IMPACTS ON AGRICULTURE

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Agricultural production in Victoria includes the dairy, lamb and mutton, grains and perennial and annual horticultural sectors, with Victorian farmers contributing a major proportion of the Australian production total in many of these sectors. All these industries are exposed in different ways to weather and climate extremes. With projected warming of approximately 0.8°C by 2030 and by 1.4–2.7°C by 2070 (emissions dependent), and most climate models indicating reduced rainfall for the Victorian region (median of model results projecting a reduction of 4% by 2030 and 6%–11% by 2070; emissions dependent), a range of sector-specific impacts could result. Increases in extreme events, such as heatwaves (e.g. for Mildura, days >35°C could nearly double from 32 to 59 annually by 2070), bushfires and drought, as well as an increased chance of extreme rainfall are all anticipated. Increasing frequencies of extreme events have the potential to affect agricultural production more than changes to the mean climate. For example, the exceptional heatwave that occurred in south-eastern Australia during January and February 2009 resulted in unprecedented impacts, with significant heat-stress related crop losses reported at many sites. Flooding in 2011 was also very costly to Victorian farmers with many crops being lost in the floodwaters and reduced agricultural production costing an estimated Au$500–600 million. Responses to climate variability already practised by the farming sector will inform some adaptation options that will assist farmers to cope in an increasingly challenging environment. As well as taking advantage of their underlying resilience, initiatives aimed at increasing the adaptive capacity of farmers are being implemented at many levels in agricultural communities.

Key words: adaptation, agriculture, climate change, extreme events, impacts.

AGRICULTURAL production in Victoria is diverse, with nearly half the total value coming from the dairy industry. Approximately one-quarter of Victoria's production comes from the grains sector and >10% comes from lamb and mutton production, with perennial and annual horticulture also contributing. As a proportion of Australian production, Victorian farmers' output represents a large proportion of the total in many sectors (Table 1; McCaskill 2010).

All these agricultural industries are exposed in different ways to weather and climate extremes. Given projected warming and most climate models indicating a drying climate for the Victorian region, exposure to these extremes is likely to increase. Impacts are sector dependent, with increasing mean temperatures affecting crops by changing the timing of plant phases, such as seedling emergence or budburst, flowering and ripening times. Animal production may benefit due to fewer cold spells, although heat stress impacts increase for stock in a warming climate. Cropping enterprises may experience fewer frosts, however a drying climate could result in reduced yields. To reduce their exposure to the range of impacts the changing climate is likely to cause, farmers will be required to consider a range of adaptation strategies.

IMPACTS ON ANIMAL PRODUCTION

Warmer conditions are projected for Victoria's intensive livestock-producing regions, raising the likelihood of heat stress in stock (Miller et al. 2010). Heat stress results in significant economic and production losses for dairy operators (Aharoni et al. 2005), with optimal temperatures for lactating dairy cows in the range 5–25°C (Roenfeldt 1998). At temperatures >26°C, cows can no longer cool themselves, their milk composition changes and production declines.

Along with reduced productivity, reduced reproductive success has been associated with heat stress in cows (García-Ispierto et al. 2007) and sheep (Stokes et al. 2010), although in cooler

Table 1. Value of some important agricultural industries in Victoria

Industry sector	Value* (Au$ million)	% Victorian production value	Victorian production/ Australian production (%)
Dairy	3052	46	67
Grains	1498	23	15
Lamb/mutton	869	13	40
Pome fruit	300	5	50
Grapes–wine	283	4	19
Stone fruit	241	4	27
Potatoes	155	2	22
Grapes–fresh and dried	149	2	61
Brassica vegetables	83	1	37

*Source Australian Bureau of Statistics 2007/08 agricultural survey, unpublished Excel sheet Value of Agricultural Commodities Produced Gross value reported.

regions projected declines in frost days may result in fewer lambing losses (McCaskill 2010). Further, with housed livestock production, changes to energy demand for maintaining production sheds at the optimal temperature and humidity are likely to occur (Miller et al. 2010).

Reduced wool production and quality may occur in some marginal areas where pasture growth is reduced. Nevertheless, there may be increased productivity in areas with current high rainfall (Harle et al. 2007).

With projected warming, pasture growth rates in southern Australia during autumn or winter may be enhanced, or at least start earlier in the season provided that water is available (Miller et al. 2010). If availability of water is reduced, however pasture production will be adversely affected, with ryegrass-dominant pastures in particular not persisting in drier conditions (Callow et al. 2006) and growth ceasing above 30–35°C. These changes in pasture productivity will, in turn, affect livestock production. One study predicts that changes in livestock production will be of the same order as changes in rainfall (McKeon et al. 2008). Reduced rainfall and runoff will also reduce water security for stock, as well as for plant and shed cleaning.

GRAINS

Australian grain crop yields are likely to be impacted by combinations of higher levels of CO_2, increased temperatures and changes in rainfall, in order of diminishing confidence (Howden et al. 2010). In Victoria, the benefits of higher CO_2 may be offset by projected higher temperatures and less rainfall (Anwar et al. 2007; Stokes & Howden 2010). Temperature increases will accelerate plant developmental rates, with the timing of germination, seed set and harvest being affected (Howden et al. 2010). Suggestions for optimising phenology for high yield by breeding for slower-developing spring types and using later times of sowing are drawn from results of modelling studies performed at a free air CO_2 enhancement facility in Horsham, Victoria (Mollah et al. 2009; O'Leary et al. 2010).

There may be impacts on the quality of feed grains and fodder produced. Higher CO_2 concentrations could result in declines in grain nitrogen and hence protein and flour quality (Rogers et al. 1998), with studies indicating more fertiliser nitrogen will need to be applied to southern Australian wheat production zones under future CO_2 environments (Lam et al. 2012). To compensate, the importance of leguminous-based pasture rotations may become more important in future (Howden et al. 2010).

PERENNIAL HORTICULTURE

For perennial horticulture, the timing of budburst, flowering, fruit set and harvest will be impacted by warmer temperatures. Already some signs of change have been observed. For example, a study covering 12 regions located in southern Australia reported a trend to earlier maturity of wine grapes in 43 of 44 vineyard blocks studied (Webb et al. 2011). The trend to earlier maturity was associated with warming temperature trends for all the blocks assessed in the study. Of interest, advances in the more recent 1993–2009 period were greater than over the longer term: 1.4 days/year for 1993 compared with 0.8 days/year for 1985–2009 (Fig. 1).

In future, not only will the harvest occur earlier in the season (and therefore a warmer period), but also in a warmer projected climate. There is a ‘double’ warming impact due to the earlier harvest. These shifts in the timing of winegrape maturity can have implications for grape growers given it is well established that the temperature at and leading up to harvest influences winegrape quality (Jackson & Lombard 1993; Coombe & Iland 2004).

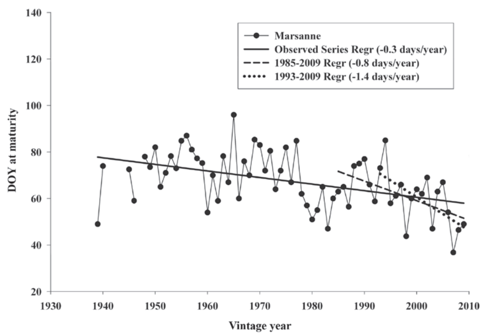

Fig. 1. Trends in rate of change in day of year (DOY) at maturity for three time periods at Marsanne (central Victoria): observed series (1939–2009), 1985–2009 and 1993–2009. Regr, linear regression. (Reproduced with permission from Webb et al. 2011)

For many deciduous plants, breaking dormancy requires the accumulation of chilling temperatures throughout winter, followed by warmer weather in spring (Schwartz 2003). A reduction in the accumulation of chilling temperatures has already been observed at some sites in Victoria (Darbyshire et al. 2011), with further reductions potentially affecting crop production (Darbyshire et al. 2012). Exactly how a warming climate will affect the timing of budburst is not straightforward. For example, in Batlow (a cool region in the ACT), although chill is prolonged with a warming climate, the projected warmer spring still dominates the dormancy-breaking process, leading to earlier bloom time. In contrast, at Manjimup (a warmer region in WA), chill accumulation is already marginal in the current climate. With warming, chill is noticeably delayed and the limited influence of warming in spring does not compensate for this, leading to an overall delay in budburst (Darbyshire et al. 2012; Fig. 2). This regional variation in response has implications for future changes to frost incidence during the flowering period for apples (Darbyshire et al. 2013).

Much of perennial horticulture relies on supplementary irrigation over the summer growing period. With projected rainfall reductions there may be reduced reliability of irrigation water supply (Webb et al. 2008). On the positive side, reduced rainfall may result in decreased disease pressure for horticultural and viticultural cropping (Magarey 1994).

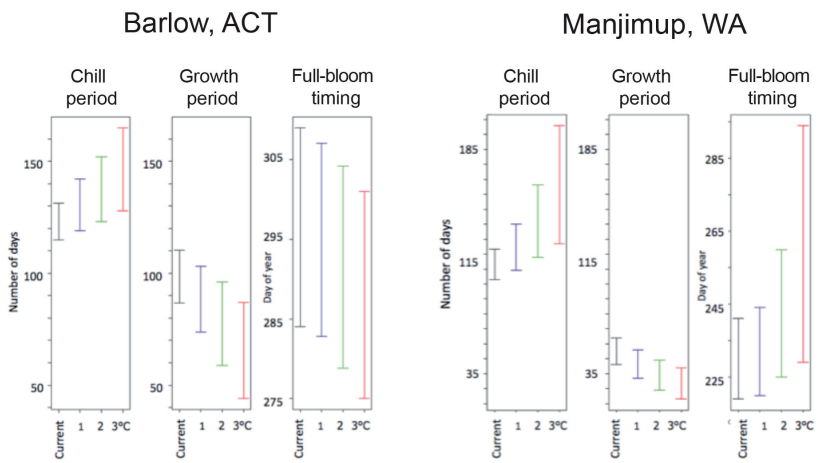

Fig. 2. Range of days for the chill period and growth period in the current climate, and given a 1°C, 2°C or 3°C warming, and the effects of climate on the timing of full bloom in Batlow, ACT, and Manjimup, WA. See Darbyshire et al. (2012) for the methodology and description of the data sources used to produce this figure. (Reproduced with permission from Darbyshire et al. 2013.)

EXTREME EVENTS

Increases in heatwave occurrences (Alexander & Arblaster 2009), increased risk of bushfires (Lucas et al. 2007), an increased area affected by drought with a reduction in recurrence interval (Hennessy et al. 2008), as well as an increased chance of extreme rainfall (CSIRO and Bureau of Meteorology 2007) are all anticipated and are being considered by agricultural communities as they prepare for climate changes.

Increasing frequencies of extreme events have the potential to affect agricultural production more than changes to the mean climate. For example, the exceptional heatwave that occurred in south-eastern Australia January and February 2009 resulted in impacts across many agricultural sectors. Anecdotal evidence reported internal temperatures of exposed fruit of up to 60°C, the fruit was often unsaleable or, what was harvestable, had a shorter storage life (e.g. Fig. 3).

The impact of this same heatwave on vineyards was unprecedented, with significant heat stress-related crop losses at some sites. Wine grape production in 2008/2009 was estimated to have been 1.7 million tonnes, approximately 7% or 119 000 tonnes lower than the 2007/2008 harvest (Gunning-Trant 2010). The fall in production was caused largely by a shortage of irrigation water in some regions and the south-eastern Australian heatwave (Gunning-Trant 2010).

Bushfires have a direct effect on stock, pasture and grain crops. An interesting, although just as devastating, effect is found with winegrapes exposed to the smoke from bushfires. Wine is adversely affected by smoke taint-related compounds that are detectable only after the fermentation process is complete. Losses due to smoke taint found in wine produced after bushfires in north-east Victoria (2006/2007) were estimated to be approximately Au$75–90 million (Whiting and Krstic 2007). After experiencing several years of smoke-tainted wine, one large winery has elected to expand to a region with a lower risk of bushfires (Smart 2010).

Flooding in 2011 was also very costly to Victorian farmers, with many crops being lost in the floodwaters. Reduced agricultural production by at least Au$500–600 million was reported in 2010/2011, with significant impacts on the production of fruit and vegetables, cotton, grain sorghum and some winter crops. The main impact for livestock appears to have been associated with disruptions to transport and other infrastructure support (Australian Bureau of Agricultural and Resource Economics and Sciences 2011).

In more recent extreme rainfall events (summer 2010/2011), lower-lying parts of vineyards were found to be worst affected, with increased disease pressure and berry splitting reported and transport access and logistics also disrupted (Webb 2011).

WORKER HEALTH IMPACTS

Heat stress is one of the biggest health risks associated with heat waves. Hot weather places extra strain on your body as it tries to cool itself to its preferred temperature of 37 C. Farmers working outside or in farm buildings or sheds that have poor cooling methods are at particular risk (Kjellstrom et al. 2009).

ADAPTATION

Responses to climate variability already practised by the farming sector will inform some adaptation

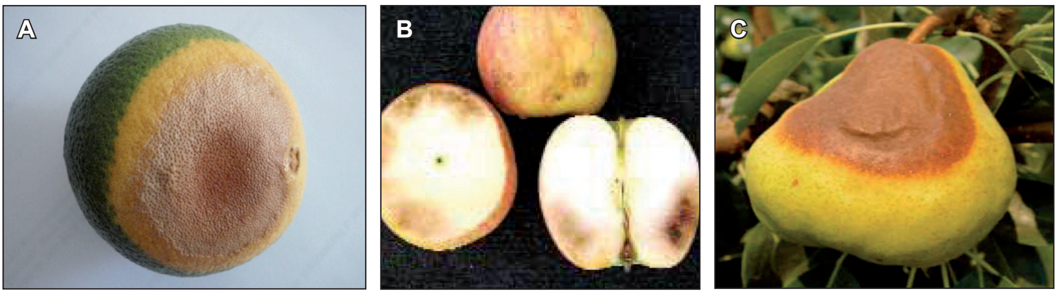

Fig. 3. Effects of direct radiation damage to (A) oranges, (B) apples and (C) pears during January and February 2009 heatwave in south-east Australia. (Pome fruit photographs courtesy of Malcom McCaskill, Victorian Department of Primary Industries.)

options, assisting farmers to cope in an increasingly challenging environment. Traditional adaptation options, such as shifting sites, changing varieties, breeding new varieties, changing or modifying timing of operations, applying artificial shade or strategically using irrigation water, have been documented (Stokes & Howden 2008).

Further to these options, other strategies can be considered. For example, by assessing the management decisions made by viticulturists after a heatwave (Webb et al. 2010), those found to have a significant influence on the severity of the impact were identified. For example, much lower damage was observed if the growers watered their vineyard prior to the onset of the heatwave, rather than if they waited to water until the day of the onset of the heatwave

Better understanding of observed responses can lead to surprising results and potential adaptation strategies. For example, advancing harvest dates (Fig. 1) were not only caused by a warming climate. Drying soil moisture, reducing yields and, over longer periods, advances in management were all found to contribute to the advancing ripening trend (Webb et al. 2012). By conducting a targeted attribution analysis, potential adaptation options were identified as some drivers of the trend to earlier maturity and these are then able to be manipulated through directed management initiatives

Websites directed at managing heat events (e.g. http://www.coolcows.com.au/index.htm, accessed August 2013) or building the knowledge capacity of farmers (e.g. 'climate dogs' explain some of the major climate drivers in Australia; see http://www.dpi.vic.gov.au/agriculture/farming-management/weather-climate/understanding-weather-and-climate/climatedogs, accessed August 2013) can assist farmers to adapt to projected climate shifts.

SUMMARY AND CONCLUSION

Climate change will impact Victorian agricultural production. Changes to average temperature affect the phenological phases of plants, reducing suitability for some enterprises in some regions. The increasing frequency of heat stress events will affect both plant and animal production, as will reducing the frequency of cold extremes. With most climate models indicating a drier future climate for Victoria, access to water is likely to be reduced, and this will have impacts on all agricultural sectors, although, depending on the region and particular sector, impacts can be either positive or negative, with the overall outcome a net balance of both.

Victorian farmers will adapt to changes in climate in order to minimise adverse impacts by modifying normal farming operations. Initiatives aimed at increasing the adaptive capacity of farmers are being implemented at many levels in agricultural communities. As well as taking advantage of their underlying resilience, farmers will learn from collective experiences as extreme climatic events occur more often. Past assumptions will be tested with ongoing learning. With access to targeted information, farmers can build a knowledge capacity to assist them with continuing production in this changing climate.

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