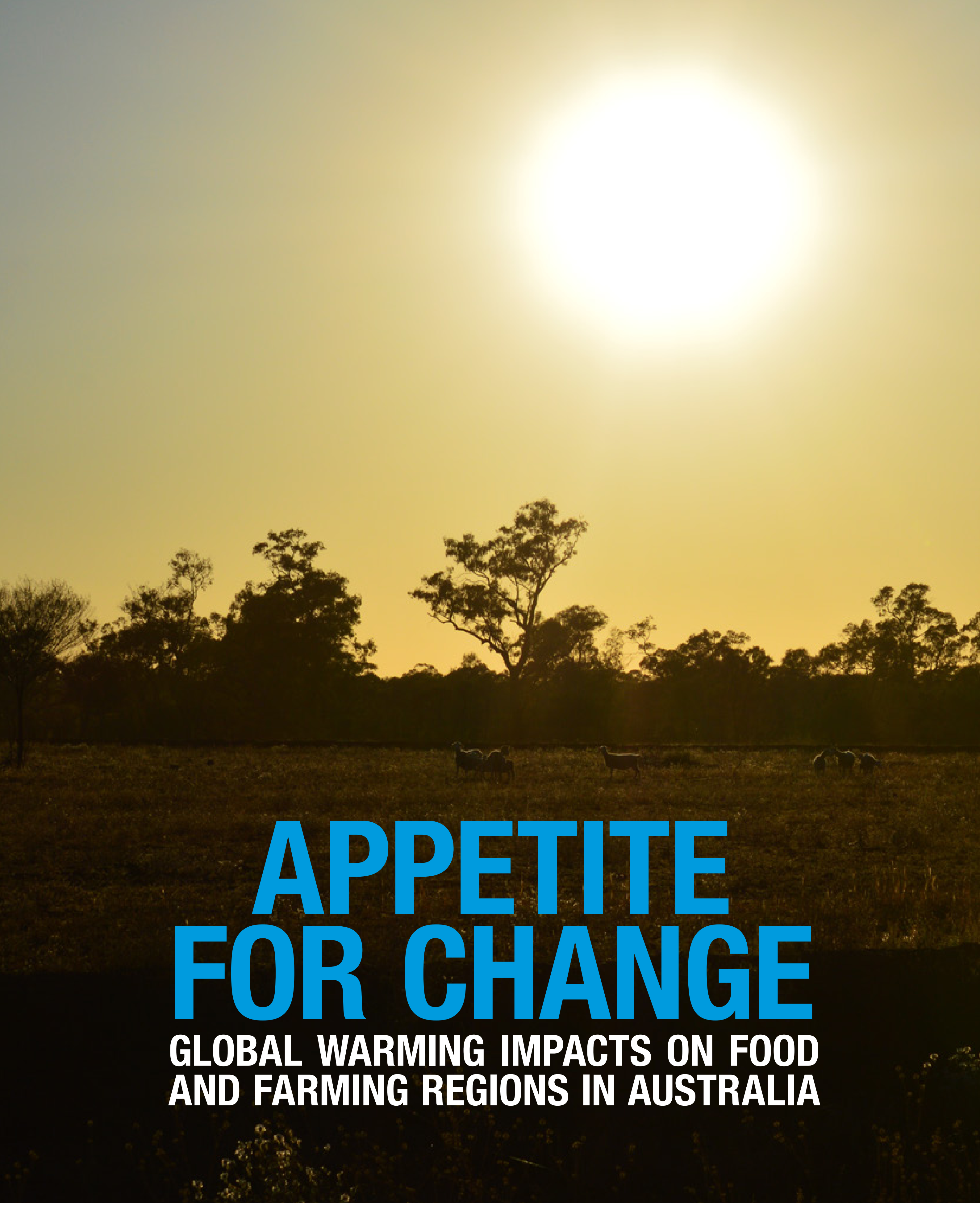

APPETITE FOR CHANGE

GLOBAL WARMING IMPACTS ON FOOD AND FARMING REGIONS IN AUSTRALIA

PREPARED BY THE UNIVERSITY OF MELBOURNE FOR EARTH HOUR 2015

THE UNIVERSITY OF MELBOURNE

MELBOURNE SUSTAINABLE SOCIETY INSTITUTE

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Dr Rebecca Darbyshire researches climate change impacts and adaptation options for the Australian fruit tree industry. She is particularly focused on understanding temperature-based effects and assessing where and when these impacts will occur. This allows industry to minimise potential damage and to identify and take advantage of likely benefits.

Associate Professor Rob Day is a marine ecologist in the School of Biosciences at the University of Melbourne. His research focuses on the sustainable management of fisheries, especially sharks and abalone, and on the immune capacities of abalone in aquaculture. Diseases are dangerous on farms where animals are close together, so farmers try to exclude disease and maintain their animals' immune capacity at a high level.

Professor Frank Dunshea is head of the Department of Agriculture and Food Systems at the University of Melbourne. He is a fellow of the Nutrition Society of Australia and chairs the Australian Academy of Science's National Committee for Nutrition. His research, including on functional food and nutrition, ecompasses 700 published journals, conferences, books, patents and technical articles.

Associate Professor Richard Eckard is director of the Primary Industries Climate Challenges Centre based at the University of Melbourne. He is an advisor to the Australian, New Zealand and British governments and the UN's Food and Agriculture Organisation on climate change research in agriculture. He leads research on enteric methane, nitrous oxide and whole farm systems modelling of mitigation and adaptation strategies.

Dr Sigfredo Fuentes is a senior lecturer in Wine Science at the University of Melbourne and the international co-ordinator of The Vineyard of The Future initiative, a multinational collaboration to research climate change impacts on viticulture. In the past five years, he has published 70 articles including more than 30 that have been peer-reviewed in scientific journals.

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Dr Anneline Padayachee is involved in research and teaching, particularly in the area of nutritional food science, at the University of Melbourne. She was named the 2012 National Fresh Science winner and the 2013 recipient for The Nutrition Society of Australia's Excellence in Nutrition and Dietary Fibre Research Award.

Dr Ian Porter is an Associate Professor with La Trobe University and Director for the Centre of Excellence in Smoke Taint Research within the Department of Environment and Primary Industries. He leads research on mitigation of nitrous oxide and smoke taint in wine from bushfires and controlled burns, and advises government and agricultural industries on technical and policy issues related to environmental sustainability.

Dr Sabine Tausz-Posch is a lecturer in crop science within the Department of Agriculture and Food Systems at the University of Melbourne. Her research focuses on understanding crop performance in a changing climate; the majority is conducted within the Australian Grains Free Air CO2 Enrichment project, where crops grow under future atmospheric CO2 conditions.

Foreword

Richard Eckard

With 93% of the food we eat grown here in Australia, the future of Australian farming matters to all of us.

Australia is lucky to have a strong agricultural sector that plays a pivotal role in contributing to the Australian economy and defining Australian culture. In 2012-13 the gross value of total Australian agricultural production was $48 billion.[1]

But Australian agriculture is at a turning point. We are halfway through what scientists refer to as the 'critical decade' to act on climate change.

And with less than a 1-degree global average rise in temperatures, climate change is already impacting a suite of Australian-grown commodities and will continue to impact farmers if stronger global efforts to reduce carbon pollution are not forthcoming.

Australian agriculture is heavily reliant on predictable rainfall and temperature to maintain production of high quality food. Australian farmers have always faced a highly variable climate, but now climate change adds significant additional complexity to their management.

According to the CSIRO, production from cropping and livestock is projected to decline by 2030 over much of southern Australia due to increased drought and the fact that the availability of nutrients will limit productivity in most Australian landscapes. Heat and drought are likely to reduce the quality of grain, grape, vegetable, fruit, and other crops. A 20% reduction in rainfall could reduce pasture productivity by 15%, and livestock weight gain by 12%, which would substantially reduce farm income. There is likely to be a southward movement of pests and diseases as the southern regions warm.[2]

Food production in Australia will need to adapt to the inevitable impacts of climate change. But there are limits to the temperatures and extreme weather events that farmers will be able to adapt to. Some industries are already relocating to new regions now more suited to their production systems, causing disruption to rural communities.

I urge you to read this report and make your voice heard by calling for greater action to reduce greenhouse emissions for the sake of our food and farmers.

This Saturday 28th March, I will participate in Earth Hour to make a stand for the future of Australian agriculture. By taking part in Earth Hour we can all build momentum towards action on climate change to help ensure future generations can enjoy the healthy, fresh food that we were lucky enough to grow up with.

References for this Foreword are from:
1 http://www.abs.gov.au/ausstats/abs@.nsf/mf/7503.0
2 CSIRO (2011) available at http://www.publish.csiro.au/?act=view_file&file_id=CSIRO_CC_Chapter%204.pdf

Preface

Anna Rose

There's a saying in Australia that "from little things, big things grow."

Earth Hour started right here in Australia, with ordinary people doing the simple action of turning off their lights for an hour to show they care. It has now spread to over 7,000 cities in more than 160 countries across the globe, inspiring literally billions of people.

The symbolic hour has grown into the world's largest grassroots movement for the environment, with Earth Hour-inspired projects and initiatives supported by WWF globally throughout the year.

In 2015 Earth Hour is very proud to have partnered with the University of Melbourne to highlight the need to solve climate change for the sake of our fresh food and farming communities.

All Australians are proud of our farmers for feeding and clothing the nation, but Aussie farmers are on the frontline of rising temperatures and more extreme weather.

The good news is that we have all the solutions we need to move away from generating electricity by burning coal and gas - fossil fuels that make global warming worse, leading to the higher temperatures, more extreme weather events and changes in pests and weeds that are already affecting our key farming regions.

Instead, we can take advantage of Australia's abundant and affordable renewable energy sources. By switching to alternatives like solar and wind, we can cut carbon pollution and help protect the fresh food and farming communities that make our Aussie lifestyle so great.

We hope this report helps shine a light on an often-overlooked reason to reduce greenhouse-gas emissions: the future of our food and the viability of our faming communities.

Setting stronger targets to reduce greenhouse-gas emissions, and planning now to transition to a 100% renewable future, is crucial to ensure future generations can enjoy the healthy food we have been so lucky to grow up with.

Earth Hour is just one hour, but it drives conversations about climate change in millions of homes, businesses, schools and community organisations around Australia and the world.

That one little action – turning off the lights – is amplified when hundreds of millions of people around the world do the same thing at the same time.

No-one can do everything to solve climate change, but everyone can do something. On Earth Hour, and in every hour, we can all play our part in demonstrating our #AppetiteForChange.

Purpose and format of this report

In 2015, Earth Hour in Australia will celebrate Australian food and farmers, reminding us of the need to tackle global warming for the sake of our rural communities and our supply of good quality fresh food.

As part of this year's initiative researchers at the University of Melbourne have been working with Earth Hour Australia to identify the impact global warming is having on key farming regions across the country and on different foods grown by our farmers.

The result is this 28 page report which is divided into two sections.

Section 1

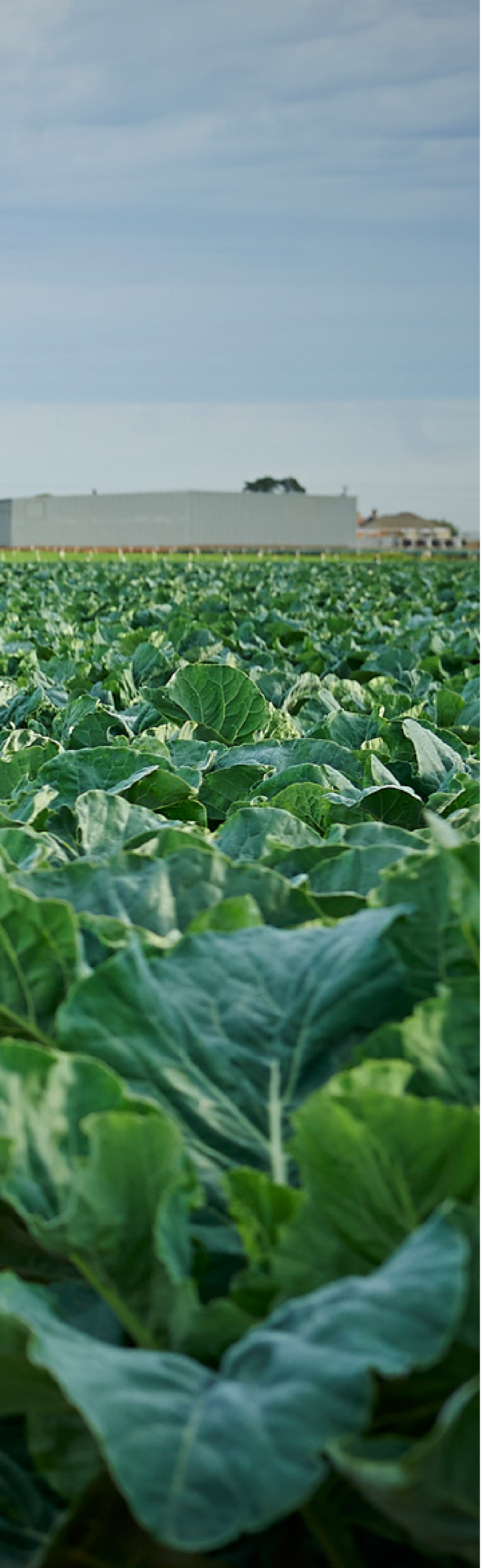
The first section by Professor David Karoly, outlines the impact that global warming is having on the following regions:

- Dry interior
- Mediterranean
- Temperate sub-humid and sub-tropical sub-humid
- Sub-tropical moist and tropical warm-season moist
- Tropical warm-season wet and tropical wet
- Cold wet and temperate cool-season wet

Section 2

The second section of this report looks at the impacts of global warming on a list of 55 household food items.

This comprehensive list has been compiled for the first time and covers everything from wheat, seafood and dairy products to poultry, meat, grains, and fruit and vegetables.



Contents

REGIONAL CLIMATE CHANGE SUMMARIES

Professor David Karoly, University of Melbourne

References for all of these summaries are BoM and CSIRO (2014), CSIRO and BoM (2007) and Reisinger et al. (2014)
See full reference list in the biography at the end of the report.

Zone 1
Dry Interior

This region includes much of inland Australia, with an arid climate, high temperatures in summer but much lower temperatures in winter, low rainfall and high evaporation. It has a highly variable climate with some very wet years leading to large-scale flooding, such as in 2010-11 and 1974-75. Temperatures in the region have increased significantly over the past 100 years, by about 1°C, with most of this warming since 1950, but there has been no long-term trend in rainfall. Continued substantial warming is expected over the rest of this century, from 0.5°C to 1.6°C by 2030 (compared with the 1980-1999 average temperature) and up to 5°C or more by 2070 with ongoing high emissions of greenhouse gases. This warming will be associated with more frequent heat waves and hotter hot days throughout the year, and less frequent frosts in winter. Changes in mean rainfall are uncertain, with possible increases in the intensity of infrequent heavy rain events. Changes in water availability in this region mainly depend on rainfall changes, so they are uncertain. It will continue to be dry, and even hotter than now, with occasional very wet years.

Zone 2
Mediterranean

The south-west of Western Australia, southern South Australia and western Victoria have cool, wet winters and hot, dry summers. In winter, cold fronts and storms from the Southern Ocean bring cold air and rain. In summer, the storms don't reach the land and hot, dry air moves south from inland. The south-west has experienced some of the biggest climate changes observed anywhere in Australia, warming about 1°C over the past 100 years with winter rainfall declining substantially since about 1960. This decline has been directly linked to human-caused climate change (Delworth and Zeng, 2014).

Continued warming is expected over the rest of this century, from 0.6°C to 1.2°C by 2030 (compared with the 1980-1999 average) and up to 4°C by 2070 with ongoing high greenhouse-gas emissions. This will mean fewer cold days and nights, more hot days and nights, fewer winter frosts and more summer heat waves. The number of days above 35°C is expected to increase by about 20 per cent by 2030 and possibly more than double by 2070. Further rainfall decline is expected, particularly in winter, though to what extent is uncertain. More frequent and intense droughts, as well as bush fires, are expected.

Zone 3 & 4

Temperate sub-humid and sub-tropical sub-humid

This region across much of NSW and inland southern Queensland has warm to hot summers and cool to cold winters, with moderate rainfall throughout the year. Rainfall, though, can vary significantly year to year, from droughts to flooding. Temperatures have risen over the past 100 years by about 0.8°C, with most warming since 1950. There has been no clear long-term trend in yearly rainfall, with large decadal variations, but there is a tendency for less rain in the cool season and more in the warm. Continued substantial warming is expected over the rest of this century, from 0.6°C to 1.2°C by 2030 (compared with the 1980-1999 average) and up to 4°C or more by 2070 with ongoing high greenhouse-gas emissions. More hot days and nights, and fewer winter frosts, are expected, with a substantial increase in the number and intensity of heat waves and bush fires. Rainfall will continue to vary greatly from year to year though long-term annual changes are uncertain. Rainfall is expected to continue to decline in the cool season but possibly increase in the warm season. The intensity of heavy rain events is expected to increase, particularly in the warm season.

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Zone 5 & 6

Sub-tropical moist and tropical warm-season moist

The coastal areas of eastern Australia, from north Queensland to the south coast of NSW, experience a warm to hot summer and a somewhat cooler winter, with heavy rainfall in the warm season. To the north, occasional tropical cyclones in the warm season bring extreme rainfall and damaging winds and storm surges. Temperatures have increased significantly over the past 100 years, by about 1°C, but there is no clear long-term trend in rainfall due to large decadal variations. Continued substantial warming is expected over the rest of this century, from 0.6°C to 1.3°C by 2030 (compared with the 1980-1999 average) and up to 4°C by 2070 with ongoing high greenhouse-gas emissions. A substantial increase in the number and intensity of heat waves and hot days and nights is expected. There will continue to be large variations in rainfall from year to year but long-term changes in rainfall are uncertain. However, the intensity of heavy rain events is expected to increase, particularly in the warm season.

Zone 7 & 8

Tropical warm-season wet and tropical wet

The far north of Australia is warm to hot throughout the year, with a pronounced wet season from about November to April. The wet season brings very heavy rainfall and infrequent tropical cyclones with extreme rainfall and damaging winds and storm surges. Temperatures don't vary much from day to day, but are a little lower in the winter dry season. Temperatures have increased over the past 100 years by about 1°C, with greater warming at night. There are large variations of rainfall from year to year, with a small increase since about 1960, particularly in northern Western Australia.

Continued substantial warming is expected over the rest of this century, from 0.5°C to 1.2°C by 2030 (compared with the 1980-1999 average) and up to 4°C by 2070 with ongoing high greenhouse-gas emissions. A substantial increase in the number of heat waves and hot days and nights is expected. There will continue to be large variations in rainfall from year to year but longterm changes are uncertain. The intensity of heavy rain events is expected to increase. Tropical cyclones are expected to decrease in frequency but increase in intensity.

Zone 9 & 10

Cold wet and temperate cool-season wet

This region across much of southern NSW, Victoria and Tasmania experiences a cold winter and warm to hot summer, with rainfall throughout the year but more in the cool seasons. It has pronounced year-to-year variability of rainfall ranging from droughts to very wet years. Temperatures have increased significantly since 1950, by about 1°C. There has been no clear longterm trend in rainfall, with large decadal variations. Continued substantial warming is expected over the rest of this century, from 0.6°C to 1.3°C by 2030 (compared with the 1980-1999 average) and up to 4°C by 2070 with ongoing high greenhouse-gas emissions. A warming climate will be associated with more hot days and nights, including more summer heat waves, and fewer cold days and nights, including fewer winter frosts. The number of days hotter than 35°C is expected to increase by about 20 per cent by 2030 and possibly more than double by 2070. Rainfall is expected to decline in the cool season although the magnitude is uncertain, with no clear change in summer rainfall. The reduced rainfall and higher temperatures are expected to lead to more frequent and intense droughts and bush fires, and greater stress on water resources.

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THE EFFECT OF CLIMATE CHANGE ON AUSTRALIAN PRODUCE

Key Findings

All references for this section can be found in the bibliography at the end of the report.

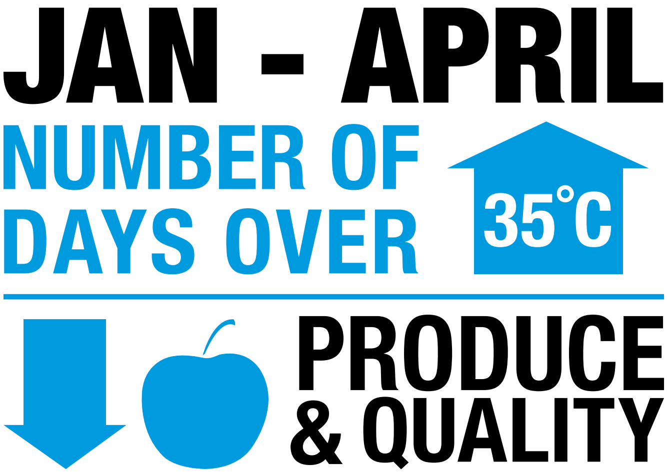
A

ALMONDS

Almonds are a perennial nut crop native to Mediterranean climates characterised by warm, dry summers and mild, wet winters. As a temperate nut, almonds require winter chilling to flower in the spring. Restricted winter chilling due to a warming climate is likely to delay flowering until later in spring, when high temperatures will restrict pollination and fruit set. Almond plants can also lose significant amounts of water at night, which will be exacerbated by higher night-time temperatures, negatively affecting the quality and quantity of production.

APPLES

Apples are sensitive to extreme heat conditions with very hot conditions during the maturation period (January to April) potentially lowering yield and quality. As little as 10 minutes of extreme sunlight is enough to cause penetrative burns through apple skin, so with climate change expected to increase the number of days hotter than 35°C in fruit-growing regions such as the Goulburn Valley, higher rates of sun damage are likely. Adapting farm practices, such as using shade netting will be required but, will also add to production costs.



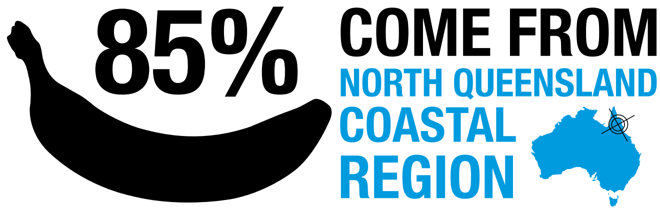
AVOCADOS

Avocados grow on subtropical fruit trees that need a frost-free climate with little wind, as high winds can increase moisture stress, dehydrate the flowers and reduce pollination. Temperature is the main climate factor affecting viable production. Hot weather can cause sunburn damage and yield smaller fruit. Temperatures above 35°C can reduce flowering, because some types of avocado trees only produce flower buds under cool temperatures, and affect fruit development. As the climate warms, daily temperature ranges will narrow in the tropics and sub-tropics, reducing the overlap between the open stages of male and female plant parts and thus pollination chances.

B

BANANAS

Up to 85 per cent of Australia's bananas come from the north Queensland coastal region. This area is exposed to tropical cyclones which can destroy large portions of banana crops, as occurred with Cyclone Yasi in 2011. Future changes to tropical cyclone activity in north--eastern Australia are somewhat uncertain. Studies have projected that climate change may lower the frequency of cyclones, supported by recent historical analysis but increase their intensity, leading to greater crop and infrastructure damage when cyclones do develop.



BAR COD

The bar cod, or banded rock cod, is a deep water fish with a wide distribution, coping with water temperatures from southern NSW to northern Queensland, so should not be much affected by higher temperatures, and may extend further south. But it may be affected by the decreases in oxygen and increased acidity expected due to climate change. We have little information on how severe these effects may be.

BARLEY

Climate change has three key effects on barley. More atmospheric carbon-dioxide increases yields of crops such as barley by about 0.2 per cent a year and may lead to reduced grain protein. Hotter temperatures will lower yields. It is predicted that by mid-century these two factors will largely cancel each other out, followed by net declines in both yield and quality. There remains uncertainty about how global warming will affect rainfall but the risk appears to be for less rain, and hence lower grain yields, across southern Australia's cropping belt, although small increases in some areas are possible.

BARRAMUNDI

Wild Australian barramundi are caught near northern river mouths, and these fish are also farmed in Queensland, NSW and South Australia. Barramundi live in rivers as juveniles then grow into males and migrate to estuaries to mate after rain. As they grow larger they turn into females. This life cycle means they will be affected by expected increased rainstorms, the changed timing of floods and nutrients carried down rivers, and the loss of mangrove areas due to future sea level rise and more frequent storms. Farmed fish should grow faster at warmer temperatures.

BEEF - INTENSIVELY FARMED, SOUTHERN AUSTRALIA

Beef production in southern Australia typically relies on cattle breeds of temperate origin, such as Angus and Hereford, grazing intensively managed pastures. Warmer and drier climates in the future will pose significant challenges to these beef-production systems. Pasture-growing seasons are expected to contract, leading to lower and more variable animal stocking rates and increased reliance on supplementary grain feeding. Reduced rainfall will limit capture of runoff to supply drinking water, an issue highlighted during the Millennium Drought. Increased heat stress may lead to farmers choosing more heat-tolerant cattle breeds possibly of lower meat-eating quality.

BEETROOT

Considered in some quarters to be as iconically Australian as vegemite or lamingtons, beetroot grows best between 18°C and 25°C. Temperatures above 27°C potentially cause bolting (prematurely running to seed) and poor colouring. High temperatures can cause light and dark rings to form in the root (zoning) that is undesirable for processing. High soil temperatures also increase the incidence of root disease, affecting beetroot quality.

BLUEBERRIES

Blueberries are an excellent source of antioxidants and the Australian industry now sells $135 million per year. Most berries are sold fresh, being handpicked and on the shelf within 24 hours. Most blueberries are grown in NSW, Victoria and Tasmania as low temperatures (ideally 10 to 12.8°C) and fairly high humidity causes flowers to stay open for the longest pollination time from dawn until midday, producing greater yields. Hotter temperatures will decrease pollination time, eventually restricting production to the cooler regions of Victoria, southern NSW and Tasmania, and requiring increased cooling during processing and transport.

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C

CABBAGE

Cabbages are easily grown under a wide variety of conditions. Cool, moist weather results in the best quality heads, though some varieties produce acceptable heads during warmer periods of the year. Climate change is likely to shorten the winter growing season of cabbage by up to a month by 2030 unless more adaptable varieties are developed. Higher temperatures will result in a longer period of pest activity, especially if production is extended into traditionally cooler periods.

SHORTEN GROWING SEASON UP TO 1 MONTH

CANOLA

Canola is a bright, yellow flowering plant that in the past 40 years has become one of the most important crops for making vegetable oil. Canola oil is classified as being cardio-protective because of its substantial amounts of essential unsaturated fatty acids but low amounts of saturated fatty acids. Increased carbon-dioxide levels in the atmosphere predicted by mid-century will diminish canola oil's health benefits, reducing the level of healthier unsaturated fatty acids by about 23 per cent while the level of unhealthier saturated fatty acids will remain the same.

CAPSICUM

Capsicums are grown commercially in frost-free, tropical and subtropical areas throughout Australia. Most production occurs in Queensland, South Australia and Victoria. Warm conditions over a five-month growing period are necessary for high yield and quality, with temperatures of 20-25°C being ideal for growth. Temperatures above 27°C during the ripening phase result in the fruit developing a yellowish colour, while temperatures above 30°C can cause flower buds to fall, fruit scorching and reduced pollination, all leading to lower yields. In some regions there may be increased risk of damage from frosts due to reduced cloud cover.

CARROTS
More Australian households – 95% – buy carrots than any other vegetable. They are also the nation's most valuable vegetable export. Carrots can grow in temperatures between 10°C and 25°C but the best conditions are between 15°C and 18°C. Warmer temperatures adversely affect the carrot's flavour, texture and physical structure. Higher temperatures associated with climate change are likely to make carrot production less viable in warmer areas with shifts to cooler regions such as Tasmania.

CAULIFLOWER
As with other brassica crops, cauliflower is a rich source of minerals and compounds beneficial to health and may help prevent cancer. Cauliflowers grow better in cool conditions. Excess heat negatively affects head development and size, while increases in soil temperatures promote a major soilborne disease, known as "clubroot", in brassicas. Rising temperatures may lead to cauliflower production shifting to cooler regions in Australia.

CHICKEN
Chickens are susceptible to heat stress, with the best temperature range for them to thrive being 18°C to 22°C for broilers (birds destined to be eaten), and 19°C to 22°C for laying hens. Heat stress on broiler chickens causes reduced feed intake, poor weight gain and poor meat quality. For laying hens, effects include poor laying rate, reduced egg weight and shell quality, reduced fertility and increased mortality. Intensive poultry industries rely heavily on feed such as wheat and barley, thus any negative impact of climate change on the grain industry will have flow on costs to poultry production.

CHICKPEAS
Chickpeas are grown from northern Western Australia to Mediterranean-climate regions in south-western Australia, sub-tropical southern Queensland and more recently in eastern Australia. Climate changes are expected to bring more drought, heat and cold weather events in different climatic zones. Heat stress (35°C or above) during flowering and pod setting leads to flower drop, reduced pod and seed set, and consequent yield loss, especially in eastern Australia. Frost (below 0°C) and cold (below 10°C) also reduce the yield of winter sown chickpea, due to damage to flowers, reduced early pod formation and seed filling.

CUCUMBERS
Cucumbers have been cultivated for over 3000 years. They grow on a creeping vine and are usually more than 90% water, thus highly dependent on irrigation or reliable rainfall. Higher temperatures will accelerate cucumber emergence, flowering and fruit setting, and promote the plant producing more male flowers, considered less desirable than female ones. Risks to achieving good yields include a shorter fruiting period and deteriorating conditions for pollinating insects, on which the cucumber's separate male and female flowers depend for propagation and fruit set.

D

DAIRY - CHEESE PRODUCTION
Milk volume and quality for cheese production is likely to be affected by warmer temperatures and increased frequency of heatwaves. Heat stress on dairy cows typically reduces milk yield by 10-25%, and by up to 40% in extreme heatwave conditions. Such conditions also reduce the quality of pastures, leading to a decline in the quality of milk for cheese production. Lower quality diets for dairy cows lead to changes in milk protein content and composition that reduce cheese yield and quality, and increase dependence on grain supplements.

E

EGGPLANT
Eggplant, popularly used in cuisines from the Mediterranean to Asia, is known around the world by a variety of more exotic names including aubergine, melongene and brinjal. A species of nightshade, it is related to both the tomato and the potato. As a tropical perennial plant, climate change is likely to enable eggplant to be grown further south in Australia, in areas where frost currently limits production. However, high temperatures will lead to fruit drop, low fruit quality, and malformed fruits.

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H

HONEY

A wide range of plants, including key food and pasture crops, produce commercial quantities of nectar. Apiarists target different flowering plants and seasons to produce honey of varying flavour and quality. Horticulture also depends heavily on insect pollination to maximise yields. While honey bees can withstand high temperatures and closely regulate their hive's temperature to between 34°C and 35°C, in extremely hot weather they gather water rather than nectar to keep the colony cool, reducing the quality of honey generated. Climate change will alter the areas that different honey bees live in and the seasonality of their food plants, altering synergistic and competitive relationships with other species.

K

KALE

Kale, or a plant very similar too it, was one of the most commonly eaten vegetables throughout Medieval Europe until the development of the domesticated cabbage. In recent times this brassica has seen a resurgence in popularity due to its nutritional benefits. It grows best in temperate climates; cooler weather makes maturing leaves sweet whereas heat increases their bitterness. Higher temperatures associated with climate change are therefore likely to reduce the viability of currently suitable growing areas in Australia.

KANGAROO

Kangaroos are highly adapted to Australia's often dry, infertile country and highly variable climate. A female kangaroo is usually permanently pregnant except on the day she gives birth, with the ability to delay an embryo's development until the previous joey can leave the pouch. This strategy, called "diapause", regulates birth and growth rates according to conditions and resources. As a result, the supply of kangaroo as a sustainable food source can be highly variable. Meat quality is also likely to be poorer where climate change increases the incidence and intensity of stressful conditions.

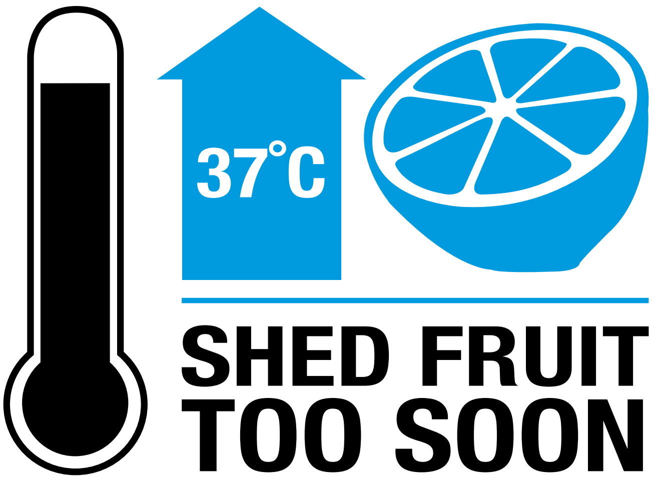
L

LAMB

"Spring lamb" refers to the seasonal peak of lamb produced during spring. This production system relies on sheep grazing on highly nutritious pastures during winter and spring. Climate projections for reduced spring rainfall, and greater variability in rainfall patterns in southern Australia, will challenge this traditional production system. Alternative systems will be needed to adapt. In some regions this could include greater use of drought-tolerant native shrubs such as saltbush, and perhaps also increased feedlot-finishing of lambs to manage the uncertainty of seasons.

LEMONS

Lemons are grown commercially throughout the Australian mainland and are the dominant citrus crop in central NSW and the Northern Territory. Lemon trees flourish in warmer, sunny climates with mild winters so will potentially cope better than other crops with a changing climate, provided they have enough water. Their optimum temperature range is 25-30°C. Temperatures over 37°C can cause trees to shed fruit too soon, reducing yields. In the southern states shifting production further southwards is less of an option, since lemon trees are frost-sensitive, with spring frosts a particular risk if trees have flowered due to warmer winters.



LENTILS

Lentils are the world's oldest known food crop. In Australia they are a high-value annual winter legume mainly grown in Victoria and South Australia. Climate changes have already affected yields throughout lentil-growing areas largely due to drought, frost and diseases. Drought limits lentil seed yield as low soil moisture and high temperatures during reproduction and pod-filling leads to poor seed set and later pod cracking.

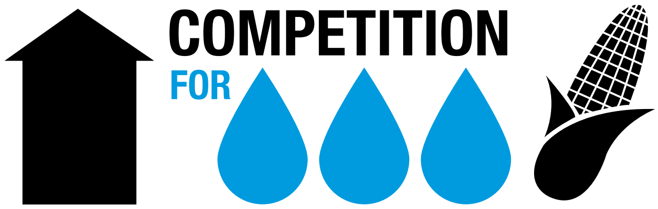
M

MACADAMIA NUTS

Macadamia nuts are the only major food crop native to Australia, having evolved in the rainforests of northern NSW and southern Queensland as a favoured food of Australia's first inhabitants. More than 20,000 hectares of macadamias are now under cultivation. These areas will be adversely affected by hotter, drier conditions on Australia's east coast due to climate change. In this part of Australia there is not enough water for irrigation at critical times for macadamia pollination and fruit maturation. Nut yield and quality may also be affected.

MAIZE/CORN

Maize, better known as corn, is one of the big three global cereal crops along with wheat and rice. Higher temperature may increase maize yields in temperate areas but reduce them in many tropical areas where temperatures exceed 35°C. In Australia more than half of total production comes from rain-fed agriculture, where yields are highly variable and increasingly affected by drought and extreme heat. Likewise, irrigated maize faces increasing competition for water. Further development of varieties and management techniques might help reduce future yield losses but only if they take into account likely future climate conditions.



MANGOES

Mangoes thrive in the heat and are well suited to the tropical and subtropical areas of the Northern Territory, Queensland, NSW and Western Australia. A warming climate could well increase growth rates, pollen viability and fruit set. However, temperatures above 45°C will affect fruit development, particularly induction, size and number of flowers. Unpredictable rains during pre-flowering and flowering periods may cause poor fruit set, while any increase in tropical cyclone intensity will damage crops. Climate change could see mango growing move further south. Conversely, traditional growing areas will experience risks of abnormal flowering and fruit set with reduced quality and yield.

O

OCTOPUS

Four octopus species are commercially fished in southern Australia. Southern and gloomy octopus frequent seagrass beds, pale octopus live on sandy bottoms and maori octopus inhabit reefs and deep water. Females lay one clutch of eggs, care for them until they hatch, then die. All species span a wide temperature range, eat many prey types and are opportunistic, suggesting possible ability to adapt to warming, but computer modelling projections for pale octopus indicate warming could lead to eventual decline. Increased carbon-dioxide may make octopus more vulnerable to predators, and combined climate factors may have complex effects.

OLIVES

Olives are mainly produced in lower rainfall Mediterranean climates, meaning wet winters but hot, dry summers. Climate change could have a positive impact on the olive industry by extending the range in which the trees can viably grow, as they tolerate hot climates and drought conditions. In Australia, bush fires have destroyed large olive plantations, with younger trees more susceptible to death from fire. However, older olive trees can recover from fire with careful pruning.

ONIONS

Onions are Australia's fourth largest vegetable crop, making up about 9% of our total vegetable production, with South Australia and Tasmania being the dominant growing areas. Though a reasonably hardy crop, it grows best with cooler temperatures during early development; higher temperatures cause "bolting", meaning flowering stems begin to grow early, with the result being smaller bulbs and reduced quality. The crop is prone to attack by a number of pests and diseases predicted to increase with climate change. Warmer temperatures will also tend to reduce time to harvest onions.

ORANGES

"Citrus greening disease" poses a significant threat to orange production because it can cause trees to die or render fruit unfit for sale. While Australia is currently free of the insect (the Asian citrus psyllid Diaphorina citri) that carries the bacterium causing the disease, the bug's potential entry into Australia is of great concern. Hotter temperatures will advance the timing but shrink the window of new leaf growth the insect needs to reproduce. As a result, by 2070 southern areas of Australia previously too cold will become suitable habitat, while potential habitat will reduce across northern Australia.

P

PEACHES

Peaches are a perennial crop grown across southern Australia. In winter, peach trees enter a dormant phase, protecting the tree from cold weather damage. Once dormant, enough exposure to winter chill is needed before regrowth starts again. Without enough winter chill by spring, flowering is disrupted, leading to lower yields of fruit. Climate change effects on peach growing will differ greatly among regions. Minimal impacts are anticipated for Tasmania, for example, while the southwest of Western Australia is expected to experience notable declines in cold weather. Hormonal and other treatments can be used to partly compensate.

PLUMS

Plums are a perennial crop and ripen over spring and summer. Historical observations in Tasmania show plums are ripening earlier in the season. This trend is related to both warmer temperatures and drier conditions. If these trends continue, we may see various types of fruits ripen about the same time. This would compress the window of time for harvesting, requiring either more fruit pickers for a shorter period or, since securing such casual labour can be difficult, picking fruit too early or too late, reducing plum quality and value.

PORK

Increased temperatures and more frequent heat waves are likely to increase heat stress for intensively produced livestock. Pigs are particularly sensitive to heat stress since they don't possess sweat glands – the phrase to "sweat like a pig" is a fallacy – so they have to get rid of excess heat through panting or wallowing in water or mud, which is not an option in most modern production systems. Heat stress is particularly serious for the modern lean, healthy pig due to its high metabolic rate, reducing their food intake and production.

POTATOES

Potatoes are susceptible to a disease known as "late blight", which rots the tubers and makes them inedible. Late blight can devastate crops as shown by its major role in the Irish potato famine in the 1840s. High temperature and humidity are its main causes. Climate change predictions show the risk of late blight is likely to rise by 2050 then decrease towards the end of the century in line with earlier planting times. For Australia's potato-growing regions in the southwest and along the eastern seaboard, however, the increase in risk predicted by 2050 is considered modest.

PRAWNS/SHRIMP

Eleven prawn species are fished around Australia. Currents flowing down the east and west coasts are strengthening, producing much warmer temperatures and southerly shifts of many species. Tropical Banana, Tiger and King prawns may move further south, and NSW greasyback and school prawns could become more rare. Freshwater from severe storms will benefit some species but harm others. Warming may make prawns grow faster in farms, but diseases are likely to become more severe, and storms may destroy farm ponds. It is not yet clear how prawns will be affected by warmer, more acidic seawater with lower oxygen content.

R

RASPBERRIES

Raspberries are a deciduous temperate fruit crop that requires substantial winter chilling, relatively cool summer temperatures (below 30°C) and a rainfree harvest period. Root temperatures should also not exceed 24°C. Winter chilling of more than 800 hours between 0°C and about 9°C is required to give uniform bud break and flowering in spring. Climate change could lead to insufficient chilling in many regions, resulting in uneven bud break and erratic flowering. This would make crops more susceptible to damage from extreme temperatures in summer, when it is ripening, reducing berry production and quality.

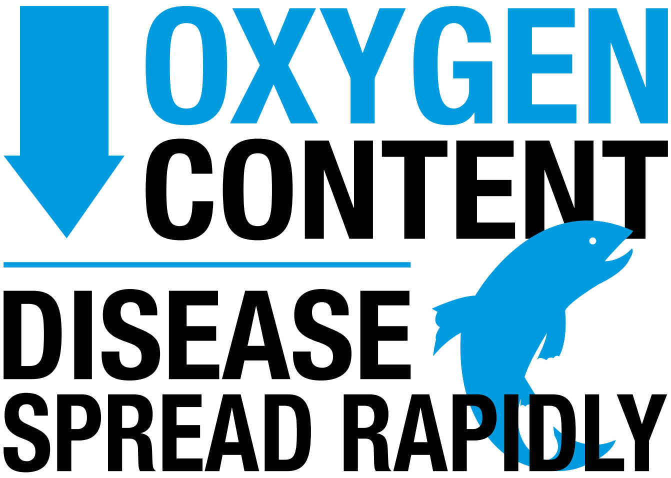
RICE

Irrigated paddy rice depends on ample water to grow. Climate change is likely to reduce reliable rainfall and pressure on water availability in Australia's current major rice-growing regions. Higher carbon-dioxide levels typically increase biomass production but not necessarily yield in rice. Higher temperatures can decrease yield by causing rice flowers to become sterile, meaning no grain is produced. Research indicates a 1ºC rise in nighttime temperature may reduce rice yields by about 10 per cent. Possible adaptations include growing in more northerly regions, irrigating more efficiently and using dryland varieties, but these will have substantially different culinary characteristics.

S

SALMON

Atlantic salmon are farmed in pens in the cold waters around Tasmania. Growth is optimal between 7°C and 17°C, but the Tasman sea is experiencing the greatest rate of warming in the southern hemisphere, with farms are already near the upper limit in summer. Salmon deaths are often associated with amoebic gill disease, which can spread rapidly in pens as waters warm. Selective breeding may improve resistance, and seasonal forecasting of water temperatures reduce risks. However, the combined effects of warmer water, lower oxygen content and ocean acidification are likely to make salmon farming more difficult.



SOYBEANS

Soybeans are an annual summer legume grown in irrigated or heavy-rainfall areas of southern Australia. Climate change is likely to lead to unpredictable rainfall and a lack of water at times, which will affect soybean production. An extra one-degree increase in summer temperatures could decrease yields by 16%, but this could be partly offset by available water resources. However, the area used for soybean cropping in south-west NSW has recently shrunk due to the high cost of water. Drought-tolerant varieties will help sustain production to meet domestic demand and tap the non-genetically-modified international market.

SCALLOPS

Saucer scallops are fished (and farmed using sea-ranching) across northern Australia, while Southern scallops are fished in Victoria and Tasmania. Seas off southeast Australia are warming faster than anywhere else in the southern hemisphere. Together with associated changes in oxygen and food, this may mean Southern scallops could effectively disappear from our plates. Both Northern and Southern scallops will have to cope with more acid seawater, which is likely to thin their shells, reduce their growth, survival and reproductive success, and make them less able to elude predators. We do not know how much scallops can adapt to future conditions.

SUGAR CANE

Sugar cane is grown In Australia from northern NSW through to far north Queensland. As a tropical plant, with optimum growth between 32°C and 38°C, rising temperatures associated with climate change are unlikely to reduce yields dramatically. The heat may even favour southern regions. However, temperatures above 38°C reduce the rate of photosynthesis and increase respiration, leading to less accumulation of sugars. In addition, as most of Australia's sugar cane is grown on coastal flats, sea-level rise and saltwater flooding through cyclone-induced storm surges will pose a major risk to production by 2050.

SWEET POTATO

The vitamin-rich sweet potato – which despite its name is only distantly related to the potato – is a significant food crop in the developing world, and may become even more important to global diets as the world warms. It can be grown in hot conditions, is relatively drought-tolerant, prospers from higher levels of atmospheric carbon-dioxide and has many varieties with adaptive potential. There may, however, be some risk to current areas of commercial cultivation in Australia, predominantly in Queensland, from higher rainfall events, since water-logging can cause tubers to rot.

SYDNEY ROCK OYSTERS

Higher temperatures, more rainstorms and more acidic seawater are predicted in estuaries, where oysters are farmed. Oyster larvae grow more slowly and die faster under these conditions but recent work suggests they may be able to adapt as climate change intensifies, as oyster parents exposed to more acid water produced larger, faster growing larvae, and selective breeding of oysters has resulted in larvae that survive better. However, other work shows that even with a chance to adapt over time, oyster shells are likely to be thinner and thus weaker, and that future conditions may reduce oysters' resistance to diseases.

T

TOMATOES

Tomatoes are an annual irrigated crop grown across Australia, with Queensland and Victoria the largest producers. In some regions, hotter temperatures may allow for a greater number of cropping cycles per year, increasing production. However, fruit set may be reduced when temperatures are moderately above ideal levels, partly due to a reduction of pollen viability. Reliable water supplies will be increasingly important but more difficult to guarantee.

DIFFICULT TO GUARANTEE WATER SUPPLIES

W

WALNUTS

Walnuts are a perennial nut crop native to Mediterranean climates with warm, dry summers and mild, wet winters. They are grown commercially in Tasmania, Victoria and NSW, with smaller orchards located in South Australia and south-west Western Australia. As with other temperate nut crops, walnuts require winter chilling to flower in late spring. Global warming will affect winter chilling, resulting in late and erratic flowering. High temperatures at flowering and fruit set, together with potentially restricted supplies of irrigation water, make walnuts are particularly vulnerable to future conditions.

WHEAT

Wheat growing is strongly affected by rainfall and temperature. Future projections indicate lower and more variable production and increasing proportions of grain of low dietary value. While higher levels of carbon-dioxide in the atmosphere will increase plant growth, termed the “fertilisation effect”, this extra growth requires more nitrogen and can reduce baking quality with lower grain levels of protein and important micronutrients. Zinc and iron concentrations, for example, are projected to be 5-10% lower mid-century, adding to the already significant pressure of disease associated with malnutrition. Increased heat stress will also reduce wheat’s dough-making characteristics.

WINE GRAPES

Wine grape growing is Australia’s largest fruit industry. Most production comes from areas with a favourable temperate or Mediterranean climate. Iconic grape-growing regions such as Margaret River in Western Australia, the Barossa and Riverland in South Australia, Sunraysia in Victoria and the Riverina in NSW will be the most affected by higher temperatures and lower rainfall, especially for red varieties such as Shiraz, Cabernet Sauvignon and Merlot. While conditions for wine-growing will improve in places like Tasmania, up to 70% of Australia’s winegrowing regions with a Mediterranean climate will be less suitable for grape growing by 2050.

70% WINEGROWING REGIONS LESS SUITABLE GRAPE GROWING BY 2050

Y

YELLOWEYE MULLET

Yelloweye mullet live along the temperate and cold-water coasts of Australia and New Zealand. They are omnivorous and can cope with large differences in sea temperature. They grow faster in warmer waters and have a wide tolerance for salinity, so may be relatively resistant to climate change. But the bays and inlet habitats where juveniles live could be affected by more severe floods and droughts. Projections of lower oxygen content in water and increases in water acidity and temperature will negatively affect them. More acidic water conditions may, for instance, make mullet less able to smell predators.

Z

ZUCCHINI

Zucchini is a member of the gourd family, which includes pumpkins, cucumbers, squash and melons. It is considered to be one of the easiest vegetables to grow in temperate climates, so long as it gets sufficient moisture (being 96% water). Rapid germination and vigorous growth occur at soil temperatures between 18°C and 32°C. Zucchini responds very well to elevated levels of carbon-dioxide but is susceptible to extreme temperature events and has little drought tolerance. Higher temperatures and higher atmospheric carbon-dioxide levels may also increase the risk of diseases like powdery mildew.

What farmers are saying


© Lisa Saad / WWF-Aus

John Said
Leafy Greens farmer
Werribee VIC, Gatton QLD, Adelaide SA

“There’s no doubt climate change is a reality now. We’re seeing abnormal temperatures. We’re seeing abnormal fluctuations in weather patterns… Climate change will certainly disrupt food security, there’s no doubt about that.”


© Jim Filmer / WWF-Aus

David Bruer
Winemaker
Langhorne Creek, SA

“Should we address global warming? We have no bloody future if we don’t. I worry very much about my children. I just wonder what their future is.”


© Lynda Faiers Photography / WWF-Aus

Lynne Strong
Dairy farmer
Jamberoo, NSW

“Climate change is one of the top pressures facing farmers. If we as a community do not slow down climate change our access to a variety of nutritious, affordable foods will disappear. This is the reality.”


© Rosey Boehm / WWF-Aus

Graham & Annemarie Brookman
Pistachios famers
Gawler, SA

“The most spectacular effect of climate change on us is the impending demise of our main crop.”


© Photo courtesy of Rob McCreath

Rob McCreath
Crop farmer
Felton, QLD

“Farmers are at the pointy end of climate change. Last year was our hottest on record, this one’s shaping up to be even worse, and we’ve got a raging drought over a vast area. In spite of the overwhelming scientific evidence, our idiotic politicians are hooked on coal and gas, which is the cause of the problem.”

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