What are the Main Factors in Determining the Effectiveness of Daylight in Woodlands?

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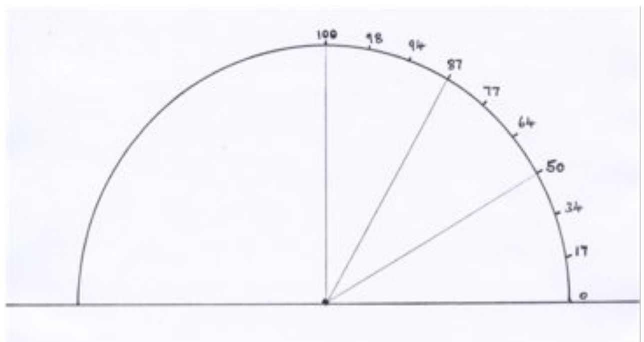
The first slide represents the hemisphere of the sky and demonstrates that one of the main factors in determining the amount and effectiveness of light is the angle at which a beam of light reaches the ground.



Relative effectiveness of light from different angles

This is something I had not fully grasped previously. About 45 years ago, after I had been working as a woodland manager for a couple of years, I spent a year as a research student and used light sensors to measure light under artificial screens and in areas of forest, to study the growth of sycamore and Norway maple seedlings in response to various environmental factors. Later, when I was working with the Institute of Terrestrial Ecology, I did some further work, and used light meters and shading to obtain different levels of shade. But I am not sure that I understood the subject very well.

I still don't understand it fully, but over the last 2 or 3 years I have been trying to get a better grasp of the subject and have been walking round forests with a light meter, which I purchased from Skye Instruments. This is very useful because it means that I can try to guess what the light level will be, "if I go over there will the light be half what it is here, or a tenth, or whatever?", and then check it. The light meter is calibrated to record the wavelengths of light that are effective for photosynthesis and it picks up light from different angles and corrects it according to the cosine rule, which is fundamental. This rule is saying that light that hits the ground from above has full force. If it is coming from near the horizon you can almost ignore it because the effectiveness of this light is very slight.. If the light is coming from 10° above the horizon there will be only about 17% of the light energy that you would have if the light was coming from above. So when you are in the forest and there is a gap above you, this is a lot more effective than a gap to one side.

We also need to think in three dimensions, which I can demonstrate with this white-painted football. Although on a two-dimensional diagram it looks as though quite a lot of light is coming from above (with a fair quantity of energy), on a hemisphere of the football, whilst the angle of 45° above the base represents half of the arc, it is only a quarter of the area of the hemisphere in three dimensions, and yet the amount of light which is coming from that quarter of the sky represents at least half of the total energy from the whole hemisphere. So what is happening above you in the forest can be more important than what is happening to the side. It is not a simple progression from 100% to 0%. If light arrives from an angle of 60° or 70° above the horizon the site receives almost as much light energy as from 90° above the horizon. So the strength of the sunshine at mid-day in mid-summer here at Westonbirt is very similar to the strength of the sun in the Tropics. In years gone by people used to say "Oh, we are going to the Tropics, we shall have to wear pith helmets to stop all this extra radiation coming in", but it isn't so very different in the tropics, as I understand it. But don't take anything I say too seriously. It is the speakers who come after me who are the experts!

This is (the interior) of the Pantheon in Rome. I came across it by chance a few years ago. It looked a rather insignificant building from the outside. It was built about 1800 years ago and was the largest dome in the world at that time and for about the next 1500 years, and is illuminated by what they call an oculus (or hole) at the top, which occupies about 4% of the floor area. The oculus provides all the natural light that comes into the building. There is some reflection because there is some polished marble, but the space is lit fairly adequately by that small hole at the top of the roof. The same applies if you have done a loft conversion and put some windows in the roof of your house. Even on a fairly dull day the amount of light coming through is fairly appreciable. As I understand it about three times as much light will be obtained from a window on a flat roof as compared to a window on a vertical wall, even if there are no obstructions in the way; and if there are obstructions such as trees to one side then the difference will be greater. The logic of that, as I tried to express in a paper in the Arboricultural Journal about 18 months ago (Helliwell 2008), is that if you want to have trees and buildings in fairly tight conjunction (as we seem to have to these days if we are going to get any trees at all) then it will be better to have windows in the roof, maybe with an atrium within the building. I know this isn't exactly continuous cover forestry, but it involves the same principles. I find myself talking about the same issues with planning officers and architects as with woodland owners.

Percentage Hours of Sunshine

Southern England	42%	(58% cloudy)
Northern Scotland	27%	(73% cloudy)

These are figures for the percentage of hours of sunshine in different parts of the UK. In an area such as Westonbirt the sun is obscured by clouds for more than 50% of the time. In some parts of northern Scotland you can't see the sun for 73% of the time. So if you are relying on light to grow plants or supply light to your windows, then the diffuse light from the sky is the only reliable source. Direct sunlight is not reliable because it is not there a lot of the time, and when it is there it comes from different angles at different times of the day, and different times of the year, and it seems to me that we often concentrate too much on the direct sunlight aspect. Fairbairn (1963) talked about growing trees in groups, and said that aspect was very important. It might be, but if you are involved in continuous cover you are not usually making sizeable groups, and the amount of direct sunlight you get in the small gaps in the canopy that we are normally dealing with is very limited and irregular, and whatever is growing there has to be reliant on diffuse light which is coming from the sky as a whole rather than the more-or-less point source of the sun.

Total Average daily radiation per m^2 on a level surface at Cambridge (kw hrs)

	June	December
open field	5.5 (100%)	0.7 (100%)
"large clearing"	1.4 (25%)	0.15 (21%)
"small clearing"	0.8 (15%)	0.15 (21%)
birch woodland	0.4 (7%)	
Beech woodland	0.1 (2%)	

Solar radiation, rather than just light, covers a wider range of wavelengths. In an open field in Cambridge measurements made in 1962-3 recorded 5.5 kw per hour per m^2 in the middle of summer and 0.7 kw in December, showing a significant seasonal difference. In a large clearing there was about 25% as much as in the open, in a small clearing 15%, in birch woodland about 7%, and in beechwood about 2%. These are general indicative figures which it is useful to have at the back of your mind. If you go into solid unthinned Sitka spruce then you will be down to less than 1%, even though your eyes might adjust to it and there may be enough light to see by. Photo A (on page 6) illustrates this, and there is not a single plant growing there, except perhaps some algae or mosses (and the trees). So the difference in the amount of light between the outside and inside of woodland can be quite large, and also there can be quite a lot of variation within the woodland. The figures below are taken from a variety of sources. They cannot be absolute because they are expressed as a % of light elsewhere, and this figure will depend to some extent on where you are and what the weather is like.

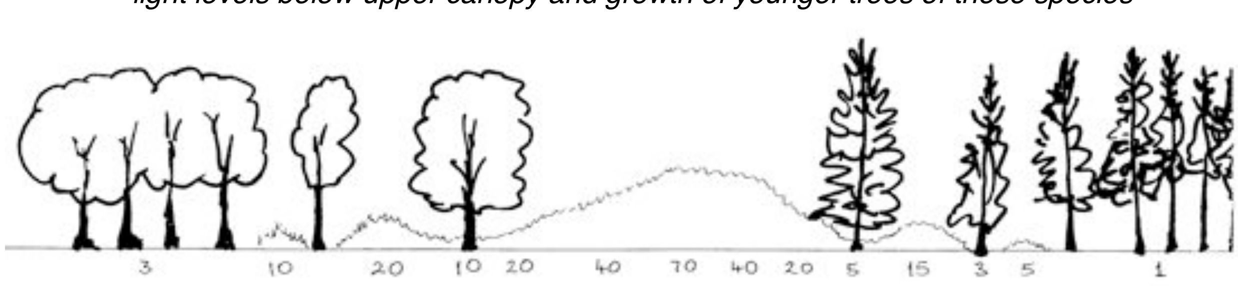
Approx % minimum daylight levels for survival & growth of trees

	"Survival"	"Growth"
Yew	2	4
Western Hemlock	2	4
Beech	2	5
Ash	3	7
Sycamore	3	7
Oak	5	10
Sitka Spruce	5	12
Birch	5	15
Scots Pine	5	15
Larch	6	18

Obviously, if there is about 2% light, which is the amount you might have in a beech woodland, you might get a yew seedling to survive, but it is not going to grow very much, and with a bit more light you might get some other species to survive for a few months, but to obtain growth you need more light, and to obtain very much growth you will need even more.

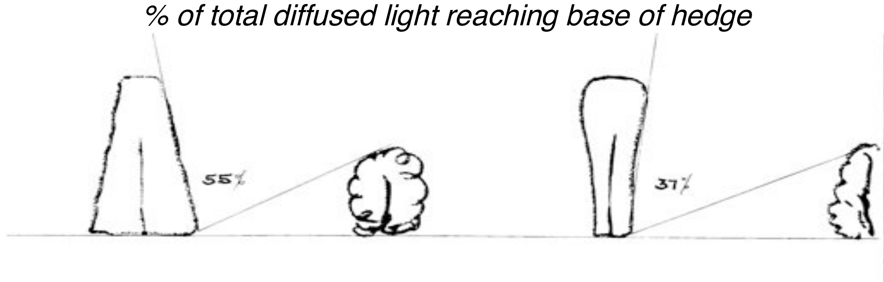
In the diagram below there is on the right a spruce plantation which has been thinned near the edge. The figures along the bottom are intended to indicate the percentage of full light. To the left is an oak woodland.

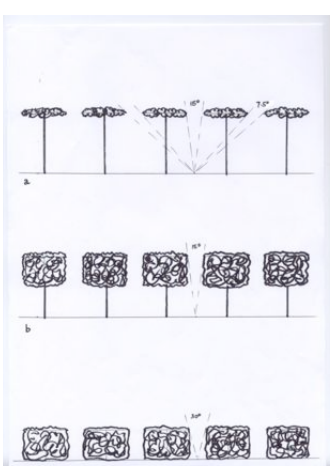
Even-aged oak woodland (on the left) and Sitka spruce (on right) indicating approx. % summer light levels below upper canopy and growth of younger trees of these species



The diagram below indicates why, when you are trimming a hedge, it needs to be wider at the bottom than at the top, particularly if there are obstructions at the side. The light which is reaching the hedge is coming predominantly from above, and the bottom of the hedge can be too heavily shaded if the top of the hedge is broader than the base. I have put in some indicative figures; the bottom of the hedge on the left is getting over half the maximum amount of available diffuse daylight and the hedge on the right is getting only just over a third.

% of total diffused light reaching base of hedge





This diagram is to illustrate, in very diagrammatic form, a situation where, if you were to look down from above, each set of trees would have the same ground cover, with a little over 50% ground cover beneath the canopies. In the first example there would be an average of just less than 50% of daylight at ground level, with slight variations depending whether you are under a gap or under the canopy of a tree.

With the deeper canopy in the second example there will only be about 30% of the light reaching the ground because more of it will be intercepted. Even though there is the same amount of total ground cover, any light coming in at an angle is likely to be intercepted by these crowns; and if the crowns came right down to the bottom that would be even more. And the 30% which does get past the canopy will be more variably distributed. It might be as much as 50% in one place and only 20% in another, and even more variable in the third example.

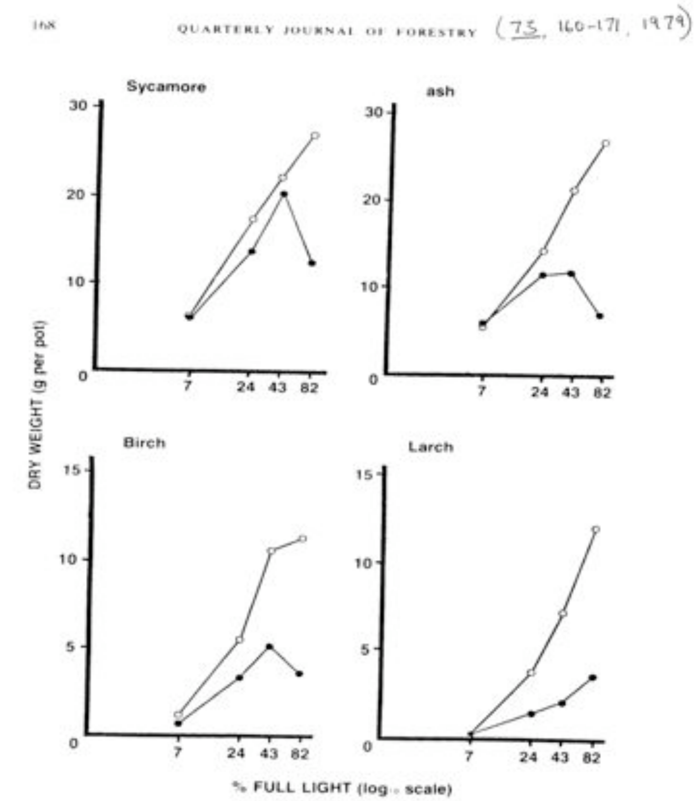


Figure 1. Dry weight of tree seedlings under different light intensities after two growing seasons in the presence (closed points) and absence (open points) of naturally seeded weeds.

This diagram is from a paper based on work which I did with Tony Harrison about 30 years ago, with several thousand tree seedlings on a variety of soils, with different light levels; and in some of which we removed the weeds. The straight line, which is on a logarithmic scale shows the increasing growth of the seedlings with increasing amounts of light, but if weeds are allowed to grow a point is reached where more light makes the weeds grow more, such that they interfere with the growth of the tree seedlings. It is the same with all of these species except larch (which seems to benefit from more light even when weeds are present. I have included this to illustrate the fact that light is not the only factor in determining growth; other things interact. Such other factors may include the growth of other plants, humidity, and possibly temperature. All of these are important.

Photo A

This shows a stand of very dense spruce where there is not enough light for anything else to grow – down to about 1% at ground level.

Photo B

This Photo shows a stand of spruce which has been thinned, so there is more light coming in, although at ground level, there are a lot of trees that have filled in the gaps the light levels might still be fairly low.

Photo C

This is a nature reserve area in Finland with pine and spruce over 40 metres tall, but it is thinning itself out a bit and starting to get some spruce regeneration

Photo D

This Photo was taken at the meeting we had with CCFG in Finland about 11 years ago. When I took the photo there appeared to be plenty of light, but you can see that it was in fact fairly dark.

I am trying to gain a better understanding of these matters, but there are still questions in my mind. For instance, is the quality of the light less important than quantity? There are references which support this view, and my own experience tells me that quantity is more important than quality, in the forest.

Rodney Helliwell *graduated in forestry in 1961 and has had a varied career in woodland management, research, nature conservation, arboriculture, and landscape design, and since 1978 has worked as an independent consultant. He has published numerous papers and several books, on a variety of topics, and was a founder member of Pro Silva and of the Continuous Cover Forestry Group. With an interest in continuous cover forestry which spans almost 50 years, he is concerned that this type of silviculture still appears to be poorly understood by many forestry professionals and woodland owners in the UK, and would like to be able to retire in the knowledge that matters are likely to progress in the future.*

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