National Rural Health Alliance

Position paper: Rural health policy in a changing climate – three key issues

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… healthy and
sustainable rural,
regional and remote
communities

National
Rural Health
Alliance

Postal Address: PO Box 280 Deakin West ACT 2600
Address: 10 Campion St Deakin ACT 2600
Phone: 02 6285 4660
Fax: 02 6285 4670
Email: nrha@ruralhealth.org.au

Contents

Introduction

Globally and nationally, there is growing recognition of the critical need for action on climate change. From international organisations such as the United Nations and Australian research bodies such as the CSIRO, the evidence is clear on the science of climate change and there are calls for that evidence to inform government action. It is also clear from the science that the need for action is becoming more urgent.

The National Rural Health Alliance (the Alliance) views climate change as a significant and enduring threat to health, and considers that the adverse health risks are greater in rural and remote communities.[1] In its *Position Statement: Climate change and rural health*, released in 2019, the Alliance called on Australian governments to urgently escalate the adoption of adaptation and mitigation strategies for climate change driven by human activity.[1] The Alliance has also urged the need for consideration of the health impacts of climate change in the development of a National Preventive Health Strategy.[2] This paper considers some of the specific threats to health posed by climate change, and possible health and policy measures for rural and remote areas in light of these risks. The paper focuses on three areas of particular relevance for rural and remote Australia:

- extreme weather events
- food security
- vector-borne disease.

Climate change

The Intergovernmental Panel on Climate Change (IPCC) explains climate change as:

> … a change in the state of the climate that can be identified (eg by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.[3]

That is, climate change is a sustained change in weather patterns which may be due to natural causes or driven by human activities (anthropogenic contributions). Anthropogenic contributions to climate change include activities such as the burning of fossil fuels for energy, land clearing and deforestation, and industrial manufacture. The effect of these activities centres on their capacity to increase greenhouse gas emissions, leading to an effect that traps heat in the lower atmosphere. This atmospheric warming, in turn, has consequences for air and sea surface temperatures, patterns of rainfall, sea levels, glacial loss and ocean acidification, and also increases the likelihood of extreme weather events.

The IPCC has estimated that, since 1880, the global average increase in land and ocean surface temperature is around 0.85°C, with 90 per cent of the accumulated temperature increase accounted for by ocean warming.[3] The IPCC considers that the changing climate is linked to increasing extreme weather events globally, including decreased minimum temperature extremes, increased maximum temperature extremes, sea level rises and high rainfall events. The IPCC notes that, in Australia, heatwave frequency is likely to have increased in the past 70 years.[3]

Closer to home, the Bureau of Meteorology and CSIRO, in their *State of the Climate 2020*, report that Australia has warmed by 1.44°C since 1910, with much of that rise occurring since 1950. In fact, Australia's climate has warmed by over 1°C since 1960.[4] Most of this warming has been absorbed by southern oceans, and the seas surrounding Australia are both rising and acidifying.[4] Furthermore, there is evidence of increases in extreme weather events (including heatwaves and extreme fire weather) and the length of the fire season, as well as declines in winter rainfalls in southern Australia and higher rainfall in the north – all of which are predicted to continue (indeed, worsen) into the future.[4] Each of these conditions brings particular risks to the health of all Australians. The *State of the Climate 2020* highlights that 'This shift in extremes has many impacts on human health, ecosystems and infrastructure and informs climate impact and risk assessments.'[4] The health-related impacts of climate change can be through either direct or indirect effects and may have physical or mental wellbeing and social dynamic components. Direct effects include storms, drought, flood, fire or heatwave events; indirect effects include the influence of climate change on water and air quality, as well as land use and agriculture. Additionally, climate change may lead to disruption due to social unrest, conflict or forced displacement due to environmental changes.[5] The resulting range of health impacts include death and injury, respiratory and cardiovascular diseases, heat-related illness, infectious disease outbreaks, undernutrition, and detrimental effects on mental health and wellbeing.[6]

Deloitte Access Economics[7] have considered the effects of health damage from climate change on labour productivity. Their analysis models an increased incidence of mortality and morbidity in the working population, and the associated reduction in number of hours worked, resulting in lower levels of labour productivity.

Rural and remote Australian communities are, for numerous reasons, particularly prone to the health-related impact of climate change. The geographic location of rural and remote communities renders them at risk of extreme weather events such as heatwaves, extended periods of low rainfall or drought, or high rainfall. Rural community demographics such as higher proportions of older Australians and Aboriginal and Torres Strait Islander peoples, greater incidence of chronic disease, comorbidities and poor mental health[8] mean that already susceptible groups experience greater health challenges. Furthermore, rural and remote communities face existing socioeconomic disadvantage including higher rates of unemployment, poverty, welfare dependency, digital exclusion, lower rates of educational attainment and reduced access to appropriate health services. In some communities, infrastructure such as housing, telecommunications, transport, and sanitation is also lacking. Lastly, climate change has been described as a risk multiplier, exacerbating existing health challenges and other disadvantage.[9] This accumulation of social, economic and environmental burden leaves many communities in rural and remote Australia highly vulnerable to the health risks associated with climate change.

This is highlighted by Deloitte Access Economics[7] who note that 23 per cent of the Australian workforce is employed in emission-intensive industries that are directly exposed to disruption if Australia does not plan for a global transition. They note that this will hit Australia's regional areas the hardest. For Australia, the short-term costs of disruption and unplanned economic change tend to be local – and a failure to address them in a timely way can put future benefits out of reach for regional economies. Australian regional areas are more exposed in this regard – over half have emission-intensive employment that makes up 20 to 60 per cent of total employment. Therefore, the economic, social and consequential health impacts of not implementing a planned transition from these industries will be significant, particularly for the most affected regions.

In terms of emission-intensive industries, a 2017 study[10] found the carbon footprint attributed to health care was 7 per cent of Australia's total, with hospitals and pharmaceuticals being the major contributors. The study suggests the need for carbon-efficient procedures, including greater public health measures, to lower the impact of health care services on the environment – and there is international leadership underway to address this issue.[11]

The Climate and Health Alliance (CAHA) has launched a *Framework for a National Strategy on Climate, Health and Well-being for Australia*[12] (the CAHA Framework). The CAHA Framework identifies seven areas of policy action which must be taken at the federal, state or territory, and local level to achieve the vision of 'a fair and environmentally sustainable national policy framework that recognises, manages and addresses the health risks of climate change and promotes health through climate change action'. The National Rural Health Alliance is a supporter of the CAHA Framework and the comprehensive areas of policy action it outlines.

Recommendations

As highlighted in the CAHA Framework, there is broad scope for policy action to address the health implications of climate change. After consideration of the three areas of particular relevance for rural and remote Australia – extreme weather events, food security and vector-borne disease – the Alliance makes the following recommendations.

1. As it is clear that the cost of inaction on climate change will be much higher than the cost of action, governments in Australia should act immediately to introduce policies and incentives to reduce the nation's greenhouse gas emissions and mitigate climate change impact.
2. Governments should ensure the transition to a sustainable economy is managed and planned to support those regions and sectors of the economy most affected by climate change, through the development of regionally specific transition plans that support the viability and sustainability of communities and businesses.
3. Governments must prioritise and support research to assist rural, regional and remote communities to better adapt to and mitigate the direct and indirect effects of climate change on health, including the impact of extreme weather events, risks to agriculture and food security, and the potential threat of vector-borne diseases.
4. Governments will need to address the implications of climate change in their health care planning in terms of prevention, early intervention, primary care, secondary care, tertiary care, crisis and trauma management, mental health service provision, and health care workforce education and training. This planning will also need to incorporate the additional costs to health care from both direct and indirect effects of climate change.
5. Governments and other support agencies should determine how best to ensure those members of society already disadvantaged by inequitable access to health care – including those Australians living in rural and remote areas – are not further disadvantaged by the impact of climate change on health.

The three key issues

Extreme weather events

Australian climate observations

Temperature

Observation of surface air temperature provides evidence that the Australian climate has warmed by 1.44 °C since records began in 1910, with temperature increases observed in all seasons and for both day and night.[4] Although the Bureau of Meteorology and CSIRO, in their *State of the Climate 2018*, report that the Australian climate is subject to considerable year-to-year variability, this is now occurring on top of a warming trend.[13] Most warming has occurred since 1950, with eight of the ten warmest years taking place since 2005. Very high monthly maximum and very warm monthly minimum temperatures are both now happening 12 per cent of the time (2003–17), compared with 2 per cent between 1951 and 1980. The number of days each year where the Australian area-averaged daily mean temperature is extreme (above the 99th percentile of each month) is increasing. These extreme heat events commonly occur over more than 40 per cent of the country.

Rainfall

Although Australian rainfall is highly influenced by meteorological phenomena and therefore displays considerable variability, an underlying long-term trend is evident of reduced rainfall between April and October in south-western and south-eastern Australia.[13] In these regions, 17 out of 20 of the April to October periods since 1999 have had below-average rainfall. Since 1970, south-west Western Australia has seen a 20 per cent reduction in rainfall between May and July compared with the 1900 to 1969 average. A 26 per cent reduction has been observed since 1999. Conversely, northern Australia has experienced an increase in rainfall in all seasons since 1970. There is evidence that a higher proportion of total rainfall has occurred on heavy rain days in recent decades (although natural variability is large).

Cyclones

There has been a decrease in the number of tropical cyclones observed since 1982. However, natural meteorological variability makes it difficult to quantify trends in cyclone intensity.

Fire weather

Fire weather, measured using the Forest Fire Danger Index (FFDI), estimates fire danger taking temperature, rainfall, humidity and wind speed into account.[13] The most extreme 10 per cent of fire weather days (using FFDI measures) have increased in recent decades in many areas of Australia, especially in the south-east. This has been associated with an increase in the length of the fire season.

Australian climate predictions

The Bureau of Meteorology and CSIRO predict that there will be ongoing increases in temperature and reductions in southern rainfall – resulting in more frequent extreme heat events, more time spent in drought and an increase in intense heavy rainfall which can be associated with flash flooding.[13] This is coupled with the observed trend of an increased length and intensity of the fire season in south-eastern Australia.

Direct and indirect effects of extreme heat events

The direct effects of heat on human health range from minor to more severe heat-specific illnesses (rashes, cramps and heatstroke) and the exacerbation of pre-existing conditions.[14] It is both the maximum temperatures and the number of days such temperatures persist, as well as the opportunity for temperatures to reduce overnight, that help to determine human resilience to heat.[15] Those who are older, have chronic health conditions, undertake physical work outdoors, or have poor temperature control in their indoor environment are more vulnerable.[15]

Controlling the temperature of the living environment, whether by passive design or active means, has been proposed as an essential component of healthy housing.[16] There are concerns that internal temperature control is not adequately addressed by housing in some Australian Indigenous communities.[17] Rising air temperatures, poor-quality housing and energy poverty interact to multiply the impact of extreme heat on our most vulnerable communities.

Data from South Australia and Victoria suggest that hospital admissions and deaths increase during heatwaves[14], although regional differences in this relationship indicate a degree of heat adaptation at the population level that means some areas are more vulnerable than others.[18] Hospital admissions have been found to increase for adults with various groups of pre-existing conditions including cardiovascular disease (CVD), respiratory disease, mental disease, diabetes, dehydration, and 'effects of heat and light'.[19] When breaking these disease categories down further, 'other diseases of the respiratory system' – many related to infection – were found to increase significantly, while asthma admissions reduced.[19] There was no difference between subcategories of CVD. Psychoses were the only category of mental disease for which admissions increased. Unlike adults, hot temperatures and heatwaves have been found to increase childhood emergency department admissions for asthma, with those aged 0–4 years at highest risk.[20] The specificity of these breakdowns has implications for prevention and adaptation strategies.

Damage to services and infrastructure because of extreme heat – for example, power outages due to system overload, impacts on mobile phone networks and increased strain on health services – can affect health outcomes indirectly.[15]

Acute and long-term impact of bushfires, flooding and storms

The primary health impact of bushfire is injury and loss of life associated with the event. Heavy rainfall due to storms can lead to flooding, rise to levels and increased flow in rivers and storm water, and overflow of dams; there can also be associated coastal storm surges.[15] People can drown or be injured by debris from damaged infrastructure and the environment.[15]

Bushfires, floods and storms can all result in psychological trauma, defined as 'any event that involves exposure to actual or threatened death, serious injury, or sexual violence'.[21] The experience of trauma can contribute to the development of mental illness.[21]

This was quantified in a cross-sectional survey, conducted after the 2010–11 Queensland floods, that looked at the prevalence of disaster-related trauma and emotional impacts in a population-representative sample.[22] The authors found that 62 per cent of respondents reported being 'affected in any way', with a higher percentage (around 90 per cent) of residents of outer regional and remote areas affected than in major cities. The prevalence was also higher for those experiencing the most social disadvantage (70 per cent). While 3.9 per cent of respondents thought they might be 'badly injured or die', this increased to 7.5 per cent in remote areas and 11.5 per cent in outer regional areas – four and six times, respectively, more than for those in major cities. In response to their experience, 14.3 per cent of respondents felt 'terrified, helpless or hopeless', peaking at 24.7 per cent in remote areas; all regional and remote areas experienced a higher prevalence than major

cities, along with those at the highest levels of socioeconomic disadvantage. At two to five months post-disaster, 7.1 per cent of respondents were 'still currently distressed', one in six of whom were distressed 'all or most of the time'. This increased to 12.9 per cent of people in remote areas. Of all those 'still currently distressed', 8.6 per cent were 'worried about how they would manage' and, of these, over a third were worried 'all or most of the time'. The prevalence of this state increased with remoteness. The authors reported the results of their research to be consistent with other studies utilising diagnostic instruments, lending weight to their assertion that extreme weather events have a significant impact on mental health and wellbeing in the short and medium term, and this relationship increases with remoteness.

In a longitudinal study of the psychological impact of the 2009 Black Saturday Victorian bushfires on communities differentially affected by the fires, it was determined that the majority of people are resilient to trauma and recover with time (as indicated by reducing prevalence of adverse psychological outcomes). However, many remain symptomatic or are newly symptomatic at around five years post-disaster, with rates of mental health problems remaining higher than national levels.[23] The most highly affected communities continued to have a higher prevalence of psychological conditions and there was a relationship between the conditions studied. The prevalence of probable post-traumatic stress disorder and major depression in highly affected communities was 10.9 per cent, with 6.2 per cent of respondents experiencing severe psychological distress. The extent of ongoing life stress was a predictor for delayed development of fire-related probable post-traumatic stress disorder. Problem alcohol use was found to be high in all communities and remained high over time. This research illustrates the persistent nature of the mental health and wellbeing implications of extreme weather events, and the need to account for this when generating policy.

Smoke generated by bushfires can affect respiratory health through its impact on air quality. At its worst, 19 weeks of continuous fire activity in eastern Australia in 2019–20 resulted in a population-weighted $PM_{2.5}$ (small particulate matter) exposure level more than 14 times the historical mean.[24] Modelling based on air quality monitoring data, baseline incidence rates and exposure–response risk coefficients proposed that bushfire smoke was responsible for 417 excess deaths, 1124 hospitalisations for cardiovascular problems and 2027 for respiratory problems, along with 1305 asthma presentations to emergency departments. The costs of smoke-related physical health impact from the 2019–20 bushfires alone are estimated to be in the order of $2 billion to date – a fourfold increase on the next highest season (2002–03) and almost ten times higher than the median since 2000.[25]

Heavy rainfall can damage services and infrastructure in a similar manner to extreme heat events – by impacting power supply and transport infrastructure – with an additional effect on water supply, sewerage treatment and public buildings.[15] Flooding can increase the risk of infections by food-, water- and vector-borne disease.[15] Bushfires can also cause considerable damage to services and infrastructure with resultant impacts on health.

There is a relationship between remoteness and loss of income due to flood, with residents of regional and remote areas more likely to have reported damage to income-producing property and a disaster-related loss of income after the 2010–11 Queensland floods.[22] Residents of remote areas were 6.8 times more likely, and those in outer regional areas were 3.6 times more likely, to be displaced from their homes than those in major cities. Disruption to income-generating capacity and the social upheaval of being displaced is likely to have subsequent health consequences.

Long term impact of drought on mental health and wellbeing

Drought has an impact on people who work on the land or are involved in associated industries, along with their communities. It has been associated with accumulated mental health exposure for people living in rural areas.[26] Drought can cause stress, and this is more likely in farmers who are younger, both live and work on a farm, experience financial hardship or are isolated geographically.[27] Prolonged stress can result in psychological distress and can cause or influence mental health disorders.[21]

The impact of drought on mental health is thought to be modulated by the characteristics of the drought and the remoteness of the resident. People living in areas with a population of fewer than 1000 who experience a cumulative long period of drought, coupled with a recent prolonged unbroken dry period (long and constant), reported higher levels of psychological distress on a Kessler-10 (K10) scale.[26] Their levels of distress are in the sub-clinical range of moderate distress, putting them at increased risk of developing a mental health disorder.

An association has also been found between drought severity and suicide in rural males aged 30 to 49 years. In a retrospective study, there was a 15 per cent increase in the relative risk of suicide in this demographic group when the drought index rose.[28] A link has been proposed between background levels of psychological distress (to which drought contributes) and suicide.[29] The burden of disease attributable to suicide and self-inflicted injuries increases with remoteness and is one of the five most burdensome disease or illness states in outer regional or remote and very remote areas in Australia.[30]

This population group already faces barriers to help-seeking and accessing care due to sociocultural factors, availability of health services, and structural barriers such as travel and cost.[29,31] These drivers of inequity must be addressed in responses to health outcomes and climate change.

Climate change and the health burden of extreme weather

The observed changes to the Australian climate, including increasing temperatures and alteration to rainfall patterns, are having a measurable effect on the health and wellbeing of Australians – particularly those living in rural, regional and remote areas. Changes in climate patterns are leading to more frequent extreme heat events, longer and more intense bushfire seasons, more time spent in drought, and more frequent heavy rainfall events resulting in flooding.

Health consequences of extreme weather include increased hospital admissions and deaths during heatwaves, particularly for those with pre-existing health conditions; death, injury, psychological trauma and mental illness due to bushfires and floods; smoke-related illness associated with bushfires; and long-term mental health impacts of drought. Indirect effects on infrastructure, health systems and individual income-generating capacity amplify these problems, particularly in regional, rural and remote communities where there are elevated levels of disadvantage across multiple domains.

Without action, these changes to climate are predicted to continue to increase in the future, along with the associated health burden and economic cost. Future policies must recognise the health impact of climate change – including its influence on extreme weather events – and act to safeguard against this. The recently released *Royal Commission into National Natural Disaster Arrangements Report* reinforces this position.[32]

Food security

Food security exists where 'all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'.[33] Conversely, the World Health Organization states that 'Food insecurity exists when people do not have adequate physical, social or economic access to food.'

The *Foodbank Hunger Report 2019* found that, in the previous year, more than one in five Australians (21 per cent) or about five million people, have been in a situation where they have run out of food and have been unable to buy more. Children represent 22 per cent of food-insecure Australians. Food insecurity is higher among some groups, affecting around 22 per cent of Aboriginal and Torres Strait Islander peoples, around 11 per cent of those unemployed and 16 per cent of rental households.[34]

There are many groups in rural and remote Australia that are vulnerable to the effects of food insecurity. Community demographics such as higher proportions of older Australians and Aboriginal and Torres Strait Islander peoples, or greater incidence of chronic disease, comorbidities and poor mental health, mean that already susceptible groups experience greater health challenges. Furthermore, rural and remote communities face existing socioeconomic disadvantage including higher rates of unemployment, poverty, welfare dependency or digital exclusion; lower rates of educational attainment; and reduced access to appropriate health services.

Food insecurity is generally associated with low-income households, but can also be due to high food costs, poor nutrition literacy, difficulty in accessing fresh and nutritious food, difficulty in accessing food preparation and storage infrastructure, or poor or insecure transport links.

Food insecurity has a significant effect on both physical and mental health and wellbeing. It is widely acknowledged that food insecurity has adverse health and social effects across the whole of life – from infancy through to old age. The human health impact includes higher rates of chronic disease and this is felt most significantly in rural and remote communities.

There is growing evidence that climate change is a significant threat to health, including through its effects on food security. Climate change is affecting agriculture and food prices, and it is likely that the situation of those populations currently facing food insecurity will become more precarious, and the number of people subjected to food insecurity and the consequential health impact will increase.

The Intergovernmental Panel on Climate Change's (IPCC) special report *Climate Change and Land*[35] notes that the food system is under pressure from non-climate stressors (population and income growth, and demand for animal-sourced products) and from climate change. These climate and non-climate stressors affect the four pillars of food security – availability, access, utilisation and stability.

The IPCC's report makes a number of observations regarding food security and climate change, with a high level of confidence, including:

- observed climate change is already affecting food security through increasing temperatures, changing precipitation patterns, and greater frequency of some extreme events
- food security will be increasingly affected by projected future climate change
- vulnerability of pastoral systems to climate change is very high
- food security and climate change have strong gender and equity dimensions.

Michael et al[36] note that, with respect to food security in Australia, we have enjoyed an unprecedented level of food security for more than half a century. However, there are new uncertainties emerging and it would be unrealistic – if not complacent – to assume the same level of food security will persist simply because of recent history.

Australia produces close to 93 per cent of its own food. In the 2018 overall global food security index (GFSI) ranking compiled by the Economist Intelligence Unit, Australia ranked sixth of the 113 economies sampled. However, this ranking dropped to thirteenth after the addition of a weighting for 'susceptibility to natural disaster and impact of weather events'.[37]

On the global stage, Australia is a significant food producer. As well as producing the majority of its domestic food requirements as noted above, Australia exports 76 per cent of its agricultural products, accounting for over 10 per cent of the global dairy export market and representing the third-largest beef exporter, behind India and Brazil.[38]

Significantly, Australia has 0.3 per cent of the world's population and 3.4 per cent of the world's arable land. Therefore, Australia has an important and growing responsibility for supporting food security in other countries. For example, China has 22 per cent of the world's population and 7 per cent of its arable land. Michael et al[36] estimate that, by 2050, domestic demand for food is likely to be almost 90 per cent above demand in 2000, accompanied by a similar rise in demand for exports.

The vulnerability of Australian agricultural output to the effects of climate change will, therefore, have domestic and global food security implications.

Climate change will affect food security in the following ways:

- adverse effect on agricultural output
- disruption to supply chains
- negative effect on Australia's agricultural competitiveness
- increased threat from pests and diseases
- threatened food security due to disruptions to global security.

Adverse effect on agricultural output

There is firm evidence that the changing climate will have a significant effect on agricultural output across the world, and that Australian agriculture is particularly susceptible to the impact of climate change.

A key finding of the Climate Council[39] is that climate change is making weather patterns more extreme and unpredictable, with serious consequences for Australia's agricultural production. Water scarcity, heat stress and increased climatic variability in our most productive agricultural regions, such as the Murray–Darling Basin, are key risks for our food security, economy, and dependent industries and communities.

Climate change is also affecting the quality and seasonal availability of many foods in Australia. For example, many foods produced by plants growing at elevated levels of carbon dioxide have reduced protein and mineral concentrations, thus reducing their nutritional value. Heat stress reduces milk yield by 10 to 25 per cent and up to 40 per cent in extreme heatwave conditions.[39]

The National Climate Change Adaptation Research Facility (NCCARF)[40] has highlighted that, without adaptation, the grazing industry is likely to experience declining pasture productivity and quality; livestock heat stress; changes to pests, weeds and diseases; and increased soil erosion due to more frequent droughts and intense storms.

The Food and Agriculture Organization of the United Nations[41] has identified that agriculture absorbs 26 per cent of the economic impact of climate disasters, rising to 83 per cent for drought in developing countries. There are, therefore, clear links between climate change, agricultural output and food security.

Disruption to supply chains

Australia is extremely vulnerable to disruptions in food supply through extreme weather events. This is likely to affect rural and remote communities disproportionately. The movement over time to streamline supply chains, to adopt a 'just in time' approach, has resulted in little additional capacity or flexibility in supply chains. The Climate Council[39] has noted that, in Australia, there is typically less than 30 days' supply of non-perishable food and less than five days' supply of perishable food in the supply chain at any one time.

Therefore, any disruption to supply chains due to extreme weather events will quickly affect food security for all Australians, but particularly those in rural and remote Australia. The increased incidence of extreme weather events associated with climate change will therefore increase the risk of food insecurity for many Australians.

Negative effect on Australia's agricultural competitiveness

Australia's international competitiveness in many agricultural markets will be challenged by the warming climate and changing weather patterns. Australia is projected to be one of the regions most adversely affected by future changes in climate, in terms of reductions in agricultural production and exports.[39]

Australia's agricultural competitiveness will be adversely affected by any increase in production costs, any interruptions to production capacity or any reductions in the productivity of agricultural resources. All of these competitive influences will be negatively affected by climate change.

The NCCARF finds that weather events, particularly extremes, are critical drivers of agricultural profitability. The most pervasive impact is drought, which disrupts cropping programs, reduces stock numbers, and erodes the productivity and resource base of farms – threatening long-term sustainability. Many of Australia's soils are ancient, weathered and infertile. Poor soils, together with a highly variable climate, create challenges to developing sustainable agricultural systems. Outbreaks of pests, weeds and disease can occur in climatically 'good years', pushing farmers beyond their financial capacity.

The Climate Council[39] have highlighted that more frequent and intense heatwaves and extreme weather events are already affecting food prices in Australia. Climate change is also increasing the variability of crop yields. Food prices during the 2005–07 drought increased at twice the rate of CPI, with fresh fruit and vegetables the worst hit, increasing 43 per cent and 33 percent respectively. Reductions in livestock numbers during droughts can directly affect meat prices for many years.

Cyclone Larry destroyed 90 per cent of the North Queensland banana crop in 2006, affecting supply for nine months and increasing prices by 500 per cent. The 2009 heatwave in Victoria decimated fruit crops, with significant production losses of berry and other fruit crops. In fact, the Australian Centre for International Agricultural Research (ACIAR)[42] estimate that 26 per cent of all climate-related disaster damage and loss is absorbed by the agricultural sector. Collet[38] concludes that Australia is at risk of being left behind by its competitors, stating that current policies suggest Australia is out of step with the rest of the world on climate change – reducing funding to climate change research at a time when the some of our main competitors are investing with more urgency.

Increased threat from pests and diseases

Climate change will have health implications for humans due to changes in the transmission and distribution of vector-borne diseases. Climate change will also, however, affect the transmission of plant and animal pests and diseases.

The Crawford Fund[43] finds that Australia will not be immune from plant and animal pest and disease challenges induced by changing climate. They state that Australia should enhance biosecurity precautions and investment in order to minimise the risk of new diseases and pests affecting the health of Australians and our food production systems. Organisations such as the CSIRO should be adequately funded to increase agricultural and natural resource research capacity, in order to deal with climate change effects, including threats from pests and diseases. Managing the spread of significant plant pests and diseases is critical to food security and farmers' incomes, both nationally and at the global level.

Threatened food security due to disruptions to global security

The direct threat to food security from the effects of climate change on agriculture can also adversely affect global security. Global food security is essential for international peace and security. In addition to the threats to food production in Australia, climate change will exacerbate food security issues in Australia's neighbouring countries. Vulnerability to the threat of food insecurity is extreme in less-developed countries with high populations heavily reliant on a limited range of agricultural crops, as well as countries with high levels of poverty, low incomes and poor infrastructure.

Climate change will also exacerbate flooding, cause sea-level rise and intensify cyclones. The threat from climate change disasters will have a severe impact on food supply chains and ecosystem services including fresh water. These events could lead to humanitarian disasters in many nations.[43] The Crawford Fund highlights that many countries depend heavily on both the reliability of the annual monsoon in Asia and continuity of water supply from the Himalayan 'water tower'. Climate change is already impacting on the latter and a failed monsoon would have devastating consequences for most of South Asia.

The Crawford Fund has also analysed a number of recent incidents of conflict and concluded that food insecurity, often in the context of extreme weather events, has been a major contributor to conflict across many regions of the world.

Role of agriculture in addressing climate change

The link between climate change, agriculture, food security and human health is clear. However, agriculture itself contributes between a third and a quarter of global greenhouse gas emissions, so the sector has a major role to play in responding to climate change.[41] Unsustainable agricultural practice has been a major driver of climate change, including through deforestation to increase the land available for agriculture.

Despite agriculture's role in releasing greenhouse gas emissions, the land and agriculture can also mitigate greenhouse emissions by absorbing greenhouse gases. As expressed by Howden[44], this means our land resources are both part of the climate change problem and potentially part of the solution.

Howden notes that while the food system emits nearly a third of the world's greenhouse gases, land-based ecosystems absorb the equivalent of about 22 per cent of global greenhouse gas emissions. This happens through natural processes that store carbon in soil and plants, in both farmed lands and managed forests as well as in natural carbon sinks such as forests, seagrass and wetlands.

The potential for agriculture to do more to reduce emissions can be realised through planting trees and using sustainable land management practices that increase soil organic matter.[45] There is also an important role for governments to provide incentives for agriculture to reduce its contribution to climate change and increase its contribution to climate change mitigation.

Many farmers are recognising the impacts of climate change and the key role they can play in finding solutions. In Australia, Farmers for Climate Action is a movement of farmers, agricultural leaders and rural Australians working to lead climate solutions on their farms. They advocate together to influence their sector and the government to implement climate policies that reduce pollution and benefit rural communities.[46]

Climate change, food security and health

Climate change is having global health consequences. In Australia, rural, regional and remote communities are at the forefront of climate change impacts, which have a significant negative effect on their social, cultural, economic and environmental health and wellbeing.

Climate change is a risk multiplier, in that it exacerbates pre-existing health and social issues.[47] For rural communities experiencing significant social and health inequities, including food insecurity, climate change accentuates these inequities, adding an additional burden to an already socioeconomically and environmentally challenged population.

Australia has one of the highest per capita emissions of carbon dioxide in the world, with 0.3 per cent of the world's population releasing 1.07 per cent of the world's greenhouse gases. When accounting for per capita emissions, Australia has the third highest emissions in the world after Saudi Arabia and Kazakhstan.[48]

Communities in rural and remote Australia are highly vulnerable to the health-related effects of climate change, including through the risk of food insecurity. Australia needs to act to reduce its contributions to greenhouse gas emissions, ensure agriculture is managed in a sustainable way and mitigate the risk for rural and remote Australians of food insecurity due to climate change.[48]

Vector-borne disease

Both globally and within Australia, there is concern that changes in weather patterns as a result of climate change, together with the consequences of adaptation and mitigation strategies, will lead to alterations in the geographic spread of disease vectors. If realised, this wider geographic dispersal will effectively increase the number of people exposed to future health risks associated with vector-borne disease pathways.

What are vector-borne diseases?

Vector-borne diseases may be bacterial, parasitic or viral in nature. They require a living organism to transmit infection from an animal or human host to an uninfected target. Most commonly, disease vectors are insects and transmission occurs via an insect bloodsucking or biting the human or animal host and subsequently infecting the human target. Prominent vectors include mosquitoes, ticks and various flies, and prominent diseases include malaria, dengue, chikungunya, yellow fever, Ross River fever, Barmah Forest virus and Zika virus.[49] This paper focuses on insect-borne diseases. Diseases such as Q fever and psittacosis, which are carried by larger animals including cattle, sheep, goats or birds, are not discussed. Vector-borne diseases carry with them a significant global health burden, leading to premature death, disability, or repeated and chronic illness; they account for 17 per cent of infectious disease cases and are responsible for over 700,000 deaths annually.[49] Malaria alone accounts for over half of these.[49]

The high burden posed by vector-borne diseases globally is attributable, in part, to the lack of enduring and effective chemotherapies. Significantly, the widespread use of chemotherapy for endemic vector-borne diseases is associated with pathogenic drug resistance, rendering them of limited use in the long term. In the case of malaria, two of the four known human malarial parasites have developed resistance to available chemotherapies[50]; additionally, vaccine development is complex for malarial disease due to its parasitic basis, and none are approved for widespread use.[51] There are no effective drug-based prophylactics or treatments approved for dengue, Ross River fever, Barmah Forest virus, chikungunya, or Zika virus.[52] The lack of available chemotherapies for globally significant vector-borne diseases means that, to date, a high reliance has been placed on personal prevention, vector surveillance and control measures to curb the spread. Complicating the control of vector distribution is the problem of insecticide resistance in key species[53], so the importance of personal prevention and surveillance measures is heightened.

Vector-borne diseases of importance in Australia

Locally significant vector-borne diseases are monitored within the Australian Government's National Notifiable Diseases Surveillance System. Endemic to Australia and comprising the vast majority (over 80 per cent) of vector-borne notifications, are the mosquito-borne diseases Ross River virus and Barmah Forest virus. While not endemic to Australia, dengue fever is also of public health significance due to the presence of transmitting mosquito species and periodic outbreaks.[54] Most cases of dengue notified in Australia are acquired overseas. Local acquisition of malaria has been observed in Australia, but is uncommon[55], and notified infections of other vector-borne diseases of global significance have, to date, been imported into Australia (such as chikungunya and Zika virus).

Ross River virus

Ross River virus is the most common vector-borne disease in Australia. It is a debilitating condition which manifests as arthritic pain in peripheral joints (peripheral polyarthralgia), with fever, rash and fatigue common co-indications.[55] For many patients, arthralgia becomes chronic and, as such, the personal and public health burden associated with the disease is high.[56]

There are more than 40 mosquito species implicated in the spread of Ross River virus, with three strongly associated with transmission outside of metropolitan areas. Two *Aedes* variants (*vigilax* and *camptorhynchus*) are found along the northern and southern Australian coastlines and are prominent in wetland habitats, whereas *Culux annulirostis* is found throughout mainland Australia and is associated with freshwater sources.[57] A further *Aedes* variant, *notoscriptus*, is associated with transmission in cities and their outskirts, and is linked to water storage in metropolitan areas.[57]

Conditions which favour Ross River fever transmission are strongly associated with patterns favouring outbreaks of the transmitting mosquito species and include higher rainfall and tide maxima.[58] The effect of temperature is region-dependent, with average temperatures favouring outbreaks in northern Australia, lower than average temperatures favouring outbreaks in arid regions, and higher than average temperatures favouring outbreaks in the southern, temperate regions of Australia.[58] Currently, Ross River virus spreads year-round in the tropical north of Australia and exhibits a high degree of seasonality in the south.[58] Additionally, weather events (high temperature and rainfall) appear to be especially important drivers of disease outbreak in southern Australia.[59] Data indicate that, in the last 25 years, annual absolute notifications have been highest in Queensland, followed by New South Wales and Western Australia, with several notable large outbreaks in Victoria. Notification rates relative to population, on the other hand, have been highest in the Northern Territory, followed by Queensland and Western Australia.[60]

Barmah Forest virus

Barmah Forest virus is the second most significant vector-borne disease in Australia. It shares some characteristics with Ross River virus – it is not fatal, but it is debilitating and manifests as arthralgia, with other symptoms including joint inflammation (arthritis), muscle pain (myalgia), fever, rash and fatigue.[61,62] Typically, Barmah Forest virus has a shorter duration than Ross River virus.[62] It spreads from marsupial reservoirs (infected animal hosts) to uninfected humans via various mosquito species.

There is evidence that maximum temperature is an independently important driver of Barmah Forest virus spread, with high rainfall also playing a role. Higher temperatures are thought to promote outbreaks due to their ability to truncate the period to infectivity following mosquito ingestion of the virus, shorten larval incubation periods, and increase adult mosquito survival rates[63] – in essence, higher temperatures mean more mosquitoes which are more infectious. Annual absolute notifications of Barmah Forest virus have tended to be highest in Queensland, New South Wales and Western Australia over the past 25 years, whereas notification rates are highest in the Northern Territory, followed by Queensland and Western Australia.[60]

Dengue

While not endemic to Australia, dengue is of public health concern due to the level of imported cases. Dengue is a viral condition which manifests as fever, pain (headache, joint and muscle pain), fatigue, rash, gastrointestinal upset and, in more severe cases, haemorrhage or shock. While serious, dengue is rarely fatal and usually resolves within a matter of weeks.[64]

Imported cases and the presence of mosquito vectors (primarily *Aedes aegypti*) throughout Queensland facilitate periodic local outbreaks of dengue, primarily in north and central Queensland.[65] Another carrier, *Aedes albopictus*, is presently restricted to the Torres Strait and has a more limited capacity to serve as a dengue vector, however, this species does serve as a local transmitter of the virus.[65] As there are no vaccines or specific treatments for dengue fever, mosquito breeding and habitat control is key to managing the risk of outbreak, as are personal protective measures.

Like Ross River and Barmah Forest viruses, climatic and weather conditions influence transmissibility and, thus, the likelihood of local outbreaks; however, temperature appears to exert complex effects on dengue vectors. Vector efficiency is influenced by virus incubation timeframes (the period within which infection is detectable in mosquitos following dengue exposure). Virus incubation timeframes and, thus, infectivity, appear to favour higher temperatures.[65] However, high daily temperature fluctuations can either favour[66] or discourage[67] transmissibility, depending on underlying mean temperature. Conversely, mosquito mortality appears directly proportional to temperature – mortality rates increase with higher temperatures[66] and temperature variability.[67]

Climate change and vector-borne disease in Australia

As highlighted above, as the vectors commonly involved in the transmission of vector-borne diseases are cold-blooded arthropods, they are highly sensitive to environmental conditions – changes in climate and weather patterns have the capacity to influence their survival, reproduction, and geographic dispersal. While the incidence of vector-borne disease in Australia has historically been relatively low by global standards, there is concern that climate change will alter vector distribution, exposure and infection rates.[68,69,70]

Importantly, vectors of interest in Australia are influenced by warmer temperature, temperature variability and rainfall conditions – all of which are implicated in climate scenarios now and into the future. It is conceivable that higher rates of vector-borne disease transmission and altered geographic dispersal will emerge as secondary effects of climate change, with a high consequential health burden. However, modelling of likely effects of climate change on vector-borne disease transmissibility and distribution is complex, with the overall effect highly dependent on microhabitat, the balance of temperature and rainfall changes, and extreme weather events.[15] In general, however, it is expected that:

- warmer air temperatures will speed up vector development, infectivity, and survival rates
- higher humidity will enhance survival, prolonging the vector's infectious lifetime
- heavy rainfall will promote still water pooling and favour an increase in vector populations
- warmer southern temperatures will promote the geographical spread of vectors of importance
- adaptation measures, including changes to rainwater storage, will create fertile breeding grounds for vectors.[15]

Further, Bambrick[15] highlights the potential for increased geographic dispersion of aggressive, dengue-transmitting mosquitoes to be of particular concern for Australia in climate change scenarios. Somewhat complicating matters is that persistent drought might reduce the spread of Ross River virus in south-eastern Australia[71] and temperature maxima, beyond an upper threshold, might adversely affect vector survival rates[72], leading to transmission decline.

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National Rural Health Alliance – member organisations

Allied Health Professions Australia Rural and Remote
Australasian College for Emergency Medicine
Australasian College of Health Service Management (Regional, Rural and Remote Special Interest Group)
Australasian College of Paramedicine
Australian and New Zealand College of Anaesthetists and Faculty of Pain Medicine
Australian Chiropractors Association (Aboriginal and Torres Strait Islander Rural and Remote Practitioner Network)
Australian College of Midwives (Rural and Remote Advisory Committee)
Australian College of Nursing (Rural Nursing and Midwifery Community of Interest)
Australian College of Rural and Remote Medicine
Australian Dental Association (Rural Dentists' Network)
Australian General Practice Accreditation Limited
Australian Healthcare and Hospitals Association
Australian Indigenous Doctors' Association
Australian Nursing and Midwifery Federation (rural members)
Australian Paediatric Society
Australian Physiotherapy Association (Rural Advisory Council)
Australian Psychological Society (Rural and Remote Psychology Interest Group)
Australian Rural Health Education Network
Congress of Aboriginal and Torres Strait Islander Nurses and Midwives
Council of Ambulance Authorities
Country Women's Association of Australia
CRANAplus
Exercise and Sports Science Australia
Federation of Rural Australian Medical Educators
Isolated Children's Parents' Association
National Aboriginal Community Controlled Health Organisation
National Association of Aboriginal and Torres Strait Islander Health Workers and Practitioners
National Rural Health Student Network
Optometry Australia (Rural Optometry Group)
Pharmaceutical Society of Australia (Rural Special Interest Group)
Regional Medical Specialists Association
Royal Australasian College of Medical Administrators
Royal Australasian College of Surgeons (Rural Surgery Section)
Royal Australian and New Zealand College of Obstetricians and Gynaecologists
Royal Australian and New Zealand College of Psychiatrists
Royal Australian College of General Practitioners Rural Faculty
Royal Far West
Royal Flying Doctor Service
Rural Doctors Association of Australia
Rural Health Workforce Australia
Rural Pharmacists Australia
Services for Australian Rural and Remote Allied Health
Society of Hospital Pharmacists of Australia
Speech Pathology Australia