Evaluating the netting of apple orchards in the Adelaide Hills with the development of a business case tool for growers.

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Evaluating the netting of apple orchards in the Adelaide Hills with the development of a business case tool for growers.

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Apple and Pear Growers Association of South Australia Inc

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1 Project context

1.1 South Australia's apple and pear industry

For South Australia's apple and pear industry, the Adelaide Hills are a key asset, with relatively high rainfall, and cool climate conditions in an otherwise dry state. The region generates on average 85% of the state's total pome (apple and pear) fruit production and most of its premium quality fruit. In 2007–08, this share of production was worth approximately $39.1 million at the farmgate (Houston and Rowland, 2008). The Riverland and South-East produce early- and late-season fruit respectively but these are comparatively minor elements of the South Australian industry. It is unlikely that either could fully replicate the role of the Adelaide Hills as the key production district, and any significant loss of capacity in the Hills would jeopardise the South Australian industry as a whole.

The Lenswood region, located in the central Adelaide Hills, is the traditional centre of this industry. The combination of favourable soil, rainfall and temperature conditions, along with reliable groundwater, has seen the development of a major apple producing district comprising an estimated 800 hectares of orchards. The presence of these orchards has led to the establishment of an extensive support infrastructure (including the Lenswood Coldstores, and various other cool storage facilities, packing lines, and supporting rural supply companies).

The Apple and Pear Growers Association of South Australia (APGA) and through its members, seeks to continually improve their farming systems towards increased sustainability, efficiency and the adoption of world's best practice, while ensuring long term economic returns. In doing so the APGA seeks to maintain and increase the productive capacity of their industry.

The apple and pear industry is able to improve and adapt, but needs to ensure that actions, such as permanent netting enclosures, are based on well-founded evidence and that a sound business case can be developed for individual growers - Susie Green CEO, APGA. Such a business case needs to evaluate long and short term economic and environmental considerations into growers planning and decision making processes.

Whitaker and Middleton 1999, considered the profitability of hail netting apple orchards and found that netting was profitable for most varieties that were considered within the Queensland study site. While such a study provides beneficial supporting evidence, similar assessments must be made with current prices and within the Adelaide Hills context, which has a much lower incidence of hail, but has other drivers such as sunburn and bird damage.

Growers, having experienced significant crop production and quality losses in 2013 (due to the effects of heat) have been particularly receptive to considering and collaborating in the project. This window of heightened awareness has significantly improved the capacity of the project to engage with the industry sector.

1.2 Project scope and objective

While individual tree netting has occurred commonly in the central Adelaide Hills for some time, it is becoming more common to see netting attached to permanent supporting structures. It is these permanent

netting enclosures which will be assessed within the CBA.

The project sought to develop a business case for the utilization of permanent netting enclosures within Adelaide Hills apple orchards on an individual grower basis. Each business case will be underpinned by the cost benefit analysis (CBA) tool, which will be run by individual growers or their representatives. Input data is based on best available information and grower knowledge. The results of the CBA are automatically uploaded into the business case template which growers will be able to print and utilize within their planning and decision making processes. The CBA tool and business case report are available for download on the APGA website and have been delivered through APGA training and extension processes.

1.3 Project outcomes

The project has the following outcomes:

- An evidence base on the costs and benefits of permanent orchard netting in the Adelaide Hills and their influencing factors;
- A CBA tool, which is underpinned by the evidence base and tailored to the specific circumstances of the grower;
- A business case template which incorporates the results of the CBA with the general findings and overarching principles within the evidence base;
- The availability of the CBA tool on the APGA website, which integrates with the business case template; and
- Training and extension to facilitate the use of the CBA tool and business case report.

It is envisaged that the intended audience for the business case report would be finical institutes, or potentially grant funding programs.

2 Orchard productivity and grower profitability

Netting is an investment in orchard productivity with impacts on grower profitability. In order to understand how permanent orchard netting impacts productivity a general understanding of the grower profitability is required.

2.1 Profitability - yield, pack-outs and price

Grower profitability is a relationship between yield, pack-outs and price. If we first consider yield, there is the **total potential yield** (the total amount of fruit grown /ha or /block) and then the **harvested yield** (which is the total potential yield, minus the fruit which is discarded or culled in the orchard due to physical damage, skin colour or blemishes). Permanent netting will reduce the cull percentage and hence increase the harvested yield.

Once picked into bins the harvested yield can be graded within the packing process. The quality of fruits intended for the fresh market is expressed as **pack-out** percentage. A pack-out of 80% generally means that 80% of the fruit can be sold in the fresh market and 20% is sent for juicing or is waste. Permanent netting will reduce the impacts on fruit quality and will therefore increase pack-out and will reduce waste, hence increasing **pack out**.

The relationship between those attributes which affect yield, pack-outs and price are not straightforward, with inter-relationships between attributes. Many of the attributes will be impacted by orchard netting with the project describing these relationships by considering their likelihood of occurring and their impact.

Increases in yield, pack-out and price significantly improves grower returns. For example export/first class, seconds and juice grade fruit obtain in the order of $1000-$2000/t, $600 -$800/t and $0-$100/t respectively. With packing costs of $800/t, growers clearly focus on achieving the highest pack-out for premium fruit. If pack-out goes below 40-50% the entire bin will generally be sent to juice, to minimise packing and storage costs (pers. comm. Paul James, Lenswood Cold Stores Co-Operative Society Limited).

3 Drivers for orchard netting

In recent years, apple orchardists within the Adelaide Hills have begun to invest in permanent netting enclosures, primarily as a means of protection against hail damage, but also against damage from birds (refer Figure 3-1). Local anecdotal evidence and peer reviewed research in other states, indicates that there are several other drivers for establishing permanent netting which need to be considered within the evaluation of any business case.

Permanent netting is an investment in orchard productivity. It is therefore essential to use the beneficial effects of netting to greatest advantage, while at the same time minimize any adverse effects. A discussion of the drivers for orchard netting and potential risks – with management strategies is outlined below. Knowledge of the driving factors has been used to develop scenarios for the CBA and are also summarised within the business case template.

Figure 3-1: Permanent orchard netting in the Adelaide Hills

3.1 Impact on Yields

As stated **harvested yield** is the total yield, minus the fruit which is discarded or culled in the orchard due to physical damage, skin colour or blemishes.

Trials completed during the period 2007-2010 within the Lenswood area for Sundowner and Pink Lady indicated that the cull rate was approximately 8% - 10%[1] (James, 2011), with the most likely reason for fruit cull being:

- Pink Lady: bird damage (20%), factors associated with shape and colour (17%) sunburn (13%) and codling

[1] Pink Lady annual cull rate varied between 6.5 – 11.1%, with an average of 8.9%
Sundowner annual cull rate varied between 7.9 – 10.7%, with an average of 9.8%

moth (13%), and to a lesser extent wind rub and hail damage, and

- Sundowner: Shape and size (33%), sunburn (22%), bird damage (20%), codling moth (13%), and to a lesser extent wind rub and hail.

Of these impacts, bird, hail and wind damage and sunburn will be reduced by permanent netting enclosures, thus reducing the cull rate and hence increasing the harvestable yield. Pack-out for this fruit was approximately 86%, and hence improvements in pack-out could also be achieved with netting and a reduction in the percentage waste would increase the packed yield. For example, McClymount et al., 2013 concludes that "*A very low proportion (less than 1%) of the fruit grown under netting would have been culled due to sun damage, and approximately 8% would have been downgraded due to minor sun damage*. *This contrasts markedly with the non-netted area of the orchard, where up to 6% of fruit would have been culled due to sun damage and 10% would have been downgraded*" – based on studies completed in Shepparton.

Once picked into bins, local APGA of SA trials conducted in 2014, found that the yields (tonnes per hectare of harvested fruit) from both the netted and non-netted sites at Lenswood (which were planted with Pink Lady™ strain Rosy Glow on M26 rootstock), were very similar (84t/ha). Whereas, Smit (2007) in studies in South Africa showed that meaningful interactions between net and crop loads treatments was only found for fruit mass of Royal Gala and Fuji, with no difference for Braeburn and Cripps' Pink. Such cultivar variations are describe further in Section 3.2.6.

Yield can also be influenced by water stress and chill accumulation as described below.

3.1.1 Water use efficiency

Irrigation water supply can often be less than total crop water requirement. This leads to tree water stress and subsequent loss in fruit size and yield in the apple orchard[2]. To a varying degree this is currently the case for most apple growers in the Adelaide Hills, with most orchardists not being able to fully met crop water requirements due to limitation in water availability. Under netting, water use efficiency (WUE - defined as the harvestable yield per unit of water used) is likely to increase with greater production of higher quality fruit from the available water supplied.

Recent research from netting trials currently being undertaken by the Department of Agriculture and Food in Western Australia, initially showed a 15-20% water savings under netting[3] and more recently has reported saving of up to 45%[4]. This is primarily due to lower evapotranspiration (as a result of increased humidity and reduced wind speed) and offers the potential for improved WUE. The experience of Geoffrey Thompson Orchards is similar with water savings of up to 30%[5].

Current water use for apple and pear orchards in the Adelaide Hills is highly variable depending on water availability, variety and planting density. Current water use is typically in the range of 3 to 8 ML/ha with

2 http://www.hin.com.au/__data/assets/pdf_file/0006/17871/Water-deficits-and-apple-productivity.pdf
3 https://www.agric.wa.gov.au/water-management/netting-saves-water-apple-demonstration-site?page=0%2C2
4 http://www.abc.net.au/news/2015-04-16/netted-orchard-saves-on-water/6396952
5 As described in the Farmview video developed by the Department of Environment and Primary Industries Victoria – Netting to reduce damage http://www.depi.vic.gov.au/agriculture-and-food/horticulture/farmview-videos/farmview-season-2-episode-3.2

average yields of approximately 40 tonnes/ha (varying from 25 tonnes to 100 tonnes/ha). Local APGA netting trials have not reflected that same WUE (as described above) over the 2013-14 summer. It was considered that the irrigation results were inconclusive as the trial was impacted by an unseasonal rainfall event (with 115mm of rain recorded on the 4 days following the 14th February, 2014) which replenished the soil profile for the remainder of the summer (Apple and Pear Growers Association SA, 2014).

Connell & Goodwin 2007 indicate that a 50% irrigation deficiency (DI) lead to a 40% reduction in yield of Pink Lady in Year 1 and a 16% reduction in Year 2. Based on an average 30% yield reduction for a DI of 50% and assuming a linear relationship between yield a water inputs (as shown in Connell & Goodwin 2007) then a DI 20% could lead to a yield reduction of approximately 12%. If the converse relationship is true, then a potential water savings of 20% under netting could lead a conservative 5-10% increase in yield.

The actual water saving under netting will depend somewhat on type of netting, with the greater the reduction in solar radiation the greater the reduction in water requirement (pers. comm. Lexie McClymont, Department of Primary Industries, Victoria), cultivar and several other factors. However for the purpose of the CBA a conservative potential water savings of 20% under netting has been utilised with corresponding 5-10% increase in yield.

Schrader et al. 2003, Lolicato, 2011 and Racsko et al. 2012, also observed that fruit on trees that are under water stress are more susceptible to sunburn than trees with higher water potential. Even very short-term crop water stress (i.e. changes in daily crop water demand due to heat waves) is likely to increase the risk of sunburn Lolicato, 2011. Fruit burns less if the trees are irrigated regularly – due to the ability of the tree to regulate its temperature by transpirational water loss (Racsko et al. 2012).

The relationship between water stress susceptibility to pest and disease also requires consideration in the broader management context, but hasn't been specifically considered with the scenario development for the CBA.

In the longer term improvements in WUE may be off-set by reductions in available irrigation water (refer Section 3.4 – Future trends in drivers).

3.1.2 Plant heat stress

Tree health is impacted by the climate variables temperature and rainfall. The temperature ranges assumed to be appropriate for the cultivation of apple are an annual mean temperature range of 6-14°C and a mean temperature range of 13-21°C from mid-spring to mid-autumn (Sugiura et al. 2005; Sugiura and Yokozawa 2004). Average temperature at Lenswood do not vary considerably between years. Evaporation is more variable over annual cycles, while rainfall shows even greater annual variation (refer Apenndix 11.1 for average monthly temperature and rainfall data).

Trends in mean temperatures during the growing season and dormant season at Lenswood since 1958 show marked increased in temperature since 1999 (refer Appendix 11.2). Since 1999, all but one year recorded temperatures in the top 10% of recorded annual temperatures during the growing season. Increasing temperatures lead to heat damage (including sunburn as described in Section 3.2.1) and changes to phenological patterns such as advancement in flowering dates.

Currently, in many of Australia's pome fruit-growing regions, extreme heat events are common with

incidences of extreme heat days increasing historically (Alexander et al.2007) (refer **Error! Reference source not found.** for information on increasing trends in heat events for Mt Barker). At greater than 36°C apple trees 'shut down' - which slows flower formation, fruit development, fruit size and ripening, with tempeartures at and for several weeks after bloom being shown to be critical for fruit size (Webster 1997 and Annon, 1998). After a heat event fruit is often downgraded in the packing process due to reduced storage life (Thomson et al. 2014), refer Section 3.2.7.

Another impact of warmer mean temperatures is the hastening of phenological development after budburst (in spring and summer), which may cause fruit to ripen earlier (i.e. in February instead of in March), when extreme heat conditions are more likely to occur. This may increase the risk of hot northern winds and heat evenst damaging fruit just before picking time, when it is generally most vulnerable to such conditions.

The weather of the 2013/14 season within the Adelaide Hills was particularly severe. Extreme heat events in January and February impacted on fruit quality and yields, particularly of earlier varieties. During the extended periods of extreme temperatures, fruit size was retarded due to plant stress. Fruit sugars developed rapidly but fruit colour was poor[6], and uneven ripening was observed. In addition, fruit exposed to direct sunlight was affected by sunburn (refer Figure 3-2), with an estimated 20-30% of damage experienced on some varieties. Local studies at this time in Lenswood[7] showed that the heat event reduced the potential diamater of Pink Lady apples by 2mm with a corresponding decrease in yield of approximatley 10% (pers. comm. Paul James Lenswood Cold Stores Co-Operative Society Limited).

It is expected that that the occurrence of heat waves will continue to increase in both frequency and severity (refer Section 3.4).

Netting reduces daytime temperatures by 1-3°C on warm days (Middleton 2015) or up to by 3-6°C during hot periods – maintaining optimum metabolism and fruit growth/ripening. Smit (2007) had similar findings in studies in South Africa showed that leaves under netting were cooler by 1.7-3.9°C on a mild day and by 4.3-6.2°C on a hot day.

3.1.3 Winter chill accumulation tree health

Apple trees require chilling for maximum productivity. Production challenges can occur during mild winters when fruit trees do not accumulate sufficient winter chill to meet chill requirements. Light and variable

[6] A specific example of a less recognised impact is that colour development in apples occurs through the production of anthocyanin, which is reduced by high temperatures.

[7] The diameter of Pink Lady and Gala fruit where measured weekly over 15 and 17 patches respectively, during the 2013-14 season. On January 14th 2014, a heatwave occurred, with 5 consecutive days over 39°C. As compared with project Pink Lady diameters, actual measurements were a total of 2mm less over the forth coming month. This loss in growth was not regained by the time the apples were picked in late April. The results for the earlier variety Gala were considerably different, with no marked change in growth rate after the heatwave.

flowering and a protracted flowering period[8] may result from insufficient accumulation of winter chill. These conditions can markedly affect fruit yield through poor pollination, increased risk of frost damage or by directly reducing the amount of fruit produced[9] . Putland et al. 2011 also state that there can be a reduction in fruit colour.

Chill accumulation varies greatly between years and depends on the method by which chill accumulation is calculated. Historic 20 year (1980-1999) annual average provided by Putland et al. 2011, indicate that at Lenswood chill accumulation was:

- Chill hours 0-7.22ºC from 16 May to 10 Sep – 758 hours
- Dynamic chill portions from 16 May to 10 Sep – 84 portions

The median minimum monthly temperatures at Mount Barker has increased by approximately 0.7°C since 1926 (from 7.8°C to 8.5°C); with reductions in winter chill units in the Central Adelaide Hills over the same period (refer Appendix 12.2). Darbyshire et al. 2013 supports this finding, indicating that the present chill portions (based on the Dynamic Model) is currently 80.7 (or a reduction of approximately 4% as compared with the historic 20 year annual average).

While future climate projections indicate that chill accumulation will continue to be reduced at Lenswood (refer footnote[10] and Appendix 12.3), the 2030 projections indicate values will still be within the required thresholds for local varieties. Therefore this driver is less important than other drivers such as water availability and sunburn.

It is also understood that netting has very little impact on air temperature, and is not likely to have a significant impact on chill accumulation. As a result, chill accumulation has not been included within the scenario development for the CBA.

3.2 Improved product quality

Local APGA of SA trials in 2014 have shown that there are significant reductions in hail, sunburn, bird

[8] An extended flowering period is reflected in a long harvest period where additional picks are needed because fruit quality on the tree is non-uniform. This can add considerably to the cost of harvesting but if growers do not conduct these extra picks, overall quality and pack-out can be reduced (Thomson et al. 2014)

[9] http://www.piccc.org.au/sites/piccc/files/Horticulture%20winter%20chill%20fact%20sheet%20FINAL_1.pdf

[10] Although Lenswood dormant season is considered reasonably cool (with temperatures around 10 to 11°C), the more complex chill accumulation models indicate that chill accumulation can be eroded easily. A small amount of future warming will decrease chill accumulation, although the amount is largely dependent on the method used to calculate this parameter (Thomas and Hayman 2015). For example, Putland et al. 2011 states, based on the Dynamic model (which is the considered the current best practice model by many practitioners[10]), chill portions decile 5 declines from 83 to 76 under historic +1ºC and ranging from 77 to 79 under the three global climate models, refer Appendix 12.2. Similarly, Darbyshire et al, 2013, reports a reduction of chill portions (based on the Dynamic model) ranging from 73.9 to 76.6 (or a 5 to 8% reduction) under historic +1ºC scenario. Few estimates of varietal chill requirements have been reported in chill portions, with the exception Golden Delicious - stated to be 50. Hence while chill proportions are reducing there does appear to be a reasonable buffer between the required and the projected chill proportions.

damage and susceptibility to resultant storage breakdown when netting has been utilised (Apple and Pear Growers Association SA, 2014). Other product quality benefits include fruit colour, skin finish and russet, while fruit set is reduced with fewer multiple clusters (leading to reduced thinning costs). During the APGA trial, it was estimated that the top one quarter of the trees lost approximately 90% of the fruit load to birds, with an estimated 20% of fruit damage on the remainder of trees through sunburn, bird damage and hail damage, leading to an overall estimated of 30% fruit damage. The other location which was considered in the APGA trial had significantly less fruit damage (5%) within the non-netted site, showing the possible variation between locations.

These impacts on fruit quality and the subsequent pack-outs are major drivers when considering profitability of netting – with profitability significantly improved when growers receive premium price.

It is generally considered that within the Adelaide hills the predominate product quality drivers for netting are the constant risk of sunburn, the variable risk of bird damage and the significant risk of hail – when it does occasionally occur.

3.2.1 Sunburn

Types of sunburn and temperature thresholds

The pome industry is vulnerable to short periods of high temperature during the fruit development period (October to March) Thomson et al. 2014. Sunburn typically occurs when fruit surface temperature (FST) goes above 45°C. Schrader et al. 2003 states that during trials that FST never exceeded 45°C on days when the maximum air temperature was less than 30°C, and that when the maximum air temperature was greater than 35°C, max FST almost always exceeded 45°C[11]. Based on this understanding threshold temperatures for sunburn damage classes have been utilised in several studies, refer Table 3-1, and have been used to develop CBA scenarios. The work of more contemporary studies[12] has also been considered, which modified these thresholds for specific varieties and have included specific thresholds for under netting.

Table 3-1 Temperature threshold for sunburn damage

Air temperature	Effect
30°C to 35°C	Damage is variable, depending on wind, exposure to direct solar radiation and humidity
Greater than 35°C	High risk of browning damage, max FST almost always exceeded 45°C

11 It is noteworthy that wind reduces the temperature differential between air and fruit surface temperature by facilitating the transfer of heat to the air (Schrader et al. 2003), and that wind speed is reduced by approximately 50% under netting.

12 It is noteworthy that more contemporary studies indicate that that fruit are at risk of sun damage when:

- The FST threshold for Royal Gala apple was 52 °C ± 1 °C for 10 min for necrosis and 47.8 °C for 1 hour for browning (Schrader et al. 2001).
- Based on FST determined by Schrader et al. 2001, Darbyshire et al. 2015 determines a conservation air temperatures threshold of 34.1°C for browning and 38.7°C for necrosis (non-netted orchards) and 37.9 °C for browning under netted orchards for Royal Gala.
- McClymount et al., 2013, utilises a more conservative FST than Schrader et al. 2001, of 46°C threshold FST for Royal Gala in the Shepparton, and thus set air temperatures thresholds of 28°C (non-netted orchards) and 33°C (netted orchards).

Greater than 40°C	High risk of a necrotic patch

Source: Holmes, *et al.*, 2009 cited by Lolicato, 2011

Racsko et al. 2012 (based on the review of several studies) indicate that Granny Smith is highly susceptible to sunburn, while Fuji is moderately sensitive and Pink Lady is less sensitive. Racsko et al. 2012 further state that '*cultivars that ripen early (e.g., Gala) can sunburn severely some years, but escape damage other years. This is more dependent on when or if the FST thresholds are exceeded rather than specific susceptibility of the cultivar to sunburn*'.

Fruit damage

As stated previously, local APGA trials completed during the period 2007-2010 within the Lenswood area provided the reason for orchard cull, with sunburn representing 13% and 22% for Pink Lady and Sundowner, respectively (James 2011). A heat wave event in January 2009 in the Goulburn Valley provides an example of large yield losses (30%–70%) due to sun damage (Thomson et al. 2014).

Gordon, 2007, states that just one day at over 35°C maximum daily temperature can cause 20% or more fruit to be down graded especially if stored for any length of time (as the blemish caused by even mild sunburn worsens in storage). In some cases sun damage will become evident only after a period of cool storage (Lolicato, 2011) refer 3.2.7 for a discussion of storage resilience.

Racsko et al. 2012 (based on a review of several studies) state that most sunburn occurs at the top of the tree, with the greatest percentage of sunburn fruit found in the northeast quadrant of the canopy. It is also understood that bird also preference fruit at the top of the tree leading to combined impacts for these fruit.

Contributing factors to sunburn risk

Racsko et al, 2012 state that '*high temperature and sunlight exposure are the primary direct factors that determine if sunburn damage occurs – with these direct factors defined as those that are required for induction of sunburn. Several other factors indirectly influence the induction of sunburn. Indirect factors are defined as factors that alone cannot induce sunburn, but can interact with the direct factors to influence the appearance of the symptoms and the severity of damage'.* The indirect factors which increase the risk of sunburn include:

- Low cloud cover,
- Low relative humidity
- Reduced air circulation (i.e. wind movement)[13]
- Orchard management (i.e. pruning and thinning), with decreased foliage protection increasing the risk of sunburn;
- Type of rootstock;
- Fruit size (with larger fruit more likely to burn than small fruit[14]) and

[13] In modeling apple fruit surface temperatures, Thorpe (1974) showed that a wind speed increase from 0.3 to 4.0 m·s−1 resulted in a temperature drop of 5◦C at the fruit surface.

[14] Sunburn seldom occurs until apples reach a diameter of 45 mm (surface area of 64 cm2); this size is normally attained 7 to 8 weeks after full bloom. Before this stage, the fruit surface area is not sufficient to absorb adequate solar radiation to increase the FST to the minimum threshold, Racsko et al. 2012.

- Fruit position on the tree, with fruit more likely to burn if it is located on the tree periphery.

Specifically, Thomson et al. 2014, states that any increase in the maximum air temperature experienced during the fruit development period or a reduction in wind experienced during these periods of high temperature will increase the risk of fruit damage prior to harvest.

Many of these factors are affected by netting as discussed in Section 5.2, with the benefits of netting discussed below.

Benefits of netting

Netting provides protection by shielding fruit from solar radiation. This lowers FST and reduces fruit exposure to UV-B radiation (McClymount et al., 2013). Specific results from Australian trials are provided below:

- In Western Australia, the maximum FST recorded was 55°C when the maximum daily temperature was 38°C. Within this trial there were about twice as many days when FST went above this threshold in the orchard without netting (17 days) compared to fruit grown under the nets[15] (8 days).
- In a Victorian trial, daily maximum FST were as much as 6°C lower under netting. Fewer fruit under netting reached temperature thresholds for occurrence of sunburn browning (46–49°C) and fruit under netting did not reach temperature thresholds for sunburn necrosis (52°C).
- McClymount et al., 2013, report that in trails conducted in Shepparton, the maximum FST in the non-netted area was 54.1°C, as compared with 49.6°C under the netted area (4.5°C lower under netting), resulting in a 37% reduction in browning due to sunburn and a practical elimination of necrosis.
- Darbyshire et al. 2015, states that for trails conducted in Shepparton, thresholds for browning Royal Gala are reduced from 34.1°C to 37.9°C with netting (3.8°C higher under netting), thus reducing the number of days which sunburn may occur from 13 to 7 days (reduction of 54%) and with an associated 50% reduction in damage for fruit under netting.

Therefore netting will reduce sunburn damage, but not completely prevent it.

Darbyshire et al. 2015, also provides information on the likelihood of threshold being exceeded at Lenswood. Based on the historic distribution of the data (10th – 90th percentile) there are between 0 – 6 days when the threshold of 34.1°C for sunburn will be exceeded. This decreases to 0 - 2 days when netting is in place and a threshold of 37.9°C is applied. Given the reduction in the likely number of days when sunburn thresholds will be exceed in Lenswood, the damage to fruit will also be reduced by approximately 50%. Given the reduction in the likely number of days when sunburn thresholds will be exceed in Lenswood, the damage to fruit will also be reduced by approximately 50%.

Warmer summers also hasten the development of fruit - shifting ripening from milder autumn and late summer conditions towards hotter mid-summer conditions and further increasing the likelihood of sunburn.

[15] Source http://apal.org.au/netting-benefits-changing-climate/

Figure 3-2: Example of sunburn on apple crop

3.2.2 Bird and bat

Background

While some basic information is known about losses caused by birds, there has been little research that has ameliorated the problem (Bomford, 1992), with an inability to accurately and consistently quantify and predict crop damage. As a result, local estimates of the likely range of crop damage have been utilised, within the context of a general understanding of bird impacts.

Many bird species, including both native and introduced species, are responsible for damage to horticultural crops. A major pest to apple and pear orchards in the central Adelaide Hills is the Adelaide rosella and rainbow lorikeet, which can cause severe damage to buds, flowers and ripening fruit. Musk lorikeets are also known to be persistent feeders, for example it has been reported that in the Mt Lofty Ranges large flocks visited a pear orchard every day for 3 weeks until the crop was eliminated. These species are protected under the National Parks and Wildlife Act 1972 and destruction of these birds to prevent damage to commercial crops can only be carried out if a destruction permit under Section 53 has been issued. The European starling and Silvereye can also have an impact.

Few published estimates are available of total horticultural losses caused by birds in Australia. However a recent national survey of horticulturists indicates that the average damage for apple and pears was 13% (1700 growers surveyed) (Tracey, 2007). Other estimates of fruit damage in the Mount Lofty Ranges to apple, pear and cherry trees suggest that damage levels range from less than 5% to 50% (Graham 1996; Graham et al. 1999).

Fruit damage

While losses to the industry as a whole are often low, losses to individual growers may be severe, and losses

are distributed patchily in space and time (Bomford, 1992). Typically, flocks of pest birds concentrate their feeding and habitually visit particular areas and ignore others (Tracey, 2007). Local APGA trials in 2014, support this finding with approximately the top one quarter of the trees loosing approximately 90% of the fruit load to birds, with an estimated 20% of fruit damage on the remainder of trees through bird damage and other causes. The other location which was considered in the APGA trial had significantly less fruit damage (5%) within the non-netted site, showing the possible variation between locations.

At an orchard level, the characteristics of the property or crop and the surrounding area, are perhaps the most important factors affecting levels of bird damage. Such characteristics include:

- Crops with adjacent suitable roosting habitat or perching sites, such as native vegetation, or windbreaks are more likely to suffer greater damage (Tracey, 2007);
- The size and shape of the cropping area also influence bird damage, with smaller fields often being more susceptible than large fields (Johnson et al. 1989); and
- Earlier ripening varieties in some areas are known to suffer significantly greater bird damage than later maturing varieties.

Birds cause losses to horticulture by damaging or removing shoots, stems, foliage, buds or fruit; by damaging infrastructure, including irrigation systems; or by secondary spoilage through infection with moulds, yeasts or bacteria or through insect damage (Tracey, 2007). Bird damage can also make it necessary to harvest early, resulting in a downgrading of both the quality and quantity of fruit (Tracey, 2007). Damage to foliage, particularly by cockatoos and rosellas, occurs where the birds clip branches, stems and whole fruits, damage buds and growing tips, or pull up seedlings – damaging the current and subsequent seasons plant growth (Tracey, 2007). In a survey of 20 cherry orchards in South Australia, one quarter suffered bud damage of over 60% (Sinclair and Bird 1987), with results likely to be similar for apple trees.

As stated local APGA trials completed during 2007-2010 within the Lenswood area, provided the reason for orchard cull, with bird damage representing 20% for both Pink Lady and Sundowner (James 2011).

Netting and other management strategies

Shooting is probably the most universally practiced and most ineffective bird control technique used in Australia (Bomford, 1992), while scare devices may be counterproductive (Flemming, 1990) and hence alternative approaches to these management strategies are required. Permanent netting enclosures have been found to be cost-effective for new, intensively grown cherry orchards with high-yielding fruit, even at moderate to low levels of bird damage (Sinclair, 1990).

Using nets to physically prevent birds from gaining access to crops is an effective way of reducing or preventing damage. As bird damage is often variable and difficult for growers to predict, one of the attractive features of exclusion netting is that it reduces uncertainty and the need to monitor the risk from birds. Netting also overcomes increasing concerns about the use of chemicals, animal welfare issues, and restrictions on the use of acoustic devices under noise pollution control legislation (Tracey, 2007).

In the long term reducing access to food is essential for reducing populations of pest birds.

Flying foxes

Flying fox damage to orchards in South Australia does not have a significant impact currently. However, populations of flying foxes in Adelaide are on the increase and are a potential future risk to apple crops in

the Adelaide Hills. Evidence from eastern states is of significant damage to fruit crops from flying foxes, particularly under certain conditions. For example, research indicates that flying fox damage is greatest when environmental conditions cause native blossoms not to flower[16].

The challenge to address flying fox damage in the future will need to be addressed. A significant amount of research both in Australia and overseas at this stage has failed to identify a deterrent method that has achieved the success rate of full canopy netting[17].

3.2.3 Wind

Wind speeds are significantly reduced under netting - with 50% lower wind speed compared to outside the netting (Middleton 2015). Under wind conditions, tree movement causes apples to rub on one another or on tree limbs creating blemishes. Blemished fruit are reduced to second grading or juice, with significantly reduce returns. Decreased wind under the netting, also enables the more timely and efficient use of sprays. Netting is also highly effective in reducing spray drift.

Local APGA trials completed during 2007-2010 within the Lenswood area provided the reason for orchard cull, with wind representing 4.5% and 1.4% for Pink Lady and Sundowner, respectively (James 2011), and hence is significantly less than the damage done by sunburn or birds.

3.2.4 Hail

The Bureau of Metrology does not specifically record hail, and hence providing specific data on the likelihood of hail occurring in the central Adelaide Hills is difficult. As a result, local estimates of the likely range of crop damage and probability of occurrence have been utilised within the development of CBA scenarios.

Local AGA trials completed during 2007-2010 within the Lenswood area, provided the reason for orchard cull, with hail representing 2.3% and 2.6% for Pink Lady and Sundowner respectively (James, 2011) and hence is significantly less than the damage done by sunburn or birds.

Severe hailstorms not only damage the current crop but can cause structural and bud damage to trees that may reduce or wipe out the apple crop for the subsequent 2 or 3 seasons. While the subsequent season impact is known, hail storms of this intensity are very unlikely and have not been included within development of the CBA scenarios.

Little in know about the history of hail, and little can be said with confidence concerning how extreme weather events (such as hail) will change in the future, although there is an indication that hail risk may decrease over the Mount Lofty Ranges (refer Figure 3-3). While this is the case, it is considered to be prudent to include hail within development of CBA scenarios.

[16] https://www.daf.qld.gov.au/__data/assets/pdf_file/0006/71970/Flying-fox-control-methods-research.pdf
[17] https://www.daf.qld.gov.au/__data/assets/pdf_file/0006/71970/Flying-fox-control-methods-research.pdf

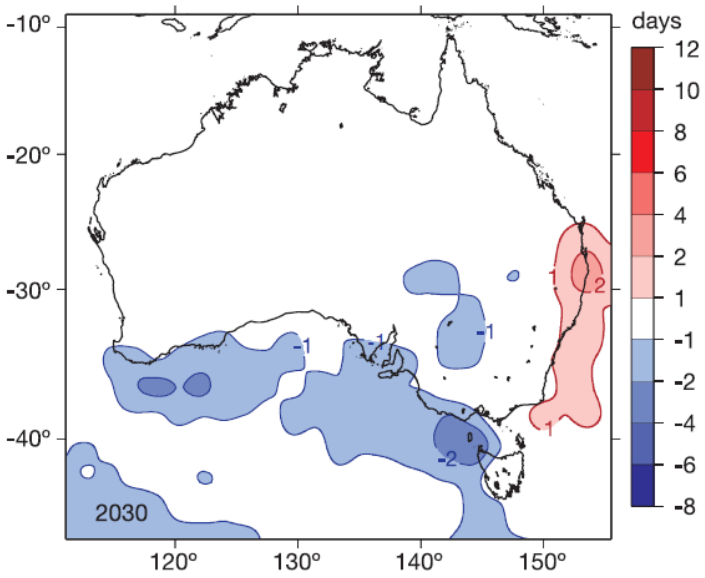

Figure 3-3 Projected changes in hail risk (hail-days per year) for 2030 from the CSIRO Mark 3.5 model for the SRES A2 scenario. Blue regions indicate a decrease in hail risk and red regions indicate an increase in hail risk (Source Niall and Walsh, 2005).

3.2.5 Frost

Apple trees require frost-free conditions at bud stage, with production losses occurring if frost occurs. The Bureau of Metrology does not specifically record frost, and hence providing specific data on the likelihood of frost occurring in the central Adelaide Hills is difficult.

To analyse future frost risk, changes to two processes must be considered; the timing of frost occurrence and the timing of flowering. The interaction of these processes will dictate potential risk (Darbyshire, 2014).

Frost formation relies on the combination both weather variables (for instance, temperature, humidity, wind speed) and environmental conditions (for instance, topography, distance from water and vegetative cover). This complexity in frost development has hindered the development of a predicative model of frost that is applicable to a wide range of locations and timespans (Darbyshire, 2014). As such, frost events are usually approximated using minimum temperature thresholds (such as those used in Putland et al. 2011).

While changes in timing of bud burst and flowering due to warming temperatures in the future may result in potential for increased frost risk (Kaukoranta et al., 2010), results from Lenswood (refer Appendix 12.3), indicate that the historic frequency[18] of frost[19] was 0.2 days, which reduced slightly to 0.1 days under most climate scenarios. Thomson et al. 2014 concluded *that given the rate of change in the annual maximum temperature, there is a more pressing need to adapt to more intense heat events than there is to a reduction in cold,* which would affect impacts of frost and winter chilling.

[18] For the 20 year period from 1980-1999.

[19] Defined as nights with a minimum of less than 0 °C.

While Gordon 2007 and Blackburn 2007 under netting temperatures were marginally higher on cold nights, it appears that this increase in temperature may be in the order of 0.2°C and therefore not a significant impact (pers. comm. Lexie McClymont, Department of Primary Industries, Victoria). As a result, frost has not been included within the development of CBA scenarios.

3.2.6 Variety influence

Losses due to sun damage can be significant depending on the fruit type and variety (Lolicato, 2011).

For example, Racsko et al. 2012 (based on the review of several studies) indicates that Granny Smith is highly susceptible to sunburn (with the market having a low tolerance for any skin colour variations for this cultivar), while Fuji is moderately sensitive and Pink Lady is least sensitive to sunburn. Racsko et al. 2012 further state that 'cultivars that ripen early (e.g., 'Gala') can sunburn severely some years, but escape damage other years. This is more dependent on when or if the threshold FST is attained before harvest rather than specific susceptibility of the cultivar to sunburn'. Similarly Gordon, 2007, state that Fuji, Braeburn and Granny Smith are especially susceptible to both sunburn and wind rub, with Lolicato, 2011, also listing Royal Gala as susceptible to sunburn.

While this variation in cultivars susceptibility to sunburn is known it is not considered to be large, with Schrader 2003, after test 10 cultivars for minimum FST, finding a range between 46 to 49°C (equivalent to 34 to 36.6 °C maximum air temperature[20])

Variations in damage from other impacts such as birds, and water stress and chill accumulations are also known. While this is the case it was too complex to include on the CBA tool

3.2.7 Impact on product quality and storage resilience

The APGA 2014 trials showed that there was a reduced susceptibility to resultant storage breakdown for fruit which had been grown under netting. For example, the fruit[21] that was picked from the non-netted site reported additional losses during storage due to rots and fruit breakdown. It was estimated that the final losses from the non-netted site were approximately 60% of the initial crop potential. Losses from the netted site were less than 5%. Fruit breakdown during storage leads to a compounding of issues with growers costs associated with harvest, packing and storage occurring and then fruit being downgraded to juice, where the price may be as low as 10 cents per kilogram (Gordon, 2007).

While, storage breakdown is implicitly included in the CBA as reflected in the marketable yield and pack-out, the drivers behind storage resilience have not be modelled specifically.

3.3 Other drivers

Grower and picker OHS – Netting reduces daytime temperatures by 1-3°C on warm days (Middleton 2015) or up to by 3-6°C during hot periods. This reduction in temperature improves comfort of orchard works and

[20] Based on http://hort.tfrec.wsu.edu/les/enviroStress.pdf, with the relationship: y = 1.17x + 6.21, where y = FST and x = maximum air temperature.

[21] Fuji variety (type Nagafu 2) on M106 rootstock.

thereby reduces OHS risks.

Variable growing and harvesting costs - Picking efficiencies[22] and reduced thinning and mature tree punning costs occur under netting. This will be off-set to some degree by increased pollination costs, as bees need to be actively managed within permanent netting enclosures, refer to section 5.4.

3.4 Future trends in drivers

The above Sections on drivers for netting have described the current situation. However, when considering the evaluation of permanent orchard netting and the return on investment over a defined period of time, future trends in these drivers need to be considered and where significant included within the CBA.

For example the main climate associated trends include:
1. Changes to mean temperature - which will affect phenology (the timing of events, such as flowering) through changes to chill accumulation which may influence tree growth and fruit ripening processes. Advanced phenology is also likely to hasten ripening processes (earlier). The spectrum of weeds, pests and diseases is also likely to change with warmer temperatures.

2. Changes to extreme maximum temperatures and to a lesser extent minimum temperatures. These events may be heatwaves and will contribute to sunburn and heat stress.

3. Changes to the timing and amount of rainfall - which will influence the soil and plant water balance and have an impact on disease and fruit quality.

4. Changes to the quality and quantity of water available for irrigation

Currently there is a higher degree of confidence in changes to temperature than to rainfall, and we also understand that increases in mean temperature could also be influenced by possible increases in temperature variation (leading to more extreme events –such as heat waves), refer Figure 3-4.

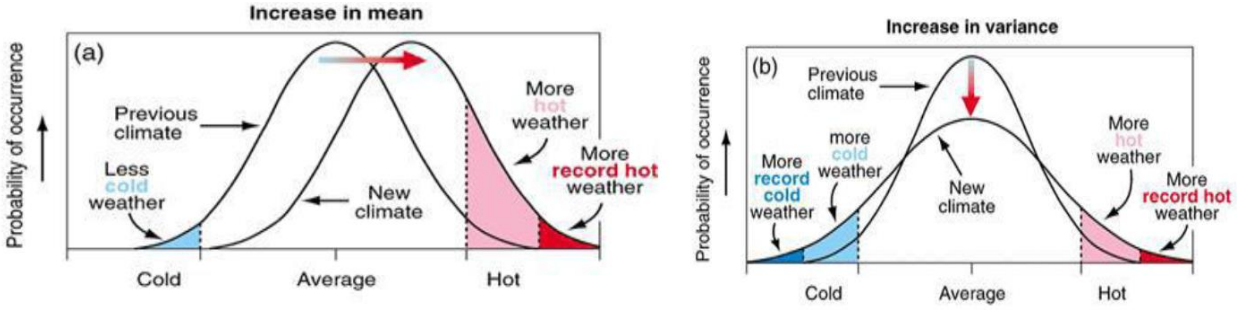

Figure 3-4 Illustration of effects on extreme temperature (IPCC 2007)
For a normally distributed variable such as temperature a small increase in its long-term mean can produce substantial changes in the probability of extreme heat events. When this increase in mean

[22] More uniform fruit sizing and better/consistent colouring means fewer picking cycles per crop-season - e.g. Galas 1-2 picks instead of 3-4. Bins can be spaced more closely because of higher picking density on each cycle, meaning reduce work activity and faster 'turnaround' (less walking for pickers to bins). Picking cost currently $65/bin (110bins/ha = $7,150/ha) – Efficiencies under netting could reduce picking cost to $40/bin (110bins/ha = $4,400/ha).

temperature is combined with an expected increase in the variance then there would be expected to be much more extreme hot temperatures.

Table 3-2 provides a summary of key drivers, their trend over the next 15 years (at 2030)[23] leading to changes in impact.

[23] Climate projections are sourced from Charles SP and Fu G, 2015, Statistically Downscaled Projections for South Australia, Goyder Institute for Water Research Technical Report Series No. 15/1, Adelaide, South Australia

Table 3-2 Drivers for netting, future trends and potential impacts

Driver	Trend (assessed at 2030)	Impact
Water use efficiencies	The 2030 climate projections for the Australian apple growing regions (Putland et al. 2011) predict potential changes in annual rainfall and growing season rainfall at Lenswood of 2%-12% and 2%-8% respectively (refer Appendix 11.3). The extent to which these changes in rainfall will lead to reductions in water run-off (and hence the capacity to harvest surface water for irrigation) is dependent on a large number of factors. Recent regional hydrological studies assessing the impacts of climate change on surface water on the Onkaparinga Catchment indicate that the annual median surface water flows are likely to decrease by 14% (during the time period 2016-2045) and with spring median flows decreasing by 19% (over the same time period) Westra et al. 2015. By 2030 it is also known that evaporation losses will increase by 3% and 4% at Lenswood (refer Appendix 11.3), and with potential evapotranspiration increasing by 2.5 to 4% (Thomas and Hayman, 2015), with the most significant increase occurring in spring. Maximum daily annual temperatures are likely to increase by 1^{o}C (refer Appendix 11.3), while increased CO2 concentrations may lead to increased apple photosynthetic rates and WUE (Putland et al. 2011).	With regard to water use, it is likely that the principal effect of a changing climate will be on water supply with potential reductions in water supply for overland flow captures of up to 20% (Westra et al. 2015). It is also understood, that there will be an increased requirement for irrigation water to compensate for reduced water stored within the soil profile (Thomas and Hayman, 2015). In contrast, the potential effects on tree water use is more uncertain but likely to be of a much lower magnitude given that the highest predicted increase in potential evapotranspiration is 4%, which will be somewhat offset by increases in CO2 (which leads to greater WUE).
Sunburn	Sunburn typically occurs when FST go above 45 - 46°C, which is equivalent to 33 to 34°C. Increased temperatures and heatwaves, with the maximum daily annual temperature likely to increase by 1^{o}C. In this case the new average values for days above 35°C or 40°C approached what is currently a 1 in 10 year event (Putland et al., 2011). In addition increased temperatures and the impact on daily temperatures, warmer summers will hasten the development of fruit - shifting ripening from milder autumn and late summer conditions towards hotter mid-summer	Increased frequency of crop damage from sunburn, with increased total crop damage from each event.

Driver	Trend (assessed at 2030)	Impact
	conditions. Thus increasing the likely frequency of sunburn.	
Changes in mean temperature	Increased temperatures and heatwaves, with the maximum daily annual temperature likely to increase by 1°C.	A major impact of temperature is likely to be advanced phenology or crop development, in some cases this will move ripening processes that are happening in autumn into warmer periods of late summer (Putland et al. 2011). Expansion in the ranges of diseases and pests, such as fruit fly, that are now limited by temperature (Putland et al. 2011).
Extreme heat damage	Increased frequency and intensity of heat events. Under this scenario there will be 7.7 additional days (an increase of 25%) when the maximum temperature is over 30°c and 3.8 additional days (an increase of 56%) when the maximum temperature is over 35°C at Lenswood by 2030 (Based on Historic+1.0°C – refer Section **Error! Reference source not found.**).	Increase frequency and damage from sunburn. Reduce yield and fruit quality (including poor fruit colour and un-even ripening) Local studies at Lenswood showed that a heat event reduced the potential diameter of Pink Lady apples by 2mm with a corresponding decrease in yield of approximately 10% (pers. comm. Paul James Lenswood Cold Stores Co-Operative Society Limited).
Damage from bird and bats	While birds currently impact crop quantity and quality, there is a potential risk that flying foxes could also impact crops in the future. Populations of flying foxes in Adelaide are on the increase and are a potential future risk to apple crops in the Adelaide Hills. Evidence from eastern states is of significant damage to fruit crops from flying foxes. It is assumed that the collective impact of birds and bats will increase by a small incremental amount. There is no data to underpin this, but it is know that birds will have a greater impact on un-netted orchards as more and more orchards are netted.	Increased damage from birds Increased damage from other animals including flying foxes.
Hail damage	Little can be said with confidence concerning how extreme weather events (such as hail) will change in the future, although there is an indication that hail risk may decrease over the Mount Lofty Ranges.	Potential small decrease in the frequency of crop damage from hail, with decreased total crop damage from each event, however the uncertainty in this prediction is very high.

4 Risks from orchard netting and changes to farming practices

4.1 Risks

There are some potential risks when permanent netting enclosures are installed within an orchard. These risks can be actively managed so that the benefits can be more fully realised. Table 4-1 provides a list of known risks and management strategies.

Table 4-1: Potential risks and management strategies

Risk	Management Strategy	References
Access for bees	Place hives under the netting, allow an adequate gap between the top of the tree and the net cover, and temporary removal of netting, or Sections of it, during flowering can also assisting pollination.	Middleton et al. (2000a, b).
Accelerated tree vigour	Control tree vigour with appropriate pruning strategies and use of appropriate rootstocks.	Middleton and McWaters 2002 Lolicato, 2011
Less light penetration Expect light reduction from 12 to 25% depending on; the row orientation; whether the net is gable or flat net; and the time of year as the angle of the sun dips lower in the sky in the autumn so this may have an impact on late maturity varieties.	Maintain good light distribution throughout the canopy with pruning and thinning. Reflective matting can be used as a ground cover.	Middleton and McWaters 2002 Gordon, 2007 APGA of SA 2014 Lolicato, 2011
Winter chill accumulation	As different varieties within a species vary significantly in their chill requirements, there is scope to overcome the risk of insufficient chill accumulation through appropriate variety selection. Alternatively the use of rest breaking agents could be utilised. The use of evaporative cooling through use of sprinklers may enhance chill accumulation.	Thomas and Hayman (2015) Thomas, Hayman and James (2012)
Lower fruit mass Fruit mass declined more rapidly with increasing crop load under nets than in the open	Ensure appropriate thing practices.	Smit 2007
Sensitivity to sunburn Fruit grown under netting is more sensitive to sunburn than if in the open	Removal of netting (in the case of roll back systems, and the pruning or thinning, should be mindful of temperature forecast avoiding periods where threshold for fruit damage may be exceeded.	Smit 2007

5 Netting

5.1 Type

Permanent netting enclosures can be designed to support netting that can be retracted or extended for different periods of the growing season, or they can be designed to support netting that is permanently attached and tensioned to form a complete, immovable cover Lolicato, 2011.

The most common type of netting structure is designed and built from treated pine poles and tensioned cables. The net covering can be either flat or gabled, depending on the design of each structure. Flat-topped structures are designed to stretch under a build-up of hail, while some of the gabled structures are designed to allow hail to open up gaps ('design to fail') that will allow a build-up of hail to fall through the valley of the gable Lolicato, 2011.

The two types of net structures which have been included within the CBA are:

- Flat-top
- Trellis-release (i.e. 'design to fail')

Over new/redeveloped orchards and over currently planted orchards.

It is also noted that such permanent netting enclosures require development approval from the Adelaide Hills Council – as the structure is considered a 'building' under the provisions of in the Development Act 1993. Pursuant to the aforementioned Act, the construction of a building requires development approval and requires the submission of a development application to Council together with the supporting information outlined below[24]. Costs will be associated with gaining this approval and these have been included within the CBA.

5.2 Microclimate

Under netting the microclimate is changed, with relative increase in humidity (10 to 15%) and a decrease in wind (by approximately 50%), a slight reduction in daytime temperatures 1 to 3°C, a reduction in sunlight levels (25%) with an associated reduction in FST[25].

Primarily due to lower evapotranspiration, soil moisture levels tend to decline more slowly under netting, and offers the potential for improved WUE (refer Section 3.1.1) and targeted reductions in irrigation to control tree vigor (Middleton and McWaters, 2002).

A wide range of netting is available differing in net density, weave pattern and colour, which can have a significant influence on the resultant micro-climate. For example:

- Hail netting, which has a much finer mesh (two millimetres) than that required for birds, reduces light levels by 20%–25% if black, 18% if grey and 12%–15% if white (Middleton and McWaters 1996).
- Net colour is an important factor in the amount of solar radiation reaching the tree and thus plays an important role in fruit quality aspects such as red colour development and fruit mass and size (for

24 Refer http://www.ahc.sa.gov.au/ahc-resident/Documents/Permanent%20Environmental%20Covers.pdf
25 http://www.virtualorchard.net/idfta/cft/2002/april/page51.pdf

example white netting is generally preferred for reducing sunburn issues and for assisting with fruit colour development, Lolicato, 2011). Changes to solar radiation reaching the tree also influence WUE.

Permanent shade netting may cause excessive shading in low sunlight intensity periods during spring that could potentially promote excessive shoot length, delay the onset of flowering and reduce fruit set. To avoid these problems netting can be designed to be pulled back to allow sunlight into the orchard when necessary or through other orchard management techniques such as changes in the choice of rootstock and in pruning and irrigation practices, especially in the case of vigorously growing varieties.

The micro-climate under the net can also lead to an improved environment for the growth of ground cover (orchard sward), particularly in dry years. The groundcover in turn leads to reduced evaporation and soil erosion, and improvements in soil structure and fertility with the additional organic matter[5].

5.3 Capital and maintenance costs

Initial capital costs of netting an orchard in the Adelaide Hills can range from approximately $43,000 - $72,000 per hectare (based on discussions with netting installers). For further information on the factors influencing cost see Section 6.3.1.

The main structure should have a useful life of about 40 years, whilst nets will require replacement in 12 to 15 years.

Annual netting maintenance costs may include maintenance to the structure, maintenance to the net and insuring the structure. Properly constructed, flat top systems can be expected to be virtually maintenance free for the first 10 years with about 5 hours of labour/ha/yr thereafter (until the net requires replacement). Similarly, the trellis-release system can be expected to be virtually maintenance free for the first 5 years with about 8 hours of labour/ha/yr thereafter (until the net requires replacement) (James Grigson, pers. comm.).

5.4 Variable costs associated with netting

Some variable costs are likely to be higher under netting due to the increased yield and packout. For example, first class apples cost more to pack, freight and market than processing apples. In the orchard additional beehives will need to be hired. These additional costs will be taken account of in the model.

6 CBA method

6.1 Scope

A financial analysis tool developed for this project uses the cost benefit analysis (CBA) method, and has been undertaken according to the principles and method outlined in the Commonwealth Government's Handbook of Cost-Benefit Analysis (Department of Finance and Administration 2006). It analyses the costs and benefits that accrue to the grower who is making a decision about installing permanent netting over an un-netted orchard block.

The key characteristics of the CBA method employed in this study include the following.

- The CBA includes a base case, that is, the benchmark against which the 'with netting' scenario is compared. The base case is defined as what occurs without netting the block.
- The CBA is conducted over a 20 year time period and results were expressed in terms of net benefits, that is, the incremental benefits and costs of the 'with netting' scenario relative to those generated by the base case scenario[26].
- Costs and benefits are specified in real terms (i.e. constant 2015 dollars). Past and future values are converted to present values by applying a discount rate of 8 per cent.
- In order to account for uncertainty, sensitivity analysis was undertaken using a range of values for key variables (Appendix 13).
- The evaluation criterion employed in the analysis is net present value (NPV)[27], benefit-cost ratio[28] (BCR) and internal rate of return[29] (IRR).

Table 6-1 and Table 6-2 list, in qualitative terms, the benefits and costs associated with the 'with netting' scenario and the base case ('without netting') scenario.

Table 6-1 Benefits associated with permanent netting

Scenario	Benefit	Beneficiary	Valued in Monetary Terms	Sources of Information
Base case (without netting) scenario	Produce sales. Yields and first class packouts expected to decrease over time due to climate change and reduced food sources for birds	See below	See below	See below

[26] Where incremental benefits = ('with netting' benefits – 'without netting' benefits) and incremental costs = ('with netting' costs – 'without netting' costs).

[27] NPV was defined as discounted net benefits, where net benefits = (incremental benefits – incremental costs).

[28] The BCR was defined as (discounted incremental benefits) / (discounted incremental costs).

[29] The discount rate at which the NPV of an investment scenario is equal to zero.

With netting scenario	Produce sales. Netting is expected to increase yields and first class packouts relative to the base case.	Grower	Yes	Grower, studies referred to in Section 3
	Residual value of project capital (i.e. netting)	Grower	Yes	Grower, permanent netting installers

Table 6-2: Costs associated with permanent netting

Scenario	Cost	Bearer of the Cost	Valued in Monetary Terms	Source of Information
Base case (without netting) scenario	Marketing costs. Expected to decrease over time as yields and first class packouts decrease	See below	See below	See below
	Grading and packing costs. Expected to decrease over time as yields and first class packouts decrease	See below	See below	See below
	Orchard costs	See below	See below	See below
With netting scenario	Netting installation costs	Grower	Yes	Grower, permanent netting installers
	Netting maintenance costs	Grower	Yes	Grower
	Marketing costs. Expected to be higher relative to the base case.	Grower	Yes	Grower
	Grading and packing costs. Expected to be higher relative to the base case.	Grower	Yes	Grower
	Orchard costs. Slightly higher than the base case due to use of additional pollination services.	Grower	Yes	Grower

6.2 Data and assumptions used to quantify benefits

This section of the report details the method, sources of information and assumptions used to estimate the benefits listed in Table 6-1.

6.2.1 Produce Sales

Produce sales are based on expected yields and packout rates to different classes of fruit and the gross prices received by growers for those different classes of fruit. In this analysis the classes of fruit considered were simplified to three categories: export/first class, second class and juice/process fruit.

In the tool, growers are asked to provide estimates of mature yield (tonnes per ha) and packout rates (percentages) assuming no netting. They are also asked to provide low, average and high gross prices ($ per kg) they expect for the three categories of fruit.

An expected price for each category of fruit is derived using a Beta PERT distribution (Vose 1996), calculated as follows:

Average price = (low price+(4*average price)+high price)/6

The model does account for changes in yield as trees get replaced and replanted or grafted. Growers provide the following information in this regard:

- Current age of trees
- Age of trees when mature yield is achieved
- Replacement age of trees

The model calculates a yield for immature trees and calculates when the trees will be replaced in the future.

6.2.2 Yield effects of netting

Yield under netting can be reduced if not managed appropriately (see Section 5.2). In this model it has been assumed that the block is managed appropriately for the changed conditions under netting and the costs associated with these changes in management have been taken into account (see Section 6.3.5). The model considered the following positive yield effects of netting:

Effects based on assumptions contained within the model only:

- Water stress
- Heat stress.

Effects based on grower-provided data and assumptions contained within the model:

- Sunburn
- Birds
- Windrub
- Hail.

Water stress (discussed in Section 3.1.1) and heat stress (discussed in Section 3.1.2) impact upon yields

principally. There will be some impact on quality in terms of some downgrading of fruit, however it was assumed that these stresses do not result in fruit being dropped ('culled') in the orchard. These kinds of impacts are less site specific than sunburn, birds, wind rub and hail.

The effect of sunburn, birds, wind rub and hail impacts can be quite site specific, and therefore growers are asked questions in the model about these impacts that enable the current yield impact to be determined. These impacts cause fruit to be culled in the orchard.

To estimate the yield effect of these impacts, model users were asked to provide the expected mature harvested yield (i.e. the yield that is sent to packhouse/processing/juicing for a year of mature yield without hail damage) assuming no net and the equivalent typical quantity of fruit culled(i.e. dropped/not picked). Model users were then asked to apportion the cull fruit to the cull causes, namely sunburn, bird/bat damage, wind rub and other. The other category being a 'catch all' category for other causes for culling that are not affected by netting, e.g. codling moth damage. From this information the proportion of total potential yield lost to these causes could be determined.

Damage from hail storms can vary enormously from one place to another, and also over time. Therefore it is difficult for the grower to estimate a 'typical' level of damage from hail. In the model, growers are asked to describe the hail history for the block for the last 20 years from which an annualised quantity of culled fruit could be estimated.

The key assumptions used to estimate the impact on yield for 'without netting' and 'with netting' scenarios, both currently and projected forward 15 years are described below for each impact.

Water stress

As discussed in Section 3.1.1, netting was assumed to result in a water savings of 20 per cent (due to improved water use efficiencies) with a corresponding 7.5 per cent immediate increase in yield (i.e. the midpoint between 5 and 10 per cent). As discussed in Table 3-2, it is expected that by 2030 that there will be 20 per cent less water available. In other words, this would mean that the gains in yield under netting would dissipate to zero by 2030; and therefore under the base case there would be zero yield gain/loss now trending to a 7.5 per cent reduction in yield by 2030.

Heat stress

As discussed in Section 3.1.2, heat waves and unseasonal hot weather can have a number of impacts on fruit trees. In the model this has been simplified to the main impact observed in the Adelaide Hills, namely a reduction in the size of the fruit, which results in a drop in yield. Based in the information provided in Section 3.1.2, a reduction of daytime temperatures of 1-3^{o}C on warm days or up to by 3-6^{o}C during hot periods under netting has been utilised, with a corresponding 2.5 per cent increase in yield assumed (i.e. a less than 5 per cent change).

Under the projected climatic conditions by 2030 it has been assumed that there will be an increase in temperature and the likelihood and intensity of heatwaves, with the maximum daily annual temperature likely to increase by 1^{o}C. Under netting, it is assumed that the increase in temperature will be offset by the shading effect of the netting, i.e. a 2.5 per cent improvement in yield now trending to zero per cent improvement by 2030. Without netting (i.e. the base case), increases in temperature and the occurrence of heatwaves will lead to a conservative 2.5 per cent yield reduction, i.e. zero yield improvement now trending

to a 2.5 per cent decrease in yield by 2030.

Sunburn

Current losses for the 'without netting' scenario are derived from data input into the model by the user (as described previously in this section).

Based in the information provided in Section 3.2.1, under netting a 50 per cent reduction in the number of days when the threshold for browning damage was exceeded and a total removal of the occurrence of conditions which would lead to sunburn necrosis can be expected. In the model, it was therefore assumed that netting results in a 50 per cent reduction in culls due to sunburn.

Under the projected climatic conditions by 2030, based on the climate models referred to in Section 3.2.1, it is estimated that there will be 25 per cent increase in the number of days when the temperature is over 30^0C and browning can occur and a 56 per cent increase in the number of days when the temperature is over 35^0C and sunburn necrosis can occur. We can therefore expect under both netted and un-netted blocks that the incidence of sunburn will increase. For the 'without netting' scenario it was assumed that by 2030 the damage from sunburn would increase over current levels by 7.5 per cent (i.e. between 5 and 10 per cent), whereas the 'with netting' scenario it was assumed the damage from sunburn would increase over current levels by 2.5 per cent (i.e. less than 5 per cent).

Birds/bats

Current losses for the 'without netting' scenario are derived from data input into the model by the user (as described previously in this section).As discussed in Section 3.2.2, permanent netting can fully exclude birds and flying foxes and therefore can reduce the damage to zero. However for this to occur the netting structure requires sides. Many permanent nets in the Adelaide Hills area do not have sides currently (James Grigson pers. comm.). Nets without sides do currently reduce the fruit damage with only edge trees affected, because birds do not like to fly under nets. It was assumed that for netting without sides the damage is reduced from un-netted levels by 90 per cent.

Into the future it can be expected that more crops will be netted, and pressure on un-netted blocks will increase. It was assumed for the 'without netting' scenario, the increase in damage would be 7.5 per cent (i.e. 5 to 10 per cent) over current levels by 2030. For the 'with netting' where the net has no sides, the damage levels would be 10 per cent of current un-netted damage increasing to 15 per cent of current un-netted damage.

Wind rub

Current losses for the 'without netting' scenario are derived from data input into the model by the user (as described previously in this section). There is very limited discussion in the literature about the impact of netting on wind rub damage (where fruit rub against other fruit or the tree creating scarring). It is noted that wind speeds under netting are significantly reduced and anecdotally damage due to wind rub is reduced (Paul James pers. comm.). It was assumed that netting reduces wind rub damage by 50 per cent over un-netted conditions.

Climate models cannot reasonably predict future wind conditions at fine scales required for this project, therefore for future projections no change in damage levels was assumed for both the 'with' and 'without' netting scenarios.

Hail

Current losses for the 'without netting' scenario are derived from data input into the model by the user (as described previously in this section). Depending on the type of netting installed, the damage from hail can be reduced or eliminated. Two types of netting structures are accommodated in the model. The trellis-release structure specifies pin-hail netting in the Adelaide Hills which protects against the type of hail encountered in the Adelaide Hills. The flat-top structure specifies three grades of netting: 12 mm (protects against heavy hail, not often specified), 16 mm (protects against light hail) and 20 mm (protects against birds, not specified for hail protection). In the model, it was assumed that the pin hail netting and the 12 mm and 16 mm netting on flat top structures reduced the impact from hail to zero, whereas it was assumed that the 20 mm mesh on flat-top structures had no impact on hail damage.

Climate models cannot reasonably predict future hail conditions at fine scales required for this project, therefore for future projections no change in damage levels was assumed for both the 'with' and 'without' netting scenarios.

Other

Other causes of culls were kept constant for both the 'with' and 'without' netting scenarios.

6.2.3 Packout effects of netting

The literature generally indicates that the types of impacts to yield discussed in Section 6.2.2 also have flow on impacts in terms of quality and therefore on packouts. There is very little quantitative data on the effect on packout, however the general consensus is that if these impacts become more severe, then the quality of the fruit is reduced and if these impacts are lessened, the quality of the fruit improves. Discussions with Lenswood Coldstores (Paul James, pers. comm.) suggest that un-netted blocks in the Adelaide Hills have packouts typically in the range of 80 to 85 per cent export/first class fruit (this is the expected quality in average seasons and packouts can, of course, vary from this with specific events and bad seasons). Under netting, blocks typically (and more consistently) yield 90 per cent or more export/first class fruit and fruit sent for juicing is between 2.5 to 3 per cent of the pack out.

In this model, for the 'without netting' scenario it has been assumed that any losses to harvested yields above current losses going forward is reflected in an equivalent loss to export/class 1 packout, cascading down the grades if all the losses cannot be absorbed by the preceding grade. For the 'with netting' scenario it was assumed that 2nd class volumes are reduced by 50 per cent or 7 per cent of pack out, whichever is less; and juicing/processing volumes are reduced by 50 per cent or 3 per cent of pack out, whichever is less. This means that the export/first class packout will increase in comparison to the 'without netting' scenario and will be 90 per cent or more.

6.2.4 Residual value of project capital

A residual value of project capital was estimated as a straight-line depreciation of assets over their useful lives for the 'with netting' scenario. The netting structure (i.e. the frame) was assumed to have a useful life of 40 years, and the netting assumed to have a useful life of 15 years for black nets, 14 years for grey nets and 12 years for white nets (Lindsay Adams, pers. comm.).

6.3 Data and assumptions used for quantifying costs

This section of the report details the method, sources of information and assumptions used to estimate the costs listed in Table 6-2.

6.3.1 Netting installation costs

These costs apply to the 'with netting' scenario only. It was assumed that both the structure and netting would be installed in the first year of the analysis.

In the model, growers are able to put in costs from quotes for the block, or if they do not have a quote the model can estimate the installation costs based on their responses to questions about the type of structure that will be installed and the site conditions.

The following costs were confirmed by netting suppliers/installers:

- Structure materials
- Netting materials
- Structure labour
- Netting labour
- Site preparations
- Development approval.

Development approval is estimated to be approximately $5,000 per application regardless of the size of the structure (James Grigson, pers. comm.).

The other determining factors of the installation costs are:

- The type of structure (flat-top or trellis release) and for flat-top, the mesh size
- The site area
- Whether the structure has netting on the sides
- The site shape (whether it is regular (i.e. approximately square/rectangular) or irregular in shape)
- The site slope (flat-top only).

The following assumptions on costs were derived from discussions with net installers/suppliers

Type of structure

The base price for a structure covering a 4 ha non-sloping site, rectangular in shape and no sides was estimated to be:

Trellis-release:

- $45,000/ha

Flat-top:

- 20 mm mesh: $42,500/ha
- 16 mm mesh: $47,500/ha
- 12 mm mesh: $55,000/ha

The cost of installation is determined from the base price adjusted by the maximum variance of the following factors.

So, for example a flat-top structure with 16 mm mesh, with sides, on a flat, one ha site, the estimated cost would be $71,250 (i.e. $47,500 plus 50 per cent).

Site area

Table 6-3 provides the assumptions for the increase in the base price in relation to site area. Once sites are less than 4 hectares, the cost to net the site increases due to more poles and wires.

Table 6-3 Increase in the base price ($/ha) in relation to site area

Ha	<1	1	2	3	4+
Flat-top	50%	50%	25%	12.5%	0%
Trellis-release	61%	17%	11%	5.5%	0%

Side netting

Netting on sides of structures is assumed to increase the base price by 10 per cent.

Site shape

A regular site shape (i.e. square or rectangular) does not increase the base price, whereas an irregular site shape is assumed to increase the base price by 25 per cent.

Slope

Table 6-4 provides the assumptions for the increase in the base price in relation to site slope. For flat-top structures if there is a slope the price can increase as pole height may need to increase to ensure enough clearance above the trees. For trellis-release structures there is no increase in price because the poles are placed close together and the structure can follow the slope.

Table 6-4 Increase in the base price in relation to site slope

Ha	Up to 1:12 gradient	1:12 to 1:6 gradient	1:6 to 1:4 gradient
Flat-top	0%	10%	25%

6.3.2 Netting maintenance costs

Annual netting maintenance costs may include maintenance to the structure, maintenance to the net and insuring the structure. The model allows growers to input their expected costs. Properly constructed, flat top systems can be expected to be virtually maintenance free for the first 10 years with about 5 hours of labour/ha/yr thereafter (until the net requires replacement). Similarly, the trellis-release system can be expected to be virtually maintenance free for the first 5 years with about 8 hours of labour/ha/yr thereafter (until the net requires replacement) (James Grigson, pers. comm.).

6.3.3 Marketing costs

On the basis of discussions with Lenswood Cooperative (Matt Shultz, pers. comm.) and APGASA (Susie

Green, pers. comm.), the marketing costs considered were:

- Freight to market
- Commission
- Levies.

Growers input the freight and commission rates ($/kg) into the model. Current apple levies[30] are included in the model.

6.3.4 Grading and packing costs

Grading and packing costs are included in the model. Storage costs have been excluded, because these arrangements can be complex and vary from season to season. Working on the basis that the storage costs would not vary between the 'without netting' and 'with netting' scenarios, excluding this cost will not affect the cost benefit analysis results. Growers input the grading and packing cost rates ($/kg) into the model in the following manner:

- Tipping/grading
- Packing – export/first class
- Packing – second class

The grading and packing costs under the 'with netting' scenario are higher because of the higher proportion of export/first class packout and because there are higher volumes (due to higher harvested yields) going through the packhouse from the block.

6.3.5 Orchard costs

Orchard costs (i.e. variable costs to manage the block) considered in the model:

- Weed and pest control (e.g. herbicides, pesticides, insecticides, pheromones, pest and disease monitoring)
- Nutrition (e.g. fertilisers, soil conditioners, foliar sprays, leaf/soil testing)
- Chemical thinning
- Pollination (e.g. hive hire)
- Irrigation (e.g. electricity, irrigation system maintenance)
- Contract operations (e.g. hand thinning and pruning, picking, freight to pack house, etc.)
- Machinery costs (e.g. fuel, oil and grease, machinery maintenance)
- Hired labour
- Other

Growers input the orchard cost rates ($/ha) into the model, assuming mature yield without netting.

Blocks under netting require additional pollination services (i.e. hive hire) and this is taken into account in the model. The grower inputs the data on the expected additional pollination services required under

30 http://apal.org.au/research-development-extension/levies/

netting (see Section 7.5).

7 Cost benefit analysis tool

A CBA tool has been be developed to enable growers and others to calculate the expected profitability of netting apple orchards. Given the variability in management practices, prices, yields, production costs and site conditions, an 'average' analysis is not particularly useful to the individual grower. Hence, the CBA tool has been set up to allow a high level of input by the grower to calculate the expected profitability of netting for the grower's own orchard.

The CBA tool is set up with a number of sheets/tabs:

1. Introduction
2. Main menu
3. Yield, packout & prices
4. Orchard & post harvest costs
5. Netting costs
6. Data summary
7. Gross margin
8. Impact assumptions
9. Financial analysis
10. Business case results

Each sheet is briefly described following.

7.1 Introduction

This tab describes the background to and function of this tool.

7.2 Main menu

This is the 'table of contents' tab which allows users to navigate around to various sheets in the tool.

7.3 Yield, packout and prices sheet

This is the first of three tabs on which the user enters data about the orchard block. The user enters data on:

- Block information (block identifier, variety, area, current age, age at mature yield, age at replacement)
- Harvested yield (expected mature harvested yield without net)
- Orchard culls (expected cull tonnage at mature yield without net, apportioned causes of culls)
- Packout (expected packout to export/first class, second class and process/juice at mature yield without net)
- Gross prices (low, average and high prices for export/first class, second class and process/juice)

This information is used to estimate yields and sales. It is also used in the calculations for post-harvest costs.

7.4 Orchard and post-harvest costs

This is the second of three tabs on which the user enters data about the orchard block. The user enters data

on:

- Orchard costs (without net)
- Marketing costs
- Grading and packing costs.

For more details on the types data collected see Sections 6.3.3, 6.3.4 and 6.3.5 respectively.

This information is used to estimate costs of production.

7.5 Netting costs

This is the third of three tabs on which the user enters data about the orchard block. The user enters data on:

- Site details (site shape and slope, see Section 6.3.1 for more details)
- Netting details (type of structure, mesh size where applicable and whether there will be side netting, see Section 6.3.1 for more details)
- Netting installation costs (quote details on materials, labour, site preparation and development approval, see Section 6.3.1 for more details)
- Netting life expectancy (mesh life expectancy based on the colour of the net, see Section 6.2.4 for further details)
- Netting maintenance costs (ongoing structure, net and insurance costs)
- Other ongoing netting costs (beehive hire).

This information is used to estimate the initial investment costs and replacement costs for the netting and the ongoing costs associated with the netting.

This sheet is set up so that a grower can either input details from a netting installation quote for the block, or to estimate the netting installation costs if a quote is not available. This caters for growers who may be at different stages of their planning i.e. from growers who are early in their planning and are wishing to decide whether to pursue netting to growers who are advanced in their planning and are seeking figures for their business case.

7.6 Data Summary

This sheet summarises the previous three sheets of input data. It is a review sheet for model users and includes buttons to navigate back to the input data sheets.

7.7 Gross margin

This sheet uses information provided in the yield, packout and prices and the orchard and post-harvest costs sheets to put together a gross margin for the block and on a per ha basis.

7.8 Impact assumptions

This sheet details the assumptions for the effect of netting on the following yield and packout impacts:

- Water stress

- Heat stress
- Sunburn
- Birds/bats
- Wind rub
- Hail

It calculates the yields and packouts based on the assumptions set out in Section 6.2.2. This sheet is hidden in the public version of the model.

7.9 Financial analysis

This is the sheet on which the financial analysis is undertaken. Data is taken from the preceding sheets (principally the data summary and impact assumption sheets) to develop future flows of costs and benefits for the base case ('without netting' scenario) and the 'with netting' scenario. The analysis is taken out to 20 years. The benefits and costs considered are those described in Table 6-1 and Table 6-2 in Section 6.1. The cumulative flows of benefits and costs are discounted. From these discounted cashflows the following indicators have been estimated:

- Net present value (NPV): value of the netting to the grower taking into account future flows of costs and benefits. Netting is worthwhile if the NPV is greater than zero.
- Benefit cost ratio (BCR): the ratio of incremental benefits of netting to the incremental costs of netting. Netting is worthwhile if the BCR is greater than one.
- Estimated payback period: the time (years) that will elapse before the netting has paid for itself in additional profit on the basis of discounted flows of costs and benefits.
- Internal rate of return (IRR): discount rate at which the NPV is zero. Netting is worthwhile if the IRR is greater than the discount rate used.
- Equivalent annual return (block and per ha): is the NPV presented as an annual figure.

7.10 Business case results

Once the grower has completed their analysis they can use the figures presented in the results sheet in the model in their business case. The following results are presented:

- Increase in total packout under netting in percentage terms and tonnes per ha
- Increase in premium grade (i.e. first class/export) packout under netting in percentage terms and tonnes per ha
- Premium grade average gross price
- Increase in revenue (i.e. fruit sales) and increase in production costs under netting
- Increase in gross margin under netting
- Benefit cost ratio
- Internal rate of return
- Payback period.

8 Business case

The collation of information will also underpin the business case, by providing information on best available context and specific case studies as considered relevant. The outputs from the CBA will be loaded into the business case template by the grower to provide a tailored product for those involved in the enterprise decision making process.

9 Delivery, training and extension

One of the key components to the successful adoption of the tool was the delivery, training and extension of development information.

A workshop was hosted on the23rd of September with 15 growers and industry stakeholders to communicate:

1. How the model was developed
2. How to use the model
3. Where the model can be found.

Workshop participants were also asked to provide their feedback regarding the model, with improvements completed based on this feedback.

Intrinsic within this process was also the extension of the tangible benefits of netting in sustainable orchard production. These key benefits were also communicated to growers through newsletter articles focusing on different aspects of netting benefits.

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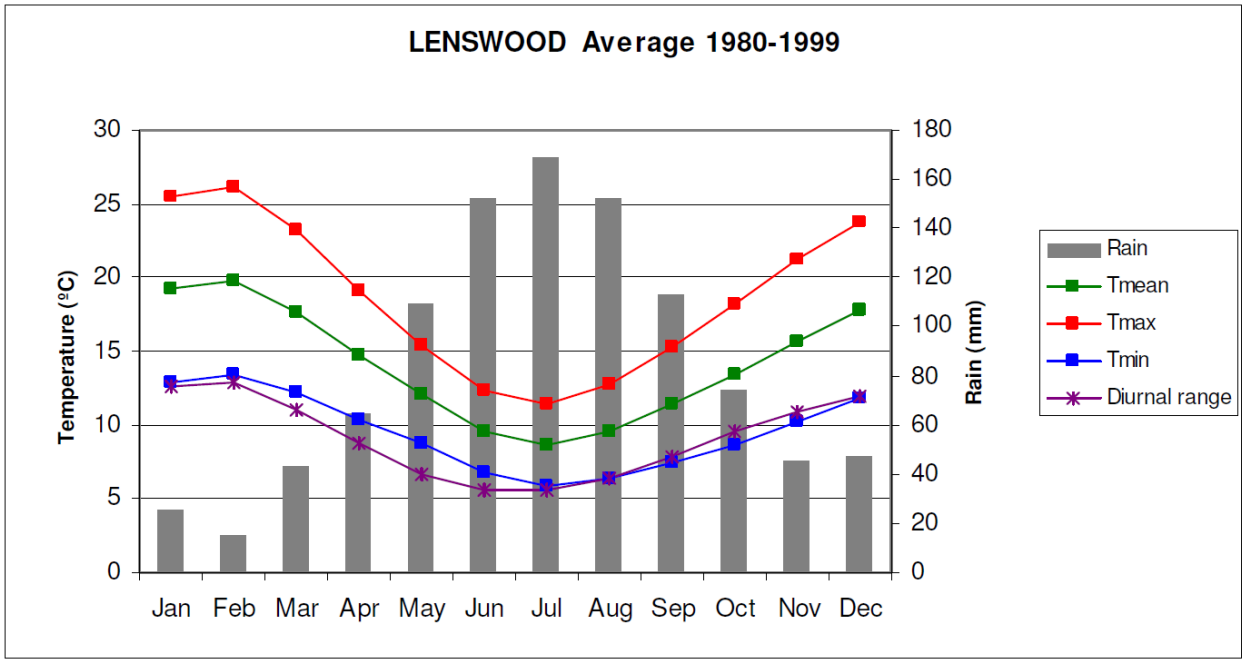
11 Appendix– Climate

11.1 Average monthly rainfall and temperature

Figure of average monthly rainfall and average temperature expressed as mean temperature (Tmean), maximum daily temperature (Tmax), minimum daily temperature (Tmin), and the diurnal range in temperature (Diurnal range). Tmean calculated as (Tmax+Tmin)/2, and Diurnal range calculated as Tmax-Tmin. Averages calculated for the 20 years period from 1980 to 1999.

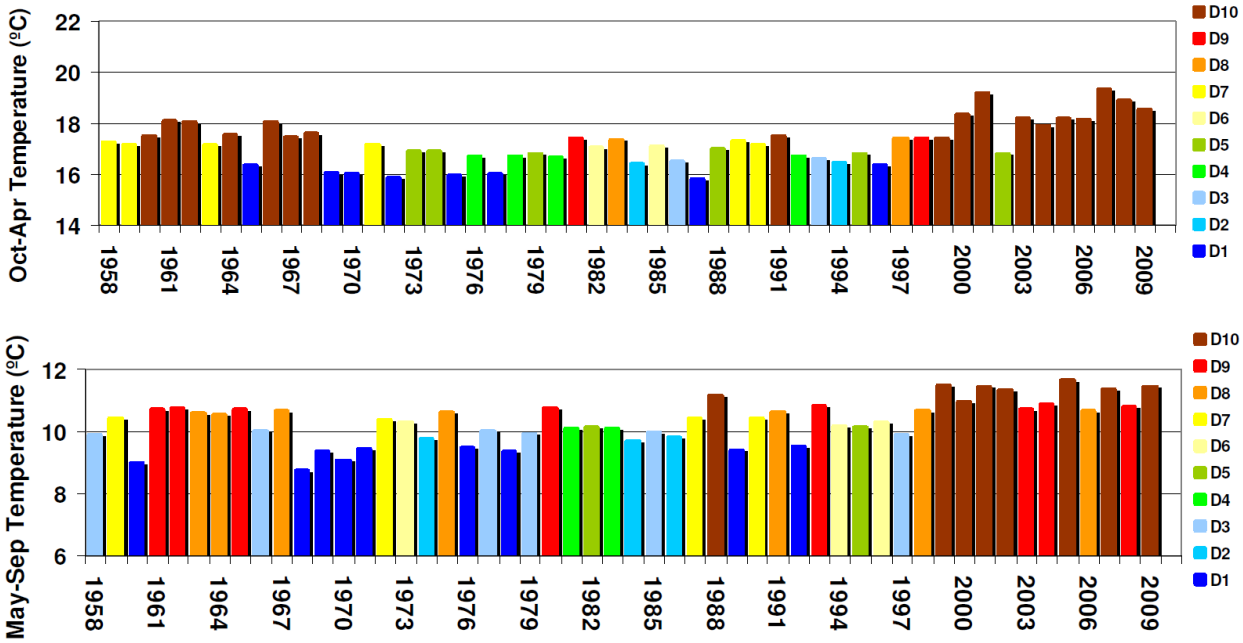
Figure 11-1 Average month temperature and rainfall data (1980 – 1999) source Putland et al. 2011



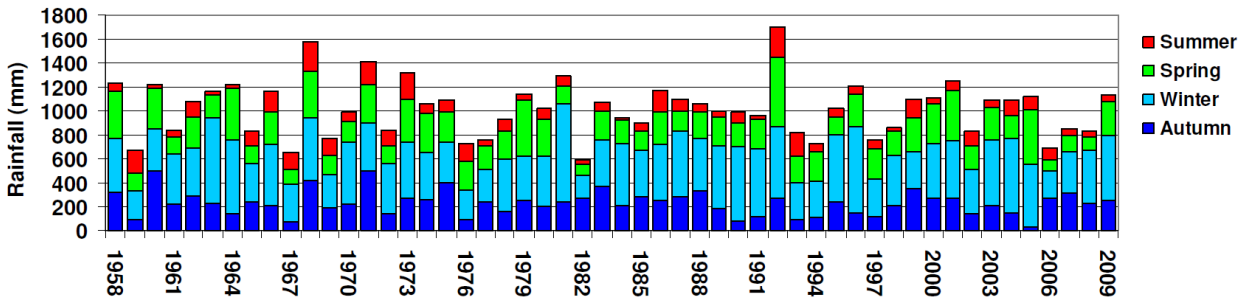
11.2 Trends in climatic factors from 1958 to 2009

Data from the period from 1958 to 2009 are used to calculate cumulative values per year or per season and average values per year as required. Data from the 20 year period from 1980 to 1999 were used to calculate the temperature deciles of mean temperature during the growing season (Oct to Apr) and the dormant season (May to Sep) Putland et al. 2011.

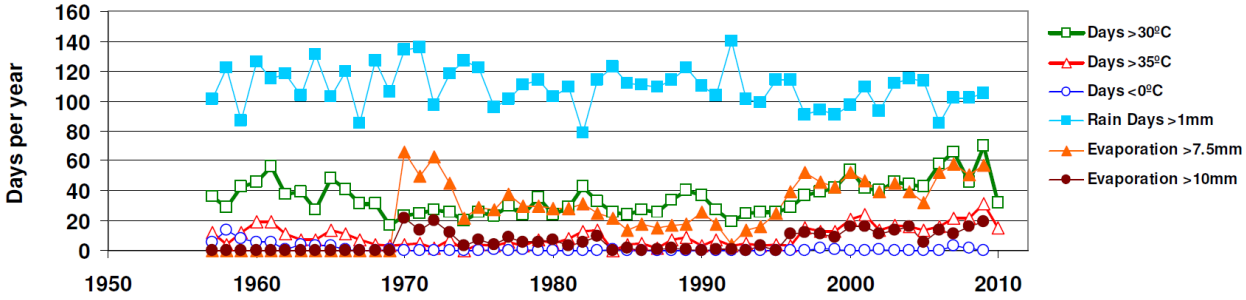
Figure 11-2 9.2 Trends in climatic factors from 1958 to 2009 (Putland et al. 2011)



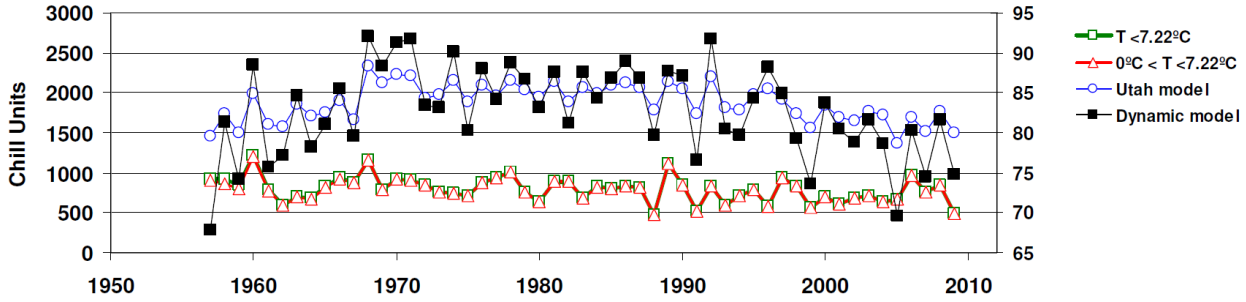
Graphs of annual growing season mean temperature and dormant season mean temperature for the years 1958 to 2009. Growing season was considered to be from 1 October to 30 April the following year, while dormant season was taken to be 1 May to 30 September. The deciles were calculated for the years 1980 to1999 and coloured from blue representing cooler years in decile1 to brown representing warmer years in decile10. In effect there will be two out of the 20 years in each decile. The values for individual years for the 52 years from 1958 to 2009 are shown as bars and categorised and coloured according to these deciles. A trend towards orange and red colours indicates a warming trend, while a trend towards green and blue colours indicates a cooling trend.



A graph of annual cumulative rainfall is shown with seasons categorised. Autumn was considered to be from March to May; Winter was considered to be from June to August; Spring was considered to be from September to November; and Summer was considered to be from December to February.



A graph shows the average number of days per year in each of the 52 years from 1958 to 2009 when a particular threshold for a climate variable was exceeded are shown. Days per year when Tmax was greater than 30°C and 35°C are shown. Days per year when rainfall exceeds 1mm are shown. Days per year when evaporation exceeds 5mm and 7.5mm are shown.



Chill accumulation per years is shown for each of the 52 years from 1958-2009 when calculated using each of four chill accumulation models. These models include chill hours when temperature <7.22°C; chill hours when temperature is <7.22°C but greater than 0°C; Utah chill units calculated by the Utah model; and chill portions calculated by the Dynamic model. Note the units for chill portions (calculated from the Dynamic model) are on the right hand axis.

11.3 Future climate scenarios

Putland et al. 2011 provides the following climate scenarios for Lenswood, refer

Table 11-1 Climate scenarios for Lenswood (Source Putland et al. 2011)

LENSWOOD	Historic	Historic+1.0ºC	Historic+2.0ºC	Miroc3.2(hires)	MRIcgcm2.3.2	CSIRO Mk3.5
	Mean	Mean	Mean	Mean	Mean	Mean
Tmean (ºC) annual	14.1	15.1	16.1	14.8	14.8	15
Tmean (ºC) in growing season	16.9	17.9	18.9	17.7	17.6	17.8
Tmean (ºC) in dormant season	10.3	11.3	12.3	10.9	11	11.1
Avg Tmin (ºC) in dormant season	7.1	8.1	9.1	7.7	7.8	7.8
Tmax (ºC) in hottest month	26.8	27.8	28.8	27.6	27.4	27.8
Tmin (ºC) in hottest month	13.9	14.9	15.9	14.6	14.5	14.7
Tmax (ºC) in coldest month	11.3	12.3	13.3	12	12.1	12.2
Tmin (ºC) in coldest month	5.7	6.7	7.7	6.3	6.4	6.4
Number of days Tmax>30ºC	30.7	38.4	45.3	36.3	35.5	37.9
Number of days Tmax>35ºC	6.8	10.6	14	9.7	9.3	10.2
Number of days Tmax>40ºC	0.2	0.5	1.5	0.4	0.3	0.4
Number of days Tmin<2ºC	2.8	0.7	0.2	0.9	0.8	0.8
Number of days Tmin<1ºC	0.7	0.1	0.1	0.2	0.2	0.2
Number of days Tmin<0ºC	0.2	0.1	0	0.1	0.1	0.1
Number of days Tmin<-1ºC	0.1	0	0	0.1	0.1	0.1
Number of days Tmin<-2ºC	0	0	0	0	0	0
Chill hours <7.22ºC	758	452	239	554	513	515
Chill hours 0-7.22ºC	758	452	239	554	512	514
Chill units UTAH	1955	1688	1346	1787	1758	1728
Chill portions DYNAMIC	84	77	69	80	79	79
Chill hours Coldest month	958	867	776	898	889	883
Rain (mm) annual	1010			987	956	888
Rain (mm) in growing season	316			302	310	290
Rain (mm) in dormant season	695			686	648	599
Evapn (mm) annual	1219			1255	1269	1269
Evapn (mm) in growing season	976			1001	1012	1012
Evapn (mm) in dormant season	241			253	256	256
Number of days evapn >5mm	92.1			92.2	94.4	94.4
Number of days evapn >7.5mm	25			26.5	27.2	27.2
Number of days evapn >10mm	4			4	4.3	4.3

The table of means shows average values for the 20 years period from 1980-1999. The historic mean and its coefficient of variation (CV) are shown. Means for values under climate change scenarios of step

increases in temperature of 1.0°C and 2.0°C, and changes in temperature, rain and evaporation for 2030 under a SRES scenario of A1FI predicted by the three GCM's of Miroc3.2(hires), MRICGCM2.3.2, and CRIRO Mk3.5 are shown. These changes were made to the historic climate record to simulate new climate records.

Pultand et al. 2011 provide more detail on chill accumulation considering the decile response to increases in temperature and with different GCM's. Based on the model Chill hours (0 to 7.22°C), and the decile 5, chill hours under all predicted climate scenarios would be equal to or less than the level of chill accumulation that currently happens in a 1 in 10 year warmest year to occur in 5 out of 10 years. Or based on the Dynamic chill portions (which is the considered the current best practice model by many practitioners), decile 5 declines from 83 to 76[31] under historic +1ºC and ranging from 77 to 79 under the three global climate models.

Lenswood						
	Chill hours (0 to 7.22°C)			**Dynamic chill portions**		
	Min	decile 1	decile 5	Min	decile 1	decile 5
historic climate	469	591	795	70	76	83
historic +1°C	201	309	**480**	60	68	**76**
historic +2°C	89	172	**268**	53	57	**68**
Miroc3.2(hires)	290	397	**586**	61	71	79
MRI-CGCM2.3.6	251	361	**548**	62	70	79
CSIRO mk3.9	259	364	**548**	61	69	77

Source Putland et al, 2011. Chill accumulation calculated by two models using simulated hourly temperature data; Chill hours between 0°C and 7.22°C, and the Dynamic chill portions. Data of minimum recorded (Min), decile1 and decile5 of the Historic Climate and climate predicted by step changes in mean temperature of 1.0°C and 2.0°C, and by climate predicted by three GCMs: Miroc3.2(hires), MRI-CGCM2.3.2 and CSIRO Mk3.5. The values in bold represent the decile5 value of chill accumulation in a predicted climate that is less than decile1 of the historic climate. I.e. if this predicted climate eventuated we would expect equal to or less than the level of low chill accumulation that currently happens in a 1 in 10 year warmest year to occur in 5 out of 10 years.

[31] **Equal to or less than the level of chill accumulation that currently happens in a 1 in 10 year warmest year to occur in 5 out of 10 years.**

Putland et al. 2011 provides deciles from the historic climate record and the impact of adding 0.5, 1.0, 1.5 and 2.0°C temperature to the historical record. The MIROC model predicted an increase in Tmean of 0.73°C by 2030, while MRI model predicted an increase of 0.73°C, and CSIRO model predicted an increase of 0.90°C.

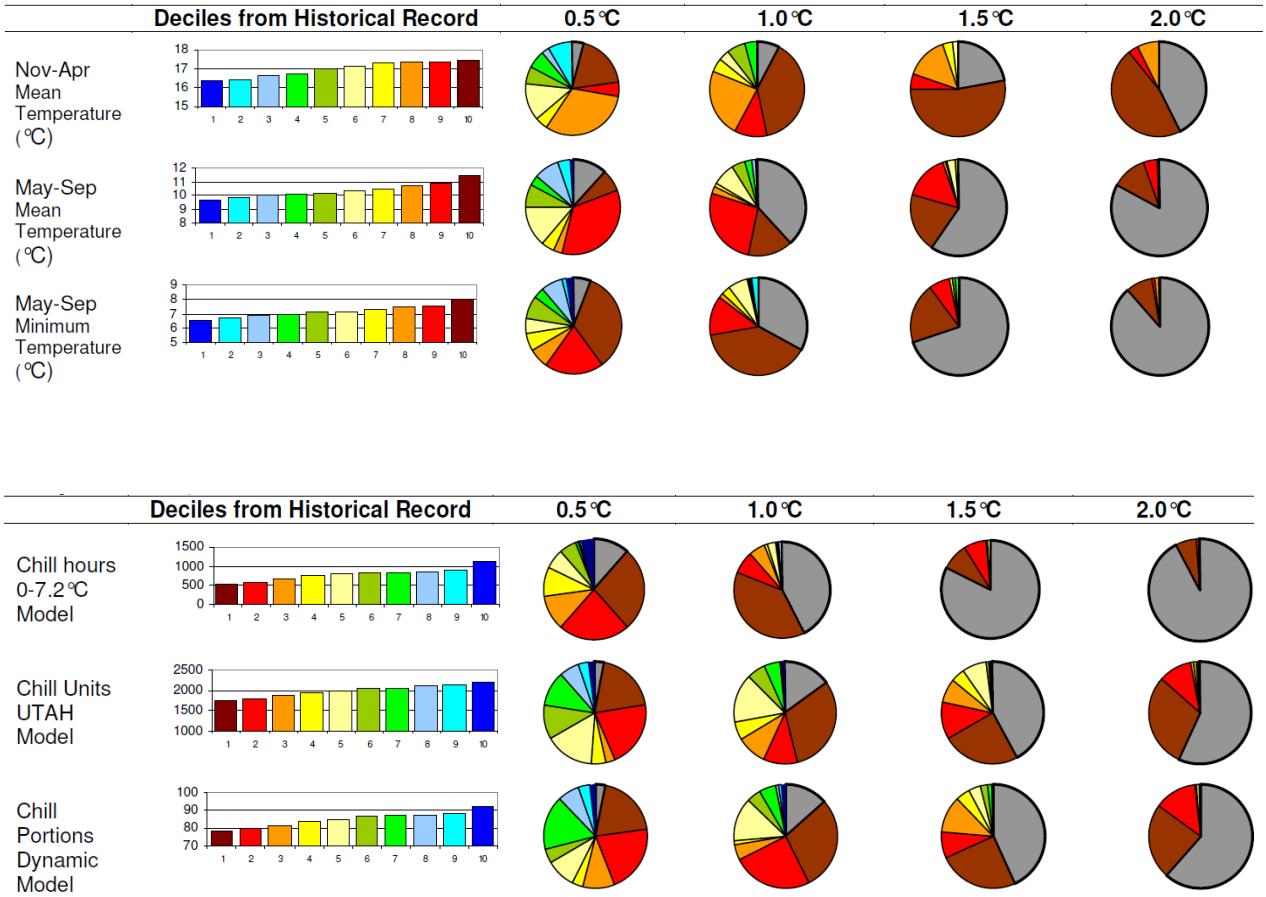
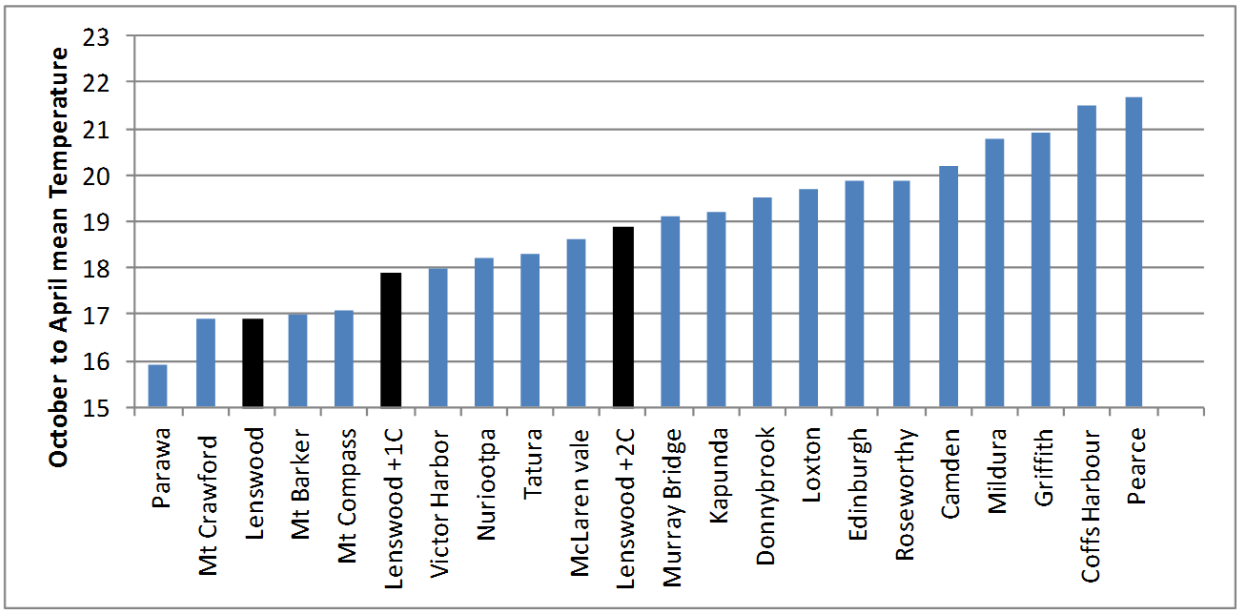
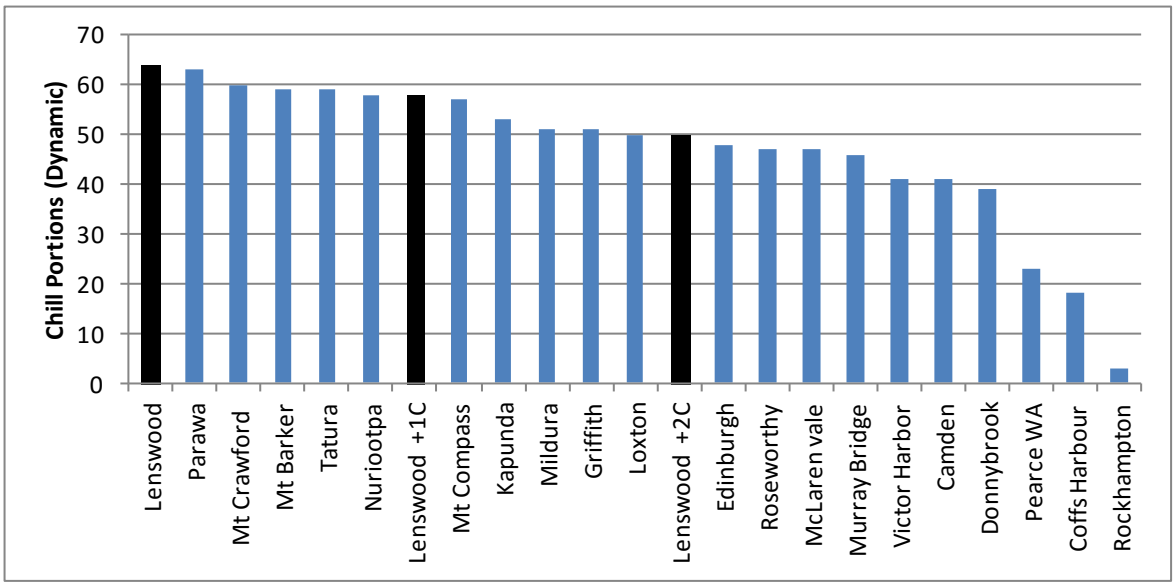


Figure 11-3 Declies from historic record and impact of adding future temperature trends. (source Putland et al. 2011)

Figure provides deciles from the historic climate record of growing season (Oct to Apr) Temperature, dormant season (May to Sep) temperature, and chill hours calculated as hours between 0-7.22°C, chill units calculated from the Utah model and chill portions calculated from the Dynamic model, and the impact of adding 0.5, 1.0, 1.5 and 2.0°C temperature to the historical record. The MIROC model predicted an increase in Tmean of 0.73°C by 2030, while MRI model predicted an increase of 0.73°C, and CSIRO model predicted an increase of 0.90°C.



The mean temperature from 1st October to 30th April during the baseline period (1980-1999) at locations within the Mount Lofty Ranges, for Lenswood with a projected increase in mean temperature of 1°C and 2°C, and for several homologue locations in Australia.



Chill accumulation measured by the Dynamic Model during the baseline period (1980-1999) at locations within the AMLR NRM region, for Lenswood with a projected increase in mean temperature of 1°C and 2°C, and for several homologue locations in Australia.

12 Appendix – Sensitivity analysis for CBA

Table 12-1 Block assumptions, model version 0.2

Block information			
Block name/identifier	Forest		
Area (ha)	4.0		
Variety	Pink Lady		
Current age of trees (yrs)	4		
Replacement age of trees (yrs)	15		
Yields & losses			
Block at maturity	%	t/ha	Block (t)
Average annual potential yield	100.0%	64.0	256.0
Average annual harvested yield			
Excluding hail damage	93.8%	60.0	240.0
Including hail damage	91.3%	58.4	233.6
Average annual culls			
Sunburn	1.3%	0.8	3.2
Bird/bat damage	3.1%	2.0	8.0
Wind rub	0.3%	0.2	0.8
Hail	2.5%	1.6	6.4
Other	1.6%	1.0	4.0
Packout		t/ha	Block (t)
Export/1st Class	92%	53.7	214.9
2nd Class	4%	2.3	9.3
Juice/Process	4%	2.3	9.3
Total	100%	58.4	233.6
Prices	Low	Average	High
Export/1st Class ($/kg)	0.71	1.90	2.18
2nd Class ($/kg)	0.41	0.45	0.50
Juice/Process ($/kg)	0.11	0.11	0.11
Gross margin		$/ha	Block ($)
Gross income		95,247	380,986
Less			
Marketing costs		14,682	58,730
Grading and packing		32,208	128,830
Orchard costs		16,711	66,845
Gross margin		4,266	17,064
Netting costs		$/ha	Block ($)
Structure materials		7,480	29,920
Netting materials		11,220	44,880
Structure labour		9,818	39,270
Netting labour		18,233	72,930
Site preparations		0	0
Development approval		1,250	5,000
Total		48,000	192,000
Netting life expectancy			
Colour of net	White		
Netting (yrs)	12		
Structure (yrs)	40		
Netting maintenance costs	$/yr		
Structure maintenance	1,000		
Netting maintenance	1,000		
Insurance	4,750		
Extra hive hire	800		
Discount rate	8%		

Table 12-2 Total yield impact assumptions

Impact	Without net		With net	
	2015	2030	2015	2030
Water stress	0%	-7.50%	7.50%	0%
Heat stress	0%	-2.50%	2.50%	0%
Sunburn (a)	100%a	107.5%a	50%a	52.5%a
Birds (b)				
w/o sides	100%b	107.5%b	10%b	15%b
with sides	100%b	107.5%b	0%	0%
Wind rub (k)	100%k	100%k	50%k	50%k
Hail (d)				
Bird netting (20 mm)	100%d	100%d	100%d	100%d
Other netting	100%d	100%d	0%	0%
Other (f)	100%f	100%f	100%f	100%f

Notes: a: % cull due to sunburn, b: % cull due to bird damage, k: % cull due to wind rub, d: % cull due to hail, and f: % cull due to other reasons (not affected by netting).

12.1 Sensitivity Analysis Results

Based on the data and assumptions provided in Table 12-1 and Table 12-2, the results of the financial analysis are as follows:

- Net present value (NPV) of $46,800
- Benefit cost ratio (BCR) of 1.07
- Internal rate of return (IRR) of 12 per cent.

Results of the sensitivity analysis are provided in Table 12-3.

Table 12-3 Results of the sensitivity analysis

Variable (value used)	Sensitivity	Value at which NPV<0	Notes
Discount rate 8%	Moderate	12.4%	As expected
Area 4.0 ha	High	2.6 ha	Cost of netting rapidly rises below 4 ha relative to income. Result is as expected.
Current age of trees 4 years old	Moderate	0 years and 13 years	Get lowest NPV's when there are low/nil yields in years following installation of net
Age at mature yield 6 years	Moderate	9 years	As expected
Replacement age 15 years	Moderate	10 years	As expected
Harvested yield 60 t/ha	High	46 t/ha	High cost of netting requires fairly high yield threshold to generate sufficient additional income to cover netting installation costs
Orchard culls 6 t/ha	High	4.1 t/ha	A significant proportion of benefits of netting are realised through culls
1st class packout 92%	Minimal	5%	Result insensitive until packout reaches 15%, NPV goes negative at 5%. In our model impacts preferentially go to 1st class. Because the impact tonnage are generally smaller than the 1st class packout tonnage, there is no relative change to packout costs/income until the original packout gets to 15%.
1st class average price $1.90/kg	High	$1.70/kg	As expected.
Orchard costs $16,711/ha	Nil	N/A	As expected. Costs do not change between the netting and no netting scenarios.
Freight $0.14/kg	Moderate	$0.27/kg	As expected
Commission 5.50%	Moderate	12.50%	As expected
Grading $0.22/kg	Moderate	$0.35/kg	As expected
Packing (1st class) $0.35/kg	Moderate	$0.47/kg	As expected
Netting installation base price $42,500/ha - flat-top)	High	$52,700/ha	As expected. Significant upfront cost, plus significant net replacement cost in 12 years.
Structure mainenance $1,000/block	Low	$5,500	As expected. Small cost. Same analysis applies to netting maintenance or hive hire
Netting insurance $4,750	Moderate /low	$9,200	As expected.
Water stress 7.5% gain in yield	High	5%	7.5% gain in yield with netting. Large impact on yields & packouts, e.g. doubling in gain gives 4-fold increase in NPV
Heat stress 2.5% gain in yield	Moderate	0.30%	2.5% gain in yield with netting. Moderate impact on yields & packouts, e.g. doubling in gain doubles NPV
Sunburn 50% reduction in impact	Low	Does not become negative	Very small impact, unless sunburn is a major impact in itself. The same thinking can be applied to birds, wind rub and hail - impact depends on the amount of culls and whether the impact is a significant proportion of those culls