

# The Changing Climate: Impacts and adaptation options for South Australian primary producers



**DROUGHT  
RESPONSE**



**Government  
of South Australia**  
Primary Industries  
and Resources SA



# **The Changing Climate:**

## **Impacts and adaptation options for**

### **South Australian primary producers**

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*Australian agriculture has learned to deal with a wide range of climate conditions over the past century ... existing climate stresses and pressures will provide a sound underpinning for identifying future risks.*

Farming Profitably in a Changing Climate, A risk management approach,  
Steffan et al, Department of Agriculture, Fisheries and Forestry

# The situation

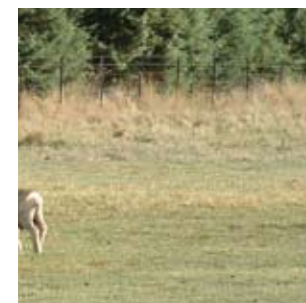
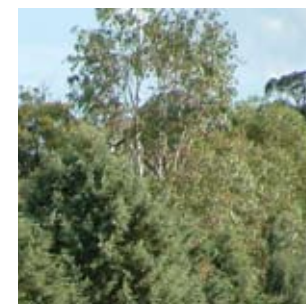
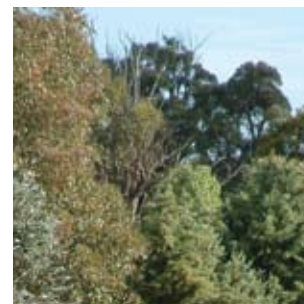
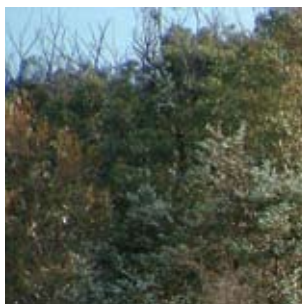
Change has always been part of Australian agriculture. Farmers have long faced a range of pressures – market supply and demand cycles, shifting bureaucratic requirements and a challenging environment.

But climate change – widely agreed to be an inevitable part of the global landscape – may well eclipse all these factors in terms of the adaptation required to remain viable.

Given the potential impact of climate change, both 'mitigation' and 'adaptation' strategies are needed. Farm enterprises and agricultural industries can make some changes to reduce greenhouse gas emissions, and there are activities and strategies that can help farmers adapt to the impact of climate change.

The good news is that techniques for reducing agriculture's greenhouse gas emissions frequently also improve efficiency. While adapting to a changing climate presents significant challenges, it may also unearth fresh opportunities.

To succeed, farm businesses will need to learn how to overcome the challenges and maximise the opportunities. The keys will be preparedness, responsiveness and adaptability.



# The big picture

*Hardest of all, the most effective adaptive responses in agriculture to climate change will sometimes require fundamental changes in attitudes, policies and institutions.*

The Garnaut Climate Change Review, July 2008

**There are knowledge gaps in the science that underpins climate change. It is impossible to be definitive about issues such as the impact of water availability in different regions throughout a growing season or how the frequency of extreme events such as fires, floods, droughts and storms might alter. This means that a risk management approach is the most effective way for rural industries and communities to prepare for, and respond to, climate change.**

The impacts of long-term climate change on agriculture could include more weeds, pests and diseases; changes in pasture growth and livestock carrying capacity; an increase in extreme weather events; and changes in rainfall patterns combined with higher temperatures.

The extent of the negative effects could be reduced by strategies such as using resources more efficiently, converting to more drought-tolerant crop cultivars and exploring more diverse income opportunities.

However, not all enterprises will be in a position to make the significant changes necessary to remain viable in this changing environment.

'Big picture' decisions will also be needed to put farm management and production decisions into the context of financial viability and the needs of individuals, families and communities.

*Better and earlier knowledge will allow farmers to make timely decisions on whether new money should continue to be invested in locations that seem to be severely damaged by climate change or whether it is better to find new livelihoods in less challenging locations.*

The Garnaut Climate Change Review, July 2008

The impacts of climate change will differ from sector to sector, region to region and enterprise to enterprise. As with all business decisions, every proposed strategy should take into account each individual enterprise's particular circumstances.

Some possible business management decisions do not involve a change in farming practices. Increasing insurance against extreme events and utilising the Farm Management Deposits scheme to manage risk could be part of preparing for the unknown implications of the changing climate.

ABARE, in its National Assessment of the Vulnerability of Agricultural Industries and Regions to Climate Change, presents three broad risk management options for climate change adaptation:

1. Diversification – reducing risk through varying the sources of income, possibly including off-farm activities.
2. Consolidation – increasing efficiency by improving economies of scale so that extra efforts yield proportionately greater revenue.
3. Relocation – moving the entire farm enterprise to a different location, where climate change impacts are expected to be less or more manageable.

This booklet suggests enterprise level mitigation and adaptation options, but such activities should be assessed in the context of these broader, big picture business decisions.



# Expected impacts of climate change

**Already the driest State, on the driest continent on Earth, climate change presents South Australia with a particularly challenging future. For agriculture, the challenge is even more marked. According to the Australian Government's climate change website, uncontrolled climate change will put at risk South Australia's agricultural production, valued at \$3.6 billion in 2006/07.**

The CSIRO report on climate conditions (Suppiah et al, 2006) outlined climate projections for 2030 and 2070 for South Australia. In broad terms, the State can expect:

- Higher temperatures, including more extreme hot days, with spring and summer warming more than autumn and winter.
- Associated health and mortality implications for an ageing population, and increasing energy demand for air-conditioning.
- Decreased rainfall in agricultural regions (especially in winter and spring).
- Greater frequency and severity of drought.
- Decreased flows in water supply catchments including the Murray-Darling.
- Increased flood risk (despite drier average conditions).
- Shifts in conditions affecting viability of crops and biodiversity.
- Increased incidence or severity of bushfires.
- Coastal hazards related to the effect of ocean warming on sea levels, combined with storms of possibly increased intensity.
- Damage to infrastructure from, for example, coastal erosion, flooding and extreme heat.



*Australian farmers will need to be adaptable to cope with, and even take advantage of, climate change.*

Dr Mark Howden, Climate Adaptation Flagship, CSIRO

# What this booklet aims to do

**The science behind climate change is complex. It involves the physical and chemical actions, reactions and interactions of the oceans, atmosphere, polar and glacial regions.**

Rather than attempt to explain the scientific detail or restate statistics, this booklet attempts to:

- Present the **probable impacts** of climate change on South Australia's main farming sectors.
- Identify **adaptation options**, using mainstream information sources such as the CSIRO and the government's Department of Climate Change. The Bibliography and Reading List provide further references.
- Canvass **opportunities** that may arise from the impacts of climate change on South Australian agriculture. Because the science is evolving, this information is speculative.

- Outline steps that can be taken at an industry and on-farm level to minimise the effects of climate change by **reducing greenhouse gas emissions**.

This booklet focuses on three sectors: broadacre cropping, livestock and horticulture including viticulture. It does not attempt to cover forestry and farm forestry due to their links with the proposed Carbon Pollution Reduction Scheme.

The authors *do not* evaluate the science behind the information, nor attempt to give any opinion or comment; they aim to simply provide a consolidated summary of the current scientific views.

The limits of science and the conflicting modelling information are likely to remain unresolved for some time. Individuals and businesses must make their own determination about the relevance of the science, the proposed impacts and suggested adaptation options.

If you wish to better understand the science behind climate change, read the 'Frequently asked Questions' on the Australian Government's climate change website [www.climatechange.gov.au/science/faq/index.html](http://www.climatechange.gov.au/science/faq/index.html) or the CSIRO's Climate Change in Australia website <http://www.csiro.gov.au/resources/Climate-Change-Technical-Report-2007.html>

If internet access is an issue, phone the Department of Climate Change on (02) 6274 1888 to request further information.



# Adapting to climate change – industry options

*The identification of adaptation options, particularly those that can deliver other production or environmental benefits, is key to enhancing the adaptability of the land sectors.*

– [www.climatechange.gov.au](http://www.climatechange.gov.au)

The following pages discuss factors that you might consider in your usual business planning process, in the context of potential climate change impacts.

The topics are not exhaustive, nor should they be considered in isolation.

The suggested adaptation options should be assessed in the context of the individual farming enterprise, as some adaptation techniques might have counter-balancing effects.

For example: planting trees on farm may offset carbon, and provide wind breaks and shelter for livestock, but trees require water. With an expected reduction in rainfall, and high costs to access water, this adaptation technique may not be viable for all enterprises.

The Impacts and Adaptation strategies are designed to stimulate thought. Any proposed strategy should be considered in the context of each enterprise's own circumstances.

**BROADACRE CROPPING** pages 10-23

**GRAZING AND INTENSIVE PRODUCTION SYSTEMS** pages 24-35

**HORTICULTURE AND VITICULTURE** pages 36-47

*It is not a foregone conclusion that a warmer, high CO<sub>2</sub> world will overall be worse for Australian farming industries (although there is a high probability that it will be), but in the process of transition, which is likely to last for centuries, significant changes in practice and perhaps location may be required.*

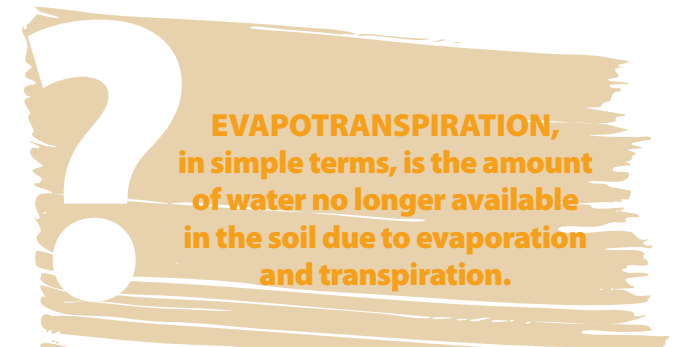
Mark Howden et al. Climate change and farming systems: impacts and adaptations, Faculty of Agriculture, Food and Natural Resources Symposium 2008, The University of Sydney, 13 June 2008

## Rainfall

Annual rainfall across South Australia is projected to decline and the drop is likely to be higher in winter and spring. For the cropping industry, the amount and timing of rainfall is vital but shifts in rainfall patterns will affect each grain-growing region differently.

### IMPACTS

- Warmer conditions will increase potential **evapotranspiration**, which may affect crop growth.
- Increased evaporative losses will increase water requirements and put additional pressure on water availability for irrigation.
- South Australia's drier fringe of temperate cropping regions is likely to suffer the most as a result of less rain. For example, drier spring weather could result in more shrunken grains, and an increased risk of shot heads and stained grains.
- Some crops, such as canola and some pulses, may not be viable in areas where rainfall is reduced due to their sensitivity to dry conditions.
- Reduced rainfall may restrict options and times for crop rotation.
- Heavier falls of rain may provide increased opportunities for water harvesting, but may also cause flooding, erosion and other damage.
- While the likelihood of an increased summer rainfall is debatable, such a scenario could affect South Australia's grains regions. Wetter summer conditions can lead to fungal, pest and weed problems.



## ADAPTATION OPTIONS

- Techniques that make best use of available soil moisture and manage the soil moisture profile will be useful for responding to rainfall risks.
- Increasing atmospheric CO<sub>2</sub> concentration, while not fully tested, may provide benefits by increasing water use efficiency, partly off-setting yield declines from expected lower rainfall.
- Given the expected decline in spring rainfall, consider earlier seeding and the use of varieties that have shorter growing seasons.
- Improve tactical response through opportunity cropping according to the seasonal outlook and other yield predictive information, such as stored soil moisture, time of seeding, etc.
- Maximise water use efficiency and soil moisture by using the following farm management principles:
  - zero tillage;
  - retaining crop residues;
  - wider row spacing and lower seeding rates (note, this can increase exposure of soil to erosion risk and loss of moisture);
  - monitoring of soil moisture to ensure any irrigating is optimised and crop rotations are appropriately managed; and
  - weed control, particularly deep-rooted perennial weeds.
- Consider growing deep-rooted perennial crops where possible as they have the ability to improve water use efficiency.
- The use of forage crops may be increased after significant summer rains.
- Landscaping may assist in directing heavy falls of rain into water storage areas such as dams and may be useful in limiting erosion damage. New dams may be required to take advantage of heavier showers.
- Crop yield declines in fringe cropping areas may require transformational change in farming systems.
- Where dry-land cropping becomes less attractive due to climate change impacts, diversifying with livestock could be considered. (Remember: livestock will also be affected by climate change.)

## OPPORTUNITIES

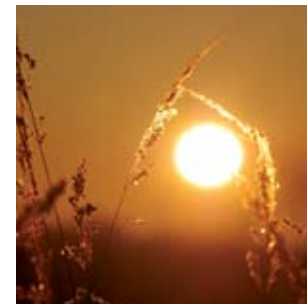
- Lower production of annual crops could be off-set by an increased planting of perennials such as lucerne that would make better use of summer rains. This may extend the duration of rotations.
- Drier conditions may make waterlogged areas in the State's South-East more productive at certain times of the year.
- South Australian grain growers have already had significant success with opportunistic cropping, taking advantage of unusual summer rains. This strategy could become more widely used.

## Temperature

Temperature affects evaporation and vapour pressure deficit (the difference between moisture content of the air and its potential moisture content at that temperature). These changes, in turn, affect transpiration of water from plants, evaporation from soil and water storages, and water use efficiency of plants.

### IMPACTS

- As temperatures increase, soil and plant moisture conservation and water storage may be affected.
- With higher temperatures expected at certain times of the year, crops may suffer, for example, a heat shock in spring, which may affect grain protein development.
- Temperature increases may restrict the time the plants have to accumulate radiation and nutrients, shorten the growing season and possibly reduce crop yield and quality, for example, smaller grain size and grain cracking. This could be counteracted by possible increased yields due to boosted CO<sub>2</sub> levels.
- Some current production areas may become marginal with increasing temperatures.
- With rising minimum temperatures, fewer frosts are expected. However, if rising minimums are accompanied by greater variability, there may be an increased risk of unexpected frost at critical times.
- An increase in temperatures and possibly humidity in the summer months might increase a crop's susceptibility to fungal diseases and pests.



## ADAPTATION OPTIONS

- Each cropping site needs to be evaluated to select the most suitable varieties, and risk assessments should be used to determine resilience and sustainability in more marginal areas.
- Select cultivars (either new or existing) with more drought and pest/disease resistant varieties and those better suited to high temperatures.
- With expected higher temperatures and reduced rainfall in South Australia, introduce crop varieties with earlier flowering characteristics to allow 'grainfill' to occur in the cooler, wetter times of the year.
- Success of earlier planting depends on the autumn breaking rains, so ongoing reassessment of planting options in each region will be necessary as the impacts of climate change become better understood.
- Be prepared for opportunistic cropping and different approaches as conditions vary unexpectedly. For example, consider hay rather than grain crops to avoid hot conditions at the time of grain filling.
- Consider introducing or increasing the integration of livestock in the farm program to reduce dependency on cropping; and developing alternative pasture options for integrated livestock such as native pastures, grazing cereals and perennial pastures. (Remember: livestock will be affected by climate change, too.)
- If the rate of temperature change is similar for night and day temperatures, then efficient moisture use can be enhanced by:
  - increasing crop residue cover, particularly with low-tillage use;
  - planting high water-efficient plants;
  - establishing crop cover in high moisture loss periods;
  - weed control; and
  - maximising capture and storage of surplus rainfall through the use of raised bed techniques and directing flows to storage areas.

## OPPORTUNITIES

- While higher temperatures might reduce grain protein levels, this may be counteracted by higher nitrogen/protein levels in the grain from sound management under low rainfall conditions.
- Fewer frosts may provide earlier planting options and, consequently, increased yields, as 'grainfill' is more likely to occur in the cooler months where water stress is lower.
- Higher temperatures may enable the use of summer-growing grain and pulse species such as sorghum in temperate regions where these crops are not currently in rotation.

## Soils

Adopting management practices that improve the efficiency of nitrogen use can generate benefits for farm profitability, while also reducing greenhouse impacts and improving environmental sustainability.

### IMPACTS

- Inefficient nitrogen use can lead to additional nitrogen loss through ammonia volatilisation and nitrate leaching and run-off.
- Under heavier rainfall scenarios, increased erosion and leaching of nutrients may lead to changes in soil quality; a decrease in rainfall may reduce soil cover, increasing the risk of wind and water erosion.
- Soil compaction or waterlogging may cause anaerobic soil conditions favouring **denitrification**.
- Increases in soil acidification may occur due to increased carbon dioxide concentrations.
- Increased rainfall intensity, along with increased CO<sub>2</sub> levels, may increase drainage below the root zone contributing to dryland salinisation. This may be offset in areas where autumn and winter rainfall is reduced.

**?** DENITRIFICATION is the conversion of nitrate to nitrous oxide and nitrogen gas forms, which are unavailable to plants and are lost to the atmosphere.





## ADAPTATION OPTIONS

- Reduce erosion and other climate change risks, such as the leaching of nutrients, by:
  - retaining stubble;
  - reducing any fallow periods;
  - reducing dry-sowing in high risk areas; and
  - establishing contour banks where appropriate.
- Reduce the potential for increased salinity by using deep-rooted plants such as perennials in rotations or intercropping on low capability land, where there is likely to be reduced vegetation cover. Increased use of deep-rooted perennials, especially on less viable land, can help reduce the risk of soil erosion.
- Use soil or plant testing to assess available nitrogen supply prior to fertiliser application; apply nitrogen fertiliser based on a calculation of target yield and crop nitrogen requirement over the growing season; and use split applications, rather than a single large application, to ensure maximum plant uptake and minimum nitrogen losses. Consider foliar application when supplementary nitrogen is required.
- Ensure soils are well drained to minimise waterlogging. Catchment management may need to be modified to adjust to effects of rainfall on soil drainage.
- Avoid applying fertilisers (especially nitrate) to very wet soils and incorporate fertiliser at the top of raised beds or ridges to avoid wet areas. Where possible, place fertiliser below the soil surface to limit ammonia volatilisation. Also, time fertiliser application to minimise loss via denitrification or volatilisation (for example, if top dressing urea, apply before irrigating or rainfall).
- Ensure continuous plant cover (between growing seasons and between row crops) to avoid losses of nitrogen. However, wide row and skip row plantings, while exposing more soil to erosion and leaching risk, can increase yield in low rainfall seasons.
- Consider the potential for continuous year-round ground cover during cropping cycles, for example, direct drilled wheat in perennial clover.
- Aim to build organic matter in soils through pasture rotations or by adding composted material; use gypsum to improve soil structure and help avoid anaerobic conditions. Options include the production and application of 'compost tea', 'biochar' or worm castings to improve soil quality, carbon retention and productivity.

## OPPORTUNITIES

- Increased CO<sub>2</sub> concentrations might reduce grain protein levels, but can also boost water use efficiency and increase yields.
- With an increased interest in compost tea and biochar-type soil conditioners, there may be opportunities in the on-farm production and sale of these products.

## Increase in atmospheric carbon dioxide levels

Closely monitoring soil nitrogen levels will give a useful indication of soil health in an environment of increasing atmospheric carbon dioxide.

*A key adaptation to engage in now may be to invest some research effort into identifying plant characteristics that will be responsive to projected changes (in CO<sub>2</sub> levels), incorporating them into breeding programs so that genetic variation in these characteristics is maximised and maintained in breeding programs for recombination to take place.*

CSIRO, An overview of climate change adaptation in Australian primary industries – impacts, options and priorities, p196 (2008)

### IMPACTS

- Increased CO<sub>2</sub> may increase crop fertility and productivity, but there are drawbacks that may negate these gains.
- Elevated CO<sub>2</sub> may increase the reliance on nitrogen fertiliser to maintain current production rates. This could result in lower grain nitrogen and therefore protein and flour quality, though the amount of reduction differs with each cultivar and the nitrogen supply to the crop.

### ADAPTATION OPTIONS

- Increase the use of legume-based pastures and leguminous crops and/or add more fertiliser or alternate crop rotations to counteract declines in grain protein.
- Shift to markets that prefer low protein grain. For example, low protein barley is sought after by makers of the Japanese distilled alcoholic beverage, shochu.

### OPPORTUNITIES

- Higher protein cultivars or cultivars more resistant to a decline in grain protein with increasing CO<sub>2</sub> levels in the atmosphere may be developed.
- There may be opportunities to provide low-protein feed grain, as livestock feed rations can be manipulated to adjust protein levels.
- The development of bio-fuels may deliver opportunities to the cropping industry.
- The biscuit wheat market requires low protein, soft wheat varieties, opening new niche opportunities for suitable grains. However, competition in this market is likely to increase globally as the impacts of climate change affects other growing regions similarly.

# Irrigation water

While most broadacre cropping in South Australia is maintained with rain rather than irrigation water, those who do irrigate will see increased demand, and competition for supply, especially during dry periods.



## IMPACTS

- An increase in variability of supply and rationalisation of water is likely, with reduced availability in some locations and some seasons.
- Variable water supplies and reduced river flows may increase irrigation salinity, reducing water quality and affecting plant growth and soil health.

## ADAPTATION OPTIONS

- Develop efficient on-farm irrigation techniques with appropriate scheduling, application and water transfer systems. For example, 'deficit irrigation' is one way to maximise water use efficiency for higher yields per unit of irrigation water applied.
- Increase the proportion of water applied that reaches the root zone, through:
  - better monitoring of soil moisture conditions to improve timeliness and quantity of irrigation; and
  - effective use of water management technologies, i.e. shifting from sprinkler to drip or micro spray irrigation systems.
- Increase water storage capacity to better meet irrigation requirements.
- Use computer-controlled soil moisture probes and irrigation scheduling to regulate irrigation frequency and manage salt levels.
- Reduce the use of scarce irrigation water resources for low value crops.
- Protect the soil by retaining mulch and other crop by-products on the land.

## Pests and diseases

Higher average temperatures may encourage an earlier pest presence and affect the usual windows of opportunity for control. They may also increase the numbers of certain pests and diseases and boost the possibility of a shift in their distribution to more southern regions. Other pests and diseases might disappear from certain areas.

### IMPACTS

- While warmer temperatures may force some species to relocate, adapt or perish, some pests will be better able to survive milder winters, and species that are active in summer will probably develop faster.
- Climate change may activate 'sleeper' pests and pathogens and entirely new strains might develop. Some native species might invade or become over-abundant in new areas.
- Warmer winters in southern Australia may increase the incidence of viral diseases such as Barley Yellow Dwarf virus, which depends on transfer by aphids. Milder winters may also decrease the amount of plant pathogens killed annually, increasing the risk of spread of disease.
- Unpredictable frosts may have an impact on the lifecycles of pests, diseases and temperature-dependent fungi.
- Climate change may affect the balance between soil pathogens and their antagonists, though there is uncertainty about how. There is a possible increased risk of the spread and proliferation of soil-borne diseases as a result of more intense rainfall events, coupled with warmer temperatures.
- The effect of increased temperature and CO<sub>2</sub> enrichment may change disease dynamics from the point of view of the pest. Host-pathogen interactions have been found to change, and **herbivory** may increase, in high CO<sub>2</sub> environments.
- Disturbed habitats may be more easily colonised by pest animals and weeds, for example, after a drought.
- Pests such as Heliiothis moths, armyworms, sucking bugs and locusts respond strongly to climate signals.

**A herbivore is an animal that eats plants, so HERBIVORY is the act of eating plants. Herbivory can have substantial impacts on habitat health, the structure and diversity of plant and soil invertebrate communities and the productivity of economically important crops.**

## ADAPTATION OPTIONS

- Both integrated pest management at a farm-level and area-wide pest management strategies at a regional level are required.
- Undertake closer monitoring and more responsive management of diseases and insect pests. Consider developing and using a quality **Decision Support System** which is based on a quantitative understanding of the ecology of each pest to avoid surprise outbreaks.
- Producers may need to adjust the timing of pest control as pest life cycles, such as that of the red-legged earth mite, respond to climate change.
- Consider greater use of beneficial microbial agents.

**?** An example of a **DECISION SUPPORT SYSTEM (DSS)** is the **CSIRO's 'maNage Wheat'**. It is a DSS that provides support on the timing and application of nitrogen fertiliser to wheat crops for particular paddocks and seasons. <http://www.csiro.au/science/psmh.html>

## OPPORTUNITIES

- The severity of some diseases (such as Take-all) may lessen with drier conditions.
- Producers may be able to take advantage of the high-stress conditions that traditional pest species will face, by reducing population numbers and host species whenever economically feasible and encouraging the adaptation of more desirable species.
- Pests such as rabbits may struggle with the longer periods of dry feed, possible higher prevalence of **C4 grasses**, higher temperatures and expected increased effectiveness of calicivirus under drier conditions.



**?** **C4 GRASSES** have a photosynthetic pathway that allows them to adapt to hot climates and an atmosphere low in carbon dioxide. They are considered warm season grasses.

## Weeds

**Increased carbon dioxide levels associated with climate change are expected to enhance weed growth, although this will be specific to the weed species and environment in which it grows. Higher temperatures and increased humidity during summer could increase the likelihood of a shift in distribution of certain weed species from northern to southern regions.**

### IMPACTS

- As the climate and growing patterns change, weeds might 'out compete' more desirable forage plants in rangeland areas.
- Higher temperatures might lead to an increase in the populations of more aggressive, deep-rooted, warm-season perennial weeds such as Convolvulus and Silverleaf Nightshade.
- There is a possibility that climate change will favour increased growth of some native plants to the extent that they will become weeds. Unpalatable native species (such as *Eremophila mitchellii* and *E. sturtii*) might become over-abundant in South Australia as they have in New South Wales, especially if summer rainfall increases.
- While the likelihood of increased summer rainfall is debatable, such a scenario may boost weed production. This could also mean there is a 'green bridge' for diseases of winter crops to spread to summer crops and vice versa.
- Weed species with short generation times are better equipped to evolve and increase their tolerance of warmer temperatures.
- Weeds with efficient seed dispersal mechanisms such as water or wind may be better able to take advantage of the expected extreme events of flood and dust storms.
- If producers increase the frequency of herbicide application to tackle a growing weed problem, there is the potential to increase herbicide residues on crops to a point that may exceed defined maximum limits in some markets and possibly to increase incidence of herbicide resistance, adding to the cost of control measures.
- Increased weed distribution can provide a habitat for pests and diseases. Disturbed habitats may be more easily colonised by pest animals and weeds, for example, after a drought.
- Drought-stressed weeds are more difficult to control with post-emergent herbicides than plants that are actively growing, for example systemic herbicides that are translocated within the weed, need active plant growth to be effective. Pre-emergent herbicides such as triazines or atrazine or herbicides absorbed by plant roots need soil moisture and actively growing roots to reach their target species.

## ADAPTATION OPTIONS

- Carry out weed risk assessment modelling for agricultural crops to identify current and potential weeds posing the greatest threats.
  - Identify weed species that host pests and diseases and maintain highly active control programs on these particular weed species.
  - Reduce the reliance on herbicides through a stronger focus on integrated weed management (such as combining various techniques for weed control such as crop competition, grazing management and cultivation in combination with strategic herbicide use). Improve response to new weed issues as soon as they emerge.
  - Increase the resilience of land systems through Landcare activities and stewardship initiatives.
- Be aware of weed problems emerging in neighbouring regions before they invade the local area.
  - There is currently a ban on genetically modified cropping in South Australia, but should the ban lift, consider the use of genetically modified crops that are herbicide tolerant if weed control requires increased spraying.



## OPPORTUNITIES

- Australia has an advantage when it comes to matching cropping systems to climates as our agricultural systems span a wide range of climates, from the tropics to the temperate zone.
- There may be the potential to use weeds to make bio-fuels. The Invasive Species Council has some concerns with this concept. For example, Giant reed (*Arundo donax*) reportedly yields the highest biomass of any crop from Mediterranean to subtropical areas. However, it is also a serious weed in riparian ecosystems, appearing on the International Union for Conservation of Nature's list of 100 of the World's Worst Invaders.

## Extreme events

Hail storms, heat stress, high winds, floods, heavy rains and frosts are predicted to increase in frequency and severity.



### IMPACTS

- Extreme rainfall events and flooding can cause crop destruction, soil erosion, increased salinity, sedimentation of waterways and damage to farm infrastructure.
- Changing fire patterns and fires are expected. Fire size, frequency and intensity affect species composition and structure for both flora and fauna. Large hot fires can also have a devastating effect on water quality as subsequent rain can wash exposed sediment into water courses.
- Both fire and flood events will be probably accompanied by high winds, putting crop, livestock and farm property at risk.
- Extreme temperatures can cause undesirable physiological responses. Heat stress days during flowering, for example, can interrupt integrated bee pollination.

### ADAPTATION OPTIONS

- Improve use of seasonal forecasting in combination with observations of on-farm conditions, such as soil moisture at planting, to improve decision making.
- Develop strategies to hedge production risks and manage climate variability, for example, specific cultivars or protected cropping for high value crops.
- Reduce the potential for increased salinity and erosion, caused by extreme events, by using deep-rooted perennials in rotations or intercropping and on low capability land.
- When designing or building new infrastructure, take into account the expected increase in extreme events and, where possible, strengthen and reinforce existing buildings.



# General impacts

## IMPACTS

- Climate change may bring shifts in local and international markets, changing the nature of competition. For example, if a number of countries have an issue with low protein in wheat, the biscuit wheat market might see a growth in competition.
- Croppers in the drier fringes of South Australia may experience increased financial volatility. Changes of landuse in marginal cropping areas might be required.

## ADAPTATION OPTIONS

- Of all the agricultural sectors, cropping is one that should certainly pursue the concept of measuring and monitoring its own climate.
- Croppers in the fringe areas of South Australia could consider more extensive crop rotations, relying more on opportunity cropping, making just-in-time decisions dependent on the climate and even avoiding annual crops altogether.

## OPPORTUNITIES

- There may be branding, marketing and product development opportunities in a climate change-affected marketplace, where consumers seek environmentally sustainable products.
- New technologies and tools have been and are continually being developed to help croppers better assess the specific conditions of their farms.
- New enterprises and forms of enterprise present alternative opportunities; such as processing, energy generation and supply, and bio-sequestration.



## Pasture productivity and quality

Rising CO<sub>2</sub> levels and increasing temperatures, along with changing rainfall patterns, will alter pasture productivity. Climate change is expected to favour those plants that have shorter growing seasons, are unpalatable and have adaptive mechanisms other than just seed, for example, geophytes such as corms, bulbs or rhizomes.

### IMPACTS

- While CO<sub>2</sub> can stimulate plant growth, it usually comes at the expense of protein content and increases some non-structural carbohydrates, which affects pasture/forage quality and digestibility. Increased carbon dioxide will boost the growth of weeds too.
- Deep-rooted, woody plants and legumes are likely to have an advantage over grasses at higher CO<sub>2</sub> levels due to their ability to tap deep water reserves while still competing with grasses for moisture in the shallow soil layers.
- Elevated CO<sub>2</sub> levels could increase the risk and rates of salinisation as it increases the deep drainage component under pastures. This may also result in rising watertables.
- It is believed that changes in rainfall are likely to lead to changes in plant species composition. For example, where climates become drier and hotter, pasture composition is likely to favour more xeric (water-conserving) species.

### ADAPTATION OPTIONS

- Use a consistent, conservative stocking rate and consider more strategic spelling, rotation and grazing of paddocks.
- Change the mix of pasture to a better balance of perennials and annuals to match nutrition to stock demand and climatic conditions.
- Consider increasing the use of native grasses and palatable species, which are often able to rapidly respond to short and long-term changes in the climate.
- Where possible, increase the amount of forage cropping during winter. Change timing of cutting silage and hay to better match the changing pasture growth curve.
- Modify timing of mating based on seasonal conditions and fodder availability.

*Deep-rooted woody plants and legumes are likely to be advantaged over grasses at higher CO<sub>2</sub> levels, both because of higher CO<sub>2</sub>-sensitivity of growth and because of the ability to tap deep water while still competing with grasses for moisture in shallow soil layers.*

CSIRO, An overview of climate change adaptation in Australian primary industries – impacts, option and priorities, p235

# Soils

**Adopting soil management practices that improve the efficiency of nitrogen use can generate benefits for farm profitability, while also reducing greenhouse impacts and improving environmental sustainability.**



## IMPACTS

- Heavy rainfall events are more likely to result in changes in soil quality through increased erosion and leaching of nutrients. Soil compaction or waterlogging may cause anaerobic soil conditions favouring denitrification. These conditions can favour some weed species such as Cape Tulip and docks.
- Inefficient nitrogen use in the combination of soil type and rainfall factors, and management practices such as fertiliser placement, can lead to additional nitrogen loss.
- An expected increase in dry days and droughts will increase risks of soil erosion, dust storms and salinity. Reduced rainfall overall may lead to reduced soil cover and higher wind erosion risk.
- An increase in soil acidification due to increased carbon dioxide concentrations is also possible.

## ADAPTATION OPTIONS

- Ensure soils are well drained to minimise waterlogging. Avoid applying fertilisers (especially nitrate) to very wet soils and incorporate fertiliser at the top of raised beds or ridges to avoid wet areas. Place fertiliser below the soil surface where possible to limit ammonia volatilisation; and time application to minimise loss.
- Reduce the potential for increased salinity by using deep-rooted plants such as perennials in rotations or intercropping and on low capability land.
- Use soil or plant testing to assess available nitrogen supply before applying fertiliser. Apply nitrogen based target yield and crop requirement over the growing season; and use split applications, rather than a single large application. Consider foliar application when supplementary nitrogen is required.
- Ensure continuous plant cover (between growing seasons and between row crops) to avoid losses of nitrogen. Retain stubbles after harvest.
- Reduce the velocity of storm water run-off and erosion by strategic placement of tree belts on slopes.
- Build organic matter in soils through pasture rotations or by adding composted material. Use gypsum to improve soil structure and help avoid anaerobic conditions.

## Temperature

The expected continued rise in temperatures will increase animal heat stress issues, particularly in intensive production systems.



### IMPACTS

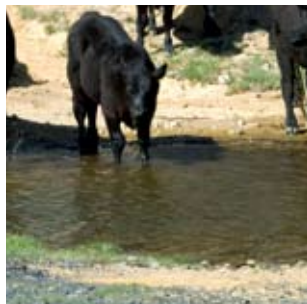
- With warmer, drier conditions, particularly in winter and spring, changes are expected in the growth patterns of pasture and crops.
- With rising minimum temperatures, fewer frosts are expected. However, if rising minimums are accompanied by greater variability, there's an increased risk of unexpected frost at critical times for pasture and crop growth.
- Increasing temperatures may result in some current production areas becoming marginal, and already marginal country in South Australia becoming unviable. Some of the more marginal cropping land may return to grazing country.

### ADAPTATION OPTIONS

- Construct shelter and shade structures for animals.
- Select crop and pasture varieties that are better suited to drought conditions.
- Warming may allow new crop varieties and animal species to be grown in traditionally cooler climate production areas. For example, hardier sheep breeds might adapt to warmer conditions better than merinos.
- Undertake risk assessment to assess sustainability in more marginal areas. Where necessary, and if possible, production systems may have to be relocated to more favourable climates.

# Rainfall

The timing of rainfall has a direct impact on pasture productivity and forage quality. Careful management of the soil moisture profile to increase the infiltration rate may help livestock producers cope with increased or unseasonal rainfall.



## IMPACTS

- Warmer conditions will increase water requirements while also increasing evaporative losses, putting pressure on water availability for irrigation and livestock.
- While the likelihood of an increased summer rainfall is debatable, such a scenario would impact on weed types, proliferation and management techniques.
- Heavier falls of rain may provide increased opportunities for water harvesting, but may also cause flooding and run-off damage.

## ADAPTATION OPTIONS

- Respond to changing risks using techniques that make best use of available soil moisture.
- Consider the design shape of new dams to maximise the capture of run-off and minimise evaporation, i.e. make them deep with a small surface area.
- Landscaping may assist in directing heavy falls of rain into water storage areas such as dams and may be useful in limiting erosion damage.
- Plant trees near dams to cool the area and reduce evaporation; and consider other techniques being developed, such as the application of **monolayers**.
- While uncertainty continues, increasing atmospheric CO<sub>2</sub> concentration may provide benefits by increasing water use efficiency, allowing the same crop yield for less water use.

**A MONOLAYER is a single, closely packed layer of atoms, molecules, or cells, growing on a surface.**

## Irrigated pastures

With increasing temperatures and changes in rainfall patterns, irrigation demand will increase. Increasingly unreliable water supplies and rationalisation, with reduced water availability in some locations and some seasons, will affect pasture productivity.

### IMPACTS

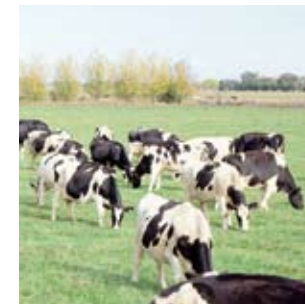
- Critical water allocations along the River Murray corridor may require irrigators to manage low and zero allocations at different times of the season/year.
- Variable water supplies and reduced river flows may lead to increases in irrigation salinity, reducing water quality, affecting plant growth and soil health.

### OPPORTUNITIES

- More efficient water use can lower production costs and, in many cases, improve productivity directly.

### ADAPTATION OPTIONS

- Reduce the use of scarce irrigation water resources for low value crops and pasture varieties.
- Increase the proportion of water applied that reaches the root zone, through:
  - systems that better monitor soil water conditions to improve timeliness and quantity of irrigation;
  - effective use of water management technologies, i.e. shifting from sprinkler to drip or micro spray irrigation; and
  - use of gypsum to improve/remediate soil structure.
- Increase water storage capacity to better meet irrigation requirements.
- Use computer-controlled irrigation scheduling and soil moisture probes to regulate irrigation frequency, and to manage salt levels.



# Extreme events

**Hail storms, heat waves, high winds, heavy rains and frosts are major climatic risks which have the potential to cause damage to livestock and pasture, infrastructure and productivity.**

## IMPACTS

- Significant crop losses and downgrades from extreme weather conditions are possible. Undesirable physiological responses from increasing frequency of extreme temperature events may reduce animal growth and increase animal trauma.
- Extreme rainfall events and flooding may cause soil erosion, salinity and sedimentation of waterways, as well as damage to farm infrastructure.

## ADAPTATION OPTIONS

- Improve on-farm forecasting of seasonal conditions (medium- and long-term forecasts).
- Develop strategies to hedge production risks and manage climate variability, for example, select specific cultivars better suited for variable conditions and use protective plantings for high value crops.
- Reduce the potential for increased salinity and erosion, caused by extreme events, by using deep-rooted perennials in rotations or intercropping and on low capability land.



## Animal health

Climate change will substantially increase the number of heat stress days, which might affect the overall viability of some intensive farming.

Heat stress reduces productivity and reproductive rates, increases mortality rates and raises concerns about animal welfare. It has been suggested a 1°C increase in global average temperature may mean that passively ventilated or free range pig production units may no longer be viable in the eastern States.

### IMPACTS

- Demand for energy is likely to increase in situations where livestock are currently farmed in indoor, climate-controlled conditions, such as modern meat chicken farms.
- Animals respond to heat stress by:
  - increasing body temperature;
  - increasing respiration;
  - changing their metabolic rate and maintenance requirements;
  - increasing water intake;
  - increasing evaporative water loss;
  - reducing feed intake;
  - changing blood hormone content; and
  - possibly becoming more susceptible to parasites.
- Temperatures above 27°C exceed the comfort level for dairy cows, dramatically affecting milk yields.
- Decreased rainfall and increased temperatures cause animals to require more water to combat heat stress. This may force the purchase of additional water.
- Sourcing supplementary feed for animals is likely to become more difficult and more expensive with the impacts of climate change.





## ADAPTATION OPTIONS

- Agist stock away from affected areas.
- Change calving patterns.
- Consider climate-controlled production sheds through mechanical or natural air conditioning, bearing in mind that housing dairy cattle where the climate can be controlled may prove too costly.
- Decrease energy demand in production sheds with innovative building designs and materials. Also, consider supplementary or complete power generation onsite. For example, sheds could be suitable sites for **photovoltaic** cells to supply electricity. Wind power and co-generation using effluent are also possibilities for power generation.
- Apply heat abatement through water misting and evaporative cooling of stock.

**?** **PHOTOVOLTAIC** cells generate electricity when exposed to sunlight. They were first developed for use in space, providing power for satellites.

- Build and maintain shelter and shade structures, and/or re-establish shelter trees.
- Increase the use of forage cropping and supplementary feeds.
- Select for heat-tolerant phenotypes in breeding plans. Hardier animal breeds and cross-breeds may be selected, though in the broader context. Using tropically adapted *Bos indicus* cattle, for example, may come at the expense of productivity, fecundity and meat quality.



## OPPORTUNITIES

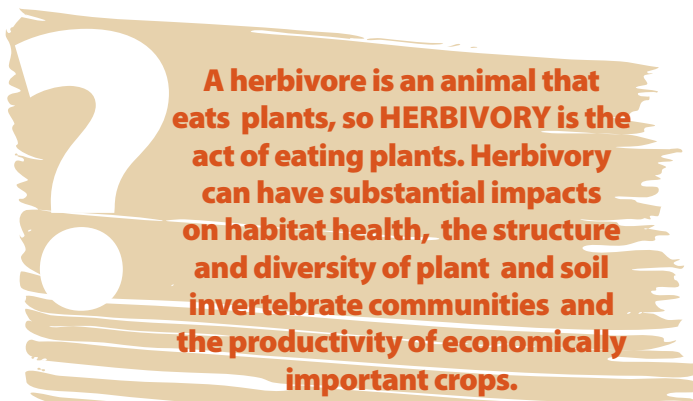
- Possibility of developing new breeds and cross-breeds to better cope with Australia's climate variability. For example, introducing traits that reduce heat stress such as a lighter, shorter coat could be introduced into traditional breeds.

## Pest and diseases

Higher average temperatures may widen the ranges of diseases and pests and affect the usual window of opportunity for control. They may also increase the numbers of some pests and diseases and the possibility of a shift in their distribution to more southern regions.

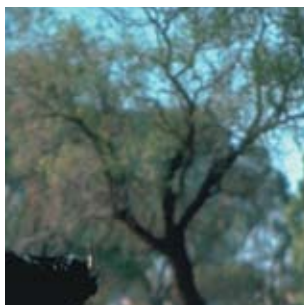
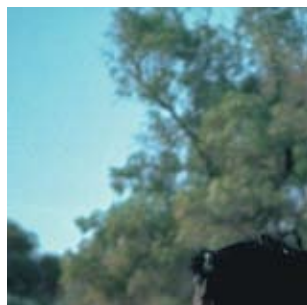
### IMPACTS

- Changes may make conditions more favourable for the spread of insect-borne diseases (such as Bluetongue) and existing pests (such as locusts) that respond strongly to climate signals.
- Some pest species will be able to modify their life cycles to respond to climate change. Pest species not currently in Australia might find more favourable conditions under climate change, increasing the risk of possible invasion and impact. Some native species might invade or become over-abundant in new areas.
- Blowfly populations could increase as flies breed better and grow faster in warmer conditions.
- Milder winters may decrease the amount of plant pathogens killed annually, increasing the spread of disease.
- The risk of soil-borne diseases spreading and proliferating may increase as a result of more intense rainfall events and dust storms (coupled with higher temperatures).
- The effect of increased temperature and CO<sub>2</sub> enrichment may change disease dynamics from the pest's perspective. Host-pathogen interactions have been found to change, and **herbivory** may increase, in high CO<sub>2</sub> environments.
- Feed and water shortages in extreme seasons may increase competition between kangaroos and domestic livestock. Kangaroos may be better able to adapt to changed conditions and become dominant. At the same time, feral goats and camels may have a competitive advantage over native species, posing a threat to conservation.



## ADAPTATION OPTIONS

- Apply a flexible integrated pest management approach.
- Undertake closer monitoring and more responsive management of diseases and insect pests and predators.
- Adjust the timing of pest control, as pest life cycles such as that of the red-legged earth mite respond to climate change.
- The use of baiting to control pest animals such as foxes may be more effective when food is scarce.
- Increase use of fly-strike prevention products for sheep.



## OPPORTUNITIES

- If numbers of pests such as feral goats and camels increase, there may be increased commercial harvesting opportunities.
- Producers may be able to take advantage of the stress conditions that traditional insect pest species will face, by reducing population numbers and host species whenever economically feasible and encouraging the adaptation of more desirable species.
- Pests such as rabbits may struggle with the longer periods of dry feed, higher temperatures and expected increased effectiveness of calicivirus under drier conditions.

## Weeds

Higher average temperatures could increase the likelihood of a shift in distribution of weeds from northern to southern regions and an increase in the proliferation of weeds better suited to changed conditions.



### IMPACTS

- Elevated carbon dioxide levels are expected to enhance weed growth, although this will be specific to the weed species and environment in which it is grown.
- As the climate changes and growing patterns alter, weeds and low palatability **C4 grasses** such as Coolatai grass might 'out compete' more desirable forage plants in both rangeland and southern areas.
- Drought-tolerant ornamental species such as succulents, C4 grasses, winter bulbs and Mediterranean shrubs may naturalise and spread to become weeds.
- Increased weed distribution can provide a habitat for pests and diseases. An increase in the use of herbicides to control weeds may cause an increase in resistance to herbicides. There is also the potential for increased withholding periods for livestock, which restricts the market options.
- An increase in weed types and invasiveness could affect wool quality and value (e.g. increased incidence of summer burr weeds such as Bathurst burr or innocent weed), in addition to increasing production costs.
- Conditions under climate change such as soil compaction or waterlogging may favour some weed species such as Cape Tulip and docks.

### ADAPTATION OPTIONS

- Increase the resilience of land systems through Landcare and stewardship initiatives.
- Improve response to new weed issues as soon as they emerge.
- Enhance conditions for growth of pasture grasses to out-compete weeds.
- Consider using biocontrols where possible to manage weeds to reduce input costs and use of herbicides.
- Apply managed grazing techniques such as rotational grazing and strategic herbicide use to reduce weeds and improve pasture.

**C4 GRASSES** have a photosynthetic pathway that adapts them to hot climates and an atmosphere low in carbon dioxide. They are considered warm season grasses.

# General impacts

## IMPACTS

- More floods and drought are expected to increase pressure on land use and economic returns.
- Livestock carrying capacity may be affected by a combination of expected changes.
- Expected changes in fire patterns and an increase in fire events, fire size, frequency and intensity will affect both flora and fauna species composition and structure. Large, hot fires can also have a devastating effect on water quality as water courses can fill with sediment in the rains that follow fires.
- Possible shifts in local and international markets. For example, shorter, milder winters in the Northern Hemisphere might alter the demand for wool.

## ADAPTATION OPTIONS

- Use improved seasonal forecasts in all short and long-term farm management decisions.
- Prepare emergency bushfire plans.
- Maintain awareness of trends in international supply and demand for food and fibre.



## OPPORTUNITIES

- The international meat industry is affected by both competition and global grain prices, both of which will be affected in some way by climate change. This might favour Australia if producers can adapt effectively to their own climate change scenarios.
- New enterprises present alternative opportunities, such as processing, energy generation from livestock waste and bio-sequestration.
- Breeders of sheep and cattle better suited to the new environment may have increased commercial opportunities. This may include supplying other States, such as Queensland, with livestock that have previously been unsuitable for their climatic conditions.
- Niche markets and marketing strategies resulting from climate change impacts may present opportunities to savvy producers. For example, new breeds of meat animals, branding based on environmental stewardship, innovative technologies and techniques to sustain production and develop a unique marketing 'story'.

## Irrigation water

**Water is expected to become scarcer under climate change, with reduced rainfall and increased demand for irrigation water. This has implications for horticulture, as a major water user.**



### IMPACTS

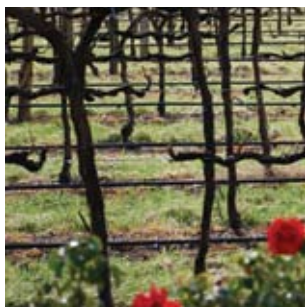
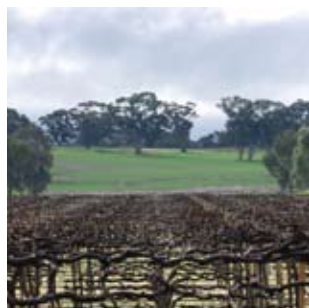
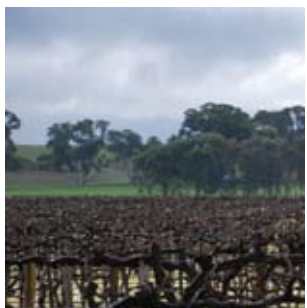
- Variable water supplies and reduced river flows may lead to increases in irrigation salinity, reducing water quality and affecting plant growth and soil health. Water quality can have significant impact on horticulture management practices.
- Increased demand, increasingly variable water supplies and rationalisation are expected, especially during hot and dry periods, as is reduced water availability in some locations and in some seasons.
- Critical water allocations along the River Murray corridor will require irrigators to manage plantings with reduced allocations at different times in the season.
- Increased incidence of severe weather conditions may require the types of irrigation systems used and timing of irrigations to be modified.

### ADAPTATION OPTIONS

- Prioritise the use of scarce irrigation water resources away from low-value crops.
- Assess crop and water management practices to reduce variability in yield and quality. For each crop, assess modified growth and changed water requirements under new climatic conditions.
- Increase irrigation efficiency, through:
  - enhanced monitoring of soil water conditions to improve timeliness and quantity of irrigation; and
  - effective and efficient use of water management technologies, i.e. upgrading to efficient irrigation systems and enhanced use of monitoring and timing equipment.
- Use computer-controlled irrigation scheduling and soil moisture probes to help regulate irrigation frequency and to manage salt levels.
- Increase water storage capacity to better meet irrigation requirements.
- Reassess the types of ground cover crops used to preserve moisture in the soil.

# Rainfall

The amount of overall rainfall in South Australia is expected to drop, though there may be more heavy falls, and the timing of rain events will shift.



## IMPACTS

- For most horticultural crops, the timing of rainfall is important. For viticulture, the biggest risk is late summer rainfall which can lead to splitting, ringing, disease exposure and rot. Such conditions could also increase fungus and bacterial infections.
- Heavier falls of rain may provide increased opportunities for water harvesting, but may also cause flooding and run-off damage.
- Warmer conditions and reduced rainfall will increase water requirements while also increasing evaporative losses, putting pressures on water availability for irrigation.
- A possibly more humid late summer may lead to modifying variety selection. For example, possible use of grape varieties with looser bunching.

## ADAPTATION OPTIONS

- Careful management of the soil moisture profile will help horticulture producers cope with drier conditions. Techniques that make best use of available soil moisture will be useful for responding to changing risks across most horticultural industries.
- While uncertainty continues, increasing atmospheric CO<sub>2</sub> concentration may provide benefits by increasing water use efficiency and allowing the same yield from less water.
- Landscaping may assist in directing heavy falls of rain into water storage areas such as dams and may be useful in limiting erosion damage.

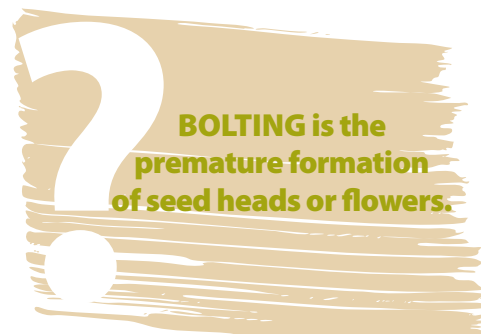
## Temperature

Expected higher temperatures may reduce the extent of land that is available for cool climate horticulture. There are maximum temperature limits for some crop varieties, which may modify land-use capability.



### IMPACTS

- With warmer, drier conditions, particularly in winter and spring, more rapid phenological progression is expected in horticulture crops, with earlier ripening and possible reductions in quality and yields.
- Some common cultivars of pome fruit have shown an adverse reaction to excessively warm conditions, with problems such as sunburn, water-core and lack of colour. Expected increased potential for downgrading product quality due to sunburn and other negative temperature impacts.
- Warmer temperatures may increase the frequency of **bolting** in some vegetables, such as lettuce, parsley, spinach and silverbeet.
- Some crops are very sensitive to temperature change. For example with wine grapes, an increase in average temperature by just 2 to 3°C will significantly change grape quality and wine style.
- The expected continued rise in winter temperatures will affect the required chilling hours for many fruit varieties, particularly stone and pome fruit, and nuts, which have very specific winter-chilling requirements.
- With rising minimum temperatures, the incidence of frost may decrease. However, rising minimums are likely to be accompanied by greater variability, resulting in an increased risk of unexpected frost at critical times.
- Higher night temperatures can be a problem for some late-harvested varieties of fruit and grape varieties that need to be harvested and handled in the cooler temperatures.





## ADAPTATION OPTIONS

- With little scope for adapting through relocation, at least in the short term, the main adaptive strategy available to the fruit industry may be moving to varieties that have a lower chilling requirement.
- Undertake risk assessment to assess sustainability in more marginal areas (e.g. chilling requirements, increased frost risk, increased quality problems).
- Develop apple and pear cultivars (either new or existing) with lower chilling hour requirements and greater pest and disease resistance.
- Use chemical dormancy breakers to help counteract the lack of suitable chilling hours.
- Implement localised microclimate assessment systems.
- Consider evaporative cooling as a technique for reducing sunburn, along with shade nets and some commercial **kaolin**-based coatings that often repel pests as well. Shade nets have the added benefit of preventing hail damage.

**?** **KAOLIN is used in some horticulture products to repel pests in the horticulture industry. Kaolin is a non-toxic particle film that places a barrier between the pest and its host plant. The active ingredient is kaolin clay, an edible mineral long used as an anti-caking agent in processed foods and in such products as toothpaste.**

## OPPORTUNITIES

- Warmer night temperatures and a reduction in frost frequency may allow planting of earlier bearing viticultural and other horticultural varieties, though the unpredictable nature of frosts remains a risk.
- Higher temperatures tend to shorten the period of growth of individual crops. The opportunity to plant earlier in the season or harvest later, may extend the growing season for crops such as lettuce, french beans and tomatoes.
- With shorter phenological cycles, double cropping may become possible, e.g. lettuce.
- Warming may allow new varieties to be grown in cooler climate production areas.



## Soils

Adopting management practices that improve the efficiency of nitrogen use can generate benefits for farm profitability, while also reducing greenhouse impacts and improving environmental sustainability.

### IMPACTS

- Inappropriate nitrogen use for the soil type or rainfall factors, and management practices such as fertiliser placement, can lead to additional losses of nitrogen through ammonia volatilisation and nitrate leaching and run-off.
- Heavier rainfall scenarios may see changes in soil quality through increased erosion and leaching of nutrients.
- Soil compaction or waterlogging can cause anaerobic soil conditions favouring **denitrification**.
- Increased erosion and leaching of soil nutrients is also possible under dryer summer conditions and more extreme weather events.
- Increases in soil acidification due to increased carbon dioxide concentrations are possible.

**?** **DENITRIFICATION is the conversion of nitrate to nitrous oxide and nitrogen gas forms, which are unavailable to plants and are lost to the atmosphere.**



## ADAPTATION OPTIONS

- Use soil or plant testing to assess available nitrogen supply prior to fertiliser application; apply nitrogen fertiliser based on a calculation of target yield and crop nitrogen requirement over the growing season; and use split applications, rather than a single large application, to ensure maximum plant uptake and minimum nitrogen losses.
- Ensure soils are well drained to minimise waterlogging. Avoid application of fertilisers (especially nitrate) to very wet soils and before heavy rainfall events. Place fertiliser below the soil surface where possible to limit ammonia volatilisation; and time fertiliser application to minimise loss via denitrification or volatilisation (if top dressing urea, apply prior to rainfall or irrigation events). Consider foliar application when supplementary nitrogen is required.
- Ensure continuous plant cover (between growing seasons and between row crops) to avoid losses of nitrogen by leaching or denitrification. Retain prunings and stubbles after harvest.
- Aim to build organic matter in soils through pasture rotations or by adding composted material. Use gypsum to improve soil structure and help avoid anaerobic conditions. Consider the production and application of 'compost tea' or 'biochar' to improve soil quality, carbon retention and productivity.

## OPPORTUNITIES

- Adopting management practices that improve the efficiency of fertiliser use can generate benefits for farm profitability, while also reducing greenhouse impacts and improving environmental sustainability.
- With an increased interest in soil conditioners such as worm castings, compost tea and biochar, there may be commercial opportunities in the production of these products.

## Plant production cycles

**Expected greater seasonal variability will affect quality and yields.**

### OPPORTUNITIES

- Increased atmospheric CO<sub>2</sub> concentrations may benefit productivity of most horticultural crops, although the extent of this benefit is not fully understood at this stage, and may depend on the availability of nitrogen and water.
- Opportunities to grow previously unsuitable grape varieties in different wine growing regions may be realised as average temperatures rise with climate change.

### IMPACTS

- Changing conditions are expected to affect flowering, pollenisation and fruit set.
- Changes in time to harvest for some crops and locations can be expected and may require revised crop scheduling and marketing responses.
- Hot dry spells and fewer chilling periods will affect plant production and yield of perennial fruit crops. Changes in the suitability of cultivars for current and future production locations are expected.
- Higher carbon dioxide concentrations may lead to more canopy growth and shading, leading to potential decreases in fruitfulness. Due to changing levels of CO<sub>2</sub>, additional fertiliser applications may be required to maintain product quality, though this may have other impacts as well. The real effects of increased atmospheric CO<sub>2</sub> are not yet fully understood.
- It is expected the winegrape cropping calendar will change. Phenological shifts in winegrape vines may result in ripening in a warmer part of the season. With earlier harvest in a warmer climate, the temperature of the ripening period in some regions will become too high to produce balanced wines from some or maybe all grape varieties growing there now.

### ADAPTATION OPTIONS

- Make changes to varietal choices and site management:
  - source new 'longer season' varieties; and
  - undertake research on altering management practices to change bud burst, canopy density, etc.
- Change cultivars or develop new, more phenologically suitable cultivars for projected climate conditions. For example, crops with extended flowering periods such as peas and pumpkin, are generally less sensitive to heat stress, compared with those with tighter flowering times such as cauliflower and broccoli.
- Increase the use of environmental netting structures to protect crops, enhance fruit quality and improve water use efficiency.
- For many perennial crops, plan for earlier harvest times and address marketing issues such as access and timing.
- Assess the potential for new sites, considering varietal performance and chilling requirements.
- A shorter grape growing season and earlier ripening will compress harvest dates, with subsequent pressure on picking, crushing, transport, and winemaking resources.
- There may be changes in wine flavours and styles for key regions that have reputations and secure markets based on their current styles.

# Extreme events

**Hail storms, heat stress, high winds, heavy rains and frosts are major climatic risks causing potential damage to horticulture crops, productivity and infrastructure.**

## IMPACTS

- Horticulture producers in flood-prone areas face an increased risk of flood damage.
- Extreme rainfall events and flooding may affect soils and crops via soil erosion, salinity and sedimentation of waterways, as well as damage to farm infrastructure.
- With the possible increase of dust storms, layers of dust over greenhouse coverings can reduce the transmission of thermal radiation.
- Some wine-growing regions in or near high-risk fire areas not only face the direct risk from an expected increase in fire events, but also the indirect damage to wine caused by smoke taint. In recent years, smoke damage has been reported many hundreds of kilometres away from the source of the fire.

## ADAPTATION OPTIONS

- Improve medium and long-term forecasting of seasonal conditions.
- Develop strategies to hedge production risks and manage climate variability, for example, specific cultivars or protected cropping for high-value crops.
- Modify the management of the inter-row environment to take into account potential frost risk and the impacts of high rainfall events such as erosion and salinity.
- Consider canopy protection using netting in fruit orchards to increase protection from heat stress, frosts and hail.



## OPPORTUNITIES

- Many believe 'controlled-environment horticulture', a combination of greenhouse and hydroponic production systems, presents a substantial opportunity in the future, with the ability to control the climate, maximise water use efficiency and continue high-quality, high-volume production of food.
- South Australia already has significant greenhouse infrastructure and so is well equipped to expand controlled-environment horticulture opportunities.
- New enterprises and forms of enterprise present alternative opportunities, such as processing, energy generation and supply, and bio-sequestration.

## Pests and diseases

Higher average temperatures may encourage an earlier pest presence and affect the usual windows of opportunity for control. It may also increase the number of certain pests and diseases and boost the possibility of a shift in their distribution to more southern regions. Other pests and diseases might disappear from certain areas. Many pests such as *Heliothis* moths, armyworms, sucking bugs and locusts respond strongly to climate signals.



### IMPACTS

- A changing environment will modify pest and disease life-cycles, alter current relationships, and require adjustments to existing integrated pest management practices and monitoring systems. Climate change may activate 'sleeper' pests and pathogens and entirely new strains might develop. The range of diseases and pests such as fruit fly, which are now limited by temperature, may expand.
- Milder winters may decrease the amount of plant pathogens killed annually, and increase the spread of disease, and may present more favourable conditions for some pests. For example, the Diamondback moth is a significant pest to brassicas, but does not usually survive cold winters.
- Unpredictable frost may also restrict opportunities to destroy temperature-dependent fungi.
- Increased incidence of downy mildew, powdery mildew, botrytis, and parasitic nematodes may also occur.
- Increased hail and storm damage may leave produce vulnerable to pest and disease invasions.
- Variable climatic conditions may lead to an increase in disorders such as tip burn and blossom-end rot.
- The effect of increased temperature and CO<sub>2</sub> enrichment may change disease dynamics from the pest's perspective. Host-pathogen interactions have been found to change, and **herbivory** may increase, in high CO<sub>2</sub> environments.
- Increased risk of spread and proliferation of soil-borne diseases as a result of more intense rainfall and wind events (coupled with warmer temperatures).

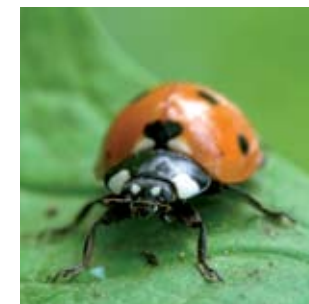
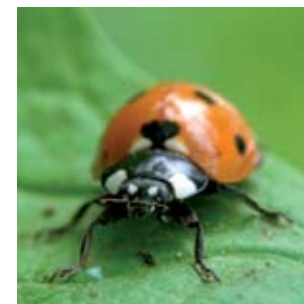
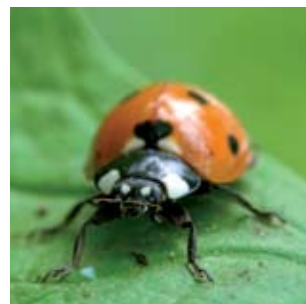
**?** A herbivore is an animal that eats plants, so **HERBIVORY** is the act of eating plants. Herbivory can have substantial impacts on habitat health, the structure and diversity of plant and soil invertebrate communities and the productivity of economically important crops.

## ADAPTATION OPTIONS

- Undertake closer monitoring and more responsive management of diseases and insect pests and predators to avoid surprise outbreaks. Modify pest management practices and change timing and methods of pest management and control strategies.
- Maintain host free zones around commercial producers. For example, eliminate hawthorne and other host species for cherry slug and codling moth within 600 metres of commercial orchards.
- Promote better on-property hygiene.
- Increase the use of weather recording stations within horticultural growing regions for better predictive modelling for pests and diseases.
- Integrate more 'biocontrol' techniques to reduce increased use of pesticides. For example, Montdorensis is a predatory mite that feeds on the larvae of western flower thrips, tomato thrips and onion thrips, broad mites and tomato russet mite. Montdorensis prefers warmer, greenhouse situations.

## OPPORTUNITIES

- For perennial horticulture and vines, located in the cooler temperate part of southern SA, disease incidence may reduce with lower rainfall in spring.
- Producers may be able to take advantage of the stress conditions that traditional pest species will face, by reducing population numbers and host species whenever economically feasible, and encouraging the adaptation of more desirable species.
- Pests such as rabbits may struggle with the longer periods of dry feed, higher temperatures, and expected increased effectiveness of calicivirus under drier conditions.



## Weeds

**Higher temperatures could increase the likelihood of a shift in weed distribution to more southerly regions. Increased carbon dioxide levels are expected to enhance weed growth, although this will be specific to the weed species and the environment in which it grows.**



### IMPACTS

- Increased weed distribution can provide a habitat for pests and diseases. If herbicides are used in greater volumes, there is the risk of increasing resistance as well as the cost of control measures. There is the potential for increased herbicide residues on crops to exceed defined maximum limits, which may affect both domestic and export market potential.
- The increased extremes expected with climate change, such as long dry or drought periods interspersed with occasional very wet years, may worsen weed invasion because established vegetation (both native and crop) will be weakened, leaving areas for invasion. Weeds with efficient seed dispersal mechanisms, such as water or wind, may be better able to take advantage of the expected floods and dust storms.
- Disturbed habitats may be more easily colonised by pest animals and weeds, for example, after a drought.
- Drought-stressed weeds are more difficult to control with post-emergent herbicides than plants that are actively growing. For example, systemic herbicides that are translocated within the weed need active plant growth to be effective. Pre-emergent herbicides or herbicides absorbed by plant roots need soil moisture and actively growing roots to reach their target species. Drying winter and spring rainfall trends have the potential to reduce the effectiveness of pre-emergent herbicides such as triazines or atrazine.
- There is the chance that climate change will favour some native plants to the extent that they will become weeds.



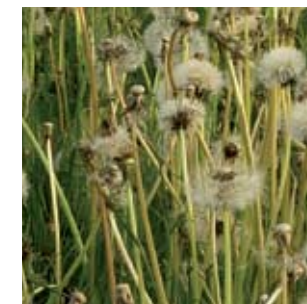
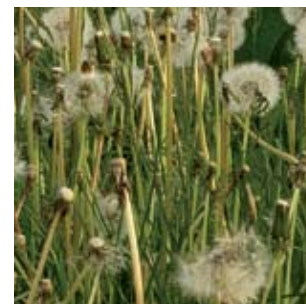
... sustained stimulation of photosynthesis and growth of perennial weeds could occur as CO<sub>2</sub> increases ...

CSIRO, An overview of climate change adaptation in Australian primary industries – impacts, option and priorities, section on horticulture in temperate and Mediterranean climates, p. 186

## ADAPTATION OPTIONS

- Undertake closer monitoring and more responsive, integrated management of weeds. Use weed risk assessment modelling to identify current and potential weeds posing the greatest threats to horticultural crops.
- Practise integrated weed management to reduce the reliance upon herbicides for weed control and minimise risks of herbicide resistance. Options might include combining various techniques for weed control such as crop competition, cultivation in combination with strategic herbicide use and biocontrols.

- Identify weed species that host pests and diseases and maintain active control programs on these particular weed species.



## OPPORTUNITIES

- Increased groundcover may reduce soil erosion and increase moisture retention.
- Increased weed numbers will increase the amount of organic material available for conversion to supplement soils.

## Carbon accounting

Agriculture is a significant contributor to Australian greenhouse gas emissions. According to the Department of Climate Change, agriculture (not including energy or transport) was responsible for an estimated 15.6% of Australia's greenhouse gas emissions in 2006, making it the nation's second largest emitter. However, agriculture, along with farm forestry, has the potential to help the mitigation of greenhouse gas emissions by the sequestration of carbon into soils and vegetation.

As both a source and potential sink for emissions, agriculture's role in an emissions trading scheme will be an important one. To date, agriculture has been one of the Australian industries that has worked at reducing its emissions. The increase in direct drilling and tree

planting has already had a positive impact on agriculture's contribution to the national emissions levels.

At this stage, the Australian Government has excluded agriculture from the first phase of the national Carbon Pollution Reduction Scheme (emissions trading scheme) with a decision expected by 2013 on whether to include agriculture by 2015 at the earliest. The debate – tackling complex issues of measuring and monitoring agricultural emissions – is heated and is expected to continue for some time.

One of the major hurdles in determining agriculture's role in an emissions trading scheme is linked to the agreed international rules that should govern it. By ratifying the Kyoto Protocol, the Australian government has committed

to the internationally-set carbon accounting rules as they currently stand.

While Australia has, for now, chosen not to include agriculture in its current carbon inventory, Article 3.4 of the Protocol is an important one for Australian agriculture. It documents the rules for fixing carbon and nitrogen from the atmosphere by agriculture. The rules make no allowance for separating man-made and naturally occurring carbon. Some people feel this means that in drought years agriculture's apparent emissions would be exceptionally high and so, too, would be the Australian government's liability. When the Kyoto Protocol was ratified, Australia committed itself to legal liability and money has to be spent in off-sets to keep the emissions account in balance.

This presents a dilemma for Australian agriculture: the potential to be rewarded for natural carbon sequestration in agriculture is linked with the potential to be penalised under the existing international rules of carbon accounting when emissions are high.

A major reason 2015 has been set as a target date for possible inclusion of agriculture in the Carbon Pollution Reduction Scheme is that the details of a possible post-Kyoto, multilateral agreement may be known by then. This would include details of the accounting rules that would apply to agriculture.

**In relation to greenhouse gas emission, land-based emissions are known as 'sources'. Systems that remove greenhouse gases are known as 'sinks'.**

**Plants, when actively growing and photosynthesising, act as a sink of carbon but when they respire, are destroyed, decay or are burnt, the stored carbon is released into the atmosphere. Carbon is also released into the atmosphere from grazing animals, as they digest food, and from agricultural and soil management practices such as ploughing and fertiliser applications.**

In the meantime, agriculture will still feel the effects of the emissions trading scheme. Electricity and fuel providers, for example, will have to buy permits and participate in the scheme, probably resulting in higher-priced inputs for farmers. However, the Australian Government's Carbon Pollution Reduction Scheme White Paper (December 2008) states that it will assist all households and businesses move toward a low pollution future.

The likely technological developments in the mitigation of greenhouse emissions are also unknown. How will emissions be measured and monitored in agriculture? Will new technologies emerge that dramatically reduce agriculture's emission profile? Will new, clean energy sources quickly develop? To what extent will the unleashing of market forces through an emissions trading scheme accelerate these changes? The answers to these questions will become evident at some future stage, but cannot be predicted with any certainty.

*Small-scale farm plantations may encounter relatively high transaction costs [in an emissions trading scheme] that make them less economic, unless mechanisms are developed that enable small-scale off-sets to be efficiently pooled.*

Mick Keogh, Australian Farm Institute, 'Primary industries and greenhouse emissions trading – research and information needs', The National Climate Change Research Strategy for Primary Industries Phase 1 Report, [sites.lwa.gov.au/ccrspi/index.php?q=node/21](http://sites.lwa.gov.au/ccrspi/index.php?q=node/21)



## Greenhouse gas reduction techniques on-farm

### There are practical farm management activities that can reduce an enterprise's greenhouse gas emissions.

The following guidelines are from a report being prepared by the Department of Climate Change, *Farming for the Next Generation*. While not yet published, we have permission to list the measures as a guide for managing greenhouse emissions.

There are good reasons to pursue strategies to reduce emissions, as a number of mitigation strategies also boost efficiency and productivity. However, these activities are untested and will need to be evaluated on-farm.

Abatement costs and opportunities vary between regions and industries, and changing energy, transportation and material costs over the medium and long term will affect them. Note: some activities will appear inconsistent with others and so must be evaluated on merit.

*"...if we can produce the same amount of food and fibre (or more) using less fuel, fodder, fertiliser, etc, then not only are we minimising our impact on the climate but, through efficiency, operating more profitably!"*

Primary Industries and Resources SA, [www.pir.sa.gov.au](http://www.pir.sa.gov.au),  
Adapting to Climate Change



# Managing greenhouse emissions from soils

**Nitrous oxide (N<sub>2</sub>O) is a significant greenhouse gas. According to the Department of Climate Change, one kilogram of N<sub>2</sub>O has the same warming potential as 310 kilograms of carbon dioxide.**

Most of Australia's nitrous oxide emissions (around 60%) come from agriculture, particularly following the application of nitrogen fertilisers to pastures and crops.

Plants often use less than 50% of applied nitrogen; the remainder is lost to the environment and so contributes to our emissions. Adopting farm management practices that improve nitrogen efficiency can reduce greenhouse impacts while boosting environmental sustainability and profitability.

## WHAT YOU CAN DO

- ✓ Manage agricultural soils to minimise nitrogen loss.
- ✓ Ensure soils are well drained to reduce waterlogging.
- ✓ Avoid application of fertilisers to saturated soils, especially nitrate, applying to raised beds or ridges where possible.
- ✓ Build organic matter in soils through pasture rotation or by adding compost.
- ✓ Add gypsum to improve soil structure and help avoid anaerobic soil conditions.
- ✓ Where possible, ensure continuous plant cover to avoid losses of nitrogen by leaching or denitrification.
- ✓ Avoid burning crop residue and retain stubbles and prunings where practical.
- ✓ Where possible, use conservation tillage and controlled traffic practices in broadacre cropping.
- ✓ Apply nitrogen fertiliser based on calculations of target yields and crop nitrogen requirements across the growing season.
- ✓ Use soil or plant testing to assess available nitrogen prior to applying fertiliser.
- ✓ Where possible, place fertiliser below the surface to limit ammonia volatilisation.
- ✓ Consider foliar application when additional nitrogen is required.

## Managing methane from livestock

**Methane produced by sheep and cattle during their digestion of feed is estimated to be around 12% of Australia's total greenhouse gas emissions.**

Shifting farm management techniques to direct more of this feed energy into productive uses can reduce greenhouse emissions while improving livestock efficiency.

Action across all the areas of nutrition, feed management, animal health, genetics and herd management will deliver the best outcomes for both greenhouse emissions and enterprise productivity.



### WHAT YOU CAN DO

- ✓ Improve quality of pasture or forage, or supplement the diets of grazing livestock with grain or other nutrient-dense feeds, especially during summer.
- ✓ Manage the legume content and maturity of pasture through, say, rotational grazing to maximise the quality and value of feed to stock.
- ✓ Use feedlots for beef cattle to reduce finishing times through high quality diets.
- ✓ Where possible, match the feeding allowances published by the Feeding Standards for Australian Livestock throughout the production cycle. (CSIRO, 2007)
- ✓ Boost the efficiency of the animal's rumen through feed additives.
- ✓ Aim for genetic improvement resulting in shorter finishing times.
- ✓ Select rams and bulls for efficient feeding conversion and other traits in productivity.
- ✓ Consider cross-breeding to boost hybrid vigour to improve production efficiency.
- ✓ Cull inefficient animals and select to increase productivity, improve product quality and increase disease resistance.
- ✓ Manage the herd or flock to improve the health and nutrition of breeding animals.
- ✓ Develop and implement a disease management plan.

# Managing waste in intensive production systems

**The decomposition of waste from intensive livestock systems results in carbon dioxide, methane and nitrous oxide. The National Greenhouse Gas Inventory estimates that this element of farming accounts for 9.5% of Australia's total emissions.**

Higher greenhouse gas emissions in livestock waste are due to high concentrations of organic matter, high moisture content, complex carbohydrates, and high levels of nutrients such as potassium, nitrogen and phosphorus. Elevated levels of one or more of these factors in manure can be linked to inefficient feed utilisation. Focusing on ensuring high feed conversion efficiency can benefit the enterprise and the environment.



## WHAT YOU CAN DO

- ✓ Provide improved pastures, high-quality fodder and grain-based supplements to improve digestibility of rations.
- ✓ Process grain to maximise digestibility and minimise the volume of organic matter in manure, as is achieved with steam-flaking or grain-tempering.
- ✓ Consider using a ration formulation model and/or mass balance model such as AUSPIG, PIGBAL, DAIRYBAL, BEEFBAL, to formulate rations designed to maximise digestibility and minimise animal nutrient excretion.
- ✓ Reduce spillage and spoilage through carefully designed feeding systems.
- ✓ Monitor feed areas to ensure animals are not being over-supplied with feed.
- ✓ Avoid land application of slurries or manure during wet conditions.
- ✓ Manage stockpiles of waste through methods such as composting, to avoid anaerobic conditions.
- ✓ De-water storage ponds by irrigating crops or pastures, to reduce anaerobic conditions.
- ✓ In large feedlots, consider covering anaerobic ponds to trap biogas for use in heat or electricity generation.

## Preserving and enhancing on-farm carbon stocks

**A practical contribution to reducing greenhouse emissions can be made at the farm enterprise level by establishing and preserving vegetation, or creating forest sinks. Conserving soil carbon can also have the same outcome.**

Trees and other plants take up (sequester) carbon dioxide from the atmosphere as they grow, through the process of photosynthesis. Carbon is stored in the leaves, roots and branches of the plant and oxygen is released back into the atmosphere.

Carbon is an essential element in healthy soils, boosting fertility and improving water holding capacity, aeration and nutrient mobility, and giving plants a more favourable environment for establishment and growth. Carbon stored in the soil rather than present in the atmosphere as carbon dioxide, also helps avoid the negative impact of greenhouse gases.

Preserving carbon sequestering plants and soil carbon are ways of reducing greenhouse gas emissions, as well as improving farm productivity.

### WHAT YOU CAN DO

- ✓ Establish new tree plantations, selecting species and preparing the site to maximise survival and growth.
- ✓ Encourage the regeneration of native trees and shrubs, keeping livestock out of some areas by fencing.
- ✓ Protect existing native plants from fire, land clearing and animals.
- ✓ Use the **National Carbon Accounting Toolbox** to estimate carbon sequestration in forest systems.
- ✓ Adopt conservation tillage options.
- ✓ Incorporate and preferably retain crop residues. Don't burn stubble.
- ✓ Utilise animal wastes such as manures, to enrich cropping soils, and as nutrients for growing trees.
- ✓ Consider the possibilities of 'biochar' (semi-carbonised organic material) to utilise organic waste and sequester carbon in the soil (as the science and technology becomes clearer).
- ✓ Avoid periods of bare fallow.
- ✓ Control grazing to prevent exposure of bare soil.
- ✓ Rotate crops, including rotations of perennial pastures and legumes.



# Improving on-farm energy efficiency

By improving the energy efficiency of farm practices and using alternative fuels wherever possible greenhouse gas emissions can be reduced while cutting the cost of electricity and fuel use.



## WHAT YOU CAN DO

- ✓ When selecting new farm equipment, consider energy efficiencies.
- ✓ Switch to alternative fuels such as LPG and natural gas, where possible, and consider on-farm renewable energy sources, e.g. wind farms, photovoltaic cells.
- ✓ Consider obtaining energy from renewable sources such as solar and wind.
- ✓ Identify the main on-farm areas where energy is used and develop a long-term strategy for reducing high energy use and replacing inefficient machinery.
- ✓ Survey and design paddocks to maximise operating efficiency and accommodate controlled traffic systems, where possible.
- ✓ Optimise the use of natural lighting and ventilation in farm buildings.
- ✓ Insulate buildings, heating and cooling pipes, storage and refrigeration machines.
- ✓ Install energy efficient lighting in farm buildings.
- ✓ Keep farm machines serviced and well maintained.
- ✓ Adopt conservation tillage and controlled traffic systems in cropping enterprises.
- ✓ Improve the efficiency of fertiliser and chemical application through less frequent application, to save on fuel consumption.
- ✓ Match the requirements of irrigation pumps to engine power.
- ✓ Use techniques like soil moisture monitoring to improve the efficiency of irrigation.

# Climate change research and activities

**A lot of research is being undertaken by industry and government to support work at a farm level. This research is a critical step in closing knowledge gaps on climate change and its impacts. Here are a few examples of ongoing research projects:**

## **The kangaroo question**

Meat and Livestock Australia is funding several projects to develop tools for livestock producers and feedlot operators to lower their emissions and adapt to climate change. One such project involves research that has isolated four specific bacterium from the gut of the red and grey kangaroo that prevent methane from being produced (and emitted), and increase the efficiency of converting native pasture feed to energy and meat. [www.mla.com.au](http://www.mla.com.au)

## **Methane-reducing vaccine**

The CSIRO, with a commercial partner in Western Australia, is researching a novel way to reduce the methane emissions of livestock. They are trialling the use of a vaccine that inhibits methane-producing organisms in the animal's gut. [www.merinodev.com.au/](http://www.merinodev.com.au/)

## **Frost gene identification**

While there is a ban in South Australia on genetically modified crops, there is work elsewhere to investigate opportunities with gene identification to potentially develop frost resistant plants. The Molecular Plant Breeding Cooperative Research Centre (MPBCRC) intends to develop genetically modified (GM) wheat with enhanced tolerance to frost. [www.molecularplantbreeding.com](http://www.molecularplantbreeding.com)

## **Smoke-tainted wine**

With the incidence of bush fires likely to increase under certain climate change scenarios, the Australian wine industry is researching smoke damage and what can be done to prevent disastrous future losses through smoke taint. [www.awri.com.au](http://www.awri.com.au)

## **'In ute' soil health tool for vegetable growers**

AUSVEG is committed to a project that will develop, publish, promote and disseminate a soil identification and interpretation reference guide for vegetable production, designed for easy use from the ute or tractor. [www.ausveg.com.au](http://www.ausveg.com.au)

## Reducing evaporation from dams

Water stored in dams, particularly shallow on-farm dams, has high evaporative losses. In small dams this can be reduced through physical dam covers, but large dams are more problematic. The CRC for Future Irrigation is conducting a project designed to improve the reliability of evaporation mitigation technology, by developing new monolayer application systems and a better understanding of factors affecting monolayer performance.

[www.irrigationfutures.org.au](http://www.irrigationfutures.org.au)

## Dairy industry – strategic commitment

Dairy Australia's 2009-13 Strategic Plan outlines the industry's approach to handling the challenges of climate change. [www.dairyaustralia.com.au](http://www.dairyaustralia.com.au)

## Capturing and using methane from animal waste

The Rural Industries Research and Development Corporation (RIRDC) has published a report that brings together available information about research and development on methane capture and use that is applicable to the intensive livestock industries in Australia and New Zealand, and makes recommendations as to where future research and development should be targeted. This brings Australia's intensive livestock industries closer to understanding the potential for the capture and use of methane from animal waste in intensive agricultural industries. [www.rirdc.gov.au](http://www.rirdc.gov.au)

## Climate information for farm management decisions

The Managing Climate Variability (MCV) Program aims to provide practical tools to incorporate weather and climate information into farm business decisions. The program aims to improve seasonal forecasting, provide tools and services for managing climate risk, and increase the adoption of climate risk management. MCV has already contributed to the evolution of seasonal climate forecasting tools such as Australian Rainman, Yield Prophet, Whopper Cropper and AussieGRAASS. [www.managingclimate.gov.au](http://www.managingclimate.gov.au)

## Reducing the impact of climate variability in grain production

This project, led by the South Australian Research and Development Institute, aims to identify key risks to grain production under climate change, and develop tools such as a flowering calculator and potential yield calculator to assist in risk management. [www.sardi.sa.gov.au](http://www.sardi.sa.gov.au)

## Researching our Farming Future

The Future Farm Industries Cooperative Research Centre (FFICRC) is playing a role in developing new farming systems and technologies for adoption by Australian farmers to ensure they are well prepared for the impacts of climate change and drought. [www.futurefarmcrc.com.au](http://www.futurefarmcrc.com.au)

# Additional reading

## The Australian and global situation

The Garnaut Climate Change Review website is worth a visit, with several resources available along with the Final Report. [www.garnautreview.org.au](http://www.garnautreview.org.au)

## Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC, 2007) has produced its 4<sup>th</sup> Assessment Report *Climate Change 2007*, which draws together and integrates up-to-date policy-relevant scientific, technical and socio-economic information on climate change for the benefit of policy makers and those from other professions. [www.ipcc.ch](http://www.ipcc.ch)

## Carbon Pollution Reduction Scheme

The Australian Government is establishing an emissions trading scheme as part of an effective framework for meeting the climate change challenge. Carbon Pollution Reduction Scheme: Australia's Low Pollution Future White Paper is now available from the Department of Climate Change. [www.climatechange.gov.au](http://www.climatechange.gov.au)

## The South Australian situation

PIRSA, SARDI and Rural Solutions SA has prepared *A Guide to Climate Change and Adaptation in Agriculture in South Australia*. This document helps explain the science behind climate change and provides information on climate change trends and projections. [www.pir.sa.gov.au](http://www.pir.sa.gov.au)

## Farming for the Next Generation

Keep a look out for the Department of Climate Change's new publication, currently in preparation, with a working title, *Farming for the Next Generation – Guidance for Managing Greenhouse Gas Emissions*. The publication provides a guide to greenhouse gas emission reduction on-farm. The material on reducing greenhouse gas emissions on-farm that we have published in this PIRSA booklet came from this draft Department of Climate Change publication, though it has not been officially released yet. [www.climatechange.gov.au](http://www.climatechange.gov.au)

## Masters of the Climate

The Managing Climate Variability R&D Program is supported by the major agriculture industry bodies in Australia. It has published the *Masters of the Climate* series, providing more than 25 case studies of farmers successfully responding to our already challenging and variable climate. [www.managingclimate.gov.au](http://www.managingclimate.gov.au)

## Wine Innovation Cluster – tailor a climate change adaptation response for your business

The Wine Innovation Cluster (WIC) is an alliance of five major research and development organisations on the Waite Campus, Adelaide, South Australia. It provides state-of-the-art facilities and capabilities for integrated grape and wine research across the production value chain ... 'from vine to palate'. The partners are: The Australian Wine Research Institute (AWRI), CSIRO, The South Australian Research and Development Institute (SARDI), The University of Adelaide and Provisor Pty Ltd. The WIC can develop and deliver customised solutions to enable the wine industry to adapt to, and mitigate, the effects of climate change. [www.wineinnovationcluster.com](http://www.wineinnovationcluster.com)

## Dairy Info Sheets

Dairy SA Info Sheets that may be of use to dairy producers, cover such topics as the principles of 'environmentally friendly' shedding; thermal efficient design; renewable energy sources; and others, providing tips on reducing energy costs. While they are designed for those starting a new dairy, there are still practical tools that could be incorporated into an existing operation.

[www.dairyindustrysa.com.au](http://www.dairyindustrysa.com.au)

## Meat and Livestock Australia's climate change centre

Visit this link for useful tools, topical publications and a reference list of relevant, worthwhile websites.

[www.mla.com.au](http://www.mla.com.au)

## Land Water & Wool

Land Water & Wool was a national research and development program providing woolgrowers with practical tools to help manage natural resources sustainably and profitably. In the climate change section there are useful publications such as *The Potential Impact of Climate Change on Woolgrowing in 2029*. [www.landwaterwool.gov.au](http://www.landwaterwool.gov.au)

## Vegetable Industry

Horticulture Australia Limited has produced a publication, *Vegetable Scoping Study into the Implication of Climate Change*. [www.horticulture.com.au](http://www.horticulture.com.au)

## Environmental Protection Agency SA, State of Environment Report 2008

The *State of the Environment Report* recognised climate change as a significant threat in South Australia. [www.epa.sa.gov.au](http://www.epa.sa.gov.au)

## Greenhouse gas emissions from livestock

Mechanisms for establishing a stable, low-emission, modified rumen fermentation include: biological control directed at methanogens and associated organisms, vaccination, the establishment of effective acetogenic and bacteriocin producing populations.

*Greenhouse Gas Emission from the Livestock Sector, What do we know, what can we do?* was prepared by Dr Roger Hegarty, NSW Agriculture, to contribute to the work of the Greenhouse and Agriculture Taskforce. It is available via [www.climatechange.gov.au](http://www.climatechange.gov.au)

## Forest sinks

The Australian Government's Planning Forest Sink Projects – A Guide to Forest Sink Planning, Management and Carbon Accounting provides more detailed information.

[www.climatechange.gov.au/land/publications/forestsinks-planning.html](http://www.climatechange.gov.au/land/publications/forestsinks-planning.html)

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These are the main reports and texts used for the content of this report. The most useful of the websites visited are listed in the Additional Reading.

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