Pat Ryan.

031123

THE AFFECT OF TREE SHELTER ON AGRICULTURAL PRODUCTION

David Bicknell
NSCP Landcare Project Officer
Department of CALM
ESPERANCE WA

This paper was prepared for presentation at a workshop. It aims to give some of the positive reasons for establishing tree windbreaks in agricultural systems.

Most of the published material on windbreaks does not relate well to tree windbreaks in a Mediterannean climate. Some infomation from recent Western Australian work is presented. and some other Australian references are summarised.

"Shelter" is used in the title to cover windbreaks and shelter. Most of this article deals with designed windbreaks.

It is worth remembering the following:

* Tree windbreaks prevent erosion - or cause it
* Tree windbreaks increase crop and pasture growth - or decrease it
* Tree windbreaks can reduce livestock losses - or increase them
* Tree windbreaks should be about 50 % permeable - or much less

Expected benefits of tree shelter in agriculture

* Reduction in mechanical damage to pasture and crop plants. This damage has not been extensively quantified, but is thought to be common on exposed pastures and some crops. 'Bruising', splitting of stem and leaf material, and removal of the waxy cuticle have been documented.

* Reduced evaporative demand on soil. Slowing windspeed reduces evaporation and leaves more soil moisture available for photosynthetic activity. Under some conditions this will lead to increased water usage, reflected in greater production.

* Livestock shelter. The effect of cold winds, with or without rain, has been extensively monitored and researched in Australia. The most obvious instances of gains from shelter are for off-shears sheep, and recently born lambs.
  Other expected gains, more difficult to quantify in the field, are from modifying microclimatic effects on energy demands of livestock. Most of this work relates to the effect of cold.
  Changes in 'social' and grazing behaviour of sheep in relation to shelter has been observed and researched.

* Control of wind erosion. This is an obvious, but apparently poorly understood benefit from reducing windspeed with trees.
  The design principles have been widely researched, but the field design is less well understood.
  The benefits come from preventing sand blasting, and preventing the loss of topsoil containing valuable nutrients.

* Improved management conditions. Lower windspeeds will usually allow more days suitable for spraying, and improved operator conditions to work in. Stopping dust and grit entering the house is usually a high priority !

* Increased water use. 'Windbreaks' and other tree plantings will use more water than the pastures they replace. This is particularly so near swamps and sumps, saline areas, drainage lines, and seeps.
  On clearly defined 'intake' areas, trees are very suited to prevent recharge.

* Tree and shrub products. Secondary products can increase the value of windbreaks. The type of product will be determined by the environment and the management demands on the farmer.
  Examples of secondary products are;
  sawlogs
  poles and posts
  fuel wood
  fodder
  honey, oil, and flowers

Western Australian information on the value of tree windbreaks for crop production.

There is very little accurately quantified data available in WA on this topic.

Most of the material available is farmer observation, sometimes with coarse estimates of production changes.

A measuring program was started in 1988 at Esperance to find the effects of young *Pinus radiata* windbreaks on lupin and oat yields (23). This work was done near Gibson, in a 450mm rainfall zone. The soil was between 2.5 and 4.5 meters deep fine, podsolized sand.

Pine windbreaks were established by the farmer, Garry English, in 1984 as part of a program to prevent soil erosion and allow cropping. The windbreaks are parallel, about 200m apart, and run approximately North-South.

The 'lands' have been cropped on a wheat-lupin rotation until 1988, then oats were introduced for an oat-lupin rotation. Lupin and oat yields were measured in 1988. Nine 'treatments' with four replicates were harvested for each crop; cutting 20 meter long plots with a Department of Agriculture trial harvester.

Lupins in 1988 showed a distinct response to the windbreaks on the Western and Eastern sides (Fig 5). This was interpreted as a response to protection from the cold North-Westerlies in early winter, and protection from the dry Easterlies in spring.

Lupins are more susceptible to cold growing conditions than are the cereals. Also, lupin flowers are particularly susceptible to stress.

If the center lupin value is taken to be an 'open paddock yield', then the nett yield increase between the windbreaks is about 27 per cent. Allowing for the area under the windbreaks, the nett yield increase is 19 per cent. It is possible that the actual yield increase is greater than this, because the center value is at 20 tree heights from the windbreaks, and there is likely to be some windbreak effect at this distance.

The return on costs of establishment in 1984 till the single benefit of 1988 was estimated at 28 per cent per annum. This is obviously an underestimate, because there has been a reduction in soil loss, and yield increases in other years.

Oats in 1988 did not give a clear response to the windbreaks (Fig 6).

In 1989, plots were harvested every 10 meters between the windbreaks, with four replicates.

At the end of this article, there are a number of references that can be used to follow up the details of reported gains and losses from windbreaks in agriculture.

The figures below are taken from the literature, and some comment is given as to its applicability in Western Australia.

LIVESTOCK RESPONSES TO WINDBREAKS

Post shearing losses of sheep from cold average about one per cent per year. This figure is conservative, and hides the fact that losses in some areas are consistently higher (1).

A Western Australian example is reported for the losses during a summer storm in 1982 (2, 3). Although this was an extreme example, it points out that the degree of shelter has to be taken in to account.

Losses from autumn shearing through to early spring are commonly observed (7), and have been the focus of animal welfare activity in Victoria.

Lamb losses. On average, there may be more than 15% of all lambs born, die of exposure (4). Very high losses have been recorded under conditions of high windspeed and relatively light rainfall (5).

An indication of the regularity of such losses is found in the Esperance Shire statistics. Over the twenty years of data collected, there were four years of severe lamb loss. Individual farmers have admitted that lamb marking in 1981 was often around 10 to 20 per cent (D Bicknell, personal communication). The Shire average was reported to be 48 per cent for that year, and is higher than 70 per cent in a 'normal' year (Fig 1. 19)

It is reasonable to expect that 50 per cent of lamb losses can be prevented with adequate shelter (6). Under severe conditions, lambing 'havens' give a much higher degree of protection. This form of shelter costs very little, and gives high economic benefits (8, 9, 10, 11)

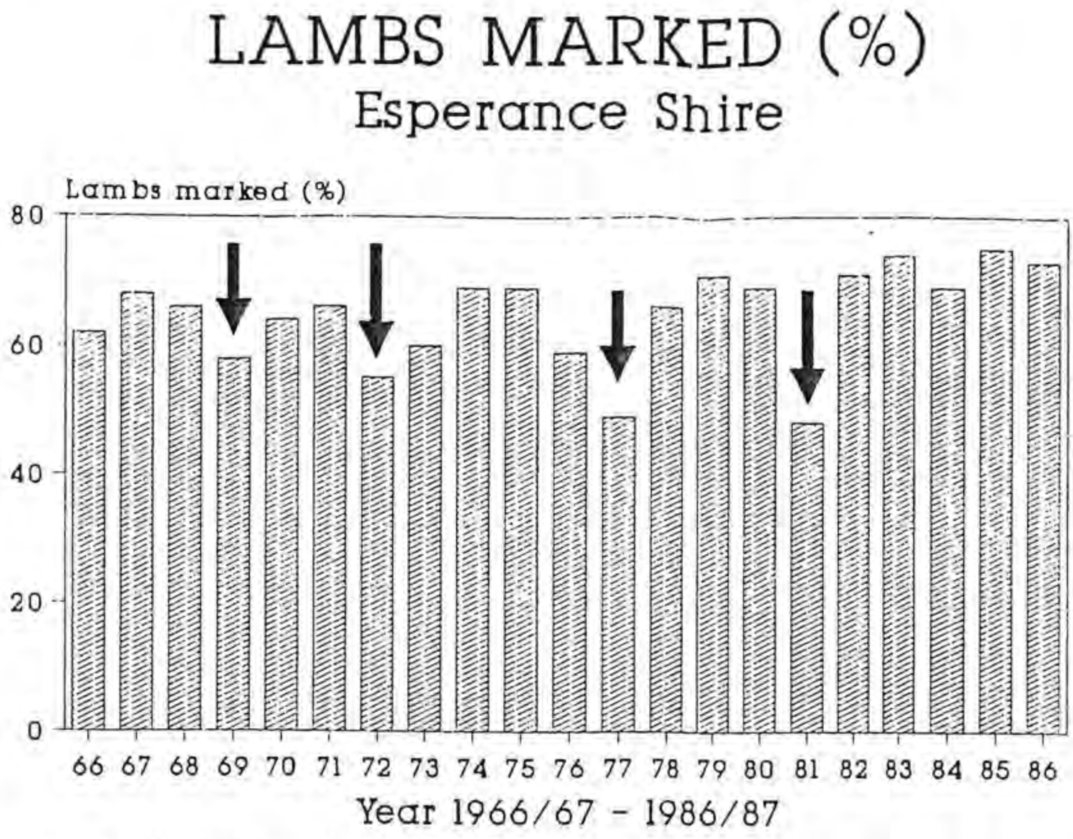
Energy requirements for maintenance and wool growth.

Most of the work published relates to pen studies. If this information can be extrapolated to the field, quite small reductions in windspeed can reduce energy needs (12).

An example is a reduction in windspeed from 3m/sec to 2m/sec can result in a 10% saving in maintenance energy requirements (1, 12).

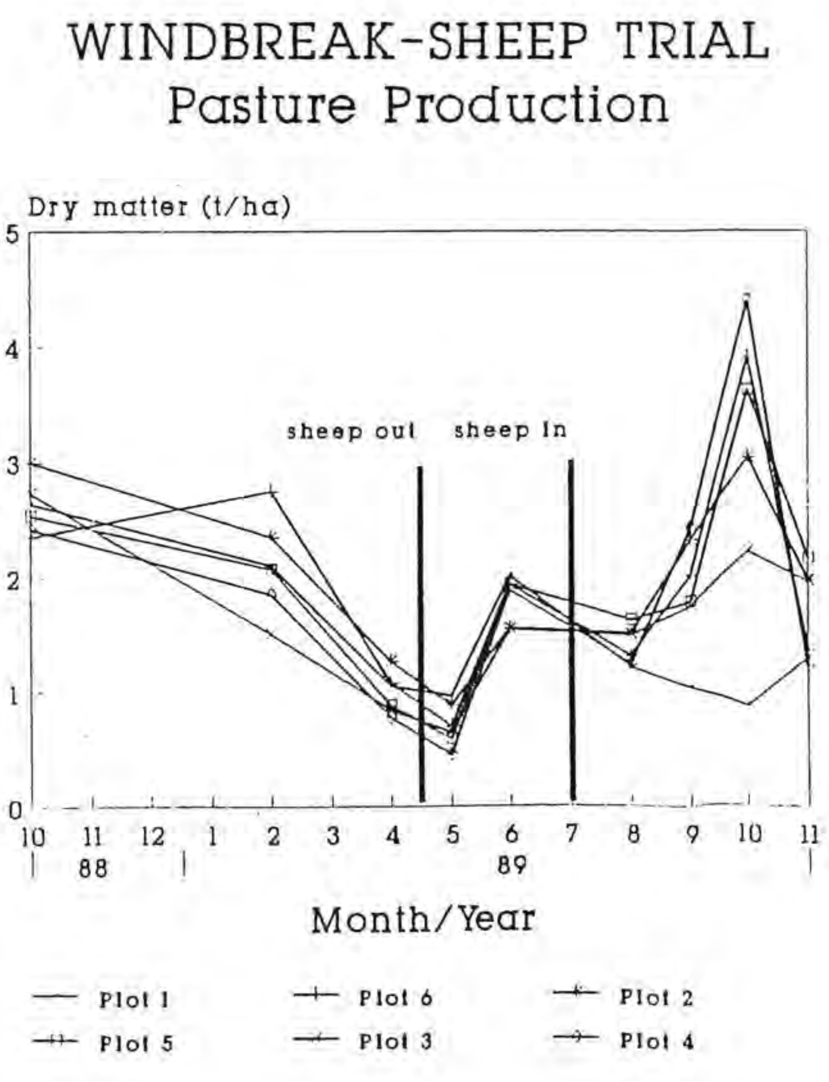
Wool growth studies have shown marked increases in wool growth (31% over a five year period) and body weight using windbreaks at high stocking rates (13). The windbreaks were of corrugated iron, and the gains were largely due to pasture gains. Many other references are available, mostly relating to the effect of cold stress (1, 14, 15)

Fig 1



David Bicknell, NSCP Landcare Project

Fig 2



There are few trials reported using field studies with tree windbreaks. Many have used artificial shelter or grass barriers. The results from these studies is hard to extrapolate to a tree system.

Trees, as long lived perennials, develop complex interactions with their environment. The usually reported interaction is root competition with pastures and crops for moisture and nutrients.

A trial was established in Esperance in 1988/89 to investigate the effect of a young *Pinus radiata* windbreak on pasture and sheep production (20). The trial has shown marked differences in pasture growth at different distances from the trees (Fig 2), but no significant difference in sheep bodyweight (Fig 3). The small differences in fleece weight were not related to pasture growth.
A complication of the site demonstrates the confounding factors found in farm systems. The pines were planted into deep sand (a species requirement) and the sand became shallower further away. This soil type change is associated with a pasture species change and the occurrence of non-wetting sand near to the pines (Fig 4)

It is thought that non-wetting has been accelerated by the presence of the windbreak. Sheep have been observed to graze more often in the shelter of the windbreak, leading to conditions favouring clovers and development of water repellancy. The pasture near the windbreak is now poorer than before, not better, and has hidden any effect the shelter is having.

PLANT RESPONSES TO TREE WINDBREAKS

This is the area that has been most widely reported in the overseas literature. There have been many reviews and 'rediscoveries' of the costs and benefits of windbreaks (16, 17, 18).

Unfortunately, this is the topic that is rarely taken to be relevant except where the work was done. This is often because not enough of the background data has been recorded. For instance lack of rainfall or soil description.

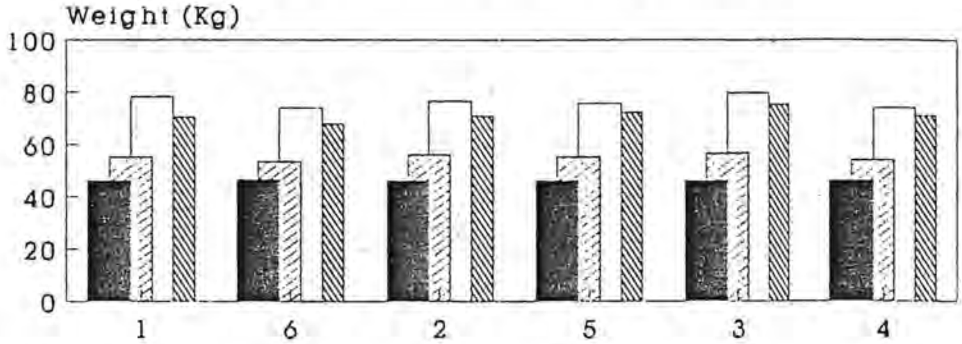
A table of "Past studies concerning shelterbelt effects on cop yields" is given by J Kort (21). Most of the reported material relates to snow trapping windbreaks. However, there are instances of Mediterranean and Marine climatic areas with crop yield increases of up to 35% (22).

Yield increases of pastures and crops, out to about 15 tree heights in the lee of shelterbelts, of about 20 to 30% are often quoted (1, 12). However, the size and direction of a change in yield varies with crop, season, soil types, tree species, windbreak orientation and so-on.

It is important to use data from well constructed windbreaks with the correct management to show the potential gains from tree windbreaks.

Fig 3

WINDBREAK ON SHEEP PRODUCTIVITY
'Jangarri' - Gibson



	1	6	2	5	3	4
27/5/89	46.2	46.4	46.1	46.3	46.3	46.3
28/6/89	55.4	53.7	56.3	55.4	56.4	53.9
06/10/89	78.5	74.1	76.8	75.9	79.6	73.9
15/2/90	70.6	67.8	71	72.4	75.3	71

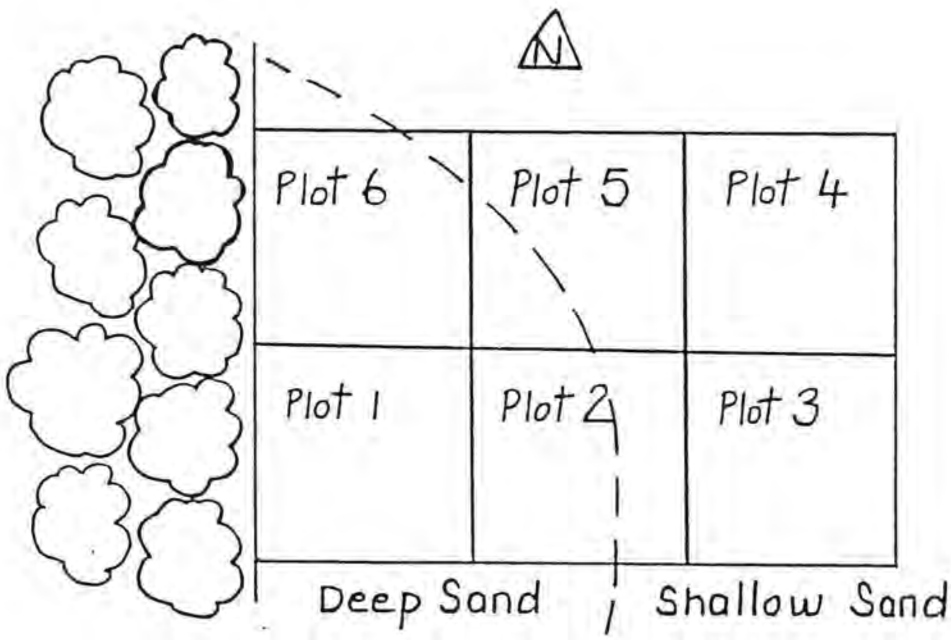
Plot Number

27/5/89 28/6/89 06/10/89 15/2/90

David Bicknell, NSCP Landcare Project

Fig 4

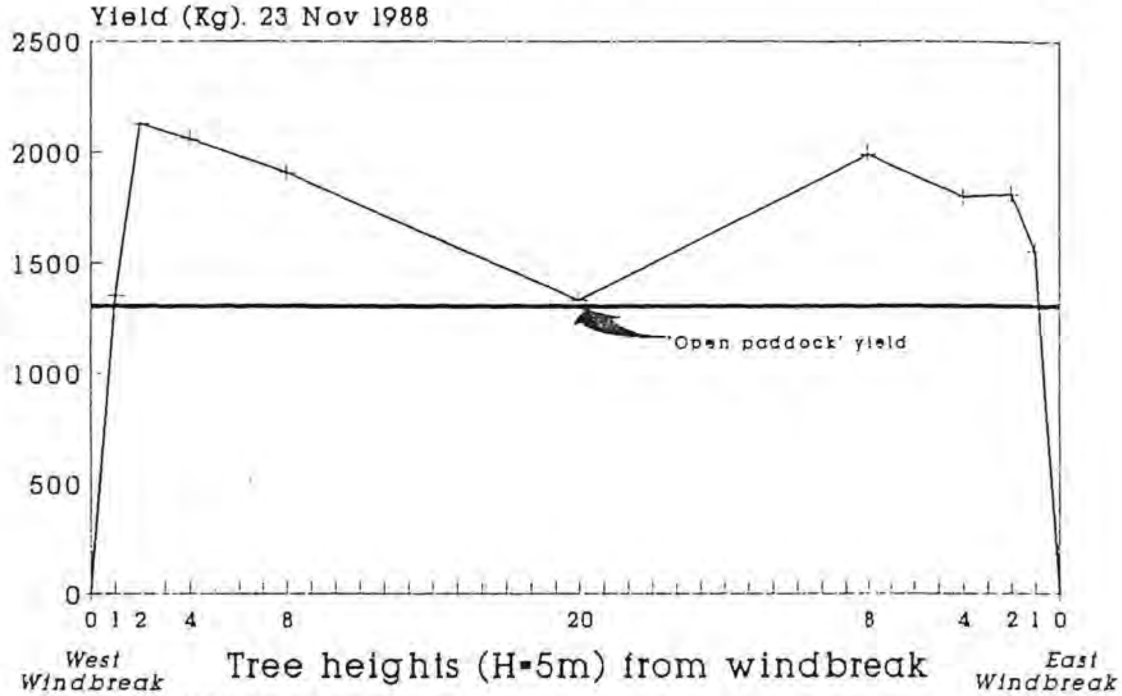
WINDBREAK ON SHEEP PRODUCTIVITY
'Jangarri' - Gibson



David Bicknell, NSCP Landcare Project

Fig 5

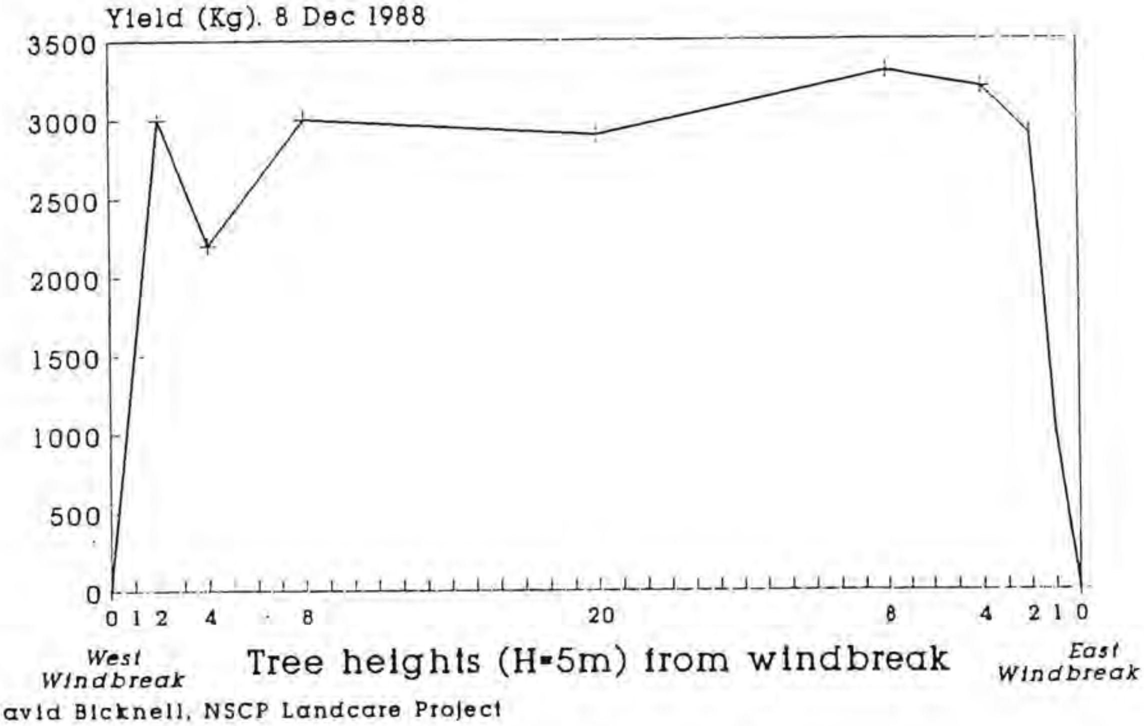
WINDBREAK EFFECT ON CROP YIELD
Lupin yield between parallel windbreaks



David Bicknell, NSCP Landcare Project

Fig 6

WINDBREAK EFFECT ON CROP YIELD
Oat yield between parallel windbreaks



David Bicknell, NSCP Landcare Project

Fig 7

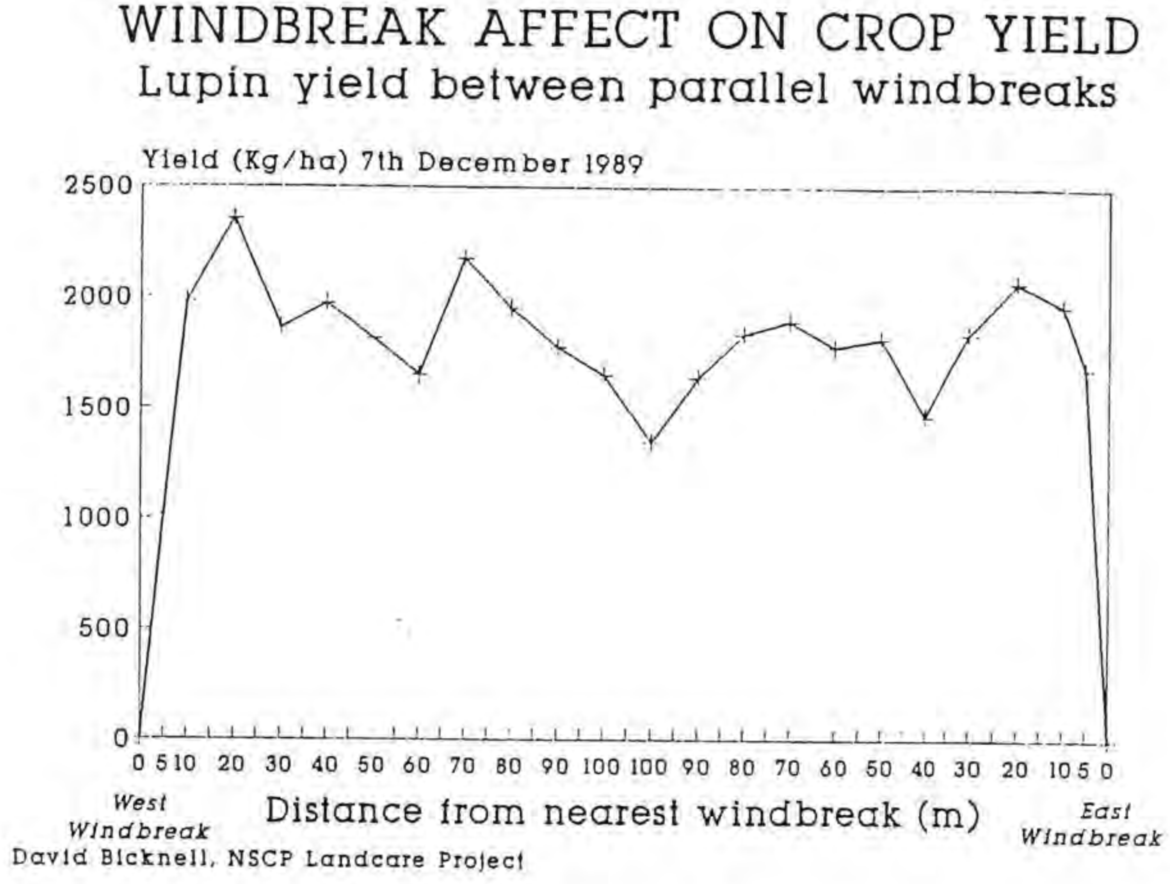
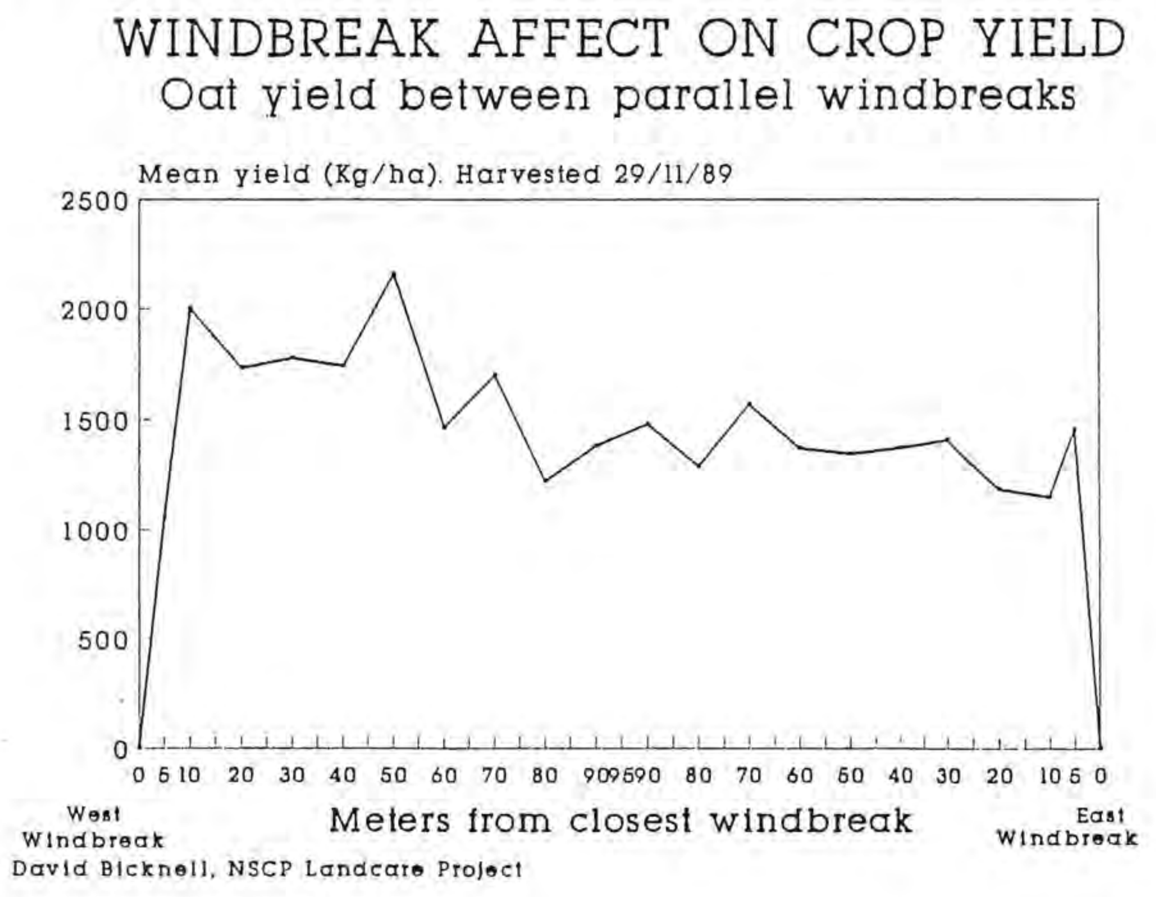

WINDBREAK AFFECT ON CROP YIELD
Lupin yield between parallel windbreaks
Yield (Kg/ha) 7th December 1989
2500
2000
1500
1000
500
0
0 5 10 20 30 40 50 60 70 80 90 100 100 90 80 70 60 50 40 30 20 10 5 0
West Windbreak
Distance from nearest windbreak (m)
East Windbreak
David Bicknell, NSCP Landcare Project

Fig 8


WINDBREAK AFFECT ON CROP YIELD
Oat yield between parallel windbreaks
Mean yield (Kg/ha). Harvested 29/11/89
2500
2000
1500
1000
500
0
0 5 10 20 30 40 50 60 70 80 90 95 90 80 70 60 50 40 30 20 10 5 0
West Windbreak
Meters from closest windbreak
East Windbreak
David Bicknell, NSCP Landcare Project

Variation in yield across the paddock is more evident with more measuring points (see an explanation below). However, the yield increase due to windbreaks has been estimated at 30 per cent between the windbreaks. About 17.5 per cent was from the Western windbreak, and 12.5 per cent from the Eastern windbreak.

This gives a nett yield increase of 22 per cent (allowing for the land taken up by the windbreaks).

Oats in 1989 appeared to respond to the Western windbreak and not the Eastern windbreak (Fig 8). This has not been estimated yet. It appears to be about 10 per cent gain between the windbreaks; giving about 2 per cent gain nett.

There are several problems interpreting this information. There is a complex interaction between the elements of the system; it should not be compared to a set of imposed treatments such as in a crop variety trial.

The cropped area between windbreaks is 200m by 2000m. The planting, fertilizing and harvesting machines are not exactly the same width, and therefore there are lines of higher and lower yields along the long axis of the paddock. This effect in one crop year then affects the following crop in the rotation.

Weather that affects crop growth differs between years, and therefore gives widely differing responses to the windbreak.

Les Webster, farming East of Esperance, recorded a 47 per cent yield increase in the lee of a three year old windbreak. Three rows of *Pinus pinaster* were planted on the North-West side of a sand paddock. The wheat crop was sandblasted several times at the beginning of the season.

From the one year's results, it was estimated that investment in a windbreak gave an annual interest return of 40.6 per cent. The windbreak is now taller, and continuing to work *especially* in the worst seasons.

WIND AND WINDBREAKS

Tree windbreaks are highly variable between sites, species, design and so-on. To interpret the value of a windbreak, it is necessary to understand its design and management in the field.

A common recommendation is to have a 'porosity' of about 50 per cent. This is thought to allow a longer lee effect and reduce turbulence. However, there are more likely to be 'holes' in high porosity windbreaks established in agricultural areas. Denser windbreaks give more protection close up, and may be able to avoid turbulence problems.

An example is given in Figs 9 and 10. Fig 9 shows the windspeed recordings for a single line, mature *Pinus pinaster* windbreak, about 20 meters tall. The porosity along the line was not even. Points to note are the relatively high windspeed close to the trees (all measurements taken at 1.5 m), and the level of turbulence. Turbulence is indicated by the high 'gusting' windspeed and its variability.

The windbreak in Fig 10 is a three line, mature *Pinus pinaster* planting about 20 meters tall. Porosity is lower, and more even along the line. Note that there is low windspeed next to the trees, and that the gusting and steady windspeed rise steadily with increasing distance from the windbreak.

Windbreaks in the Garry English example above are three row *Pinus radiata* with low porosity in the bottom half of the trees, and increasing porosity toward the top. Windspeed recordings reflect this (Fig 11).

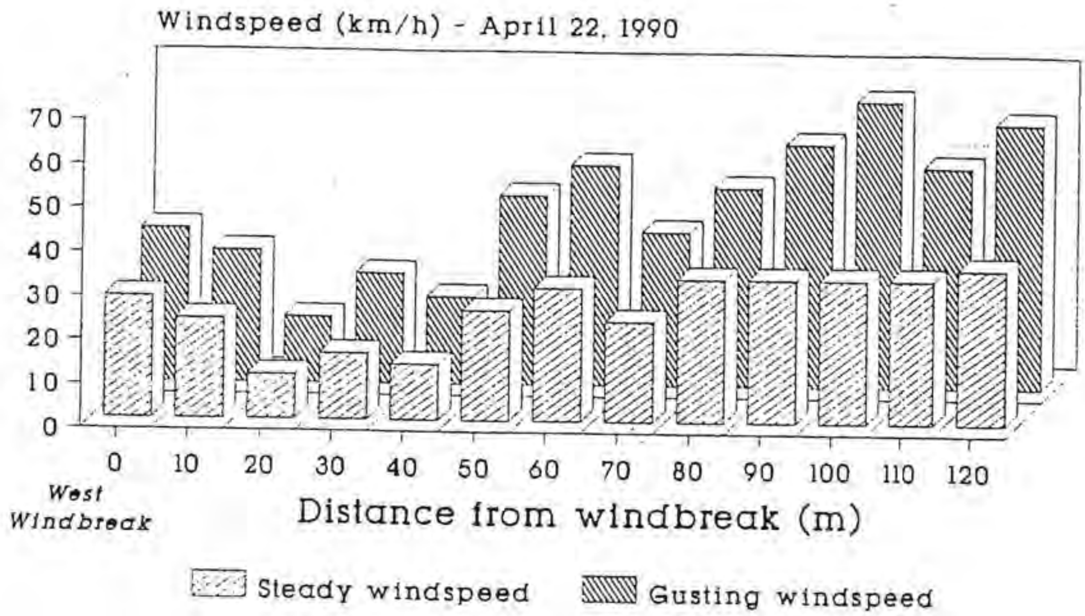
Note that the relative, or per centage reduction in windspeed, <u>may</u> be independant of windspeed, but the contrrol of eosion is a more important measure.

There are 'thresholds' of windspeed for erosion to occur (5 to 8 meters per second at a given height ?), above which the erosiveness increases as the cube of windspeed. Small reductions in windspeed therefore have a large affect on erosiveness.

Windbreak design and layout can be planned, knowing the 'wind-roses' and the erosion risks for a given site.

Fig 9

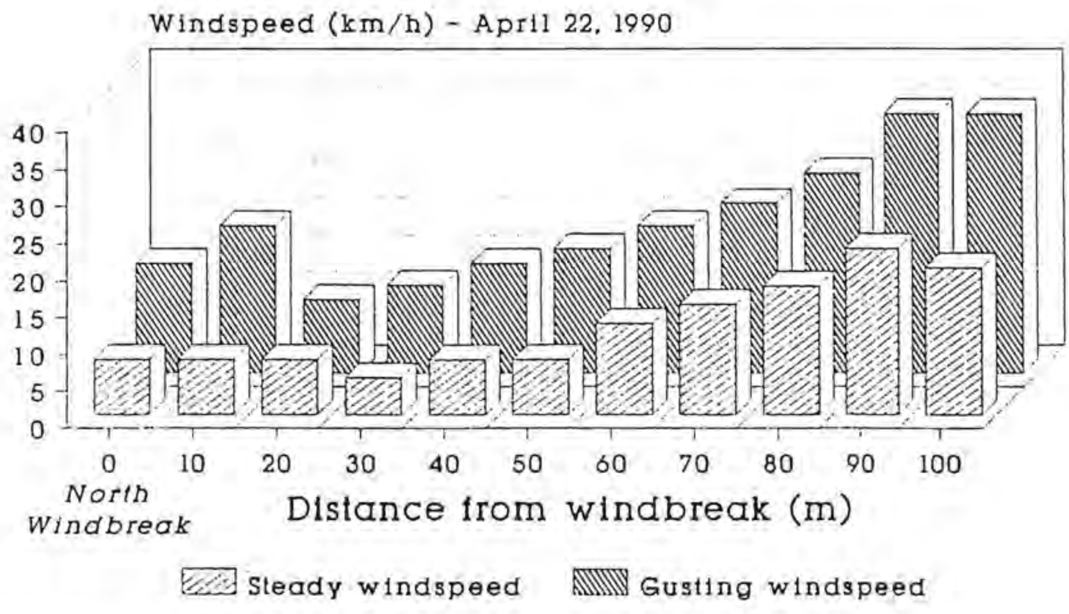
WIND SPEED READINGS
R Silburn - Pine windbreaks
North Westerly wind



David Bicknell, NSCP Landcare Project

Fig 10

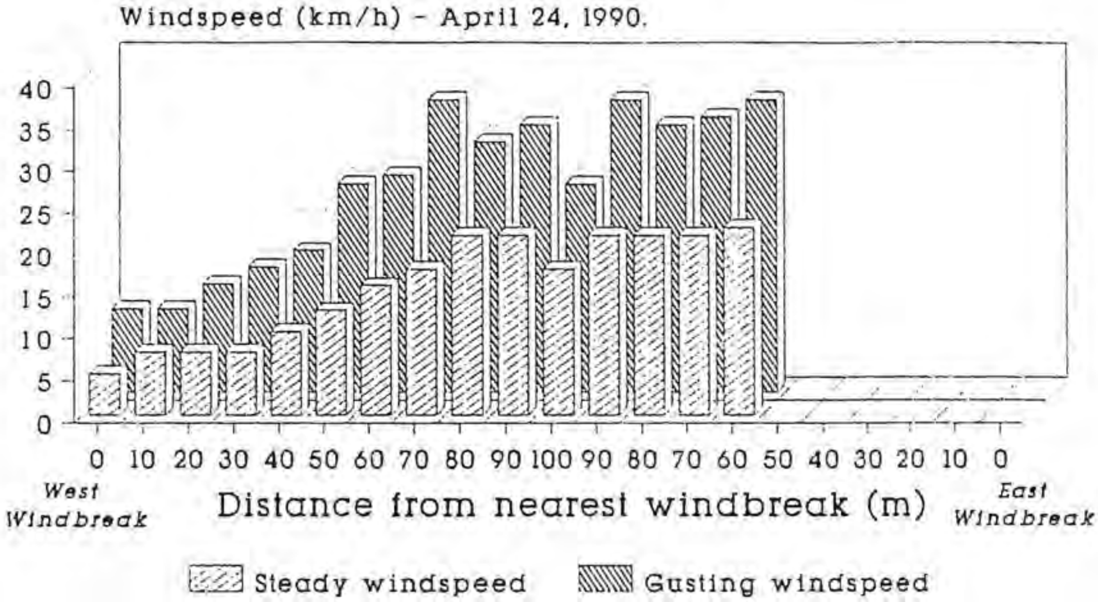
WIND SPEED READINGS
R Silburn - Pine windbreaks
North Westerly wind



David Bicknell, NSCP Landcare Project

Fig 11

WIND SPEED READINGS
G English - Pine windbreaks
West South West wind



David Bicknell, NSCP Landcare Project

<u>REFERENCES</u>

13 Lynch J J and Donnelly J B (1980) <u>Changes in pasture and animal production resulting from the use of windbreaks</u> Aust J Agric Res. 31:967 - 979.

14 Bottomley G A (1979) <u>Weather conditions and wool growth</u> in <u>Physiological and environmental limitations to wool growth</u> p 127. Eds J L Black and P J Reis, Uni New England Publ Unit: Armidale.

15 Hopkins P S and Richards M D (1979) in <u>Physiological and environmental limitations to wool growth</u> p 321. Eds J L Black and P J Reis.

16 Caborn J M (1957) <u>Shelterbelts and micro-climate</u> Forestry Commission Bulleting No 29, Edinburgh H M Stat Office.

17 <u>Windbreak Technology</u> Eds J R Brandle, D L Hintz and J W Sturrock. Rock Int Symp on Windbreak Technology, Nebraska June 1986. Elsevier 1988.

18 <u>Windbreaks and Shelterbelts</u> World Meteorological organization Tech. Note No 59 Switzerland 1964.

19 Bicknell D (1990) <u>Windbreaks and Shelterbelts on Farms</u> in <u>Agroforestry - Integration of trees into the agricultural landscape</u> Ed P Scott. WA Department of Agriculture, Division of Resource Management Tech Report No 102.

20 Bicknell D, Vincent D <u>Sheep and pasture productivity in relation to as young *Pinus radiata* windbreak</u>. Unpublished. Part of a National Soil Conservation Program project, Esperance CALM, WA 1989.

21 Kort J (1988) <u>Benefits of windbreaks to field and forage crops</u>. In "Windbreak Technology" Eds J R Brandle, D L Hintz and J W Sturrock. Elsevier 1988.

22 Sturrock J W (1981) <u>Shelter boosts crop yield by 35 per cent: Also prevents lodging</u> NZ J Agric., 143: 18 - 19.

23 Bicknell D, Vincent D <u>Young *Pinus radiata* windbreak affect on annual crop yield</u> Unpubilshed Research Project Plan RRP No 60/88. Part of a National Soil Conservation Program Project, Esperance CALM, WA 1988.

R E F E R E N C E S

1 Bird P R (1984), Effect of Trees on Agricultural Productivity. In Proc. Symp "Focus on Farm Trees II". Uni New England, Armidale May 1984. Canberra Publishers and Printing Company, Canberra.

2 Baker S K, Chapman H M and Williams I H (1982). Losses of sheep after shearing due to adverse weather. Proc Aust Soc Anim Prod. Seminar at Darkan, WA.

3 Buckman P G (1982). A survey of post shearing losses following summer rain in South Western Australia. Department of Agriculture, Narrogin. Unpublished (?).

4 Arnold G W and Dudzinski M L (1978) in Ethology of free-ranging domestic animals. Elsevier.

5 Obst J M and Day H R (1968). The effect of inclement weather on mortality of Merino and Corriedale lambs on Kangaroo Island. Proc Aust Soc Anim Prod 1968 7: 239 - 242.

6 Donnelly J R (1984). The productivity of breeding ewes grazing on lucern or grass and clover pastures on the tablelands of South Austral. III Lamb mortality and weaning percentage. Aust J Agric Res 35: 709.

7 Hutchinson J C D (1968). Deaths of sheep after shearing. Aust J Agric Anim Husb 8: 393.

8 Alexander G, Lynch J J, Mottershead B E and Donnelly J B (1980). Reduction in lamb mortality by means of grass wind-breaks: Results of a five year study. Proc Aust Soc Anim Prod Vol 13.

9 Egan J K, Thompson R L and McIntyre J S (1976). An assessment of overgrown Phalaris tuberosa as shelter for newborn lambs. Proc Aust Soc Anim Prod 11: 157 - 160.

10 Ive J R (1986). The value of tree windbreaks for reducing lamb mortality on sheep properties in South-Eastern Australia. Proc Int Symp on Windbreak Technology. Eds D L Hintz and J R Brandle. Great Plains Ag Council Publ No 117.

11 Mc Laughlin J W, Egan J K, Poynton W McL (1970). The effect upon neonatal lamb mortality of lambing systems incorporating the use of partial and complete shelter. Proc Aust Soc Anim Prod, 8: 337 - 343.

12 Bird P R, Lynch JJ and Obst J M (1984) Effort of shelter on plant and animal production Proc aust Soc Anim Prod 15:270.

..../2