

Trees for shade and shelter

Introduction

Trees arranged either as windbreaks, woodlots or scattered individually through paddocks can improve productivity by protecting stock, crops and pasture from extremes of weather and climate. The value of providing shade and shelter depends on how important these extremes are in limiting your current productivity.

This chapter addresses the following questions:

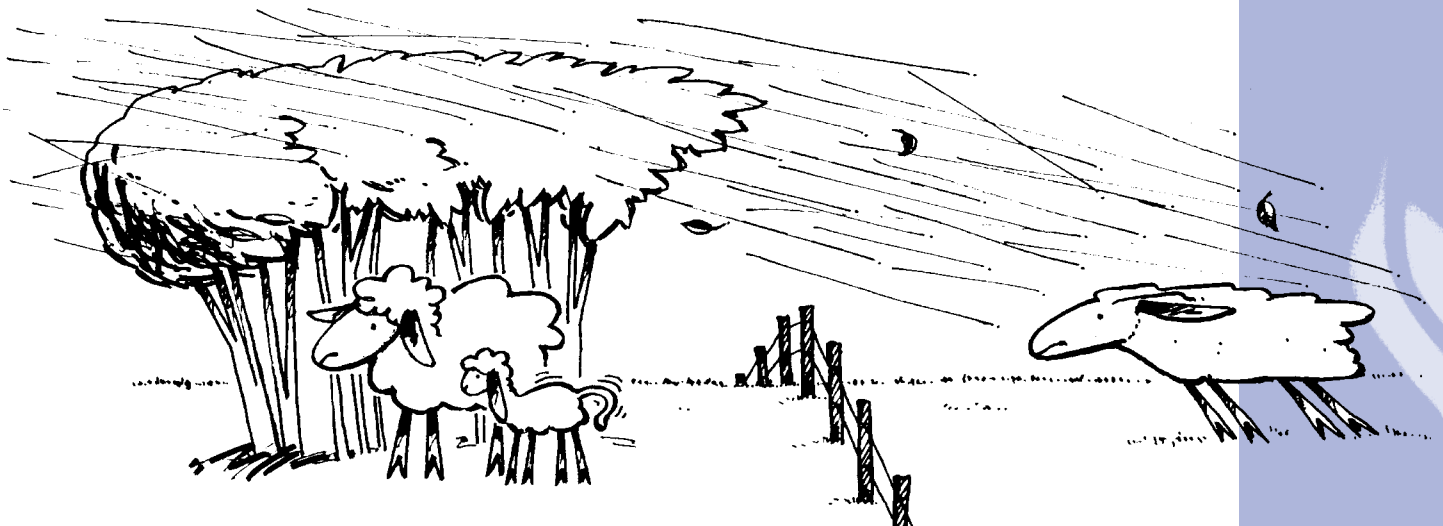
- what are the effects of shade and shelter upon animal and plant productivity?
- how do tree windbreaks affect shade and shelter?
- what things do I need to know before I design and plant a windbreak?
- how can I design tree windbreaks to maximise shade and shelter benefits?

- what other tree arrangements will also provide shade and shelter?
- what can I monitor to test whether I am benefiting from shade and shelter?

What are the effects of shade and shelter on productivity?

There are five main ways that shade and shelter influence productivity. These are:

- the protection of plants;
- the protection of livestock;
- the alteration of microclimate;
- competition; and
- reduction in soil losses.



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These are discussed in more detail below.

Protection of plants from direct wind damage

Trees can provide protection from wind damage, especially for high value products such as fruit and crops.

Strong winds directly damage plants through abrasion and sandblasting; stripping and tearing of leaves; and lodging of whole plants at either the root or stem. Abrasion will make crops susceptible to disease infestations. Such damage can then limit growth rates and final yields in pastures and crops. Blowing sand and soil particles also bury young seedlings during wind erosion events. Thus horticultural products can be reduced in quality and quantity as a result of direct wind damage. For example, kiwi fruit are easily damaged by rubbing and abrasion even from moderately strong winds.

Protection of livestock from heat and cold stress

Providing shade is important in tropical to subtropical climates, not only for improving feed conversion efficiencies but to prevent cattle deaths

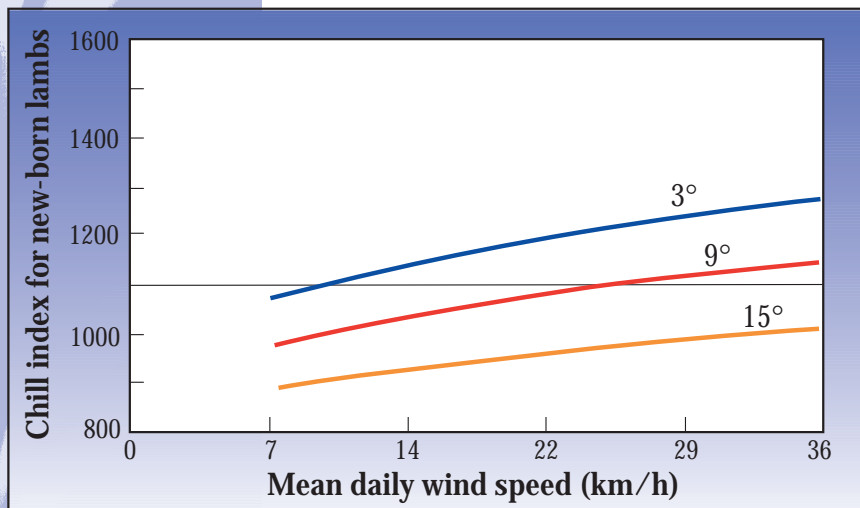
due to heat stress. Heat stress has also been found to reduce fertility in sheep and affects the well-being and size of calves.

Energy requirements by livestock are reduced by shelter from cold winds, especially during rain and snow. This translates into improved growth rates, livestock yields and productivity.

Figure 17 shows the way that heat losses (plotted as a chill index) in new-born lambs depend on mean daily air temperature (3°, 9° and 15°C) and wind speeds. If the chill index exceeds 1100, new-born lambs will lose so much heat that they will die.

Using this figure, we can see that even at 9°C, the heat losses exceed the critical value of 1100 in moderately strong winds (around 30 km/h). Reducing the wind speed to about 15 km/h reduces heat losses to safer levels. At air temperatures of 3°, wind speeds need to be reduced to less than 10 km/h to prevent dangerously large heat losses. This graph does not include the effects of rain, which will further increase heat losses.

Figure 17: The effect of wind and temperature on heat losses from new-born lambs



HINT

Combining pre-lamb shearing and windbreaks is one way of reducing lambing losses. New-born lambs are greatly affected by cold conditions. If ewes have been shorn, they too will feel the cold and are more likely to seek shelter, taking their lambs with them to the protection of the trees.

Mortality rates in newborns can therefore be reduced as a result of shelter from the wet and cold. Similarly, shelter can reduce losses of shorn sheep which occur in cold, wet and windy conditions – losses as high as 100,000 have been reported in Victoria for a single extreme event.

Trees can provide a protected environment for grazing and breeding livestock.

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Changed microclimate and water use

Shade and shelter affect productivity indirectly because of changes in the microclimate and water use. Planting trees can improve crop yields and pasture growth because a more favourable microclimate is created by shelter – warmer daytime temperatures, increased humidity and, in many cases, better growing conditions.

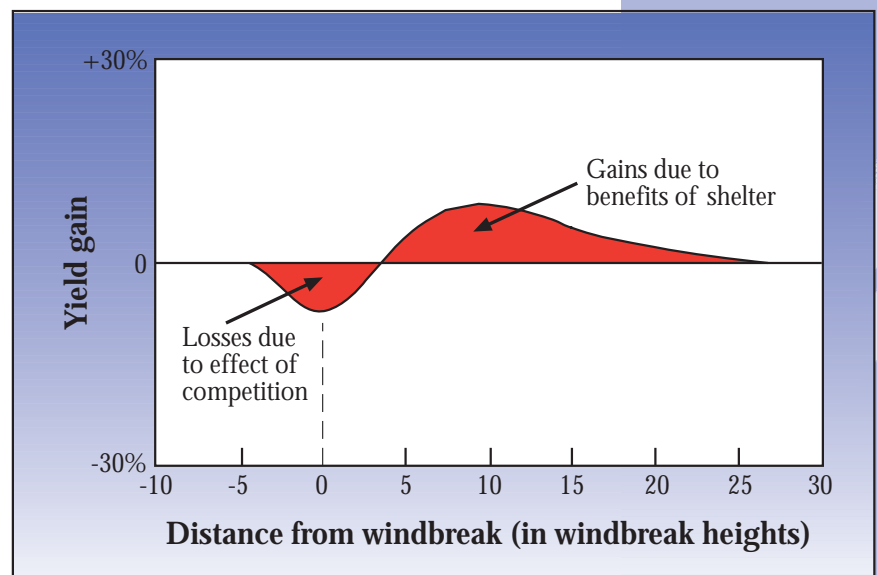
Sheltering crops that are well supplied with water (such as irrigated crops) from hot, dry winds will reduce evaporative water losses, conserving soil water and improving grain yields. In dryland agriculture, shelter may reduce soil evaporation early in the season, leaving more water available for plant growth later in the season.

The microclimate near trees is also modified by shading from direct sunlight by day, and protection from radiation losses at night, leading to lower maximum and higher minimum air temperatures. While plants growing next to trees may be protected from frost at night, shading in the early morning could prolong frost duration in other parts of the paddock. Providing shade from direct sunlight prolongs unirrigated pasture growth into summer because the rate of soil water loss is reduced.

An example of the effects of shade and shelter on crop growth is illustrated in Figure 18 which shows crop yields plotted against distance from a windbreak (positioned at the zero line in the graph). Distances from the windbreak are given in units of windbreak heights (H) – negative to indicate upwind and positive to indicate downwind of the windbreak. Using this, we see that crops growing next to a 10 m tall windbreak will have lower yields in the zone within 20 m of the windbreak because of competition for light, water and nutrients (see below). Away from the windbreak, the more favourable microclimate created by shelter can lead to yield gains in a zone that extends from 30 m

(3H) to 150 m (15H) downwind of the windbreak. For a crop growing next to a 10 m tall windbreak, this means that yield may be increased as far as 150 m downwind. These yield gains usually balance, or even outweigh, the losses due to competition and land taken up by the windbreak.

Figure 18:
The effect of a
windbreak on
crop yields



Competition for light, water and nutrients

Tree windbreaks compete with neighbouring plants – pasture or crops – for light, water and nutrients. Competition effects can extend several tree heights away from the tree canopy, as illustrated in Figure 18.

Competition is not always bad. For example, increased water use by trees may reduce a waterlogging problem and so improve productivity. If, however, the soil moisture store must sustain plant growth through spring and/or summer then increased competition for moisture may limit crop or pasture growth.

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Shading, which is competition for light, is beneficial if plants already have sufficient quantities of light for growth and water is limited, because of lower evaporative water losses. However, shade may be limiting if there is insufficient light for growth, if shading increases the duration of frost, or if it leads to waterlogging.

Reduced soil losses through wind erosion

Wind erosion not only damages plants directly, but removes the nutrient-rich topsoil (see 'Trees for soil conservation'). This and the fact that the wind's ability to transport soil increases exponentially with wind speed mean that using shelter to reduce soil losses is an efficient way to achieve enhanced, sustainable agricultural productivity in Australia.

Other effects

Wind is a means of transport for many pests – shelter reduces the transport of pests away from a particular area and so may simplify spraying. Windbreaks make effective buffer strips for reducing the risk of spray drift. Trees attract predatory birds and insects which feed on pests, and pollination can also be improved by shelter. A negative effect of attracting birds and animals is that they may also damage or feed on the sheltered crops. The warmer, humid microclimate created with shelter may also increase the incidence of fungal diseases.

H I N T

Fleece rot and fly strike

Grazing of woolly sheep in paddocks with high tree numbers can cause fleece-related problems. Either stock these paddocks with freshly shorn sheep or allow free access to adjourning open paddocks.

Windbreaks grown in pasture or cropping areas can be very effective firebreaks, especially if the windbreak trees have low combustibility.

How do tree windbreaks affect shade and shelter?

Trees provide shade by intercepting the sun's direct rays (Figure 19a). The area of shade depends on the height of the tree and the elevation of the sun above the ground. Figure 19b illustrates the shaded area cast by a north–south oriented windbreak at a range of latitudes and for different times of the day. The insets show examples of distance shaded (in windbreak heights) for a location at 35°S (eg Wagga Wagga, NSW).

For a location at 40°S, say Hobart, we can use Figure 19b to calculate the area shaded by a 10 m tall windbreak oriented north–south. In summer, the shaded area is less than 5 m at midday and 10 m at 9 am or 3 pm. By mid winter, a 20 m strip is shaded at midday and this grows to 40 m in the morning and afternoon. This shaded area in winter occupies the entire sheltered zone described below.

Windbreaks provide shelter by deflecting the approaching wind up and over the windbreak, around the edges and through any gaps within the windbreak. As a result, wind speeds are reduced.

The greatest wind speed reductions are found in a 'quiet' zone immediately behind the windbreak (see Figures 20 and 21). The % of upwind wind speed used in Figure 21 is a measure of this wind speed reduction – it is simply the actual wind speed at a particular location expressed as a fraction of the wind speed far upwind of the windbreak.

Extending beyond the quiet zone is a sheltered area where wind speeds are still somewhat reduced, but the air may be slightly more turbulent. This sheltered area extends to at least 20 windbreak heights (20H) downwind of the windbreak.

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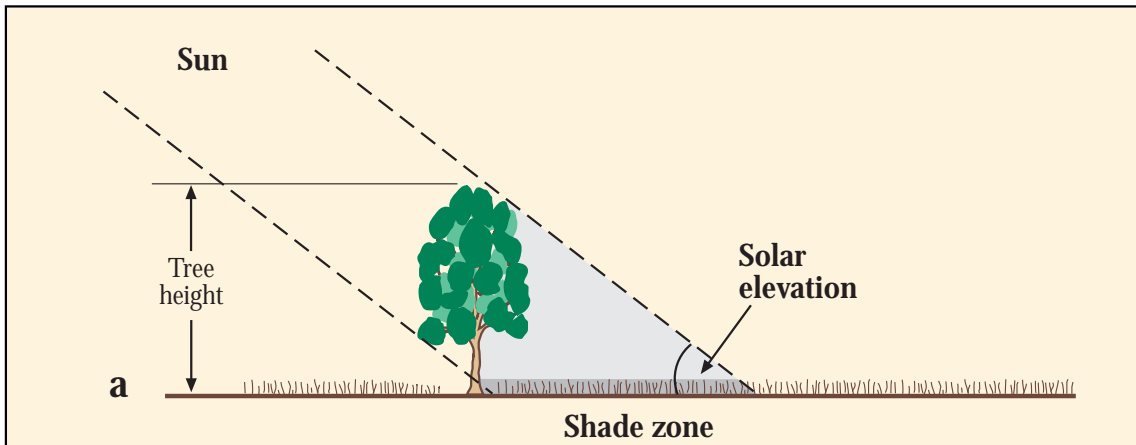
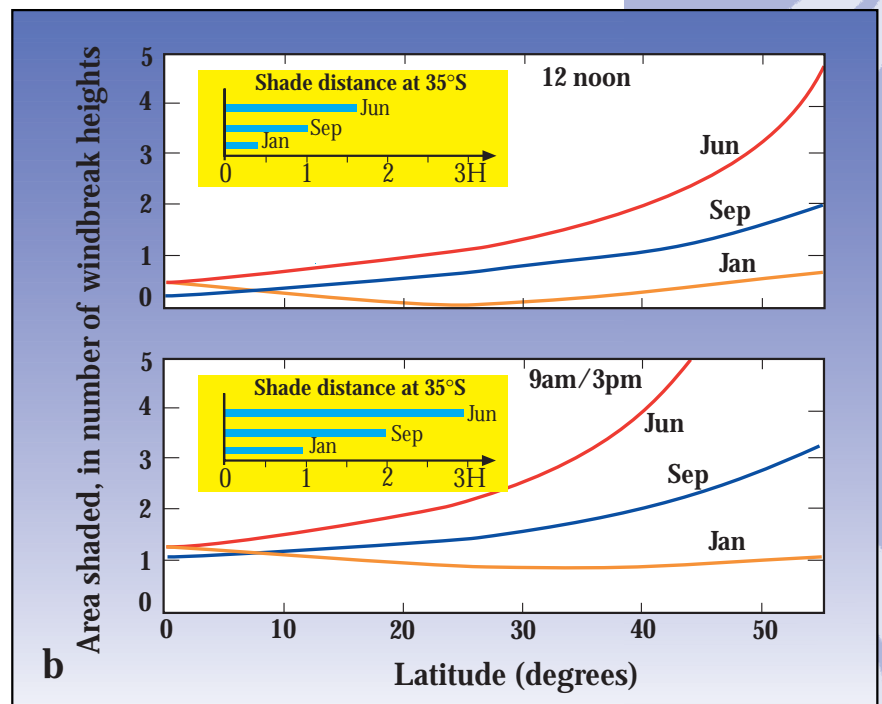


Figure 19:
Tree windbreaks
provide shade

The **amount of wind speed reduction** depends on the gaps, or 'openness', of the windbreak (called the porosity) and its length. **The size of the sheltered area** depends on the height of the windbreak.

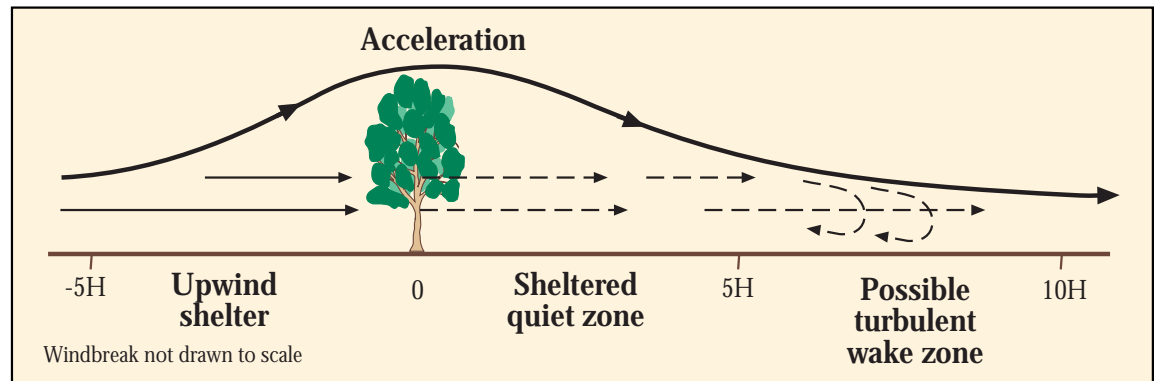
These points can be seen by using the example in Figure 21 which is for a windbreak with roughly 50% foliage and 50% gaps. For a 10 m tall windbreak, the lowest wind speeds will be felt 50 m (5H) downwind. At this spot, the wind speed is about 50% of its upwind value. A location 150 m (15H) m downwind of the 10 m tall windbreak will still be sheltered, but the wind will have increased to 80% of its upwind speed. Note also that the wind begins to slow even before the windbreak is reached – at about 50 m (5H) upwind for a 10 m tall windbreak.

The approaching wind direction is important for shelter. Figures 20 and 21 assume that the wind is blowing almost at right angles (within about 40°) to the windbreak. If the wind blows at a large angle across the windbreak then the sheltered area may be reduced in size.



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Figure 20: The effect of a tree windbreak on airflow



Key questions to consider before you start planning and designing windbreaks on your farm

Before even beginning to design a windbreak system for your farm, you need to consider the following questions.

Why do I need a windbreak?

Is your aim to provide maximum shelter over a small distance, perhaps to protect a small number of stock or a high value horticultural crop? Or are you willing to have a smaller, but adequate, shelter effect over a larger area? The latter option might be more appropriate for sheltering broadacre cropping areas. Alternatively, you might be most interested in providing shade for stock and pasture production, in which case closely spaced, tall windbreaks or scattered trees may be required.

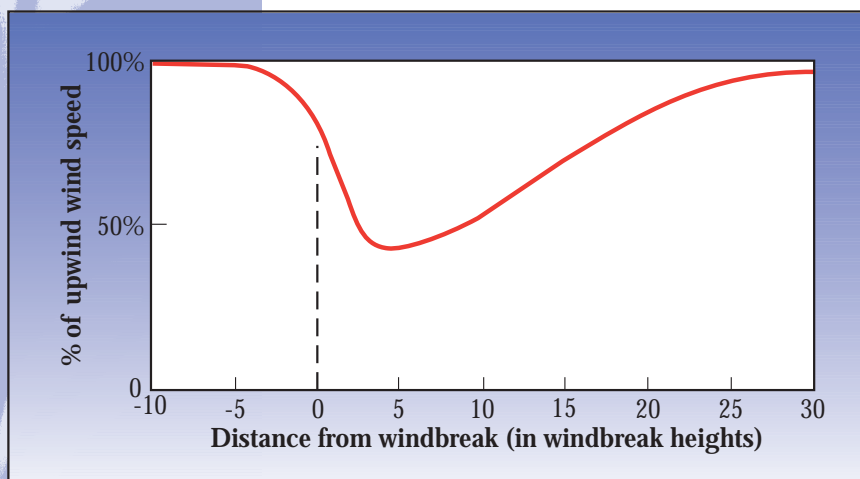
What are the climate extremes from which I require protection?

Do you require shelter from a particular wind direction? Do these winds vary seasonally? For example, many parts of southeastern Australia need shelter from hot, dry north-westerlies in the summer and cold south-westerlies in the winter. A familiarity with the local climate and topography of your property is needed to determine those places most exposed to damaging winds.

What is the nature of the return I expect from my windbreak?

Shade and shelter affect productivity in two ways. Firstly, shelter can provide protection from

Figure 21: The effect of a windbreak on wind speed and shelter



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extremely damaging, but infrequent, weather events. If such events are likely on your farm then a windbreak is like an insurance policy. It will reduce large productivity losses due to crop damage or livestock deaths, but this may happen only once in a decade. The benefits of the windbreak in this example are infrequent and unpredictable, but they are very large when they occur.

On the other hand, the greatest benefit from shade and shelter may be a gradual improvement in productivity over the course of all growing seasons. The return from your windbreak in this scenario may not be large on an annual basis, but it is more reliable and will realise a long-term financial gain.

Will competition improve or limit productivity?

Planting tree windbreaks can introduce competition between the trees, soil and other plants (pasture, crops) for light, water and nutrients. Productivity will sometimes be improved as a result of competition, as illustrated in the earlier example of waterlogging or in the case of dryland salinity (see chapters on soil conservation and salinity). The principle here is to consider carefully, in consultation with an agricultural extension officer, those factors that limit productivity in your enterprise. This will enable you to decide whether you need to encourage or restrict competition for water, nutrients and light. Three examples of ways to manage competition are discussed below.

Careful selection of windbreak tree species. For example, if shading is a concern then deciduous trees often have sufficient stems and trunks to act as an effective windbreak but with less shading in winter. Select tree species whose root growth and architecture reduces or enhances competition as appropriate.

Manage your windbreak. Consider using management practices such as root pruning or

thinning of the canopy if your aim is to reduce water uptake by the trees.

Design an appropriate windbreak arrangement.

The effects of competition can be managed by considering the spacing and configuration of your windbreaks or by selecting an alternative arrangement for trees on your property.

The last is by far the most effective way to manage competition and is taken up in the following discussion on windbreak design.

Designing a windbreak to maximise shade and shelter benefits

There are two main factors to consider when designing a windbreak system to provide shade and shelter – windbreak structure (porosity, shape, width, length and height) and windbreak layout (orientation, spacing and configuration).

1) Windbreak structure

Porosity

A windbreak's ability to reduce wind speeds depends primarily on its porosity. **A more open or porous windbreak allows more air to flow through the trees and so provides less shelter – that is, there is a smaller reduction in the wind speed downwind.** This effect is illustrated in Figure 22.

A windbreak's porosity can be assessed in the paddock. Simply stand at a spot in front of, and at right angles to, the windbreak and estimate the relative percentages of foliage and gaps (see Figure 22). This visual estimate is a fairly good guide to the porosity of the windbreak.

Maximum shelter is best achieved with a dense windbreak (less than 30% porosity).



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The most sheltered location will be close to the windbreak, within about 3 windbreak heights. The airflow beyond this point may become more turbulent with a possible increased risk of damage to plants – especially easily damaged horticultural crops.

A medium porosity windbreak (roughly 50–60% open spaces and 40–50% tree when viewed from directly in front) will also provide adequate shelter. The most sheltered location may be slightly further away from the windbreak (around 5–6 H) and there is less risk of damage to horticultural plants.

The size of the sheltered area will be very similar for both high and low porosity windbreaks – as shown in Figure 22. Claims that porous windbreaks provide shelter over larger areas than dense windbreaks have been exaggerated in the past.

Thus, managing the porosity of your windbreak is probably less important than managing the windbreak height (which determines the shelter distance) and maintaining a uniform porosity.

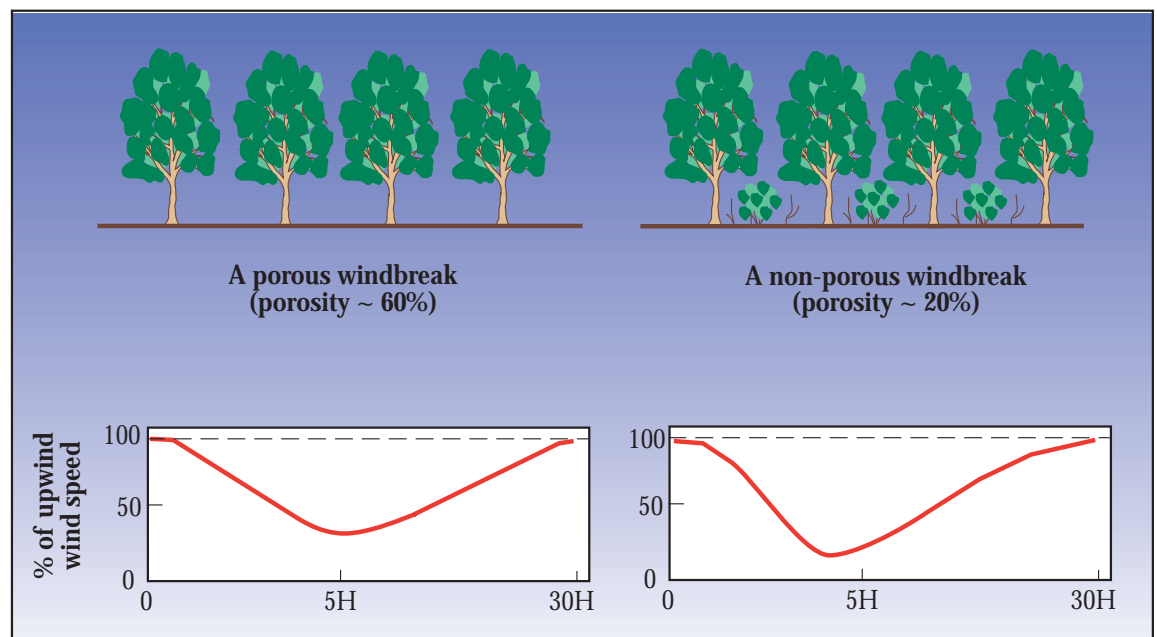
Height and length

The size of both the shaded and sheltered zone behind a windbreak depends more on windbreak height than it does on porosity, which is why shade and shelter effects are expressed in terms of windbreak heights.

HINT

Woolly sheep often don't take advantage of shelter at lambing time. Handfeeding next to the trees will help overcome this problem.

Figure 22: The effects of a high porosity and low porosity windbreak on wind speed



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The area of sheltered land per unit area of windbreak can be maximised by growing relatively narrow, tall tree windbreaks. A

fast-growing windbreak, or planting a windbreak on a bank, is the quickest way to increase the size of the shaded and sheltered area. If shade for stock is required, the large shaded area provided by a tall windbreak will reduce the negative effects of stock camps on soil erosion.

A windbreak should be as long as possible, at least 20H, because flow around windbreak ends will erode the sheltered zone.

Linking the windbreak into existing shelter, woodlots or forests is another way of achieving shelter over as large an area as possible.

Shape and width

An ideal windbreak will have a uniform porosity along both its length and height. Gaps either in the trunk space or along the break due to dead trees or a gateway can lead to strong 'jets' of wind that may be more harmful than an absence of shelter. More than a single row of trees will usually be needed to maintain an adequate and uniform porosity. A streamlined cross section is, however, not necessary for a medium porosity windbreak. Windbreaks also should be protected from grazing animals to prevent gaps at the base of the tree trunks.

Windbreak width is of secondary importance, apart from the need to have enough tree rows to ensure the health of the windbreak trees and to maintain an appropriate porosity. Very wide blocks of trees, where width greatly exceeds height, are still an effective windbreak except that the sheltered area downwind may be smaller.

An example of planning windbreak structure

Figures 21 and 22 can be used as a guide to planning windbreak structure. Say you wish to

shelter an area extending from your windbreak out to 100 m and you have planted a windbreak which will grow to a maximum height of 5 m. Planting and maintaining a medium porosity windbreak which is at least 100 m in length will be your best chance of getting a shelter effect to 100 m (20H). The maximum wind speed reduction that you can achieve with this windbreak will be about 50% and this will be experienced about 25 m downwind of your windbreak. If you allow your windbreak to become more dense, as in the second panel in Figure 22, then you will have achieved a greater reduction in wind speed – to about 20% of the wind's strength upwind. This latter scenario is probably most appropriate if you wish to achieve maximum shelter (such as for sheltering stock or a homestead) and increased levels of turbulence are not important.

2) Windbreak layout

Orientation

The best windbreak orientation is at right angles to the prevailing winds. If the wind blows at an angle across the windbreak, then the sheltered zone may be smaller (Figure 23). However, the last graph in Figure 23 illustrates the important point that some degree of shelter is experienced for a large range of approaching wind directions as long as your windbreak has adequate length.

Choosing the right orientation for a windbreak requires a knowledge of the local wind climate – from which winds do you require the most shelter? If you are fortunate and only require protection from one prevailing direction then a single windbreak will be adequate.

Unfortunately, damaging winds often vary with the seasons – for example, hot, dry north-westerlies in the summer and cold south-westerlies in the winter. You must then choose between a single windbreak orientation which provides some shelter

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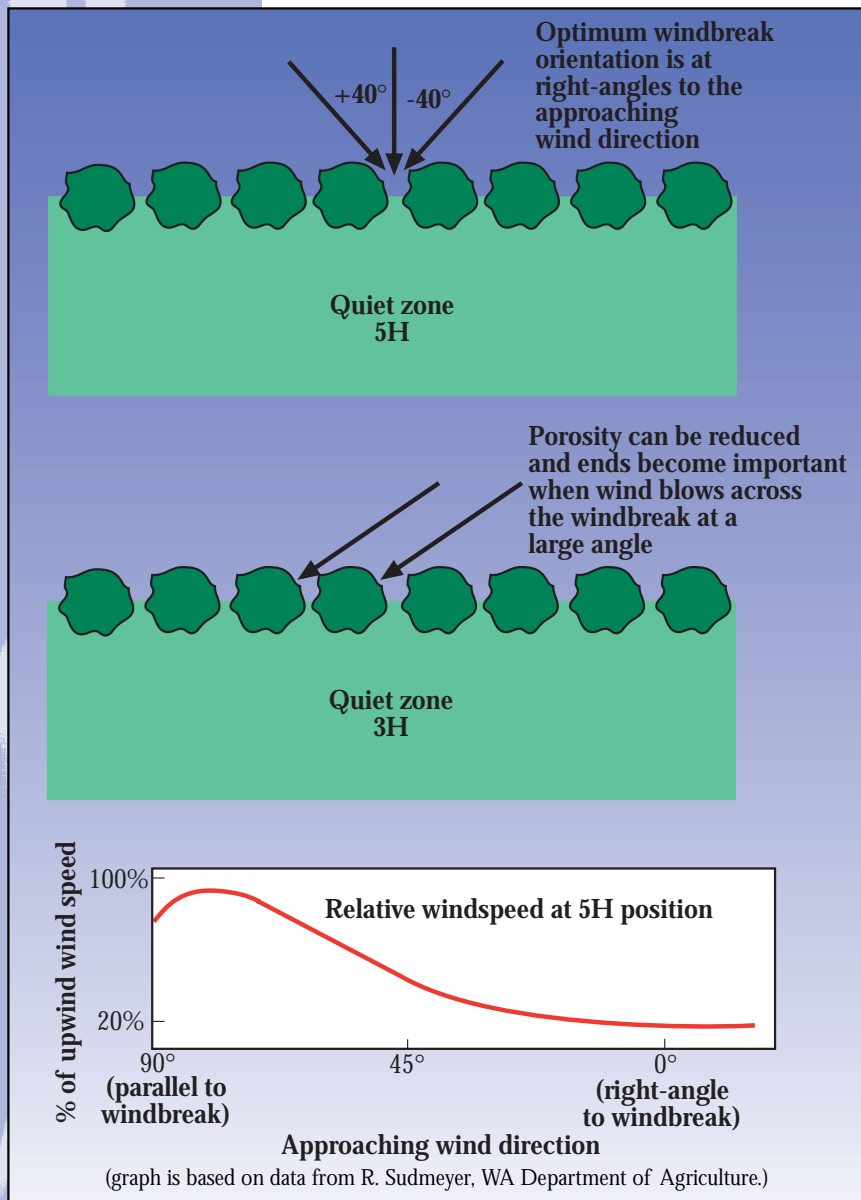


Figure 23: Orienting your windbreak to achieve the maximum shelter

in both seasons, or establishing a grid of windbreaks to maximise shelter from all wind directions (Figure 24). This latter option requires a carefully designed windbreak system which minimises costs and productivity losses: some alternatives are described below. You should also refer to the chapter on capturing multiple benefits.

Spacing between windbreaks

In selecting an optimum spacing of individual trees or windbreaks, you need to consider how much competition is appropriate; what other activities will be affected by the location of trees (mustering of stock, spraying, sowing and harvesting); and for what purpose shade and shelter are required.

Shading only extends over a few windbreak heights, so closely spaced trees (around 5H) may be needed for maximum shading.

A very sheltered environment can also be created by using a 5H spacing, but much wider spacings will be needed if competition is a problem. Fortunately, a sizeable shelter benefit is achieved even with spacings of 20H.

Windbreaks spaced more than 20H apart have little influence on each other except for one important effect. As the density of windbreaks increases, not just on your farm but across the region, the greater is the regional-scale sheltering. This means that the shelter felt in a particular paddock results not just from the windbreak on that paddock, but also from any other trees and topography on your own and your neighbours' farms. **Converting as little as 2% (20 m tall windbreaks spaced 25H apart) of a landscape into tree windbreaks could achieve a 30% reduction in wind speed.**

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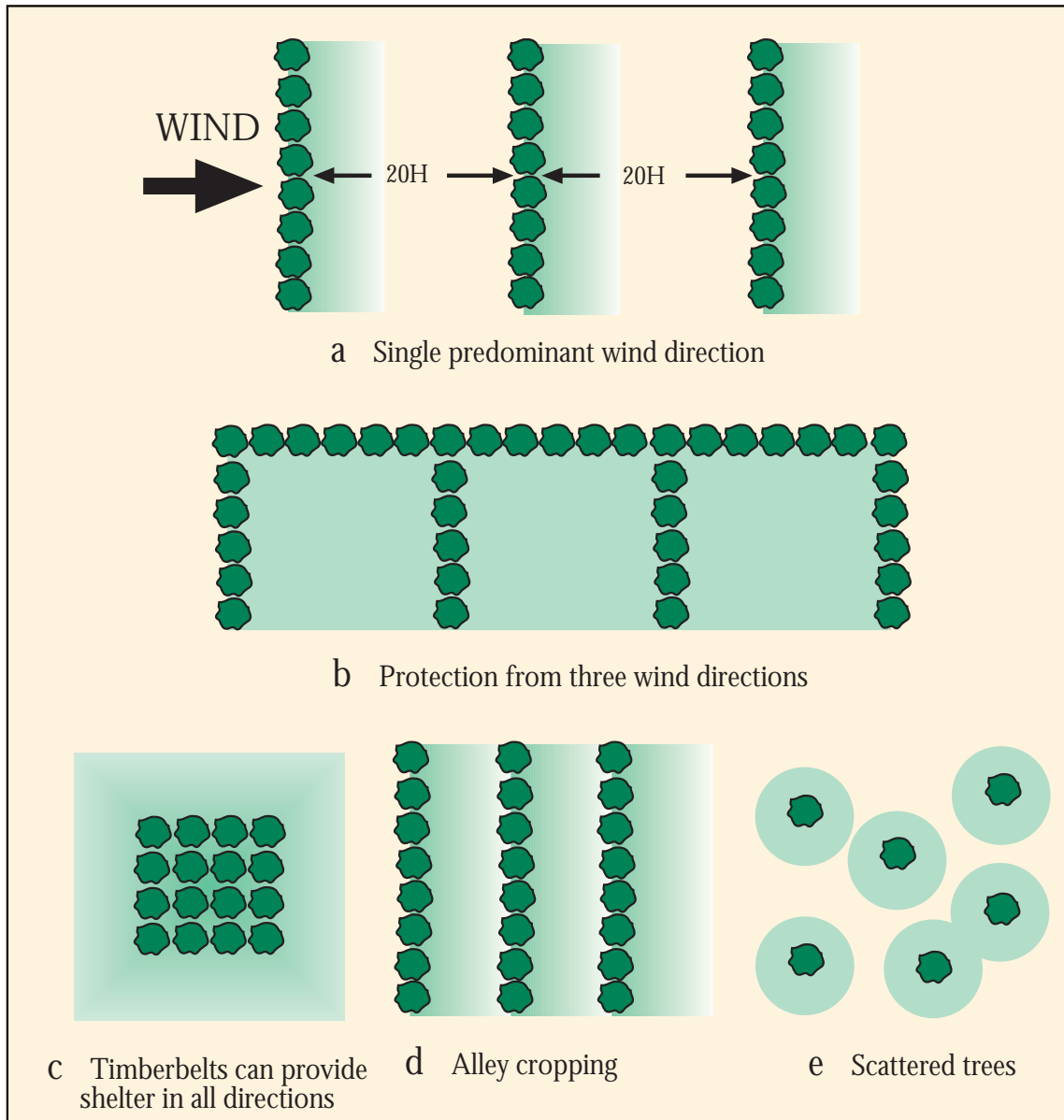


Figure 24:
Choices of
windbreak
configurations:

- (a) parallel windbreaks for a single, predominant wind direction;
- (b) a windbreak grid for protection from 3 wind directions;
- (c) a timber block, which provides shelter and shade in all directions;
- (d) alley cropping; and
- (e) scattered trees, which provide maximum shade, shelter and competition

Alternative tree arrangements to achieve shelter and shade

The potential for competition increases as the windbreak/crop (or pasture) interface becomes larger. **Tall, single windbreaks, less than 3 rows wide, have the smallest ratio of interface length to sheltered distance and so are a good option to minimise productivity losses from competition and to maximise shade and shelter.**

Planting windbreaks around paddock edges in a grid (Figure 24b) also maximises the area sheltered compared to the area affected by competition. Timber blocks (see ‘Trees for wood products’) are similar, simply because the effects of competition inside the block of trees do not limit the timber yield. Planting large areas with trees to provide timber can increase water use (see ‘Trees for controlling dryland salinity and waterlogging’) and provides shade and shelter.

If your aim is to maximise competition either to achieve shade or increase water use, then alternative configurations would include alley cropping (see ‘Trees and shrubs for fodder’) and possibly scattered trees. Trees scattered across a paddock, either in clumps or as single trees, provide most of the shade and shelter benefits described above if an adequate density is established. Such an arrangement may not be suitable for broadacre cropping and can be expensive to establish in grazed pasture where seedlings must be protected from stock.

For any of these alternative tree configurations, different management practices will be needed to ensure that the shade and shelter benefits are not compromised. For example, some alternatives to pruning lower branches in woodlots (which create unwanted gaps in the lower trunk space) include:

- planting an appropriate composite of species;
- leaving a buffer row around the downwind edge of the tree lot; and
- enclosing the tree lot with a medium porosity fence.

Monitoring

Once you have established windbreaks on your property, a monitoring program is a useful way of checking whether the benefits described earlier are being achieved.

You should compare all your observations against a control: ie observations of stock or paddocks that are not receiving shade or shelter. Long-term records will be needed. Some useful details to monitor and record include:

- sheep deaths in sheltered and unsheltered paddocks;
- milk yields from stock in sheltered and unsheltered paddocks;
- stocking rates and length of time between rotating stock;
- bales of hay per paddock – compare sheltered with unsheltered;
- whether harvester bins fill more quickly in sheltered paddocks;
- use a yield mapper (available for hire in some agricultural districts) to see whether windbreaks affect yield across the paddock, especially in a year with extreme weather; and
- obvious signs of plant damage after extreme events such as rain and wind storms.

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References / Further reading

Bird, P.R., Bicknell, D., Bulman, P.A., Burke, S.J.A., Leys, J.F., Parker, J.N., van der Sommen, F.J. and Voller, P., (1992). The role of shelter in Australia for protecting soils, plants and livestock. *in* Prinsley, R.T. and Allnutt, J. (1992), eds, 'The Role of Trees in Sustainable Agriculture', *Agroforestry Systems*, 20 (1-2), 59-87.

Heinjus, D. (1992). *Farm Tree Planting*. Department of Agriculture South Australia and Inkata Press, 84 pp.

The following volume has many interesting research articles:

Brandle, J. R. and Hintz, D. L. (1988). "Windbreak Technology", (Eds.) *Agric. Ecosystems Environ.* 22/23.



Capturing benefits in addition to shade and shelter

Good windbreak design and layout can achieve a considerable amount of shelter with only a small percentage of land under trees – say less than 5%. This provides an opportunity to capture other benefits, particularly those associated with wind erosion and nature conservation.

Other benefits to capture	Opportunity	Thing to look out for
Wood	Timber can be produced from multi-row windbreaks, particularly for high value managed trees	The requirement for uniformity of a windbreak may conflict with timber management practices such as thinning and pruning
Salinity and waterlogging	Windbreaks which can access laterally moving groundwater may have some benefit on water-tables immediately downslope	The minimum area planted to trees which will give a windbreak effect may be too small to impact on local water-table levels
Soil conservation	Design for shelter and reduction of wind erosion are entirely compatible	Apart from wind erosion, serious attempts to rehabilitate or protect degraded land will require more trees than single row windbreaks
Fodder	Trees in a windbreak could be browsed or lopped during drought periods Pruning and thinnings can produce fodder (usually of low quality)	Windbreaks are unlikely to produce a significant volume of feed Browsing will affect windbreak porosity and uniformity
Nature conservation	Windbreaks linking remnants can act as wildlife corridors Windbreaks composed of multiple species will improve habitat diversity Some tree species act as fire retardants	
Scenic quality	Positive impact if vegetation shelter layout follows natural and/or cultural landscape characteristics Species diversity (grasses, shrubs & trees) will increase scenic quality	Straight windbreak rows planted at right angles to prevailing winds may conflict with the often curved lines of the natural landscape (ridges, creeks)