Shelterbelt Design Guidelines for Climate Change

Cardinia Shire Council

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DOCUMENT TRACKING

Project Name	Shelterbelt Design Guidelines for Climate Change
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Status	**Final**
Version Number	**V12**
Last saved on	**7 February 2022**

This report should be cited as 'Eco Logical Australia 2020. *Shelterbelt Design Guidelines for Climate Change* . Prepared for Cardinia Shire Council.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from Cardinia Shire Council, Port Phillip and Westernport Catchment Management Authority, Western Port Catchment Landcare Network, Bunyip Landcare Group and the landholders of Garfield, Garfield North, Bunyip and Tynong. Eco Logical Australia wishes to acknowledge the Bunurong people of the Kulin nation, the Traditional Owners of Bunyip and surrounding areas.

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Executive Summary

The *Shelterbelt Design Guidelines for Climate Change* have been developed through consultation with landholders who were affected by the 2019 Bunyip Fire Complex and aim to provide key information needed to design and construct shelterbelts that are resilient to climate change and assist in mitigating the local climate change impacts including higher temperatures, reduced rainfall and more extreme weather events including drought, heatwaves, bushfires and intense storms. It also provides easy access to key recommendations on shelterbelt orientation, planting density, location, species selection and maintenance to adapt to climate change, increase agricultural production, protect built assets and enhance biodiversity.

Shelterbelts have been used for decades to reduce the impacts of extreme weather conditions across agricultural areas and to favourably change local climatic conditions to optimise crop and animal production. Strong winds, together with drought, flood and extremes of temperature are among the major natural causes of crop and animal production losses and these impacts are predicted to increase in severity under climate change. Most shelterbelts in southern Australia were established to reduce crop and livestock exposure to the extremes of wind and temperature created after the original landscape was cleared.

In 2019 the Bunyip Fire Complex severely impacted the townships of Bunyip North, Tynong North, Garfield North and Tonimbuk. Following the 2019 bushfires, it is timely that the design of shelterbelts is revisited to include climate change considerations.

The Guidelines demonstrate that there are significant benefits to be gained from planting shelterbelts under climate change and provides details on:

- The benefits of planting shelterbelts.
- How to plan and design shelterbelts that will mitigate climate change impacts.
- How to select species that will survive future climatic conditions,
- Site planning and preparation.
- Shelterbelt management.
- Example design principles to assist whole of farm planning.

1. Introduction

In 2019 the Bunyip Fire Complex severely impacted the townships of Bunyip North, Tynong North, Garfield North and Tonimbuk. Around 15,000 hectares was burnt, and 300 properties affected. Anecdotal evidence from Bunyip Landcare members and landholders indicated that fire behaviour was variable across the area depending on shelterbelt orientation, length, species composition and other variables. Cardinia Shire Council has been granted funding to conduct research into shelterbelt designs which will inform landholders undertaking farm rehabilitation and future whole farm planning.

Cardinia Shire Council has developed *Shelterbelt Design Guidelines for Climate Change* (the Guidelines) for landholders across the Cardinia Shire and beyond. The focus is on farm shelterbelts, but the design principles can be applied to a range of rural properties. Developed in consultation with landholders, the Guidelines are informed by an extensive literature review, interviews and site visits which occurred across a range of properties with differing shelterbelt design, topography, orientation and species selection. Landholder observations and anecdotal evidence are included as quotes throughout this report.

When original shelterbelts were placed in the landscape (some over 25 years ago) climate change was not the foremost consideration. Historic planting arrangements, species composition and design of shelterbelts is not consistent with current and future climate. This publication provides information on designing shelterbelts to better cope with the predicted impacts of climate change. This includes designing shelterbelts to minimise the effects of bushfire on properties, increase resilience to drought and provide multiple benefits to biodiversity and agricultural productivity.

Section 2 provides an overview of the benefits of shelterbelts.

Sections 3 and 4 highlight the effect of bushfire, the risk of climate change and subsequent modifications to shelterbelt design to mitigate climate change impacts.

Sections 5-7 are a guide to the planning and design process. There are five example shelterbelts with landscape cross-sections and design notes. These examples illustrate the design principles for shelterbelts in paddocks, adjacent to infrastructure, for wildlife, to buffer riparian areas and on hills/slopes. Shelterbelt designs may differ depending on the desired outcome (e.g. environmental benefit, protection of livestock, asset protection etc.) and landholders will need to consider the appropriateness of each design for their property.

Section 8 draws attention to the importance of planting preparation and maintenance.

Section 9 includes information on selecting suitable plants that are more resilient to climate change impacts, especially drought and increasing bushfire risk.

Section 10 provides a summary of shelterbelt design recommendations under climate change and further resources and references.

1.1 Scope

Designing shelterbelts for climate change involves planning, designing, planting and managing shelterbelts across a property to not only accommodate current climatic extremes but also those likely to be experienced over the growth and establishment phases of the shelterbelt. This demands that we look ahead and incorporate the likely future climate of 2030 to 2050 into the planning and design of new shelterbelts across Australia.

The Guidelines for climate change can be used to create new – or modify existing – shelterbelts. The Guidelines consider several factors that include:

- Understanding how climate change will affect key variables including rainfall, and temperature at the local scale.
- Creating shelterbelts that may reduce the predicted impacts of climate change at the local scale (e.g. drought and increased bushfire risk).
- The location, orientation, length, width and height of shelterbelts to meet on farm outcomes (e.g. ecological benefit, pasture improvement, reduction in fire risk).
- The need for ongoing maintenance.

These design guidelines are aimed at providing key principles for landholders to employ on their properties to improve the resilience of their agricultural system to a rapidly changing climate. The guidelines are intended to inform site specific implementation plans which would optimise the design of the shelterbelt to the specific climate, soil, water availability, exposure and aspect considerations at each site.

The guidelines have been prepared based on the latest climate projections available in 2021. Already, the climate projections for Victoria out to 2050 show extreme heat and fire conditions which we have not experienced in our recorded history in Australia. Under these conditions; namely prolonged heatwaves with temperatures above 50°C, extreme and prolonged drought and severe winds producing catastrophic fire danger; the integrity and resilience of both shelterbelts and the agricultural systems they are designed to protect will be severely compromised and catastrophic failure is plausible.
Design principles can only assist in reducing the threat of climate change impacts to an upper bound. Risk mitigation and adaptation potential in broadacre agricultural systems have an upper limit beyond which the controls and treatments for risk of extreme phenomena such as severe heatwave, drought and fire will be rendered futile. Without a significant reduction in global carbon emissions the climate of Cardinia Shire is likely to experience a greater frequency of days, months and years with unprecedented drought, heatwave and bushfire impacts. The rapidly increasing threat posed by these phenomena cannot be designed out of any system which uses combustible organic material for production or protection in the landscape, including shelterbelts. These design guidelines therefore need to be assessed along with an implementation plan which specifies the likely set of tolerable limits for shelterbelt establishment, maintenance, resilience and recovery from climatic impacts at each site. If the climate continues to be forced beyond these limits then there is a clear risk that the shelterbelts will not be able to serve their intended function, they may be severely compromised and in extreme situations add to the fuel available for a catastrophic fire event.

1.2 Purpose

Climate shifts pose a significant threat to natural environments, infrastructure, and communities now and in the future. Climate change is increasing the intensity, frequency and duration of both heatwaves and drought conditions, in Australia's southeast. This is driving an increase in dangerous fire weather, and the frequency and severity of bushfires across the region.

Victoria is one of the most bushfire prone areas in the world. The combination of vegetation, climate and topography creates ideal conditions for bushfire. Population growth in high risk locations means that these community need to be well prepared for bushfires. Shelterbelts that utilise appropriate design principles and plant selection can reduce the likelihood of climate change impacts to crops, livestock and infrastructure at the local scale.

A holistic approach is the best way to ensure proper climate change preparation for your land. These Guidelines should form part of a combination of bushfire and climate change protection and mitigation measures. These include:

- House and building design, siting, construction and maintenance.
- Whole of farm plan (e.g. annual preparation of fire breaks, intensively grazed areas near assets and infrastructure, provision of effective firefighting equipment, weed control, species selection for plantings and crops).
- Shelterbelt Implementation Plan
- Erosion Management Plan
- Preparing a Bushfire Survival Plan.

These guidelines should be used to inform separate site specific Shelterbelt Implementation Plans which then form a fundamental component of integrated climate change management plans across rural landholdings. In the development of the implementation plans landholders will likely have to confront necessary trade-offs associated with designing and implementing shelterbelts for future climate change. Some of these trade-offs will be relatively minor such as selecting species for better drought tolerance results less wind protection, less shade and/or slower growth. Other trade-offs in the implementation plans may be more significant such as high planting density to provide the best wind protection on an exposed site producing a higher fuel loading which could result in an intense fire and downwind ember attack. It important to carefully consider these trade-offs at each site and understand how reducing one hazard such as wind chill or wind erosion could result in an increased risk of another hazard such as fire or drought impact.

2. Shelterbelt benefits

Shelterbelts provide a variety of benefits that need to be considered when deciding on whether to include them as part of a whole of farm plan. Key benefits of shelterbelts to properties are summarised in Table 1.

> *"All aspects of our farm were improved due to the presence of shelterbelts."* Garfield North landowner

Table 1. Shelterbelt benefits

	Benefits of shelterbelts
Crops and pasture	Decrease wind speed reducing plant damage [1,2]. Encourage earlier germination; plant growth and improved water use efficiency[3,4]. Provide protection from extreme weather events such as frost[5,6] Improve growing conditions in the area 5-25 times the height of the shelterbelt, by warming soil temperature and increasing humidity Reduce erosion by decreasing wind speeds and water flows, holding soil together, and increasing infiltration [7] Trees can extract nutrients from deep in the soil and concentrate them in the surface layer. This positive effect on nutrient cycling has a positive influence on pasture growth in the vicinity of the trees[8]. E.g. acacias fix nitrogen in the soil, enhancing pasture growth.
Livestock	Increased live weight gain, with experiments showing that strong wind and rain events can double the need for energy for maintenance for sheep and cattle[9–12] Reduced loss of newborns, lower mortality, higher fertility, and reduced incidence of some diseases[9,10,13]. Provision of shelter reduces this stress, and therefore reduces maintenance costs such as food supplementation[5].
Biodiversity and ecosystem services	Encouraging habitat and food sources in shelterbelts for beneficial fauna can help prevent insect pests from reaching levels where damage occurs[14,15]. Permanent strips of vegetation within a field such as a shelterbelt may attract beneficial fauna year-round, especially insects, birds and bats[16,17]. Birds also perform important ecosystem services such as pollinating plants and dispersing seeds. A healthy bird community can remove 50% percent of the insects produced (about 30 kilograms per hectare per year)[17,18].
Economic	Increase in dairy milk production[9]. Increasing stock fertility, milk production and decreasing mortality of calves[10]. Improved efficiency of production (live-weight gain or milk output per unit of feed)[11]. Improved plant growth and increased pasture and crop production, by reducing moisture loss from soils and transpiration in crops and pastures[5,6]. Sheltered sheep show a 31% increase in wool production and a 21% increase in live-weight[5,10]. Pasture productivity in areas protected by trees is significantly higher than adjacent open sites. Productivity on average can be 26% higher per unit land area, with the largest effect occurring in winter[19]
Asset protection	Reduce wind speed by up to 30% and decrease the forward rate of fire spread by up to 20% in open grassland areas[20,21].

"The only thing we find is that some people see shelterbelts as the wick of the fire and that they promote fire, but I would like more people to look more to the benefits that they provide all of the other times, waterway protection, stabilisation and biodiversity."
Tynong landowner

3. Bunyip Complex Fire and Shelterbelt fire behaviour

3.1 Bunyip Complex Fire behaviour

The Bunyip Complex Fire burnt from 1 March to 8 March 2019. During this period, the Forest Fire Danger Index (FFDI) ranged from high (12-24) to very high (25-49). Fire behaviour was driven by high temperatures (>35°C) and north/north-easterly winds with average wind speeds ranging from 20 km/h to 30 km/h and wind gusts reaching up to 50 km/h. The fire was ignited by lightning in the Black Snake Range and Weatherhead Range in the Bunyip State Park. By mid-morning on the 2nd of March spot fires to the south between Helmet and Burgess Tracks emerged ahead of the main fire front. The main fire front burnt in a southerly direction and by late morning on the 2nd of March additional spot fires had emerged on private property to the south. By mid-afternoon on the same day fires ignited by spotting joined with the main fire front. On the 3rd of March 2019, a cool change led to a rapid fall in temperature and change in wind direction, spreading the fire into Garfield North, Tonimbuk and Maryknoll, eventually reaching the Bunyip River.

The fire led to extensive damage including the loss of 29 homes, livestock and other infrastructure (e.g. sheds and fences). The fire also caused significant damage to native vegetation and on-farm shelterbelts.

"Fire transferred at the ground level across the grass paddock on my property. The shelterbelts actually increased the intensity of the fire at the position of the shelterbelt. The Pinus spp. plantings on my property however prevented the fire spread into my house."
Bunyip North landowner

3.2 Fire behaviour in shelterbelts

Fire behaviour in shelterbelts is heavily influenced by topography, location, orientation, vegetation type and arrangement.

Shelterbelts situated at the top of hills or leading up a hill may be more prone to bushfire because as the slope increases so does the speed of the fire, its intensity and flame length, depending on fuel arrangement, compactness, and the height of the fuel bed. Flames and radiant heat preheat the vegetation ahead of the fire. This dries it out, making it easier to ignite. Higher intensity fires will consume larger and taller fuel elements than a lower intensity fire. The amount of fine fuels available on the ground, elevated fuels such as grasses, ferns and shrubs, and type of bark on trees has more influence on fire behaviour than the location of the fuels on the slope. However, there is a strong interaction between wind and terrain in influencing fire behaviour and locating shelterbelts midslope may assist in disrupting the connection of the wind with the terrain.

Shelterbelts placed at right angles to the wind direction slow the fire spread, while shelterbelts placed in line with the direction of wind can be used by the fire to travel at speed.

Vegetation composition in shelterbelts will affect the amount of fuel available and how easily a fire will spread throughout a property. If the shelterbelt is comprised of just trees, the fire can rapidly spread under the canopy into surrounding paddocks. Additionally, fire can crown into the tree tops generating a significant number of embers which can be carried kilometres by the wind.

Fine fuels such as leaf litter readily dry out, ignite and then be carried by wind as embers. Shrubs, low branches and other elevated fuel can act as ladder fuels, allowing fire to climb into the canopies of trees, significantly increasing bushfire intensity. Loose barked (candle barked) and rough fibrous barked trees have increased ember spotting potential.

Breaking up the continuity of the vegetation (for example through fire breaks) can limit the spread of fire and reduce the risk of fire impacting built assets. If the fuel is widely spaced, the flames from one fuel particle cannot easily heat and ignite the next fuel particle. This applies across the different fuel layers. For example, canopy length and load, and the distance from the surface fuel layer to the base of the live canopy, are fuel characteristics that influence crown fire potential and spread[23]. Horizontal fuel continuity also determines dead fuel moisture content dynamics and within-stand wind speed, and the sustainability of crown fire propagation[23].

3.2.1 Shelterbelts and the Bunyip Complex Fire

It is difficult to determine the impact shelterbelts had on the Bunyip Complex Fire behaviour. Anecdotal evidence from landholders suggests that shelterbelts oriented north-south acted to spread the fire across their properties and into surrounding bushland (ELA 2020). Shelterbelts oriented north-south would also be unlikely to have reduced wind speed, a key determinant in reducing the spread of fire. Figure 1 provides a visual representation of north-south orientated shelterbelts in the Bunyip bushfire complex fire extent which may have played a role in spreading the fire on private land.

> *"The fires ran up and down the shelterbelts and moved along the property via the shelterbelts – so no, I did not at all witness the shelterbelts reduce fire effect on my property or reduce fire spread."*
> Garfield North Landowner

Stakeholder interviews and site visits asked landowners to provide observations on the behaviour of fire on their properties. The following commonalities were identified:

- Shelterbelts increased the fire ferocity/intensity at most properties.
- Shelterbelts acted as a conduit for fire, particularly those oriented north-south (the fire direction).
- Shelterbelts spread fire into pasture areas at a small number of properties.
- Some species within shelterbelts (e.g. Blackwood (*Acacia melanoxylon*) were fairly fire-resistant.
- There was significant native vegetation regeneration post fire.

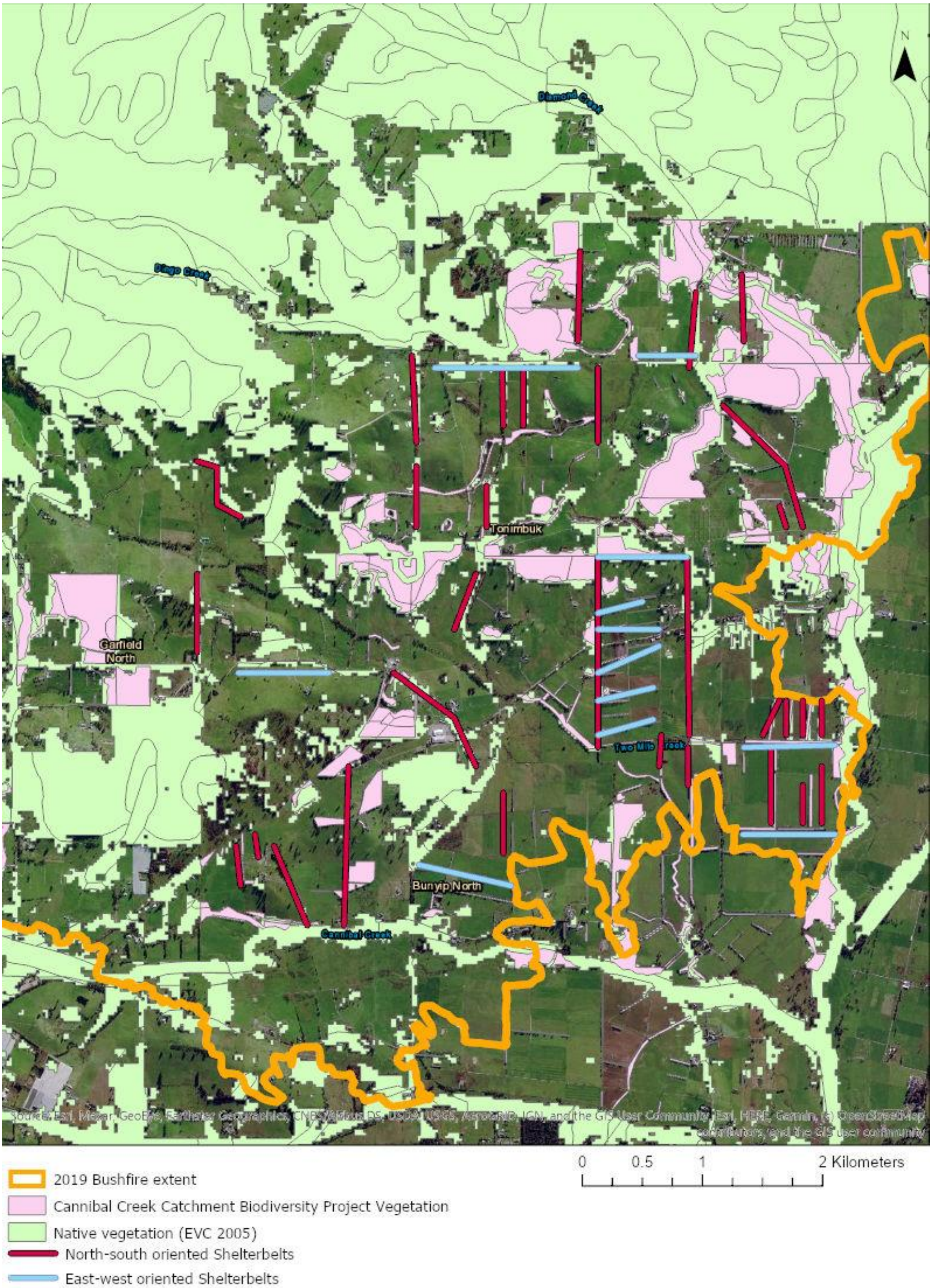


Figure 1. Bunyip fire complex extent, native vegetation and north-south oriented shelterbelts.

4. Climate change and shelterbelts

4.1 Current and future climate trends

Average summer maximum temperatures across Cardinia Shire have risen by approximately 1.5 degrees since 1970, while annual rainfall has declined by approximately 50 mm per decade[24]. Climate models suggest average summer maximum temperatures in the region will continue to significantly increase into the future. Current projections are for summers in the region to be approximately 2°C warmer than 1990 levels by 2050 if the world continues to release greenhouse gases in a business-as-usual growth scenario. This scenario, known as RCP 8.5, is used for all projection information in this section with global emissions continuing to track at or above this scenario over the past 20 years. This means extreme temperatures are expected to exceed 50°C across much of Victoria during the hottest days of future summers. The number of hot days above 35°C per year at Cranbourne is expected to increase from an average of 5.9 (1981-2010) to 13.6 (2040-2059) with a plausible range of up to 20 days per year.

Future climate extremes are projected to change significantly due to continued increases in greenhouse gas emissions. It should be recognised that it is the changes in such extremes and in compound climatic events, when multiple climate extremes occur in sequence or together, which pose the most significant threat to environments, infrastructure, and communities in the years ahead. Compound extreme events are especially important in Victoria which is susceptible to strong interannual climate variability produced by complex interactions of the El Nino and La Nina cycles of the Pacific interacting with the Indian Ocean Dipole cycles to the northwest of the continent.

A compound extreme event sequence which is particularly relevant to bushfire in Victoria is usually severe prolonged drought with severe heatwaves combined with extreme winds producing an extreme or even catastrophic bushfire risk across vast areas. The region is significantly exposed to compound climate extremes and natural hazards such as drought, bushfires, severe wind speeds and extreme temperatures, both very hot and cold. These hazards are projected to increase in frequency and/or severity [25]. Recent studies have confirmed a trend toward more frequent and severe compound climatic events across southern Australia with a high likelihood of events occurring which exceed any historical experience.

The worsening fire weather conditions in southeast Australia in recent decades, and projections of a warmer and drier future climate translate into even greater fire risk in the future [24]. There is high confidence that the number of fire days where the Forest Fire Danger Index is greater than the 95th percentile for 1986–2005 is projected to increase by 8 days per year by the 2050s under high emissions (or a 42% increase).The 95th percentile represents the worst 365 days of Forest Fire Danger Index values over the 20-year reference period, 1986-2005.[25].

Significant increases in evapotranspiration demand and drought conditions are projected across the Western Port Region - Average annual rainfall is projected to decrease from 1986-2005 averages by approximately 9%by 2030 and up to 20% by 2070[24]. Rainfall in the Western Port region is projected to decline in all seasons but especially in spring, with a 15% reduction by 2030 and a 30% reduction by 2080 compared to the 1986-2005 reference period. Reduced average rainfall, groundwater recharge reduced streamflow will also adversely impact on ecological values in the region. Values impacted are likely to include: waterway, wetland and vegetation health and the viability of maintaining vegetation in areas such as streetscapes, parks and shelterbelts [25].

4.2 Shelterbelts and climate change

Climate change will impact shelterbelts and the services they provide. Impacts anticipated to occur are:

- Increased temperatures may push local native species outside their climatic envelope or window of tolerance increasing plant mortality [26]. This may reduce the viability of planting local native species.
- Novel weeds may emerge in the landscape[27] and in shelterbelts. These could outcompete native plants, reduce biodiversity and increase maintenance costs to landholders[27]. If novel weeds are fast growing grasses or shrubs, prone to drying in drought conditions, they may also increase fuel loads and therefore bushfire risk on properties.
- Novel pest species may emerge which impact the species used in the shelterbelts, such as beetles and borers, resulting in dieback or death of individual trees or entire shelterbelt plantings
- Increased likelihood of droughts may reduce the available time for planting shelterbelts and increase maintenance costs (e.g. watering and or replanting to replace lost plants).
- Increased evapotranspiration demands combined with increased frequency, severity and duration of drought may result in dieback or death of shelterbelts planted with species with low or even moderate drought tolerance
- Increased intensity and frequency of fires may also result in increased loss of shelterbelts to fire. This will decrease overall environmental and agricultural benefits of shelterbelts if they cannot be replaced. In addition, increased fire frequency will increase replacement costs (e.g. fencing, replanting) and overall productivity for landholders.

Shelterbelts designed with climate change in mind may act to mitigate the local impacts of climate change by:

- Slowing surface water flow and increasing water infiltration, promoting the natural retention of water, thus reducing the impact of drought[28].
- Reducing soil erosion from floods as vegetation in shelterbelts intercepts and slows surface water run-off before it builds into damaging flow[28].
- Providing shade and shelter for livestock and native wildlife from the increasing severity and duration of heatwaves
- Acting as barrier against destructive windstorms and high winds, reducing soil erosion, mitigating crop damage and reducing impacts on livestock[1,6].
- Reducing the intensity and spread of bushfires by slowing windspeed and reducing ember generation.

4.3 Impact of climate change on shelterbelt design

Climate change impacts are likely to result in core modifications to shelterbelt design. This will include:

- Altering the location and structural components of shelterbelts.
- Changing the type of species to be planted.

4.3.1 Structural components

Climate change will require rethinking the structural components of shelterbelts (height, orientation, location to other shelterbelts and to built assets, length, width, shape and continuity/uniformity). This can include:

- Reducing the number of midstorey species to decrease the amount of ladder fuel (fuel that can carry a fire burning in low-growing vegetation to taller vegetation).
- Shelterbelts wider than 5-10 m to further reduce windspeed and slow the fire front.
- Ensuring shelterbelts are orientated to the prevailing winds – noting that these may vary across a property as a result of topography.
- Providing gaps between remnant vegetation, shelterbelts and built assets to reduce head fire width and flame length and provide less opportunity for bush fires impacting infrastructure.

4.3.2 Plant selection

Selecting local native species for planting under a rapidly changing climate may no longer be an appropriate methodology as local provenance plants may be unable to survive under climate change[29]. Shelterbelt design should therefore consider alternative methods to source plants for shelterbelts. This could include sourcing plants from a broader climatic range to ensure plantings survive under future climate change scenarios[29–31].

> *"The wattles, blackwoods, didn't seem to burn as hard, or didn't burn. Suckers have come up. A couple of areas (of blackwoods) in shelterbelts and they have all come back. Maybe there's not as much bark under them, so didn't burn as intense."*
> Bunyip Landowner

Future plant selection in shelterbelts could utilise tools to undertake 'climate readiness' analysis for revegetation. This includes web-based tools such as the Atlas of Living Australia (ALA). The ALA's search and analyse function can be used to identify whether a species currently occurring on a property will still be suited to the area under future climate change conditions[31]. ALA can identify the natural geographic range of a species and whether it may have potential to tolerate the conditions predicted to occur under climate change scenarios[31]. The climate analogues tool from the Climate Change in Australia website can also be used to assess locations which currently experience the climate projected to occur across Cardinia Shire out 2050 and beyond. Note that climate (temperature and rainfall) is only one factor that will determine whether a species will survive at a site. Soil, topography, microclimate, species interactions and a range of other factors will all influence whether a species has the capacity to survive and persist at a site.

5. Shelterbelt design

Climate change will influence how shelterbelts are designed and their effectiveness at mitigating climate change impacts. Key climate change modifications to shelterbelt design that need to be considered when planning for shelterbelts are outlined in the following sections.

"I'd like to see some guideline recommendations, specifically design specifications to discourage shelterbelts being a conduit for fire. I'd like information on particular species that are less flammable, and I'd like to understand the significance of the understorey and its effect on fire and wildlife." Tynong Landowner

5.1 Structural elements

5.1.1 Density and width

Density depends on the proportion of solid material, mainly branches and foliage within the shelterbelt. The optimum density of a shelterbelt depends on its purpose. A high-density shelterbelt provides shelter over a shorter distance and can provide maximum shelter for stock. However, a high-density shelterbelt creates turbulence on the leeward (sheltered) side of the shelterbelt and provides less shelter effects further away from the shelterbelt (Figure 2).

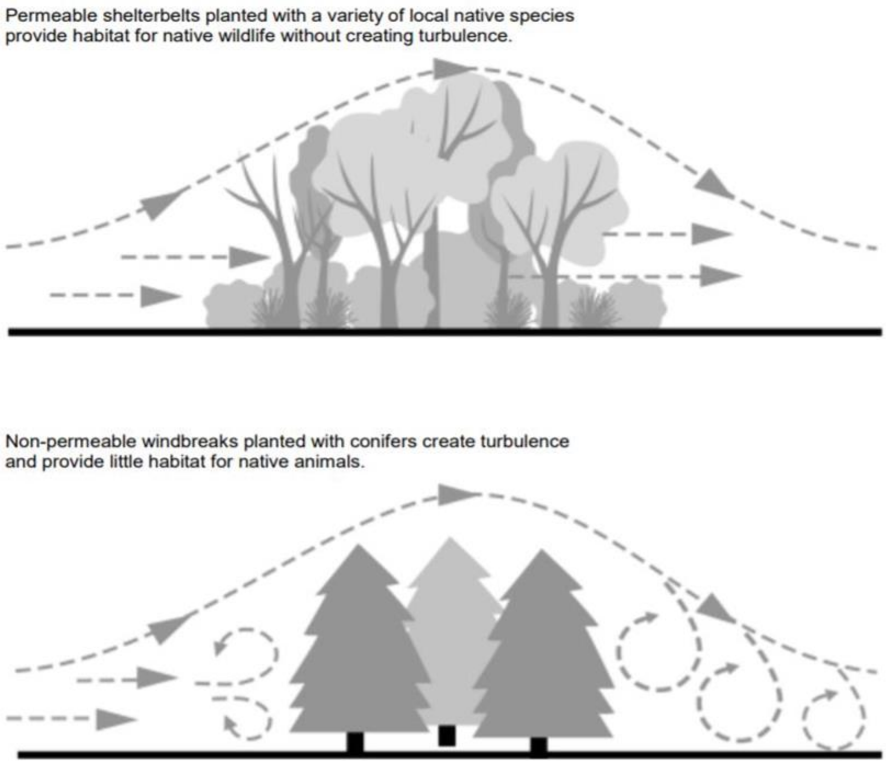


Figure 2. The effect of density (permeability) on wind flow and turbulence[39]

On average, a medium density shelterbelt (40-60% density) will be beneficial in reducing climate change impacts, particularly bushfire risk[20]. Planting at a consistent density of 40-60% across the length of a shelterbelt reduces the intensity and spread of bushfires by slowing windspeed and reducing ember generation. Moderate density plantings also provide other benefits under climate change including:

- Binding the soil and reducing erosion from wind and water.
- Mitigating flooding by reducing surface water runoff during high intensity rainfall events.
- Providing additional shade and shelter to livestock and crops, reducing heat stress caused by increased temperatures.
- Greater drought resilience than high density planting due to lower evapotranspiration demands

To increase the density of shelterbelts, use plants that comprise groundcovers, shrubs and trees and increase the number of rows in the shelterbelt. Plants can also be spaced closer together;

Table **2** gives the recommended plant spacing's within each row for a medium density shelterbelt. If the goal of shelterbelts is to reduce bushfire risk site design and implementation should ensure that there is discontinuity between fuel layers (i.e. a gap between shrubs and tree species at maturity; see Section 6 for more information), with consideration to planting guidelines within the bushfire site assessment area and defendable space.

Table 2. Recommended plant spacing's within each shelterbelt row

Height of mature vegetation	Plant spacing (metres)
Shrubs (up to 5 metres)	1.5-2.5
Medium trees (up to 15 metres)	2.5-4
Tall trees (above 15 metres)	3-4

Wider shelterbelts are preferable (greater than 10 metres). Wide belts provide a greater reduction in windspeed, further reducing the intensity and spread of bushfire across a property.

The width of a shelterbelt will depend on the function required for the shelterbelt. For example, if a small area is required to be sheltered with a high degree of protection, a denser, wider (e.g. 20 to 30 metres wide) shelterbelt with an even arrangement of species will be effective.

5.1.2 Height

The higher the shelterbelt, the larger the area of shelter provided (Figure 3). To maximise height, include at least one row of the tallest native species that grow in the region, and consider fast growing species. The shelterbelt should contain plants of different heights, with as many rows as possible, to reduce the possibility of gaps which result in an acceleration of windspeed, thus increasing the risk of fire spread.

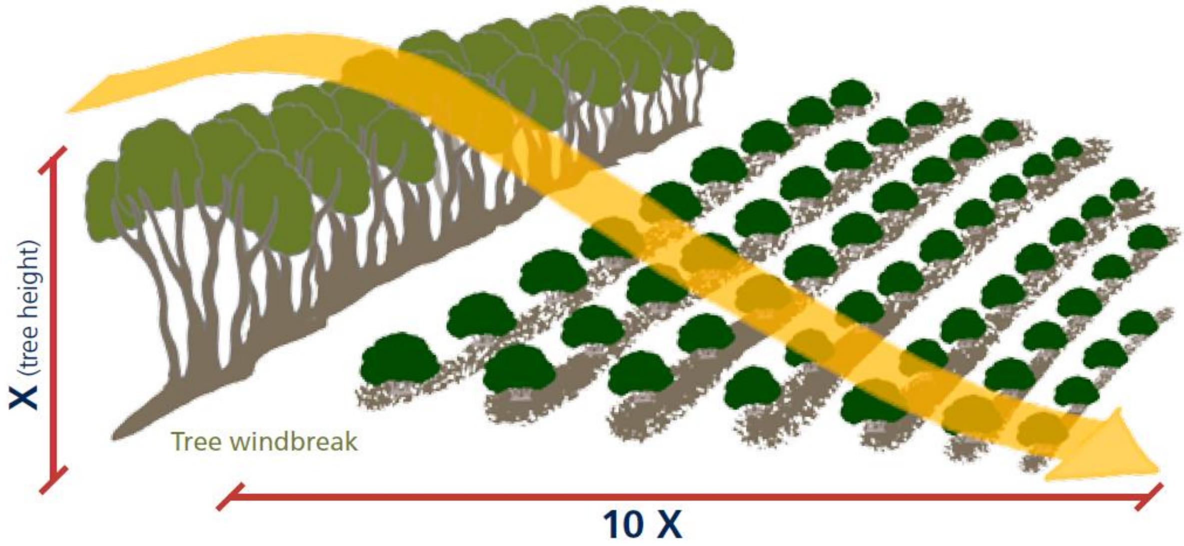


Figure 3. Protection offered by shelterbelt can be 10X the height of the tallest trees[6]

5.1.3 Number and type of rows

To maximise benefits, best practice shelterbelts are five rows wide, but 2-4 rows will still provide greater efficiency compared to single row shelterbelt designs[32]. Rows can be established by direct seeding or tube stock planting with the aim to achieve the desired five rows where possible. Increasing the number of rows in the shelterbelt has the added advantage of decreasing the impact of some of the plants not surviving the initial establishment period. Rows should be spaced between 2 to 4 metres apart to allow the plants to grow relatively unrestricted[32]. A five-row shelterbelt can consist of tall canopy trees planted in centre rows, with smaller bushy plants on the outside[20,22]. Planting only trees can create problems because wind flow will increase in speed, as it moves below the canopy, thereby reducing the effectiveness of the shelterbelt as a wind barrier.

Placing shrub species on either side of rows of trees has several benefits. It provides better habitat for wildlife, and larger tree branches are less likely to damage fencing if they fall. Shrubs on the outside rows also avoid being shaded out by the taller species. Growing a canopy of tall trees and layers of understorey trees and shrubs enhances diversity and structure within a shelterbelt and provides habitat for many kinds of beneficial fauna.

5.2 Layout

The direction of prevailing and other winds and the location of stock and crops that require protection are major deciding factors on the orientation of shelterbelts. Shelterbelts should be placed perpendicular to prevailing winds[33,34]. No single orientation of a shelterbelt will provide protection from all winds. Therefore, several belt orientations will provide greater shelter.

Although shelterbelts are commonly linear, for example following existing fence lines, non-linear shelterbelts are also effective. The incorporation of remnant vegetation will provide a cost-effective shelterbelt and one that enhances biodiversity values. Ideally shelterbelts should form a grid using north-south and east-west orientations, with shelterbelt placement occurring outside of the bushfire site assessment area (i.e. 150 m around any key infrastructure assets such as houses) to protect against increased bushfire risk predicted under climate change. If excessive shade is a concern, north-south orientations are the best format. This will provide shade for stock at different times of the day and protection from winds coming from all directions. A different form of shelter is provided by cluster plantings, which are an economical way of providing shelter for livestock, although not nearly as effective as a continuous shelterbelt. Cluster or block plantings in a paddock enable livestock to preferentially select appropriate shade or shelter.

To reduce shading, leaf litter and competition from tree roots, shelterbelts should be planted at least 10 m from the cropping area. A greater buffer area is needed for tall windbreak species. Enough room should be left to prevent ripping of tree roots and vehicle access and turning space. A greater distance between crop and shelterbelt is required when trees are planted to the north of the cropping area to minimise shading in winter.

The length of a shelterbelt will vary greatly based on available area, local topography and objectives of the shelterbelt. The influence of the shelterbelt length on shelter effectiveness lies on the ends of the shelterbelt. Wind speeds at the end of a windbreak are generally greater than those at the open area. This is caused by the flow around the ends of the shelterbelt, where the wind seeks the path with least resistance. Maximising shelterbelt length will increase its effectiveness. The extent of protected area provided by a shelterbelt will equal the length of the belt x height of shelterbelt x 10 [32]. The minimum length should be 10 times the height of the tallest vegetation layer. For example, if the tallest tree is 25m, the shelterbelt should be 250m long [32].

Figure 4 shows some common shelterbelt layouts, with option c) showing how to create access through the shelterbelt, while decreasing wind tunnelling.

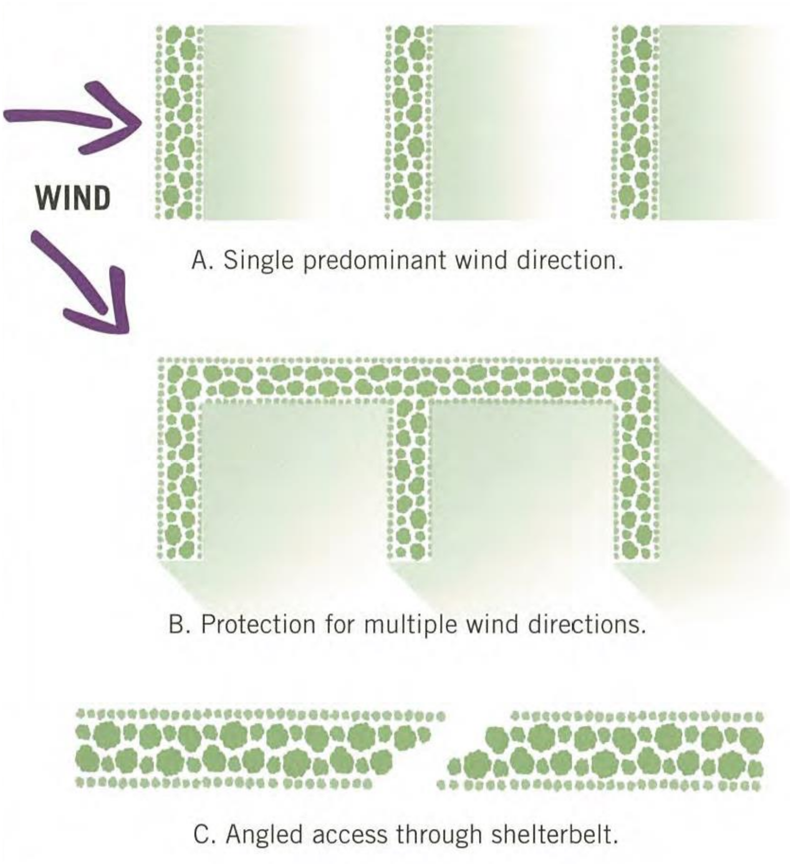


Figure 4. Common shelterbelt configurations (adapted from Abel et al. 1998)[35]

5.2.1 Spacing between shelterbelts

Repeat shelterbelts at certain width apart will maximise benefits. It is recommended for sites with low to medium exposure to wind, to space shelterbelts at between 30 to 35 times the height of your shelterbelt[36].

For example, if a shelterbelt will grow to 20 metres high, shelterbelts should be spaced between 600 and 700 metres apart. If a site has high exposure to winds, or a high degree of protection is required, a spacing of 20 to 25 times the height of the shelterbelt will be most effective, which equates to 400 to 500 metres apart if the shelterbelt will grow to 20 metres.

5.2.2 Continuity and uniformity

The continuity and uniformity of shelterbelts influences shelter efficiency. Any gaps or separations in a shelterbelt will concentrate wind flow, which creates a zone on the leeward side of the gap or separation where the wind speed exceeds that on the open field[34]. Therefore, lanes or other openings through a windbreak should be avoided, where possible. To ensure safe access and egress across a property there will be a need for gated entries through shelterbelts – these should be angled to decrease wind tunnelling (see Figure 5).

5.3 Species selection

Species selection is critical to ensuring plantings survive the predicted impacts of climate change (i.e. drought, low rainfall). Most failures of tree plantings occur because the wrong species have been selected for site conditions, poor site preparation has occurred, and/or they are planted at the wrong time of year. The key to selecting the most suitable native trees and shrubs for shelterbelts is to match the site (geology, soils, climate, aspect and elevation) with the best local plant species and communities adapted to that site.

In addition to providing biodiversity benefits, it is best practice to select several species of trees and shrubs for use in shelterbelts to prevent losses of all the trees if there is an outbreak of insect pests or tree diseases. The species mix should also include species that are best suited to future climate change conditions, determined from tools such as the Atlas of Living Australia (ALA).

It is recommended to use natives in shelterbelts, as they have the following advantages:

- Good survival rates: able to survive most hazards such as fire, frost and drought.
- Need minimum water and fertilizer.
- Require minimum follow up management during establishment.
- Able to attract beneficial fauna.
- Naturally regenerate which can decrease the costs of maintaining shelterbelts.
- Suitable for future climate scenarios.

6. Types of shelterbelts

The following five shelterbelts provide practical examples and design guidelines for planting shelterbelts. Different shelterbelts will be used for different reasons and landowners will need to decide which shelterbelt designs are most appropriate according to their priorities (e.g. asset protection, wildlife habitat, stock/crop protection). Shelterbelts should be considered in the context of a Whole of Farm Plan (see Section 7).

6.1 Model 1: Paddock shelterbelts

The primary objectives of paddock shelterbelts are protecting crops and soil from climate change impacts (e.g. wind erosion, flooding and bushfire), improving the micro-climate for crop production and protecting livestock from adverse weather. Recommended design principles for paddock shelterbelts are outlined in Figure 54.

Key climate change considerations for paddock shelterbelts include:

- Identify areas on the property which are likely to be prone to high winds and high temperatures (e.g. north facing slopes). Shelterbelts in these areas may help to mitigate climate change impacts including erosion and reduced soil moisture.
- Orient shelterbelts towards prevailing winds to protect crops and livestock from extreme weather events.
- Break up the continuity of fuel available to reduce bushfire risk by providing separation between shrubs and trees to remove ladder fuels and break up direct fuel corridors (i.e. direct connection to remnant native vegetation or paddock trees).
- Vegetation should be continuous and planted at a density of 40-60% to reduce wind speed and provide protection for crops and livestock as well as catching embers.
- There should be a minimum gap of 2 m between understorey vegetation (e.g. grasses) and the tree canopy to reduce bushfire risk.

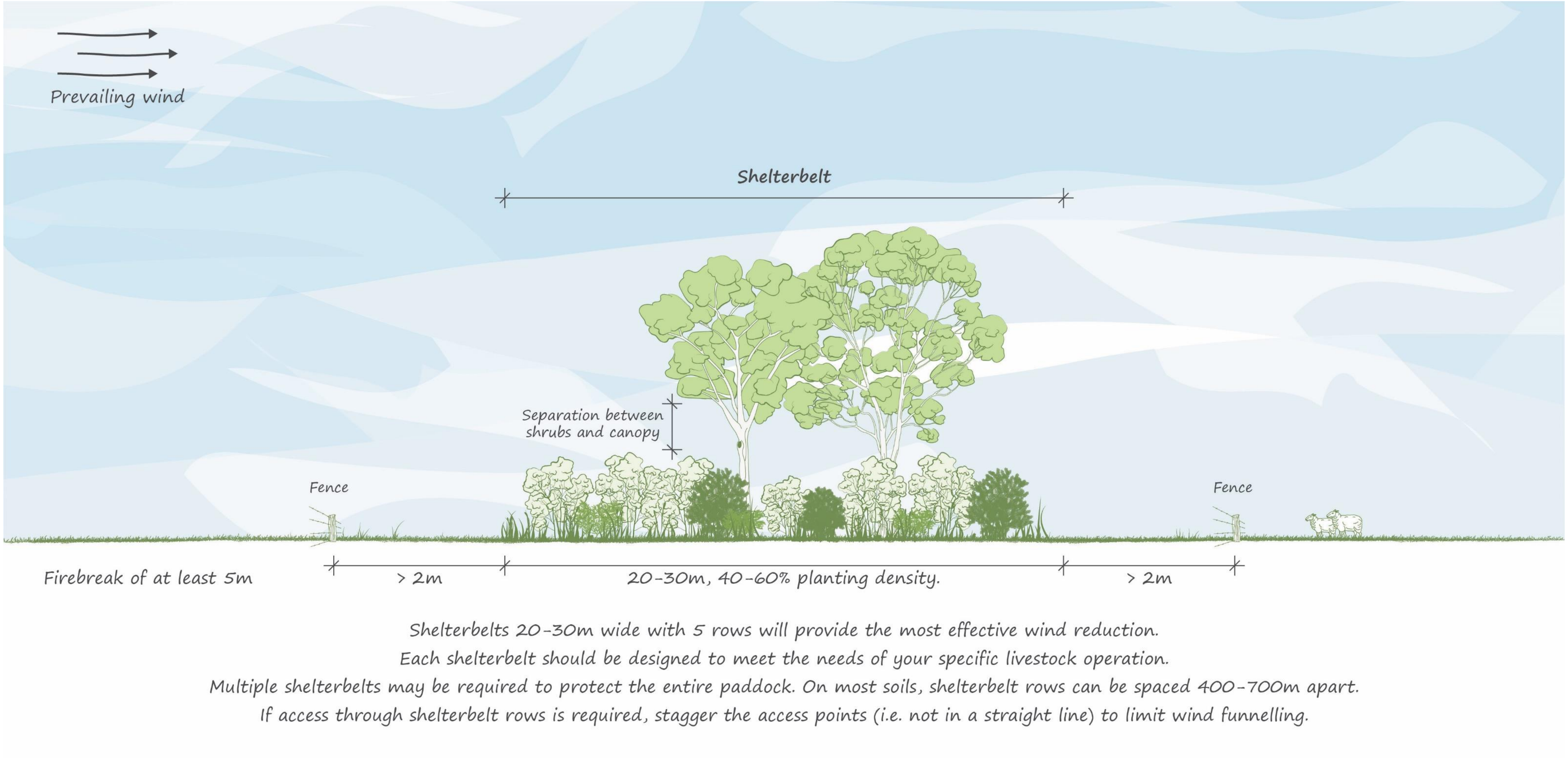


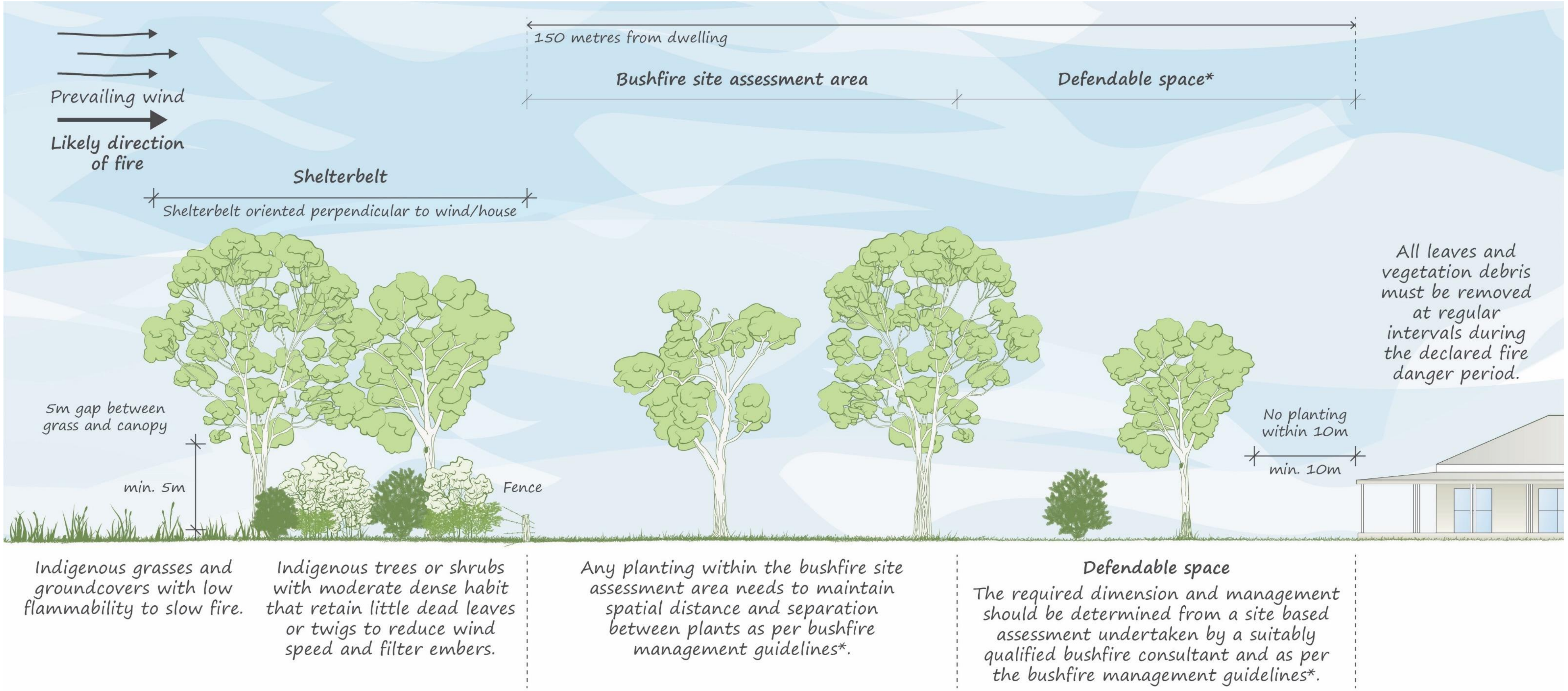
Figure 5. Paddock shelterbelt design

6.2 Model 2: Shelterbelts around built assets

Many shelterbelts are on larger farming properties surrounded by pasture paddocks and grasses. Climate change and associated increased temperatures and low rainfall will result in rapid drying of this vegetation over summer, providing a pathway for fire spread from the paddock to the shelterbelt and areas surrounding houses and other assets (e.g. sheds, stables etc.).

Location and careful placement of vegetation in shelterbelts to protect key assets from bushfire is important. The strategic placement of shelterbelts outside the bushfire site assessment area of the house block can reduce wind speed and catch embers produced by the fire. Climate change design considerations for shelterbelts adjacent to built assets include:

- Shelterbelts should be well maintained with low lying branches removed and consider slashing or mineral firebreaks.
- Shelterbelts should be located at least 150 m from the built asset, situated outside of the bushfire stie assessment area.
- Shelterbelts should be perpendicular to prevailing winds and the asset where possible.
- Break up the continuity of fuel available to any fire by providing separation between shrubs and trees to remove ladder fuels and break up direct fuel corridors (i.e. direct connection to remnant native vegetation).
- Vegetation should be continuous and planted at a density of 40-60% to reduce wind speed and catch embers.
- There should be a minimum gap of 2 m between understorey vegetation (e.g. grasses) and the tree canopy.
- Shelterbelts should not ‘lead’ potential fire toward built assets.



Notes

For dwellings constructed prior to 2009, *clause 52.12 Bushfire Protection Exemptions* allows a cleared zone of 10m around dwellings, followed by a cleared understorey zone to 50m where there is a Bushfire Management Overlay, or cleared understorey zone to 30m where there is no Bushfire Management Overlay.

For dwellings constructed after 2009, the defendable space is defined in the Bushfire Management Plan in the permit based on the distances defined in *clause 53.02 Bushfire Planning*.

Figure 6. Shelterbelt near built assets design

6.3 Model 3: Wildlife shelterbelts

Wildlife shelterbelts provide areas for nesting, feeding and breeding for many birds and other animals. They also provide shelter from severe weather and protection from predators. Habitat can be defined as the kind of place where a living organism (e.g. bird, fish, mammal, plant) lives. All species need food, water, shelter (cover) and space to survive. Wildlife shelterbelts can contribute food and a secure habitat for a diverse wildlife community.

Many wildlife species need a minimum amount of a habitat type. Too small an area will not be used. Vegetation can be used to connect several small, isolated areas within a landscape, thus making it more viable and increasing the usable space for wildlife. Shelterbelts can also act as habitat stepping stones, supporting species movement through the landscape. Cardinia Shire Council is developing a strategic Biolink Plan which can inform the optimal locations to create linkages for plants and animals.

Create contour plantings that follow natural waterways, creeks and the topography of the land to provide more edge appeal for wildlife. This produces pockets where wildlife prefers to feed, nest and seek refuge from predators. Gently curving tree rows creates more edge and attracts more wildlife to the planting. Corridors provide safe routes from one habitat area to another. If connecting shelterbelts to remnant vegetation on your farm, consider leaving a 30 m gap between the shelterbelt and the remnant vegetation. This can provide fuel discontinuity and assist in preventing the spread of surface fire through shelterbelts onto the farm.

Climate change design considerations for wildlife shelterbelts include:

- Plant drought tolerant native species that are suitable for future climate scenarios.
- Break up the continuity of fuel available to reduce bushfire risk by providing separation between shrubs and trees to remove ladder fuels and break up direct fuel corridors (i.e. direct connection to remnant native vegetation or paddock trees).
- Vegetation should be continuous and planted at a density of 40-60% to reduce wind speed whilst maintaining adequate habitat for a range of wildlife.
- There should be a minimum gap of 2 m between understorey vegetation (e.g. grasses) and the tree canopy to reduce bushfire risk.
- Shelterbelts should be located at least 150 m from any built assets.

When siting a shelterbelt primarily for biodiversity outcomes, consider the following options for sites in order of priority (Figure 7):

1. Preserve or restore natural corridors, such as gullies, minor waterways and creeks.
2. Add, restore or build on existing corridors. If possible, include scattered remnants in new corridors as this protects these sites from further decline.
3. Create new shelterbelts on green field sites in desirable locations to provide linkages.

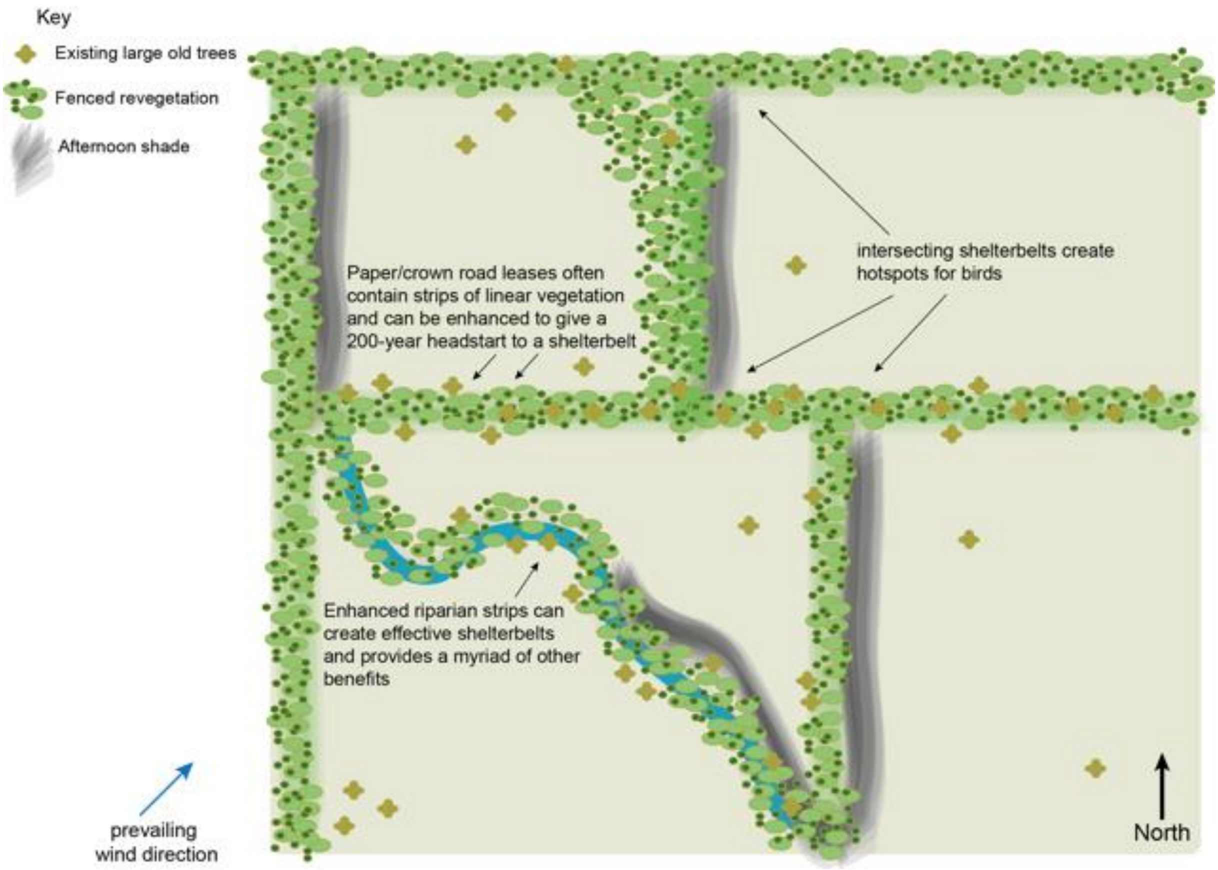


Figure 7 Shelterbelt placement can increase connectivity enabling wildlife to move across the landscape[37]

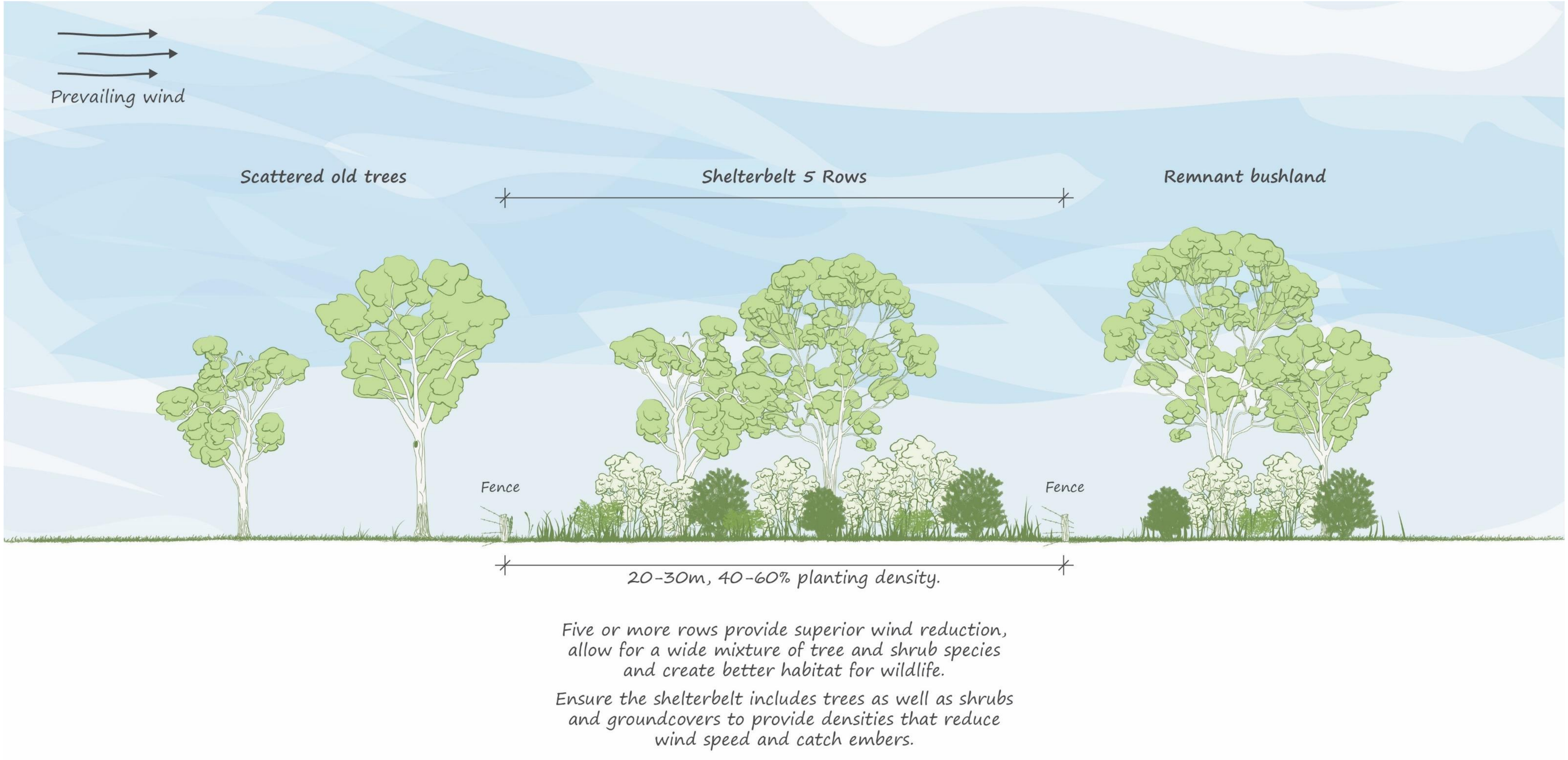


Figure 8. Wildlife shelterbelt design

6.4 Model 4: Riparian buffer shelterbelt

Prior to developing a planting plan for a riparian buffer shelterbelt, conduct an inventory of the riparian area, including existing vegetation, slopes, soil types, potential problems (e.g. slumping, erosion), signs of current wildlife use, adjacent land use and natural areas. A riparian buffer should be designed to mitigate the impact of land use adjacent to the water body.

Riparian buffers are planted around diverse types of water bodies such as rivers, streams, creeks, lakes, or wetlands. To be effective the composition of these buffers should be tailored and relevant to each riparian planting type. Implement a planting option that is suitable for the area chosen to be planted. Some water bodies have irregular perimeters, topography and other physical characteristics that may affect your planting options. For example, a typical planting modification to consider is the variability in the width of land available for planting within the riparian zone. The width of a riparian buffer is a key factor in the overall design of the planting. As the width of the riparian buffer increases the greater the beneficial results generated from the planting.

An effective riparian buffer strip has three vegetation zones (toe, middle and upper), each parallel to the water body. In a three-zone buffer strip, the toe comprises groundcover and shrub species that can survive periodic inundation. The middle contains tree and shrub species and the upper comprises larger tree species with deep root systems to act to stabilise the bank (Figure 9).

Managing riparian areas to adapt to changes in climate is not fundamentally different to current best practice. Existing pressures and threats may be exacerbated and compounded by climate change. Best practise natural resource management can alleviate existing and future pressures by improving land use planning and agricultural practices, restoring landscape connectivity, managing invasive species and improving water quality.

The protection and revegetation of riparian areas is one of the biggest opportunities to improve landscape condition across a range of biodiversity, water and carbon objectives[38]. By implementing sound management, riparian areas will be more resilient to the impacts of climate change, including:

- Increased bank stability.
- A decrease in weed infestations.
- Increased native vegetation, biodiversity and habitat.
- Improved water quality, turbidity and nutrient levels.
- improved stock health.
- Contributions to the food web for in stream biota.
- Increased shading of streams, therefore keeping water temperatures within their natural range.

These following key design considerations will increase the resilience of riparian areas to cope with and respond to climate change impacts[38]:

- Maximise landscape connectivity through riparian plantings, and through joining up and buffering significant remnants on farm with revegetation.
- Make new plantings or buffers for remnants as wide as practicable (the width chosen is highly dependent on the function of the buffer e.g. bank stability 5 m, sediment removal 10 - 30 m, and wildlife habitat 10 - 300 m.)

- Use local species for habitat plantings, including understorey species, but broaden the genetic base[29,30] within species as much as possible to better enable species to survive increased periods of drought or shorter, more intense periods of water inundation.
- Get the basics right in site preparation, establishment (especially weed control) and protection from grazing animals.
- From a water yield, water quality and in-stream habitat perspective, riparian revegetation should ideally be targeted to the northern and western sides of streams (to maximise shading benefits) and in the areas most vulnerable to erosion. It should be sufficiently wide to be ecologically viable and to offer useful terrestrial habitat corridors.

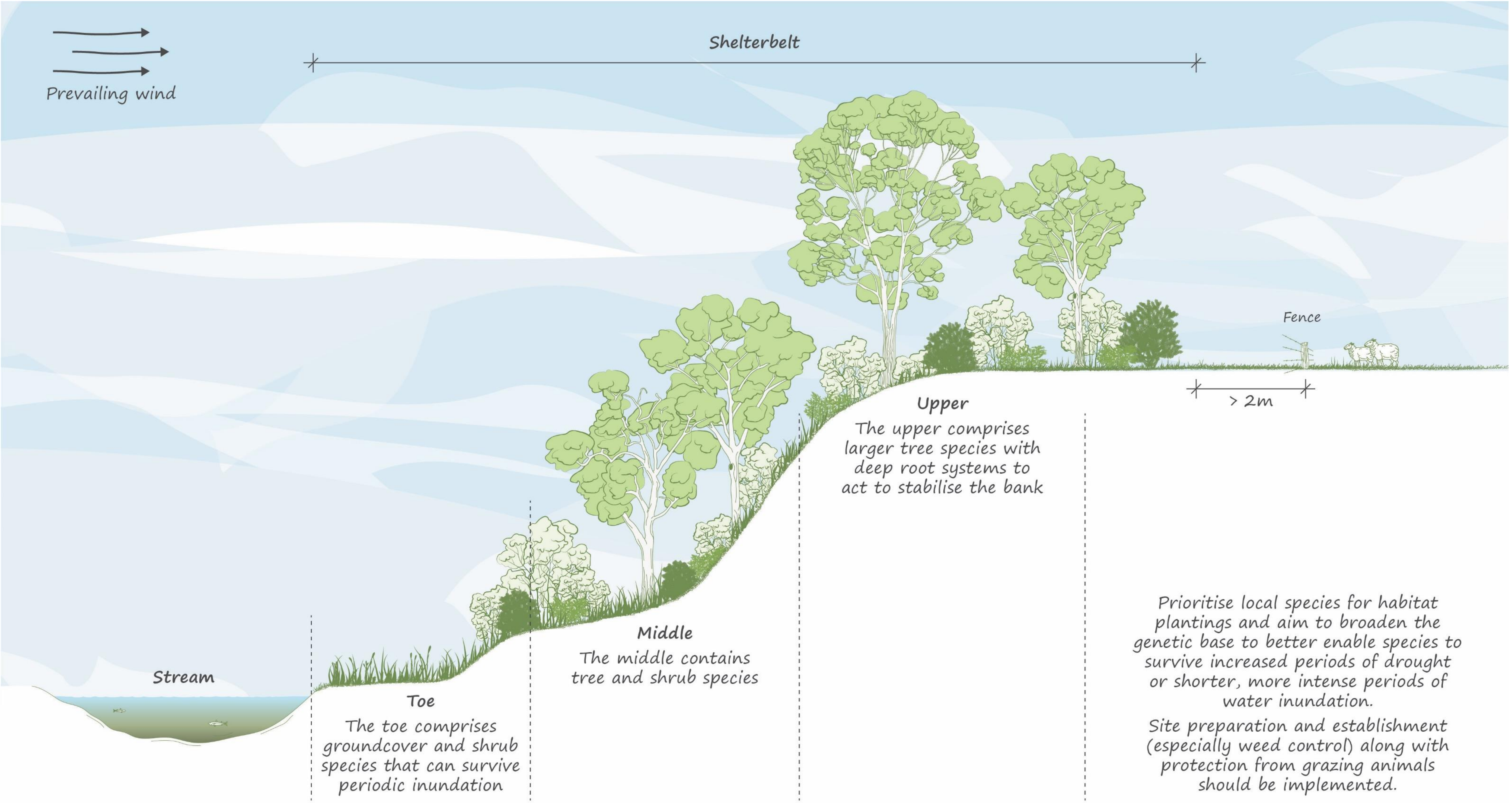


Figure 9. Riparian buffer design

6.5 Model 5: Shelterbelts on hills/slopes

Shelterbelts planted on hills and slopes require specific climate change design considerations:

- Plant shelterbelts along the mid-slope of hills to reduce wind speed, slow the speed and intensity of fire and potentially reduce the distance embers can travel during a fire[39,40].
- Consider planting shelterbelts on northerly to westerly aspects to reduce windspeed and ground temperature.
- Vegetation located on these slopes is more prone to drying out and species selection should include drought tolerant and climate ready species.

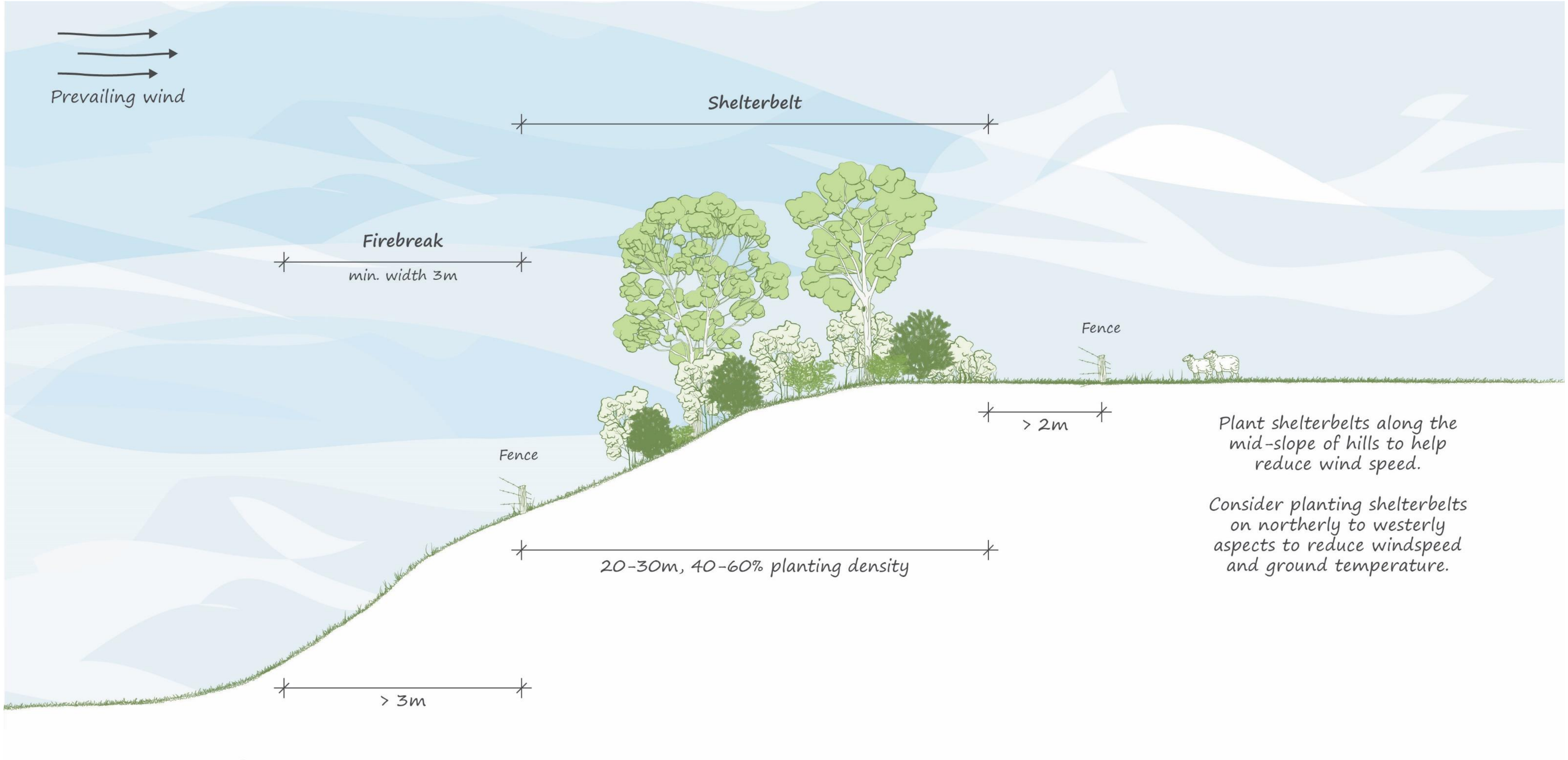


Figure 10. Shelterbelt on hills/slopes design.

7. Planning a shelterbelt

The objectives, location and use of shelterbelts will vary from property to property and within properties and should be included in Whole Farm Planning.

Planning involves reviewing current arrangement of paddocks, native vegetation and infrastructure at a property level and determining how shelterbelts can be utilised and for what purpose in the landscape. Planning the location of a shelterbelt is influenced by many factors, including the location of existing property infrastructure, prevailing seasonal winds, soil type, problem areas of erosion and salinity, remnant vegetation, use of non-arable areas, the need for shade and other on-site specific features. The plan should match the equipment that you will use to prepare the site, available space (e.g. width of shelterbelts), type of vegetation and maintenance (i.e. weed control after the shelterbelt has been planted).

When planning shelterbelts landholders should consider:

- Locating the shelterbelt where it will be most effective in helping achieve the objectives identified in the Whole Farm plan (e.g. increased livestock productivity, reduced risk of ember attack on infrastructure, and/or biodiversity conservation etc.).
- Designing shelterbelts to fit the available space and to meet your objectives. The design must consider proper spacing to allow for optimum tree growth and the use of maintenance equipment.
- Selection of tree and shrub species that are drought tolerant and well adapted to your soil and climatic conditions, with consideration of predicted future climate scenarios.
- Preparation of the planting site and fencing to exclude livestock.
- Arranging for labour and equipment to plant the trees.
- Providing care and protection for young seedlings.
- Controlling weeds after shelterbelt establishment.

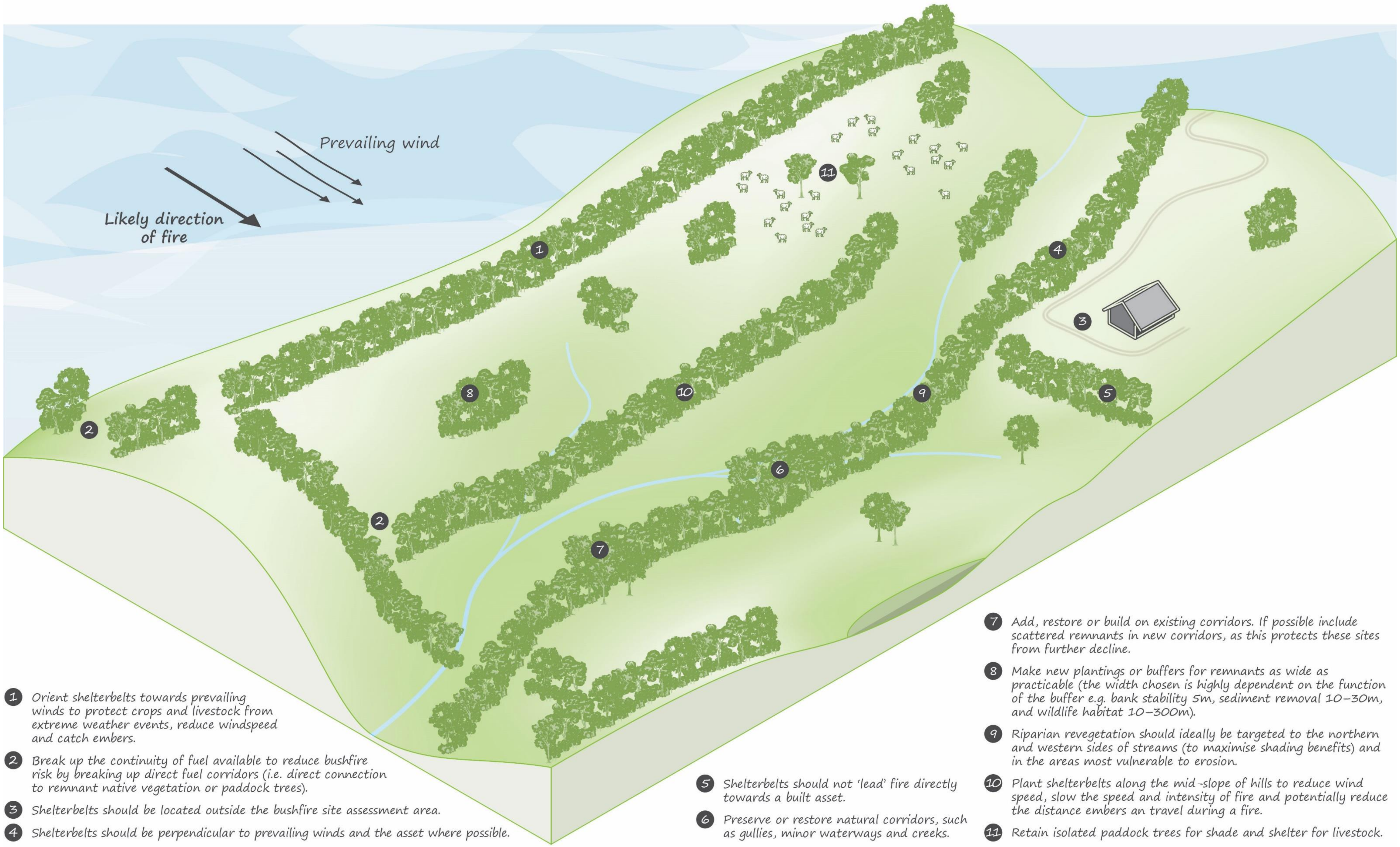


Figure 11. Whole farm planning design

7.1 Shelterbelt planning key steps

Planning, starting with property observation is important to establish objectives and effective shelterbelt layout. Key steps include:

1. **Conduct a property assessment**
    a. Identify initial areas of concern and verify needs. Also, identify other conditions that could be improved by, or limit the effectiveness of a shelterbelt at your site.
    b. Walk around the property and observe which direction your strongest winds come from.
    c. Identify where shelter is particularly needed. Consider planting across slope to influence wind movement and fire spread. Plan your shelterbelt to be located at right angles to your prevailing winds wherever possible and note all other areas where trees could be planted. Decide on the width of your shelterbelts, remembering that four or more rows (five rows is considered best practice for a range of benefits) provide more benefits than one row[32].
2. **Conduct a landscape assessment**
    a. Identify livestock rotations, crop locations, key infrastructure, dams and problems in the surrounding area that could affect, or be affected by, a shelterbelt.
    b. Consider defendable space around assets and infrastructure.
3. **Determine objectives**. For example:
    a. Biodiversity conservation.
    b. Bushfire site assessment requirement
    c. Agricultural productivity.
4. **Develop alternative shelterbelt designs**
    a. Developing a shelterbelt design may require creating a few alternatives to consider and choosing the most suitable. A complete shelterbelt plan will indicate its location, size, and tree and shrub composition. Also include a management and maintenance plan.
5. **Implement**
    a. Source plants from Landcare or Native Nursery.
    b. Source and purchase tree guards (if using).
    c. Prepare the soil by ripping (if required).
    d. Complete initial weed control (if required).
    e. Plant vegetation.
6. **Monitor and maintain**
    a. Monitor the survival and growth of plantings.
    b. Maintain weed control. If shelterbelts are designed to protect key infrastructure from fire, consider other maintenance (e.g. removal of low branches pruning of lower limbs and branches to 2 m above the ground to separate canopy trees from understorey shrubs).

8. Planting and maintaining shelterbelts

This section provides general guidance for landholders on preparing, planting and maintaining shelterbelts irrespective of their chosen objectives or design.

8.1 Preparing and planting shelterbelts

Preparation for the establishment of shelterbelts should include the following steps:

- Decide on the appropriate technique for revegetation for the site. For example, direct seeding, planting of tube stock, or allowing natural regeneration.
- Undertake necessary weed control to prepare the site, in accordance with the revegetation type. Reducing competition with weeds provides much better chances of successful establishment.
- Assess whether ripping or other soil disturbance is required at the site.
- Construct any fencing as required prior to planting, including access requirements.
- Consider guarding new plants and what type of guards may be most appropriate for the site, depending on the key threats (e.g. rabbits, kangaroos, deer, etc.).

More guidance on site preparation and planting techniques can be found in publications listed in the *Additional Resources* section.

8.2 Maintenance

Periodic maintenance is required to enable shelterbelts to meet the desired objectives. The level of management required to maintain your site generally decreases as the shelterbelt becomes established. Things to consider include:

- **Pest animals** - Increased cover can also create habitat for pest species such as cats, rabbits, foxes and Indian mynas. Control programs may be required.
- **Weeds** - Keep an eye out for the appearance of new and existing weeds and control as required. Over time, litter from trees and shrubs will fall to create mulch, reducing the sunlight and moisture for weeds to become established.
- **Fences** – Undertake regular fence inspections and complete maintenance as required.
- **Grazing** – Stock should be totally excluded from your shelterbelt.
- **Fire management** – Consider leaving fallen timber on the ground in your shelterbelt to increase structure and diversity of habitat for wildlife. If the shelterbelt objective is to reduce bushfire risk (e.g. located near key infrastructure including houses) remove low lying branches, fine surface fuels and ensure discontinuity between fuel layers to reduce bushfire risk. Slashing or mineral firebreaks.
- **Replanting** – Natural mortality is likely to occur in shelterbelts. Consider replanting both trees and shrubs as needed to maintain an appropriate density of plants.
- **Structural management** – Over time the density of your shelterbelt may change. For example, the shelterbelt may develop a higher density than desired, and this may be addressed by selective removal or pruning of plants to reduce the density and mitigate risk

of bushfire. To increase density at ground level, trees may be felled close to the ground to allow them to coppice.

9. Choosing suitable plants

There are several characteristics to consider to make informed decisions when selecting plants for a shelterbelt. It is important to remember that all plants can burn under the right conditions (i.e. typically in extreme fire weather), therefore the focus of plant selection should be consideration to drought tolerance and future climate suitability, as changing climatic conditions, including increased temperature and reduced rainfall may reduce the survivability of some species.

This may include sourcing individual plants of the same species from outside the local area[29,30]. For example, Eucalypts often have a broad geographic range with some individuals existing in areas where the climate currently matches the predicted future climate. Sourcing seed from these populations and planting them in shelterbelts may increase the survivability of plantings as they will be more resistant to drought, high temperatures and reduced rainfall.

It is important that plants are selected in discussion with your local indigenous nursery or Landcare group, as they will provide good local available knowledge on which species to plant. Climate readiness tools such as the ALA web app (see section 4.3.2) will also assist with determining which species are best suited for future climate scenarios.

Conclusions and recommendations

Climate change will affect the future design of shelterbelts. Increased periods of drought, higher temperatures, reduced rainfall, increased fire risk and more intense storms necessitate a change in how shelterbelts are selected and designed. Climate change impacts affect how shelterbelts should be oriented, their planting density, location, species selection and maintenance. Shelterbelts will continue to provide a range of benefits under climate change including protection of crops and livestock, protection of built assets from fire, wildlife habitat, erosion protection and improved water quality. The following recommendations are for landholders planning to implement shelterbelts for climate change as part of a whole of farm plan:

- The location, orientation, length, width and height of shelterbelts should be selected to meet specific farm outcomes (e.g. ecological benefit, pasture improvement, reduction in fire risk).
- Maximise connectivity across a property through shelterbelts whilst maintaining fire protection measures (e.g. firebreaks). This will reduce windspeed across the property acting to reduce the severity and intensity of bushfire, protect livestock and crops, provide wildlife habitat and reduce water runoff and erosion.
- Place shelterbelts perpendicular to prevailing winds. Several shelterbelts of different orientation may be required in a paddock.
- Make shelterbelts as wide as practicable to maximise shelter, wildlife habitat and bushfire protection benefits.
- Provide gaps between remnant vegetation, shelterbelts and built assets to reduce bushfire intensity and likelihood of spreading across a property.
- Shelterbelts should be located at least 150 metres from built assets.
- Use local species for habitat plantings, including understorey species, but broaden the genetic base within species as much as possible to better enable species to survive increased periods of drought or shorter, more intense periods of water inundation. Seek advice from a local indigenous nursery on the most appropriate species to plant.
- Plant for the future climate by incorporating native species from a drier analogue climate such as Albury to provide greater diversity and resilience to projected future climate changes
- Reduce the number of midstorey species to decrease the amount of ladder fuel (fuel that can carry a fire burning in low-growing vegetation to taller vegetation).
- Plant at a medium density of 40-60% in each shelterbelt to effectively reduce windspeed.
- Include tall native species that grow in the region and consider fast growing species to increase the area of shelter provided.
- Plant shrubs that grow to a maximum height of 5 metres and maintain separation between shrubs/groundcovers and tree canopy to reduce likelihood of fire entering tree canopy.
- Maintain a minimum 5 metre firebreak between the shelterbelt and crop/livestock operations and remnant vegetation to provide fuel discontinuity and allow for emergency vehicle access in a fire event.
- Fence shelterbelts to prevent stock access.

- Plant shelterbelts 400 – 700 metres apart. Shelterbelts with high wind exposure should be planted closer.
- Lanes or other openings through a windbreak should be avoided, where possible. However, to ensure safe access and egress across a property there will be a need for angled gated entries through shelterbelts.
- Site preparation and ongoing management are essential

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Additional resources

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Revegetation Techniques. Greening Australia.

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Florabank Guidelines: http://www.florabank.org.au/

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