say that they slow down the wind or they reduce the wind speed and they redirect the wind which will modify the micro climate and micro environment that maybe favorable for crop growth ok. So, modification micro climate or environment may or may not be sometime it is favorable or not favorable. But, we have to design the wind break in a such a way that we get maximum benefit from this ok.

So, this modification in microclimate include such as it can improve the ecological aspects ok. It can enhance the biodiversity or it can improve the ecological aspect, or that region. Or sometimes when we use some irrigative method; irrigation methods such as sprinkler which use which does not does not require a very high wind speed, ok. So, sometimes we use we sprinkler irrigation in which very high wind speeds are not desirable.

So, the by placing a proper windbreak we can reduce the erosive power of wind, we can reduce the wind speed. And, the effectiveness of irrigation can be enhance and sometime also such as like in other irrigation methods, because of the wind erosion, the wind or dust may get, soil particles may get deposited over the irrigation channel or drainage lines.

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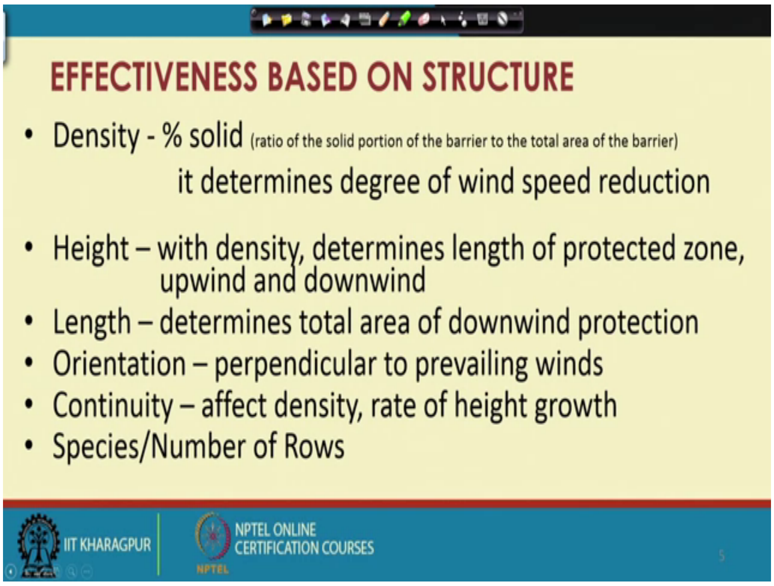


So, we need lot of maintenance; maintenance operation is required. So, by placing a proper functioning windbreak we can reduce the maintenance cost ok. So, let us see the effectiveness of windbreak based on its structure ok. So, when I say structure, it means the density of the wind break, then height of the windbreak, length of the wind break, its orientation with respect to the prevailing winds or dominating wind direction. Then, continuity whether it is continuous or some gaps are there, then which kind of species or sub combination or species we are choosing for the wind break and, number of rows that is arrangement which is used.

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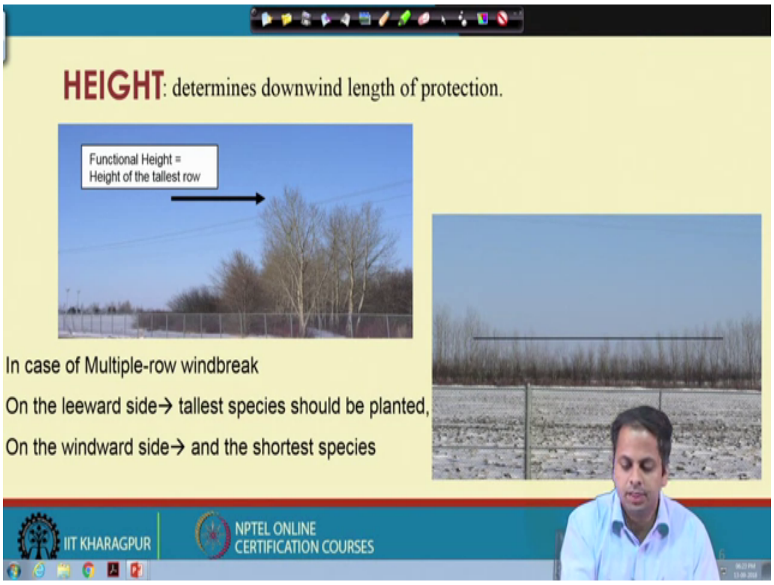


So, this all factors that determines the overall effectiveness of the windbreak; so, we will be looking this parameters one by one in the next slides, ok. So first, the height; so, height of the windbreak is actually defined. So let us say, suppose so, we are planting windbreak here ok.

So, the height is defined by height of tallest row of trees, ok. So, in case of suppose you are call if you are planning for multiple row of wind breaks, ok. So, the functional height of that windbreak will be height of tallest row, ok. So, height of tallest row is actually the height of that windbreak. So, that is the height which can be which is a design height and it determines this importance of height is like; because this height determines the downwind length of protections.

So for example, by placing of windbreak over a this region ok. Suppose if you are placing some windbreak here. So, the height of this windbreak it determines the length or so, the height of the windbreak ok, determines the length of protection downwind to this windbreak ok. So in that case, in that sense, height is very important parameter. So, the effect of height we can see here.

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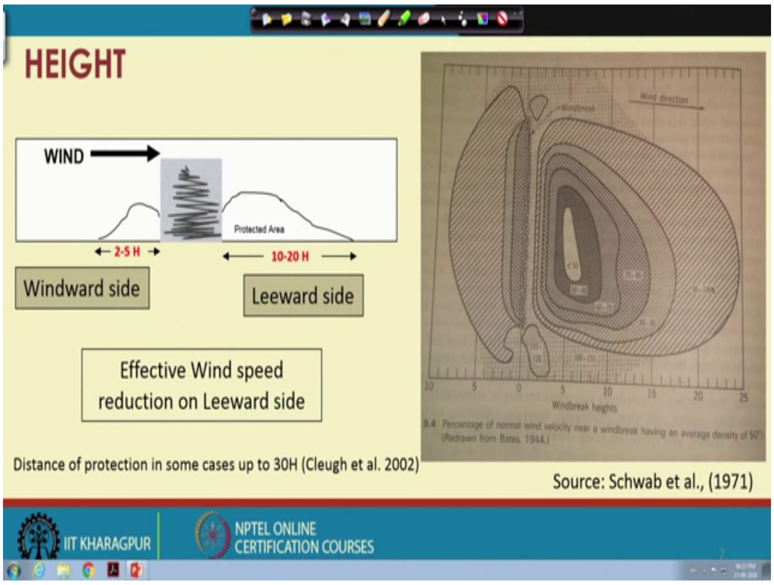


So, suppose this is a some kind of wind barrier one cross section of wind barrier and this is some this is height H, let us say this is height H here. So, the effect of so purpose of wind winds break is to reduce the wind speed ok. So, our desired area is this one ok. So, we are planning for leeward side of the wind side; leeward side of the wind break. So what we can see if the height of this windbreak is H, so, we can get a maximum reduction of the wind speed till at a distance of 10 to 20 H. Means, 10 to 20 times height of this windbreak.

So, the effect of wind reduction are measurable, till a distance of 10-20 H from this windbreak ok. So sometimes, if you place a proper arrangement or some sometimes if you use proper combination of high density and low spacing species, you can achieve protection of around 30 H also. So, not only on the leeward side, but on the windward side also we can see there is reduction in the wind speed and this reduction is visible. This reduction can be visible till the height till the length of 2-5 times height of the windbreak, ok.

So, both on the windward side and leeward side we can see the effect effective wind speed reduction. So, but we here we are planning for the leeward side ok. So similarly, in this in this figure also you can see which is taken from Schwab et al to 1971 suppose this is the windbreak ok, this is a windbreak and here this numbers actually represent the percentage of normal wind. So, when I say the 50 here. So, what does 50 mean here? So wind speeds are here like 50 percent of the normal condition wind speed.

So, there is a 50 percent reduction over this region. Similarly, over this region you can see there is a wind speed is around 50 to 60 percent of the normal condition. So it means, there is a reduction of 40 to 50 percent reduction. Here, the reduction is 30 to 40 percent similarly; here reduction is 10 to 20 percent. So, what you can see? So most of the protected, like effective production area, you can see at the length of 10 to 20H. So, here we can see the most of the effectiveness is visible till around 17 H length.

Once you go away from that you can still measure some kind of reduction, but the reductions are very less here around only 10 percent reduction. Similarly, this is the leeward side ok. This is the leeward side and this is the windward side ok. In windward side also you can see there is a reduction in wind speed of around 10 percent reduction here. Carefully if you see here over this region, this region and this region which are actually at the very near or adjacent to the end of this wind break. So, you can see the velocities are here. Here are 110 to 120 percent that means, the wind speeds are actually very high compared to the open field.

So, here the wind speeds are very high because what happens, when you construct or when you design, when you plan a windbreak here. When you construct a windbreaks here, so, the our objective is to stop the wind or to reduce the wind speed, but it forms a low pressure area over this region. So, because of this low area formation, so, wind from the neighboring side will rush to fill that low and the Wind speed will get increased over this region ok. So, these are the regions, where we get maximum amount of maximum speed.

So, you need to be very careful while deciding the length of the windbreak. So, this we will be discussing in the next subsequent slides as well ok. Now here, we are discussing about the height. So, most of the effect is visible till the height around 10 to 15 H.

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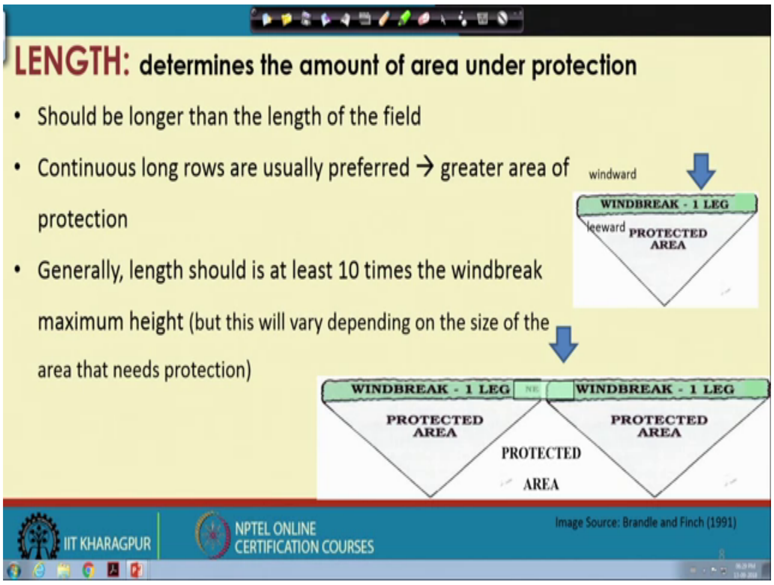


Now, length; length is also very important parameters because it determines the amount of area which will be under protection. So, suppose for this for this windbreak. So this will be the area. So, in the last slide we have seen the area of protection of over that particular length ok. So, length is very important parameters that determines the amount of area will be covered will be protected ok. The length the length should be longer than the length of field. So, when you are designing a windbreak the length of the field ok. So, the length of this windbreak should be longer than the length of field.

So ideally, you should there should be continuous long rows should be preferred. The continuous long rows should be preferred because they provide greater area of protection, and generally this length should be at least 10 times the height of maximum height of windbreak ok, but that depends on your requirements again ok. So in case if you are if you are wind if the length is not enough you can place you can increase the length so that the area of protection can be increased ok.

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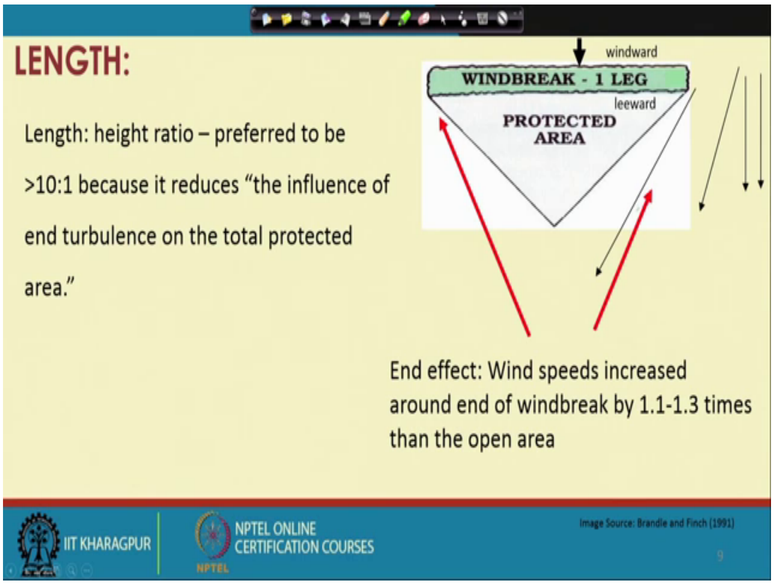


So as I said earlier, the length to height ratio of the windbreak should be 10 is to 1 because by maintaining this ratio, you can reduce the influence of end turbulence on the total protected area. So in the last example, we was seeing that.

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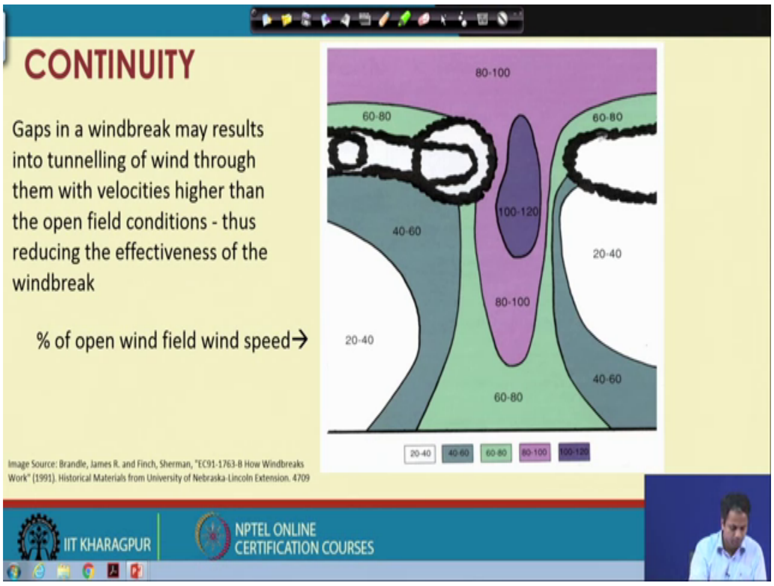


So in this example, what we are looking that effect of length we can see here. So, over this area, if you can see if the length is not sufficient, so the wind speeds are very higher. So, if your if your length is very short, then this erosive wind can damage, then they can cause more damage to your field. So, the length should be at least 10 times than the height of windbreak ok. So it means, for 1 meter of windbreak, height of wind break, you need at least 10 meter length of windbreak ok.

So, here we can see the so, here over the ends this is the end effect actually you can see. So, wind speeds are increase around end of the windbreak by amount 1.1 to 1.3 times than the open area. So here, as I said earlier also the winds are very high speed here. So, your effect, the length of design length should be more than the field length for which you are going to give the protection ok.

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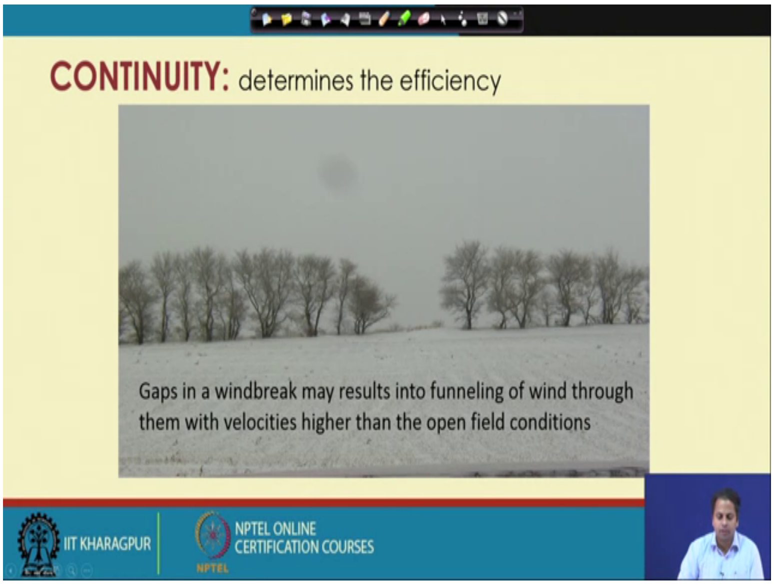


Now, continuity; so this continuity is actually very important because it determines the effectiveness or efficiency of your effectiveness of your windbreak ok. So, this is a example this figure shows the effect of continuity. So suppose this is a windbreak, and it has come break in between. So this is a some gap in between. So because of this gap, there is a increase in wind velocity.

So, this numbers represent the percentage of wind velocity compared to the open window field condition ok. So, here the wind speeds are more than the actual wind speed in the open field. That is, 100 to 120 percent. So, if we you would have construct windbreak a continuous wind break then we would have achieved a greater reduction in wind speed over this region.

But because there is a gap here, so the winds are coming in winds are approaching at very high speed here. And the effect of wind speed, effect of windbreaks are less or this region. So of so here also, you can see the effect is around like only 20 percent reduction is there. Here you can see the reduction is quite well around 60 to 60 to 80 percent because the wind speeds are around 10 to wind speed around 20 to 40 percent, but effectively because of this gap, the overall protection area the effectiveness of windbreak has been reduced ok.

So, the care has to be taken that gap should be avoided, and suppose if it is unavoidable if you want to place some kind of gaps in between to allow some access lane. So in that case, you can think of choosing multiple rows of windbreak, so that and the access length can be provided at some angle to the prevailing wind direction ok. So, the effect of so, the effect of gap can be minimized and effectiveness can be still can be still can be achieved.

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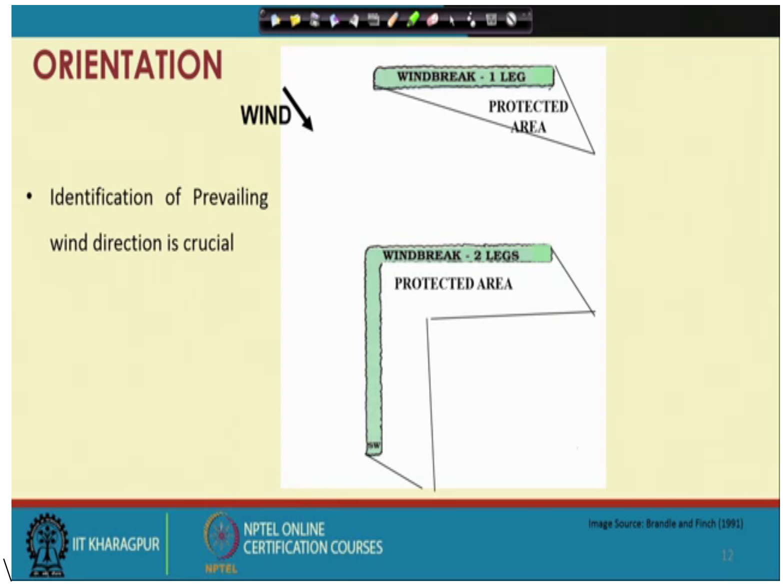


The next is the Orientation. So first designing windbreak, you should know the prevailing wind in your area ok. So, what is mean by prevailing wind? So, by prevailing wind mean we mean that, so, maximum probable wind direction for your field over a year. So once you know that predominant direction, you can plan your, you can plan your windbreak in direction perpendicular to that to that direction.

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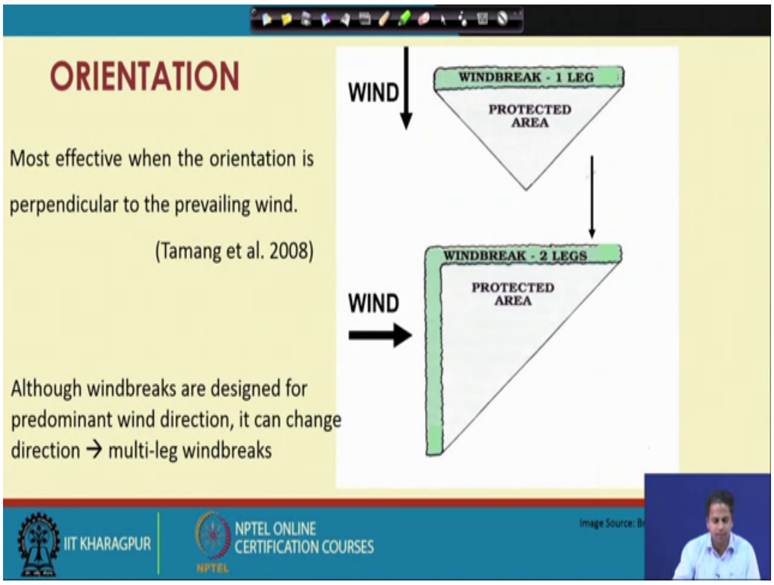


So, in the next slide we will see that. So, orientations of the wind breaks are most effective, if they are placed perpendicular to the prevailing wind. So, once you know the prevailing wind direction. So, the placement of windbreaks should be perpendicular to the perpendicular direction of prevailing wind. So, you can get maximum amount of you can get maximum amount of wind speed reduction over the downwind area or leeward side. So sometimes when we say, when you know the predominant area but it is not always true that wind will only flow in that direction because wind is a climate variable and it is a variable that often changes its direction as well as magnitudes under the influence of large scale large scale processes as well local scale disturbances.

So, winds actually winds direction and magnitude changes, but predominant direction will remain same. So, what you can do? You can place one windbreak over a direction which is more predominant across the direction which is more predominant, and another windbreak to any other direction, where the effect of you may feel that the wind direction may change. So, you can so you can think of multiple windbreaks. Multiple leg windbreaks to increase the area protected.

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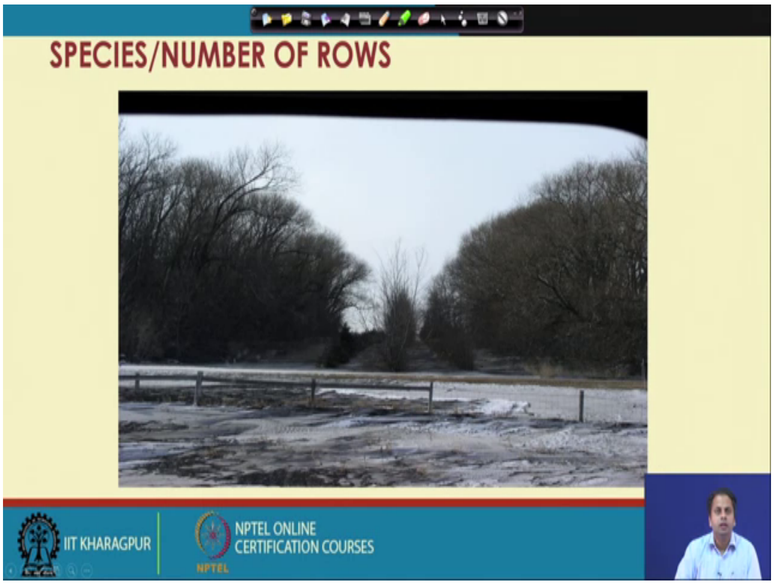


Then another thing is this kind of species which we are choosing for the windbreak and number of rows ok. So, in order to select the windbreak we have to choose the species or combination of some species in a such a way that, they are more adopt like they are favorable to that climate or they can sustain over that climate and whatever our design objective is there. So whatever amount of reduction in wind speed or let us say, first know or protection forms cold wind we want. So that kind of thing can be decided by selecting a proper kind of windbreaks pieces, tree species.

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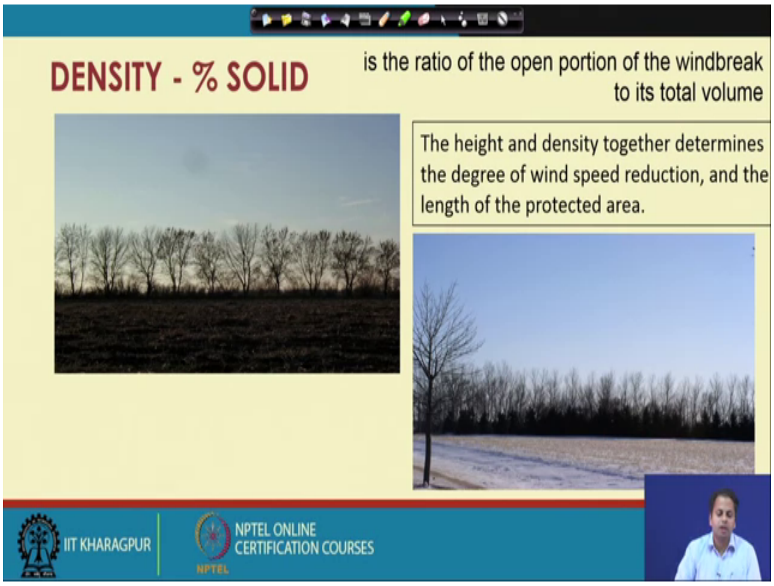

And then the number of rows ok; so, number of rows sometimes depends on the requirement or space constraint you have to decide on the number of rows ok. Now, another important parameters are density of the wind break. It is a most important parameter which actually affects in combination with height and length it affects the overall protected area, the extent of protected area ok. So, the density is nothing but the percentage solid or it is a you can in general use you can say that it is a ratio of open portion of the windbreak to its total volume ok.

So as I said, the height together with density and length determines the overall effectiveness of wind speed reduction and of course, the length of protected area. So, density is the most important parameter here. We will be seeing in the next slide as well ok, sorry.

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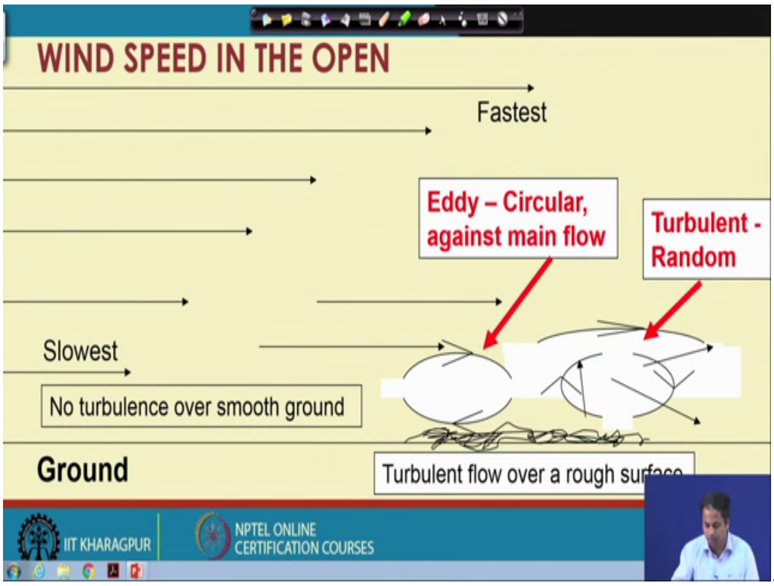


So, before going further let us see the wind speed profile. So, we know that when there is a open or bare surface. So, bare surface does not have any roughness. So, the winds are wind speeds are increasing, by a factor of logarithm of heights.

So, wind speeds are slowest here but when you go up, the wind speeds are increasing by a factor of proportional to the logarithm of height and, but if the some roughness is present over the ground, then there will be some disturbance. There will be some turbulent flow and there will be some Eddy motion. Eddy motion means, there will be some deviation from the mean flow ok.

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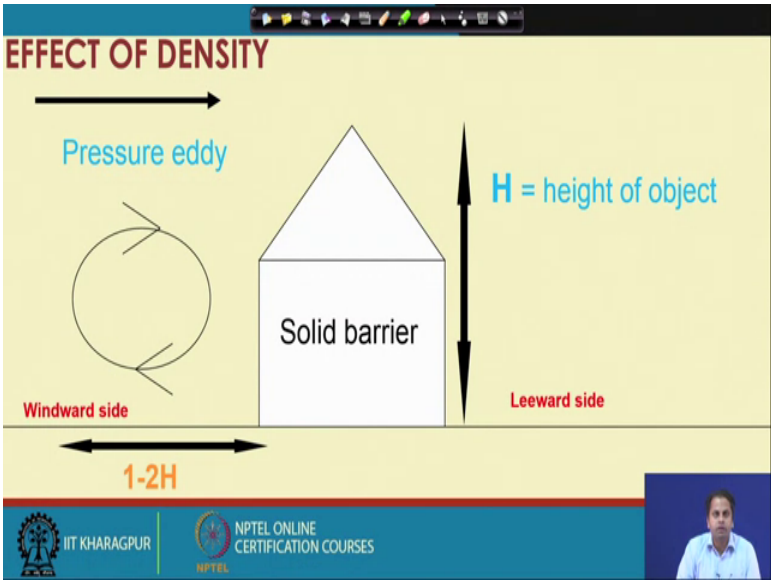


So, that cause some turbulent motion ok. So, this is some basic term that I was trying mention here ok. So, now we will see the effect of density. So, let us say for windbreak we are placing a solid barrier here which actually has close to 100 percent density ok. So, it is not allowing any air to pass through it ok. So, it is the porosity is very less ok. So, what happens when the very high wind velocity is strikes here, so what happens?

So, very when very high wind speed velocity strikes here, so it is not able to pass through this solid barrier and there is a formation of pressure eddy over this region. So, because of this formation of pressure area eddy o, we can see the some reduction in wind speed also here. So, this effect of pressure eddy can be visible, to the distance of 1 to 2 H on the windward side similarly, on the leeward side as well. If you see, because of this solid barrier which is not allowing air to pass through it.

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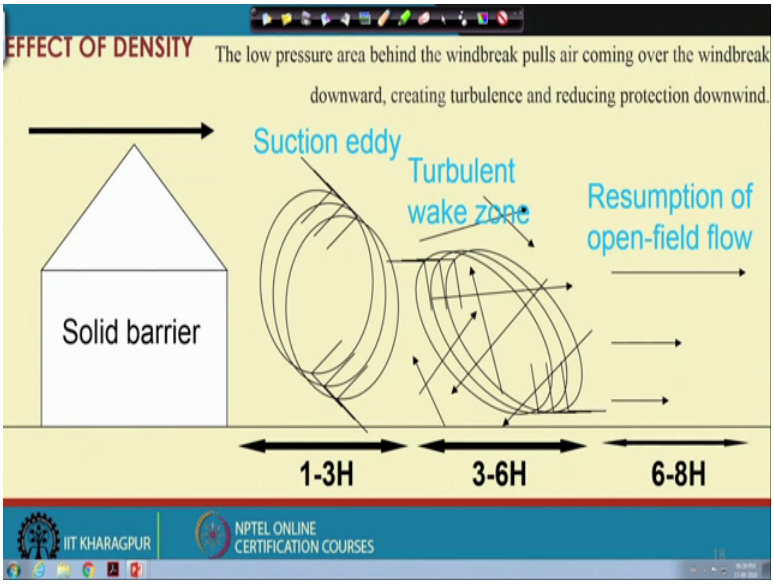


So, winds are very high in motion they are getting deflected here and because since its there is no there is no air movement not air movement in the sense, like air is not passing through this solid barrier. So, there is a very low pressure formation. Formation of low pressure over this region so, to fill this low pressure, so the winds rush over this region with very high wind velocity. So this is, so this region is known as the Suction eddy ok.

So, this will form a Suction eddy whose effect will be visible till a distance of 1 to 3H ok. So, because of that there will be lot of turbulence, and the this is a Turbulent wake zone which can be seen till the length of 6H. And after that, there will be resumption in open field open field flow velocity ok.

So, what it means that because of this low pressure formation here, behind the solid barrier the windbreaks pulls the air coming over the wind break downward and creating turbulence, turbulence and reducing the protection downwind. So, the effectiveness of the windbreak will be or effective or extent of area under protection will be reduced.

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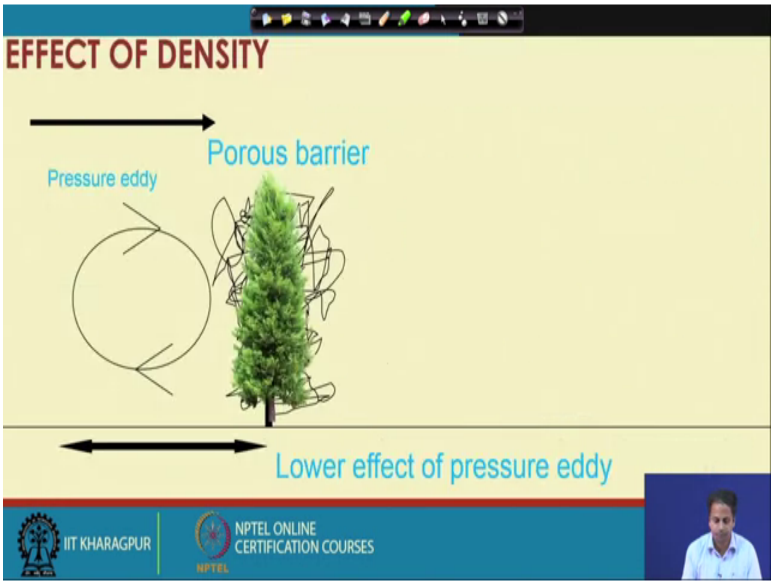


Now let us, let us replace that solid barrier with the porous barrier ok. So, let us say we are planting some porous barrier here. So, let us see what happens. So, since now this porous bar barrier is allowing some air to pass through it ok.

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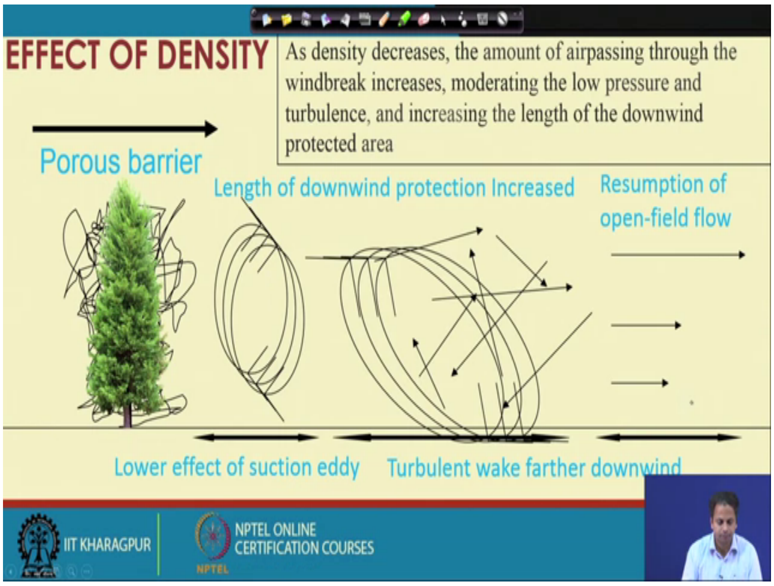


So, there is a moderation in the air flow here. So, the effect of pressure eddy will reduce so, on the windward side. Similarly, on the leeward side, similarly on the leeward side, because now air can pass through it not like in case of solid barrier there was very less flow but here actually air can pass through it. Or in case solid sorry it was the flow was not there actually the it was non porous but here, in case of porous barriers the winds can pass through it.

So there is a modification in the wind flow here. So as a, here the density of this, now as the density of this porous barrier is decreased the amount of air passing through the wind break is increasing. So, it is allowing more air to pass through it and it moderates. So, by allowing wind by allowing more amount of air passing through wind break it moderates the low pressure and turbulence and increasing the length of dominant protect area. So, the lower left of suction eddy so, the so what we can see here, so because of this porous media the length of downwind protection can be increased ok.

So here, the turbulent wake is farther downward, its compared to the solid barrier here ok, and resumption to the open field open field flow condition are further shifted to the farthest away.

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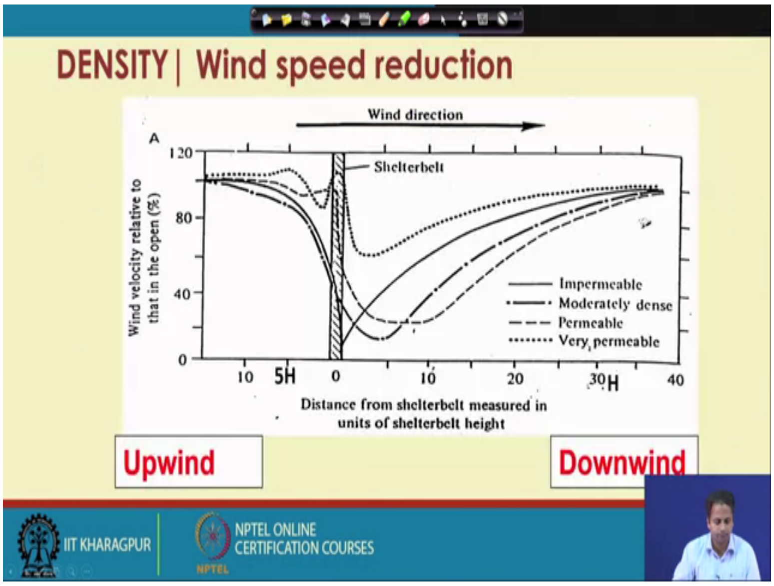


Now, this diagrams shows the effect of wind speed reduction if you are using different kind of layers. Permeable layers, moderately dense layer, permeable layer and very permeable layers ok.

So, let us say this is our, this is our the wind barrier or wind break in the form of wind break or shelterbelt let us say and on x axis we have wind velocity relative to the to the open, open condition and on x axis we have distance from the wind barrier. So, this is our wind barrier. So, this is our windward side and this is our leeward side. So, what we can see when the layer is actually highly impermeable that is, which is represented by the solid line, sorry. So, this is a solid line which is represented by a solid line here. So, when the barrier is impermeable, that means, it is not allowing air to pass through it.

So, we can see the till the distance of let us say 5 to 7 H there is a some significant amount of reduction in wind speed, but you go when you go away from this distance so there is not such very much reduction in wind speed ok, then contrary if you see a very permeable. So, in permeable there is not significant change. So, at very near to the wind break the wind flow condition was around like 90 percent let us say 100 percent here, that is open flow condition and near to let us say for 7 H or 8 H, it is around 60 to 70 percent.

So, there is not much change. So, the effectiveness of this wind break is depending on the porosity or density of this what kind of material what kind of species we use as a wind break. So, if we use moderately dense and permeable. So, we can achieve maximum length of protection here. So, this we will see we will see in the next slide as well ok.

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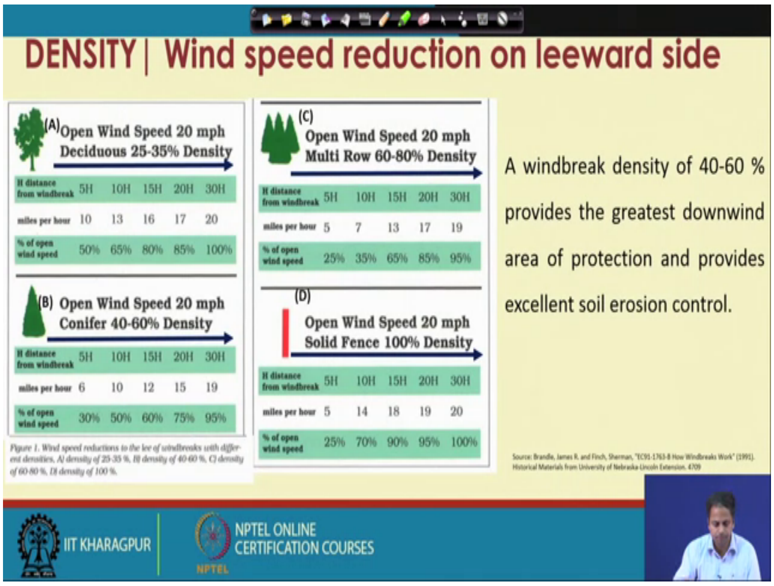


So, say here again this shows, this figure or this slide shows a four cases in which we are varying the density. So, in the first case, that is A, so we are using deciduous tree which is having 25 to 35 percent density. In the case B we are using 40 to 60 percent density of by placing conifer tree in the case C, we are using if you want to suppose increase a multiple if you want to use multiple rows ok. So let us say, our density is 60 to 80 percent here by placing multiple rows of conifer tree and by placing a solid fence. So, let us say there is 100 percent density. So, what is a effect on wind speed reduction? Let us see that ok. So, in case of first case, when the when we have placing deciduous tree with 25 to 35 percent density.

So, we can see at a distance of 5H around 50 percent reduction is observed Whereas, at a distance of 15H we can see the winds are at 80 percent means 20 percent reduction is observed. So, here at the distance of 20H the wind speeds are 85 percent compared to the open field. It means the 15 percent reduction. Whereas, at the distance of 30H the winds are normal to the, or winds are similar to the open field ok. So, we can say the effectiveness of this wind, effect effectiveness of effectiveness of this wind break is in reducing the wind speed can be observed till 20H ok. Similarly, in the case B if you see, the density is 40 to 60 percent.

So, the density is 40 to 60 percent here. So, in that case so, it for a distance of 5H as you can see there is 70 percent reduction whereas, at a distance of 20H, there is a 25 percent reduction. So, which is very high then this less density less density windbreak and we can also see over a distance of 30H we can also have some 5 percent reduction in wind speed. Whereas, in case of in case of multiple row; multiple row with density multiple row of conifer trees with the density of 60 to 80 percent we get we have get almost similar to that, similar to that of the case B, but slightly improved. But over the 30H we get almost similar reduction ok. So, its effect is most visible near to the windbreak so, here 75 percent reduction as compared to the 70 percent reduction here.

Whereas, in case of solid fence there is 100 percent density we can see. So, maximum density we can achieve that 25 percent near to the windbreak, whereas, when we move away from this wind break. So, at the height at the distance of 20H we can only get 5 percent reduction. Whereas, in case of conifer tree it was 25 percent in case of 20H 25 percent deciduous tree it was around 15 percent. So, here in case of solid fence we can only get only 5 percent reduction ok. So, the windbreak density of 40 to 60 percent provides a greater downwind area of protection and provide excellent soil erosion control measure.

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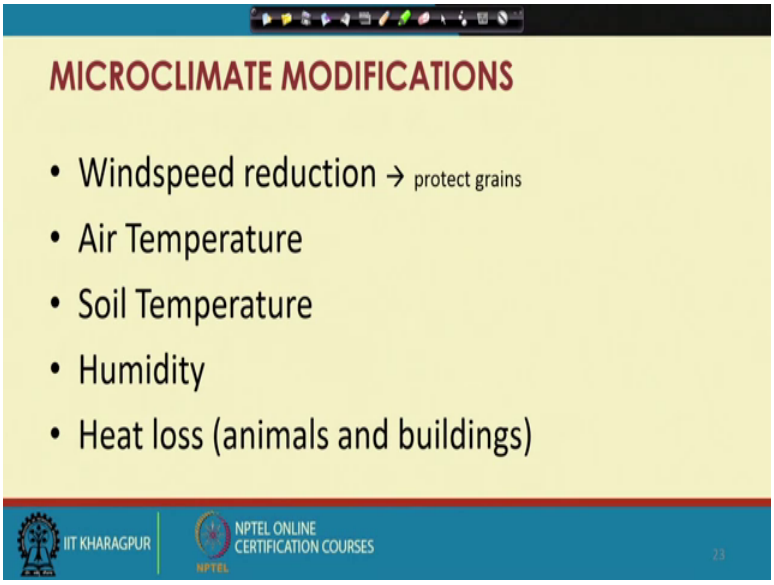


So, now let us see, how it is modifying the microclimate ok. So, since the wind speeds are reduced here. So, it can modify the air temperature, soil temperature, relative humidity, day time air temperature, night time air temperature, heat loss etcetera. These are the parameters that can be affected by the by modification of microclimate because of the reduced wind speed ok.

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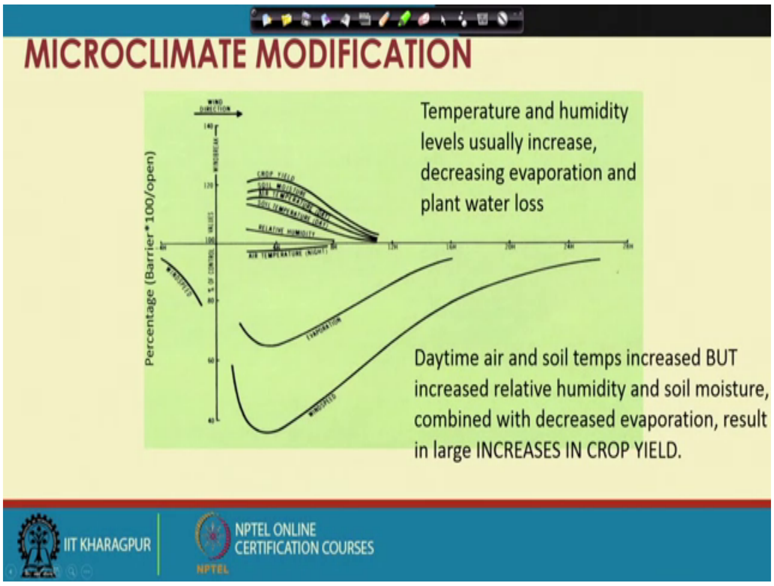


So, this is a very important figure. So, here we can see on the x axis, oh sorry, on the y axis we can see, percentage of control. That means, percentage so, by placing barrier values by placing barrier multiplied by 100 divided by values that are there in the open condition ok. So, this is a again the up wind side, this is down wind side and these are the different variables; a crop field, soil moisture, air temperature at day, soil temperature day, relative humidity air temperature, evaporation and wind speed. And, along x axis what we can see here is the, measured length of protection.

So, what we can see here so, we can see the height high amount of temperature, high amount of temperature and humidity because of placing this windbreak and, there is reduction in evaporation ok. So, we can conserve more moisture here, and plant water loss is also less. So, because this day time air and soil temperatures are more, but the increased relative humidity actually increase in relative humidity and soil moisture because we can conserve soil moisture here combined with decreased evaporation, it results into the higher amount of crop field ok. So, this is how a particular windbreak with particular density it modifies the overall microclimate over that region ok.

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So, to summarize that, so our goals for designing any windbreak, should be so design consideration by considering density and placement; so, this should be based on different goals. So, our goals can be either to be have to increase the crop production or for crop production or to reduce soil erosion, increase snow capture in the field or for farm street production or a living snow fence or sound barrier or for a wildlife for food cover.

So, there are different objectives and accordingly for different objective we need to modify the different density, different structural conditions. So with that I will stop here for this lecture and in the next class we will be looking at the design of shelter belts.

Thank you.