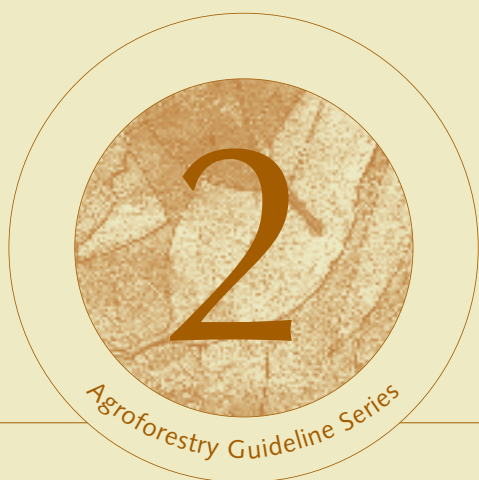
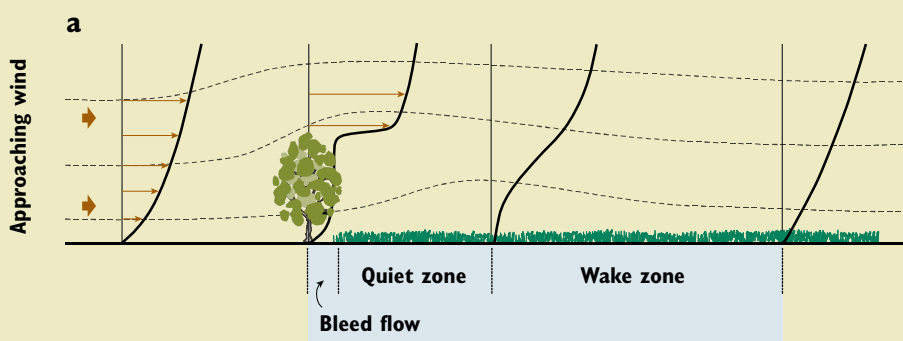
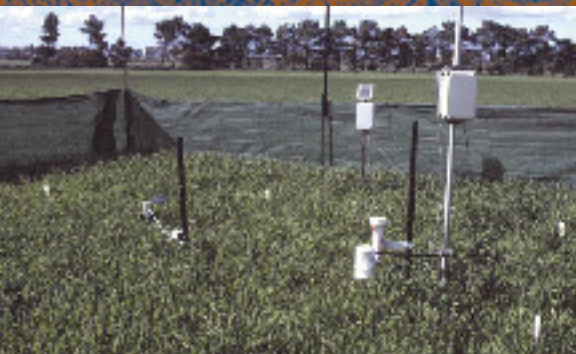
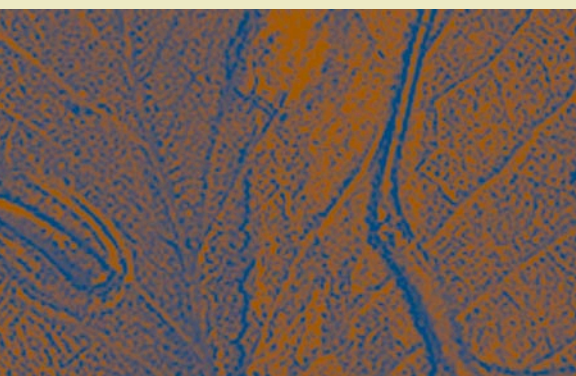




Trees for shelter

A guide to using windbreaks on Australian farms

by Helen Cleugh



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Trees for shelter – a guide to using windbreaks on Australian farms

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Foreword

The National Windbreaks Program was launched in 1993 in response to the growing recognition of the potential value of planting trees on farms — to both increase production and counter land degradation. It sought to quantify some of the impacts of windbreaks, particularly their effects on water use, crop and pasture growth, on Australian farms. A 5-year research program involving scientists from State governments, universities and CSIRO, this was by far the most comprehensive study of windbreaks undertaken in Australia.

Trees for shelter — a guide to using windbreaks on Australian farms draws upon the findings from the National Windbreaks Program, and subsequent research into the role of wind damage, to explain the way that windbreaks work; their effect on those factors that might limit productivity; and how to design and maintain an effective windbreak system. It is a resource for farmers, land managers and policy makers to assist them with the challenge of realising the potential environmental and economic gains of integrating trees into farming systems.

The research material that underpins most of this book (apart from those sources provided in the footnotes) was sourced from papers published in the *Australian Journal of Experimental Agriculture*, Volume 42:6, 2002. This publication presents the complete findings from the National Windbreaks Program.

Simon Hearn
Managing Director
June 2003

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The talent and efforts of Bob Lehane, the science writer who authored much of the text, are gratefully acknowledged. Bob turned many complex and technical research papers into text that can be understood by anyone interested in the subject.

This book would not have been possible without the research, expertise and advice of the National Windbreaks Program participants, especially Rod Bird, Simon Brooks, Peter Carberry, Michael Crawford, Tim Jackson, Holger Meinke, Stephen Mylius, Ian Nuberg, Rob Sudmeyer, and Amanda Wright. Mike Bennell also provided valuable help and support.

I acknowledge my employer, CSIRO Land and Water, and my colleagues for their support of the windbreaks research over the last 8 years. Special thanks to Greg Heath, illustrator, for his careful attention to creating figures that convey their message clearly and effectively.

And lastly, on a personal note, I am especially grateful to John for giving me the physical and mental space needed to complete this project, and the research that underpins it.



1

Why windbreaks?





What this chapter is about

This introductory chapter illustrates the potential for wind shelter to improve crop and animal productivity, especially in Australia. It maps out the structure of the book and how it should be used and concludes with a description of the National Windbreaks Program, whose results underpin much of the information presented.

Along with drought, flood and extreme temperatures, strong winds are among the major natural causes of crop and animal production losses. Probably since the beginnings of agriculture farmers have recognised the value of shelter provided by rows of trees or shrubs planted as windbreaks. The shelter protects soil, plants and livestock from the damaging effects of wind and, together with the effects of shade, alters the surrounding microclimate. Windbreaks thus have the potential to affect agricultural productivity through their impacts on animal production and by modifying the growth rates of plants, the amount of water used, and final crop yields.

Simulated yield changes as a result of wind shelter for maize, mungbean and wheat crops grown in Australia illustrate this potential. Figure 1.1 shows, on average, the effects of wind shelter on crop yields. Importantly, the long term average yield at all sites never showed a decline — while negligible at some sites, the change in yield was always positive. The largest gains, of about 20%, were simulated at locations with lower cropping season rainfall and thus a higher probability of terminal water deficit at grain fill.

The challenge for farmers is to translate these potential yield gains into an economic gain at the farm gate. This requires understanding of the way that wind limits productivity, and the frequency and direction of these limiting winds, for their particular farming system and location. They need to account for the costs associated with establishing and maintaining a viable windbreak, and identify what other products and benefits might flow from the windbreak itself.

This book provides the technical information needed for these tasks by drawing on the findings of the National Windbreaks Program, and a complementary project that succeeded the National Windbreaks Program that explored the role of wind damage in agricultural productivity.¹ This was a comprehensive, 5-year, research

¹ Bennell, M. and Cleugh, H. (2002), Integrating Windbreaks into Southern Australia Farming Systems: Managing the Impacts of Severe Wind Events. Final Report to RIRDC.

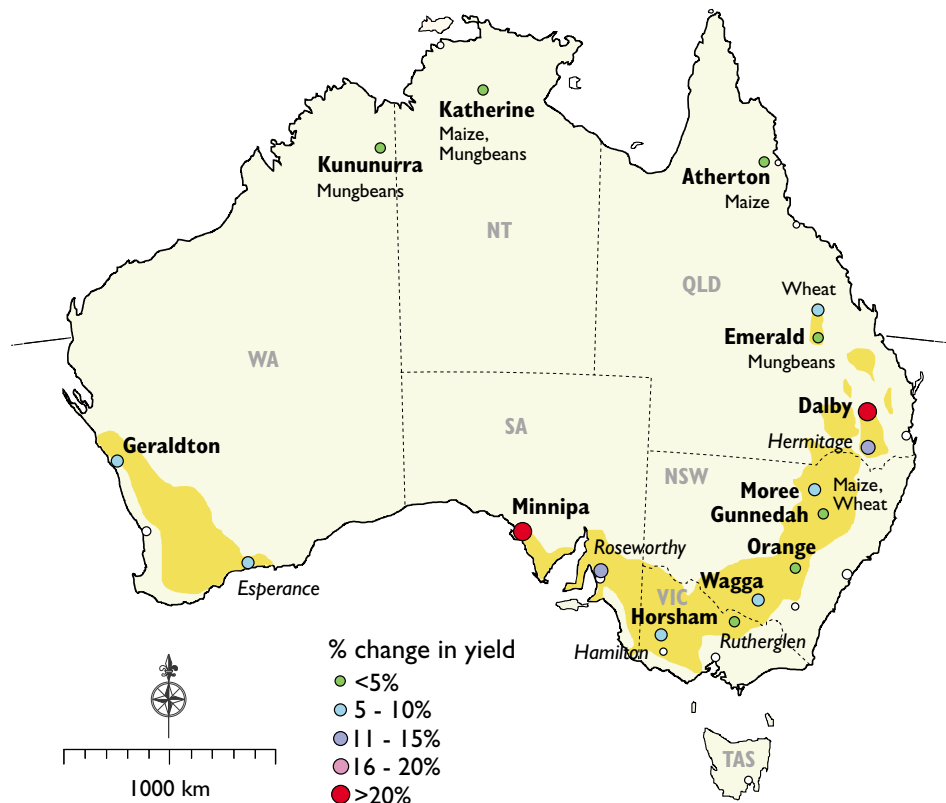


Figure 1.1 This map of Australia illustrates the main cereal growing regions of Australia (yellow region) and computer-generated predictions of the effect of wind shelter on yields for the indicated crops, averaged over 20 years. These effects were simulated using the crop yield modelling system, APSIM, which is described in Focus Box 1.3, and the long-term climate record from each site. The field measurement sites used in the National Windbreaks Program are also shown in italics.

program investigating the effects of windbreaks on agricultural productivity in Australia, using on-ground measurements, wind tunnel experiments and computer modelling. The computer simulations used to generate Figure 1.1 were a key outcome of the Program, which is described in more detail later in this chapter following a discussion of the various mechanisms by which wind can affect farm productivity — especially in Australia.

Chapter 2 outlines the Program’s main findings on the effects of windbreaks on winds and microclimate. Chapters 3 and 4 then put these findings, and data from other research, into a practical context — showing how windbreaks can help in a variety of agricultural enterprises, how to use them most effectively and how to design an effective windbreak.

Effects of wind on the farm

There are many ways — direct and indirect — that wind can affect plant and animal production. The main ones are:

- **Wind erosion**

This varies from gradual blowing away of topsoil to major erosion events that, in extreme cases, can bury crops. The fine soil fractions, which are particularly susceptible to wind erosion, contain most of the nutrients and organic matter. So even low levels of erosion will gradually reduce soil fertility.

Along with soil type and soil moisture status, wind speed is the critical influence on the severity of wind erosion. Below a threshold speed very little soil movement occurs. Doubling the wind speed causes an eight-fold increase in erosion. By substantially reducing the force of the wind at ground level, windbreaks can play a major role in protecting paddocks from wind erosion.

- **Animal production losses**

In cold weather, strong winds greatly increase the cooling impact of the low temperatures on stock through the wind chill effect. Wet conditions make the situation worse. Losses of vulnerable animals — especially newborn lambs and newly shorn sheep — are likely.

Even in situations where stock survival is not threatened, shelter from cold winds makes animal production more efficient. Stock require less feed to maintain basic metabolism — therefore more goes to promoting weight gain, wool production and so on.

- **Physical damage to plants**

This can result from leaves and other plant parts rubbing together as the wind blows them around, leaves being stripped from plants, and sandblasting — wind-blown soil particles striking plants.

Harm to leaf tissue resulting from rubbing can increase rates of water loss from plants. Damage to fruits can reduce their value. Further losses can result from the increased disease susceptibility of damaged plants.

Leaf stripping is most common in plants with large leaves such as maize and potatoes, but in other plants tearing or folding of leaves can have similar adverse impacts. The greatest yield losses occur when the damage takes place between heading and flowering. In wheat, damage to the flag leaf, the carbohydrate source for the grain, can reduce final grain yields.

Sandblasting causes both abrasion of plant tissue and leaf stripping, tearing or folding. It usually occurs early in the growing season when the soil surface is fully exposed to the wind. Major impacts are reduced growth rates and delayed heading or blooming. The growth rate reduction is greatest in plants sandblasted soon after emergence.

- **Plant knockdown (lodging)**

This is the most obvious effect of strong winds. Lodging occurs when stems bend or break near the base or roots are displaced. It is most common at later stages in the development of plants, when they are at their maximum size, and reduced yields are likely if a mature crop lodges. Reasons for this include the greater shade and humidity that the crop will experience, with an accompanying increased risk of pathogen attack. Also, lodging creates difficulties in harvesting.

- **Changes to temperature, humidity and evaporation in the sheltered area**

Slight increases in air and soil temperatures and in humidity are important aspects of the changed 'microclimate' in the sheltered area in the lee of a windbreak. So is a tendency for soil moisture to be conserved as a result of reduced evaporation and protection of plants from high levels of evaporative demand. Impacts of these changes on crop and pasture growth are complex; later chapters look at them in detail.

- **Provision of shade**

This is particularly important for reducing heat stress in stock in tropical and subtropical climates. Extreme levels of heat stress lower productivity and can kill animals.

Other impacts of windbreaks on farm productivity

As well as providing protection against the damaging effects of wind, and changing the microclimate for plants and animals as a result of wind shelter, windbreaks can bring a range of other benefits that should also be considered. These include²:

- **Control of waterlogging and dryland salinity**

The number of trees planted in windbreaks will generally be insufficient to have a major impact on what is often a regional-scale problem resulting from excessive groundwater recharge. Windbreaks may, however, have a worthwhile effect at the paddock scale where they can help to ameliorate waterlogging through the possibility of increased water use by the windbreak trees. The design, layout and location of tree plantings whose purpose is to reduce salinity can be better planned knowing where on the farm wind shelter is also required. This ensures that multiple benefits can be realised from tree plantings.

² See Abel et al. (1997) for a much more extensive discussion of the multiple benefits of farm forestry.

While increased water use by windbreak trees can reduce local waterlogging, the trees will also compete with the adjacent crop or pasture for soil water and nutrients. Careful management is required to minimise productivity losses in this ‘competition zone’.

- **Control of erosion by water**

By intercepting and slowing runoff, windbreaks planted across slopes can protect the soil from erosion during periods of heavy rain.

- **Income from production of timber and other tree products**

Windbreaks can be designed and managed in a way that allows income-producing timber harvesting without compromising the provision of shelter.

- **Fodder source**

The leaves of windbreak trees may serve as an emergency feed source in times of drought.

- **Biodiversity and aesthetics**

Windbreaks enhance the biological diversity of the rural landscape, which can bring economic as well as aesthetic benefits. For example, trees bring birds and these may eat pest insects, reducing damage to crops. Other aesthetic benefits include the return of trees to cleared landscapes and greater scenic diversity.

Effect of wind shelter on crop yields and pasture production in Australia

The principal crops grown in Australia are cereals. Rice, maize and sorghum comprise most of the summer cereals, while wheat, oats, barley and rye — often grown in rotation with either a pasture or canola, field peas and lucerne — make up the winter cereals.

The cereal-growing belt extends from the western and southern parts of Western Australia through South Australia and Victoria and northwards into Central Queensland, as seen in Figure 1.1. It spans several climatic regimes: a Mediterranean climate with hot dry summers, cool wet winters and an annual rainfall of 250–600 mm; a dry temperate climate with seasonally uniform rainfall distribution (400–650 mm); and a subtropical climate with summer dominant rainfall (450–1000 mm).

Temperature and light seldom limit productivity in this cereal-growing belt, with the exception of some parts of south-eastern Victoria and NSW, and southern WA, that are prone to winter frost. While the cropping region has a moderate to high moisture availability on average, it also experiences considerable rainfall variability. As a result, the main climatic factor that limits productivity in much of Australia's cropping region is soil moisture availability.

Wind shelter is therefore likely to improve agricultural productivity if it conserves soil water, reduces crop stress resulting from high evaporative demand and improves crop water use efficiency. Amelioration of low winter temperatures — to enhance winter pasture growth and protect vulnerable stock — is another way that shelter can improve productivity in some of the upland areas of south-eastern Australia used for grazing and pasture production. Finally, in a landscape where wind erosion is a significant cause of land degradation, using windbreaks to protect crops from sandblasting is a potentially important source of ‘green insurance’.

The National Windbreaks Program

In response to growing recognition of the potential value of planting trees on farms — to both counter land degradation and increase production — the National Windbreaks Program was launched in 1993. This major 5-year research program, involving scientists from State governments, universities and CSIRO, sought to quantify some of the impacts of windbreaks — particularly the effects on crop and pasture growth. It was by far the most comprehensive study of windbreaks undertaken, both in Australia and overseas, with research sites located across Australia’s grain and livestock growing belt.

Overseas research had found that windbreaks can increase crop yields substantially, and two Australian experiments, had pointed to the possibility of yield increases of more than 20% in the zone extending out to a distance of ten or so times the windbreak height.

To gain a clearer picture of just what yield effects Australian farmers could expect, the National Windbreaks Program ran trials with various crop and pasture plants in a wide range of locations, which are shown in Figure 1.1 and detailed in Focus Box 1.1. Just as important, it explored in detail what was driving the changes. This involved experiments with simulated windbreaks in a wind tunnel (see Focus Box 1.2) as well as detailed measurements in the field. The Program focused on the role of microclimate as the primary mechanism affecting crop and pasture growth, with damage as a secondary mechanism.

The National Windbreaks Program took an integrated view, focusing on developing a thorough understanding of the interaction between windbreaks, microclimate and crop and pasture growth. Furthermore, the Program developed a predictive capability to both generalise and interpret the results from the field trials. The crop model APSIM, described in Focus Box 1.3, was modified to include the effects of shelter on crop growth. This has been used to indicate which agricultural regions, and crops, in Australia will gain the most economic benefit from the microclimate effects of shelter on crop yields (see Chapter 3).

Focus Box 1.1: The National Windbreaks Program: locations of experimental sites and research groups

Year and Location	1994	1995	1996	1997	1995	1996	1997
	Field windbreaks				Artificial shelters		
Esperance [33° 50'S 121° 53'E] (WA Dept of Agriculture)	lupins	canola	barley	lupins	lupins	wheat	
Roseworthy [34° 33'S 138° 42'E] (Roseworthy Agricultural College)	wheat, canola and faba beans in rotation					wheat	
Rutherglen [36° 7'S 146° 31'E] (Victoria Agriculture)	lupins	wheat				wheat	
Hamilton [37° 30'S 141° 55'E] (Victoria Agriculture)	grazed perennial pasture				perennial pasture		
Warwick [28° 37'S 151° 57'E] (APSRU)						mung beans	irrigated wheat mung beans
Atherton [17° 13'S 145° 34'E] (Qld Dept of Primary Industries)	maize and potatoes in rotation						

Focus Box 1.2: Using a wind tunnel to explore windbreak effects

CSIRO Land and Water’s experimental wind tunnel facility was used extensively in the National Windbreaks Program to investigate the effects of windbreak length, height, orientation and porosity, and of multiple windbreaks, on airflow, evaporation fluxes and microclimates.

The wind tunnel has a rectangular-shaped working section — about 18 m long, 0.6 m tall and 1.8 m wide. A large fan at one end blows air down through this working section, where it is conditioned to create airflow that is similar to what one would find outside. Typical wind speeds used in the wind tunnel range from about 20 to 40 km/h.

Scale models of windbreaks are placed well downwind in the working section (Figure 1.2). The floor of the wind tunnel is lined with 3 mm tall plastic pegs,

spaced 25 mm apart, which are embedded in a heated surface. This heated, rough surface and model windbreak are an excellent replica of a paddock of tall grass (approximately 0.7 m in height) growing around a 10 m tall windbreak on a spring day in south-eastern Australia.

Very sensitive sensors are mounted on a traversing system that moves to any position in the wind tunnel, under the control of a computer. These sensors measure very small fluctuations in the wind speed and air temperature. A full survey of wind speeds and air temperatures at all locations upwind, downwind and above the model windbreak is thus possible.



Figure 1.2 Scale model windbreak placed in CSIRO's wind tunnel. The floor is lined with a heated mat and pegs to mimic a warm, rough surface similar to tall grass.



Figure 1.3 A different windbreak configuration used in the wind tunnel

Focus Box 1.3: Agricultural Production Systems Simulator (APSIM)

APSIM is a computer modelling system developed by Australia's Agricultural Production Systems Research Unit (APSRU).³ Its purpose is to simulate agricultural production systems at the paddock scale. It is a daily time-step model based on knowledge of physiological, physical and chemical processes. It is 'driven' by information on the climate (solar radiation, rainfall, temperature, humidity and wind); soil (including parameters that determine the soil water balance, soil fertility and erodability); and surface cover (including the nature of any surface residue).

APSIM is a flexible software environment for simulating systems rather than a model of a particular cropping system. Within APSIM there is a library of modules, each describing specific processes, that can be combined in meaningful ways to represent an agricultural system. Modules can be either biological (eg. crop, pasture, surface residue), environmental (eg. water balance, nitrogen balance, soil erosion), managerial (eg. tillage, irrigation, fertilisation) or economic (eg. event log).

As part of the National Windbreaks Program, APSIM was modified to account for the effects of wind shelter on soil and plant water use, and thence plant growth and final yields, for wheat, canola and maize crops.

³ McCown, R.L., Hammer, G.L., Hargreaves, J.N.G., Holzworth, D.P. and Freebairn, D.M. (1996). APSIM: A novel software system for model development, model testing, and simulation in agricultural research. *Agric. Syst.* **50**, 255-271.