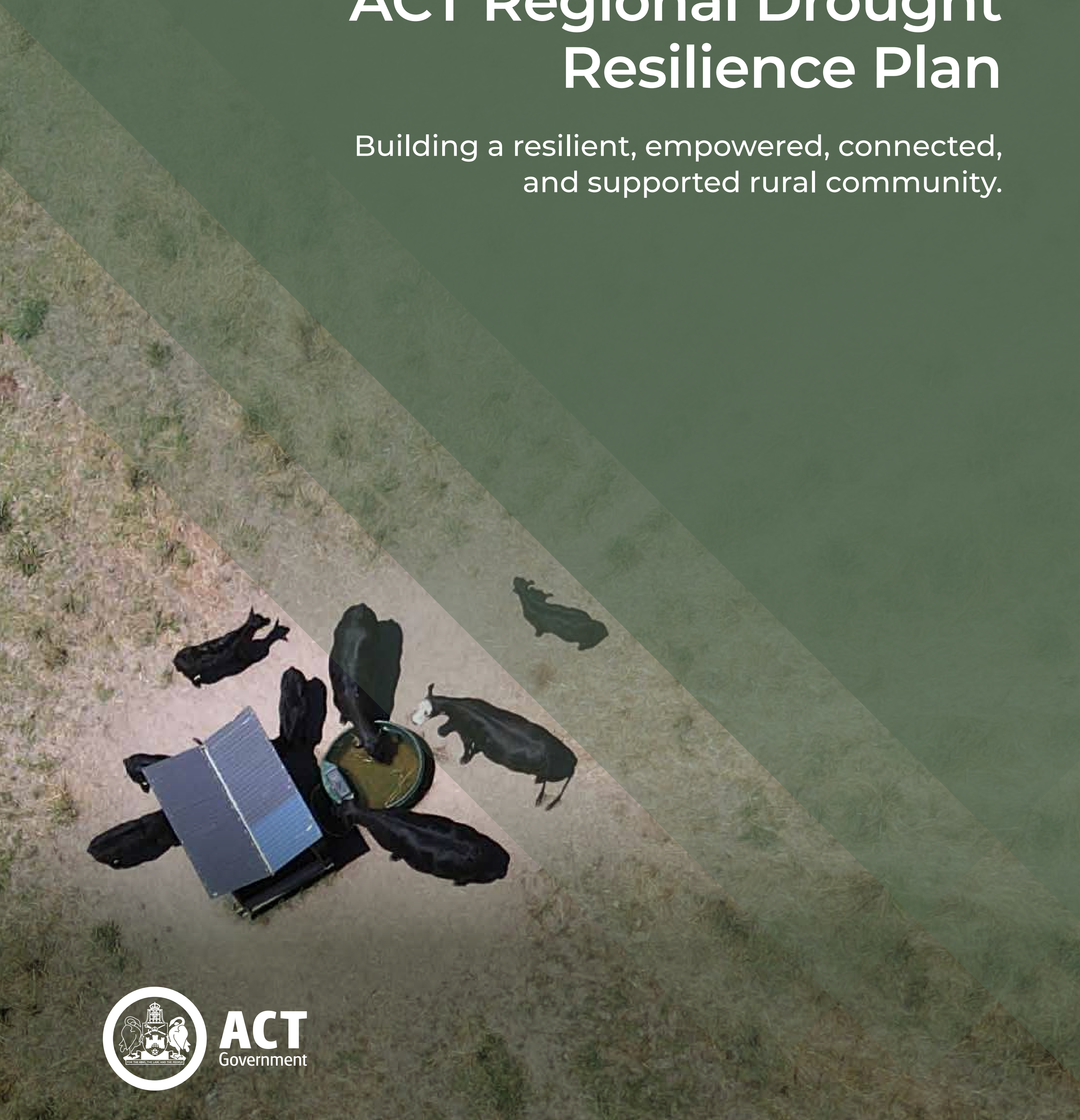
Australian Government
Department of Agriculture, Fisheries and Forestry

Future Drought Fund

ACT Regional Drought Resilience Plan

Building a resilient, empowered, connected, and supported rural community.



ACT Government

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Acknowledgement of Country

*Dhawura nguna ngurumbangu gunanggu Ngunnawal.
Nginggada dindi dhawura Ngunnawalbun yindjumaralidjinyin.
Mura bidji mulanggaridjindjula.
Naraganawaliyiri yarabindjula.*

*This country is Ngunnawal (ancestral/spiritual) homeland.
We all always respect Elders, male and female, as well as Ngunnawal country itself.
They always keep the pathways of their ancestors alive.
They walk together as one.*

The ACT Government acknowledges the Ngunnawal people as traditional custodians of the ACT and recognises any other people or families with connection to the lands of the ACT and region. We acknowledge and respect their continuing culture and the contribution they make to the life of this city and this region.

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Contents

Glossary

Key Term	Definition
Active learning	The process of reflecting and adapting behaviour in response to what is learned.
ACT	Australian Capital Territory
AECOM	Infrastructure consulting firm.
Natural Resource Management (NRM)	The Australian Capital Territory Natural Resource Management (ACT NRM) is one of 56 regional NRM organisations across Australia under the Australian Government's regional stream of the National Landcare Program 2018-2023 (NLP2) – Regional Land Partnerships (RLP).
Triple bottom line resilience	The ability of social, environment, and economic components to effectively adapt to change.
Theory of change	A method of explaining how certain actions and activities will lead to the desired outcomes.
Future Drought Fund (FDF)	The Future Drought Fund is a long-term investment fund that provides a sustainable source of funding to help Australian farmers and communities become more prepared for, and resilient to, the impacts of drought. Established under the Future Drought Fund Act 2019 (the Act) in September 2019, the Fund began with a $3.9 billion investment, with earnings to be reinvested by the Future Fund Board until the balance reaches $5 billion. The Fund is part of the Australian Government's Drought Response, Resilience and Preparedness Plan.
Regional Drought Resilience Plan	Under the Future Drought Fund, regional areas in Australia have received funding and support to develop a Regional Drought Resilience Plan to identify and guide actions to build regional resilience to future droughts.
NARCLIM	NSW and Australian Regional Climate Modelling - a NSW Government-led initiative that generates detailed climate projections, for NSW, ACT and other parts of Australia.

Introduction

The ACT has faced significant drought conditions in recent history, most recently during 2017–2019 and the Millennium drought in the early 2000s. Droughts have social, economic and environmental impacts on the ACT's rural community, and these impacts are predicted to worsen as climate change intensifies.

The ACT has faced significant drought conditions in recent history, most recently during 2017 and 2019 and the Millenium drought in the early 2000's.

Droughts pose a significant threat to the social, economic, and environmental wellbeing of the ACT's rural communities. Climate change is expected to worsen these challenges.

To address this, the ACT Government, funded by the Australian Government's Future Drought Fund (FDF), developed the ACT Regional Drought Resilience Plan (ACT RDRP). This plan recognises the vital role of the ACT's rural community, who oversee the ACT's rural and non-urban lands. While their contribution to national primary production might be modest, their sustainable agricultural practices are essential for effective natural resource and biosecurity management, offering significant environmental benefits for the entire Territory.

Developed in partnership with the ACT's rural community, the ACT RDRP incorporates best-practice resilience planning principles to build the drought resilience of the ACT's rural community across environmental, economic, social, and governance (EESG) aspects. It also harnesses the valuable region-specific knowledge and skills of these residents.

The ACT RDRP leverages the community's past experiences with droughts and examines future climate change scenarios. It empowers rural stakeholders to share ideas, plan for drought resilience, and identify priorities. This approach aims to equip rural landholders and farmers with the knowledge and resources necessary to improve their response to future droughts.

The ACT RDRP is coordinated and complementary to many other ACT Government strategies, plans, and approaches that address our local environment, community, and economy. This plan will help guide future investments and actions to build a resilient, empowered, connected, and supported rural community in the face of drought.

The purpose of the ACT RDRP is to:

- **Prepare the ACT rural community for future climate impacts**
- **Build environmental, economic and social resilience to droughts**
- **Identify innovative and transformative drought projects to guide future investments**
- **Improve natural resource management**

The Future Drought Fund

The FDF is the Australian Government's investment to build drought resilience in Australia's agriculture sector, the agricultural landscape, and within communities. The FDF provides $100 million each year for drought resilience initiatives that help farmers and rural communities prepare for the impacts of drought.

The Regional Drought Resilience Planning program is one of the foundational programs under the FDF which provides funding and support to local governments and community to partner together to develop Regional Drought Resilience Plans.

Regional Drought Resilience Plans are community led plans that build capability and empower regional communities to come together to share ideas, discuss the best ways to build resilience to drought in their region and identify their priorities for action.

The plans will ensure regional communities are well placed to take advantage of future funding opportunities under the FDF.

Future Drought Fund (FDF)

→ **Regional Drought Resilience Planning (RDRP) program**

→ **Regional Drought Resilience Plans** (community led)

Development of the ACT RDRP

To develop the ACT RDR plan, consultancy firm AECOM was engaged to deliver a study on climate and drought resilience risks and planning in the ACT. This study was conducted in 2022 in partnership with the ACT rural community. The study aims to better understand how the ACT the rural community has prepared for and managed previous droughts, and how they intend to plan for and managing future droughts.

The study included:

- The collation of existing climatology (historic and current climate for the Territory).
- Collation of future climate projections for the Territory.
- Stakeholder engagement via one-on-one interviews, a workshop with ACT rural landholders, and an online survey to develop an understanding of landholders current consideration of droughts and future climate change.
- A desktop review of current and future droughts on ACT rural landholdings and ACT rural households and adaptation actions they have underway or planned.
- Reporting and follow-up desktop research to consolidate findings.

The ACT RDRP includes a high-level overview of the AECOM study: Climate and Drought Resilience Risks and Planning (2022) (**Appendix 1**).

A second study, Drought mitigation through farm diversification in the ACT 2022[1] (**Appendix 2**), was undertaken by the Australian Farm Institute (AFI) for the ACT Government to identify opportunities for ACT and region farmers to diversify their on-farm income, to help maintain farm viability during drought and downturns in commodity prices. The AFI study specifically addresses opportunities for increased income from existing farm practices improved farm diversification in the ACT and barriers and opportunities to farm diversification in the ACT to support drought mitigation for farming enterprises.

Plan Sequence:

- The draft ACT RDRP submitted for independent assessment by CSIRO February 2023 and feedback has been considered in the finalised draft (May- July 2023).
- The draft ACT RDRP submitted to ACT Cabinet for consideration (August to December 2023) before being released for public consultation.
- Targeted consultation with key stakeholders on the draft ACT RDRP from December 2023 and wider community consultation February- March 2024.
- Listening report published in April 2024.
- Final plan endorsed by ACT Government August 2024.
- The ACT RDRP submitted to the Australian Government for approval September 2024.
- Once approved by both the ACT and Australian Government, the ACT RDRP will be published on the ACT Government and FDF websites and an implementation plan will be developed which will outline steps for delivering the Regional Drought Resilience Plan extension program 2024-2025.

Community benefit and value

Guiding best practice design can lead to social, environmental and economic benefits to the community, government and private business. Social benefits include supporting people's quality of life and overall health and wellbeing. Environmental benefits encompass the protection and enhancement of environmental assets and the inclusion of sustainable design features and travel. Economic benefits include reduced infrastructure and delivery costs as a result of efficient land-use patterns through greater density near activity centres, employment areas and active travel.

[1] Thomas, S & McRobert, K (2022), Drought mitigation through farm diversification in the ACT, Research Report, Australian Farm Institute.


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Executive summary

“The ACT rural community is empowered, connected, and supported in drought and climate change planning, preparedness, adaptation, and response, and can adapt to and absorb the impacts of future droughts.”

In 2019, the Australia Government established the Future Drought Fund under the Future Drought Fund Act 2019 (the Act). The Future Drought Fund is a long-term investment fund that provides a sustainable source of funding to help Australian farmers and communities become more prepared for, and resilient to, the impacts of drought.

Under the Future Drought Fund, regional areas in Australia have received funding and support to develop a Regional Drought Resilience Plan. The ACT Government has received funding under this fund to prepare a Regional Drought Resilience Plan for the ACT Region.

The purpose of the ACT Regional Drought Resilience Plan is to:

- **Prepare the ACT rural community for future climate impacts**
- **Build environmental, economic and social resilience to droughts**
- **Identify innovative and transformative drought projects to guide future investments**
- **Improve natural resource management**

As our climate changes the impact of future droughts will be more keenly felt in our community and our economy. The ACT has experienced several periods of serious and severe drought. three recent examples include 1982, 2001-2009 and 2017-2020.

During the 2017-2020 drought, the ACT experienced:

44% decrease in average rainfall

91% decrease in soil moisture

80% increase in extreme heat days

To understand possible future drought-related impacts facing the ACT rural community, AECOM projected three future drought scenarios based on the latest NSW and ACT climate projections. Under all three scenarios, the ACT's climate is projected to become warmer and drier, and experience more extreme weather events. Periods of drought will increase in both frequency and intensity.

The five priority impacts identified for the ACT are:

01
Reduced water availability.

02
Increased weeds and pests.

03
Reduced carrying capacity of land.

04
Reduced on-farm biodiversity.

05
Reduced wellbeing of farming community.

The ACT Regional Drought Resilience Plan is a targeted response to the conditions, experiences and future of ACT farmers and communities. A suite of adaptive actions have been identified to improve resilience to future drought. These adaptation actions have been grouped under the strategic priorities of environment, economic, social and governance.

The ACT Regional Drought Resilience Plan has been developed, and prioritised, through stakeholder engagement to ensure it is targeted at rural landholders, the ACT Government and other parties.

Drought will continue to be a challenge for rural landholders and farmers in the ACT. Investment in adaptation measures to build resilience to drought will be essential to preserve rural land and farming activities within the ACT.

The delivery of this plan is not solely the responsibility of the ACT Government but guides rural landholders, government and other parties on activities to improve preparedness and response to drought.

01

Vision, goals and outcomes

ACT RDRP Vision

Our vision for the ACT is as follows:

“The ACT rural community is empowered, connected, and supported in drought and climate change planning, preparedness, adaptation, and response, and can adapt to and absorb the impacts of future droughts.”

Resilience thinking

The ACT RDRP is being developed using the Resilience Thinking framework. This framework provides an approach to addressing problems and challenges and adapting to change. While resilience can be defined as "The capacity of a system to absorb disturbance and reorganise so as to retain essentially the same function, structure and feedbacks"[2], in this context we are more focused on adapting or transforming as needed in response to change.

Why is resilience thinking important?

With environmental conditions changing rapidly, building drought resilience is more crucial than ever. This means addressing the environmental, social, economic, and governance (EESG) impacts of droughts, along with the responses needed to support rural landholders and governments in tackling future challenges[3].

How resilience thinking can be implemented in a drought plan

Experience in other parts of Australia has found that when key parts of resilience thinking, such as adaptive, local, and collaborative approaches to strategic planning, are applied to natural resource management decision-making, communities are better equipped to cope with stressors and change[4].

Active learning and adaptive governance

Active learning is an important aspect of implementing the RDRP. Active learning involves taking time to reflect and learn from experience. The ACT RDRP aims to improve government and agricultural practices by analysing what is currently working effectively, and what should be improved. Through monitoring and evaluation, the actions and recommendations set out will be regularly assessed to support active learning. The ACT RDRP is committed to framing setbacks as opportunities to improve.

The following Resilience approaches underpinned the development of the ACT's RDRP:

- → **Definitions, vision, goals and outcomes.** Key terms used in the plan are defined; the desired outcomes and goals of the plan are clearly explained and set out.
- → **Stakeholder engagement, participation, and partnerships.** Broad participation and partnership are encouraged at all stages of resilience planning/thinking.
- → **Active learning and adaptive governance.** Active learning involves learning from experience, undertaking structured reflection, and implementing that learning. Adaptive governance utilises flexibility to respond to change, whilst remaining accountable for goals and visions.
- → **Evidence base, a stocktake of past and current work and alignment.** It is crucial to have a well-informed evidence base to make decisions.
- → **System description and resilience assessment.** The region in question should be described in terms of a system with key components and connections. This system should then be analysed to see how it has historically been responding to droughts and how it is likely to respond in the future.
- → **Future scenarios.** Using megatrends and drivers of change, future scenarios can be formulated. These can be useful in stakeholder discussions to explore the challenges and opportunities which may be on the horizon.
- → **Intervention options and pathways for building regional resilience.** This involves developing options for action plans.
- → **Assessment of pathways and theory of change for recommended actions.** This involves assessing whether the proposed pathways are likely to be effective in building specified or general resilience to drought.
- → **Monitoring, evaluation and learning.** This will support accountability and will ensure that appropriate adjustments are made to actions where necessary. It also supports active learning and adaptive governance.

[2] Walker, B., & Salt, D. (2012). Resilience practice: building capacity to absorb disturbance and maintain function. Island press.

[3] Victorian State Government (2020) Goulburn Murray Resilience Strategy

[4] Sellberg, M. M., Ryan, P., Borgström, S. T., Norström, A. V., & Peterson, G. D. (2018). From resilience thinking to Resilience Planning: Lessons from practice. Journal of environmental management, 217, 906-918.

Strategic priorities

To align with the Future Drought Fund's Drought Resilience Funding Plan, the ACT RDRP is aiming to build the drought resilience of the ACT's rural community guided by four strategic headline priorities:

- → Environmental
- → Economic
- → Social and
- → Governance

These priorities are interconnected with and align with the ACT's Whole of Government Climate Change Risk Assessment, the ACT's Territory Wide Risk Assessment, and the ACT Wellbeing Framework.

Table 1: ACT RDRP Strategic Priorities and their descriptions

ENVIRONMENTAL RESILIENCE FOR SUSTAINABLE AND IMPROVED FUNCTIONING OF FARMING LANDSCAPES	
Environmental	Environmental and biophysical impacts of drought and actions relating to soils, plant and animal growth, management of invasive species, animal welfare, conservation, and regeneration.
ECONOMIC RESILIENCE FOR AN INNOVATIVE AND PROFITABLE AGRICULTURAL SECTOR	
Economic	Impacts of drought relating to farm revenues, costs, subsidies, and grants; and actions relating to financial management.
SOCIAL RESILIENCE FOR RESOURCEFUL AND ADAPTABLE COMMUNITIES	
Social	Drought impacts and responses relating to people and social networks, including their skills, knowledge, human health* (physical and mental) and culture.
EFFECTIVE GOVERNANCE	
Governance	Relationship and process of interaction and decision making in and between government and the community. This theme is distinct from others because impacts and actions are indirect and cut across all the domains, and emerge from other domain risks.

[5] BoM. (2022). Understanding Drought. http://www.bom.gov.au/climate/drought/knowledge-centre/understanding.shtml#:~:text=Drought%20is%20a%20prolonged%2C%20abnormally,be%20in%20almost%20perpetual%20drought.

Defining drought

The Bureau of Meteorology defines drought as “a prolonged, abnormally dry period when the amount of available water is insufficient to meet our normal use.”[5]

There is no universal definition of drought, and it is difficult to compare one drought to another, since each drought differs in the seasonality, location, geographic extent, and duration of the associated rainfall deficiencies. Additionally, each drought is accompanied by varying temperatures, soil moisture and water availability. Droughts typically have a slow-onset with recognisable impacts to agriculture including reduced soil moisture, reduced carrying capacity of land, and reduced on-farm biodiversity. The following factors are used to measure and track drought conditions:

- → Meteorological data (e.g. reductions in average rainfall)
- → Agricultural data (e.g. soil moisture)
- → Hydrological data (e.g. reductions in surface stream flow and deep drainage; water storage levels

More information on drought in the ACT – historic and projected, is provided in Chapter 3.

Assessing drought vulnerability and resilience

The ACT’s RDR Plan conceptualises drought risk in line with existing risk and vulnerability frameworks (Hughes et al., 2020) outlined in **Figure 1**. This framework conceptualises drought risk as a function of exposure and sensitivity, whereby farm drought risk depends both on a farm’s exposure to climate variability and the sensitivity of its production systems to that variability.

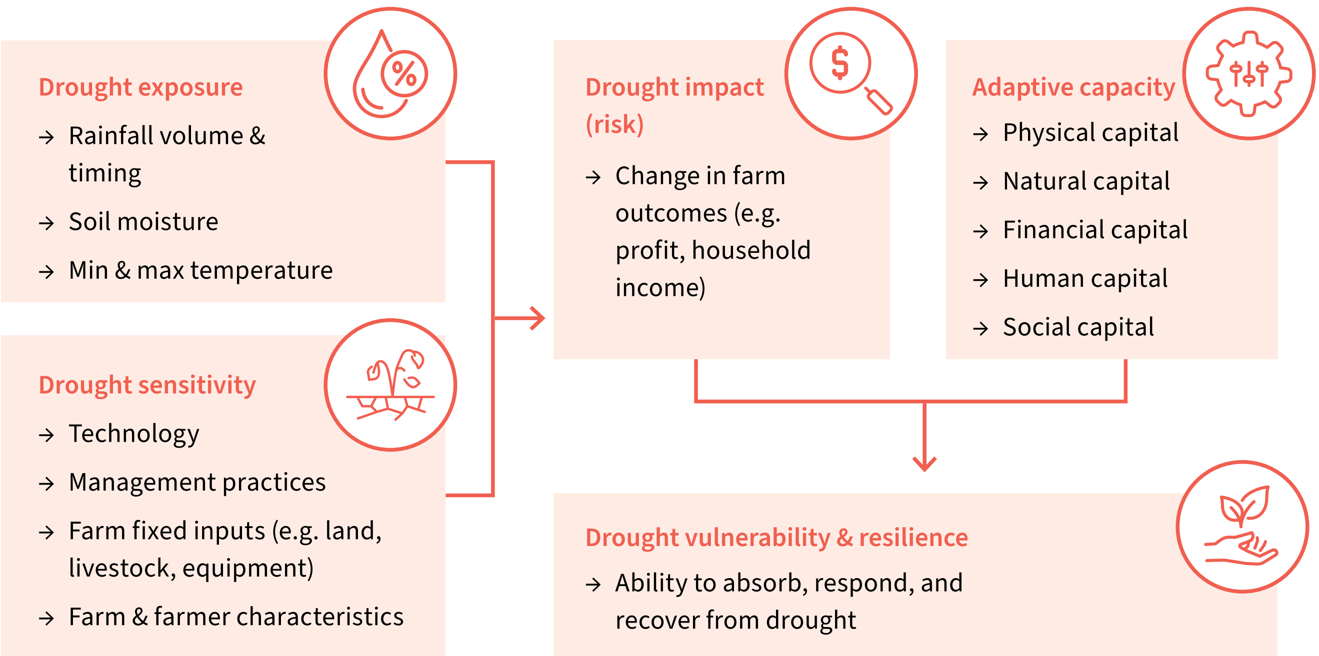

Figure 1: Framework for assessing drought vulnerability and resilience[6]

[5] BoM. (2022). Understanding Drought. http://www.bom.gov.au/climate/drought/knowledge-centre/understanding.shtml#:~:text=Drought%20is%20a%20prolonged%2C%20abnormally,be%20in%20almost%20perpetual%20drought.

[6] Hughes, N., Burns, K., Soh, W., & Lawson, K. (2022). Measuring drought risk | The exposure and sensitivity of Australian farms to drought. https://www.agriculture.gov.au/abares/research-topics/climate/measuring-drought-risk#:~:text=This%20study%20presents%20estimates%20of,to%20display%20greater%20drought%20risk.

Stakeholder Engagement

A stakeholder engagement plan was developed and implemented by AECOM with guidance and assistance from the ACT Government. Stakeholder engagement activities included face-to-face interviews with ACT rural landholders and other stakeholders, a confidential online survey of ACT rural landholders, and a workshop with ACT rural landholders.

Stakeholder engagement identified:

- ACT rural landholders' previous experience of droughts and how they responded,
- What actions they have taken to improve their resilience to drought,
- Future projections of climate change, and
- How they may need to change their enterprise to prepare for future projected droughts and climate change impacts.

Other stakeholders consulted by AECOM included representatives from ACT Government agencies and a rural advisor. A description of each stakeholder group is provided below. Outcomes from stakeholder engagement shaped the information, data and recommendations in the AECOM study. (**Appendix 1**)

Key Stakeholders

ACT rural landholders

The Territory has 159 farming families who collectively manage 180 rural leases covering 40,000ha (15%) of the ACT. Through consultation with rural landholders, this plan reflects the support the ACT rural community believes it will need to cope with future droughts. More information on the ACT rural community is provided in Chapter 2.

ACT Rural Landholders Association

The ACT Rural Landholders' Association is the peak representative body for farmers in the ACT and engages extensively with the ACT Government on matters such as land use and planning, weed and pest animal control, fire management, lease terms and conditions, land tenure, land acquisitions, boundary issues, public and third-party access to rural properties, environmental plantings, environmental regulations and soil conservation.

ACT NRM

The Australian Capital Territory Natural Resource Management (ACT NRM) is one of 54 regional NRM organisations across Australia under the Australian Government's regional stream of the National Landcare Program 2018-2023 (NLP2) – Regional Land Partnerships (RLP). ACT NRM is hosted in the ACT Government's, Environment, Planning and Sustainable Development Directorate (EPSDD). ACT NRM is responsible for managing another tranche of work under the Future Drought Fund, the Farm Business Resilience Program. ACT NRM works closely with the ACT and region community to support biodiversity conservation, sustainable agriculture and Aboriginal NRM.

The Suburban Land Agency

The ACT Suburban Land Agency (SLA) is a statutory authority within the Environment, Planning and Sustainable Development Directorate (EPSDD) portfolio, and is the largest leaseholder of rural land in the ACT.

Icon Water

Icon Water is an unlisted public company wholly owned by the ACT Government. Icon Water owns, manages and operates all water and sewerage services for the ACT, including the following dams:

- Corin Dam (70.79 GL capacity)
- Bendora Dam (11.45 GL capacity)
- Cotter Dam (76.2 GL capacity)
- Googong Dam (110.41 GL capacity)

Drought and climate change impacts on quantity, quality and availability of water is a significant concern to ICON water as the population of the ACT grows and droughts become more frequent and severe.

Office of Water

The Office of Water sits within the Environment, Heritage and Water Division of the ACT Government's Environment, Planning and Sustainable Development Directorate. The Office was established by the ACT Government to facilitate holistic and coordinated policy, planning and program delivery for water resource management within the Territory. For this purpose, the Office is responsible for facilitating cross-directorate collaboration on water management issues, leading on policy and planning for the water sector, undertaking monitoring and reporting to government on the implementation of water plans, policies, and strategies, providing the primary point of engagement with the ACT community on water sector issues, and conducting assurance reviews as requested by the Minister for Water. The Office of Water will support Canberra becoming a more climate-resilient and water-secure city.

Governance in implementation of ACT RDRP

The implementation of the ACT RDRP will be overseen under the RDRP Program Extension by:

- An internal ACT Government steering group which will meet regularly and coordinate and monitor the progress of the RDRP's implementation. The steering group will engage with the farming community on decisions relating to implementation.
- The ACT NRM Advisory Committee which will be consulted less frequently for broader decision on the direction and priorities of the RDR Plan's implementation. This will aide in ensuring the direction of the ACT RDRP's implementation is supported by the community. **Figure 2** demonstrates the governance structure.

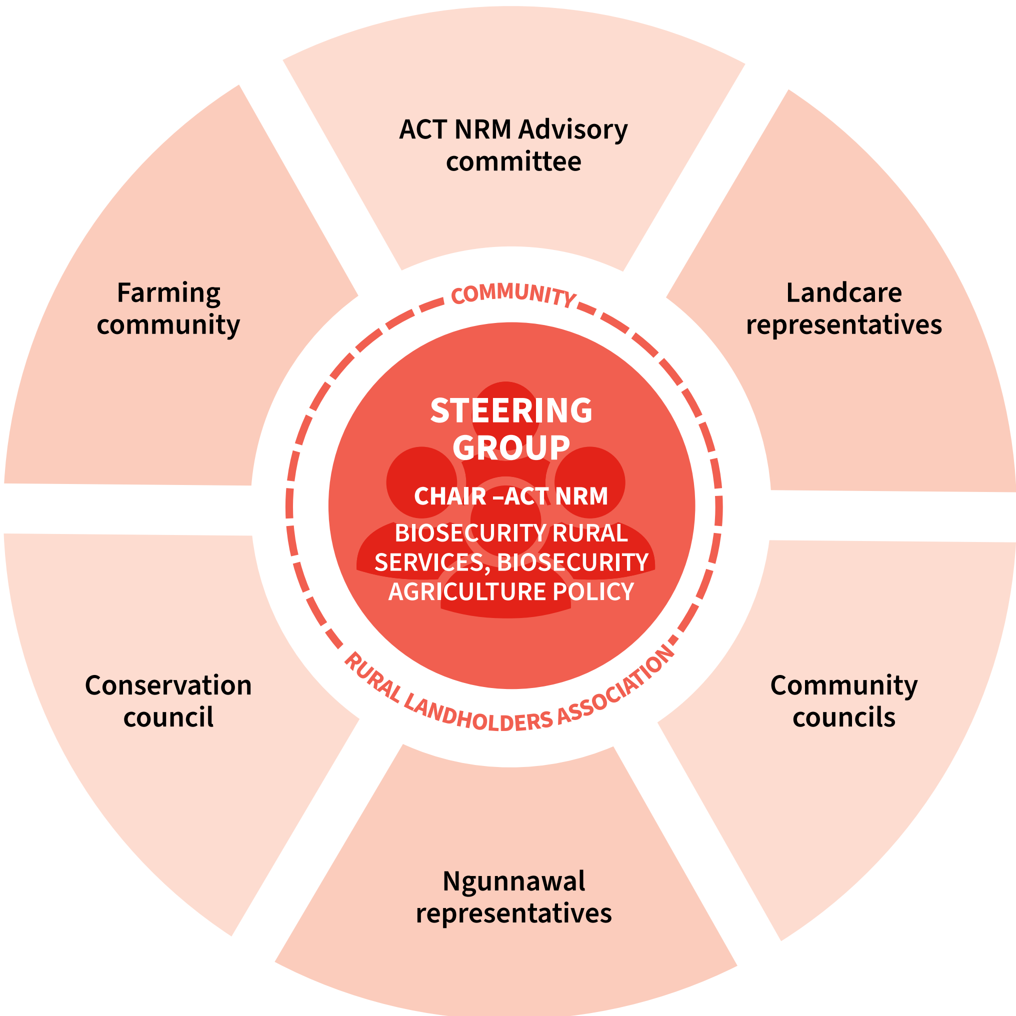

Figure 2: ACT's RDRP Nested Governance Structure

Complementing the Canberra Region Local Food Strategy

To date, the ACT has not had an established policy or strategy that details its vision for the agriculture sector in the region. Population growth in the ACT and surrounding region has led to an increased interest in local and regional produce. The Canberra Region Local Food Strategy aims to prioritise local food production, encourage economic and social prosperity through robust food systems and increase affordable and equitable access to fresh and nutritious food.

Key to the success of the Strategy will be to support sustainable urban and rural farming practises. Sustainable farming practices at all scales are part of the solution to the climate change emergency and biodiversity loss.

The ACT RDRP will be used to guide strategic decision making and build drought, and broader climate change resilience for the region's agricultural producers. By supporting farmers and food enterprises to adopt sustainable practices, the local food system can help make sure the ACT and its region build stronger climate resilience and protect its biodiversity.

Goals and outcomes

To meet our vision, the following key goals have emerged through the stakeholder consultation, literature review and the AECOM study.

Table 2 outlines how the goals relate to the strategic priorities and describes key outcomes for each goal.

GOALS	STRATEGIC PRIORITY	OUTCOMES
Enhanced water security		Rural communities have access to alternative water sources to improve water security. Rural community is considered in future water use plans.
Access to and engagement with data		Improved landholder engagement with projections of climate to enhance planning and demonstrate what sufficient preparedness looks like. Continued investment in making climate data accessible and available. Improved representation of ACT data within national data sets, enabling comparison with other regions. Improved resilience to wider climate-related shocks and stresses.
Improved land use planning		Recognition of farmers' land stewardship. Farmers are enabled to adaptively manage their land and enterprises. Land management agreements are an enabler to climate adaptation. Improved landholder ability to undertake long-term planning and investment. Landholders can adaptively manage their land and enterprises.
Supporting education		Improved landholder drought preparedness. Improved rural community engagement with climate change projections.
Building collaboration and awareness		Increased recognition of the ACT as a producing region. Further support and data for ACT's farmers.

Table 2: Goals, Strategic Priorities and Outcomes for the ACT to build drought resilience.

02

Region, community and natural capital

Our Region

The ACT Region is defined by the Territory border and area of 2,358km^2 with a population of more than 460,000 people in 2023 that is projected to increase to 700,000 by 2058. It is a service centre for the ACT and southern NSW and the ACT Government delivers both Local and State government functions. Approximately 68% of the ACT is nature reserve, national park or government-owned commercial forestry. Approximately 17% is urban land, and 15% is rural land.

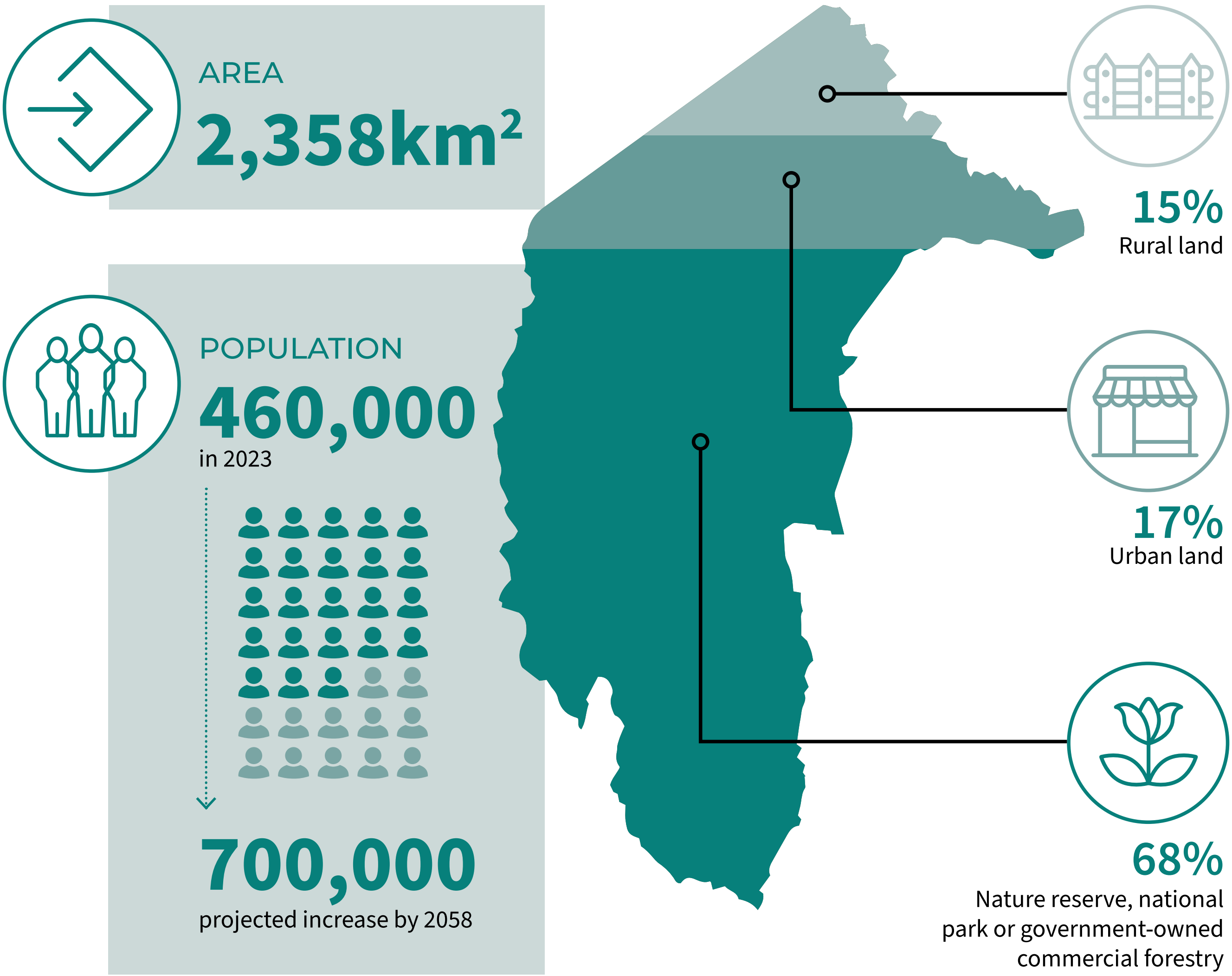

Figure 3: The ACT region

Ngunnawal Country

The ACT is located on Ngunnawal Country. As the first inhabitants of the Canberra region, the Ngunnawal people have extensive knowledge of Ngunnawal Country, and this knowledge has been passed down through the generations. Therefore, it is important to consider the role of Ngunnawal knowledge and cultural land management practices to support drought resilience.

The ACT RDRPis being drafted concurrently to the ACT Government progressing the Caring for Dhawura Ngunnawal - A natural resource plan for the ACT 2022-2042. This plan acknowledges that for thousands of years, the Ngunnawal people have cared for the natural landscape in and around Canberra, and actively manage the land to maintain and influence local ecosystems. Through undertaking cool or cultural burning, risk from fire associated with drought can be reduced.[7]

There are a range of important groups, services and programs established by the ACT Government to support Indigenous Australians to care for Country including:

→ The Dhawura Ngunnawal Caring for Country Committee

→ The Murumbung Yurung Murra Network (a network of Indigenous staff employed by EPSDD)

→ The EPSDD Reconciliation Action Plan

→ Aboriginal NRM program

→ King Brown Caring for Country Program

→ The Namadgi Rock Art Conservation Program

These programs are important in supporting the relationship between the ACT Government and the Ngunnawal community. Further exploration on the impacts of drought on traditional Ngunnawal land management and cultural activities is necessary to ensure these practices can remain resilient to a changing climate.

Further exploration on the impacts of drought on traditional Ngunnawal land management and cultural activities is necessary to ensure these practices can remain resilient to a changing climate.

The ACT does not have a Land Rights Act, Indigenous Protected Areas or a successful Native Title claim.

Overview of agriculture in the ACT

The Territory's 159 farming families collectively manage 180 leases covering approximately 40,000ha (15%) of the ACT. The Territory supports a range of agricultural enterprises, in 2020/2021, the Territory's total value of agricultural commodities produced was $9 million of Australia's total value of $70.8 billion (0.013%). Grazing (cattle and sheep) is the most common form of agricultural production followed by eggs, poultry, and others.[8]

Cattle and sheep production (including wool) contribute approximately 60% to the total $9 million value of the Australian Capital Territory's agricultural sector.[9] The approximate number of resident cattle and sheep in the ACT is 4,639 and 39,331 respectively. Collectively they make up around 0.04% of the combined national sheep and cattle population.[10]

Egg production contributed $335,000 to the $9 million value of the ACT's agricultural sector in 2021 (ABARE). There are three free-range egg producers in the ACT, with an average flock size of around 2,450 birds which together produce a total of around 1,940,000 eggs annually.

Neither intensive cropping activities nor horticulture has a high prevalence in terms of the number of farms in the ACT, with these categories represented by a small number of orchards and turf production. Production data is not well represented in national agriculture statistics, likely due to the low number of farms. ABARES' latest figures (2020/2021)4, for example, identify a total of 34 farms that are recognised as farm businesses, which is not representative of known families and businesses in the region. However, the spread of those businesses identified within national datasets is in line with general numbers represented by the full cohort of landowners. Other agricultural enterprises include egg and chicken production; horse agistment and equestrian enterprises; alpacas and llamas; fruit orchards and vegetable market gardens; nurseries; fodder cropping including lucerne, oats and other fodder crops (primarily for on-farm use); wine; olives and truffles.

This agricultural production profile is generally consistent with that of surrounding NSW regions, which also have grazing (cattle and sheep) as key agricultural activities (**Figure 4**). Broadacre cropping is more significant in the central western part of NSW, while dairy and nursery industries are more prevalent in the eastern regions.

[7] Caring for Dhawura Ngunnawal: A natural resource plan for the ACT 2022-2042 https://www.environment.act.gov.au/__data/assets/pdf_file/0019/2270710/2022-NRM-Draft-Plan-Caring-for-Dhuwura-Ngunnawal.pdf

[8] ABARES (2022). About my region dashboard. https://public.tableau.com/app/profile/australian.bureau.of.agricultural.and.resource.economics.and.sci/viz/AMR_v9_A3L/Dashboard1

[9] ABARES Regional data 'About My Region' (2020/2021) https://public.tableau.com/app/profile/australian.bureau.of.agricultural.and.resource.economics.and.sci/viz/AMR_v9_A3L/Dashboard1 Agricultural commodities (2020/2021) https://www.agriculture.gov.au/abares/aclump/land-use/agriculture-census-dashboards-sa2

[10] ABARES Regional data 'About My Region' (2020/2021) https://public.tableau.com/app/profile/australian.bureau.of.agricultural.and.resource.economics.and.sci/viz/AMR_v9_A3L/Dashboard1

[10] ABARES Regional data 'About My Region' (2020/2021) https://public.tableau.com/app/profile/australian.bureau.of.agricultural.and.resource.economics.and.sci/viz/AMR_v9_A3L/Dashboard1

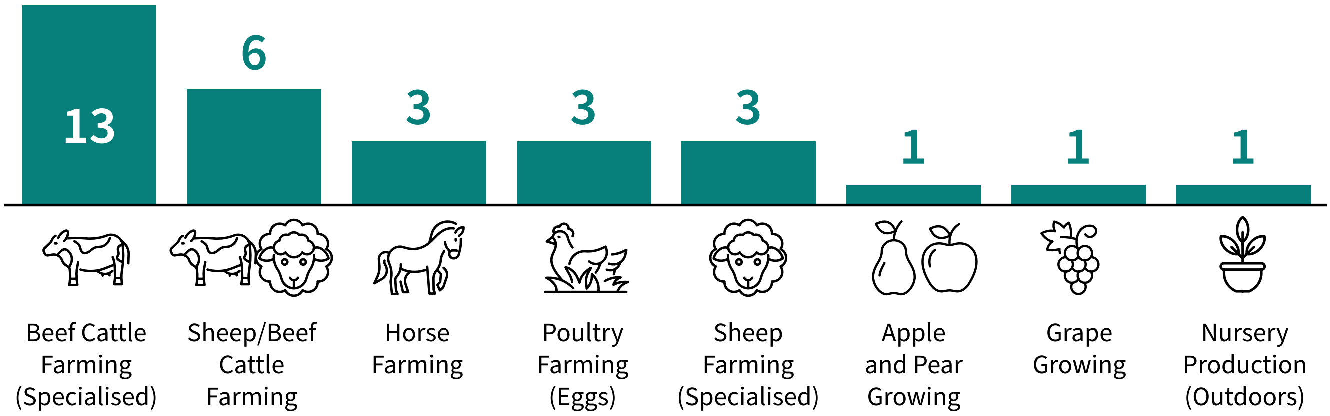

Figure 4: Number and type of farms in the ACT represented within 2020/21 ABARES data.

Agricultural production occurs primarily within areas identified as non-urban zones under the Territory Plan (**Figure 5**). Within this, agricultural production is only a specific objective on land zoned NUZ2 (rural) or more generally NUZ1 (broadacre). Permitted activities on rural and broadacre lands can be further restricted by purpose clauses in crown leases. General planning rules may allow for grazing in some regions, but purpose clauses in crown leases often specify cattle or sheep grazing and that other grazing animals (e.g., goats) or agricultural uses more generally would require a change to the lease agreement. The lease also specifies requirements for appropriate environmental management and monitoring of conservation assets including identification of pest animal and invasive plant management programs. As a total proportion of land within the ACT, these rural zonings comprise 15%.

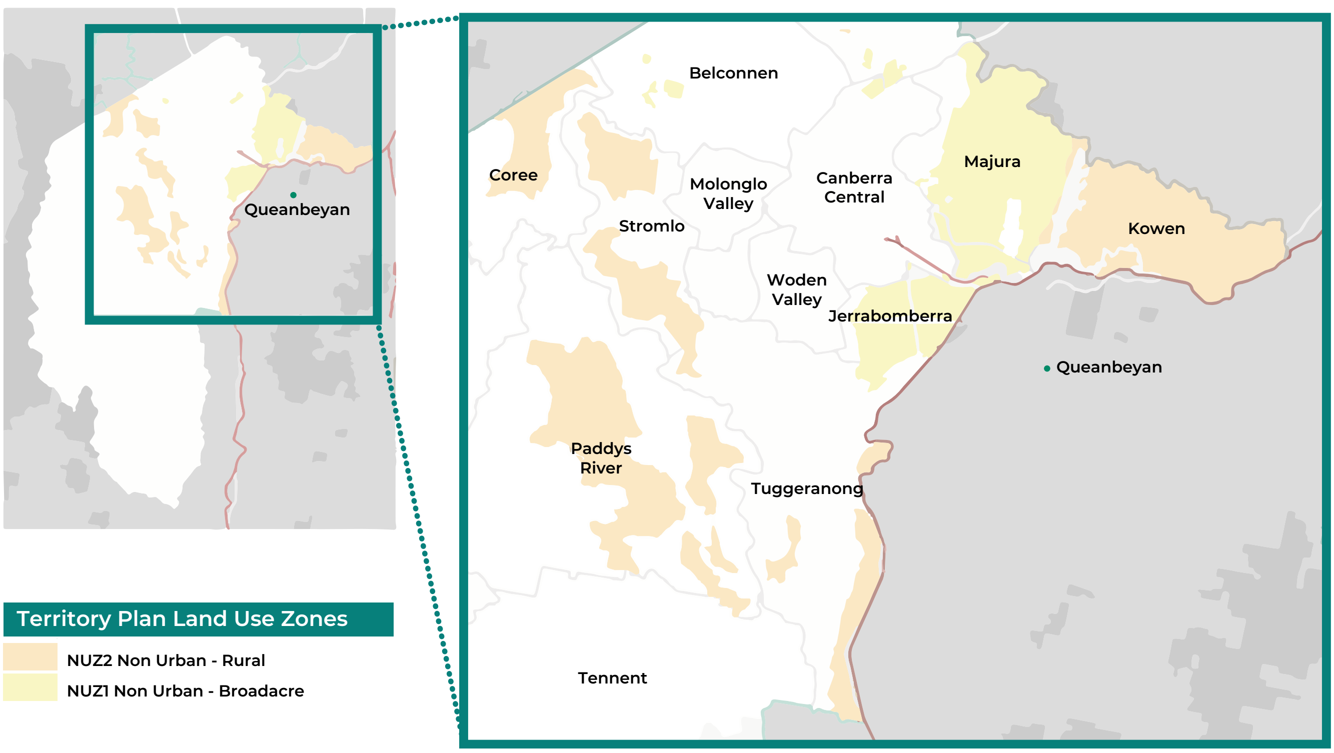

Figure 5: Agricultural land use zoning within the Territory Plan[11]

[11] ACT Government. (2022). Territory Plan. https://app2.actmapi.act.gov.au/actmapi/index.html?viewer=territoryplan

Pasture and landscape management in the ACT

Most grazing land in the ACT is comprised of one or more of the following rain-fed pastures, including:

- Native grasslands (comprised of less productive grasses such as Kangaroo Grass and Poa Tussocks)
- Modified native pastures (with remnants of clovers, and perennial pastures sown some time over the last 50-100 years, and native grasses such Red Grass, Spear Grass, Wallaby Grass)
- Highly productive native pastures (such as Microlaena) sometimes also sown with clovers.
- Introduced perennial and annual pastures such as Phalaris, Cocksfoot and Tall Fescue and introduced clovers such as Subterranean Clover
- Forage crops such as oats, winter wheat, brassica and other crops.

Most ACT rural land is used for the grazing of sheep and cattle and horse agistment. Land use is a key driver of environmental change and many environmental issues in the ACT, such as loss of biodiversity, soil acidification, loss of groundcover and erosion, result from current and historic land management practices, including land clearing, urban development, past agricultural activities, forestry operations and a high concentration of recreational activities in some areas.

Vegetation management in the ACT

Remnant native vegetation is a form of natural capital that provides numerous ecosystem services across a farming landscape. Within the ACT, these remnants include examples of endangered ecological communities in good condition, namely, Natural Temperate Grassland (NTG) and White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (BBGWL). Both these ecological communities are listed under the federal Environment Protection and Biodiversity Conservation Act 1999.

Across the ACT region, declining condition of native vegetation is having a negative impact on persistence of native flora, waterway and landscape health and farm productivity. All these impacts will be exacerbated under expected changes in climate, especially during drought.

Investment in good vegetation management will assist farmers to adapt to changing climatic conditions and coping with and recovering from drought. It will also help to protect valuable threated ecosystems, while maintaining biodiversity and landscape health.

Soil management in the ACT

Distinctive features of ACT soils, irrespective of geology, are that they have inherently acid topsoil; they have shallow (<20cm, many <10cm) topsoils; sodic (erodible) subsoils occur in drainage lines and contribute gully erosion; they have hard setting bleached A2 horizons; shallow, often stony topsoils; are organic matter deficient and generally infertile. The granitic soils tend to have deeper and sandier topsoils. The soils on metasediments are usually less fertile, saltier and stonier. ACT soils are inherently acidic, which has been compounded by some acidifying agricultural practices.

Soil constraints and projected climate change impacts

Drought and climate change are expected to impact on agricultural soils in the ACT following ways:

- Reduced rainfall and increased temperatures will lead to drier topsoil, reduced soil structure and soil porosity leading to more compacted soils, reduced soil water holding capacity, increased soil erosion and reduced plant growth and reduced soil organic carbon.
- Paradoxically – NSW and the ACT may experience an increase in macro-nutrients (the sum of calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) due to drying and warming conditions on clay-rich soils.
- Changes in soil nutrients and soil pH could impact on crop and pasture species that have specific narrow nutrient and pH tolerances, as well as the viability of new weed species.
- Increased wind erosion, loss of topsoil.
- Reduced rainfall but more frequent extreme rainfall events, particularly following droughts and drought-driven bushfires leading to increased soil erosion, loss of topsoil and loss of soil nutrients, sedimentation of waterways, loss of aquatic habitat and species.
- Reduced soil health contributing to reduced pasture/crop production and increased costs to farmers in replacing nutrients lost to erosion and supplementing lost production with purchased feed or reduced stocking rates.

Animal health and heat stress during drought

As the ACT's climate becomes hotter and heatwaves last longer, effectively managing the impact of these heat events on our production animals will be essential for the sustainability of our livestock industries. Planning for heat stress events will help reduce potential welfare issues, production losses, mortalities, and the accompanying financial and emotional impact associated with such an event. Predictive tools are available to help producers prepare for hot weather events.

Ready access to ample, good quality, cool water, which ideally is shaded during the hottest part of the day, is critical in assisting ruminants to cope with heat stress. The provision of shelter/shade with appropriate air flow can make a significant difference to the ability of livestock to cope with a heat event and help reduce potential production losses and mortalities. Where practical, dietary modifications, supplements and additives can be employed as part of a heat mitigation strategy. Where possible, husbandry activities should be planned to avoid the hottest time of the year, and the hottest time of the day. Livestock should always be managed to minimise stress and tight packing of animals in yards should be avoided. An animal showing open mouth panting with their tongue extended is severely heat affected and needs immediate attention.

What's working in the ACT to prepare for drought

ACT NRM and the Biosecurity and Rural Services Unit in the Environment, Planning and Sustainable Development Directorate provide a range of support, training, capacity building activities as well as rebates, grants and incentives to encourage participation in projects that improve farm biodiversity on farms and improve stock water infrastructure for landholders, to assist with drought preparedness and improved NRM outcomes.

Improvements in stock water and fodder storage

Growing numbers of ACT rural landholders are increasing their access to water for stock and domestic purposes through installation of bores, tanks, pipes, pumps and accessing stream water and potable town water (if economic). Improved stock water access allows landholders to open up more of their property to grazing during drought or establish sacrifice paddocks or drought lot feeding facilities. Much of this work has been assisted through rebates provided under the Australian Government's On-farm Emergency Stock Water Infrastructure Rebate Scheme.

ACT landholders are also increasing fodder storage (hay sheds, silos, silage) in order to store either farmed or purchased fodder for using during droughts. Some of this work has been supported by the ACT Rural Resilience Grants funded by the ACT Government. A number of landholders have also installed drought lot feeding facilities and sacrifice paddocks to contain stock and hand feed them fodder during drought to protect their pastures, maintain ground cover, and ensure quick recovery, diversity and reduced weed burden in recovering pastures, post drought.

Training in pasture management

ACT rural landholders are also accessing training either on their own initiative or with support from ACT NRM to increase their skills in pasture management under changing seasonal conditions, through courses such as Prograze offered by South East Local Land Services and Grazing Management training through regenerative agriculture organisations such as RCS and Holistic Management International. This training is helping them further their skills in how to measure pasture biomass and project future seasonal pasture growth based on standing biomass to inform improved farm, pasture and stock management and prepare for drought. They are also getting exposure to a range of tools that can assist in planning grazing, stock and pasture management, such as MaiaGrazing – Online Grazing Management; paper-based stock and feed budgets provided by RCS, MLA and other organisations; and the Farming Forecaster soil moisture probe which provides locally relevant data, based on local data collected at the ACT's soil moisture probe near Tidbinbilla and accessible through the Farming Forecaster website: Home page - PastureForecasting (farmingforecaster.com.au)

Farm business planning

ACT farmers have also embraced Future Drought Fund Farm Business Resilience programs offered by ACT NRM including Business Edge Training through Agrista /MLA; workshops and training in succession planning, Agri-tourism, farm diversification and other farm business activities; participated in farm business coaching and more. In addition, a core of 10-15 ACT farmers are coming together quarterly as the ACT Grazing Group, under the auspices of the ACT Regional Agricultural Landcare Facilitator and supported by grazier and chair of Upper Lachlan Landcare, to share knowledge on farm, stock and pasture management. This peer learning provides support and a forum for sharing knowledge and experiences, particularly leading into, during, and coming out of drought.

03

Climate and future drought risk

Defining drought

Drought is typically a slow-onset phenomenon that is driven by climate variables such as lower-than-average precipitation (including rain, sleet, snow, hail, or drizzle), often higher average temperatures, and increased evaporation.

It is frequently more recognisable through its associated impacts including reduced water availability, reduced soil moisture, reduced plant growth and reduced carrying capacity of the land, reduced on-farm biodiversity and more.[12] The Bureau of Meteorology defines drought as a prolonged abnormally dry period when the amount of available water is insufficient to meet our normal use. More information on defining and causes of drought is provided in Chapter 3 of the AECOM study.

ACT past droughts

Droughts are a recurring hazard in the ACT that are likely to increase in frequency, duration and intensity driven by climate change. Like much of NSW, the ACT experiences variability in its average climate conditions both over time (e.g. high temperatures in summer, low temperatures in winter) and spatially (the North-Eastern region of the ACT is warmer and drier than the alpine areas to the south-west). Large-scale weather patterns including El Niño Southern Annular Mode (ENSO), the Southern Annular Mode (SAM), and the Indian Ocean Dipole (IOD) also affect the region and the likelihood of drought. More recently, extreme climate events have increased in intensity, frequency, and duration. [13,14]

The ACT has experienced several periods of serious and severe drought, three recent examples include:

1982: Periods of rainfall deficiency which had a major impact on Canberra include the severe drought beginning in April 1982, which saw only 141.7 mm of rainfall over 9 months. Significant relief for Canberra came in the form of increased rainfall during the period of March-May of the following year.

2001 to 2009: Known as the Millennium drought, this period experienced drought episodes and a long-term decline in rainfall. For example, in February of 2004, Canberra received 79.8 mm of rainfall over a 6-month period.

2017 to 2020: Drought conditions were experienced in the ACT from 2018 to 2020. For example, in two separate 6-month periods during the two years, Canberra received less than 150 mm of rainfall. Section 3.2.2, "Drought in Focus – 2017 to 2019", explores this in greater detail.

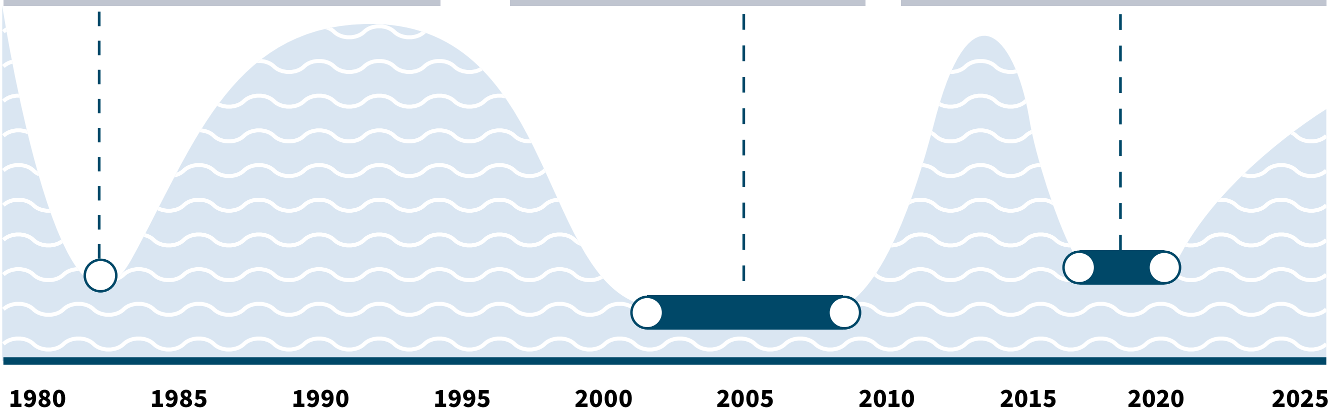

Figure 6: Periods of serious and severe drought

[12] BoM. (2022). Understanding Drought. http://www.bom.gov.au/climate/drought/knowledge-centre/understanding.shtml#:~:text=Drought%20is%20a%20prolonged%2C%20abnormally,be%20in%20almost%20perpetual%20drought.

[13] CSIRO. (2015). Climate Change in Australia Projections for Australia's NRM Regions. https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/168/CCIA_2015_NRM_TechnicalReport_WEB.pdf

[14] Australian Government, 2021, Australia State of the Environment, https://soe.dcceew.gov.au/

AECOM has compared a range of climate variables averaged over a 1910-to-1990-time frame with the same variables averaged across the 1990-to-2021-time frame, to compare recent climate trends with the longer-term historic record. This comparison shows the growing warming of the ACT climate in the 1990-2021 period, compared to the 1910 to 1990 period. This data was derived from the Bureau of Meteorology's (BOM) Australian Gridded Climate Data Set, regionalised for the study areas in the ACT. The seven climate variables compared included rainfall, Mean Maximum Temperature, Soil Moisture (root zone), and Extreme heat days (>35°C).

This comparison between the two periods established the following:

- Since 2008, there have been 13 periods of heatwaves
- The hottest temperature on record in Canberra was 44°C in 2019
- The four hottest summers and three hottest springs have occurred in the last 20 years
- 2019 saw the hottest January with a monthly average minimum temperature of 17.62°C recorded across the month, compared to 12.6°C baseline average from 1910-1990.
- On average the 1910-1990 period experienced 2.3 extreme heat days annually with the hottest year (1983) experiencing 8.71 extreme heat days
- In contrast on average the 1990-2021 period experienced 5.7 extreme heat days annually, with the hottest year, 2019, experiencing 23.34 extreme heat days.

Key climate variables that distinguished the 2017-2020 drought are captured in **Figure 7** below.

The 2017 – 2020 drought saw the lowest rainfall on record in the ACT. In two separate 6-month periods across these years, Canberra received less than 150 mm of rainfall.

The observed climate during this period included:

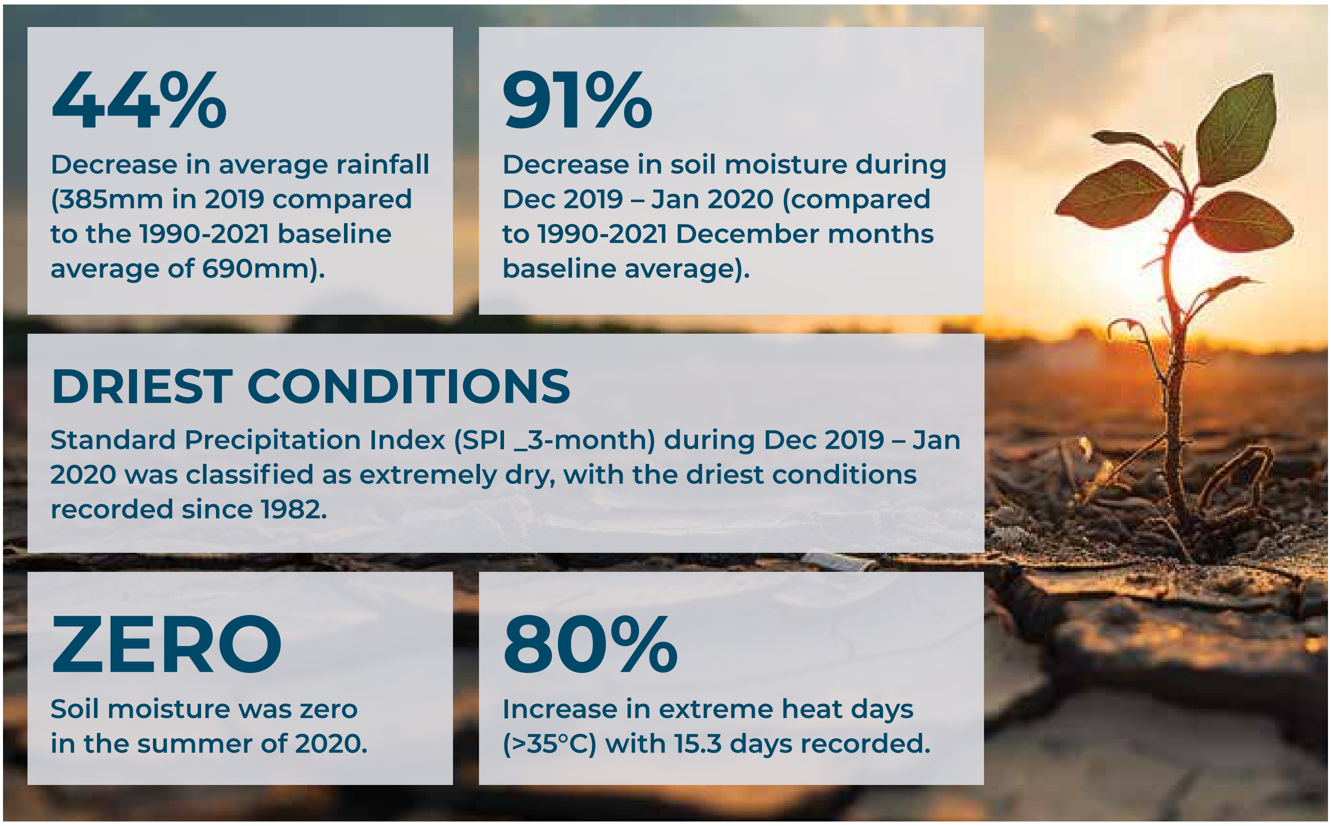

Figure 7: Drought in Focus – 2017 to 2020

Since AECOM finalised its work for the ACT, Canberra, national and global climate temperature records have been broken. 6 July, 2023 was the hottest day on record globally at 17.08°C; and June 2023, the hottest June on record globally (includes both northern and southern hemisphere temperature data); while Antarctica, a huge driver of global climate, experienced record low sea ice over winter. The Australian Capital Territory's mean maximum temperature in July 2023 came in around 2 degrees Celsius higher than the average.

Future climate and drought scenarios

Increasingly, the frequency, intensity and duration of droughts, will be influenced by climate change, which in turn will be influenced by global greenhouse gas emissions (emissions from burning fossil fuels and other activities that emit greenhouse gases to the atmosphere). This is because carbon dioxide and other greenhouse gases emitted into the atmosphere warm the planet, causing climate change.

To understand possible future drought-related impacts facing the ACT rural community, three future drought scenarios were developed by AECOM based on NSW and ACT's latest climate projections , derived from data provided from NARCLIM (NSW and Australian Regional Climate Modelling (NARCliM), a NSW Government-led initiative that generates detailed climate projections[15], for NSW, ACT and other parts of Australia.

These scenarios outline future climate change projections assuming a range of global greenhouse gas emission scenarios – ranging from an accelerated transition to a low carbon economy (whereby the world rapidly reduces green-house gas emissions and hence slows climate change); to a scenario whereby the world continues to emit high rates of green-house gases (hence doesn't address the causes of climate change, contributing to increased climate change). These scenarios are best read in the context of the AECOM study which can be found in **Appendix 1**.

Scenario analysis is an important tool for understanding and exploring the strategic implications of climate-related physical risks and opportunities. A scenario describes a path of development leading to a particular outcome. It provides an understanding of how resilient organisations are to a range of plausible climate-related scenarios, and how sensitive an organisations assets and operations are to the differences between these scenarios. Scenarios are not intended to represent a full description of the future, but rather highlight central elements of a possible future to draw attention to the key factors that will drive future developments. Scenarios are hypothetical constructs; they are not forecasts or predictions.

The three drought scenarios developed by AECOM are underpinned by what are called Representative Concentration Pathways (RCPs) which describe two potential scenarios of global climate emissions **(Table 3)**.

Table 3: Description of Representative Concentration Pathways (RCPs)

SCENARIO	DESCRIPTION OF SCENARIO[16]
RCP 4.5 (Low-medium emissions scenario – climate scenario derived from the average of the models)	Assumes a high level of mitigation (where the world reduces greenhouse gas emissions) with no active removal of atmospheric carbon dioxide. Emissions are anticipated to peak around 2070 and then remain consistent until 2100. This scenario assumes full uptake of renewable energy however no carbon capture to help reduce the levels of carbon dioxide. As a result, it is anticipated that temperature increases can be limited to 1.8°C by the end of the century (based on a 1985 – 2005 baseline) and while there will be some increase to extreme weather events due to historical climate change, these will result in medium level adaptation costs to mitigate risk (actions to manage the impacts of climate change).
RCP 8.5 (High emissions scenario – climate scenario derived from the average of the models)	Assumes minimal effort to reduce emissions. Emissions will continue to grow unchecked, marked by the continued use of conventional fossil fuel energy to power cities homes and businesses. Without sizeable intervention this scenario assumes an average temperature increase of up to 4°C by the end of the century (based on a 1986 – 2005 baseline). It will require costly adaptation to minimise the impact of extreme weather events which have continued to increase dramatically over the past century.
RCP 8.5 (High emissions scenario – climate scenario derived from the hottest/ driest model)	Same as above however when using this scenario, the the hottest and driest model is taken to assume worst case scenario, hence "hotter/ drier" climate scenario.

[15] In 2021, the NSW and ACT Regional Climate Modelling project (NARCliM 1.5) released a suite of improved climate change projections downscaled for NSW and the ACT. Compared to NARCliM 1.0 these models better capture the seasonal patterns and magnitudes of precipitation as well as the potential hotter and drier futures that are being experienced within these regions. NARCliM 1.5 also provides the added benefit of future projections for two AR5 scenarios to allow for a greater interrogation and understanding of future changes in climate in line with other modelling datasets compared to NARCliM 1.0. NARCliM 1.5 has been used to inform the climate projections for this study. Please see AECOM's study at Appendix 1 for a detailed overview of the climate data used to inform this modelling.

[16] Australian Govt. Department of the Environment and Energy, (n.d.). What are the RCPs?. https://coastadapt.com.au/sites/default/files/infographics/15-117-NCCARFINFOGRAPHICS-01-UPLOADED-WEB%2827Feb%29.pdf

Climate projections for the ACT

Under all three scenarios, the ACT's climate is projected to become warmer and drier, and experience more extreme weather events. These trends are more severe under scenarios with higher emissions. Projected higher average temperatures and reductions in average annual rainfall are likely to see periods of drought increase in both frequency and intensity. A summary of climate change projections under the 'middle' scenario RCP 8.5 (High emissions scenario) is outlined in **Table 4**.

Climate analogues

Changes to the ACT's climate now and into the future, mean it is more likely to resemble the climate of other warmer, drier regions in Australia. AECOM matched the projected future climates of Canberra with a similar climate currently experienced in another location, using annual average rainfall and maximum temperature as a basis for identifying Canberra's climate analogue locations. This allows Canberra to picture what the future climate of Canberra is under different emissions scenarios. Under the RCP 8.5 hottest and driest scenario analogue towns whose current climate represents what the ACT will look like in 2030 include Bairnsdale, Bathurst, Benalla, Albury,-Wodonga, Sale Bendigo, Young and Melbourne. Under the same scenario, in 2050 Canberra's climate will be similar to Ravensthorpe, Corowa, Echuca, Shepperton, Wagga and Kyabram.

More information on Canberra's analogue locations can be found in Chapter 3 of Appendix 1.

Table 4: Climate change projections under the 'middle' scenario for ACT in 1990-2009, 2030, 2045, 2070, 2090

Higher average temperatures

- with an **increase of about 1.8°C in both the average minimum and maximum daily temperatures** by 2045 compared to the 2000 baseline, increasing to about 3.3°C By 2070.
- **A shift towards extreme heat days** with, on average, at least 11 more days above 35°C each year by 2045, increasing to 18 more days by 2070.
- **A shift away from cold days** with, on average, more than 55 fewer days below 2°C each year by 2045, increasing up to 36 fewer days by 2070.
- **A reduction in total soil moisture** content with an 11% decrease annually by end of the century and an 18% decrease in December by the end of the century.

Likely decrease in annual rainfall

- **by 2045 by 3.1%**, further decreasing by 9% and 9.3% in 2070 and 2090 respectively.
- **Consecutive dry days (days without rainfall)** are projected to increase to 29 days in 2045, 32 days in 2070 and 36 days in 2090 compared to the 2000 baseline of 27 days.
- **Significant changes to seasonal rainfall distributions.** Summer rainfall is projected to increase and winter rainfall is projected to decrease.
- Despite the likely decrease in average rainfall, there is expected to be an **increase in extreme rainfall events,** which will also account for a great portion of all rainfall (i.e., on those days when it does rain, it is likely to be more intense, even if there are fewer days when it rains). Rainfall will likely decrease in winter and spring but increase in summer.

More detailed climate change/drought scenarios for the ACT can be found in Chapter 3 of the AECOM study.

04

Impacts of drought on the ACT rural community

The following section identifies the impacts of drought on ACT farms and the ACT farming community identified by both stakeholder engagement (workshops, interviews, and the survey) and the desktop literature review, based on future drought scenarios and climate observations.

The AECOM study uses a vulnerability framework as a lens to assist impact prioritisation by qualitatively rating exposure (i.e. to what extent does each impact affect multiple agricultural enterprise types) and sensitivity (i.e. to what extent are affected agricultural types likely to be impacted by the given impact).

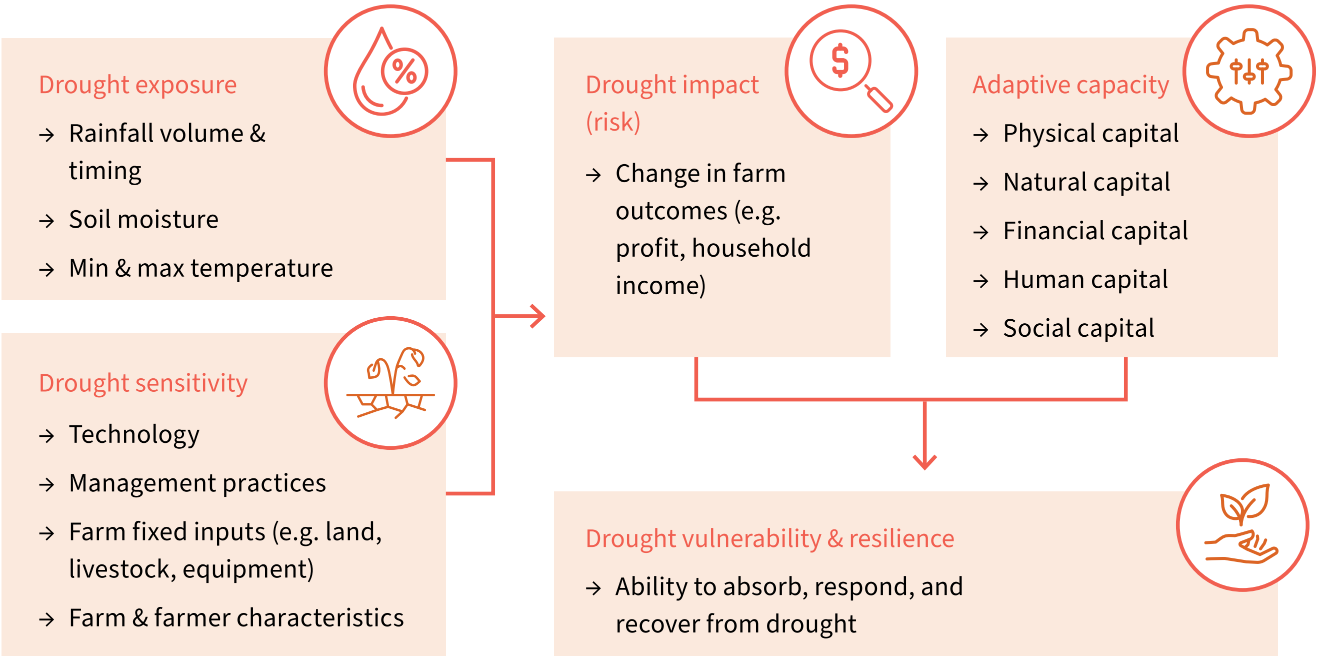

Figure 8: Framework for assessing drought vulnerability and resilience[17]

Priority impacts of drought

The Exposure and Sensitivity legend **Table 5** below, with AECOM's Impact Summary Study available at **Appendix 1**.

EXPOSURE		SENSITIVITY	
High	High degree of exposure e.g. impact will affect a very large proportion of enterprises and communities and have a significant impact on most impacted farm households.	High	High degree of sensitivity e.g. high financial and productivity impacts (for example if the farming practice has high reliance on what is being impacted).
Medium	Medium degree of exposure e.g. impact will affect multiple (and different) farming systems and communities, and the impact will be moderately significant.	Medium	Medium degree of sensitivity e.g. medium financial and productivity impacts (for example if the farming practice has moderate reliance on what is being impacted).
Low	Low degree of exposure e.g. impact will affect only a few farming systems and communities and the impact won't be significant.	Low	Low degree of sensitivity e.g. low financial and productivity impacts (for example if the farming practice has low reliance on what is being impacted).

Table 5: Exposure and Sensitivity legend

[17] Hughes, N., Burns, K., Soh, W., & Lawson, K. (2022). Measuring drought risk | The exposure and sensitivity of Australian farms to drought. https://www.agriculture.gov.au/abares/research-topics/climate/measuring-drought-risk#:~:text=This%20study%20presents%20estimates%20of,to%20display%20greater%20drought%20risk.

The AECOM study identified five priority drought impacts to which the ACT farming community and farming enterprises were generally all found to have high exposure.

The five priority impacts identified for the ACT are:

01 **Reduced water availability.**

02 **Increased weeds and pests.**

03 **Reduced carrying capacity of land.**

04 **Reduced on-farm biodiversity.**

05 **Reduced wellbeing of farming community.**

Other identified impacts are:

- Loss and damage due to increased occurrence of natural disasters
- Shifts in timing of farm activities/operations
- Damage to assets and infrastructure
- Increased crop/pasture sensitivity
- Heat stress on livestock
- Erosion of soil and crop damage
- Land becomes unsuitable for agricultural enterprises
- Increased need to import feed
- Increased financial vulnerability
- Safety and reduced employment

These impacts often affect communities across multiple strategic priorities used in this study (environmental, economic, social and governance), as impacts do not happen in a vacuum, often happen concurrently, and often have flow on effects to other areas. Despite this, this study categorises them to group specific identified impacts and actions together to assist in readability, monitoring and evaluation and to align with the FDF Strategic Priorities for drought as per **Table 6** below.

IMPACT	STRATEGIC PRIORITY			
	ENVIRONMENTAL	ECONOMIC	SOCIAL	GOVERNANCE
PRIORITY IMPACT				
Reduced water availability	●	●		
Increased weeds and pests	●	●		
Reduced carrying capacity of land	●	●		
Reduced on-farm biodiversity	●			
Loss and damage due to increased occurrence of natural disasters	●			
Reduced wellbeing of farming community			●	
OTHER IMPACTS				
Shifts in timing of farm activities/operations	●	●		
Damage to assets and infrastructure	●	●		
Increased crop/pasture sensitivity	●	●		
Heat stress on livestock	●	●		
Erosion of soil and crop/pasture damage	●	●		
Land becomes unsuitable for agricultural enterprises	●	●	●	
Increased need to import feed	●	●		
Increased Financial vulnerability	●	●	●	
Safety and reduced employment			●	

Table 6: Impact and Strategic Priority

The following sections describe the priority impacts in detail.[18]

"We were fortunate to access ground[water] allocation which meant we were able to provide clean and secure water for livestock."

Impact 1. Reduced water availability

PRIORITY IMPACT: REDUCED WATER AVAILABILITY

CONTEXT

Agricultural practices are highly dependent on the availability of water. The future drought scenarios project less water availability manifested as reduced surface water, groundwater, and soil moisture, as well as reduced water for irrigation and other uses. This is due to a combination of lower rainfall (particularly in winter and spring) and higher temperatures and hence higher evaporation reducing inflows to rivers and dams and reduced recharge rates for underground water. [D, 19] Despite increases in extreme rainfall events, soil may remain dry during these events due to increased runoff and increased soil water repellence reducing the soils capacity to soak up as much water. [D] Increases in extreme rainfall events lead to soil erosion and damage to crops and pastures.

IMPACTS

A direct impact of drought is reduced water availability and reduced soil moisture. ACT rural landholders noted reduced rainfall-derived farm surface water quantity and quality, and increased reliance on off-farm and non-surface water sources.

ACT rural landholders noted that dams and on-farm water storage dried up in droughts.[A, B, D] This reduced water availability for farms which relied on surface water. Some landholders used town water to continue to service paddocks and house water demands[B], whilst others noted a reliance on bore water to water livestock[C]. Some landholders noted they made use of natural springs to water stock. This allowed them to keep stock out of riparian corridors and protect these areas of native biodiversity.

Cropping enterprises are more sensitive to drought than livestock farms. Low water availability has a close relationship with yield for irrigated crops[D], and reduced water quality can also affect the quality of food crops.[D]

In addition to reduced water quantity, landholders noted that it was a challenge to maintain dam water quality in drought, with water quality in dams degrading and requiring treatment.

Flow on impacts of reduced water quantity and quality in drought include reduced production, and reduced stock health and growth, particularly for irrigated crops.[D]

PRIORITISATION

EXPOSURE	SENSITIVITY	
High exposure due to all farms likely to be affected by reduced water availability.	High sensitivity due to heavy reliance on water availability.	Reduced water availability because of a changing climate will have far-reaching impacts across both primary production and other agricultural enterprises in the ACT. A decrease in available water can cause production and yield to decrease impacting high value farms. Given that all farms are likely to be affected by this impact (high exposure) and all farms are sensitive to this impact (high sensitivity), this is categorised as a priority impact.

Legend: *priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[18] Given grazing systems (including both cattle and sheep) are the dominant agricultural enterprise in the ACT, there is a significant focus within the discussion on these systems. Other agricultural types (such as viticulture) are separately discussed where appropriate in AECOM's study at Appendix 1. Additional priorities have been identified by the ACT Government based on extensive engagement and first-hand experience of drought impacts on the ACT's rural community and include Heat stress on poultry, heat stress on livestock and damage to pastures and grazing operations.

[19] AdaptNSW. (2022). Climate projections used on AdaptNSW. https://www.climatechange.environment.nsw.gov.au/climate-projections-used-adaptnsw

*"Lots of weeds getting blown in
- if our neighbours have it, we'll have it."*

Impact 2. Increased weeds and pests

PRIORITY IMPACT: INCREASED WEEDS, PEST ANIMALS AND DISEASES

CONTEXT

Climate change will affect the spread and competitiveness of weeds, pest animals and diseases of livestock in the ACT, impacting on crops, pastures and livestock health and productivity

IMPACTS

It was noted that periods of drought and elevated grazing pressure resulted in weeds gaining a foothold. [A, D] This led to a proliferation of weeds following drought, of which African lovegrass was of particular concern to landholders. [A] This can have a significant impact on farm businesses recovering from periods of drought.

With minimum temperatures increasing, landholders noted that more weeds were blowing in from neighbouring properties/public land and that poor management of weeds on neighbouring properties nullified good management on their property. [A]

Weed spreading events will increase with increased incidence of flooding, bushfires, and winds [D] and transport by native and pest animal species. The costs of weed management are also likely to increase. [D] This is significant, as weeds are one of the costliest agricultural pests.[20]

Wild and feral animals may carry diseases that can infect livestock, including Foot-and-mouth disease (FMD), Johne's disease, sheep measles, Newcastle disease, leptospirosis, and anthrax.[21] Drought conditions can amplify the effects of parasites and infectious diseases through increased transmission in crowded conditions such as around water and feed sources and lowered immunity associated with poor nutrition. [22]

These impacts ultimately result in a reduction in agricultural productivity and damage to the environment and natural resources. [D] In the case of serious and highly contagious diseases such as FMD, if they were to occur in Australia, would cause severe economic losses and restrictions to Australian livestock industries and domestic and international markets for live animals, meat and animal products.

PRIORITISATION

EXPOSURE	SENSITIVITY	
High exposure due to all farms having the potential to be impacted by weed, pest animal and stock diseases infestations.	High sensitivity due to lack of control once a weed infestation occurs and the financial and lost productivity impacts that result.	Grazing industries and other agricultural enterprises are subject to these infestations and with greater climatic variations, pest plant and animal and stock disease management will become more important. Development and continual updating of farm and ACT farming community biosecurity plans addressing key threats is essential along with increased pest plant and animal and disease surveillance, especially as pest life cycles change in response to climate change. The exposure and sensitivity are high due to the significant financial impact pest plants and animals and disease have, both in terms of control and lost productivity, and in the case of diseases of stock, loss of farm income.

Legend: *priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[20] Schonbeck, M., & Tillage, B. (2011). Principles of sustainable weed management in organic cropping systems. In Workshop for Farmers and Agricultural Professionals on Sustainable Weed Management (Vol. 3, pp. 1-24). Clemson, SC, USA: Clemson University.

[21] Department of Primary Industries. (2022). Biosecurity, wildlife and feral animals. https://www.dpi.nsw.gov.au/biosecurity/animal/wildlife-and-feral-animals.

[22] Agriculture Victoria. (2022). Animal health in a drought. https://agriculture.vic.gov.au/livestock-and-animals/livestock-health-and-welfare/animal-health-in-a-drought.

“Learned to de-stock early before you graze too hard.”

Impact 3. Reduced carrying capacity of land

PRIORITY IMPACT: REDUCED CARRYING CAPACITY
CONTEXT
Carrying capacity is the average number of animals that a grazing area can be expected to support over a set period.[23] During times of drought, the carrying capacity of the land is reduced. During periods of drought, many farmers destock to sustain the remaining livestock. Strategies to minimise the economic impacts of reducing stock numbers include selling feeder animals early, reducing breeding animal numbers, and selling the entire herd.
IMPACTS
Drought results in increased costs and decreased production and income.[24] Landholders were unable to maintain pre-drought stocking levels and needed to destock during and in the lead-up to drought periods. Selling livestock enabled landholders to reduce the financial and environmental costs of keeping animals on the land in dry periods by avoiding the need to buy supplementary feed and reducing the impact of livestock traffic on bare soil [A]. Landholders used drought plans and weather predictions to decide when to destock.[B] They also noted a need to sell earlier going into a drought [A], and that it took a long time to build stock numbers back up, and recover economically from destocking.[A, B] Landholders also noted that buying-in feed was expensive and the embodied energy used to transport the feed (‘food miles’) was considered high. Landholders had to factor kangaroo grazing pressure into grazing calculations and decisions around stock management. [A] kangaroos contribute significantly to grazing pressure. To ameliorate some of these impacts, landholders allowed their cattle to graze in roadside vegetation, or ‘bush paddocks’ during drought to supplement feed and reduce the fire risk of biodiversity corridors, which could otherwise facilitate the movement of fire across the landscape. However, this can have a negative impact on on-farm biodiversity.

PRIORITISATION

EXPOSURE	SENSITIVITY	
High exposure due to the current lack of stock management techniques currently practised across farms.	High sensitivity due to the productivity and profitability loss from de-stocking as well as the long recovery times.	Grazing enterprises in the ACT have both high exposure and high sensitivity to managing appropriate stock levels due to the impacts of drought making it challenging to recover from times of destocking and the increasing costs to buy-in feed.

Legend: *priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[23] Queensland Government (2016) Understanding carrying capacity and stocking rates in grazing systems. Queensland Government. Accessed on 18 October 2022, https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/grazing-pasture/improved-production/carrying-capacity#:~:text=Long%2Dterm%20carrying%20capacity%20is,(e.g.%2010%2B%20years).

[24] MLA (2021) Drought feeding. Meat and Livestock Australia. Accessed 18 October 2022, mla.com.au/research-and-development/livestock-production/livestock-nutrition/drought-feeding/

“Following the 2003 bushfires, it took 12 years to see a possum again.”

Impact 4. Reduced on-farm biodiversity

PRIORITY IMPACT: REDUCED ON-FARM BIODIVERSITY		
CONTEXT		
Loss of biodiversity and ecosystem services (such as pest regulation, water purification, and pollination) leaves agricultural systems more vulnerable to threats such as pests, pathogens, and continued impacts from climate change. The loss of biodiversity observed by ACT landholders in drought is consistent with scientific literature.		
IMPACTS		
Impacts to on-farm biodiversity and impacts on the farm enterprise from on-farm biodiversity were noted by ACT rural landholders. The grazing pressures from kangaroos during drought were considered a significant impact, with one landholder quoting that each kangaroo was equivalent to three-quarters of the same number of sheep. That is, having 100 kangaroos grazing on the property was equivalent to carrying an additional 75 sheep. [A] The significance of kangaroo grazing impacts, which are exacerbated by drought is echoed in other jurisdictions and presents a complex environmental, social, and economic problem for management. [25]		Additionally, ACT landholders observed the impacts of the drought on on-farm biodiversity. Landholders noted that during heatwaves, small birds in enclosed nests were observed dead in their nests due to the extreme heat. One landholder noted that after the 2003 bushfires it took twelve years to see a possum on the property again. [B] Another noted that in their bush paddock, a quarter of the trees died out during drought. [B] Landholders generally felt a responsibility to support native wildlife during drought. [A] Damage to biodiversity and ecosystem functioning can have flow-on effects on farm health and productivity. Healthy ecosystems benefit farms by providing services, such as pollination, controlling soil erosion and maintaining water quality for farm use. [26 B]
PRIORITISATION		
EXPOSURE	**SENSITIVITY**	Exposure and sensitivity are high due to biodiversity loss reducing ecosystem functioning, resulting in less productive farms, and added pressure for farmers to support native wildlife.
High exposure due to all farms likely to be affected by reduced biodiversity.	High sensitivity due to the dependence agriculture has on health ecosystems.	

Legend: *priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[25] Hacker R. B., Sinclair K., Pahl L. (2020) Prospects for ecologically and socially sustainable management of total grazing pressure in the southern rangelands of Australia. The Rangeland Journal 41, 581-586. https://www.publish.csiro.au/rj/rj20006

[26] Power, A. (2010). Ecosystem services and agriculture: tradeoffs and synergies. https://royalsocietypublishing.org/doi/10.1098/rstb.2010.0143

"Increased worry about bushfires."

Impact 5. Reduced wellbeing

PRIORITY IMPACT: REDUCTION IN WELLBEING

CONTEXT

The most significant social impacts of drought include erosion of income resulting in rural poverty, increased workloads, physical and mental health and welfare issues, problematic access to services and overload on service providers, declining access to education, and isolation.[27] Some of these impacts are less applicable to the ACT context and were not raised by landholders. This could be due to the proximity to Canberra as a major source of services and employment, and the prevalence of off-farm income among the ACT rural landholder community. This means that access to services including education and health and mental health services is less affected by drought, and therefore isolation is reduced.

Other disasters such as bushfires have physical and mental health impacts on rural communities. A significant cost of the 2019-2020 bushfires was the physical health impacts from smoke inhalation by farmers and others who work outdoors, as well as the broader ACT and region community.[34]

It is well established that bushfires and other natural disasters have long-term effects on the mental health of affected individuals and communities.[28] The effects of these events can last for years.[29] The 2019 - 2020 bushfires in Australia were catastrophic and unprecedented.[30]

Studies have found that in addition to immediate distress related to financial and workload problems, people reported experiencing significant distress from the emotional impact of environmental degradation, from loss of hope for the future of their community, and from feelings of being misunderstood by the wider Australian community.[31] The stressors affecting farming communities during times of drought are likely to be associated with increased risk of mental health problems.

IMPACTS

Wellbeing impacts include:

- Reduced health and mental wellbeing from recent pressures including climate change, drought, pest plant and animal and disease outbreaks [D]
- Reduced wellbeing due to working long hours, having physically demanding work, and often being isolated socially and geographically from services [D]
- Increased concerns about bushfires, and concerns related to evacuations [A]
- Increased exposure to challenging working conditions (e.g. days with temperatures exceeding 35°C)
- Financial management pressures during periods of lower revenues and/or increased capital expenditure and operational expenditure.

PRIORITISATION

EXPOSURE	SENSITIVITY	
High exposure due to increasing frequency of climate events (droughts, bushfires, flooding etc) without sufficient recovery periods in between.	High sensitivity due to range of impacts faced including health , mental wellbeing, and financial pressures.	Climate change may increase the risk of mental health impacts among farmers as they face the hardships of practising agriculture under a changing and highly variable climate. The sensitivity and exposure are high as these impacts are making farmers and their agricultural systems more vulnerable.

Legend: *priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[27] Alston, Margaret, and Jenny Kent. 2004. Social Impacts of Drought : A report to NSW agriculture. Wagga wagga, NSW: Centre for Rural Social Research, Charles Sturt University.

[28] Black Dog Institute. 2020. Mental Health Interventions Following Disasters. Randwick, NSW, Australia: Black Dog Institute.

[29] Gibbs, L., Waters, E., Bryant, R. A. et al. 2013. "Beyond Bushfires: Community, Resilience and Recovery - a longitudinal mixed method study of the medium to long term impacts of bushfires on mental health and social connectedness." BMC Public Health.

[30] Morton, A. 2020. "Yes, Australia has always had bushfires: but 2019 is like nothing we've seen before." The Guardian, 25 December.

[31] Sartore, G., Kelly, B., Stain, H., Albrecht, G., & Higginbotham, N. (2008). Control, uncertainty, and expectations for the future: A qualitative study of the impact of drought on a rural Australian community. https://search.informit.org/doi/abs/10.3316/INFORMIT.471246494717588

Other environmental, social, economic and governance impacts of drought

Impacts from increased occurrence of natural disasters

Extreme events, especially floods and droughts, can harm crops and pastures and reduce yields. [D] Bushfire risk is also exacerbated by drought conditions due to very dry vegetation and soils and record-breaking heat.[32] Drought and heatwaves intensify the drying of dead bushfire fuel and can even lead to megafires which are defined by their enormous size and the number of resources required to bring them under control. In addition, floods can follow bushfires, compounding the effects of natural disasters. [A] There is projected to be higher occurrences of fluctuating extremes. [D] Extreme high rainfall events can also lead to erosion of soil and damage to crops, particularly where soil infiltration is reduced.

Damage to assets and infrastructure

Damage to assets and infrastructure on farms in the ACT can be caused by natural disasters including bushfires. Costs include damage to farm fencing, buildings and equipment, and a reduction in farmland values, loss of crops and pastures and livestock deaths.[34]

Bushfires resulted in long-term impacts on soil health. Fire can damage soil microbial communities, as well as many nutrient and organic matter cycling functions.[35] A landholder reported that after the 2003 bushfire the soils on their property became hydrophobic (repelled water). The recovery from this took 6 – 7 years following the bushfire.

Unsuitable land for agricultural enterprises

Land for agriculture may become less suitable for certain enterprises due to longer droughts and harsher fire weather causing crop and pasture stress and attracting new pests that thrive in warmer temperatures.[36] As a result of more extreme temperatures, a landholder with a horticulture enterprise noted that they could no longer grow crops on the same side of the hill that they had previously, and had to adapt their management accordingly to find more suitable locations.[A]

Shifts in the timing of farm activities and operations

The seasonal timing of farm management actions is changing, this is particularly prevalent in the viticulture industry (more information on viticulture is available in AECOM's Study **Appendix 1**, Section 6.6). While livestock-rearing stakeholders didn't raise this as a key impact at this stage, there is evidence this will be a rising issue into the future.[37][38] Research into climate change adaptations in Australian grazing systems synthesised research on key adaptation responses to climate change. This included changing timing of calving and lambing to fit in with changed seasonal patterns of pasture growth; and adjusting stocking rates according to seasonal conditions. ACT farmers are already using seasonal forecasting tools to make decisions around stocking rates and purchasing fodder.

In addition, many important animal diseases are affected directly or indirectly by weather and climate. These links may be spatial (with changes in climate affecting disease distribution) or temporal (with weather affecting the timing of an outbreak) or may relate to the intensity of an outbreak.

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[32] Climate Council, 2019, Dangerous Summer: Escalating bushfire, heat and drought risk, https://www.climatecouncil.org.au/wp-content/uploads/2019/12/report-dangerous-summer_V5.pdf

[33] UNSW Sydney, 2021, How heatwaves and drought combine to produce the perfect firestorm, https://newsroom.unsw.edu.au/news/science-tech/how-heatwaves-and-drought-combine-produce-perfect-firestorm

[34] Strom, M (2021) Black Summer bushfire season cost farmers up to $5 billion. University of Sydney. Accessed on 18 October 2022, https://www.sydney.edu.au/news-opinion/news/2021/12/13/black-summer-2019-20-bushfires-cost-farmers-5-billion-australia.html

[35] Farrell, M. (2020). Recovery of Australia's soils following bushfires - ECOS. https://ecos.csiro.au/soil-fire-recovery/

[36] AdaptNSW (2022) Climate change impacts on drought. https://www.climatechange.environment.nsw.gov.au/drought#:~:text=Drought%20has%20huge%20impacts%20on%20Australia's%20agriculture%20industry%2C%20causing%3A,leading%20to%20shortages%20in%20supply

[37] Henry, B.K. & Charmley, E. & Eckard, Richard & Gaughan, J. & Hegarty, Roger. (2012). Livestock production in a changing climate: Adaptation and mitigation research in Australia. Crop and Pasture Science. 63. 191-202. 10.1071/CP11169.

[38] Cullen, Brendan & Harrison, Matthew & Mayberry, Dianne & Cobon, David & Davison, Tom & Eckard, Richard. (2021). Climate change impacts and adaptation strategies for pasture-based industries: Australian perspective. NZGA: Research and Practice Series. 17. 10.33584/rps.17.2021.3476.

Heat stress on livestock

Livestock experience heat stress resulting in reduced appetites, less desire to breed, increased animal stress and significant productivity loss for the livestock industry.

"Heat stress" has been attributed to significant economic losses in production animals both overseas and in Australia. As far back as 20 years ago, annual losses due to heat stress in the USA livestock and poultry industries were calculated to be between $1.69 and $2.36 billion, with the cost to the beef industry alone being around $370 million.[39, 40]

In Eastern Australia in 1991 four thousand cattle deaths were attributed to heat stress, and in 2000 1255 cattle deaths were attribute to heat stress. In 2006, it was estimated that heat stress resulted in a $16.5 million loss to the Australian feedlot industry.

While there has been a focus on tropical, sub-tropical and arid climates, the increasing risk of the negative impacts of heat stress on the efficiency of production of grazing ruminants in temperate regions has been recognised. A significant challenge for ACT producers going forward will be preparing for and managing heat related injury in cattle and sheep.

High ambient temperature is recognised as a current and future critical problem for livestock. Increasingly, attention is being directed to find ways to mitigate financial losses and welfare concerns resulting from the impacts of heat-stress on health, growth, reproduction, and production. These impacts include:

→ Reduced growth and development

→ Compromised immunity predisposing to an increased incidence of disease

→ Nutritional deficiencies

→ Lower fertility, conception rates and birth rates, increased foetal abnormalities and death, lower birth weights

→ Reduced quality of colostrum, decreased milk production

→ Adverse impacts on meat and wool quality[41 42]

Heat stress in free-range poultry

Heat stress is one of the most important environmental stressors challenging poultry production world-wide and is considered by some to be the most debilitating stressor. Extreme heatwaves have already caused devastating losses for the poultry industry. In 2006, a major heat wave in the United States resulted in the sudden death of more than 700,000 poultry in California.

In a survey undertaken of Australian free- range egg producers, flock losses due to heat stress were ranked second only to predation. However, this is reflecting only a part of the total losses to an enterprise when the impact of heat stress on bird performance and production are also considered.

A major concern for ACT free-range egg producers will be managing flocks, both now and into the future, to minimise the impact of hot weather events and heat related injury on animal health/welfare and farm profitability.

Erosion of soil and crop damage

Extreme rainfall events lead to erosion of soil and damage to crops. Despite rain events, the soil may remain dry due to its inability to soak up as much water during an extreme rainfall event. This can increase flood and erosion risk and can be exacerbated by other extreme events. Erosion and crop damage was not raised by ACT landholders as a significant concern.

However, the ACT Government has identified the following impacts of future drought on soil:

→ Reduced rainfall and increased temperatures will lead to:

- drier topsoil, reduced soil structure and soil porosity leading to more compacted soils, reduced soil water holding capacity, increased soil erosion and reduced plant growth
- reduced soil organic carbon
- changes in soil nutrients and soil pH could impact on crop and pasture species
- increased wind erosion

[39] St-Pierre, N.R.; Cobanov, B.; Schnitkey, G. Economic losses from heat stress by US livestock industries. J. Dairy Sci. 2003

[40] Thornton, P., Nelson, G., Mayberry, D., Herrero, M. (2021) Increases in extreme heat stress in domesticated livestock species during the twenty-first century. Glob Change Biol. 27:5762–5772

[41] Lees, A. M., Sejian, V., Wallage, A. L., Steel, C. C., Mader, T. L., Lees, J. C., & Gaughan, J. B. (2019). The impact of heat load on cattle. Animals, 9(6), 322

[42] Idris M., Uddin J., Sullivan M., McNeill D.M., Phillips C.J.C. Non-Invasive Physiological Indicators of Heat Stress in Cattle. Animals. 2021; 11(1):71

- reduced rainfall but more frequent extreme rainfall events
- increased soil erosion, loss of topsoil and loss of soil nutrients
- loss of soil into waterways
- reduced soil health

Catastrophic fires, as seen in 2019-2020 fires, including the ACT's Orroral Fire caused catastrophic soil erosion turned soils hydrophobic (soils repel water and can't absorb rainfall or runoff); and reduced the seed store in the soil (pastures, native vegetation), constraining recovery of soils and vegetation crop losses due to the bushfire smoke were also a significant impact, particularly for the viticulture industry (refer to AECOM Study, **Appendix 1**, Section 6.6 for more detail on these impacts on viticulture).

Economic impacts

Economic impacts identified through stakeholder engagement and the literature review included:

→ Increased need to import feed

→ Financial vulnerability

These impacts are expanded on below

Increased need to import feed

When there is less pasture available for stock to eat due to drought, buying in feed to supplement rain-fed pastures is costly and compounded by increased costs of off-farm fodder purchased during drought periods.[B] Increased demand for feed during the most recent drought meant landholders had to source feed from further away, including Western Australia and Tasmania. Feed prices were therefore higher due to the additional transport costs [A] as well as the scarcity of feed. Higher feed costs contribute to the general trend of higher input costs experienced by farms in drought.

Financial vulnerability

Farm drought risk varies significantly across industries, with cropping enterprises more sensitive to drought than livestock enterprises. Crop yields are directly linked to weather conditions, leading to large, immediate declines in revenue during drought years. In contrast, livestock producers can smooth climate impacts over multiple years by selling livestock in drought years, which helps maintain revenues in the short-term and offset lower prices received and higher costs.[43]

The least profitable years for farmers tend to be drought years with unfavourable prices. Costs are increased for feed, fuel and fertilisers and other farm inputs such as herbicides. Nationally, average farm returns decreased in 2018-19 in drought-affected regions.[44] There is subsequently a greater need for financial assistance during drought leading to an increased need to access grants and/or to rely on off-farm income. A key factor identified by stakeholders that mitigated the impacts of the 2017 – 2020 drought was the high demand for Australian sheep and cattle which pushed prices to, in some cases, historic highs. In times of future drought, global and local political, economic, and social trends may not provide the same protections.

Impacts on pastures and grazing enterprises.

Increasing temperatures, reduced rainfall in winter and spring, and in the main pasture growing season from April to October are impacting ACT grazing enterprises. Average changes in climate parameters can mask the impacts of specific extreme events, such as consecutive days of maximum temperatures over 35°C or periods of intense rainfall, and which are outside the envelope of projected average changes to climate.

Changes in rainfall and climate are impacting pasture species by changing the persistence of temperate, cool climate, high rainfall species, such as perennial ryegrass and white clover.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[43] Hughes, N, Burns, K, Soh, WY & Lawson, K 2020, Measuring drought risk: the exposure and sensitivity of Australian farms to drought, ABARES report to client, prepared for the Department of Agriculture, Water and the Environment, Canberra, November, DOI: https://doi.org/10.25814/mqrp-rp16. CC BY 4.0.

[44] ABARES Insight, 2019, Analysis of the effects of drought and climate variability on Australian farm

Climate change and drought conditions are currently and will continue to have detrimental effects on pastures through extreme events and cascading disasters, e.g. flood, fire, heatwaves and drought. These impacts lead to greater reliance on the purchase of supplementary feed/fodder, particularly when there is high demand and prices are very high and supplies limited due to drought.[45]

Social impacts

Safety and reduced employment

Social impacts identified through stakeholder engagement and the literature review included safety concerns and reduced employment.

Physical health and welfare impacts were identified to be a concern of ACT landholders including occupational health and safety risks to farm workers with increasing temperatures. Landholders expressed heat-related safety concerns for their staff. Heat stress can also reduce labour capacity in agriculture. There were concerns that during drought and times of financial stress there is less work available for people who rely on the agricultural sector for employment.

Governance

Governance impacts were less frequently raised during engagement activities however the following impacts have been identified:

→ Managing more frequent droughts places stress on governance systems.
  - Government resources are diverted to drought response activities, redirecting staff from other strategic workstreams.
  - Introduces greater reliance on financial assistance.
  - Financial implications for the government providing grants are significant and as drought events occur more frequently and/or for longer periods they will increase in cost with time.
  - Perceptions by the greater community present reputational risks for the government if drought response is not seen as reasonable.

→ Timing of when drought is declared.
  - Concerns raised about the lack of clear direction from government authorities regarding the declaration of drought drove some challenges in farmers accessing federal financial relief. This also contributed to perceptions within the farming community they were not a priority for the government.

→ Availability of drought assistance
  - Challenges were noted by farmers regarding access to financial aid because of strict eligibility criteria.

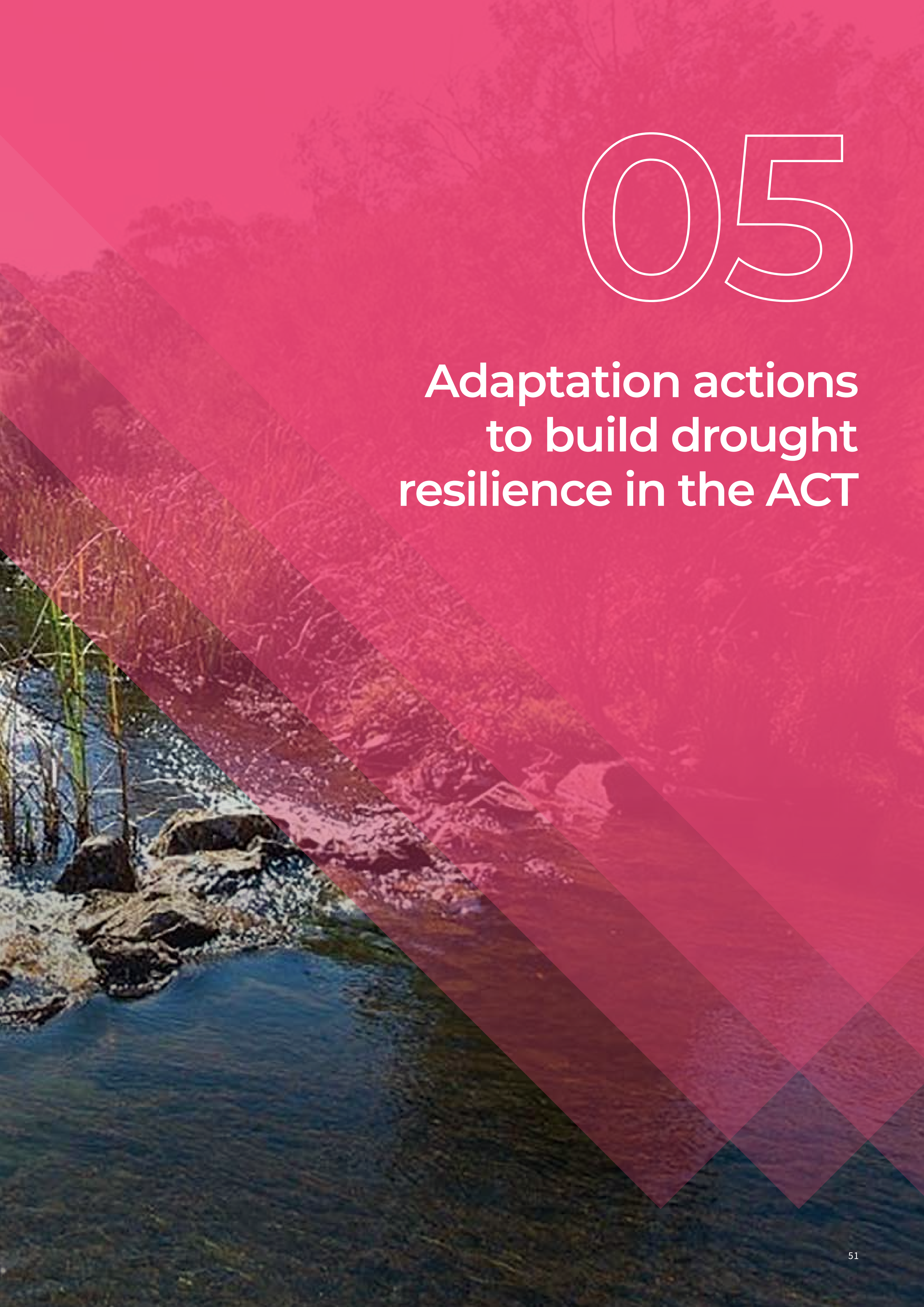
→ Different approaches between NSW and ACT impacting competitiveness.
  - Pricing of water extraction, for example, was raised as an inconsistency for farmers competing with peers over the border.

→ Simultaneous, widespread, and long duration droughts impacting ability for farmers to leverage support from other regions who were also experiencing drought conditions.

[45] Cullen, Brendan & Harrison, Matthew & Mayberry, Dianne & Cobon, David & Davison, Tom & Eckard, Richard. (2021). Climate change impacts and adaptation strategies for pasture-based industries: Australian perspective. NZGA: Research and Practice Series. 17. 10.33584/rps.17.2021.3476.

05

Adaptation actions to build drought resilience in the ACT



Overview

Farming in the ACT will continue to be affected by drought into the future. Future projections for drought mean the identification, analysis/assessment and implementation of adaptation measures is increasingly vital to protect the contribution rural landholders make towards the ACT's environment, economy, and community.

Climate adaptation on Australian farms is impeded by barriers including financial and resource limitations; behavioural barriers that limit implementation capacity by individual farmers; and unclear benefits that spread widely across society and are not appropriately captured.[46] To overcome these barriers, public-sector intervention and government support are needed to support adaptation by farmers.

Adaptation

Adaptation refers to adjustments in environmental, social or economic systems, and governance in response to actual or expected climatic changes and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.[47]

The vulnerability of agriculture towards climate change warrants a strong adaptation response to limit the impacts felt. Agricultural communities are adjusting to climate change. However, continual focus on adaptation is needed. Adaptations at an individual level include changes to on-farm practices and processes to respond to the physical risks of climate change. Adaptations at a government level include changes in decision-making to foster the implementation of these actions.

ABARES has reported evidence of strong adaptation responses from farms to climate change. In addition, improvement in management practices is helping to increase farm productivity.[48] Despite this adaptation and improvement in productivity, climate change events are becoming more frequent and severe and the time intervals between recovery periods are shortening. As a result, farm profits are becoming more sensitive to drought impacts. Further adaptation is needed to maintain resilience as well as competitiveness in international markets.

ABARES notes the following key themes in adaptation which could help offset future climate impacts:

- Improvements in technology.
- Farm structural change (such as changes to sizes of farms and degree of specialisation vs diversification).
- 'Transformational change' on farms and in the farming sector.

In addition, the Australian Government released the Drought Response, Resilience and Preparedness Plan in 2019 which focuses on 3 key areas of action for drought resilience which are captured in **Table 7**.[49] These are suggested actions and are currently being explored, not finalised.

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[46] Arunanondchai, P., Fei, C., & McCarl, B. (2017). Adaptation in Agriculture. https://www.intechopen.com/chapters/58043

[47] United Nations, n.d. What do adaptation to climate change and climate resilience mean? https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean

[48] Hughes, N., & Gooday, P. (2022). Climate change impacts and adaptation on Australian farms. https://www.agriculture.gov.au/abares/products/insights/climate-change-impacts-and-adaptation

[49] Department of Agriculture. (2019). Drought in Australia | Australian Government Drought Response, Resilience and Preparedness Plan. https://www.agriculture.gov.au/sites/default/files/documents/aust-govt-drought-response-plan_0.pdf

Table 7: Key areas of action for drought resilience identified by the Department of Agriculture, Forestry and Fisheries

IMMEDIATE ACTION FOR THOSE IN DROUGHT - MEASURES TO SUPPORT FARMERS AND COMMUNITIES FACING PROLONGED DROUGHT CONDITIONS	SUPPORT FOR WIDER COMMUNITIES AFFECTED BY DROUGHT	LONG-TERM RESILIENCE AND PREPAREDNESS - ACCEPTING THAT THE NEXT DROUGHT IS INEVITABLE AND THE IMPORTANCE OF BUILDING CAPACITY TO WITHSTAND DROUGHT PERIODS IN THE LONG-TERM.
→ Farm Household Allowance, an income support payment for farmers and their partners experiencing financial hardship. → Access to rural financial counselling services. → Access to concessional loans. → Better on-farm water management. → Providing better information. → Making up to 100GL of water available at $100 per megalitre in the southern connected Murray–Darling Basin (MDB) to increase the production of fodder, silage and pasture. → Dealing with the stress of drought through investment in mental health services. → Battling pests and weeds.	→ Keeping drought-affected regional communities open for business. → Financial counselling for small businesses. → Keeping kids in schools.	→ Future Drought Fund. → Water security initiatives. → Investment into research and development to build drought resilience. → Effective and strategic management of Australia's soil, vegetation, and water resources.

Summary of adaptation actions

Adaptation actions have been identified through stakeholder engagement activities and a desktop literature review. Focus actions have been identified through consideration of the impacts of drought in the ACT, relevance in the context of future drought scenarios, literature review, and stakeholder engagement feedback. Prioritisation of these focus actions has been informed by the frequency at which actions were raised by stakeholders (as an indicator of broad applicability across ACT's community) and through mapping to identify the potential application for actions to address impacts – prioritising those actions that address multiple impacts. This document explores a range of potential adaptive actions for consideration by rural landholders, the ACT Government, and other stakeholders. Adaptation actions have been grouped under the strategic priorities of environment, economic, social and governance and categorised into themes including land management, enterprise section, water management, stock management, infrastructure, planning and regulations, knowledge sharing and information provision, well-being, monitoring, fire management, management timing, weed and pest management, land management tools, marketing, and pasture/crop management.

During stakeholder engagement, the most frequently mentioned environmental adaptation category was land management, followed by enterprise selection, water management, stock management and then infrastructure. These categories and their respective actions are explored in the following chapter. Fundamental to all of these is drought planning at a farm-level to enable farmers to undertake a SWOT analysis and identify gaps, opportunities, risks and how they plan to improve all dimensions of farm management under future drought conditions and where Government and community play a role.

"Our farm manages high-risk fire areas through grazing management".

Environmental adaptation actions

During stakeholder engagement, the most frequently mentioned category of environmental adaptation actions was land management, followed by enterprise selection, water management, stock management, and then infrastructure. Collectively actions related to these themes comprise three-quarters of environmental categories measures identified by ACT landholders.

CATEGORY: LAND MANAGEMENT
CONTEXT
Landholders can prepare for and minimise the impacts of drought, by developing resilient land management practices. Land management covers practices which cultivate certain aspects or arrangements of the agricultural system, and which are centred on managing the land, and its capability.
ADAPTATION ACTIONS

Land management strategies identified by landholders to foster resilience in drought included:

- → Improve farm business management planning in preparation for drought and other extreme events.
- → Planting trees for shade, shelter and heat protection and biodiversity. [A,B,C]
- → Carrying less stock.
  - Having clear trigger points to de-stock which are decided on before drought. [A]
  - Having early trigger points to de-stock. [A]
- → Monitoring pastures and pasture biomass and ground cover, creating feed budgets to make informed decisions around when to buy feed and sell stock [B] Rotational grazing: grazing stock in smaller paddocks, at a higher intensity for shorter periods. [A, B, C] Time control, herd, cell, crash, and management-intensive grazing are different systems of rotational grazing. While they all have slightly different philosophies and methods, they share the central principles of high stocking rates in confined areas, limiting the amount of time that animals are grazing an area. Initial costs to install adequate fencing and stock water for effective rotational grazing systems can be high. ACT landholders who have implemented this approach noted that having small paddock sizes aided in maintaining ground cover and addressing weeds. [B]
- → Undertake regular soil testing to monitor soil fertility and pH and consider soil ameliorants where advantageous.
- → To maximise groundcover, landholders can use the following strategies. [B]
  - Groundcover is maintained at 80% or better in rural landscapes regardless of the season.[50]
  - Use of diverse exotic and native species which tolerate a range of climate conditions. [B]
  - Pasture topping (cutting off the top of a pasture to encourage growth and nutritional quality).[B]
  - Use of deep-rooted heat tolerant perennial species which can offer better pasture cover during drought by accessing moisture from deeper in the soil than annual species.[51]

[50] EPSDD, Sustainable Agriculture Investment Plan Improving the grazing resource base - Environment, Planning and Sustainable Development Directorate - Environment (act.gov.au)

[51] WaterNSW. (2022). Groundcover. https://www.waternsw.com.au/water-quality/catchment/living/managing-land/groundcover

CATEGORY: LAND MANAGEMENT

ADAPTATION ACTIONS

- Managing high-risk fire areas on farms through grazing management.[B]
  - Implementing measures to improve and/or maintain soil health such as using conservation tillage/direct drilling to establish crops or pastures to maintain soil moisture through practices such as conservation tillage.[52]
  - Establishing permanent stock containment areas for lot feeding during drought. When used strategically, containment areas take the pressure off land and soils during dry periods.[53]
  - Raising soil pH on acidic soil (for example by applying lime).[B]
  - Adding organic fertiliser additions which preserve fungal networks (e.g. turkey poo).[B]
  - Using biochar.[A, 54]
  - Introducing dung beetles.[B]
- Storing silage underground to use as drought feed.[B]
- Managing pastures for rapid regeneration following drought[53] by:
  - Not overgrazing native and exotic perennial grass stubs as this will significantly slow regeneration.
  - Sowing quick-growing crops or annual pastures to provide soil cover and act as a break crop to reduce the risk where pasture needs re-establishment.
  - Reducing erosion risk by establishing quick-growing cover crops or annual pastures where cover is required to stabilise eroding paddocks.
  - Keep stock off paddocks until ground cover is at adequate levels for maximum growth. This level will vary with location and pasture type.
  - Use rotational grazing techniques for even grazing pressure.
  - Ensure there are enough, suitably placed watering points to reduce the distance that animals must walk, and the energy required to get there, and to reduce the risk of bare soil from excessive traffic.

IMPACTS ADDRESSED

- Reduced carrying capacity of land.
- Increased weed and pest infestations.
- Heat stress on livestock.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[52] Hughes, N., Galeano, D., & Hatfield-Dodds, S. (2021). The effects of drought and climate variability on Australian farms. https://www.agriculture.gov.au/abares/products/insights/effects-of-drought-and-climate-variability-on-Australian-farms

[53] Young, M. (2022). Managing Soils During and After Drought in Grazing Systems. https://cdn.environment.sa.gov.au/environment/docs/Soil-CRC-Managing-soils-during-and-after-drought-grazing-2021.pdf

[54] Agriculture Victoria. (2022). Feed budgeting takes out the guesswork | Agriculture Victoria. https://feedinglivestock.vic.gov.au/2022/03/22/feed-budgeting-takes-out-the-guesswork/#:~:text=Feed%20budgeting%20allows%20for%20better,for%20different%20classes%20of%20stock

"We have too many endangered species. We want our farm to protect endangered grasslands and woodland."

Vegetation Management

CATEGORY: VEGETATION MANAGEMENT

CONTEXT

Native vegetation is well adapted to the harsh Australian environment and provides essential ecosystem services such as integrated pest management, microclimate cooling, water retention, healthy soils, and landscapes. Striving towards ecologically healthy and diverse farming systems provides more resilience to climate change and can improve both farm profitability and on-farm biodiversity values.

ADAPTATION ACTIONS

- Increasing the ground cover and abundance of native perennial grasses and forbs (herbaceous flowering plants that are not a grass, sedge, or rush) using rotational grazing can allow natural regeneration of shrubs and trees for shelter. Native pasture and species regeneration benefits the soil food web and nutrient cycling process by enhancing the abundance of beneficial fungi and bacteria. These benefits are the result of the increased availability of suitable habitat structure and niches for native fauna and flora species in which they find shelter from competition, protection from predators and increased availability of food and nutrients.
- Exclusion fencing around areas of natural remnant vegetation and riparian areas promotes natural regrowth, establishes shade trees, protects stream banks and rehydrates soils.
- Enhancing farm dams can lead to improvements in water quality and provide habitat for a wide variety of native wildlife. Enhanced dams can be fenced to manage the impact of stock on the dam and have native vegetation in and around the dam. As a result of stock exclusion and vegetation, the water is cleaner. An enhanced dam may also have other features such as a hardened access point for stock, variable depths, islands, or snags. Enhanced dams can provide better quality drinking water, retain water for longer, support native plants and animals, and provide ecosystem services to the surrounding landscape.
- Design and implement information and training programs to improve on farm vegetation management.
- Design and implement programs to assist landholders to restore and manage native vegetation on their properties.
- Kangaroo densities are above pre-European levels in many areas, despite most Australian states (except Tasmania and the ACT) having a commercial harvest of kangaroos, all states and territories allowing licensed shooters to cull kangaroos on their properties to reduce total grazing pressure, and some jurisdictions allowing conservation culls.[79] The ACT Government undertakes an annual 'conservation cull' of kangaroos within the urban reserves comprising Canberra Nature Park . However, the management of kangaroo grazing pressure in agricultural settings is a contentious matter.
- Revegetate with native drought resistant species to provide shade and reduce evaporative losses from sun/wind.
- Undertake Traditional Custodian cultural burning of landscapes to promote native pasture restoration and reduce abundance of annual exotic species.
- Installation of alternate livestock water sources or restricted access points to take pressure off stream vegetation in riparian areas and farm dam margins.

IMPACTS ADDRESSED

- Vegetation loss.
- Reduced carrying capacity of land.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

"Our farm is considering changing towards an enterprise that relies on less rainfall".

Enterprise selection

CATEGORY: ENTERPRISE SELECTION

CONTEXT

Climate analogues which project what the climate of the ACT might look like under different drought scenarios and identify regions of Australia currently experiencing this climate, could point to drought-tolerant species and enterprises which could be appropriate for future ACT climates. Diversification of enterprises is known to improve the resilience of food systems and farm enterprises.[55]

ADAPTATION ACTIONS

Enterprise selection should consider physical factors such as land, climate, rainfall and soil moisture and surface and groundwater availability, farm structures and machinery as well as financial and management factors [D].
Examples include:

- Selecting and diversifying toward enterprises which rely on less rainfall.[A B, C]
  - Chickens and pastured eggs. [A]
  - Enterprises with more controlled environments such as hydroponics or microgreens.[A]
  - Farm tourism and accommodation (e.g. Airbnb).[A]
  - Leasing land for other uses (e.g. solar farms).[A]
  - Bush tucker.[B]
  - Flower foraging.[B]
  - Sustainable forestry.[B]
  - Marketing and producing insects.
  - Switching from breeding to trading stock (to reduce the need to feed breeding stock through drought).
  - Having a sub-brand to buy fruit and sell wine, in addition to growing own fruit.
- Select species and breeds which are more drought tolerant.[A]
  - Use deep-rooted perennial drought-tolerant grasses. [A,B,D]
  - Use summer active pasture species.[57]
  - Use more endemic species that are tolerant of extremes in rainfall (both drought and flooding)[A] (e.g. kangaroo and wallaby grasses).[B]
  - Selection of more resilient sheep or cattle breeds (e.g. switching from merino sheep to Dorper sheep).[A]
- Technology-based enterprise management including:
  - Using knowledge gained from genomics and biotechnology tools, such as gene editing, to select crop varieties and livestock that are more climate resilient.
  - Using sensors (i.e. drones, soil monitoring probes) to measure and only provide water and nutrients (i.e. cattle licks) when and where they are needed.
  - Investigating traditional food production systems in Australia to adopt new Indigenous crops and grasses that may be better climate-adapted.

IMPACTS ADDRESSED

- Reduced carrying capacity of land.
- Reduced water availability.
- Reduced farm income.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[55] Hertel, T., Elouafi, I., Tanticharoen, M. et al., (2021). Diversification for enhanced food systems resilience. Nature Food 2, 832–834 https://doi.org/10.1038/s43016-021-00403-9

[56] Herrera de Leon, H. J., & Kopainsky, B. (2019). Do you bend or break? System dynamics in resilience planning for food security. System Dynamics Review, 35(4), 287-309.

Agriculture Victoria (2021) Managing for biodiversity. https://agriculture.vic.gov.au/farm-management/land-and-pasture-management/native-pasture-management/managing-for-biodiversity

Sustainable Farms (2022) Ways to improve natural assets on a farm: Enhance farm dams https://www.sustainablefarms.org.au/on-the-farm/farm-dams/takes-out-the-guesswork/#:~:text=Feed%20budgeting%20allows%20for%20better,for%20different%20classes%20of%20stock

[57] Cullen, B., Harrison, M., Mayberry, D., Cobon, D., Davison, T., & Eckard, R. (2021). Climate change impacts and adaption strategies for pasture-based industries: Australian perspective. NZGA: Research and Practice Series, 17, 139-148.

"Pest proof fencing, enhancing natural resources and improving storage capabilities".

Water Management

CATEGORY: WATER MANAGEMENT
CONTEXT
Soil and water conservation methods and new systems become even more important as climates fluctuate and extreme events become more frequent. [D] Water management strategies can be achieved by identifying less water intensive production options, developing better water delivery technologies, and by implementing water markets and water-sharing arrangements (currently under investigation). Optimal dam design and maintenance can reduce water loss through seepage and evaporation.[58] Water tanks can also provide additional water storage for stock watering, irrigation, household needs, and fire sprinklers. Landholders with access to bore water also reported they had a reliance on bores to supplement water supply in drought [A]. A fit-for-purpose approach to water reuse and water management can result in more efficient water use. [59]
ADAPTATION ACTIONS
Agriculture and farming are highly dependent on water however are becoming increasingly subject to water risks from climate change. [D] Water management examples include: → Use fit for purpose water sources. - Flocculating (removing sediment from) dams and on-farm water sources to improve water quality for stock and irrigation. [A] - Reuse of wastewater . → Exploiting on-farm water sources. - Covering dams to reduce evaporation. [A] - Dam enhancement [A] (e.g. deepening dams). [C] - Restoring the environment around dams to improve water capture. [A] - Increasing investment in water infrastructure systems (installing water tanks or bores). [A] - Moving away from dams toward troughs. [C] - Acquiring water licenses to use groundwater and alternative water sources [C]. → Improving water use efficiency by creating humid microclimates around crops (and grasses). [60] → Water conservation strategies for viticulture include opening and closing vine canopies to manage humidity and create a beneficial microclimate for a vine. [B] → Identifying less water intensive production options, developing better water delivery technologies and implementing water markets and water-sharing arrangements. → Investigate groundwater as a potential emergency source of water for agriculture including an increase in the groundwater monitoring program.
IMPACTS ADDRESSED
→ Reduced water availability.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[58] Agriculture Victoria. (2020). Efficient use of farm water. https://agriculture.vic.gov.au/farm-management/water/farm-water-solutions/efficient-use-of-farm-water

[59] Radcliffe, J., & Page, D. (2020). Water reuse and recycling in Australia — history, current situation and future perspectives. https://www.sciencedirect.com/science/article/pii/S2666445320300064

[60] Hatfield, J., & Dold, C. (2019). Water-Use Efficiency: Advances and Challenges in a Changing Climate. https://www.frontiersin.org/articles/10.3389/fpls.2019.00103/full

“Our farm practice is not to be overstocked, and only hold young breeding stock in drought conditions, and endeavour to have minimal supplementary feeding.” [C]

Stock management

CATEGORY: STOCK MANAGEMENT	
CONTEXT	
Stock management and land management are inherently interrelated. Good stock management can minimise the impacts of drought on the land and confer resilience.	
ADAPTATION ACTIONS	
During periods of drought, many farmers are forced to destock to sustain remaining livestock. Strategies to manage stock include: → Carrying less stock. - Having clear trigger points to de-stock which are decided on before drought. [A] - Having early trigger points to de-stock. [A] - Monitoring pastures to develop feed budgets which project pasture availability to determine when to destock and buy in feed.[61] - Limit stock to ensure groundcover of at least 70% at all times. → Developing drought lot feeding facilities, sacrifice paddocks/stock containment areas to concentrate stock in small areas and feed them fodder to protect most of the farm from damage by stock trampling and overgrazing during drought. This can also minimise energy usage by stock who would otherwise be moving around looking for sparse feed. - Construct feed storage facilities such as sheds, silos, and silage pits. - Growing and/or buying-in stock feed when fodder prices are lower and storing this feed during good seasons in preparation for droughts. - Selling feeder animals early (e.g. selling wethers first then ewes). - Reducing breeding animal numbers. [A, D] - Selling the (in some cases entire) herd. [A,B,D]	→ Rotational grazing: grazing stock in smaller paddocks, at a higher intensity for shorter periods. [A, B, C] → During the recovery phase, post drought, agisting sheep (or different grazing animals) when possible, to manage a surge in pasture growth and to reduce bushfire risk. [B] → Reducing heat stress and ensuring stock welfare.[62] → Ensuring a plentiful water supply. → Ensuring shade and shelter – including artificial shade. → Avoiding handling and transportation of animals in extreme heat. → Adding cooling misting sprays or fans for livestock (under certain conditions and ensuring the prevention of increased humidity which can cause stock mortality). [D] → Use of stock containment areas or sacrificial paddocks to defer grazing on pastures until they have recovered. This can also minimise energy usage by stock who would otherwise be moving around looking for sparse feed. → Breed selection towards more drought tolerant species. → Maintain a watching brief on emergent techniques to mitigate agricultural contribution to climate change, for example adjusting feed (such as certain algae/seaweeds) to reduce methane production.
IMPACTS ADDRESSED	
→ Reduced carrying capacity of land.	→ Heat stress on livestock.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[61] Agriculture Victoria. (2018). Stock Containment Areas | Case Study - Lachlan Ralton, Woodstock West. https://agriculture.vic.gov.au/__data/assets/pdf_file/0003/563556/Case-study-stock-containment-areas-a-flexible-management-tool.pdf

[62] Agriculture Victoria. (2022). Caring for animals during extreme heat. https://agriculture.vic.gov.au/livestock-and-animals/livestock-health-and-welfare/caring-for-animals-during-extreme-heat

"Pest proof fencing, enhancing natural resources and improving storage capabilities".

Infrastructure

CATEGORY: INFRASTRUCTURE	
CONTEXT	
Infrastructure can improve drought preparedness by increasing farmers capacity to store water and feed. This can reduce the need to buy resources during drought when availability is low, and prices are high.	
ADAPTATION ACTIONS	
Upgrading or adding on-farm infrastructure can include: → Increasing on farm storage for water, fuel, feed, grain, sileage and hay. [A, B] - More, and well-maintained dams. [A] - Rainwater storage tanks. [A] - Improved reticulation of clean stock water. [A] - Feed, grain, silage and hay storage sheds and silos. [A] - Underground silage storage to protect from fires. [B]	→ Improving fencing infrastructure to reduce paddock sizes to better manage grazing and stock density.[C] → Improve and modernise water delivery systems to reduce water losses.
IMPACTS ADDRESSED	
→ Reduced water availability. → Heat stress on livestock. → Bushfire damage.	

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

Other environmental actions

Improvements to on-farm monitoring of weather and longer-term climate trends

Drought monitoring and use of drought early warning systems is a key tool in timely risk management and drought planning.[64] Advances in technology, particularly remote sensing, soil moisture monitoring and other tools, enable landholders to make more informed decisions, which can in turn lead to more targeted management.

Drought adaptation actions relevant to monitoring include:

- Using information from the series of soil moisture probes installed across southeast NSW (including Tidbinbilla Soil Moisture Probe in the ACT) to inform decision making by helping producers assess current seasonal conditions and the likely range in pasture availability and livestock performance during the next 3-4 months. More information can be found at: https://farmingforecaster.com.au/
- Using soil moisture sensors which allow more efficient irrigation where relevant.[B]
    - Assessing pastures using satellite imagery and observations to calculate total standing dry matter (TSDM) . PastureKey by cibolabs [66] is a satellite assisted forage budgeting tool which, using time-series satellite imagery, scouts maps to optimise field pasture assessments.
    - Remote monitoring of voltage levels of electric fences on-farm. [65]
    - Tools to assist condition assessments of cattle. For example, CattleAssess3D provide assessments of body condition of live cattle in real time to enable producers and feedlots to make informed decisions to optimise carcase performance and profitability. [65]
- Keep records of significant climate factors related to temperature (e.g., number of days over 35 degrees Celsius), precipitation (e.g., average precipitation) and combined climate variables (e.g., total soil moisture content). [C]
    - Be aware of and plan for shifts in disease and pest ranges. [D]

Planning and regulations

Planning and regulations in agriculture should aim to provide opportunities to support farming enterprises to continue to operate, diversify or expand in the future. The agricultural land planning and regulatory system in the ACT provides barriers and enablers for landholders to navigate in order to take actions to adapt to drought (refer to Section 11).

Examples of planning and regulatory adaptations adopted or suggested by ACT landholders include:

- Obtaining approval to install a bore to access groundwater when surface water is scarce, where possible (this may not be possible in all areas of the ACT, due to sustainable limits on groundwater extraction). [A]
- Developing a regional drought plan to guide agricultural adaptation to drought in the ACT. [A]
- Planning and regulatory factors which influence landholders' resilience and capacity to adapt are presented in further detail in AECOM's study (**Appendix 1**. Section 11).

Knowledge sharing and information provision

Social networks and knowledge exchange is a key factor in the spread of successful drought adaptation. Studies on successful NSW farmers found they employ a range of strategies in adopting innovative management practices. These included observing signals from the landscape, independent testing and trialling, use of agronomists, and participation in farmer groups and in farmer-driven research programmes. [67]

CSIRO notes that a contributor to successful adaptation to drought is wide communication and demonstration of the benefits of new climate adaptations. [68]

There are numerous successful drought adaptation strategies and decision-making tools available. However, some ACT farmers are seeking understanding around climate predictions and adaptations, including:

- More information on climate tools and farm decision support tools (for example grazing, and pasture management).
- Evidence-based fire management, including the exploration of Indigenous Australian fire strategies such as cool mosaic burning. These strategies have had promising outcomes for fire management in other areas of Australia, and it is broadly considered that the application of these practices is likely to be beneficial. [69]

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[64] Tranka, M., & et al. (2018). Priority questions in multidisciplinary drought research. https://www.int-res.com/articles/cr_oa/c075p241.pdf

[65] Crowley, M. (2021). Four tools to tap into on-farm resilience | Meat & Livestock Australia. https://www.mla.com.au/news-and-events/industry-news/four-tools-to-tap-into-onfarm-resilience/

[66] Cibolabs, 2022, PastureKey, https://www.cibolabs.com.au/pasturekey

[67] McKenzie, F. (2013). Farmer-driven Innovation in New South Wales, Australia. https://www.tandfonline.com/doi/abs/10.1080/00049182.2013.765349

[68] Stokes, C., & Howden, M. (2011). Adapting agriculture to climate change. https://www.publish.csiro.au/ebook/chapter/CSIRO_CC_Chapter%207

[69] Fletcher, M. (2021). Catastrophic Bushfires, Indigenous Fire Knowledge and Reframing Science in Southeast Australia. https://www.mdpi.com/2571-6255/4/3/61

Fire management

Rural landholders in the ACT, like urban residents, have a duty to take reasonable care to prevent the spread of a fire from their property. Most rural landholders have a high level of awareness of the risks of ignition associated with machinery, equipment, and infrastructure, particularly during elevated fire danger conditions. Managing fire fuel load is a key component of bushfire management. [70]

Rural landholders are required to have a Bushfire Operational Plan (BOP) through the Farm Firewise program. The ACT Emergency Services Agency (ESA) supports rural landholders to prepare their Farm Firewise plans, which must be reviewed every five years and approved by the ESA Commissioner. The requirement to identify reasonable measures for managing bushfire risk and any fire management requirement is also established under Land Management Agreements (LMAs).

Drought adaptation actions relevant to fire management include:

→ The use of targeted grazing to reduce biomass. [70]

→ Installing additional water storage tanks and sprinkler systems to protect key farm assets. [A]

→ Minimising fire risk at a landscape scale.

→ Use of informal fire truck network among rural landholders. Some landholders have fire trucks and help each other out when needed.

Management timing

Adaptations to manage the direct impacts of climate changes on management timing include:

→ Changing breeding cycles to adapt to changing climate conditions (e.g., elect not to breed, avoid having lambs in frosts, match calving/lambing to fit with changed seasonal pattern of pasture growth). [B, 57]

These management decisions can be made in response to forecasts and climate indicators to ameliorate the impacts of drought.

Additionally, actions are required to manage the indirect impacts of climate change on management timing. Weed, pest animal, and disease management must adapt to shifting ranges and times of year.

Weed and pest management

Climate change will impact the timing and distribution of pests, weeds, and diseases. The effectiveness of natural enemies in controlling pests will decrease with pest distributions shifting into regions outside the distribution of their natural predators. However, new communities may provide some level of control. [70] The effectiveness of natural enemies is altered through management strategies adopted by farmers to cope with climate change. Management strategies to discourage or encourage natural enemies (e.g. small bird species) of new pest species can impact pest reduction.

Because of the diverse and often indirect effects of climate change on natural enemies, predictions will be difficult. Drought adaptation actions relevant to weed and pest management include:

→ Leasing land and agisting animals for weed control to buffer weedy areas. [B]

→ Continuing to manage weeds and being aware of, and planning for shifts in disease and pest ranges. [D]

Common ways that weeds can be introduced are by supplementary feed, through livestock movements (i.e. when returning from agistment or restocking), through contaminated seed during sowing, or contaminated machinery, and though transmission by native and pest animals. Actions that can be taken to mitigate these include:[71]

→ Restricting areas where grain and fodder are to be fed, and carefully monitoring these areas, particularly after rains, for up to two years after a drought.

→ Restricting/excluding livestock movement within catchment areas of farm dams, as manure and weed seeds can contaminate water storage systems.

→ Monitoring riparian areas and water points, as these are often accessed by native and feral animals which can vector seeds and pests.

→ Control weeds quickly after germination, and well before they set seed.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

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[70] ACT Government. (2019). Strategic bushfire Plan 2019 – 2024. https://esa.act.gov.au/sites/default/files/2019-09/ESA%20Strategic%20Bushfire%20Management%20Plan2019-2024_ACCESSIBLE.pdf

[71] Tounce, B., & et al. Weeds and drought. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0008/803294/A3-weeds-and-drought-factsheetfinal.pdf

In addition to reducing stocking rates, actions to manage the increased risk of infectious diseases to drought-affected stock can include:

- Ensuring ready access to sufficient supplies of suitable water.
- Checking stock regularly to minimise stock injuries and death.[72]
- Carefully considering using commercial lick blocks – these can be a costly form of supplementation and can be toxic to hungry stock if they contain grain or urea. [72]
- Segregating animals based on size and strength to minimise competition for supplements[73]
- Minimise handling, and the distances stock need to walk for food and water to limit the loss of body condition.[72]
- Getting advice and be careful when feeding novel feedstuffs. Chemical residues may be present which may cause poisoning or contaminate meat.[72]
- Making dietary changes slowly. Feedstuffs such as fruit, bread, urea mixes, fat, milk products and grain can cause illness in stock if fed too much too quickly. [72]
- Never releasing hungry stock onto green pasture or crops. [72]
- Creating stock containment areas (also known as drought lot feeding facilities or sacrifice paddocks) for feeding, watering, and monitoring stock. Containment areas protect paddocks from erosion, minimise walking for stock and can save labour.[72]

Land management tools

Online media and web-based tools can be used to drive informed decision-making and the adoption of new practices. Studies into knowledge-sharing around soil management noted that a multidimensional approach to education and outreach is needed that balances familiar models with new online tools and forums, to create an active learning environment that facilitates change. They noted that information provision, especially via online portals, will not necessarily result in knowledge acquisition, nor provide a dynamic learning environment that builds trust in the information and increases social capital to effect change.

There are many land-management tools to provide data and assist rural landholders in decision-making. Tools which were used and recommended by ACT rural landholders included: [A]

- Farming forecaster
- Meat and Livestock Australia (MLA) feed demand calculator
- Weatherzone and BOM apps
- RCS, MAIA and other regenerative farming pasture assessment and management tools

Social media and web-based tools can start conversations, in many cases. However, these should be followed by the face-to-face conversations, training, field tours, and hands-on demonstrations.[74]

Marketing and consumer-producer engagement

In Australia, there is increased focus on food experiences and festivals, with State and Territory Governments developing strategies based on food tourism and artisan agriculture. Sustainable tourism experiences or events are increasingly playing an important role in the business models of artisan producers, allowing them to sell directly to consumers and often add value through tourism experiences.[75]

From an economic welfare perspective, mechanisms that directly link consumers and producers are likely to improve consumer knowledge and satisfaction with foods and encourage higher-quality production techniques.[75] However, this can also play a role in fostering drought-resilient food systems.

Drought adaptation actions relevant to marketing include promoting sustainable local food to local consumers. Farmers noted that they are subject to consumer demand for certain breeds or enterprises which often do not match the breeds and enterprises that are most suited to the landscape[A]. As a result, there is a perceived pressure on farmers to conduct agricultural enterprises to fit consumer demand rather than selecting enterprises and breeds which are resilient on the ACT landscape, in the face of a changing climate. Educating consumers and promoting local, drought resilient food can assist farmers in economically benefiting from drought resilience.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[72] Agriculture Victoria. (2022). Animal health in a drought. https://agriculture.vic.gov.au/livestock-and-animals/livestock-health-and-welfare/animal-health-in-a-drought

[73] Business Queensland. (2022). Protecting your livestock in drought | Business Queensland. https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/disaster/drought/during/animal-welfare/protect

[74] Lobry de Bruyn, L., Jenkins, A., & Samson-Liebig, S. (2017). Lessons learnt: Sharing soil knowledge to improve land management and sustainable soil use. Soil Science Society of America Journal, 81(3), 427-438.

[75] Star, M., Rolfe, J., & Brown, J. (2020). From farm to fork: Is food tourism a sustainable form of economic development?. Economic Analysis and Policy, 66, 325-334.

"Our farm is considering changing towards an enterprise that relies on less rainfall".

Economic adaptation actions

Focus actions

During stakeholder engagement, the most frequently mentioned category of economic adaptation actions was enterprise selection, followed by planning and regulations, and infrastructure. Collectively, actions related to these categories comprise over three-quarters of economic adaptation measures identified by ACT landholders.

Enterprise selection

CATEGORY: ENTERPRISE SELECTION

CONTEXT

Farming enterprises remain exposed to significant climate and price risk.

Drawing on extensive meteorological data collected and analysed by government agencies, and based on on-farm experiences and observation, farmers adjust their longer-term choices of farming enterprise, modifying choice of species/breed based on the local climate, stocking rates, fodder storage, tillage methods, and so forth for the purpose of income smoothing.[52] Australian farmers have altered their mix of enterprises, adopted lower-cost methods (i.e. practices with reduced inputs, such as organic agricultural systems), and where possible, purchased or leased additional land to increase farm size in response to drought.[52]

Two key economic ways farmers manage climate and price risk are by keeping debt low and maintaining sources of off-farm income. For many farms, these strategies are vital both to ensure the long-term survival of the farm business and to minimise variation in household income. [44] Diversification of enterprises is known to improve the resilience of food systems and farm enterprises.[52] Economic diversification options can include both agricultural and non-agricultural enterprises. Farmers also use income smoothing strategies such as the farm management deposit scheme offered by the Australian Taxation Office.

ADAPTATION ACTIONS

- → Enterprise selection should consider physical factors such as land, climate, irrigation water, farm structures and machinery as well as financial and management factors.[D] Examples include:
- → Diversifying farm income to buffer against climate and market fluctuation.
- → Selecting and diversifying toward enterprises which rely on less rainfall.[A B, C] These can include agricultural (i.e. varieties of food production and methods of production) and non-agricultural (i.e. farm tourism) based production.
- → Agricultural-based diversification options:

  Greenhouse/glasshouse production (utilising wastewater and circular bioeconomy – such as in composting food waste to use the nutrients to grow more food crops).

  - Emerging crops, produce and practices (e.g. saffron, aquaculture, tree crops, mushrooms).
  - Value adding products (e.g. supplying locally sourced meat to consumers).
- → Other diversification options:
  - Farm tourism and accommodation (e.g. Airbnb).[A]
  - Leasing land for other uses (e.g. solar farms, agistment).[A]
  - Having a sub-brand to buy in fruit and sell wine, in addition to growing own fruit.[B]
  - Selling credits and offsets for ecosystem services (through market based and/or government-based mechanisms).
- → Enterprise management strategies which use weather and commodity price forecasts which predict when drought conditions or poor output prices are likely. Management can then be adapted to minimise losses, for example to reduce crop area planted and inputs applied (such as fertiliser).[D]

IMPACTS ADDRESSED

- → Reduced carrying capacity of land.
- → Reduced water availability.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[52] Hughes, N., Galeano, D., & Hatfield-Dodds, S. (2021). The effects of drought and climate variability on Australian farms. https://www.agriculture.gov.au/abares/products/insights/effects-of-drought-and-climate-variability-on-Australian-farms

[44] Hughes, N, Burns, K, Soh, WY & Lawson, K 2020, Measuring drought risk: the exposure and sensitivity of Australian farms to drought, ABARES rport to client, prepared for the Department of Agriculture, Water and the Environment, Canberra, November, DOI: https://doi.org/10.25814/mqrp-rp16. CC BY 4.0.

“We use grants available to use to upgrade existing infrastructure”.

Infrastructure

CATEGORY: INFRASTRUCTURE
CONTEXT
Infrastructure can improve drought preparedness by increasing farmers’ capacity to store water and feed. This can reduce the need to buy resources during drought when availability is low, and prices are high.
ADAPTATION ACTIONS
Management of on-farm infrastructure can include: → Use of contractors instead of buying machinery to minimise machinery costs and get high-quality machinery that is well-suited to tasks [B] This can reduce debt and ameliorate the economic stress of drought. However, such strategies should be assessed on an individual farm level. → Using financial assistance (loans and grants) to upgrade existing infrastructure. [A]
IMPACTS ADDRESSED
→ Reduced water availability. → Heat stress on livestock. → Bushfire damage.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

Other economic actions

Sale of stock

Drought adaptation actions relevant to the sale of stock include selling stock direct and avoiding feedlots and saleyards. When destocking going into a drought, weaners can be sold to feedlots. Adaptation actions around destocking to manage drought are explored further in the category Stock Management on page 61.

"ACT farmers need a regular get-together to share info and experiences."

Social adaptation actions

Focus actions

During stakeholder engagement, the most frequently mentioned category of social adaptation actions was well-being, and knowledge sharing and information provision. Collectively actions related to these categories comprise over three-quarters of adaptation categories within the social domain identified by ACT landholders.

Wellbeing

CATEGORY: WELLBEING
CONTEXT
Natural disasters, including drought, have long-term effects on the mental health of affected individuals and communities. [76] Community-led solutions that promote stress reduction, physical protection, and community cohesion can bolster resilience in crisis. [77] Educational programs including mental health-related events (for example mental health first aid training targeted at Aboriginal communities, teachers, general practice staff, youth workers, rural service providers, BBQ breakfasts at mental health service provider locations, activities, and mental health information days for young people to talk about mental health issues in a youth-focused format) and telephone crisis support have been implemented in NSW. This was considered effective in helping communities build capacity and resilience in the face of chronic drought-related hardship.[78]
ADAPTATION ACTIONS
There is evidence that the well-being of many farmers and farming families across Australia has decreased because of drought, fire and most recently floods as well as broader concerns about climate change. However, there are lots of different strategies that can support improved well-being in farming communities, including: → Creation of opportunities (formal and informal) to bring the farming community together to share experiences and knowledge. [A] → Building and supporting more formalised networks such as the ACT Rural Landholders Association and the ACT Grazing Group. → Providing support and training in succession planning and other key farm decision-making processes. → Sharing information about a range of new opportunities including carbon farming and alternative markets for biodiversity conservation. [A] → Provision and promotion of mental health support services such as telephone counselling, financial counselling information and other services.
IMPACTS ADDRESSED
→ Reduced wellbeing.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[76] Black Dog Institute. (2020). Mental Health Interventions Following Disasters. Randwick, NSW, Australia: Black Dog Institute.

[77] Humphreys, A., Walker, E., Bratman, G., & Errett, N. (2022). What can we do when the smoke rolls in? An exploratory qualitative analysis of the impacts of rural wildfire smoke on mental health and wellbeing, and opportunities for adaptation. https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-021-12411-2

[78] Hart, C. R., Berry, H. L., & Tonna, A. M. (2011). Improving the mental health of rural New South Wales communities facing drought and other adversities. The Australian journal of rural health, 19(5), 231–238. https://doi.org/10.1111/j.1440-1584.2011.01225.x

"Information, if inaccurate or insufficient, means farming is high risk and can end badly for people and places."

Knowledge sharing and information provision

CATEGORY: KNOWLEDGE SHARING AND INFORMATION PROVISION
CONTEXT
Effective individual farms' responses to climate change require farmers to have information about the different dimensions of climate change that affect them at the individual farm level, the broader industry level and nationally and internationally. State/Territory governments, industry bodies, businesses, science organisations, community-based organisations, the mass media, and social media can all play an important role in connecting key sectors of the community and sharing knowledge.[79] It was noted by ACT landholders that this function is performed to some extent by ACT NRM.[A] Farmers find community groups such as the RLA great ways to actively learn and share. There is a sense that more informal groups/ mentoring programs could exist. Although some landholders identified that this role was fulfilled for them by specific community groups relevant to their enterprise.[A] Complementary support by the government to provide information and facilitate knowledge sharing can include the provision of climate change and weather forecast information, help to evaluate the pros and cons of choices, and provision of a social safety net for those unable to adapt.[80]
ADAPTATION ACTIONS
Knowledge sharing and information provision is a key social component to adaptive, sustainable agricultural systems. Knowledge sharing and information provision actions include: → Ongoing farmer training and capacity building (field days, workshops, farm walks, newsletters, web-based information and more). → Support for different types of farming and farm diversification. → Facilitating communication between farmers to share knowledge and experiences and support improved mental health and well-being. → Developing community leadership and supporting groups to build supportive social networks and resilience (such as the ACT Grazing Group, which provides a forum to share problems solutions and experience). → Farm preparedness can be improved by providing weather and climate projections which inform on-farm management and provide climate information at scales relevant to the decisions being made and combining information on both climate variability and trends in seasonal and medium-term (decadal) forecasts.[81] → Increased investment in research, management and recovery of areas of agriculture and nature conservation post drought, fire and other natural disasters.
IMPACTS ADDRESSED
→ Reduced wellbeing.

Legend: * priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.

[79] Harman, B.P, Cunningham, R., Jacobs B., Measham, T. and Cvitanovic, C. (2015), Engaging local communities in climate adaptation: a social network perspective from Bega Valley, New South Wales, Australia, CSIRO, Australia.

[80] Freebairn, J. (2021). Adaptation to Climate Change by Australian Farmers. https://www.mdpi.com/2225-1154/9/9/141

[81] CSIRO, (2011) Adapting agriculture to climate change https://www.publish.csiro.au/ebook/chapter/CSIRO_CC_Chapter%207

Governance adaptation actions

Common themes that came out of the rural landholders' workshop, the one-on-one meetings and the survey include the 'place' of rural land within the ACT as a region; the need to recognise the important role rural land plays in providing food and fibre, supporting biodiversity and providing a buffer zone for managing bushfire risk; and the need for a clear agriculture policy that articulates these themes and acknowledges the importance of rural land.

It was noted that the ACT Government has a key role regarding planning and land use, and that identifying, valuing, and protecting rural land within the ACT has implications for the capacity of rural landholders to prepare for drought and invest in drought preparedness. Considerations raised by rural landholders included:

- → Having an appreciation for:
  - Support provided by the government to farming groups in the ACT such as the Rural Lands Association
- → Opportunities to review conditions on rural leases and the types of rural land uses permitted in association with these leases.
- → Maintaining strong relationships with key agricultural extension and research organisations and consultants in the region.
- → Having a desire for:
  - Greater acknowledgement of the social, economic, and environmental benefits provided to the ACT associated with current rural land use.
- → Stronger alignment with NSW drought measures (incl. drought declarations, financial assistance) to aid planning.
- → Investigation of opportunities to increase investment in resilience measures like NSW Government's Farm Innovation Fund, the Regional Investment Corporation's low interest loans.
- → Opening permits and approvals for certain types of rural land uses and providing support for farmers seeking to transition enterprises.
- → Reviewing water and irrigation permits for rural land with consideration which end uses provide the greatest benefits and outcomes.
- → Providing support for the establishment of a new farming systems group for graziers in the ACT and border regions, and to continue sharing information.

Case studies

Throughout stakeholder engagement activities farmers shared innovative farming techniques, financial barriers to adaptation, and the multitude of responses that they are undertaking to build resilience to drought. The following section presents three case studies including:

- Data to support rotational regenerative agriculture.
- Drought preparedness for graziers
- Adaptation in viticulture
- Government support.

Callum Brae

Data to support rotational regenerative agriculture

Callum Brae is a 150ha sheep farm (running a self-replacing fine wool Merino flock typically 350-400 head) in Symonston which has seen continuous management by the same farming family for multiple generations. The entire property comprises a mix of native grassland and native lowland woodland of high environmental value and containing a range of endangered native flora and fauna. Over this time, droughts have been a recurring challenge and, at times, have had a significant impact on pasture and livestock production, leading to reduced income and increased costs for the family. Over the last 40 years, the family have experienced first-hand the challenges that drought can bring.

Sustainability is a key ambition driving their farm management techniques, with a strong desire to enhance the endangered grasslands and woodlands and the many endangered species that are present. Rotational regenerative processes are the centrepiece to achieving these ambitions and have been in place for several decades and over that period paddock sizes have reduced, and the number of paddocks doubled. There has also been considerable investment in water storage infrastructure to mitigate the risk of lower availability of livestock water during extended dry seasons.

Rotational regenerative agriculture is a holistic approach that considers the interconnections between soil, plants, animals, and the environment, and seeks to create a sustainable and regenerative farming system. The focus at Callum Brae is on enhancing the health of the soil, improving biodiversity and habitat for endangered species through regular rotation of livestock through the paddock structure. This approach encourages native grass health and growth, maximising ground cover, increasing soil organic matter and soil water retention.

One of the main benefits of rotational regenerative agriculture is that it helps to improve the fertility and structure of the soil over time. By rotating the grazing, Callum Brae has been able to add nutrients back into the soil and reduce compaction, which can improve water retention and increase the soil's ability to support healthy pasture growth during periods of low rainfall. In addition to improving soil health, rotational regenerative agriculture has also led to other benefits for Callum Brae, including:

- Increasing the efficiency and sustainability of farming operations
- Synthetic fertilisers are not used at any time.
- Enhancing the health, productivity, and quality of animals raised on the farm.
- Providing habitat and food for beneficial insects and other wildlife.

Developing a detailed understanding of the carrying capacity of the land and pastures has been key in implementing and maintaining this approach.

Rotational regenerative agriculture can be supported by collecting data and using software in several ways. Here are a few examples:

- Tracking and analysing pasture performance: By collecting data on the performance and attributes of different native grasses, the farm has been successful in identifying which ones are most successful for their soil and climatic condition. This has helped to optimise native pasture yields and improve the efficiency of the farm.
- Monitoring soil health: By collecting data on soil health indicators such as pH, nutrient levels, and moisture content, farmers can get a better understanding of the health of their soil and identify any areas that may need improvement. This can help to optimise the use of natural amendments and reduce the need for synthetic inputs.
- Analysing weather patterns and forecasting: By collecting data on weather patterns and using software to forecast future conditions, farmers can make more informed decisions about optimising pasture and how to allocate resources.
- Managing and optimising irrigation systems: By collecting data on soil moisture levels and weather patterns, farmers can use software to optimise water supply and reduce water waste. This can help to conserve water resources and improve the efficiency of the farm.

There is a growing availability of climate-related data Callum Brae has been reviewing and using, adopting software to inform their decision-making to support these efforts. Below is a collection of tools cited as useful in their strategic planning and monitoring of conditions for better drought preparation and management outcomes.

Table 8: Better drought preparation and management outcomes

PURPOSE	TOOL
Drought resilience planning	→ Department of Agriculture, Fisheries and Forestry's DR.SAT
Monitoring climate conditions	→ Davis weather station providing detailed farm weather data. → The Commonwealth Government's CliMate tool which collates historical climate analyses relating to water variables. → Department of Agriculture, Fisheries and Forestry's Climate Services for Agriculture to review climate projections and historical data.
Bushfire monitoring	→ Bushfire.io and Hazards/Fires Near Me to set alerts for fires within designated perimeters, data on weather and fire activity.
Soil moisture monitoring	→ SoilWater app models plant available water using the app and farmers' own rainfall data. → Farming Forecaster also models plant available water analysed from multiple grassland sites in nearby regions from soil probes. → APSoil/Soil Mapp provides analysis of soil water content and other items for designated soil type, provides base data. → BOM Australian Water Outlook provides local historical, seasonal forecast and projections for rainfall, soil moisture, evapotranspiration, and runoff. → IrriSat provides an ability to monitor local soil moisture levels.
Pasture monitoring	→ Farm Carbon Calculator; FarmGas; Cool Farm Tool – detailed emission data (Scope 1, 2 and 3), validation for enteric fermentation output, carbon sequestration. → Sequestration tools including FullCam; LOOC-C (calculate sequestration potential). → Farming Forecaster to calculate projected green herbage, daily growth rates, ground cover, condition scores. → OneSoil; Data Farming; Biomass MDA for pasture monitoring, reviewing Normalized Difference Vegetation Index. → CSIRO's SoilMapp and NSW Department of Primary Industry's eSpade for soil profile data → DataFarming to identify vegetation index across properties. → CSIRO's AusFarm, GrazFeed, and GrassGro. → NSW Department of Primary Industry's Drought and Supplementary Feed Calculator to help develop rations in dry periods as well periods leading into and out of drought. → Meat and Livestock Australia's Feed Demand Calculator to understand feed requirements and biomass growth over a 12-month period. → AWI Feed on Offer library for nutritional data on specific native species. → Cibo Labs, Australian Feedbase Monitor provides satellite based online feed management data.
On farm data collection and database recording	→ Soil compaction measurements using a cone penetrometer (Agreto), recording pressure at 10cm intervals and relationship to bulk data. → Time domain reflectometer to measure volumetric water content, surface temperature and salinity index of soil. Probes to measure soil temperature and pH at various depths. → Soil health testing – assisted using Rapid Assessment of Soil Health (RASH) tool to develop a database aiding analysis. → Documenting all native and exotic species on-farm to monitor for changes to biodiversity, species dominance, etc over time. → GloSIS, ANSIS, SoilGrids and Harmonised World Soil Database to identify extensive details of soil type, content, carbon, density, and a range of soil parameters.

Tidbinbilla Station

Drought preparedness for graziers

Introduction

Drought and climate change are significant challenges facing many farmers in Australia, particularly in arid and semi-arid regions. These challenges can have a significant impact on livestock production, leading to reduced income and increased costs for farmers. This case study explores how one sheep and beef farmer in the ACT is adapting his farm to the impacts of drought and climate change.

Background

Michael Shanahan has held his property, Tidbinbilla Station, for 33 years and has seen firsthand the impacts that drought and climate change can have on his operations. In the past, he has struggled to keep his livestock healthy and well-fed during dry periods, leading to reduced income and increased costs for supplementary feeding. Typically during good climatic conditions, the farm will have up to 25,000 sheep and 1,000 cattle, whereas during drought periods this has dropped to 7,000 sheep and 150 cattle.

For his farm, the drought of 2017 to 2020 was the longest that's been experienced, and the most difficult to manage in terms of water availability despite applying learnings from previous drought events (notably 2006). There is a history of improvement still, with the millennium drought seeing better outcomes following further lessons learned during the 1982 drought event.

Current solutions

To address these challenges, Michael has continued to implement strategies on his farm to adapt to the impacts of drought and climate change. Strategies that Michael has implemented include:

- The use of native grasses (which typically perform the best in average conditions), using fertilisers to manage the composition across species, manipulating native grasses to achieve desired outcomes at the time. However, there has been a need to introduce different, non-native drought tolerant species during droughts which are more resilient to dry conditions.
- Implementation of rotational grazing practices, which involve moving cattle to different paddocks regularly to allow the grasses to regenerate and improve the health of the soil.
- Reviewing 3-month outlooks from BOM – particularly ENSO indicators. This enables medium-term planning of stock numbers, whereby stock are sold down ahead of drought conditions which reduces future feed costs and provides capital to aid operations.
- Adoption of government support through freight subsidies when importing feed, water rebates to improve on-farm water infrastructure, and grants to help build drought lots.
- In addition to improving his pasture management practices, Michael has also implemented an irrigation system that uses weather data and soil moisture sensors to optimise water use and minimise waste. The system has helped him to better manage his water resources and ensure that his cattle have access to enough water to stay healthy and hydrated during dry periods.
- The scale of Michael's farming activities still means that during drought all feed is purchased for sheep. Cattle, however, are generally able to be spread across paddocks and remain pasture-fed.

Future actions

In the coming years, Michael intends to further invest in improving the farm's drought resilience. High priority actions include:

- Improving water infrastructure: investigating the installation of a water bore, and if unavailable will build a new dam, to improve water security.
- Planting shelter belts of trees and increasing paddock trees to increase shading for stock and reduce erosion/impacts of wind.
- Improving feed storage: looking at underground storage of silage and building grain storage facilities.

- Improving capital stores: saving more cash in the bank would aid farm operations during drought and improve opportunities to invest in rebuilding stock levels following drought.
- Investigating management tools: for example, Michael is seeking cost/benefit analysis tools to understand what the cost of 100% destocking and restocking is, compared to reducing stock numbers and purchasing feed.

Conclusion

Drought and climate change are significant challenges facing many farmers, but with the right strategies and technologies, it is possible to adapt and mitigate their impacts. Key outcomes include:

- The broader implications of Michael's strategies: The strategies that Michael has implemented on his farm not only benefit his operation but also have broader implications for the environment and the community. For example, the use of drought-tolerant grasses and rotational grazing practices can help to improve the health of the soil and reduce erosion, which can benefit the local ecosystem and water quality.
- The importance of adapting to drought and climate change: The challenges of drought and climate change are likely to become more severe in the future, making it increasingly important for farmers to adapt and find ways to mitigate their impacts. Michael's farm serves as a model for other farmers looking to adapt to these challenges and find ways to build resilience and sustainability into their operations.
- The role of technology and innovation: Technology and innovation can play a critical role in helping farmers to adapt to drought and climate change. The improvements in data interrogation and the adoption of further financial modelling software help farmers to be more efficient and sustainable in their practices.

Mount Majura Vineyard

Adaptation in viticulture

The Canberra District is home to a small but vibrant viticulture community, with several wineries and vineyards located in the region. They are typically small to medium-sized operations, with many family-owned and operated. The region has a long history of viticulture, with the first grapevines planted in the region in the late 19th century. Today, the region is known for producing high-quality wines, particularly varieties such as Riesling and Shiraz.

The Canberra District's viticulture industry is supported by several organisations, including the Canberra District Wine Industry Association and the Viticultural Society of the Canberra District, which represent the interests of winemakers and grape growers in the region. The associations work to promote the region's wines and support the development of the industry. The industry is supported by several research and education organisations, including the National Wine and Grape Industry Centre (Wagga Wagga), the Australian National University's Research School of Biology and the University of Canberra's School of Science, Health, and Engineering. These institutions research topics such as grape and wine production, viticulture practices, and the impacts of climate change on the industry.

In addition to its wineries and vineyards, the region is also home to some winery restaurants and tasting rooms, which provide visitors with an opportunity to sample the region's wines and learn about the local viticulture industry.

Mount Majura Vineyard

Mount Majura Vineyard is at the top of the Majura Valley, just outside the city of Canberra. All wines are sourced from the single vineyard site, which also features a restaurant, cellar door, and vineyard tours. Water is noted as the single most significant resource for the vineyard, and concerns about the impacts of climate change are driving many changes on the property. The vineyard's water supply consists of a water bore licence which is utilised to its full capacity, an on-farm dam two to three megalitres in size (not being used as there is no surface water licence), and rainwater tanks for the winery (there is no town water supply).

Impacts of climate change

The vineyard and winery are already experiencing several impacts associated with climate change:

- → Vintage advancement describes the shift in the timing of grape harvests because of climate change. In many regions, grape harvests are occurring earlier than they did in the past due to warmer temperatures and changing weather patterns. For example, Mount Majura Vineyard has observed that on average, chardonnay grapes advance 1.5 days each year. That is, in the 30 years since the inception of the vineyard, Chardonnay now ripens 45 days earlier than it once did.
- → Similarly, vintage compression is the term used to describe the shortening of the grape-growing season due to warmer temperatures. Later-ripening varieties are ripening earlier due to warmer autumn temperatures, whereas earlier-ripening varieties were already ripening at their maximum rate in late summer. The impact of this compression at Mount Majura Vineyard has been limited by the fact that the climate is warming from a cooler base, but adaptations are being made to limit the potential for compression (see below)
- → Season-season variability has increased and is unpredictable, with large swings from cool wet seasons to hot dry ones, e.g., 2012-2013 and the other way in 2020-2021.

This has had several implications for the organisation, including:

- Changes in grape quality: Shorter growing seasons can lead to grapes that are less ripe and have a different balance of flavours compared to grapes grown in a longer season. This can affect the quality and flavour of the final wine.
- More challenges in grapevine management, such as needing to have more open canopies in cool seasons to combat disease, but more shaded canopies in hot seasons to prevent sunburn.

- Changes in the timing of winemaking: The shorter growing season can also affect the timing of winemaking and has required Mount Majura Vineyard to adjust their schedules to accommodate the earlier or later arrival of grapes. This can be particularly challenging for the winery which does not have the capacity to process the grapes within shorter or overlapping timeframes. This has flow on impacts to the availability of staff who work across multiple vineyards in the region – "we have contract pickers and it's already tough to get staff."
- Changes in the economic viability of certain grape varieties: Some grape varieties may become less economically viable because of vintage advancement/compression, as they may not be well-suited to the changing growing season. This can lead to a shift in the types of grapes that are planted in a region and adds additional challenges around the marketing of new grape varieties – "there is conservatism in the market. A new grape variety is hard to sell if people do not recognise it."

→ Scale insects are a type of pest that can be a problem for vineyards, as they feed on the sap of grapevines and can damage the plants. Mount Majura is concerned that climate change is likely to exacerbate the problem of scale insects in vineyards, with studies showing they become survive better under warmer winter conditions. Climate change can also lead to changes in the prevalence of other pests and diseases, which can affect the overall health of grapevines and make them more susceptible to scale insects. For example, if Mount Majura Vineyard is dealing with a disease outbreak, the vines may be weaker and more prone to damage from scale insects.

→ Bushfire smoke has been a genuine problem, as it can affect the quality and flavour of grapes and wine. In 2020 Mount Majura Vineyard lost the entire crop because of bushfire smoke damage. While this instance was manageable as a once-off event, consecutive events would be catastrophic for the business. Controlled burns can potentially cause the same damage, and the seasonal window for controlled burns may be shortening, making it more challenging for the authorities to conduct burns outside the time that grapes are ripening.

Adaptation activities

Mount Majura Vineyard is taking a variety of actions to adapt to climate change. Some of these actions include:

→ Changing grape varieties to counter winery and staff capacity concerns associated with vintage advancement/compression: for example, replacing Pinot that is picked in March with a new variety, Graciano, that is instead picked in late April.

→ Planting grape varieties that are more resistant to extreme weather conditions: Some grape varieties are more resistant to heat and drought than others, so Mount Majura are investigating alternative varieties.

→ Modernising irrigation systems: installation of temperature and soil moisture sensors to provide a quantitative basis for irrigation scheduling, potentially optimising irrigation and maximising water use efficiency.

→ Implementing cover cropping: for Mount Majura, cover cropping means allowing grass to grow between and under rows of grapevines to help improve soil health and reduce erosion – although this does require additional maintenance to ensure this does not interfere with grape growing it has been beneficial in the long term.

→ Using weather forecasting and monitoring systems: Using wine-making specific resources such as Wine Australia's Climate Atlas, as well as near and medium-term forecasting and monitoring systems to better understand and predict the impacts of climate change on their crops, and to make more informed decisions about irrigation, pest management, and other aspects of vineyard management.

→ Data collection and analysis: there has been a strong culture of keeping weather records on the property to understand longer-term trends. Key indicators include growing degree days; winter rainfall; Brandis Index.

→ Collaborating with researchers and industry groups: working with researchers and industry groups to develop and assess innovative approaches to adapting to climate change.

→ Managing wine inventories: to cater for years that see significant drop loss (e.g., following 2020 bushfires), there is a concerted effort to build up stock inventories during good years – "we want to have a year's worth of stock in the cellar to get us through". This has most recently resulted in departure from long-term practice by purchasing grapes from other regions, for use in a sub-brand.

→ Diversifying land use: a portion of land is leased to a solar PV farm, helping create climate-independent income streams for the business from what was previously unused land unsuitable for grape growing.

06

Further issues for consideration

Drought will continue to be a challenge for rural landholders and farmers in the ACT. Investment in adaptation measures to build resilience to drought will be essential to preserve rural land and farming activities within the ACT.

Chapter 5 explores a range of potential actions that could contribute to improved drought preparedness and response. These actions are intended to serve as a guide for various stakeholders, including rural landholders, government agencies, and other relevant parties and does not assume exclusive responsibility for implementation by the ACT Government.

Based on the observed climate, future drought scenarios, stakeholder engagement, review of climate change impacts and identifying adaptation actions, the following issues are worth considering regarding resilience to drought in ACT.

- **Diversity of agricultural enterprises within the ACT.** While sheep and cattle farming represent a large proportion of ACT's agricultural enterprises, there is a long 'tail' of diverse agricultural products produced at a smaller scale.
  - Many federal government programs which focus on improving drought resilience are targeted at either larger-scale operations, generally larger than those of the ACT farming community; or industries that have only a small representation in the ACT such as cropping and horticulture.
  - Farming practices across the ACT generally require less water (i.e., few enterprises exist that require irrigation). Cropping, for example, which is subject to relatively higher drought risk due to the high need for irrigation is not prevalent in the ACT. This has likely shielded ACT farmers from some of the more severe financial impacts seen in other regions, as well as the tendency for farm profits to become more sensitive to drought impacts over the years. At the same time maintaining stock water, stock feed and animal health during drought has incurred considerable expenditure.
  - Other enterprises, such as vineyards, need longer lead times to adapt due to the high costs in switching grape varieties and the lengthy transition times from plant/grafting new varieties and harvesting grapes from the new varieties. For example, growing and marketing new grape varieties (that may perform better under different future climate conditions) takes more time and financial investment. These expenses are also incurred by grazing enterprises that shift cattle or sheep breeds and can take years for a transition to fully occur.
- **Lack of government progress in planning for droughts.** Stakeholder feedback indicated that participants felt that the policy context to support planning for, managing, and recovering from droughts has been limited, with limited representation for the farming community within the ACT Government. This plan and other activities funded through the Australian Government Future Drought Fund aim to address this.
- **There is broader exposure to multiple climate hazards.** Whilst this study focusses on the impacts of drought, the ACT's exposure to bushfire risk was highlighted throughout stakeholder engagement. There may be a need to do additional work to support farmer preparedness for bushfires in the future, given the growing frequency and intensity of bushfires in the ACT. Experience in other jurisdictions have found that the compounding impacts of multiple sequential natural disasters can quickly erode community resilience.
- **Adoption of farm management software and the availability of farm-relevant data is increasing.**
  - Farm sizes are typically small and as such have smaller revenues and expenditure budgets. As such, small farms are less likely to have digestible climate data available to them (e.g., destocking triggers), nor access to farm management software which is generally considered cost prohibitive. However, investment in new data provision and training is increasing farmers' engagement with new data sources.
  - Studies of national scope reviewed in the context of this study often entirely omit discussion of ACT as a farming region.[82]

- The lack of accurate production and consumption data is a significant impediment to the development of sustainable food production strategies by the government and the private sector to assess diversification options that generate increased availability of locally sourced food in the ACT. This will be addressed through the Canberra Region Local Food Strategy, with a focus area identified to increase baseline data related to the food system for the region.
- Existing and emerging free tools such as Farming Forecaster appear to have good uptake, demonstrating an appetite for receiving and utilising more information to assist planning.

→ **Strong ability to adapt to climate change.** Rural landholders in the ACT are generally well positioned to prepare for future drought, reasons that support this include:

- It was identified that some rural landholders expressed that they felt confident that they would be able to introduce adaptation measures sufficient to manage the scale of changes expected. Adaptation measures such as changing stocking rates, changing breeds or species selection and diversification of farm income were identified as key measures to support adaptation and drought preparation.
- Despite this confidence, climate change projections and scenarios indicate that future drought conditions will increase in severity and frequency which may overwhelm the levels of drought preparedness able to be achieved by individual farmers. A key factor identified by stakeholders that mitigated the impacts of the 2017 – 2020 drought was beef and lamb prices and demand remaining high. In times of future drought, global and local political, economic, and social trends may not provide the same protections.

→ **Access to alternative water supplies.** Landholders have cited reliance on a range of water sources including farm collection (e.g., tanks and dams), extraction of surface water, extraction of groundwater, and use of mains water.

- The relatively short distance between rural properties and urban areas means many farms have access to mains-supplied water. While there is a higher cost associated with its use, it has meant these farmers have had security to water their core stock in times of drought.
- Several landowners interviewed have invested in bore water extraction infrastructure; however, this is not an option for all properties. Key barriers to their use include high administration fees for bores that are not in use, difficulty in getting approved where catchment allocations have been exhausted, or unsuitable geology. Existing bore water users noted that there are inefficiencies in the way water allocations are distributed, with those establishing a bore first receiving first rights to water. Where users do not use their full allocation, it means other users within the catchment lose out.
- The current use of wastewater recycling for agricultural production and other purposes in the ACT is minimal, though some farms benefit from releases by the Lower Molonglo Water Quality Control Centre.

→ **ACT rural areas often have high quality remanent vegetation.**

- This will enable potential farmer access to future natural areas stewardship payments if they are established and the areas within the ACT meet eligibility criteria.

→ **A lack of local agricultural infrastructure and skills.**

- The small agricultural market means there is limited access to key supporting infrastructure such as abattoirs and veterinary services. This raises costs associated with transport, raises food miles, and contributes to the financial viability concerns of smaller farms.
- Access to skilled agriculture labour is likely to be more constrained, with the small size of the ACT farming sector unlikely to attract career agricultural managers in the long term. Casual labour is particularly important in the context of diversification where out-sourcing of relatively unskilled activities allows landholders to devote more time and focus on diversification efforts.

[82] https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1030903/0

- **Government engagement with adaptation activities in the ACT has the potential to deliver effective action, compared to other jurisdictions in Australia.** With its single level of government structure, relatively small geographical area and small rural population, opportunities to invoke transformational change are numerous.
  - Single-level government means decision-making is simplified and the community has direct access to key decision-makers.
  - The government has the opportunity to gather good on-ground information given the small size of the community.
- **Other triggers for reviewing farm practices may also enable the consideration of climate change planning** e.g., review of farm practices or other reasons such as the potential to work towards biodiversity credits.
- **The ACT Government's management of pests and weeds on crown lands is important in alleviating their spread into agricultural land**, easing the pressure of invasive species on farm boundaries. Continued investment in providing guidance to landholders around drought recovery actions such as managing fodder, weeds etc. is appreciated.
- **A high proportion of farms receive off-farm income.** This typically implies that these landholders are more financially resilient compared to others that are entirely reliant on their farm outputs.
  - A 2020 survey by ACT NRM indicated that almost 80% of landholders surveyed (approximately 48 responses) derived at least 50% of their income from activities not related to their rural holdings. These properties most likely have a higher degree of economic security and consequently have an increased capacity to trial and adopt new systems, technologies, and other diversification opportunities.
  - Growers with part-time or full-time employment off-farm may therefore find it difficult to allocate sufficient time-resources to maximise the probability of successful diversification. A balance of capital generation and time commitment is needed.
  - Household income amongst the broader ACT community is high in comparison to the Australian average – for example, in 2021, 38.3% of households in the ACT had an income of more than $3,000 per week[83] (the Australian average was 24.3% of households). There is a sense among stakeholders that ACT residents have a higher propensity to support the purchase of premium sustainable products such as those grown in the ACT region.
- **Improvements to farm management practices that are not specifically associated with drought are ongoing.** Technology already being adopted includes minimal tillage principles, water infrastructure improvements, and investment in more advanced machinery and equipment lead to multiple improved farm outcomes, but also tend to improve the ability of farms to manage droughts when they do occur.
- **Further exploration on the impacts of drought on traditional Ngunnawal land management and cultural activities is necessary.** This knowledge can inform the development of drought preparedness and response strategies that are culturally sensitive and support the long-term resilience of Ngunnawal country.

[83] https://www.abs.gov.au/census/find-census-data/quickstats/2021/8


CAUTION

07

Theory of change

By working together, this plan empowers rural landholders, government, and other stakeholders to identify and implement strategies that strengthen drought preparedness and response.

Theory of change

A theory of change explains how undertaking actions and activities will lead to the desired outcomes of the RDRP. This is important as it sets out why certain actions are essential, and the steps necessary to realise the goals of the RDRP. This is applied through careful explanation of recommendations and commitments, sequenced over time. This will be an important aspect of the RDRP's monitoring and evaluation component and will be developed as part of the Monitoring, Evaluation and Reporting Plan (MERP) and the process can be seen in **Figure 9** below.

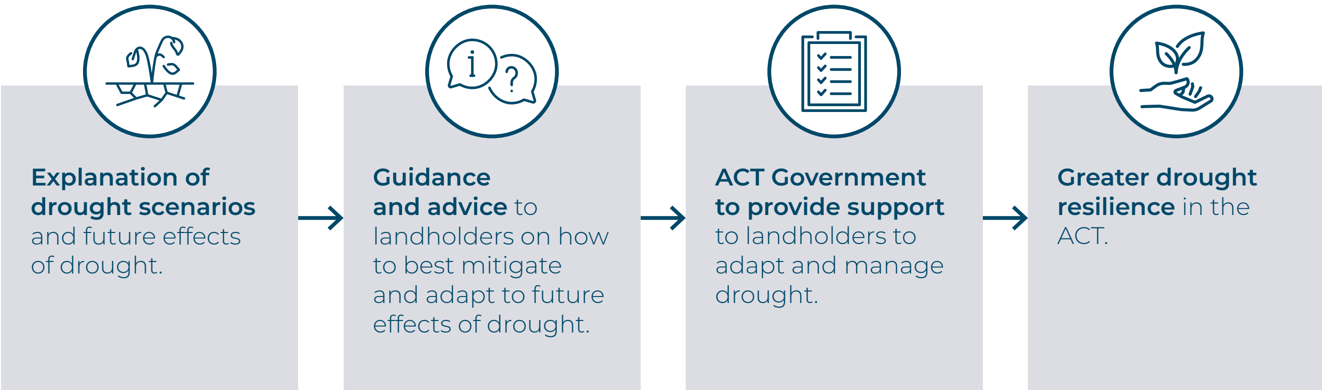


Figure 9: Theory of change diagram.

Initiatives that were highlighted by farms to be successful included:

- **Transport subsidy** where farmers bought fodder and/or water to a property, stock to/from agistment, stock to sale or slaughter, chemicals, fertiliser, and seed to farms and government covered up to 50% of the total freight cost.
- **National On-Farm Emergency Water Infrastructure Rebate** where a 25% rebate was offered for the costs associated with the purchase and installation of on-farm stock water infrastructure and infrastructure for permanent horticultural crops (grapes, olives, orchards) to improve farm resilience to drought.
- **Rural Resilience Grants** have been provided for 2018-2019, 2019-2020 and 2020-2021 to support landholders to build farm resilience. During conversations with landholders, it was noted that these grants were used to build drought lots, install siloes, construct fodder storage sheds and install a range of farm stock water infrastructure, as well as undertake post-drought weed and pest animal control.
- **The Future Drought Fund Farm Business Resilience program** which is offering training to farmers in financial management and natural resource management in preparation for drought. Under the pilot year of the program, 10 ACT farmers undertook Meat and Livestock Australia's Business Edge Training; 14 landholders have been part-sponsored to attend a range of different natural resource management training courses; 4 farm families are receiving farm business coaching; and ACT NRM has offered 3 farm business webinars.
- **ACT Environment Grants** are offered every year and provide farmers with the opportunity to seek support to protect environmental assets on their farms.

Other support offered included relief grazing, requirements for fodder purchased from interstate and financial and mental health services.

The Australian Government also provided a variety of assistance measures including[84] :

- **Farm household allowance** to provide assistance to farming families experiencing financial hardship.
- Rural financial counselling service help farmers find and apply for funds.
- Drought Communities Programme to support local infrastructure projects, to create new opportunities in drought-affected communities.

Barriers to receiving government support

Despite federal government support being available, several farmers in the ACT were not able to qualify for some of the rebates due to receiving off farm income or due to their agricultural practise not being eligible to apply. Criteria that excluded several farmers from being eligible included:

- "You are a sole trader, partnership, trust or private company and trade agricultural products" (Transport subsidy[85])
- "As owners and operators of the business you earn more than 50% of your gross income from the primary production enterprise under normal seasonal circumstances" (Transport subsidy[86])
- "As owners and operators of the business you do not have gross off-farm assets exceeding $5,000,000" (Transport subsidy[86])

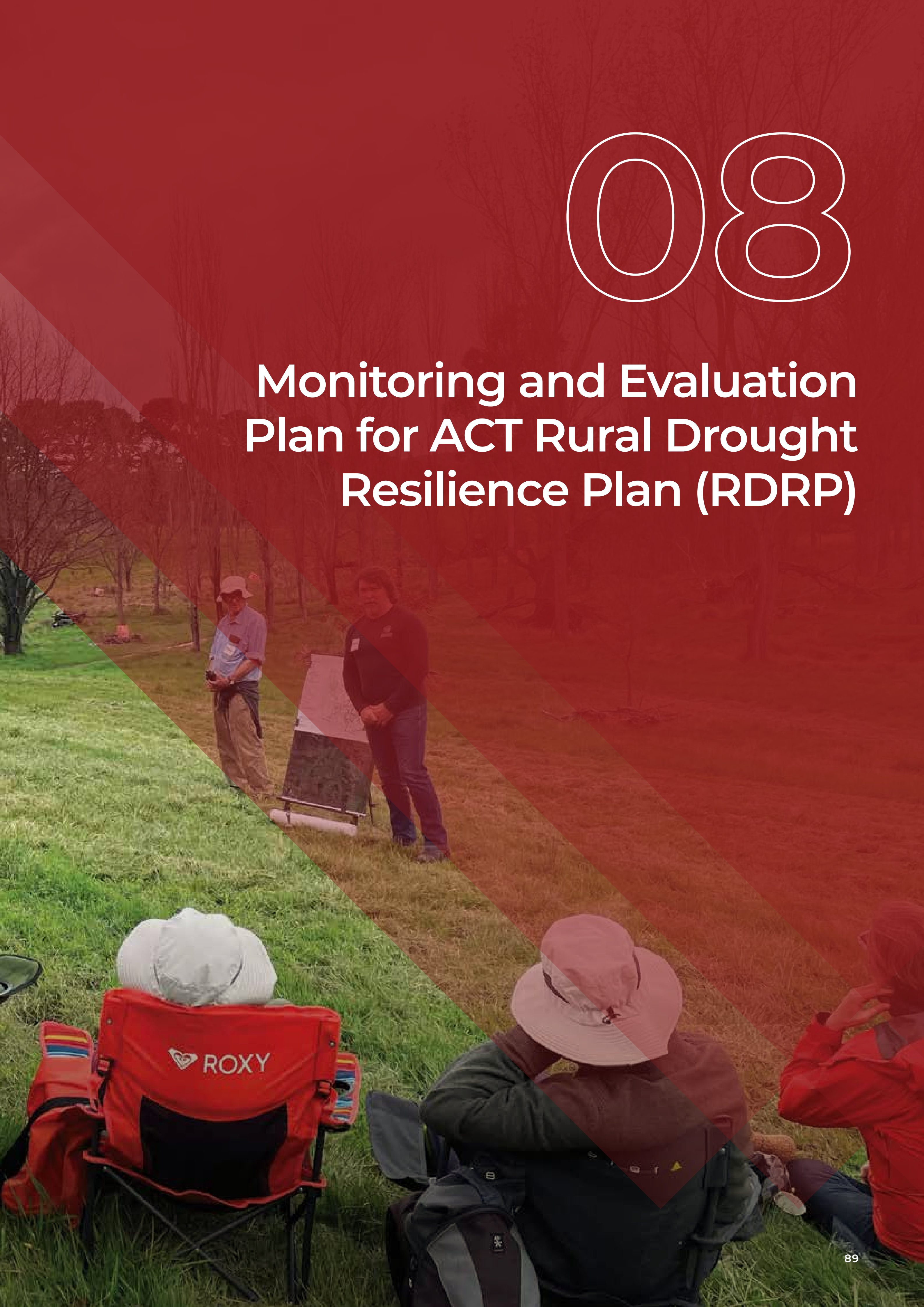
Overall, the main limitation for eligibility was due to off-farm income. The Australian Government amended the Farm Household Allowance to lift the off-farm income threshold to $100,000 and allow anyone running at a loss to access the offset.[86]

Through conversations with farmers it was also noted that there was opportunity to streamline and simplify the grant systems, access, and applications. E.g. Farmers indicated that it can take two weeks to put together a $5,000 grant.

[84] Australian Government Department of Agriculture, Fisheries and Forestry, 2020,Assistance measures, https://www.agriculture.gov.au/agriculture-land/farm-food-drought/drought/assistance

[85] ACT Government, Transport Subsidy Application Guideline (Round Two)

[86] Australian Government Department of Agriculture, Fisheries and Forestry, 2022, Farm Household Allowance, Farm Household Allowance - DAFF (agriculture.gov.au)



08

Monitoring and Evaluation Plan for ACT Rural Drought Resilience Plan (RDRP)

Vision

The ACT rural community is empowered, connected and supported in drought and climate change planning, preparedness, adaptation, and response, and can adapt to absorb the impacts of future droughts.

Overall Goal

Build the drought resilience of the ACT's rural community across environmental, economic, social, and governance aspects.

Monitoring and Evaluation Framework

This framework will guide the assessment of the ACT RDRP's effectiveness in achieving its vision and goals. It will use a mixed-method approach, combining quantitative and qualitative data collection methods.

Monitoring Indicators

Each strategic priority will have a set of monitoring indicators to track progress towards achieving its outcomes.

Strategic Priority: Environmental Resilience

Outcome 1: Rural communities have access to alternative water sources

- **Short term indicator:** Number of rebates awarded for rainwater tanks or alternative water infrastructure projects.
- **Long term indicator:** Number of rural properties with access to reliable alternative water sources (e.g., rainwater tanks, bores).
- **Data collection:** Grant program data analysis, ACT Government data.

Outcome 2: Improved resilience to wider climate-related shocks and stresses

- **Short term indicator:** Number of workshops or training sessions offered to landholders on climate projections and sustainable land management practices. Participation rate in these workshops.
- **Long term indicator:** Increased or consistent levels of community engagement and participation in drought resilience initiatives.
- **Data collection:** Workshop attendance records, Surveys, ACT Government data.

Strategic Priority: Economic Resilience

Outcome 1: Access to and engagement with data

- **Short term indicator:** Number of landholders accessing climate data projections.
- **Long term indicator:** Landholder satisfaction with the accessibility and usefulness of climate data.
- **Data collection:** Surveys.

Outcome 2: Land management agreements support climate adaptation

- **Short term Indicator:** Number of workshops or training sessions offered on farm business resilience, farm diversification.
- **Long term indicator:** Number of farms undertaking whole-of-farm planning and/or diversification planning.
- **Data collection:** Workshop attendance records, coaching engagement, Surveys.

Strategic Priority: Social Resilience

Outcome 1: Supporting education to cope with the social and psychological impacts of drought

- **Short-Term Indicator:** Number of landholders participating in drought preparedness training programs.
- **Long-Term Indicator:** Landholder self-reported knowledge of drought preparedness strategies, value of social connection, and peer to peer engagement.
- **Long-Term Indicator:** Improved landholder perception of their mental and emotional wellbeing alongside community drought resilience.
- **Data Collection:** Surveys, attendance records

Outcome 2: Increased recognition of the ACT as a producing region

- **Short-Term Indicator:** Progress on ACT Local Food Strategy.
- **Short term indicator:** Number of media articles or promotional campaigns highlighting the ACT's agricultural sector.
- **Long-Term Indicator:** Increased market opportunities for ACT-produced agricultural products.
- **Data Collection:** Media monitoring, Partnership agreements, Market analysis reports.

Strategic Priority: Governance

Outcome 1: Effective collaboration between government and the community

- **Short-Term Indicator:** Frequency and effectiveness of engagement between the RDRP Steering Group and the farming community.
- **Long-Term Indicator:** Landholder satisfaction with the level of government support for drought preparedness.
- **Data Collection:** Meeting minutes, surveys.

Reporting:

- Regular monitoring reports will be prepared to track progress towards achieving the RDRP's outcomes.
- Evaluation reports will be prepared and disseminated to stakeholders, including the ACT Government, rural landholders, and the public.
- The monitoring and evaluation framework will be reviewed and updated periodically to ensure its continued effectiveness.

Responsibilities:

- The ACT RDRP Steering Group will be responsible for overseeing the implementation of the monitoring and evaluation plan.
- The Environment, Planning and Sustainable Development Directorate (EPSDD) will be responsible for collecting and analysing data, preparing reports, and conducting evaluations.
- Stakeholders, including rural landholders, will be consulted throughout the monitoring and evaluation process.

This monitoring and evaluation plan provides a framework for assessing the ACT RDRP's impact on building drought resilience in the ACT's rural community. By tracking progress, conducting evaluations, and adapting the plan as needed, the ACT Government can ensure that the RDRP is effectively meeting the needs of rural landholders and helping them prepare for the challenges of drought and climate change.

Australian Government
Department of Agriculture, Fisheries and Forestry

Future Drought Fund

ACT Government

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AECOM

Prepared for
Environment, Planning and Sustainable Development Directorate
ABN: 31 432 729 493

Final Report

Climate and Drought Resilience Risks and Planning

22-Dec-2022
Climate and Drought Resilience Risks and Planning

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Final Report

Climate and Drought Resilience Risks and Planning

Client: Environment, Planning and Sustainable Development Directorate

ABN: 31 432 729 493

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2	25-Nov-2022	Final	Adam Davis Technical Director	
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Table of Contents

Acronyms

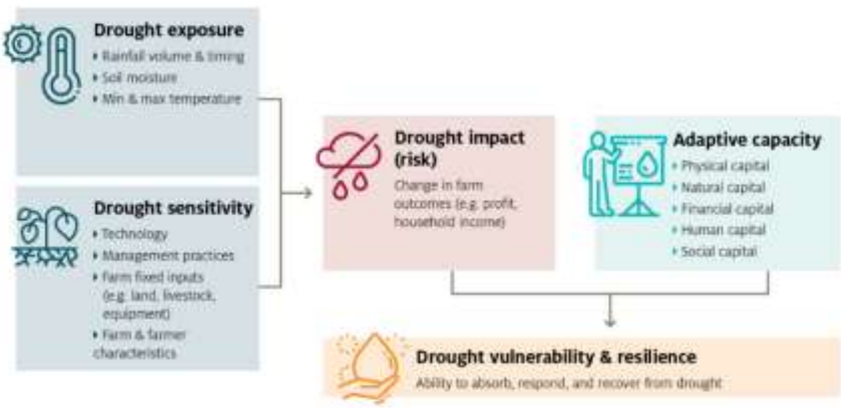
Acronym	Meaning
ABARES	Australian Bureau of Agricultural and Resource Economics
ACT	Australian Capital Territory
AEP	Annual Exceedance Probability
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Department of Agriculture Forestry and Fisheries
ENSO	El Niño Southern Oscillation
EPSDD	The Environment, Planning and Sustainable Development Directorate
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GVP	Gross Value Production
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LMA	Land Management Agreement
MDB	Murray Darling Basin
MLA	Meat and Livestock Association
NARCliM	NSW and ACT Regional Climate Modelling project
NRM	Natural Resource Management
NSW	New South Wales
NUZ	Non-Urban Zone
RDRP	Regional Drought Resilience Planning
RCP	Representative Concentration Pathway
SAM	Southern Annular Mode
SDL	Sustainable Diversion Limit
SPI	Standardised Precipitation Index
SSPs	Shared Socioeconomic Pathways
VPD	Vapour Pressure Deficit
PDO	Pacific Decadal Oscillation
IOD	Indian Ocean Dipole

Glossary

Key term	Definition
Adaptation (to climate change)	In human systems, the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2022). Adaptation actions may include physical changes to an asset to achieve or facilitate adaptation including changes/upgrades to technology and equipment, design standards for particular project elements, operational actions, or natural resource management actions (e.g., assisted colonisation, mixed-provenance plantings, restoration of key connectivity pathways to enable movement).
Adaptive capacity	The ability of institutions, systems, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences of environmental variability and change (IPCC, 2022). It includes adjustments in both behaviour and in resources and technologies.
Cascading impacts	Occur when an extreme hazard generates a sequence of secondary events in natural and human systems that result in physical, natural, social or economic disruption, whereby the resulting impact is significantly larger than the initial impact (IPCC, 2022).
Climate change	A change in the state of the climate persisting for an extended period, typically decades or longer (IPCC, 2022). Climate change may be due to natural variability or a result of human activity. In this report 'future projections' refer to projections informed by climate change modelling.
Climate hazard	*The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources*[1] In this report, the term hazard refers to climate-related hazard events (such as floods or heatwaves) and evolving trends which are likely to be hazardous to agricultural activities (e.g., change in number of hot days or the frequency of days with high rainfall).
Climate projections	Simulated response of the climate system (including variables such as temperature, precipitation, wind, solar radiation, sea level) to a scenario of future emissions or concentrations of greenhouse gases and changes in land use, generally derived using climate models. Climate projections depend on an emission scenario, in turn based on assumptions concerning factors such as future socioeconomic and technological developments that may or may not be realised (IPCC, 2022).
Climate variables	Factors that determine and govern the climate. Main factors include rain, atmospheric pressure, wind, humidity, and temperature. Changes in climate variables (such as temperature) can lead to changes in climate hazards (such as heatwaves).
Compound events	The combination of multiple drivers and/or hazards that contributes to societal and/or environmental risk (IPCC, 2022).
Consequence	Outcome of an event affecting objectives. A consequence can be certain or uncertain and can have positive or negative direct or indirect effects on objectives. Any consequence can escalate through cascading and cumulative effects (ISO, 2018).

[1] Intergovernmental Panel on Climate Change, 2014. *Climate Change 2014: Impacts, Adaptation and Vulnerability.* Page 5. https://www.ipcc.ch/site/assets/uploads/2018/03/ar5_wgII_spm_en-1.pdf

Key term	Definition
Drought	A prolonged period of abnormally low rainfall when the available water is insufficient to sustain normal use. (BoM, 2022)
El Niño Southern Oscillation (ENSO)	The oscillation between the El Niño climate phase and the La Niña phase, usually over several years. Defined as a climate pattern that describes the unusual warming of surface waters in the eastern tropical Pacific Ocean.
Emission scenarios	Possible pathways that society might take in the emission of greenhouse gases in the future.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected (IPCC, 2022).
Extreme weather event	An event that is rare at a particular place and time of year. The characteristics of what is called extreme weather may vary from place to place (IPCC, 2022).
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	FAPAR is the fraction of incoming solar radiation absorbed for photosynthesis by a photosynthetic organism (live leaves).
Greenhouse gases	Gaseous constituents of the atmosphere that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's ocean and land surface, by the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour, carbon dioxide, nitrous oxide, methane, and ozone are the primary greenhouse gases in the Earth's atmosphere (IPCC, 2022).
Hazard (climate hazard)	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC, 2022).
Indian Ocean Dipole (IOD)	Defined by the difference in sea surface temperature between two areas – a western pole in the Arabian Sea and an eastern pole in the eastern Indian Ocean south of Indonesia. The IOD affects the climate of Australia and other countries that surround the Indian Ocean Basin and is a significant contributor to rainfall variability in this region.
Infrastructure	The designed and built set of physical systems and corresponding institutional arrangements that mediate between people, their communities, and the broader environment to provide services that support economic growth, health, quality of life, and safety (IPCC, 2022).
Likelihood	The chance of something happening (ISO, 2018).
Mitigation (of climate change)	Actions taken globally, nationally, and individually to reduce greenhouse gas emissions and/or increase the amounts of greenhouse gases removed from the atmosphere by greenhouse sinks (IPCC, 2022).
Pacific Decadal Oscillation (PDO)	Defined by the leading pattern of sea surface temperature anomalies in the North Pacific basin.
Representative Concentration Pathways (RCPs)	Scenarios that include time series of emissions and concentrations of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover. The word representative signifies that each RCP provides only one of many possible scenarios. The term pathway emphasises the fact that not only the long-term concentration levels, but also the trajectory taken over time to reach that outcome are of interest (IPCC, 2022).
Resilience (climate resilience)	Ability for interconnected social, economic, and ecological systems to absorb, respond, and recover from droughts and other hazardous events ((IPCC, 2022; Hughes et al, 2020).

Key term	Definition
Risk	The effect of uncertainty on objectives. An effect is a deviation from the expected and may be positive and/or negative. Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence (ISO, 2018).
Rural landholders/ACT Farming community	Rural land in the ACT is leased by farmers, as is the case with all residential land in the ACT. The Territory's 159 farming families collectively manage 180 leases covering 40,000ha (15%) of the ACT.
Sensitivity	The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in temperature) or indirect (e.g. damages caused by an increase in the frequency of flooding) (IPCC, 2022)
Simulation	A computer simulation of global climate modelling that is built using real data.
Standard Precipitation Index (SPI)	The Standard Precipitation Index (SPI) reflects soil moisture and precipitation conditions and is the most used indicator for detecting and characterising meteorological droughts. SPI is an index where negative values are associated with below average rainfall and drought while positive values indicate wetter than average conditions.
Standardised Precipitation-Evapotranspiration Index (SPEI)	The Standardised Precipitation-Evapotranspiration Index is an extension of the widely used SPI and can be used for determining the onset, duration, and magnitude of drought conditions with respect to normal conditions in a variety of natural and managed systems.
Vulnerability	This report conceptualises drought risk in line with existing frameworks (Hughes et al, 2020) outlined in Figure 1. This framework conceptualises drought risk as a function of exposure and sensitivity, whereby farm drought risk depends both on a farm's exposure to climate variability and the sensitivity of its production systems to that variability. **Figure 1 Framework for assessing drought vulnerability and resilience[2]** 

[2] Hughes, N., Burns, K., Soh, W., & Lawson, K. (2022). *Measuring drought risk | The exposure and sensitivity of Australian farms to drought*. https://www.agriculture.gov.au/abares/research-topics/climate/measuring-drought-risk#:~:text=This%20study%20presents%20estimates%20of,to%20display%20greater%20drought%20risk.

Executive Summary

The ACT Environment, Planning and Sustainable Development Directorate engaged AECOM to conduct a study on the future drought scenarios facing ACT's agricultural community. The Study was established to build an understanding of the impacts of these scenarios on the ACT's agricultural community and support the development of the Regional Drought Resilience Strategy. This study has:

- Developed a baseline current climatology of droughts in the ACT
- Developed three future drought scenarios for the ACT utilising existing projection data, reviewing water availability, temperatures, precipitation, evapotranspiration, seasonal shifts in rainfall and other metrics associated with these scenarios.
- Assessed the impacts of those scenarios on the enterprises of the ACT farming and rural community
- Identified mitigating actions that improve climate and drought resilience.
- Provides three case studies of successful mitigation activities in the ACT

Method and stakeholder engagement

The assessment took a four-phase approach:

- Collation of **existing climatology and future climate projections** for the Territory.
- **Stakeholder engagement** was undertaken via one-on-one interviews with stakeholders, a multi-stakeholder workshop, and an online survey to develop an understanding of landholders' current consideration of droughts and future climate change
- **Desktop review** whereby impacts on ACT rural landholders and adaptation actions they have underway or planned are identified over four domains, followed by prioritisation of impacts and actions based on stakeholder engagement.
- **Reporting** and follow-up desktop research to consolidate findings.

The project employed an integrated engagement program with ACT rural landowners to gather inputs to inform the resilience plan.

Agricultural context

ACT agriculture consists of almost 160 farming families collectively managing 180 leases covering 15% of the ACT. The region supports a wide variety of agricultural outputs but geographically covers a small area compared to other Australian states and territories.

Climate context

Drought is a recurring hazard in the ACT that will likely accelerate and continue to provide challenges to the ACT's rural community in the coming years. Historically, the ACT has seen:

- 13 periods of heatwaves since 2008
- The four hottest summers and three hottest springs have occurred in the last 20 years
- The four hottest years have occurred in the last 20 years.

Three future scenarios of drought have been developed based on NSW and ACT's latest climate models. These scenarios outline future climate change projections assuming a range of global emission scenarios – ranging from an accelerated transition to a low carbon economy to a scenario of continued high emissions. Under all scenarios, the ACT's climate is projected to become warmer and drier, with more extreme weather events. These trends are more severe under scenarios with higher emissions. Projected higher average temperatures and reductions in average annual rainfall are likely to see periods of drought increase in both frequency and intensity. A summary of climate change projections under the 'middle' scenario is outlined below.

- **Higher average temperatures**, with an increase of about 1.8°C in both the average minimum and maximum daily temperatures by 2045 compared to the 2000 baseline, increasing to about 3.3°C By 2070.
- A shift towards **extreme heat days** with, on average, at least 11 more days above 35°C each year by 2045, increasing to 18 more days by 2070.
- A shift away from **cold days** with, on average, more than 55 fewer days below 2°C each year by 2045, increasing up to 36 fewer days by 2070.
- A reduction in **total soil moisture content** with an 11% decrease annually by end of the century and an 18% decrease in December by the end of the century.
- A likely decrease in **annual rainfall** by 2045 by 3.1%, further decreasing by 9% and 9.3% in 2070 and 2090 respectively.
- While an annual decrease is projected on average, there are significant changes to **seasonal rainfall distributions**. Summer rainfall is projected to increase and winter rainfall is projected to decrease.
- Despite the likely decrease in average rainfall, there is expected to be an increase in **extreme rainfall** events, which will also account for a great portion of all rainfall (i.e., on those days when it does rain, it is likely to be more intense, even if there are fewer days when it rains). Rainfall will likely decrease in winter and spring but increase in summer.
- **Consecutive dry days** (days without rainfall) are projected to increase to 29 days in 2045 and 32 days in 2070 compared to the 2000 baseline of 27 days.

Value Domains

The report outlines the impacts of drought, and responses that are being implemented, in the context of four domains. The domains encompass environmental, economic, social, and governance implications of drought events on the ACT's agricultural community.

Impacts on ACT rural landholders

Impacts felt by ACT rural landholders were collated and categorised across the four domains, and prioritised. Impacts are considered a 'priority' if they were frequently identified by stakeholders in multiple forums and re-validated through desktop review as particular areas of consequence. Priority impacts include:

- Reduced water availability and quality for livestock watering, household use, and other farm activities.
- Reduced carrying capacity of land and inability to maintain ground cover
- Increasing occurrence of weeds, pests, and diseases, challenging existing measures and requiring new methods to manage.
- Reduced on-farm biodiversity because of species loss
- Reduced well-being of the farming community concerning both physical and mental health

Actions taken by ACT rural landholders during times of drought

ACT rural landholders described actions they have taken in the past to respond to droughts, and how drought management can be improved in the future. Key actions have been identified based on stakeholder input and validated through desktop research. Key strategies were determined by the frequency with which they were raised by ACT rural landholders. These included:

- **Land management strategies** that preserve or enhance ecosystems without compromising farm production. Examples include farming appropriately to the farms carrying capacity, carrying less stock, planting trees for shade and heat protection and adding cooling misting sprays (with large droplets that can reach the skin surface, and monitoring respiration)[3] for livestock.

- **Stock management** strategies include destocking to sustain remaining livestock. Inventory reduction strategies including selling feeder animals early, reducing breeding animal numbers, in the worst-case scenarios, selling the herd, and ceasing production.
- **Water management** examples include covering dams to reduce evaporation, actions to improve water quality of water stored on-farm, dam enhancement (e.g., deepening dams) and restoring the environment around dams, increasing investment in water infrastructure systems, and seeking water extraction licenses where available.
- **Enterprise selection strategies** consider physical factors such as land, climate, access to water, farm structures and machinery as well as financial and management factors. Examples include diversifying the enterprise, undertaking greater stock rotations, changing enterprises to those that require less rainfall, switching from breeding to trading stock, selecting drought-resilient breeds of livestock, and use of perennial drought-tolerant grasses.
- **Infrastructure** strategies include installing new or upgrading existing infrastructure such as increasing on-farm storage for water and feed (e.g., dams, bores, accessing town water, piping from local streams, storage for fuel, feed, grain, etc.), improving fencing infrastructure to reduce paddock sizes to better manage grazing and density (new or upgrades), storing silage.
- **Planning and regulations** in agriculture aim to provide opportunities to adapt through the diversification of farming enterprises or expansion in the future. Examples include water licensing (getting approval for bores), seeking amendments to land management agreements, and working with the government on improving access to tools and resources.

Assessment wide findings

Farmers are concerned about drought. The 2017-2020 drought had more significant impacts than previous droughts, and for many farmers, the impacts are still being felt. Strong engagement indicated that farmers are keen to connect within the farming community and work with the ACT Government to better plan for future droughts. Key findings across engagement activities and literature reviews include:

- Most rural **landholders were confident that they would be able to introduce adaptation measures** sufficient to manage the scale of changes expected. Despite this confidence, climate change projections and scenarios indicate that future drought conditions will increase in severity and frequency which may overwhelm the levels of drought preparedness able to be achieved by individual farmers. Few saw that transformative changes in their practices were needed (e.g., existing farm enterprises becoming no longer viable or the introduction of new enterprises).
- Recognising that prolonged periods of drought can elevate bushfire-related risks, the **exposure to bushfire risk** was highlighted throughout stakeholder engagement as a major climate change-related concern. It is recommended that the relationship between drought and bushfire risk is acknowledged in the RDRP, specifically the cascading impacts of drought and bushfire on rural landholders in the ACT and upon the wider community.
- Typical drivers of vulnerability such as poor socioeconomic circumstances are not as evident amongst landholders in the ACT due to **off-farm incomes and high land values**.
- Stakeholder engagement indicated that **very few farmers had engaged previously with future projections of climate change**. To improve the engagement landholders, have with climate projections, there is a need to improve the availability of data to scales relevant to farm planning.
- Literature on agricultural drought risks across Australia regularly finds that enterprises that depend on irrigation for primary production are more vulnerable to droughts. Given the low representation of irrigators operating within the ACT, compared to other jurisdictions in Australia there is an inherent opportunity for the region to lead in having a drought-resilient agricultural community.

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[3] Department of Primary Industries and Regional Development, 2022. *Managing heat load and heat stress in sheep and cattle at saleyards,* Government of Western Australia. available at: https://www.agric.wa.gov.au/beef-cattle/managing-heat-load-and-heat-stress-sheep-and-cattle-saleyards

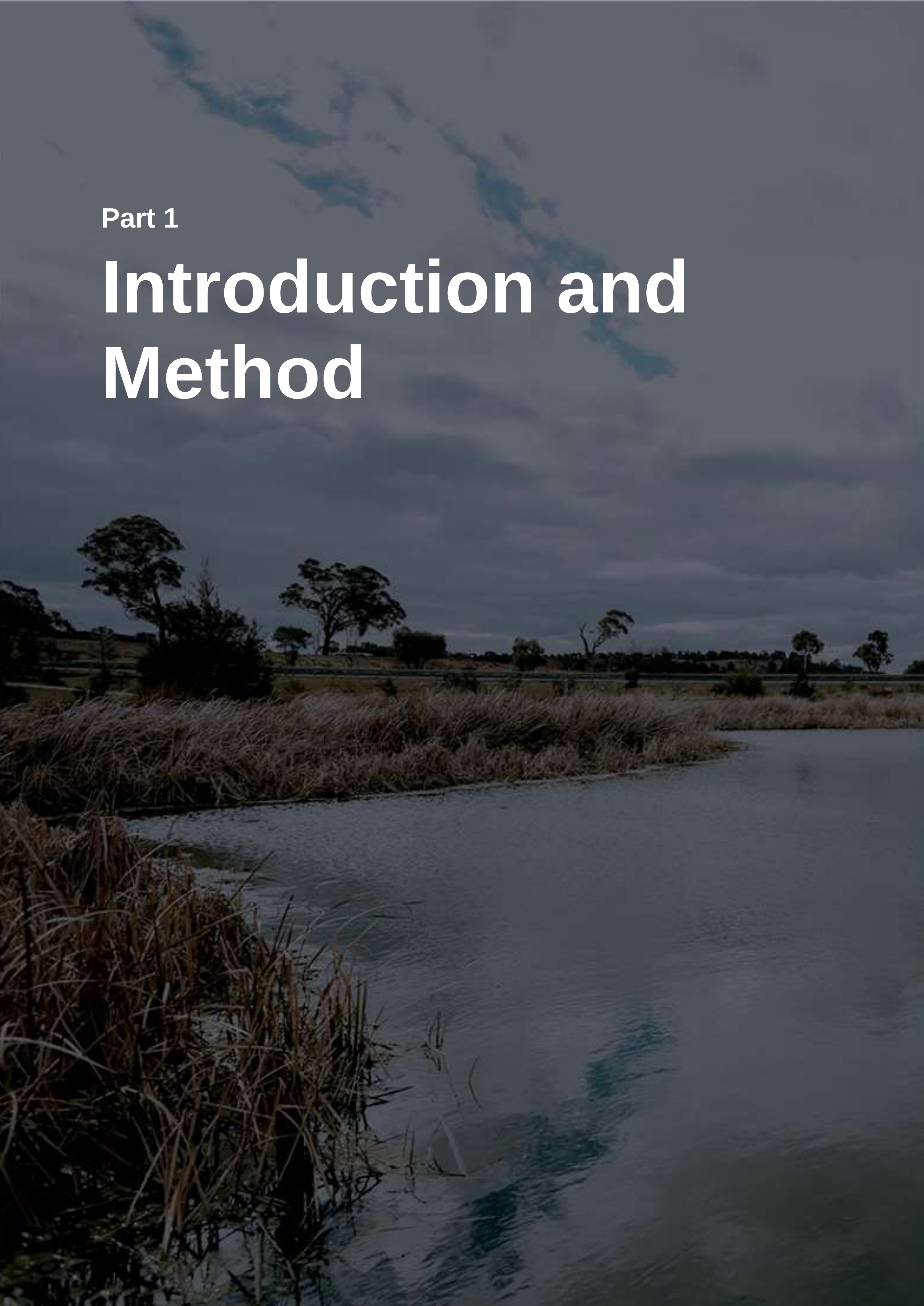
- A common theme was the reflection on the 'place' of rural land within the ACT as a region. Stakeholders shared a **desire to have the importance of rural land acknowledged and emphasised in future planning**. There is an opportunity to protect rural land from future development and emphasise the importance of rural land in supporting biodiversity and providing a buffer zone for managing bushfire risk to the region.
- **Crown leasing arrangements** create multiple challenges to adaptation. The inflexibility of lease purpose clauses challenges farmers' ability to diversify or change enterprises and impacts farm decision-making. Restrictions on secondary dwellings hinder succession planning.
- Farmers expressed concerns relating to access to **key supporting infrastructure** such as an abattoir, ACT Government staff with agronomic expertise and local agricultural product suppliers. This raises costs associated with transport, raises food miles, and contributes to the financial viability concerns of smaller farms.
- **Government engagement with adaptation activities in the ACT** has the potential to deliver effective action, compared to other jurisdictions in Australia. With its single level of government structure, relatively small geographical area and small rural population, the Government is in a strong position to make effective decisions.
- **Improvements to farm management practices that are not specifically associated with drought are ongoing.** Technology already being adopted such as minimal tillage principles, prioritising the selection of drought tolerant native pastures, and investment in on-farm infrastructure improvements (e.g., storage, fencing) is leading to multiple improved farm outcomes, but also tend to improve the ability of farms to manage droughts when they do occur.

Recommendations

Recommendations across five themes of water security; data provision; land use planning; education; and collaboration have been identified and outlined below.

<table>
<tr><th>Action</th></tr>
<tr><td>Enhance water security</td></tr>
<tr><td>Identify opportunities to review farmers' access to alternative water sources to improve water security
• Inefficient allocation of water allocations
- Review water licence allocation mechanisms to enable better sharing of water within catchments. For example, there may be opportunities to allow existing water license holders that do not efficiently use their existing allocation to trade water with others in need elsewhere in their catchment.
- Review water licencing arrangements to acknowledge higher value end uses. For example, water licences could be prioritised for enterprises in line with the Capital Food and Fibre Strategy.
• Investigate opportunities and understand barriers to greater adoption of wastewater reuse e.g. Lower Molonglo Water Quality Control Centre effluent reuse scheme which supplies water to the nearby golf course, and previously supplied to local vineyards
• Ensure that water security on farms during droughts is included in the planned ACT Water Vulnerability Assessment by the Office of Water.</td></tr>
<tr><td>Data provision and engagement</td></tr>
<tr><td>Stakeholder engagement indicated that very few farmers had engaged previously with future projections of climate change. In addition, few saw that transformative changes in their practices were needed (e.g. shifting to produce different agricultural products). To improve the engagement landholders have with climate projections, there is a need to improve scales relevant to drought planning. It was identified that the use of long-term climate projections is not strongly resonating with landowners. Therefore, there is an opportunity for improving drought monitoring and early warning systems.</td></tr>
<tr><td>Engage with projects of national scope to ensure ACT is well-represented within data sets and reporting outputs. E.g. adequate inclusion of ACT's farming community within ABARES data, ACT's inclusion within Droughthub mapping and advice.</td></tr>
</table>

Action
Recognising that droughts and bushfires are driven by many of the same changes in climate variables, it is recommended that the relationship between drought and bushfire risk is acknowledged in the RDRP. Specifically, the cascading impacts of drought and bushfire on rural landholders in the ACT and the wider community.
Land use planning
In the long term, climate futures may increase pressure for more transformative change for certain farms. This could include the emergence of new land use activities such as carbon abatement, biodiversity conservation, or renewable energy generation as complements to traditional farming. Defining ACT Government's ambitions in such spaces would aid existing landholders plan long-term farm improvement measures.
Review land use zone development controls in the Territory to seek the protection of areas of important landscape settings, or nature conservation corridors
Review change of use charges to NUZ1 and NUZ2 (rural and broadacre) zoned land where the main activity is to produce food or fibre i.e. allow ancillary uses without lease purpose change process and costs (provided there is adequate consultation and investigation of impacts of the changes)
Remove current lease and land use restrictions to enable flexibility in farming enterprise selection (e.g. switching from sheep to goats) and timing (e.g. removing minimum stock requirements during times of drought)
Introduce stewardship payments where conservation of important areas of biodiversity, landscape settings or biodiversity restricts agricultural use or could provide additional farm incomes.
Supporting education
The support ACT Government has been providing to the agricultural community is well received, and it is recommended that these activities continue. Suggested topics include: • Alternative climate-resilient enterprises that may be viable in the ACT • Extension of existing farm financial management principles and practices • Support development and implementation of farm-scale drought management plans including identification of trigger points for actions such as selling stock.
Partner with education providers to highlight climate change adaptation and opportunities in agriculture within school curriculums e.g. farm demonstrations/visits
Collaboration and awareness
Encourage the Commonwealth's development of a food security plan to identify and protect farming regions that can continue to produce food under future conditions, including the ACT and its border regions.
Support communication and marketing of produce that is more drought resilient e.g. helping to shift consumer preference to local products or away from meat breeds not suitable for ACT's climate



Part 1

Introduction and Method

1.0 Introduction

1.1 Project context

Under the Department of Agriculture, Forestries and Fisheries (DAFF) Future Drought Fund, the ACT Government has been funded to develop a Regional Drought Resilience Plan (RDRP).

The Future Drought Fund is a long-term investment fund that provides a sustainable source of funding to help Australian farmers and communities become more prepared for, and resilient to, the impacts of drought..

The ACT's RDRP will focus on reviewing and increasing the resilience of ACT's rural areas and agricultural community to drought. The project will align with other Regional Drought Resilience Plans being developed across Australia.

AECOM was engaged to undertake research as input to the RDRP being developed by the ACT Government. Specifically, they were engaged to provide a summary of climate and drought resilience risks for rural landholders in the ACT based on stakeholder engagement, a review of observed climate and the development of future drought scenarios for the ACT. This report details the results of their research including:

1. a baseline current climatology of droughts in the ACT utilising existing observational data, including that collected during the 2017-2020 drought.
2. three future drought scenarios for the ACT utilising existing projection data, primarily from the NSW and ACT Regional Climate Modelling (NARCliM) project.
3. assessing changes in related environmental parameters relevant to agriculture including water availability, temperatures, precipitation, evapotranspiration, seasonal shifts in rainfall and other metrics associated with these scenarios.
4. assessing the impacts of those scenarios on the enterprises of the ACT farming and rural community and proposing mitigating actions that improve climate and drought resilience.
5. Undertaking in-person engagement with members of the farming community through one-on-one interviews and a multi-stakeholder workshop.
6. identifying up to three case studies of successful mitigation activities in regions and farming businesses like those in the ACT to increase drought resilience or adapt to climate change, to inform future decision-making.
7. Compiling the above into a report that is readily accessible, understandable, and useable to EPSDD staff and the ACT farming and rural community.

1.2 Structure of this report

This report is structured as follows:

- Sections 1 and 2 outline the context for the study and the method for developing its findings
- Section 3 introduces drought concepts, climate data, and observed droughts in the ACT
- Sections 4 and 5 outline observed and future projections of drought-related climate variables
- Section 6 describes the impacts of drought on stakeholders
- Sections 7 and 8 describes the how the ACT's rural community has previously responded to drought
- Section 9 summarises the key findings relating to the vulnerability of ACTs farming community to droughts.

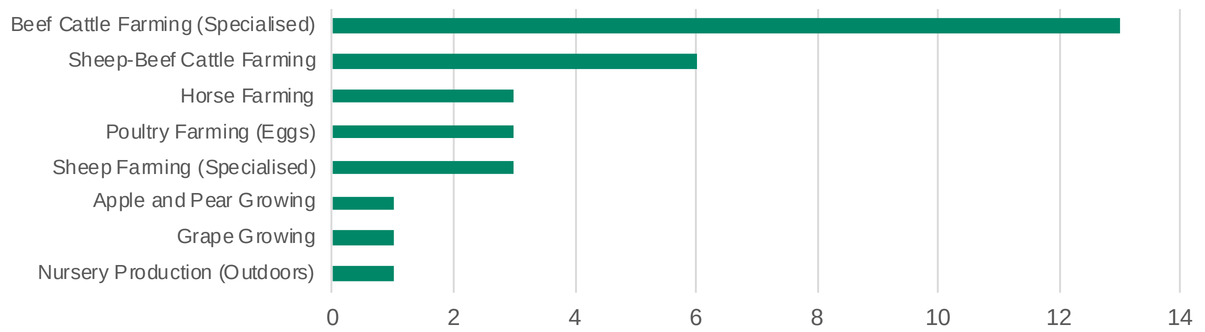
1.3 Overview of agriculture in the ACT

The Territory's 159 farming families collectively manage 180 leases covering 40,000ha (15%) of the ACT. The Territory supports a range of agricultural enterprises, in 2020/2021, the Territory's total value of agricultural commodities produced was $9 million of Australia's total value of $70.8 billion (0.013%). Grazing (cattle and sheep) is the most common form of agricultural production followed by egg, poultry, and others[4].

Neither intensive cropping activities nor horticulture has a high prevalence in terms of the number of farms in the ACT, with these categories represented by a small number of orchards and turf production. Production data is not well represented in national agriculture statistics, likely due to the low number of farms. ABARES' latest figures (2020/2021)[4], for example, identify a total of 34 farms that are recognised as farm businesses, which is not representative of known families and businesses in the region. However, the spread of those businesses identified within national datasets is in line with general numbers represented by the full cohort of landowners. Other agricultural enterprises include egg and chicken production; horse agistment and equestrian enterprises; alpacas and llamas; fruit orchards and vegetable market gardens; nurseries; fodder cropping including lucerne, oats and other fodder crops (primarily for on-farm use); wine; olives and truffles.

This agricultural production profile is generally consistent with that of surrounding NSW regions, which also have grazing (cattle and sheep) as key agricultural activities. Broadacre cropping is more significant in the central western part of NSW while dairy and nursery industries are more prevalent in the eastern regions.

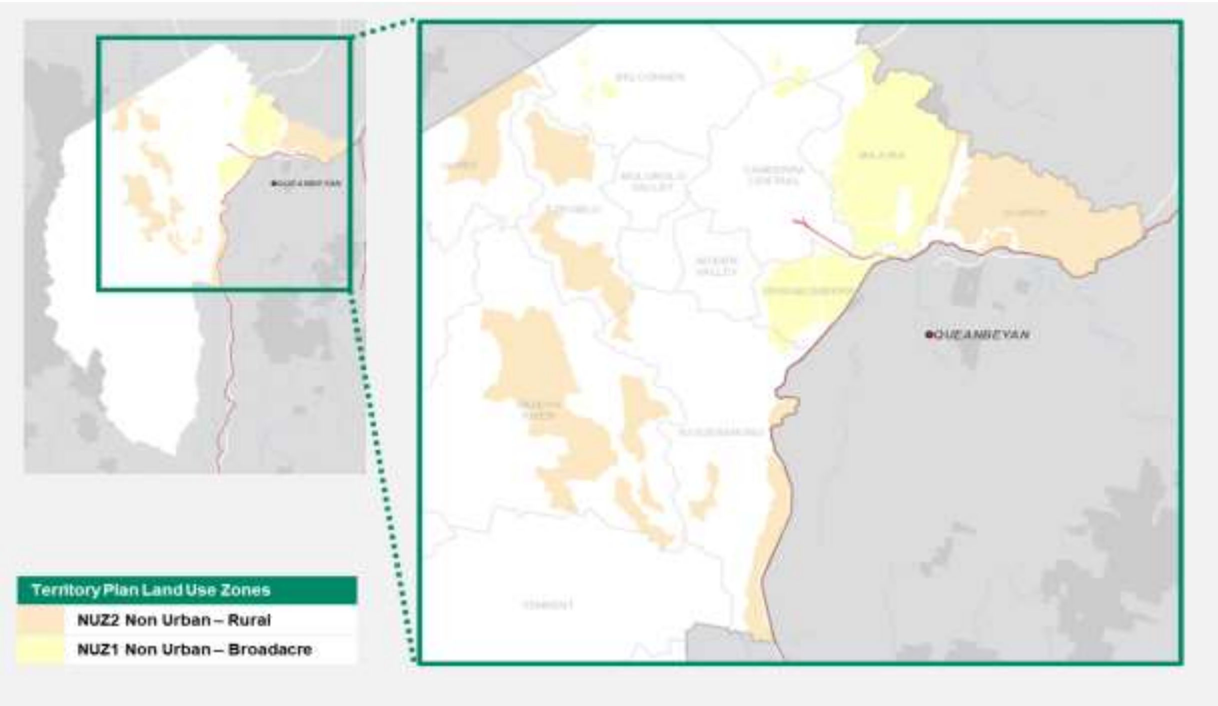
Figure 2 Number and type of farms in the ACT represented within 2020/21 ABARES data



Agricultural production occurs primarily within areas identified as non-urban zones under the Territory Plan (Figure 3). Within this, agricultural production is only a specific objective on land zoned NUZ2 (rural) or more generally NUZ1 (broadacre). Permitted activities on rural and broadacre lands can be further restricted by purpose clauses in crown leases. General planning rules may allow for grazing in some regions, but purpose clauses in crown leases often specify cattle or sheep grazing and that other grazing animals (e.g., goats) or agricultural uses more generally would require a change to the lease agreement. The lease also specifies requirements for appropriate environmental management and monitoring of conservation assets including identification of pest animal and invasive plant management programs. As a total proportion of land within the ACT, these rural zonings comprise approximately 15%.

[4] ABARES (2022). About my region dashboard. https://public.tableau.com/app/profile/australian.bureau.of.agricultural.and.resource.economics.and.sci/viz/AMR_v9_A3L/Dashboard1

Figure 3 Agricultural land use zoning within the Territory Plan[5]



[5] ACT Government. (2022). *Territory Plan.* https://app2.actmapi.act.gov.au/actmapi/index.html?viewer=territoryplan

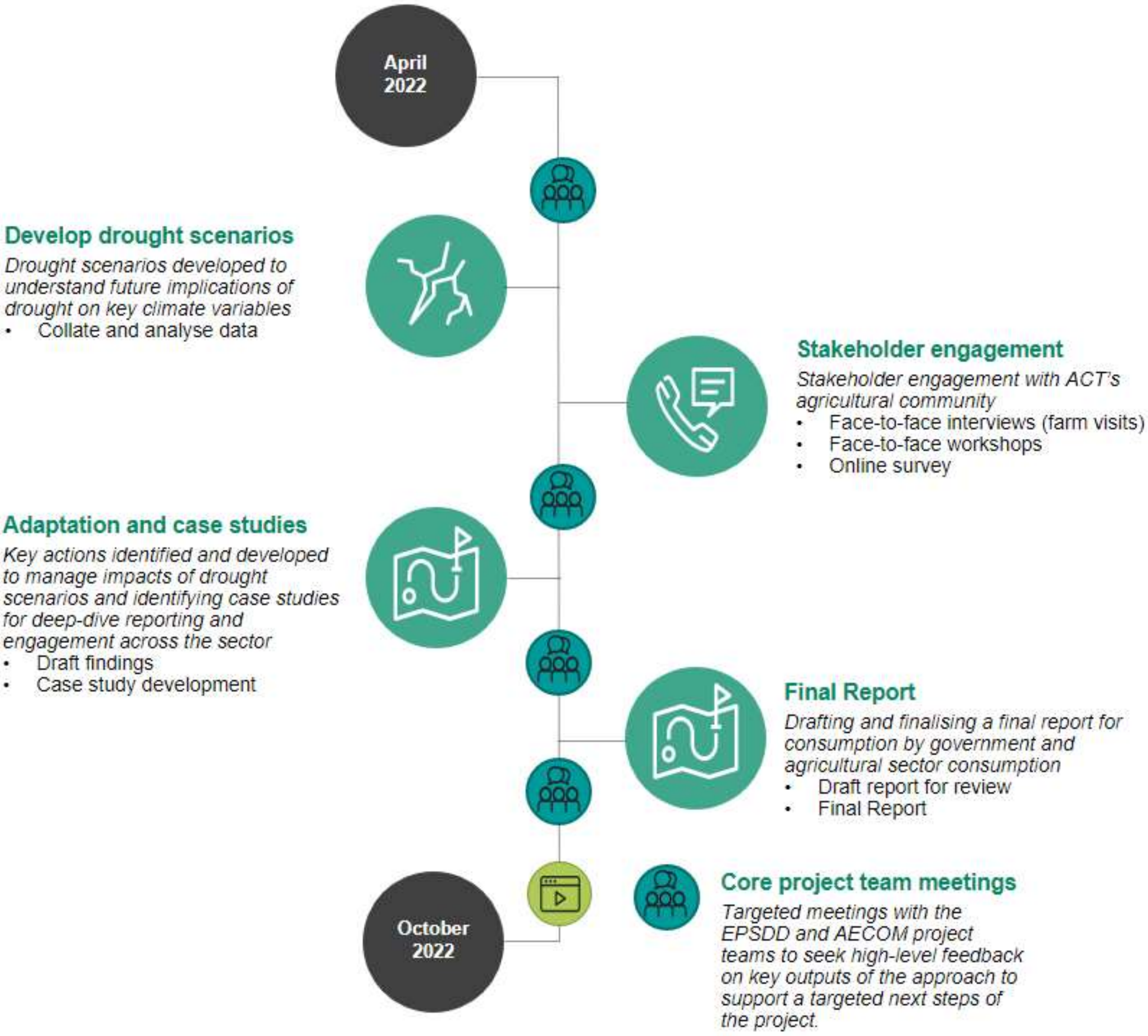
2.0 Method

2.1 Overview

Delivery of the project was undertaken in four key stages (Figure 4):

- Developing scenarios of future droughts by collating projections of future climate change
- Undertaking stakeholder engagement via interviews, farm visits, and a stakeholder workshop to understand the lived experience of drought within the ACT's farming community
- Gathering examples of how farmers have responded to drought and collating potential future actions
- Producing a final report outlining all key findings of the study.

Figure 4 Method overview



2.2 Develop drought scenarios

This report provides a summary of three future scenarios of drought for the ACT to inform the development of the ACT's RDRP. The method used to develop these scenarios is outlined below.

A literature review was undertaken to identify observed and projected impacts of drought and climate change on ACT-relevant agricultural sectors (nationally and regionally) and appropriate drought preparation and climate change adaptation responses (refer to Section 5.3). Sources reviewed included scientific papers, government websites, and community agricultural websites. For this stage of the study, this review informed the selection of climate variables to be requested from data providers. This process is described in Figure 5.

Figure 5 Method to develop drought scenarios

Data review

- Review of existing data previously collected for the ACT (i.e. NARCliM outputs from the ACT Climate Change Risk Assessment)

Gaps

- Identification of gaps and additional climate variables relevent to agriculture and drought planning

Spatial boundary

- Review of spatial boundaries and update to ensure accurate reflection of geographical spread of ACT's agricultural sector

Data request

- Collation of observed climate (Bureau of Meterology) and future climate projections (NARCliM, via NSW Government)

Data analysis

- Consolidation and analysis of data

2.3 Stakeholder engagement

Following the development of the scenarios, several stakeholder engagement activities were undertaken to identify:

- ACT rural landholders' previous experience of droughts and how they responded
- What actions they have taken to improve their resilience to drought,
- Future projections of climate change, and
- Understand what aspects of their enterprise may need to change to account for future projections.

To ensure the project captured the views of a diverse range of stakeholders, engagement activities were undertaken in three ways:

- One-on-one interviews were conducted with six landholders face-to-face and via phone to discuss the impacts of the 2017-2020 drought, and the impacts of droughts more generally. Interviews were generally held at the landholder's property or in a public location such as a café and ran for 1-2 hours.
- A three-hour landholder workshop was conducted on Wednesday 31 August at the Weston Creek Labour Club, Canberra. It was attended by 16 ACT rural landholders and one NSW rural landholder. The workshop was advertised to landholders by EPSDD via email and follow-up phone calls to encourage attendance.
- Following the workshop and additional community engagement activities, a survey, "Have Your Say – ACT's Regional Drought Resilience Plan", was sent out to the ACT rural community. The

survey sought input from ACT's agricultural community about experiences of the past drought, the challenges that were faced, and any ideas that will help build resilience to future droughts. 15 responses to the survey were received. The survey questions sent out can be viewed in Appendix F.

2.4 Adaptation and case studies

Findings from the literature review were collated alongside the engagement results. These were mapped into respective domains and themes. Priority impacts and focus actions were identified based on the frequency in which they were cited. These priority items are subject to deeper analysis and research in this report. Results have been supplemented with three case studies, which primarily draw on conversations with farmers during stakeholder engagement activities.

2.5 Final report

Drought scenarios, stakeholder engagement results and literature review findings were then consolidated to form the final report (this document).

Part 2

Baseline climate and future drought risk

3.0 Climate data and drought in the ACT

The ACT has experienced periods of drought in the past, and long-term climate change projections indicate that drought will occur more frequently and become more severe in the future. This section describes the meteorological, agricultural, and hydrological conditions that define drought, and outlines recent drought events that have occurred in the ACT.

3.1 Conditions relating to drought

Drought is typically a slow-onset phenomenon that is driven by climate variables such as lower-than-average precipitation (incl. rain, sleet, snow, hail, or drizzle), often higher average temperatures, and increased evaporation. It is frequently more recognisable through its associated impacts including reduced water availability, reduced soil moisture, reduced plant growth and reduced carrying capacity of the land, reduced on-farm biodiversity and more.

Defining drought
The Bureau of Meteorology defines drought as a prolonged, abnormally dry period when the amount of available water is insufficient to meet our normal use. There is no universal definition of drought, and it is difficult to compare one drought to another, since each drought differs in the seasonality, location, geographic extent, and duration of the associated rainfall deficiencies. Additionally, each drought is accompanied by varying temperatures, soil moisture and water availability. Droughts typically have a slow-onset with recognisable impacts to agriculture including reduced soil moisture, reduced carrying capacity of land, and reduced on-farm biodiversity[6]. The following factors are used to measure and track drought conditions:

- Meteorological data (e.g. reductions in average rainfall)
- Agricultural data (e.g. soil moisture)
- Hydrological data (e.g. reductions in surface stream flow and deep drainage; water storage levels)

Droughts are monitored through several hydrometeorological and land-surface indicators, summarised in Figure 6. There are three basic approaches to measuring drought as a physical phenomenon: *meteorological, hydrological,* and *agricultural.* All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought and impacts cascade from this deficiency[7].

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[6] BoM. (2022). *Understanding Drought*. http://www.bom.gov.au/climate/drought/knowledge-centre/understanding.shtml#:~:text=Drought%20is%20a%20prolonged%2C%20abnormally,be%20in%20almost%20perpetual%20drought.
[7] National Drought Mitigation Center, 2022, Types of Drought, https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx

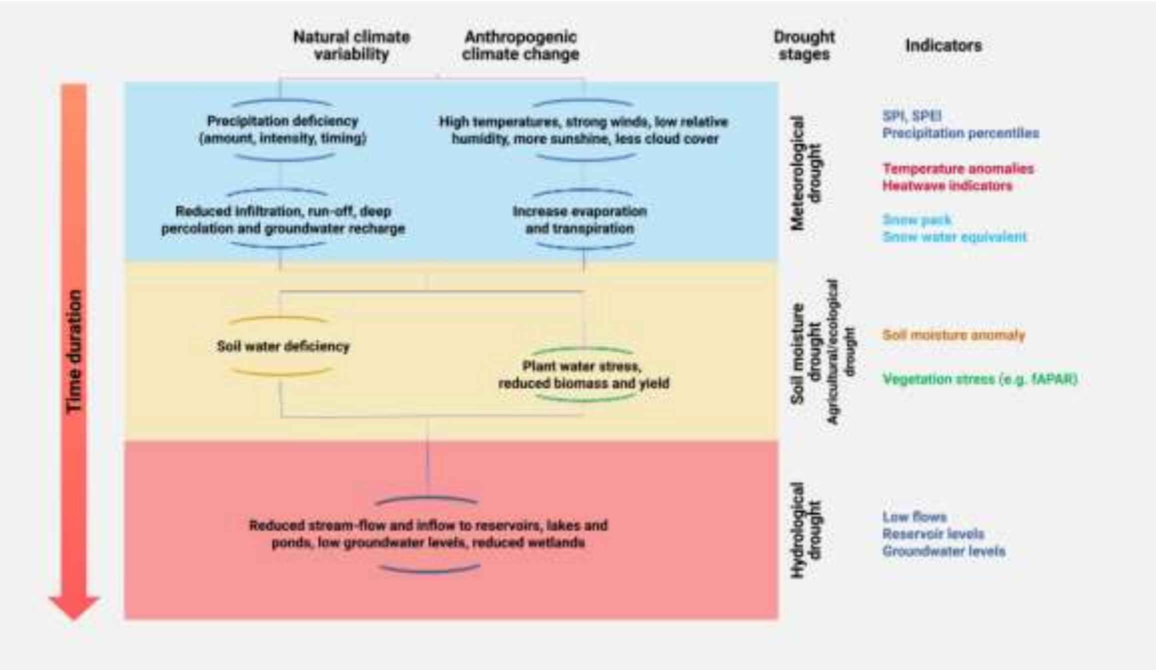

Figure 6 Schematic representation of drought propagation through the hydrological cycle, related drought stages and key influences[8]

Drought conditions arise from changes in a range of atmospheric conditions. Weather patterns relating to drought include:

- Pacific Decadal Oscillation (PDO): defined by the leading pattern of sea surface temperature anomalies in the North Pacific basin.[9]
- Indian Ocean Dipole (IOD): defined by the difference in sea surface temperature between two areas – a western pole in the Arabian Sea and an eastern pole in the eastern Indian Ocean south of Indonesia. The IOD affects the climate of Australia and other countries that surround the Indian Ocean Basin and is a significant contributor to rainfall variability in this region.[10]
- El Niño: defined as a climate pattern that describes the unusual warming of surface waters in the eastern tropical Pacific Ocean.[11] El Niño is often, but not always, associated with drought in Australia.

These weather patterns contribute to low-frequency changes in persistent atmospheric circulation patterns associated with drought conditions. For example, both El Niño and a positive Indian Ocean Dipole contribute to increased dry weather in the ACT and can increase the duration and intensity of droughts. Short-term influences on drought include weather variability and annual cycles such as wet and dry seasons, rain squalls and cyclones. Longer-term influences on drought include climate change, where long-term increases to atmospheric temperatures and changes in rainfall totals along with increased rainfall variability are observed. Changes in rainfall and rainfall variability due to climate change are the focus of this report (Figure 7).

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[8] UNDRR. (2021). *Special Report on Drought 2021.* https://www.droughtmanagement.info/literature/UN-GAR_Specia_Report_on_Drought_2021.pdf
[9] NCAR Climate Data Guide, 2022, Pacific Decadal Oscillation (PDO): Definition and Indices,https://climatedataguide.ucar.edu/climate-data/pacific-decadal-oscillation-pdo-definition-and-indices

[10] BOM, 2022, The Indian Ocean Dipole (IOD), www.bom.gov.au/climate/enso/history/ln-2010-12/IOD-what.shtml
[11] National Geographic, El Niño, 2022, https://education.nationalgeographic.org/resource/el-nino

Figure 7 shows the relationship of droughts with the weather, climate variability and climate change.

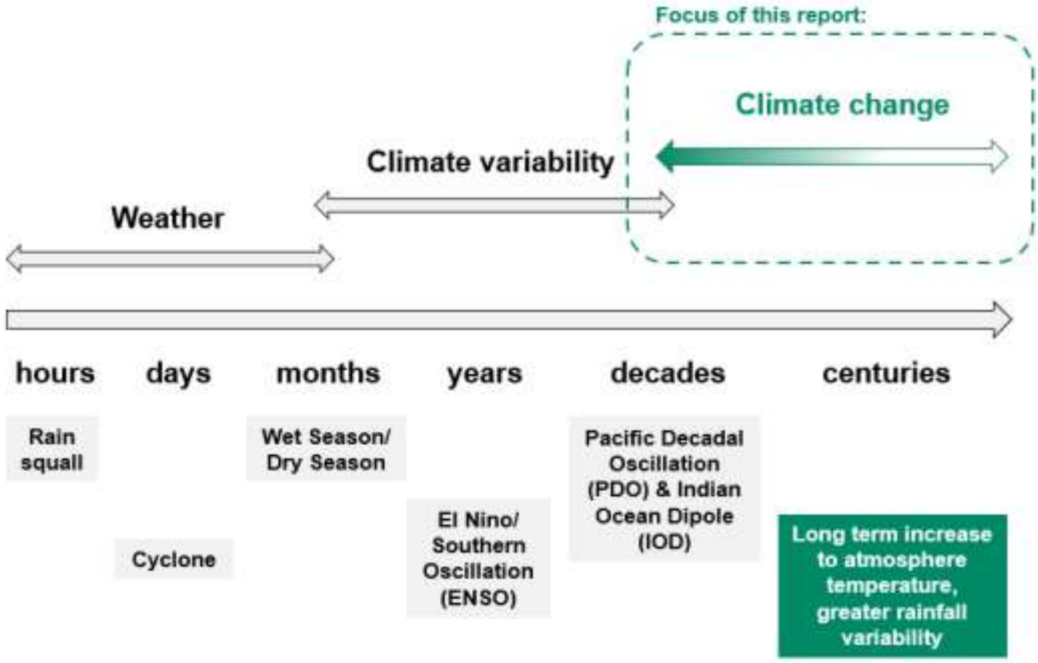

Figure 7 A guide to the timescale applicable to weather, climate variability and climate change[12]

The Standard Precipitation Index (SPI)

The Standard Precipitation Index (SPI) reflects soil moisture and precipitation conditions and is the most used indicator for detecting and characterising meteorological droughts. Negative values are associated with below-average rainfall and drought while positive values indicate wetter-than-average conditions. The index categories are as follows:

- Mildly dry (SPI less than (<) 0 or greater than (>) -0.99) e.g., soil moisture and precipitation conditions are average to slightly less than average
- Moderately dry (-1.0 > SPI > -1.49)
- Severely dry (-1.5 > SPI > -1.99)
- Extremely dry conditions (SPI less than -2.0)

SPI is a key indicator to characterise drought conditions. In the ACT, historical SPI observations show that there have been eight periods of extremely dry conditions over the past century (refer to Figure 14, Appendix F). There appears to be a relationship between SPI and average maximum temperatures which suggests that higher temperatures are generally associated with periods of drought in the ACT (Figure 15, Appendix B).

3.2 ACT experience of drought

Like much of NSW, the ACT experiences variability in its average climate conditions both over time (e.g. high temperatures in summer, low temperatures in winter) and spatially (the North-Eastern region of the ACT is much warmer and drier than the alpine areas to the south-west). Large-scale weather patterns (described in Section 3.1), including ENSO, SAM, and IOD also affect the region. More recently, extreme climate events have increased in intensity, frequency, and duration[13,14].

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[12] Australian Government, Understanding Climate Variability and Change https://www.pacificclimatefutures.net/en/help/climate-projections/understanding-climate-variability-and-change/#:~:text=Climate%20is%20the%20long%20term,trend%20in%20the%20mean%20climate.

[13] CSIRO. (2015). *Climate Change in Australia Projections for Australia's NRM Regions.* https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/168/CCIA_2015_NRM_TechnicalReport_WEB.pdf

[14] Australian Government, 2021, Australia State of the Environment, https://soe.dcceew.gov.au/

The ACT has experienced several periods of serious and severe drought, three recent examples include:

- **1982:** Periods of rainfall deficiency which had a major impact on Canberra include the severe drought beginning in April 1982, which saw only 141.7 mm of rainfall over 9 months. Significant relief for Canberra came in the form of increased rainfall during the period of March-May of the following year.
- **2001 to 2009:** known as the Millennium drought, this period experienced drought episodes and a long-term decline in rainfall. For example, in February of 2004, Canberra received 79.8 mm of rainfall over a 6-month period. Figure 8 below depicts the rainfall received as a percentile of all rainfall data on record.
- **2017 to 2020**: Drought conditions were experienced in the ACT from 2018 to 2020. For example, in two separate 6-month periods during the two years, Canberra received less than 150 mm of rainfall. Section 3.2.2, "Drought in Focus – 2017 to 2019", explores this in greater detail.

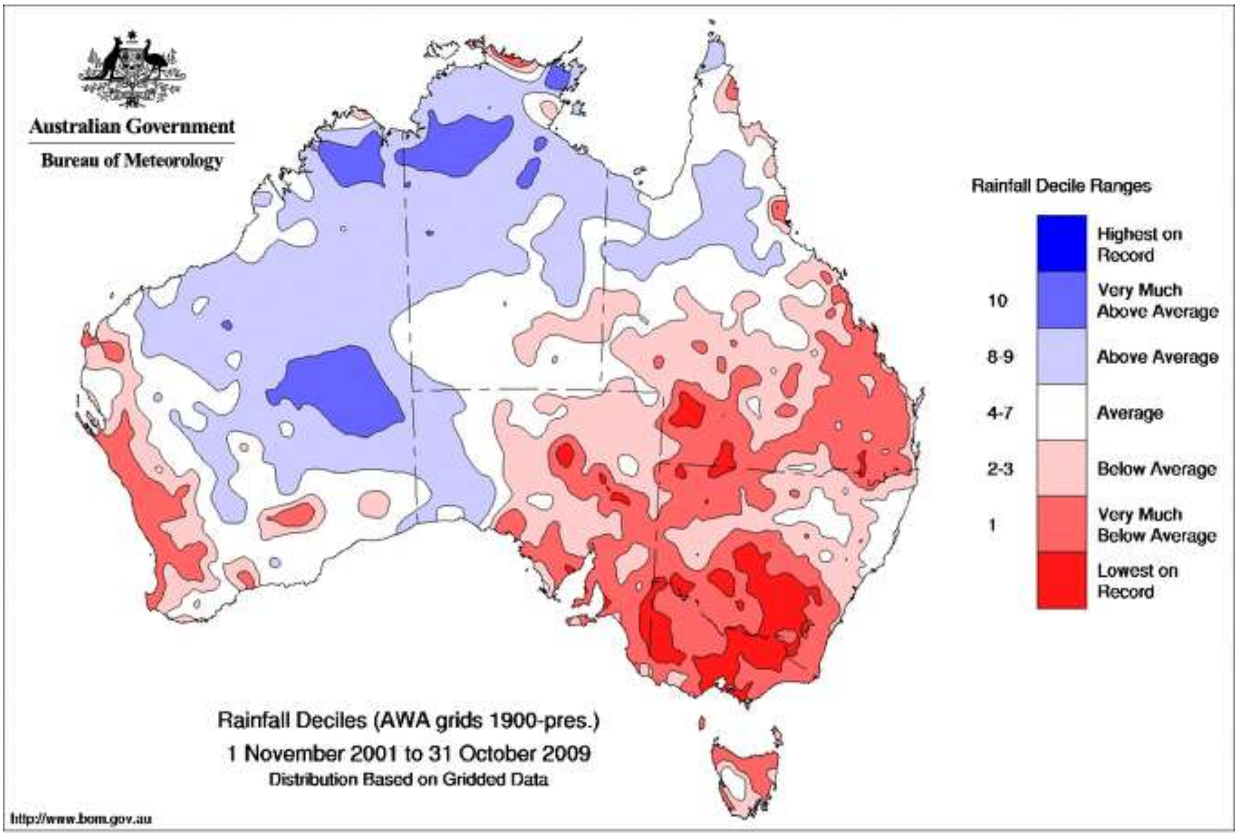


Figure 8 Rainfall Deciles November 2001 to 31 October 2009[15]

3.2.1 Agricultural water uses in the ACT

Water use in the ACT is guided by the ACT Water Strategy 2014-2044[16] which provides long-term (30-year) strategic guidance to manage the Territory's water resources. Given that the Territory is entirely within the Murrumbidgee catchment and wider Murray Darling Basin (MDB), the Water Strategy conforms to obligations under the MDB Plan[17]. Under the MDB Plan, the Water Strategy notes that the ACT has a sustainable diversion limit (SDL) for surface water of 52.5 gigalitres (GL) per annum, with a further 30,160ML per annum allocated for groundwater extraction

[15] Bureau of Meteorology. (2022). *122 years of Australian rainfall*. http://www.bom.gov.au/climate/history/rainfall/
[16] ACT Government. (2014). *ACT Water Strategy 2014–44 | Striking the Balance.* https://www.environment.act.gov.au/__data/assets/pdf_file/0019/621424/ACT-Water-Strategy-ACCESS.pdf
[17] Murray-Darling Basin Authority. (2022). *A plan for the Murray–Darling Basin*. https://www.mdba.gov.au/basin-plan/plan-murray-darling-basin

The Australian Bureau of Statistics Water Accounts 2019-2020 notes the ACT had net water extraction of 21,166 megalitres (ML) of water, with 334ML used for the purposes of agriculture (1.58%). Between 2014 and 2020 the average annual water extracted for agricultural purposes has been 236ML compared to an average net extraction of 16,201ML for the ACT (1.55%) (Figure 9). Groundwater resources in the ACT are very small in comparison to other areas in Australia. ACT Government policy limits the extraction of groundwater to 10% of the volume of long-term recharge.

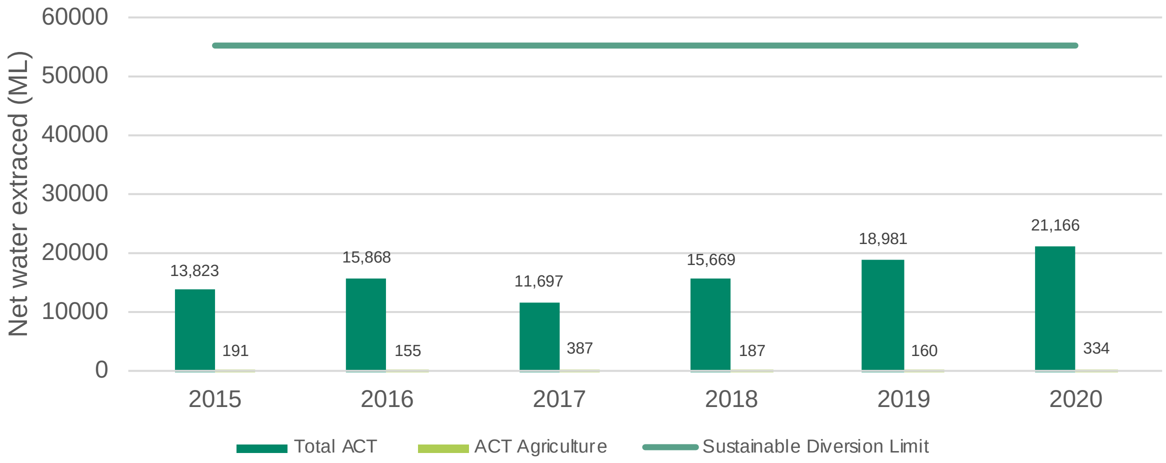


Figure 9 ACT's net water extraction and agricultural water use[18]

The ACT has four dams which are managed by Icon Water:

- Corin dam (70.79 GL capacity)
- Bendora Dam (11.45 GL capacity)
- Cotter dam (76.2 GL capacity)
- Googong dam (110.41 GL capacity).

The current combined dam capacity for the ACT is 277.84 GL.[19] During the Millennium drought, the combined storage level fell below 32% in 2007. During the most recent drought of 2017-2020, the combined storage level fell below 46%. Measures to increase dam capacity to support drought resilience have been undertaken, with the enlargement of Cotter dam in 2013 increasing the combined dam capacity by 70 GL. This upgrade resulted in an extra 62 GL of water being available during the 2019-2020 drought in comparison to the Millennium drought (Figure 10). In addition, the upgrade also resulted in no water restriction requirements as experienced during the Millennium drought.

[18] Australian Bureau of Statistics. (2021). *Water Account, Australia, 2019-20 financial year.* https://www.abs.gov.au/statistics/environment/environmental-management/water-account-australia/2019-20#data-download
[19] Icon Water. (2022). *Water Storage Levels | Icon Water*. https://www.iconwater.com.au/water-education/water-and-sewerage-system/dams/water-storage-levels.aspx

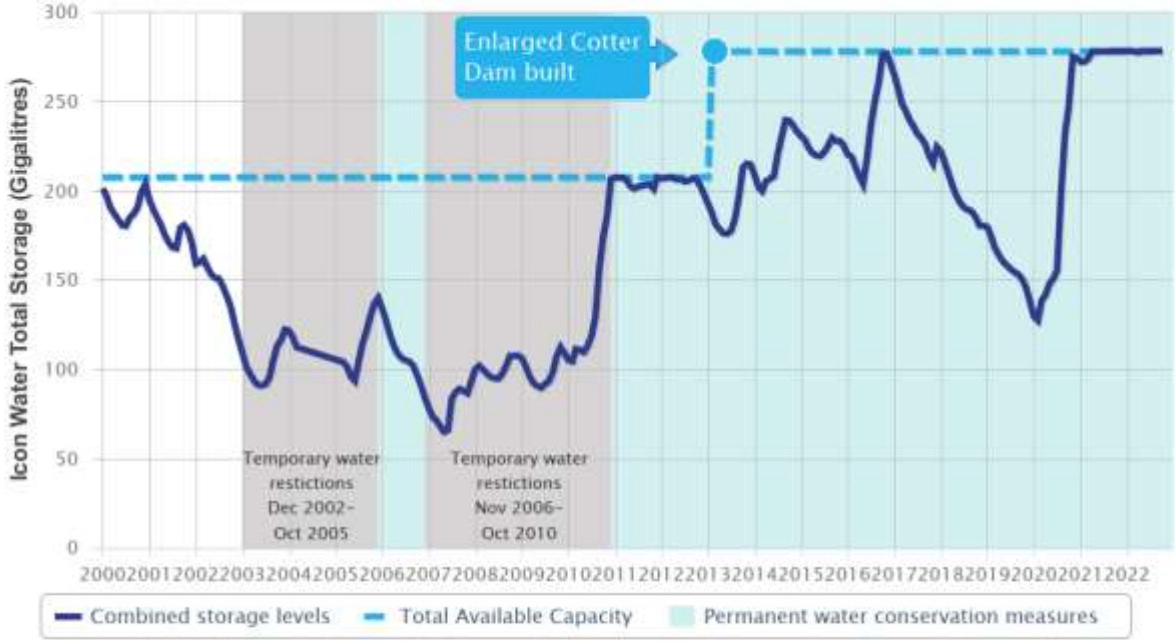


Figure 10 Historical Dam Storage Levels of Icon Water Dams[15]

While confidence that average rainfall will decrease as a result of climate change is high, modelling depicting inflows to water storage during drought periods is not well understood. Increasing average temperatures is thought to be a key driver in this changing relationship – when comparing impacts on water storage inflow between the Millennium Drought and the 2017-2020 drought, the latter was more heavily affected. Further research is required into this subject, but early findings suggest there are disproportionately higher reductions in runoff and dam inflows for every percentage change in average rainfall.

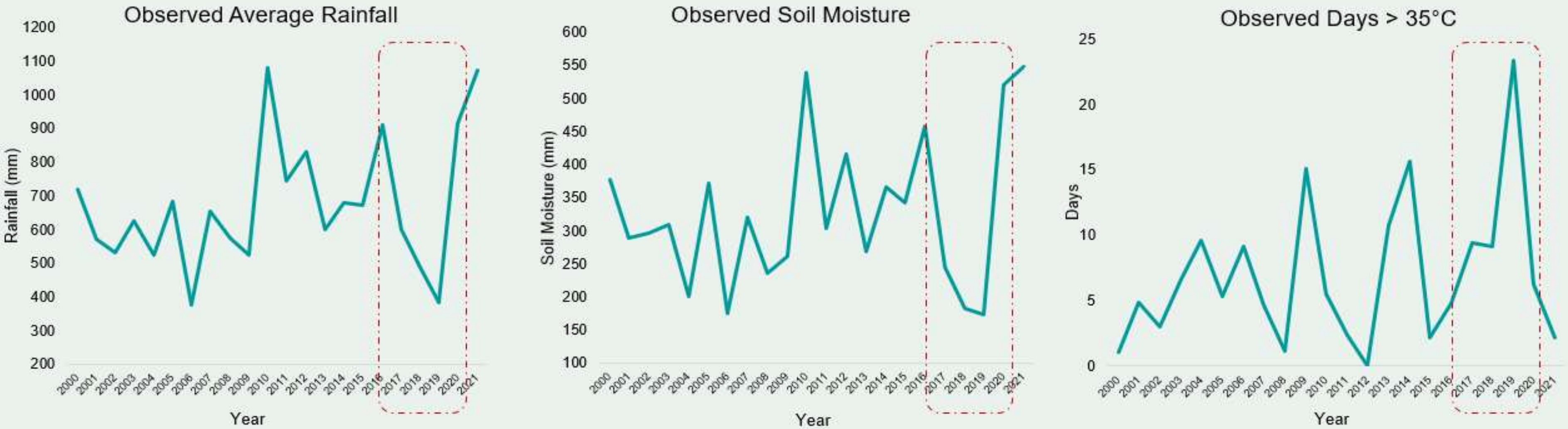
3.2.2 Drought in Focus – 2017 to 2020

2017 – 2020 Drought

There have been several periods of severe drought since Canberra's climate records commenced. Both El Niño and a positive Indian Ocean Dipole contribute to an increased likelihood of dry weather in the ACT and can increase the duration and intensity of droughts. The 2017 – 2020 drought saw the lowest rainfall on record. In two separate 6-month periods across these years, Canberra received less than 150 mm of rainfall.

The observed climate during this period included:

- 44% decrease in average rainfall (385mm in 2019 compared to the 1990-2021 baseline average of 690mm)
- 91% decrease in soil moisture during Dec 2019 – Jan 2020 (compared to 1990-2021 December months baseline average)
- Soil moisture was zero in the summer of 2020
- SPI (3-month) during Dec 2019 – Jan 2020 was classified as extremely dry, with the driest conditions recorded since 1982
- 80% increase in extreme heat days (>35°C) with 15.3 days recorded (compared to the 1990-2021 baseline average).



Observed data for North-East ACT

3.3 Spatial boundaries for climate data in the ACT

Two distinct geographical regions were identified in the ACT to assist with defining two sets of distinct climate change projections related to drought for the ACT. Two regions (outlined in Figure 11) were identified based on Districts within the Territory Plan and informed by a clear difference in climatic zones between the North-Eastern region (warmer, with a greater increase in average and extreme temperatures into the future), compared to the alpine and sub-alpine regions of the South-Western region (where the drivers of climate risk are more likely driven by a reduction in cold nights).

Given that the majority of rural landholders in the ACT are located in the North-Eastern region, climate projections and climate data related to the North-Eastern region are included in the body of this report, whilst climate projections and climate data related to the South-Western region are included in Appendix G, H and D.

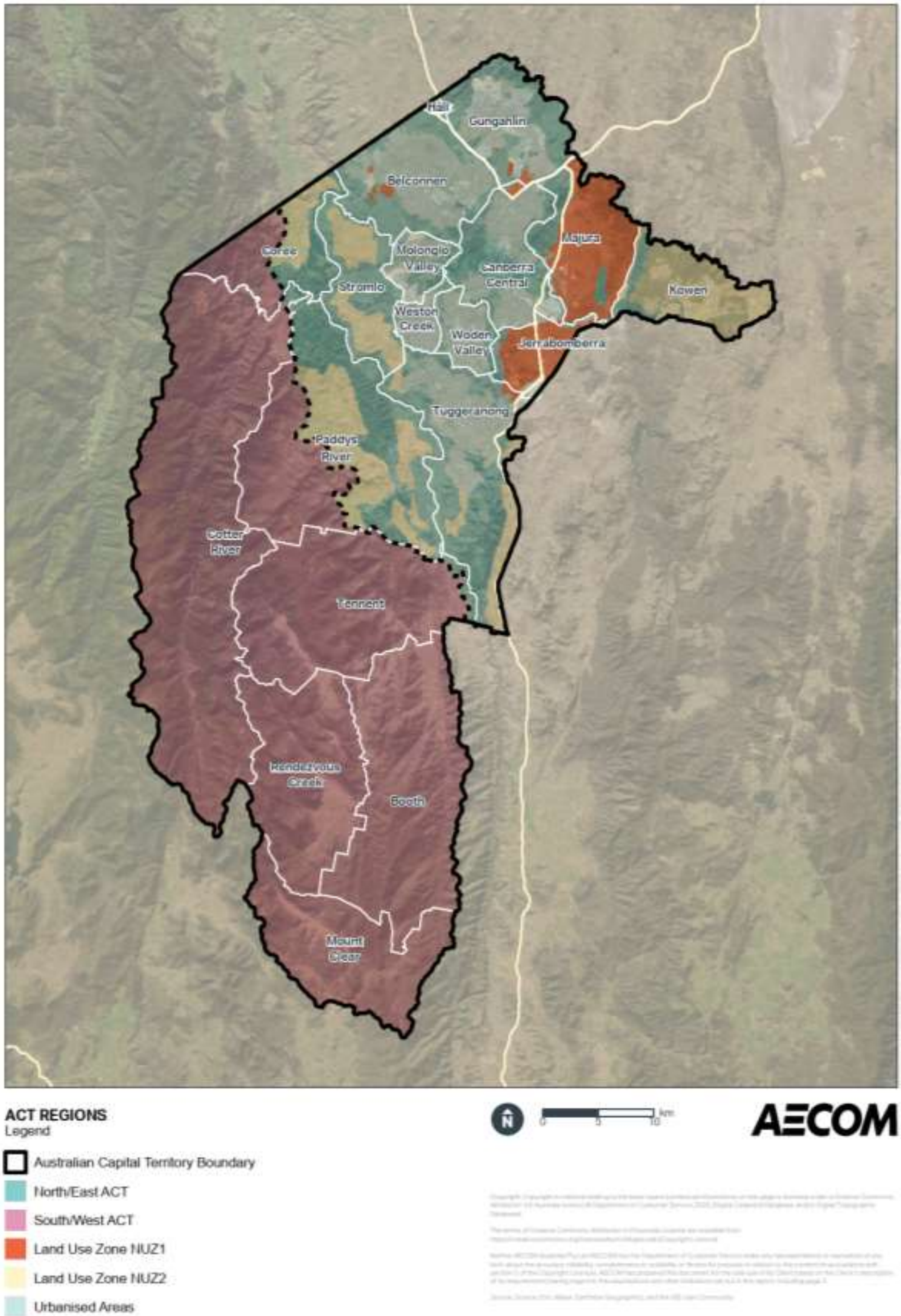


Figure 11 Map of the ACT showing the North-Eastern region (shaded green) and South-Western region (red shading)

4.0 Observed climate

To develop a historical climatology of droughts in the ACT observed annual, monthly, and seasonal data was requested for seven climate variables from the Bureau of Meteorology's (BOM) Australian Gridded Climate Data collection, regionalised for the study areas (Appendix G). Variables include:

- rainfall,
- maximum temperature,
- minimum temperature,
- soil moisture,
- standard precipitation index,
- days with minimum temperatures less than 2°C
- days with maximum temperatures exceeding 35°C.

Table 1 provides a summary of the seven climate variables, the timescales at which this data is presented (i.e. monthly, annually) and the region's representative of the data. All observed data covers the period 1910-2021 (in some cases starting from 1900). All detailed data is available under a separate copy.

Table 1 Summary of observed climate variables

Climate variable	Timescale	Period	Region
Rainfall	Annual, monthly and 4 seasons	1900-2021	
Mean Maximum Temperature	Annual, monthly and 4 seasons	1910-2021	North-East ACT
Mean Minimum Temperature	Annual, monthly and 4 seasons	1910-2021	(Section 4.0)
Soil Moisture (root zone)	Annual, monthly and 4 seasons	1911-2021	
Standard Precipitation Index (SPI)	3-month and 12-month SPI	1900-2021	South-West ACT
Days less than <2°C	Annual, monthly and 4 seasons	1910-2021	(Appendix G)
Extreme heat days (>35°C)	Annual, monthly and 4 seasons	1910-2021	

4.1 Summary of observed climate

Table 2 summarises observed climate data for each variable under two timeframes, 1910-1990 and 1990-2021. The data has been split into these two periods to compare recent trends to the longer-term record. Section 4.1 demonstrates the growing warming of the ACT climate during these periods. Refer to Appendix A for further detail on observed temperature and rainfall in North-Eastern ACT.

Table 2 Observed Climate Data Summary for North-East ACT

Climate variable		Trend	
		1910-1990	1990-2021
Temperature	Maximum temperature	• Average annual maximum temperature of 18.8°C annually	• Average annual maximum temperature of 19.6°C annually • Since 2008, there have been 13 periods of heatwaves • Hottest temperature on record in Canberra was 44°C in 2019

Climate variable		Trend 1910-1990	Trend 1990-2021
			• The four hottest summers and three hottest springs have occurred in the last 20 years • The four hottest years have occurred in the last 20 years
	Minimum temperature	• Average annual minimum temperature of 6.1°C	• Average annual minimum temperature of 6.7°C • 2019 saw the hottest January with a monthly average minimum temperature of 17.62°C recorded across the month, compared to 12.6°C baseline average
	Extreme heat days (>35°C)	• On average 2.3 extreme heat days annually • Hottest year experienced 8.71 extreme heat days (1983)	• On average 5.7 extreme heat days annually • Hottest year experienced 23.34 extreme heat days (2019) • 86% increase in 2019 in the number of extreme heat days compared to 1990-2021 baseline average • Overall significant increase in extreme heat days annually compared to pre-1990's
	Days below <2°C	• Average of 7.9 days below <2°C annually	• Average of 7.2 days below <2°C annually
Rainfall	Average annual rainfall [A]	• Average annual rainfall of 679mm	• Average annual rainfall of 686mm • Four of the driest springs in the last century have happened in the last 20 years • Two of the wettest years and two of the driest years have happened in the last 20 years
Soil moisture	Average annual soil moisture	• Average annual soil moisture of 362mm	• Average annual soil moisture of 337mm
SPI[A]	SPI-3 month	• Six periods of 'moderately' dry conditions	• One period of 'moderately' dry conditions [B]
	SPI-12 month	• Three periods of 'moderately' dry conditions • Two periods of 'extremely' dry conditions	• Two periods of 'moderately' dry conditions [B]

[A] Observed data starts at 1900. [B] Note that table displays two timeframes however with different lengths, 80 and 30 years, making it hard to compare SPI pre 1990 and post 1991 due to the same amount of time not having passed yet.

5.0 Future climate

Changes to the global climate are already being observed, with increased periods of drought, increased temperatures, more frequent extreme rainfall, flooding, and bushfires impacting agriculture worldwide. The frequency, intensity, spatial extent, duration, and timing of extreme weather events are also expected to increase. The impact of this changing climate is already being felt by the agricultural sector and events including periods of drought are expected to increase in frequency and intensity. Section 5.0 describes the projected future climate for the ACT using a range of climate variables relevant to agriculture in accordance with global greenhouse gas emission scenarios.

Scenario selection

Climate scenarios refer to the global greenhouse gas emissions scenarios which underpin projections of future climate and provide an indication of possible future impacts. Plausible physical pathways have been developed by industry and scientific groups including the NSW Government and the CSIRO and Bureau of Meteorology (BoM), based on robust scientific data and climate modelling provided by the Intergovernmental Panel on Climate Change (IPCC), to outline projected changes to the climate and anticipated responses across the public and private sector.

Scenario analysis is an important tool for understanding and exploring the strategic implications of climate-related physical risks and opportunities. It provides an understanding of how resilient organisations are to a range of plausible climate-related scenarios, and how sensitive an organisations assets and operations are to the differences between these scenarios.

Box 1 Understanding scenarios

A scenario describes a path of development leading to a particular outcome. Scenarios are not intended to represent a full description of the future, but rather highlight central elements of a possible future to draw attention to the key factors that will drive future developments. Scenarios are hypothetical constructs; they are not forecasts or predictions[20].

The purpose of this chapter is to present the rationale for proposing the climate change scenarios that will be used to assess physical risks for the ACT farming community. The scope of this chapter includes:

- Analysis and recommendation of climate (emissions) scenarios that allow for the identification of physical risks to ACT farming community.
- Analysis and recommendation of multiple time horizons to consider in developing climate scenarios and understanding future projections which are appropriate to the planning, design, and operational lives of the ACT farming community.
- Selection and understanding of the climate variables (hazards) that may result in physical risks to the ACT's agricultural sector.

Climate projections and data availability

In 2021, the NSW and ACT Regional Climate Modelling project (NARCliM 1.5) released a suite of improved climate change projections downscaled for NSW and the ACT. Compared to NARCliM 1.0 these models better capture the seasonal patterns and magnitudes of precipitation as well as the potential hotter and drier futures that are being experienced within these regions.

NARCliM 1.5 also provides the added benefit of future projections for two AR5 scenarios to allow for a greater interrogation and understanding of future changes in climate in line with other modelling datasets compared to NARCliM 1.0. NARCliM 1.5 has been used to inform the climate projections for this study.

Representative Concentration Pathways (RCPs) describe potential scenarios of global climate emissions and underly the three drought scenarios presented in this study. These scenarios are described in Table 3.

[20] TCFD, 2017, *Technical Supplement - The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities.* Page 10. https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Technical-Supplement-062917.pdf

Table 3 **Description of Representative Concentration Pathways (RCPs)**

Scenario	Description of scenario[21]
RCP 4.5 **(Low-medium emissions scenario)**	Assumes a high level of mitigation with no active removal of atmospheric carbon dioxide. Emissions are anticipated to peak around 2070 and then remain consistent until 2100. This scenario assumes full uptake of renewable energy however no carbon capture to help reduce the levels of carbon dioxide. As a result, it is anticipated that temperature increases can be limited to 1.8°C by the end of the century (based on a 1985 – 2005 baseline) and while there will be some increase to extreme weather events due to historical climate change, these will result in medium level adaptation costs to mitigate risk.
RCP 8.5 **(High emissions scenario)**	Assumes minimal effort to reduce emissions. Emissions will continue to grow unchecked, marked by the continued use of conventional fossil fuel energy to power cities homes and businesses. Without sizeable intervention this scenario assumes an average temperature increase of up to 4°C by the end of the century (based on a 1986 – 2005 baseline). It will require costly adaptation to minimise the impact of extreme weather events which have continued to increase dramatically over the past century.
RCP 8.5 **(High emissions hotter/ drier scenario)**	Same as above however when using this scenario the upper limit of the model is taken to assume worst case scenario, hence “hotter/ drier scenario”.

Time horizons

NARCliM and other climate projection projects generally include 20-year time horizons centred on a ‘fixed year’, for example, 2070 accounts for the period 2060-2079. The time horizons reviewed for this study include:

- A baseline period of 1990-2009,
- future time horizons of 2030, 2045, 2070 and 2090.

Further detail on these scenarios can be found in Appendix F.

5.1 Climate hazards and climate change projections for the ACT

Climate change modelling produces projections for various climate variables (such as temperature, precipitation, wind, solar radiation, etc), and uses a combination of these variables to derive climate hazards (such as the number of hot days, cold days, heavy rainfall days, drought patterns, extreme wind speeds, relative humidity).

Based on desktop review and stakeholder feedback, a number of variables have been selected for their relevance to the ACT’s agricultural community. Future trends as informed by relevant climate change projections are outlined below and visualised on the following pages. The climate change projections described in Section 5.2 align with the high-emission scenario (RCP 8.5). Refer to Section 5.0 and Appendix F for more detail on scenario selection. Given that most rural landholders in the ACT are in the North-Eastern region, climate projections related to the North-Eastern region are included in the body of this report, whilst climate projections related to the South-Western region are included in Appendix F.

Table 4 outlines the climate hazards investigated as part of this work and the relevance of the climate hazard to agriculture.

[21] Australian Govt. Department of the Environment and Energy, (n.d.). *What are the RCPs?.* https://coastadapt.com.au/sites/default/files/infographics/15-117-NCCARFINFOGRAPHICS-01-UPLOADED-WEB%2827Feb%29.pdf

Table 4 Climate hazards: Climate variables and future projections used to inform drought scenarios

Average annual temperature	Average annual rainfall	Soil moisture and drought indicators
• Projected Monthly Daily Maximum Temperature • Mean Daily Minimum Temperature • No. of Days per Month with Maximum Temperatures greater than 35°C • Percentage of Days with Maximum Temperature Above 90th Percentile • Warm Spell Duration Index	• Annual precipitation • Maximum Length of a Dry Spell Annually (No. of Days) • Projected Days Above 20 mm	• Total Soil Moisture Content • Standardised Precipitation Index (SPI)

5.2 Summary of future climate trends for the ACT

Table 5 Summary of future climate trends for North-East ACT[22]

Average annual temperature					
Hazard description Average atmospheric temperature increases over time **Trend** Average temperatures are increasing, with higher average maximum and minimum temperatures **Example impacts** Reduce yields of desirable crops, heat stress to livestock					
Climate variables	**1990-2009 (Baseline)**	**Future projections (RCP8.5)**			
		2030	**2050**	**2070**	**2090**
Annual average minimum temperature (°C)	6.93	8.01	8.56	9.59	10.81
Annual average maximum temperature (°C)	26.04	27.19	28.03	29.31	31.04
Annual days below 2°C	84.17	65.96	55.07	36.95	23.33
Annual extreme heat days (days above 35°C)	4.97	8.13	11.88	18.55	29.27
Average annual rainfall					
Hazard description Average precipitation changes over time and periods of dry weather including extended periods with no rainfall **Trend** Summer rainfall is projected to increase, with reductions in winter rainfall expected. Overall projected decreases in average annual rainfall however increasing intensity of extreme rainfall events[A] **Example impacts** Grazable land is dependent on precipitation					

[22] North-East region in the ACT under RCP8.5

Climate variables	1990-2009 (Baseline)	Future projections (RCP8.5)			
		2030	2050	2070	2090
Annual precipitation (mm)	629.5	634.6	610.1	570.9	548.2
Consecutive wet days *(average maximum number of consecutive days with rainfall in a 12-month period)*	5.49	5.68	5.36	5.32	5.29
Consecutive dry days *(average maximum number of consecutive days without rainfall in a 12-month period)*	27.30	27.34	29.12	32.23	36.26

Drought and soil related climate variables

Hazard description

SPI is the most used indicator for detecting and characterising meteorological droughts. Soil moisture is the amount of water in the top 2 m of soil measured in millimetres

Trend

Soil moisture and SPI are both decreasing

Example impacts

As moisture availability declines, the normal function and growth of plants is disrupted, and crop yields are reduced

Climate variables	1990-2009 (Baseline)	Future projections (RCP8.5)			
		2030	2050	2070	2090
Standard Precipitation Index *(SPI trending negative indicates drying)*[B]	-0.0172458	-0.0048	-0.14801	-0.4225	-0.6094
Total Soil Moisture Content (mm)	544.7860	543.823	529.795	506.493	482.828

[A] Projections related to storms are not available for NARCliM 1.5 and have instead been sourced from NARCliM 1.0 . [B] Standard Precipitation Index (SPI) 12-month scale for ACT. Mildly dry (0>SPI>-0.99), moderately dry (-1.0>SPI>-1.49), severely dry (-1.5>SPI>-1.99) and extremely dry conditions (SPI less than -2.0).[23]

[23] Agricultural and Meteorological Software. (2020). What is SPI(Standardized Precipitation Index). https://agrimetsoft.com/faq/What%20is%20SPI(Standardized%20Precipitation%20Index)

5.2.1 Visualisations of future projections

The following section presents visualisations of future projections for the identified climate variables using NARCLiM 1.5 projections for the North-East region of the ACT under RCP8.5. Monthly average maximum temperatures are projected to increase for all future periods; monthly average precipitation is expected to increase in summer months over time, and decrease in winter months, with an overall decrease in annual rainfall projected (Figure 12). Additional visualisations of climate projections are located in appendices to this report.

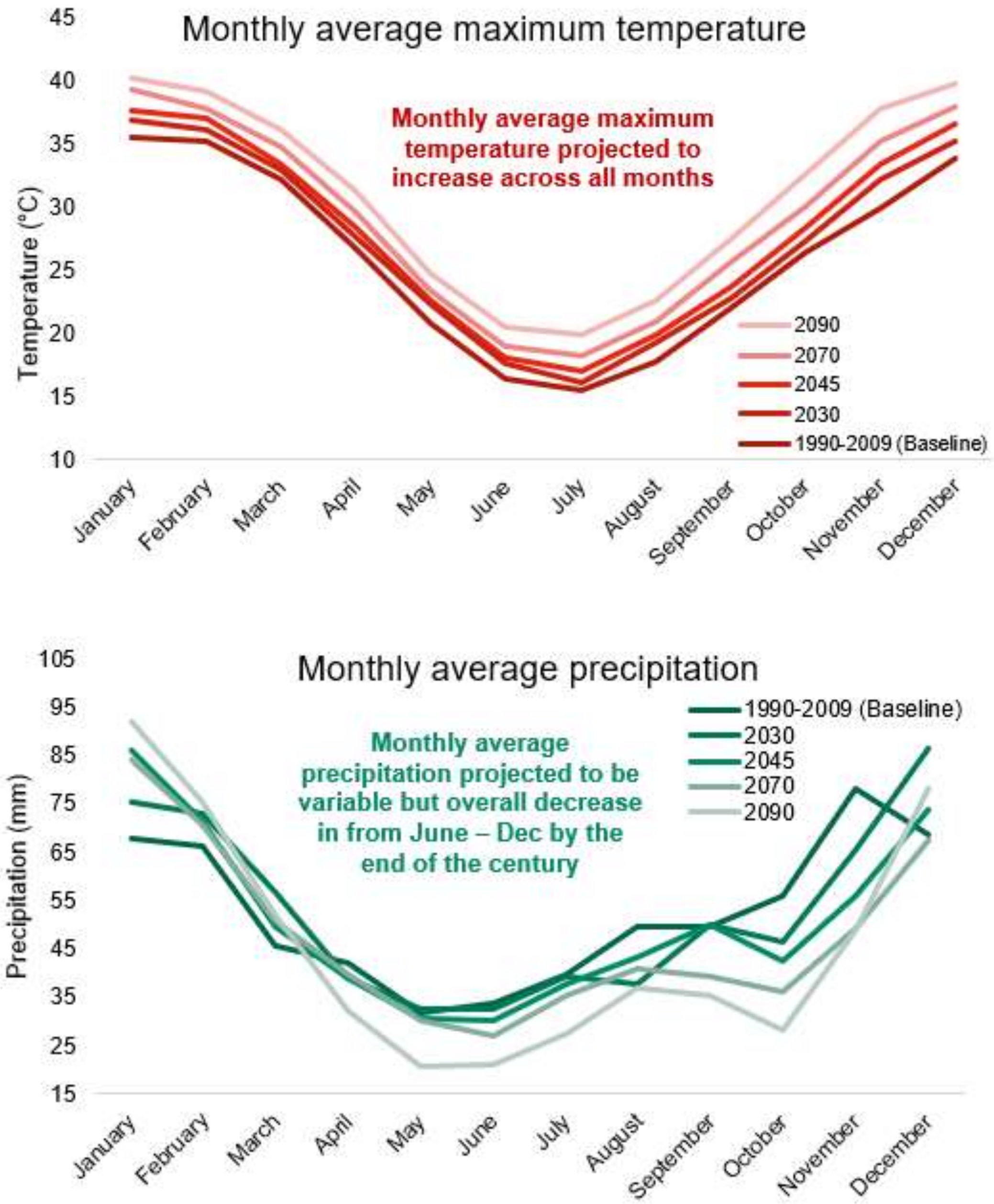


Figure 12 Future projection for temperature and rainfall variables, under an RCP 8.5 scenario for North-Eastern ACT

Another important variable for the agricultural community is vapour pressure deficit (VPD) which measures the difference between moisture content in the air and the total moisture capacity of the air when it is completely saturated. The projected increasing average temperatures and humidity decreases are likely to increase VPD. The projected increase in VPD will cause increased evaporation thus increasing the risk of crops drying out. A detailed explanation of VPD can be found in Appendix A.

5.3 Climate Analogues

Box 2 Climate Analogues for the ACT

Climate analogues is a tool that matches the proposed future climate of a region of interest with the current climate experienced in another region using annual average rainfall and maximum temperature.

The changes to the ACT's climate mean it is more likely to resemble the climate of other warmer, drier regions in Australia. The figure below matches the proposed future climates of Canberra (which can be used to be representative of the ACT) with a similar climate currently experienced in another location. These projections use the annual average rainfall and maximum temperature as a basis for identifying analogue towns and allow Canberrans to picture what the future climate of Canberra is under different emissions scenarios. Analogue towns for Canberra in 2030, 2050, and 2090 under RCP 8.5 are presented below. An overview of what agriculture looks like in these towns is presented in Table 6 and in further detail in Appendix G.

Analogue towns for Canberra under RCP8.5		
2030	**2050**	**2090**
• Bairnsdale	• Cootamundra	• Muswellbrook
• Bathurst	• Wangaratta	• Scone
• Benalla	• Corowa	• Gilgandra
• Albury-Wodonga	• Wagga Wagga	• Warwick
• Sale	• Benalla	• Condobolin
• Bendigo	• Albury-Wodonga	• Dubbo
• Young	• Mudgee	• Wellington
• Melbourne	• Young	• Parkes
		• Forbes
		• West Wyalong

CSIRO Climate Analogues Climate Projections used:
Canberra, RCP8.5 2030 - Temperature change 1°C, rainfall change 0% | Canberra, RCP8.5 2050 - Temperature change 2°C, rainfall change -5% | Canberra, RCP8.5 2090 - Temperature change 4.2°C, rainfall change -12%

Analogue towns for Canberra under RCP4.5		
2030	**2050**	**2090**
• Bairnsdale	• Wangaratta	• Cootamundra
• Bathurst	• Bairnsdale	• Wangaratta
• Benalla	• Bathurst	• Corowa
• Albury-Wodonga	• Benalla	• Wagga Wagga
• Sale	• Albury-Wodonga	• Benalla
• Bendigo	• Bendigo	• Albury-Wodonga
• Young	• Young	• Mudgee
• Melbourne		• Young

CSIRO Climate Analogues Climate Projections used:
Canberra, RCP4.5 2030 - Temperature change 0.9°C, rainfall change 0% | Canberra, RCP4.5 2050 - Temperature change 1.2°C, rainfall change 1% | Canberra, RCP4.5 2090 - Temperature change 2°C, rainfall change -4%

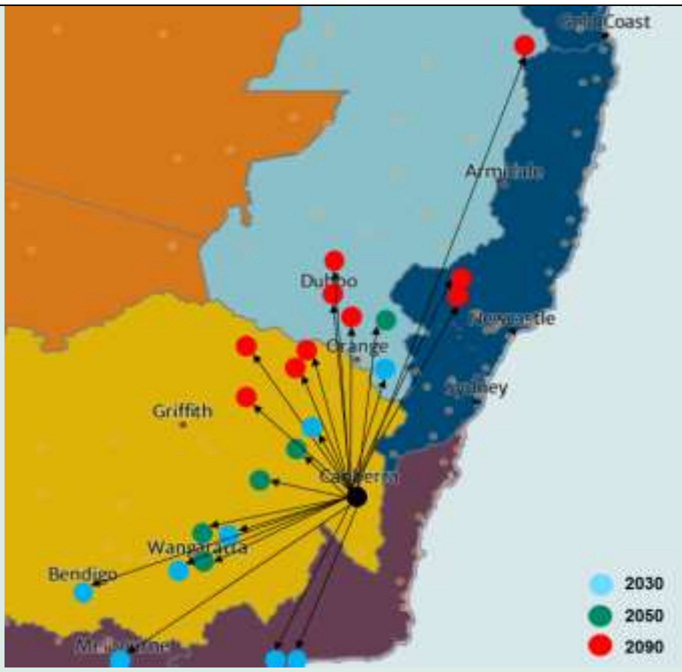


Figure 13 Analogue towns for Canberra under RCP8.5 for 2030, 2050 and 2090

Table 6 Types of agricultural practises for Canberra's analogue towns

	Bairnsdale	Bathurst	Benalla	Albury Wodonga	Sale	Bendigo	Young	Melbourne
Sheep and cattle grazing	🟢	🟢	🟢	🟡	🟢	🟡	🟢	
Cropping	🟡	🟡						🟡
Vegetables	🟡	🟡		🟡				🟡
Crops for hay		🟡				🟡		
Broadacre cropping and crop-pasture			🟡	🟢		🟢	🟡	
Pasture dryland sheep and cattle grazing								
Poultry				🟡	🟡	🟡		🟡
Nurseries and cut flowers		🟡						🟢
Fruit and nuts			🟡	🟡			🟡	🟡

Legend	
🟢	Dominant agriculture practice
🟡	Secondary agriculture practice

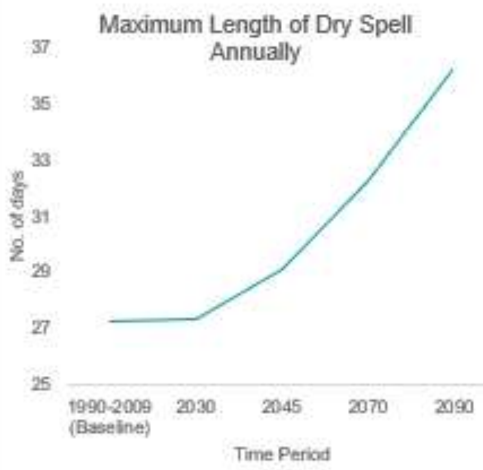
5.4 Future drought scenarios for the ACT

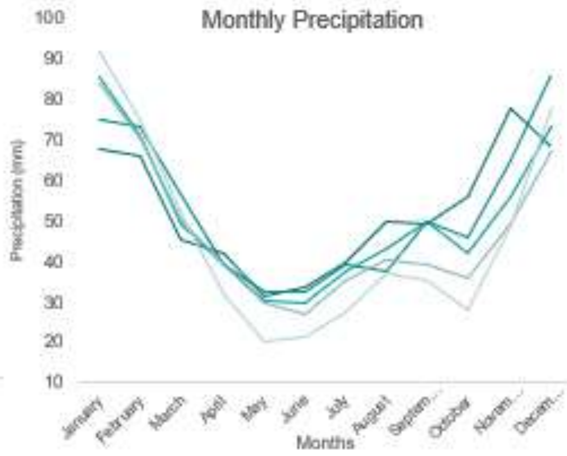
Three scenarios were reviewed to inform the development of drought scenarios for the ACT. Climate projections produced by NARCliM are the result of running an ensemble of six different climate models. Results for the average across these six models are referred is the ‘ensemble model mean’. For this study, three scenarios were developed including a low-medium emissions scenario (RCP 4.5 model ensemble mean), high emissions scenario (RCP 8.5 model ensemble mean) and a hotter/drier scenario (adopting the hottest and driest model of the RCP 8.5 model ensemble for the given time period). Appendix A summarises the future drought scenario based on a high global emissions scenario, described as RCP 8.5 (model ensemble). Future projections described are in accordance with the model assemble mean of projections under the modelling produced under this scenario. For further information regarding the low emission scenario, the ‘hotter and drier’ model scenario and the selection of drought scenarios, refer to Appendix A.

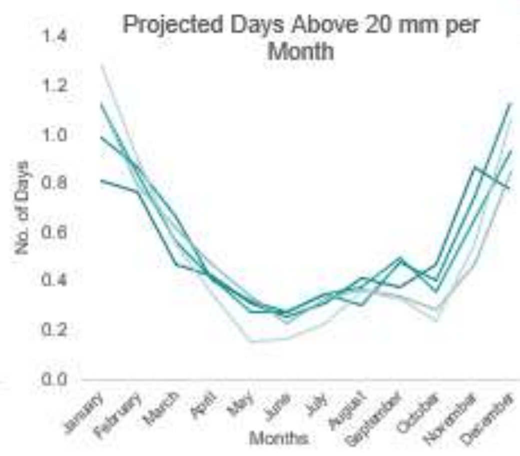
5.5 High emissions scenario for the North-East ACT

Under a high emissions scenario (RCP 8.5 model ensemble mean), it is projected that temperature will continue to increase, particularly over summer months, with a significant increase occurring towards the end of the century. Rainfall is projected to decrease annually however there will be increasing intensity of extreme rainfall events. It is also projected that consecutive days without rainfall will increase. Soil moisture is projected to decrease, particularly during August – December months, with a more significant decrease expected by the end of century. In comparison to a low emissions scenario (RCP 4.5 model ensemble mean), projections are generally more significant, whilst more mild in comparison to hotter/drier scenario (RCP 8.5 hotter and drier model).

Rainfall = *decrease annually, increase in intensity*



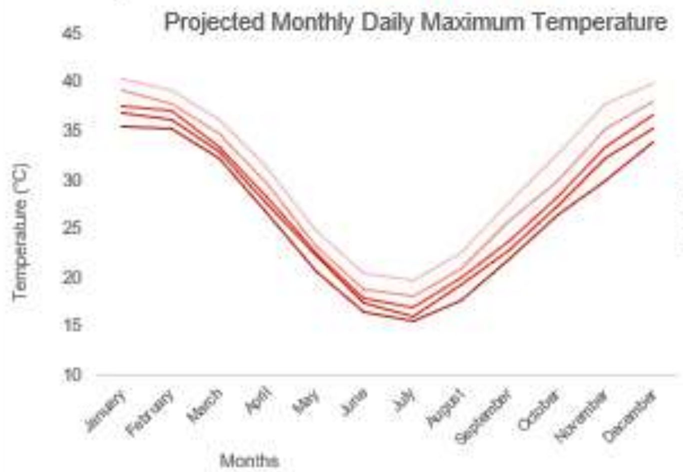


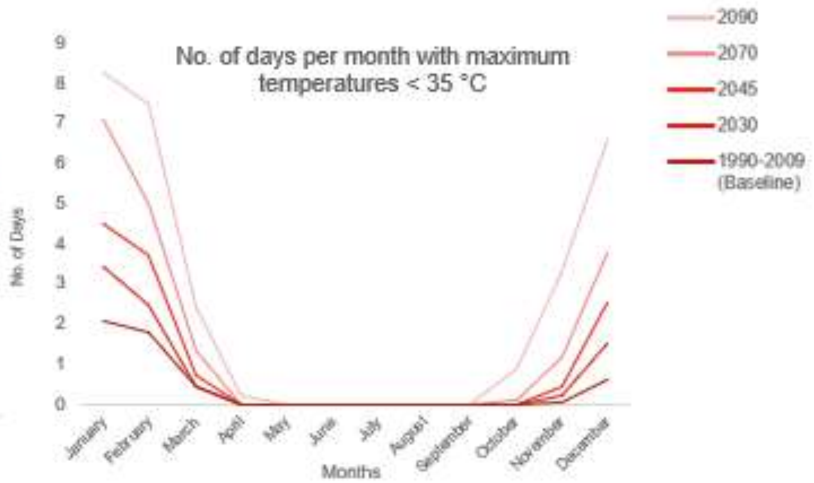


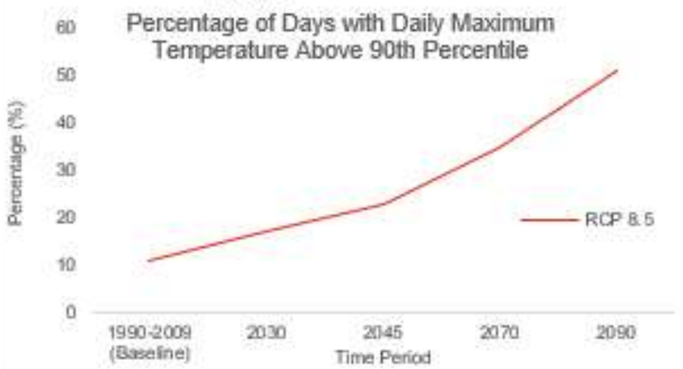
Rainfall is projected to decrease annually however increase in intensity. Projections include:

- **Decrease** in annual rainfall
- **Increase** consecutive days without rainfall
- **Increasing** intensity of extreme rainfall events

Temperature = *increase*



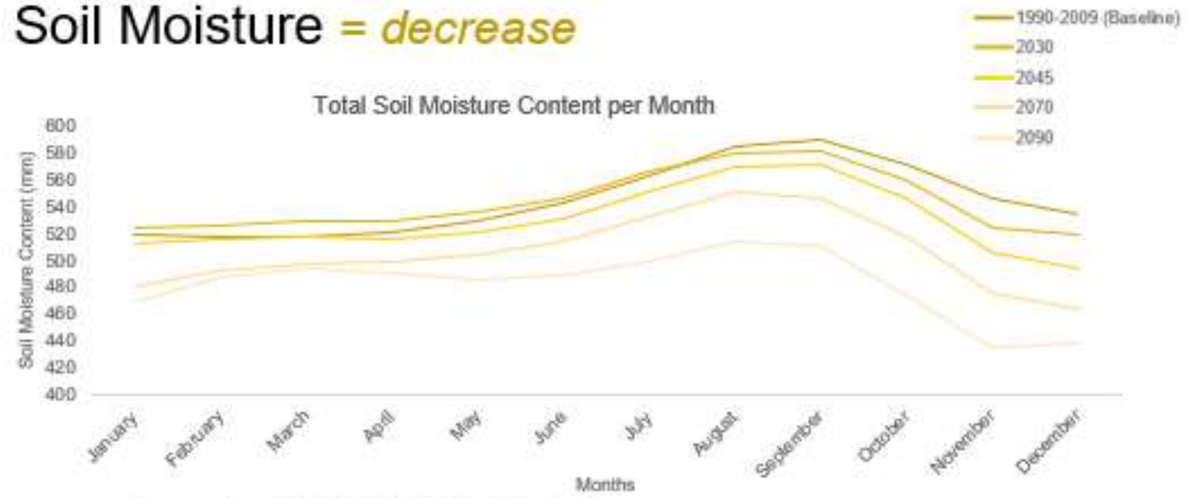


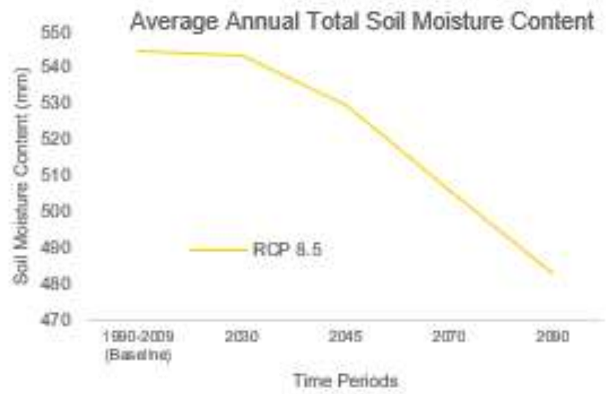


Temperatures are projected to increase. Particularly towards end of century. Projections include:

- **Increase** in projected monthly daily maximum temperatures across all months
- **One-third** of the month of **January over 35°C** in 2090

Soil Moisture = *decrease*





Soil moisture content is projected to decrease. Particularly towards end of century. Projections include:

- **11% decrease** annually by end of century
- **18% decrease** in month of December by end of century

Part 3

Impacts to ACT's agriculture sector

6.0 Impacts of drought

The future drought scenarios and climate observations described in Section 4.0 and 5.0 was presented to stakeholders during stakeholder engagement to help inform discussions regarding impact of drought on rural landholders in the ACT.

The following section presents the impacts identified by both stakeholder engagement (workshops, interviews, and the survey) and the desktop literature review.

6.1.1 Value domains

The report outlines the impacts of drought, and responses that are being implemented, in the context of four 'domains'. The domains encompass environmental, economic, social, and governance implications of drought events on the ACT's agricultural community. This framing recognises that droughts impact on-farm activities such as animal husbandry and pasture production, which drive poor outcomes in each of the domains. They are a hybrid of existing domains adopted within strategic work of the ACT Government such as the ACT's Whole of Government Climate Change Risk Assessment, the ACT's Territory Wide Risk Assessment, and the ACT Wellbeing Framework. They also align to the Future Drought Fund's three categories of environmental management, economic development, and wellbeing and social capital. It is recognised that the domains are interconnected and apply at a range of levels. In accordance with findings from the literature review and stakeholder engagement, the impacts of drought identified were categorised into these four thematic domains.

Table 7 Domains used in this report

Domain	Description
Environmental	**Environmental resilience for sustainable and improved functioning of farming landscapes** Environmental and biophysical impacts of drought and actions relating to soils, plant and animal growth, management of invasive species, animal welfare, conservation, and regeneration
Economic	**Economic resilience for an innovative and profitable agricultural sector** Impacts of drought relating to farm revenues, costs, subsidies, and grants; and actions relating to financial management.
Social	**Social resilience for resourceful and adaptable communities** Drought impacts and responses relating to people and social networks, including their skills, knowledge, human health (physical and mental) and culture.
Governance	Relationship and process of interaction and decision making in and between government and the community. This theme is distinct from others because impacts and actions are indirect and cut across all the domains, and emerge from other domain risks

6.1.2 Priority impacts identified

Priority impacts were identified based on stakeholder feedback, findings of the literature review, and analysis based on future drought scenario. A vulnerability framework (refer Glossary) was used as a lens to assist prioritisation by qualitatively rating their exposure (i.e. to what extent does each impact affect multiple agricultural enterprise types) and sensitivity (i.e. to what extent are affected agricultural types likely to be impacted by the given impact). Impacts have then been categorised by value domain.

The priority impacts of drought, in the context of the drought scenarios, the vulnerability framework developed for this project and informed by feedback from ACT rural landholders and literature, are outlined in include:

Table 8 Impacts identified, by domain

Group	Impact	Environmental	Economic	Social	Governance
Priority impact	Reduced water availability	●	●		
	Increased weeds and pests	●	●		
	Reduced carrying capacity of land	●	●		
	Reduced on-farm biodiversity	●			
	Increased occurrence of natural disasters	●			
	Reduced wellbeing of farming community			●	
Other impacts Table 17, **Appendix E)**	Shifts in timing of farm activities/operations	●	●		
	Damage to assets and infrastructure	●	●		
	Increased crop/pasture sensitivity	●	●		
	Heat stress on livestock	●	●		
	Erosion of soil and crop/pasture damage	●	●		
	Land becomes unsuitable for agricultural enterprises	●	●	●	
	Increased need to import feed	●	●		
	Shifts in timing of farm activities/operations		●	●	
	Financial vulnerability	●	●	●	
	Safety and reduced employment			●	

These impacts are discussed in detail below and a summary of all impacts can be found in Appendix E. Overall, there were five impacts identified to be driven by both a high exposure across ACT's farming community and farming enterprises were generally all found to be sensitive to their impacts. These impacts are subsequently described in detail.

The following sections describe the priority impacts within each Domain in detail. Given grazing systems (including both cattle and sheep) are the dominant agricultural enterprise in the ACT, there is a significant focus within the discussion on these systems. Other agricultural types (such as viticulture) are separately discussed where appropriate.

6.2 Environmental

The priority environmental impacts of drought included:

- Reduced water availability
- Increased weeds and pests
- Reduce carrying capacity of the land
- Reduced on-farm biodiversity
- Increased soil degradation including loss of groundcover, increased soil compaction, loss of soil carbon, reduced soil water holding capacity, and catastrophic erosion following drought-induced fires

During stakeholder engagement, the most frequently mentioned environmental impacts of drought were relating to reduced water availability (10), followed by increased weeds and pests (8), and on-farm biodiversity (5). Collectively these themes comprise three quarters of environmental impacts of drought identified by ACT landholders. Other impacts are explored further in Section 6.2.4.

6.2.1 Reduced water availability

"With the last drought, we had to monitor our water. We were fortunate to access ground[water] allocation which meant we were able to provide clean and secure water for livestock" [C]

Priority impact: Reduced water availability
Context
Agricultural practices are highly dependent on the availability of water. The future drought scenarios project less water availability manifested as reduced surface water, groundwater, and soil moisture, as well as reduced water for irrigation and other uses. This is due to a combination of lower rainfall (particularly in winter and spring) and higher temperatures reducing inflows to rivers and dams and reduced recharge rates for underground water [D, 24]. Due to increases in extreme rainfall events, the soil may remain dry despite the rain due to its inability to soak up as much water during an extreme rainfall event [D]. This can lead to soil erosion and damage to crops and pastures.
Impacts
ACT rural landholders noted reduced water quantity, and quality and increased reliance on off-farm and non-surface water sources. A direct impact of drought is reduced water availability and reduced soil pasture. ACT rural landholders noted that dams and on-farm water storage dried up in droughts [A, B, D]. This reduced water availability for farms which relied on surface water. Some landholders used town water to continue to service paddocks and house water demands [B], whilst others noted a reliance on bore water to water livestock [C]. Some landholders noted they made use of natural springs to water stock. This allowed them to keep stock out of riparian corridors and protect these areas of native biodiversity. Cropping enterprises are more sensitive to drought than livestock farms. Low water availability has a close relationship with yield for irrigated crops [D], and reduced water quality can also affect the quality of food crops. [D] In addition to reduced water quantity, landholders noted that it was a challenge to maintain dam water quality in drought, with water quality in dams degrading and requiring treatment. Flow on impacts of reduced water quantity and quality in drought include reduced production, and reduced stock health and growth, particularly for irrigated crops [D].
Climate variable
• Decrease in annual rainfall

[24] AdaptNSW. (2022). *Climate projections used on AdaptNSW*. https://www.climatechange.environment.nsw.gov.au/climate-projections-used-adaptnsw

• Increase in annual average temperatures • Reduced SPI • Reduced soil moisture content		
Prioritisation		
Exposure	**Sensitivity**	Reduced water availability because of a changing climate will have far-reaching impacts across both primary production and other agricultural enterprises in the ACT. A decrease in available water can cause production and yield to decrease impacting high value farms. Given that all farms are likely to be affected by this impact (high exposure) and all farms are sensitive to this impact (high sensitivity), this is categorised as a priority impact.
High exposure due to all farms likely to be affected by reduced water availability.	**High** sensitivity due to heavy reliance on water availability.	
Adaptation actions		
• **Section 9.4.1.1 Land management**		

Legend: *[*] priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

6.2.2 Increased weeds and pests

"*When you graze too hard, weeds can get a footing more easily."*

"Lots of weeds getting blown in - if our neighbours have it, we'll have it"

Priority Impact: Increased weeds and pests
Context
Climate change will affect the spread and competitiveness of weeds and pests in the ACT. This will impact crops and livestock.
Impacts
It was noted that periods of drought and elevated grazing pressure resulted in weeds gaining a foothold [A, D]. This led to a proliferation of weeds following drought, of which African lovegrass was of particular concern to landholders [A]. With minimum temperatures increasing, landholders noted that more weeds were blowing in from neighbouring properties/public land and that poor management of weeds on neighbouring properties nullified good management on their property. [A]. Weed spreading events will increase with increased incidence of flooding, bushfires, and winds [D] and transport by native and pest animal species. The costs of weed management are also likely to increase [D]. This is significant, as weeds are one of the most costly agricultural pests[25]. Wild and feral animals may carry diseases that can infect livestock, including Foot-and-mouth disease, Johne's disease, sheep measles, Newcastle disease, leptospirosis, and anthrax.[26] Drought conditions can amplify the effects of parasites and infectious diseases through increased transmission in crowded conditions such as around water and feed sources and lowered immunity associated with poor nutrition.[27] These impacts ultimately result in a reduction in agricultural productivity and damage to the environment and natural resources [D].
Climate variable

[25] Schonbeck, M., & Tillage, B. (2011). Principles of sustainable weed management in organic cropping systems. In *Workshop for Farmers and Agricultural Professionals on Sustainable Weed Management* (Vol. 3, pp. 1-24). Clemson, SC, USA: Clemson University.
[26] Department of Primary Industries. (2022). *Biosecurity, wildlife and feral animals.* https://www.dpi.nsw.gov.au/biosecurity/animal/wildlife-and-feral-animals
[27] Agriculture Victoria. (2022). *Animal health in a drought.* https://agriculture.vic.gov.au/livestock-and-animals/livestock-health-and-welfare/animal-health-in-a-drought

• Increase in annual average temperatures		
Prioritisation		
Exposure	**Sensitivity**	Grazing industries and other agricultural enterprises are subject to these infestations and with greater climatic variations, pest management will become more important. Producers may need to increase pest surveillance, especially as pest life cycles change in response to climate change. The exposure and sensitivity are high due to the significant financial impact weeds have, both in terms of control and lost productivity.
High exposure due to all farms have the potential to be impacts by weed infestations.	**High** sensitivity due to lack of control once a weed infestation occurs and the financial and lost productivity impacts that result.	
Adaptation actions		
• **Section 7.3.2.6 Weed and pest management**		

Legend: *[*] priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

6.2.3 Loss of on-farm biodiversity

"Following the 2003 bushfires, it took 12 years to see a possum again."

"[During a heatwave] small birds with enclosed nests all died in their nests."

Priority impact: On-farm biodiversity
Context
Loss of biodiversity and ecosystem services (such as pest regulation, water purification, and pollination) leaves agricultural systems more vulnerable to threats such as pests, pathogens, and continued impacts from climate change. The loss of biodiversity observed by ACT landholders in drought is consistent with scientific literature.
Impacts
Impacts to on-farm biodiversity and impacts on the farm enterprise from on-farm biodiversity were noted by ACT rural landholders. The grazing pressures from kangaroos during drought were considered a significant impact, with one landholder quoting that each kangaroo was equivalent to three-quarters of the same number of sheep. That is, having 100 kangaroos grazing on the property was equivalent to carrying an additional 75 sheep [A]. The significance of kangaroo grazing impacts, which are exacerbated by drought is echoed in other jurisdictions and presents a complex environmental, social, and economic problem for management.[28] Additionally, ACT landholders observed the impacts of the drought on on-farm biodiversity. Landholders noted that during heatwaves, small birds in enclosed nests were observed dead in their nests due to the extreme heat. One landholder noted that after the 2003 bushfires it took twelve years to see a possum on the property again [B]. Another noted that in their bush paddock, a quarter of the trees died out during drought [B]. Landholders generally felt a responsibility to support native wildlife during drought [A]. Damage to biodiversity and ecosystem functioning can have flow-on effects on farm health and productivity. Healthy ecosystems benefit farms by providing services, such as pollination, controlling soil erosion and maintaining water quality for farm use. [29, B]
Climate variable
• Increase in annual average temperatures

[28] Hacker R. B., Sinclair K., Pahl L. (2020) *Prospects for ecologically and socially sustainable management of total grazing pressure in the southern rangelands of Australia.* The Rangeland Journal 41, 581-586. https://www.publish.csiro.au/rj/rj20006
[29] Power, A. (2010). *Ecosystem services and agriculture: tradeoffs and synergies.* https://royalsocietypublishing.org/doi/10.1098/rstb.2010.0143

• Increase in extreme heat days over 35°C • Reduced SPI • Reduced soil moisture content		
Prioritisation		
Exposure	**Sensitivity**	Exposure and sensitivity are high due to biodiversity loss reducing ecosystem functioning, resulting in less productive farms, and added pressure for farmers to support native wildlife.
High exposure due to all farms likely to be affected by reduced biodiversity.	**High** sensitivity due to the dependence agriculture has on health ecosystems.	
Adaptation actions		
• **Section 7.3.2.9 On-farm biodiversity management**		

Legend: *[*] priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

6.2.4 Other impacts of drought

6.2.4.1 Increased occurrence of natural disasters

Extreme events, especially floods and droughts, can harm crops and pastures and reduce yields [D]. Bushfire risk is also exacerbated by drought conditions due to very dry vegetation and soils and record-breaking heat[30]. Drought and heatwaves intensify the drying of dead bushfire fuel and can even lead to megafires which are defined by their enormous size and the number of resources required to bring them under control [31]. In addition, floods can follow bushfires, compounding the effects of natural disasters [A]. There is projected to be higher occurrences of fluctuating extremes [D]. Extreme high rainfall events can also lead to erosion of soil and damage to crops, particularly where soil infiltration is reduced.

6.2.4.2 Damage to assets and infrastructure

Damage to assets and infrastructure on farms in the ACT can be caused by natural disasters including bushfires. Costs include damage to farm fencing, buildings and equipment, and a reduction in farmland values, loss of crops and pastures and livestock deaths.[32] The social impacts of bushfires are explored further in Section 6.4.1.

Bushfires resulted in long-term impacts on soil health. Fire can damage soil microbial communities, as well as many nutrient and organic matter cycling functions[33]. A landholder reported that after the 2003 bushfire the soils on their property became hydrophobic (repelled water). The recovery from this took 6 – 7 years following the bushfire.

6.2.4.3 Unsuitable land for agricultural enterprises

Land for agriculture may become less suitable for certain enterprises due to longer droughts and harsher fire weather causing crop and pasture stress and attracting new pests that thrive in warmer temperatures[34] . As a result of more extreme temperatures, a landholder with a horticulture enterprise noted that they could no longer grow crops on the same side of the hill that they had previously, and had to adapt their management accordingly to find more suitable locations [A].

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[30] Climate Council, 2019, Dangerous Summer: Escalating bushfire, heat and drought risk, https://www.climatecouncil.org.au/wp-content/uploads/2019/12/report-dangerous-summer_V5.pdf
[31] UNSW Sydney, 2021, How heatwaves and drought combine to produce the perfect firestorm, https://newsroom.unsw.edu.au/news/science-tech/how-heatwaves-and-drought-combine-produce-perfect-firestorm
[32] Strom, M (2021) *Black Summer bushfire season cost farmers up to $5 billion.* University of Sydney. Accessed on 18 October 2022, https://www.sydney.edu.au/news-opinion/news/2021/12/13/black-summer-2019-20-bushfires-cost-farmers-5-billion-australia.html
[33] Farrell, M. (2020). *Recovery of Australia's soils following bushfires* - ECOS. https://ecos.csiro.au/soil-fire-recovery/
[34] AdaptNSW (2022) *Climate change impacts on drought.* https://www.climatechange.environment.nsw.gov.au/drought#:~:text=Drought%20has%20huge%20impacts%20on%20Australia's%20agriculture%20industry%2C%20causing%3A,leading%20to%20shortages%20in%20supply

6.2.4.4 Shifts in the timing of farm activities and operations

The seasonal timing of farm management actions is changing, this is particularly prevalent in the viticulture industry (refer to Section 6.6 for more detail on these impacts on viticulture). While livestock-rearing stakeholders didn't raise this as a key impact at this stage, there is evidence this will be a rising issue into the future[35][36].

In additon, many important animal diseases are affected directly or indirectly by weather and climate. These links may be spatial (with changes in climate affecting disease distribution) or temporal (with weather affecting the timing of an outbreak) or may relate to the intensity of an outbreak.

6.2.4.5 Heat stress on livestock

Livestock experience heat stress resulting in reduced appetites, less desire to breed, increased animal stress and significant productivity loss for the livestock industry. [A, D]

6.2.4.6 Erosion of soil and crop damage

Crop losses due to the bushfire smoke were a significant impact, particularly for the viticulture industry [B] (refer to Section 6.6 for more detail on these impacts on viticulture).

Extreme rainfall events lead to erosion of soil and damage to crops [D]. Despite rain events, the soil may remain dry due to its inability to soak up as much water during an extreme rainfall event [D]. This can increase flood and erosion risk and can be exacerbated by other extreme events as described in **Section 6.2.4.2.** Erosion and crop damage was not raised by ACT landholders as a significant concern.

6.3 Economic

The priority economic impacts of drought included:

- Reduced water availability
- Reduced carrying capacity of the land

During stakeholder engagement, the most frequently mentioned economic impacts of drought were related to the reduced carrying capacity of the land for the grazing enterprises category (3). These comprised just under half of the impacts identified by ACT landholders.

Other impacts are explored further in Section **6.3.2.**

6.3.1 Reduced carrying capacity

"Learned to de-stock early before you graze too hard"

Priority impact: Reduced carrying capacity
Context
Carrying capacity is the average number of animals that a grazing area can be expected to support over a set period. [37] During times of drought, the carrying capacity of the land is reduced. During periods of drought, many farmers destock to sustain the remaining livestock. Strategies to minimise the economic impacts of reducing stock numbers include selling feeder animals early, reducing breeding animal numbers, and selling the entire herd.
Impacts

[35] Henry, B.K. & Charmley, E. & Eckard, Richard & Gaughan, J. & Hegarty, Roger. (2012). Livestock production in a changing climate: Adaptation and mitigation research in Australia. Crop and Pasture Science. 63. 191-202. 10.1071/CP11169.
[36] Cullen, Brendan & Harrison, Matthew & Mayberry, Dianne & Cobon, David & Davison, Tom & Eckard, Richard. (2021). Climate change impacts and adaptation strategies for pasture-based industries: Australian perspective. NZGA: Research and Practice Series. 17. 10.33584/rps.17.2021.3476.
[37] Queensland Government (2016) *Understanding carrying capacity and stocking rates in grazing systems*. Queensland Government. Accessed on 18 October 2022, https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/grazing-pasture/improved-production/carrying-capacity#:~:text=Long%2Dterm%20carrying%20capacity%20is,(e.g.%2010%2B%20years).

Drought results in increased costs and decreased production and income.[38] Landholders were unable to maintain pre-drought stocking levels and needed to destock during and in the lead-up to drought periods. Selling livestock enabled landholders to reduce the financial and environmental costs of keeping animals on the land in dry periods by avoiding the need to buy supplementary feed and reducing the impact of livestock traffic on bare soil [A]. Landholders used drought plans and weather predictions to decide when to destock. [B] They also noted a need to sell earlier going into a drought [A,] and that it took a long time to build stock numbers back up, and recover economically from destocking [A, B]. Landholders also noted that buying-in feed was expensive and the embodied energy used to transport the feed ('food miles') was considered high (refer to Section 6.3.2.1). Landholders had to factor kangaroo grazing pressure into grazing calculations and decisions around stock management [A]. As stated in Section 6.2.3, kangaroos contribute significantly to grazing pressure. To ameliorate some of these impacts, landholders allowed their cattle to graze in roadside vegetation, or 'bush paddocks' during drought to supplement feed and reduce the fire risk of biodiversity corridors, which could otherwise facilitate the movement of fire across the landscape. However, this can have a negative impact on on-farm biodiversity (refer to Section 6.2.3).
Climate variable
• Increase in annual average temperatures • Reduced SPI • Reduced soil moisture content
Prioritisation

Exposure	Sensitivity	
High exposure due to the current lack of stock management techniques currently practised across farms.	**High** sensitivity due to the productivity and profitability loss from de-stocking as well as the long recovery times.	Grazing enterprises in the ACT have both high exposure and high sensitivity to managing appropriate stock levels due to the impacts of drought making it challenging to recover from times of destocking and the increasing costs to buy-in feed.

Adaptation actions
• **Section 7.3.1.4 Stock Management**

*Legend: ** *priority impacts based on frequency of impact being cited by stakeholders and in literature.* ***A*** *identified through workshops.* ***B*** *identified through interviews.* ***C*** *identified by survey.* ***D*** *literature review.*

6.3.2 Other impacts

Other economic impacts identified through stakeholder engagement and the literature review included:

- Increased need to import feed
- Financial vulnerability
- Shifts in the timing of farm activities and operations.

These impacts are expanded on below.

6.3.2.1 Increased need to import feed

When there is less pasture available for stock to eat due to drought, buying in feed to supplement rain-fed pastures is costly and compounded by increased costs of off-farm fodder purchased during drought periods [B]. Increased demand for feed during the most recent drought meant landholders had to source feed from further away, including Western Australia and Tasmania. Feed prices were therefore higher due to the additional transport costs [A] as well as the scarcity of feed. Higher feed costs contribute to the general trend of higher input costs experienced by farms in drought (refer to **Section 6.3.2.2**).

[38] MLA (2021) Drought feeding. Meat and Livestock Australia. Accessed 18 October 2022, mla.com.au/research-and-development/livestock-production/livestock-nutrition/drought-feeding/

6.3.2.2 Financial vulnerability

Farm drought risk varies significantly across industries, with cropping enterprises more sensitive to drought than livestock enterprises. Crop yields are directly linked to weather conditions, leading to large, immediate declines in revenue during drought years. In contrast, livestock producers can smooth climate impacts over multiple years by selling livestock in drought years, which helps maintain revenues in the short-term and offset lower prices received and higher costs. [39]

The least profitable years for farmers tend to be drought years with unfavourable prices. Costs are increased for feed, fuel and fertilisers and other farm inputs such as herbicides [C]. Nationally, average farm returns decreased in 2018-19 in drought-affected regions [40]. There is subsequently a greater need for financial assistance during drought leading to an increased need to access grants and/or to rely on off-farm income [A]. A key factor identified by stakeholders that mitigated the impacts of the 2017 – 2020 drought was the high demand for Australian sheep and cattle which pushed prices to, in some cases, historic highs. In times of future drought, global and local political, economic, and social trends may not provide the same protections. [A]

6.4 Social

The priority social impacts of drought included:

- Reduced wellbeing of farming community

During stakeholder engagement, the most frequently mentioned economic impacts of drought were related to reduced wellbeing (3). These comprised over half of the social impacts identified by ACT landholders. Other impacts are explored further in **Section 6.4.2.**

6.4.1 Reduced wellbeing

"Increased worry about bushfires"

"[Bushfires] destroyed the community"

Priority impact: Wellbeing
Context
The most significant social impacts of drought include erosion of income resulting in rural poverty, increased workloads, physical and mental health and welfare issues, problematic access to services and overload on service providers, declining access to education, and isolation. [41] Some of these impacts are less applicable to the ACT context and were not raised by landholders. This could be due to the proximity to Canberra as a major source of services and employment, and the prevalence of off-farm income among the ACT rural landholder community. This means that access to services including education and health and mental health services is less affected by drought, and therefore isolation is reduced. Other disasters such as bushfires have physical and mental health impacts on rural communities. A significant cost of the 2019-2020 bushfires was the physical health impacts from smoke inhalation by farmers and others who work outdoors, as well as the broader ACT and region community. [32] It is well established that bushfires and other natural disasters have long-term effects on the mental health of affected individuals and communities.[42] The effects of these events can last for years.[43] The 2019 - 2020 bushfires in Australia were catastrophic and unprecedented.[44]

[39] Hughes, N, Burns, K, Soh, WY & Lawson, K 2020, *Measuring drought risk: the exposure and sensitivity of Australian farms to drought*, ABARES report to client, prepared for the Department of Agriculture, Water and the Environment, Canberra, November, DOI: https://doi.org/10.25814/mqrp-rp16. CC BY 4.0.
[40] ABARES Insight, 2019, *Analysis of the effects of drought and climate variability on Australian farm*
[41] Alston, Margaret, and Jenny Kent. 2004. *Social Impacts of Drought : A report to NSW agriculture.* Wagga wagga, NSW: Centre for Rural Social Research, Charles Sturt University.
Black Dog Institute. 2020. *Mental Health Interventions Following Disasters.* Randwick, NSW, Australia: Black Dog Institute.
[43] Gibbs, L., Waters, E., Bryant, R. A. et al. 2013. "*Beyond Bushfires: Community, Resilience and Recovery - a longitudinal mixed method study of the medium to long term impacts of bushfires on mental health and social connectedness." BMC Public Health.*
[44] Morton, A. 2020. *"Yes, Australia has always had bushfires: but 2019 is like nothing we've seen before."* The Guardian, 25 December.

Studies have found that in addition to immediate distress related to financial and workload problems, people reported experiencing significant distress from the emotional impact of environmental degradation, from loss of hope for the future of their community, and from feelings of being misunderstood by the wider Australian community.[45] The stressors affecting farming communities during times of drought are likely to be associated with increased risk of mental health problems.
Impacts
Wellbeing impacts include: • Reduced health and mental wellbeing from recent pressures including climate change, drought, pest and disease outbreaks and economic rationalisation [D] • Reduced wellbeing due to working long hours, having physically demanding work, and often being isolated socially and geographically from services [D] • Increased concerns about bushfires, and concerns related to evacuations [A] • Increased exposure to challenging working conditions (e.g. days with temperatures exceeding 35°C) • Financial management pressures during periods of lower revenues and/or increased capital expenditure and operational expenditure.
Climate variable
• Decrease in annual rainfall • Increase in annual average temperatures • Reduced SPI • Reduced soil moisture content • Increased extreme rainfall events • Increase in extreme temperatures (greater than 35°C)
Prioritisation

Exposure	Sensitivity	Climate change may increase the risk of mental health impacts among farmers as they face the hardships of practising agriculture under a changing and highly variable climate. The sensitivity and exposure are high as these impacts are making farmers and their agricultural systems more vulnerable.
High exposure due to increasing frequency of climate events (droughts, bushfires, flooding etc) without sufficient recovery periods in between.	**High** sensitivity due to range of impacts faced including health , mental wellbeing, and financial pressures.	

Adaptation actions
• **Section 7.3.2.3 Knowledge sharing and information provision**

Legend: *[*] priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

6.4.2 Other impacts

6.4.2.1 Safety and reduced employment

Other social impacts identified through stakeholder engagement and the literature review included safety concerns and reduced employment.

Physical health and welfare impacts were echoed to be a concern of ACT landholders. A safety impact identified was the occupational health and safety risks to farm workers with increasing temperatures [B]. Landholders expressed heat-related safety concerns for their staff [B]. Heat stress can also reduce labour capacity in agriculture [D]. There were concerns that during drought and times of financial stress there is less work available for people who rely on the agricultural sector for employment [A].

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[45] Sartore, G., Kelly, B., Stain, H., Albrecht, G., & Higginbotham, N. (2008). *Control, uncertainty, and expectations for the future: A qualitative study of the impact of drought on a rural Australian community.* https://search.informit.org/doi/abs/10.3316/INFORMIT.471246494717588

6.5 Governance

Governance impacts were less frequently raised during engagement activities however the following impacts have been identified:

- Managing more frequent droughts places stress on governance systems
    - Government resources are diverted to drought response activities, redirecting staff from other strategic workstreams
- Introduces greater reliance on financial assistance
    - Financial implications for the government providing grants are significant and as drought events prolong periods extend tend to increase in cost with time.
    - Perceptions by the greater community present reputational risks for the government if drought response is not seen as reasonable
- Timing of when drought is declared
    - Concerns raised about the lack of clear direction from government authorities regarding the declaration of drought drove some challenges in farmers accessing federal financial relief, and perceptions within the farming community they were not a priority for the government.
- Availability of drought assistance
    - Challenges were noted by farmers regarding access to financial aid because of strict eligibility criteria.
- Different approaches between NSW and ACT impacting competitiveness
    - Pricing of water extraction, for example, was raised as an inconsistency for farmers competing with peers over the border.
- Simultaneous, widespread, and long duration droughts impacting ability for farmers to leverage support from other regions who were also experiencing drought conditions.

6.6 Impacts on viticulture

Impacts

- **Environmental**
  - **Increased weeds and pests:** It was noted that for a vineyard, fungal problems were predicted to become less problematic if the climate became drier, however, there were concerns over scale insects and the brown marmorated stink bug [B]. Additionally, there was concern over diseases being vectored into the ACT, particularly Pierces disease - a deadly disease of grapevines [B].
  - **Shifts in the timing of farm activities and operations:** The seasonal timing for when to take management actions is changing, this is particularly prevalent in the viticulture industry. Vintage advancement (earlier ripening) and vintage compression (shorter ripening periods) are known to be placing pressure on the Australian wine industry, due to increased difficulties in harvest logistics, with growers struggling to find sufficient harvesters and wineries being forced to delay harvest due to a lack of fermenter capacity. Delays in harvest may result in yield loss due to berry dehydration, elevated grape sugar and wine ethanol concentration, and other negative impacts on fruit composition and wine style[46]
  - **Crop damage:** Bushfire smoke can taint fruit and vegetable crops, with wine grapes being particularly susceptible [B]
  - **Reduced water availability:** It was noted there was a reliance on bore water to irrigate and protect vineyards against drought and frost.
- **Economic**
  - **Financial vulnerability:** A landholder noted that due to rebates on water prices for ACT wineries it was possible to reduce water input costs and hence compete on an equal footing with NSW vineyards and wineries [A].

Actions

- **Environmental**
  - **Management timing:** Prune at different times of the year and water at night; plant earlier and later grape varieties to smooth the load of the growing season [B]
  - **Monitoring:** Temperature sensors to detect frost and turn on water pumps to protect vines[B]
- **Water management:** Using bore water for vineyard irrigation in drought and frost [B]

Legend: *[A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

[46] Bindon, K. Petrie, P. 2020 *Managing the impact of vintage advancement and compression*, The Australian Wine Research Institute, Wine Innovation Central Building, Hartley Grove, cnr Paratoo Rd, Urrbrae (Adelaide), SA 5064

7.0 Adaptation actions to build drought resilience in the ACT

7.1 Overview

Farming in the ACT will continue to be affected by drought into the future. Future projections for drought mean the implementation of adaptation measures is increasingly vital to protect the contribution rural landholders make towards the ACT's environment, economy, and community.

Climate adaptation on Australian farms is impeded by barriers including financial and resource limitations; behavioural barriers that limit implementation capacity by individual farmers; and unclear benefits that spread widely across society and are not appropriately captured.[47] To overcome these barriers, public-sector intervention and government support are needed to support adaptation by farmers.

Section 7.2 explores adaptation actions appropriate for ACT's agricultural community, identified through stakeholder engagement (workshops, interviews, and the survey) and the literature review. Of the adaptations discussed by landholders, most actions were within the environmental domain (80), followed by social (12), economic (11), and then governance (0).

7.1.1 Adaptation

Adaptation refers to adjustments in environmental, social, or economic systems in response to actual or expected climatic changes and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.[48]

The vulnerability of agriculture towards climate change warrants a strong adaptation response to limit the impacts felt. Agricultural communities are adjusting to climate change. However, continual focus on adaptation is needed. Adaptations at an individual level include changes to on-farm practices and processes to respond to the physical risks of climate change. Adaptations at a government level include changes in decision-making to foster the implementation of these actions.

ABARES has reported evidence of strong adaptation responses from farms to climate change. In addition, improvement in management practices is helping to increase farm productivity.[49] Despite this adaptation and improvement in productivity, climate change events are becoming more frequent and severe and the time intervals between recovery periods are shortening. As a result, farm profits are becoming more sensitive to drought impacts. Further adaptation is needed to maintain resilience as well as competitiveness in international markets.

ABARES notes the following key themes in adaptation which could help offset future climate impacts:

- Improvements in technology
- Farm structural change (such as changes to sizes of farms and degree of specialisation vs diversification)
- 'Transformational change' on farms and in the farming sector

In addition, the Commonwealth Government released the Drought Response, Resilience and Preparedness Plan in 2019 which focuses on 3 key areas of action including [50]:

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[47] Arunanondchai, P., Fei, C., & McCarl, B. (2017). *Adaptation in Agriculture.* https://www.intechopen.com/chapters/58043
[48] United Nations, n.d. *What do adaptation to climate change and climate resilience mean?* https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean
[49] Hughes, N., & Gooday, P. (2022). *Climate change impacts and adaptation on Australian farms.* https://www.agriculture.gov.au/abares/products/insights/climate-change-impacts-and-adaptation
[50] Department of Agriculture. (2019). *Drought in Australia | Australian Government Drought Response, Resilience and Preparedness Plan*. https://www.agriculture.gov.au/sites/default/files/documents/aust-govt-drought-response-plan_0.pdf

Table 9

Immediate action for those in drought - measures to support farmers and communities facing prolonged drought conditions	**Support for wider communities affected by drought**	**Long-term resilience and preparedness -** accepting that the next drought is inevitable and the importance of building capacity to withstand drought periods in the long-term.
• Farm Household Allowance, an income support payment for farmers and their partners experiencing financial hardship • Access to rural financial counselling services • Access to concessional loans • Better on-farm water management • Providing better information • Making up to 100GL of water available at $100 per megalitre in the southern connected Murray–Darling Basin (MDB) to increase the production of fodder, silage and pasture. • Dealing with the stress of drought through investment in mental health services • Battling pests and weeds	• Keeping drought-affected regional communities open for business • Financial counselling for small businesses • Keeping kids in schools	• Future Drought Fund • Water security initiatives • Investment into research and development to build drought resilience • Effective and strategic management of Australia's soil, vegetation, and water resources

Adaptation measures implemented by rural landholders and the ACT Government should be complementary to the initiatives being implemented by the Australian Government.

7.2 Summary of adaptation actions

Table 10 outlines actions that have been identified through stakeholder engagement activities and a desktop literature review. Focus actions have been identified through consideration of the impacts of drought in the ACT, relevance in the context of future drought scenarios, literature review, and stakeholder engagement feedback. Prioritisation of these focus actions has been informed by the frequency at which actions were raised by stakeholders (as an indicator of broad applicability across ACT's community) and through mapping to identify the potential application for actions to address impacts – prioritising those actions that address multiple impacts (Table 18). Adaptation actions have been grouped under the domains of environment, economic, social and governance and categorised into themes including land management, enterprise section, water management, stock management, infrastructure, planning and regulations, knowledge sharing and information provision, well-being, monitoring, fire management, management timing, weed and pest management, land management tools, marketing, and pasture/crop management.

Table 10 summarises the adaptation actions included within each category. Further detail on the adaptation actions within each Domain is provided in the sections that follow.

During stakeholder engagement, the most frequently mentioned environmental adaptation category was land management, followed by enterprise selection, water management, stock management and then infrastructure. These categories and their respective actions are explored in the following chapter. Fundamental to all of these is drought planning at a farm-level to enable farmers to undertake a SWOT analysis and identify gaps, opportunities, risks and how they plan to improve all dimensions of farm management under future drought conditions and where Government and community play a role.

Table 10 Summary of adaptation actions for the ACT agricultural community

Environment	Economic	Social	Governance	Category	Adaptation actions
✓ ✶				**Land management**	Strategies that preserve or enhance ecosystems without compromising farm production. Examples include farming appropriately to the farms carrying capacity, grazing rotations, carrying less stock, and planting trees for shade and heat protection [A,B,C].
✓ ✶	✓ ✶		✓ ✶	**Enterprise selection**	Enterprise selection should consider physical factors such as soils, land, climate, water access, farm structures and machinery as well as financial and management factors [D]. Examples include diversifying the enterprise [C], engaging in greater stock rotations [C], changing enterprise to one that requires less rainfall, switch from breeding to trading stock, selecting drought resilient breeds of livestock and use/establishment of perennial drought tolerant grasses [A,B,D]. These elements can be captured in drought farm planning

Environment	Economic	Social	Governance	Category	Adaptation actions
✓ ✶	✓			**Water management**	Agriculture and farming are highly dependent on water however are becoming increasingly subject to decreases in rainfall, impacting soil moisture, farm production and availability of surface and groundwater for stock and domestic use, and loss of access to irrigation water. Water management examples include covering dams to reduce evaporation, flocculating dams and farm water, dam enhancement (deepening dams [C]) and restoring environments around dams [A], increasing investment in water infrastructure systems, and reviewing water license frameworks to ensure efficient allocation across catchments [C].
✓ ✶	✓			**Stock management**	During periods of drought, many farmers are forced to actively manage stock levels, including destocking to sustain remaining livestock. Strategies to manage the impacts of destocking include increasing on-farm stockpiles of feed, increased production of silage, development of destocking triggers and thresholds in advance to support decision making, inventory reduction strategies including selling feeder animals early through to more interventionist approaches including reducing breeding animal numbers, selling the herd, or even ceasing animal production [A,B,D].
✓ ✶	✓ ✶			**Infrastructure**	Infrastructure includes on-farm built assets (fencing, water infrastructure, etc), markets and businesses that support farms. Infrastructure cited to improve farm resilience to drought include storing silage underground to protect from fires [B], construction of new dams or enlarging existing dams, installation of water tanks, improving feed storage, producing hay [B] and improving fencing infrastructure to enable better grazing management [C].
✓	✓ ✶			**Planning and regulations**	Planning and regulations encompass strategic and regulatory aspects such as land use planning, lease management, water licensing and environmental approvals. Examples include water licensing (e.g. getting approval for bores), enabling flexibility in agricultural use types within leases, and having a drought plan in place [A].
✓		✓ ✶		**Knowledge sharing and information**	Knowledge sharing and information provision are key to efficient farm production. Examples include utilising climate tools, soil probes, farming forecasts and bushfire hazard burning practises including cultural burning [B] a.
		✓ ✶		**Wellbeing**	Droughts affecting the well-being of farming communities have been well-documented across Australia. Examples to improve well-being include connecting with others [A], improving networks, and facilitating engagement for well-being [A] farm planning succession [B] and sharing information around alternative markets e.g. carbon credits [A].
✓				**Monitoring**	Actively collecting data and maintaining longer term records offers opportunities for farmers to adaptively manage their enterprise (e.g. understanding when to move livestock based on pasture biomass) and prepare for future impacts of drought (e.g. by having

Environment	Economic	Social	Governance	Category	Adaptation actions
					records of how pastures responded to previous droughts). Examples include using soil moisture sensors, temperature sensors for frost and water pumps and keeping records of the impact of different climate variables on farming systems [B].
✓				**Fire management**	Fire is an all-year-round risk-management activity for farms. Preparing for and minimising the risk of fires includes: vegetation management [A], installation of sprinkler systems on houses and farm sheds [B], farms owning their own fire trucks to rapidly respond to fires [B], intentionally overgrazing paddocks to reduce risk of fire on stock, [C] and protecting farm buildings and other infrastructure.
✓		✓		**Management timing**	Adjusting the timing of on-farm activities includes earlier planting times e.g. reproductive periods of livestock, changes to grazing timing and patterns, and adjusting to compressed timing for picking in vineyards.
✓				**Weed and pest management**	Climate change will affect the spread and competitiveness of weeds and pests in the ACT. Producers may need to increase pest surveillance, especially as pest life cycles change and respond to climate change [D]. Responses in this category include reviewing seasonal conditions that require pest control, and maintaining low pest populations to prevent their resurgence under more favourable seasonal conditions [D].
✓				**Land management tools**	There are many different land management tools available across different sectors/industries which aim to support more sustainable production while protecting and enhancing farm ecosystems. Examples include feed calculators from CSIRO and MLA that help farmers to monitor pastures, and pasture biomass; while others from MaiaGrazing and RCS enable producers to view the pasture feed they have on offer for the next three to six months and the impact of livestock stocking rates and herd structure on demand for pasture [B] to assist in decision-making [C] .
✓				**Marketing**	This category captures business management improvements such as marketing to promote agricultural products or services. Examples include promoting regenerative, sustainable, and local food [A], farm tourism or different revenue streams that are more resilient to climatic change [C].
✓				**Pasture/crop management**	Pasture management strategies that can improve productivity include reviewing drought resilience of pastures, introduction of native pasture grass species, pasture management techniques that protect soils and groundcover, crop rotations and intercropping, improved pesticide and fertiliser management [D]

Legend: *[*] priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

7.3 Environmental adaptation actions

7.3.1 Focus actions

During stakeholder engagement, the most frequently mentioned category of environmental adaptation actions was land management, followed by enterprise selection, water management, stock management and then infrastructure. Collectively actions related to these themes comprise three-quarters of environmental categories measures identified by ACT landholders.

7.3.1.1 Land management

"We have too many endangered species. We want our farm to protect endangered grasslands and woodland."

"Our farm manages high-risk fire areas through grazing management"

"We store silage underground to use as drought feed"

Category: Land management
Context
Landholders can prepare for and minimise the impacts of drought, by developing resilient land management practices. Land management covers practices which cultivate certain aspects or arrangements of the agricultural system, and which are centred on managing the land, and its capability.
Adaptation actions
Land management strategies identified by landholders to foster resilience in drought included: • Planting trees for shade, shelter and heat protection and biodiversity [A,B,C] • Carrying less stock - Having clear trigger points to de-stock which are decided on before drought [A] - Having early trigger points to de-stock [A] • Monitoring pastures and pasture biomass and ground cover, creating feed budgets to make informed decisions around when to buy feed and sell stock [B] Rotational grazing: grazing stock in smaller paddocks, at a higher intensity for shorter periods [A, B, C] Time control, herd, cell, crash, and management-intensive grazing are different systems of rotational grazing. While they all have slightly different philosophies and methods, they share the central principles of high stocking rates in confined areas, limiting the amount of time that animals are grazing an area. Initial costs to install adequate fencing for effective rotational grazing systems can be high. ACT landholders who have implemented this approach noted that having small paddock sizes aided in maintaining ground cover. [B] • To maximise groundcover, landholders can use the following strategies [B] - Groundcover is maintained at 80% or better in rural landscapes regardless of the season [51] - Use of diverse exotic and native species which tolerate a range of climate conditions [B] - Pasture topping (cutting off the top of a pasture to encourage growth and nutritional quality)[B] - Use of deep-rooted perennial species which can offer better pasture cover during drought by accessing moisture from deeper in the soil than annual species. [52] • Managing high-risk fire areas on farms through grazing management [B] - Implementing measures to improve and/or maintain soil health Maintaining soil moisture through practices such as conservation tillage [53] - Establishing permanent stock containment areas for lot feeding during drought. When used strategically, containment areas take the pressure off land and soils during dry periods. [54]

[51] EPSDD, *Sustainable Agriculture Investment Plan* Improving the grazing resource base - Environment, Planning and Sustainable Development Directorate - Environment (act.gov.au)
[52] WaterNSW. (2022). Groundcover. https://www.waternsw.com.au/water-quality/catchment/living/managing-land/groundcover
[53] Hughes, N., Galeano, D., & Hatfield-Dodds, S. (2021). *The effects of drought and climate variability on Australian farms.* https://www.agriculture.gov.au/abares/products/insights/effects-of-drought-and-climate-variability-on-Australian-farms
[54] Young, M. (2022). *Managing Soils During and After Drought in Grazing Systems.* https://cdn.environment.sa.gov.au/environment/docs/Soil-CRC-Managing-soils-during-and-after-drought-grazing-2021.pdf

- Raising soil pH on acidic soil (for example by applying lime) [B] - Adding organic fertiliser additions which preserve fungal networks (e.g. turkey poo) [B] - Using biochar [A, 55] - Introducing dung beetles [B] • Storing silage underground to use as drought feed [B] • Manage pastures for rapid regeneration following drought [54] by: - Not overgrazing native and exotic perennial grass stubs as this will significantly slow regeneration. - Sowing quick-growing crops or annual pastures to provide soil cover and act as a break crop to reduce the risk where pasture needs re-establishment. - Reducing erosion risk by establishing quick-growing cover crops or annual pastures where cover is required to stabilise eroding paddocks. - Keep stock off paddocks until ground cover is at adequate levels for maximum growth. This level will vary with location and pasture type. - Use rotational grazing techniques for even grazing pressure - Ensure there are enough, suitably placed watering points to reduce the distance that animals must walk, and the energy required to get there, and to reduce the risk of bare soil from excessive traffic.
Impacts addressed
• Reduced carrying capacity of land • Increased weed and pest infestations • Heat stress on livestock
Relevant agricultural enterprise
• Cattle grazing • Sheep grazing • Livestock agistment

Legend: *[*]priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

7.3.1.2 Enterprise selection

"Our farm is considering changing towards an enterprise that relies on less rainfall"

Category: Enterprise selection
Context
Climate analogues which project what the climate of the ACT might look like under different drought scenarios and identify regions of Australia currently experiencing this climate could point to drought-tolerant species and enterprises (refer to **Section 5.3**)) which could be appropriate for future ACT climates. Diversification of enterprises is known to improve the resilience of food systems and farm enterprises.[56]
Adaptation actions
Enterprise selection should consider physical factors such as land, climate, rainfall and water soil moisture and surface and groundwater availability, farm structures and machinery as well as financial and management factors [D]. Examples include: • Selecting and diversifying toward enterprises which rely on less rainfall [A B, C] - Chickens and pastured eggs [A, 57] - Enterprises with more controlled environments such as hydroponics or microgreens [A] - Farm tourism and accommodation (e.g. Airbnb) [A]

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[55] Agriculture Victoria. (2022). *Feed budgeting takes out the guesswork | Agriculture Victoria*. https://feedinglivestock.vic.gov.au/2022/03/22/feed-budgeting-takes-out-the-guesswork/#:~:text=Feed%20budgeting%20allows%20for%20better,for%20different%20classes%20of%20stock
[56] Hertel, T., Elouafi, I., Tanticharoen, M. et al., (2021). *Diversification for enhanced food systems resilience. Nature Food 2, 832–834* https://doi.org/10.1038/s43016-021-00403-9
[57] Herrera de Leon, H. J., & Kopainsky, B. (2019). Do you bend or break? System dynamics in resilience planning for food security. System Dynamics Review, 35(4), 287-309.

- Leasing land for other uses (e.g. solar farms) [A]
- Bush tucker [B]
- Flower foraging [B]
- Sustainable forestry [B]
- Marketing and producing insects
- Switching from breeding to trading stock (to reduce the need to feed breeding stock through drought)
- Having a sub-brand to buy fruit and sell wine, in addition to growing own fruit

• Select species and breeds which are more drought tolerant [A]
  - Use deep-rooted perennial drought-tolerant grasses [A,B,D].
  - Use summer active pasture species[58]
  - Use more endemic species that are tolerant of extremes in rainfall (both drought and flooding) [A] (e.g. kangaroo and wallaby grasses [B])
  - Selection of more resilient breeds (e.g. switching from merino sheep to Dorper sheep) [A]

• Technology-based enterprise management including:
  - Using knowledge gained from genomics and biotechnology tools, such as gene editing, to select crop varieties and livestock that are more climate resilient
  - Using sensors (i.e. drones, soil monitoring probes) to measure and only provide water and nutrients (i.e. cattle licks) when and where they are needed
  - Investigating traditional food production systems in Australia to adopt new crops and grasses that may be better climate-adapted.

Impacts addressed

• Reduced carrying capacity of land
• Reduced water availability

Relevant agricultural enterprise

Relevant agricultural enterprise

• Cattle grazing
• Sheep grazing
• Livestock agistment
• Viticulture

Legend: *[*] priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

7.3.1.3 Water management

"Our farm had to use troughs and pumps to move water from dry paddocks to useable ones"

"We need to exploit on-farm water sources"

Category: Water management

Context

Soil and water conservation methods and new systems become even more important as climates fluctuate and more extreme events become more frequent. [D] Water management strategies can be achieved by identifying less water intensive production options, developing better water delivery technologies, and by implementing water markets and water-sharing arrangements (currently under investigation).

Optimal dam design and maintenance can reduce water loss through seepage and evaporation. [59] Water tanks can also provide additional water storage for stock watering, irrigation, household needs, and fire sprinklers. Landholders with access to bore water number also reported they had a reliance on bores to supplement water supply in drought [A]. A fit-for-purpose approach to water reuse and water management can result in more efficient water use. [60]

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[58] Cullen, B., Harrison, M., Mayberry, D., Cobon, D., Davison, T., & Eckard, R. (2021). Climate change impacts and adaption strategies for pasture-based industries: Australian perspective. NZGA: Research and Practice Series, 17, 139-148.
[59] Agriculture Victoria. (2020). *Efficient use of farm water.* https://agriculture.vic.gov.au/farm-management/water/farm-water-solutions/efficient-use-of-farm-water

Adaptation actions

Agriculture and farming are highly dependent on water however are becoming increasingly subject to water risks from climate change [D]. Water management examples include:

- Use fit for purpose water sources
  - Flocculating (removing sediment from) dams and on-farm water sources to improve water quality for stock and irrigation [A]
  - Reuse of wastewater [60]
- Exploiting on-farm water sources
  - Covering dams to reduce evaporation [A]
  - Dam enhancement [A] (e.g. deepening dams [C])
  - Restoring the environment around dams to improve water capture [A]
  - Increasing investment in water infrastructure systems (installing water tanks or bores) [A]
  - Moving away from dams toward troughs [C]
  - Acquiring water licenses to use groundwater and alternative water sources [C].
- Improving water use efficiency by creating humid microclimates around crops (and grasses)[61].
- Water conservation strategies for viticulture include opening and closing vine canopies to manage humidity and create a beneficial microclimate for a vine. [B]
- Identifying less water intensive production options, developing better water delivery technologies and implementing water markets and water-sharing arrangements.

Impacts addressed

- Reduced water availability

Relevant agricultural enterprise

- Cattle grazing
- Sheep grazing
- Livestock agistment
- Viticulture

Legend: *[*] priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

7.3.1.4 Stock management

"Our farm practice is not to be overstocked, and only hold young breeding stock in drought conditions, and endeavour to have minimal supplementary feeding." [C]

Category: Stock management

Context

Stock management and land management are inherently interrelated. Good stock management can minimise the impacts of drought on the land and confer resilience.

Adaptation actions

During periods of drought, many farmers are forced to destock to sustain remaining livestock. Strategies to manage stock include:

- Carrying less stock
  - Having clear trigger points to de-stock which are decided on before drought [A]
  - Having early trigger points to de-stock [A]
  - Monitoring pastures to develop feed budgets which project pasture availability to determine when to destock and buy in feed
- Developing drought lot feeding facilities, sacrifice paddocks/stock containment areas to concentrate stock in small areas and feed them fodder to protect most of the farm from damage

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[60] Radcliffe, J., & Page, D. (2020). *Water reuse and recycling in Australia — history, current situation and future perspectives*. https://www.sciencedirect.com/science/article/pii/S2666445320300064
[61] Hatfield, J., & Dold, C. (2019). *Water-Use Efficiency: Advances and Challenges in a Changing Climate.* https://www.frontiersin.org/articles/10.3389/fpls.2019.00103/full

by stock trampling and overgrazing. This can also minimise energy usage by stock who would otherwise be moving around looking for sparse feed.[62] - Construct feed storage facilities such as sheds, silos, and silage pits - Growing and/or buying-in stock feed when fodder prices are lower and storing this feed during good seasons in preparation for droughts - selling feeder animals early (e.g. selling wethers first then ewes) - reducing breeding animal numbers [A, D] - selling the (in some cases entire) herd [A,B,D.] • Rotational grazing: grazing stock in smaller paddocks, at a higher intensity for shorter periods [A, B, C] (refer to Section 7.3.1.1) • During the recovery phase, post drought, agisting sheep (or different grazing animals) when possible to manage a surge in pasture growth and to reduce bushfire risk. [B] • Reducing heat stress and ensuring stock welfare[63] - Ensuring a plentiful water supply - Ensuring shade and shelter – including artificial shade - Avoiding handling and transportation of animals in extreme heat - Adding cooling misting sprays for livestock (under certain conditions) [D]. • Use of stock containment areas or sacrificial paddocks to defer grazing on pastures until they have recovered. This can also minimise energy usage by stock who would otherwise be moving around looking for sparse feed. • Maintain a watching brief on emergent techniques to mitigate agricultural contribution to climate change, for example adjusting feed (such as certain algae/seaweeds) to reduce methane production.
Impacts addressed
• Reduced carrying capacity of land • Heat stress on livestock
Relevant agricultural enterprise
• Cattle grazing • Sheep grazing • Livestock agistment

Legend: *[*] priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

7.3.1.5 Infrastructure

"pest proof fencing, enhancing natural resources and improving storage capabilities"

"build more underground water storage tanks and put in more shade houses."

"funding to move away from dams towards troughs"

Category: Infrastructure
Context
Infrastructure can improve drought preparedness by increasing farmers capacity to store water and feed. This can reduce the need to buy resources during drought when availability is low, and prices are high.
Adaptation actions
Upgrading or adding on-farm infrastructure can include: • Increasing on farm storage for water, fuel, feed, grain, sileage and hay [A, B] - More, and well maintained dams [A]

[62] Agriculture Victoria. (2018). *Stock Containment Areas | Case Study - Lachlan Ralton, Woodstock West.* https://agriculture.vic.gov.au/__data/assets/pdf_file/0003/563556/Case-study-stock-containment-areas-a-flexible-management-tool.pdf
[63] Agriculture Victoria. (2022). *Caring for animals during extreme heat.* https://agriculture.vic.gov.au/livestock-and-animals/livestock-health-and-welfare/caring-for-animals-during-extreme-heat

- Rainwater storage tanks [A] - Improved reticulation of clean stock water [a] - Feed, grain, silage and hay storage sheds and silos [A] - Underground silage storage to protect from fires [B] • Improving fencing infrastructure to reduce paddock sizes to better manage grazing and density. [C].
Impacts addressed
• Reduced water availability • Heat stress on livestock • Bushfire damage
Relevant agricultural enterprise
All

Legend: *[*] priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

7.3.2 Other actions

Other environmental drought adaptation actions identified through stakeholder engagement and the literature review, and covered in more detail below, included:

- Improvements to on-farm monitoring of weather and longer-term climate trends (e.g., installation of weather stations)
- Planning and regulations
- Knowledge sharing and information provision
- Fire management
- Management timing
- Weed and pest management
- Land management tools
- Marketing
- Crop management.

7.3.2.1 Monitoring

Drought monitoring is a critical component for drought early warning systems and a key instrument in timely risk management and drought planning. [64] Advancements in technology, particularly remote sensing, enable landholders to make more informed decisions, which can in turn lead to more targeted management.

Drought adaptation actions relevant to monitoring include:

- Using information from the series of soil moisture probes installed across southeast NSW (including Tidbinbilla Soil Moisture Probe in the ACT) to inform decision making by helping producers assess current seasonal conditions and the likely range in pasture availability and livestock performance during the next 3-4 months. More information can be found at: https://farmingforecaster.com.au/
- Using soil moisture sensors which allow more efficient irrigation where relevant [B]

[64] Tranka, M., & et al. (2018). *Priority questions in multidisciplinary drought research.* https://www.int-res.com/articles/cr_oa/c075p241.pdf

- Assessing pastures using satellite imagery and observations to calculate total standing dry matter (TSDM)[65]. PastureKey by cibolabs[66] is a satellite assisted forage budgeting tool which using time-series satellite imagery scout maps to optimise field pasture assessments.
- Remote monitoring of voltage levels of electric fences on-farm[65]
- Tools to assist condition assessments of cattle. For example, CattleAssess3D provide assessments of body condition of live cattle in real time to enable producers and feedlots to make informed decisions to optimise carcase performance and profitability[65]

- Keep records of significant climate factors related to temperature (e.g., number of days over 35 degrees Celsius), precipitation (e.g., average precipitation) and combined climate variables (e.g., total soil moisture content). [C]
  - Be aware of and plan for shifts in disease and pest ranges [D]

7.3.2.2 Planning and regulations

Planning and regulations in agriculture aim to provide opportunities to continue to operate, diversify or expand in the future. The agricultural planning and regulatory system in the ACT provide many barriers and enablers for landholders to navigate and adapt to drought (refer to **Section 11**). Examples of planning and regulatory adaptations adopted or suggested by ACT landholders include:

- Obtaining approval to install a bore to access groundwater when surface water is scarce, where possible (this may not be possible in all areas of the ACT, due to sustainable limits on groundwater extraction) [A]
- Developing a regional drought plan to guide agricultural adaptation to drought in the ACT [A]

Planning and regulatory factors which influence landholders' resilience and capacity to adapt are presented in further detail in **Section 11**.

7.3.2.3 Knowledge sharing and information provision

Social networks and knowledge exchange is a key factor in the spread of successful drought adaptation. Studies on successful NSW farmers found they employ a range of strategies in adopting innovative management practices. These included observing signals from the landscape, independent testing and trialling, use of agronomists, and participation in farmer groups and in farmer-driven research programmes.[67]

CSIRO notes that a contributor to successful adaptation to drought is wide communication and demonstration of the benefits of new climate adaptations.[68]

There are numerous successful drought adaptation strategies and decision-making tools available. However, some ACT farmers are seeking understanding around climate predictions and adaptations, including:

- More information on climate tools and farm decision support tools (for example grazing, and pasture management)
- Evidence-based fire management, including the exploration of Indigenous Australian fire strategies such as cool mosaic burning. These strategies have had promising outcomes for fire management in other areas of Australia, and it is broadly considered that the application of these practices is likely to be beneficial.[69] Fire management considerations are discussed further in **Section 7.3.2.4**.

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[65] Crowley, M. (2021). *Four tools to tap into on-farm resilience | Meat & Livestock Australia*. https://www.mla.com.au/news-and-events/industry-news/four-tools-to-tap-into-onfarm-resilience/
[66] Cibolabs, 2022, PastureKey, https://www.cibolabs.com.au/pasturekey
[67] McKenzie, F. (2013). *Farmer-driven Innovation in New South Wales, Australia.* https://www.tandfonline.com/doi/abs/10.1080/00049182.2013.765349
[68] Stokes, C., & Howden, M. (2011). *Adapting agriculture to climate change.* https://www.publish.csiro.au/ebook/chapter/CSIRO_CC_Chapter%207
[69] Fletcher, M. (2021). *Catastrophic Bushfires, Indigenous Fire Knowledge and Reframing Science in Southeast Australia.* https://www.mdpi.com/2571-6255/4/3/61

7.3.2.4 Fire management

Rural landholders in the ACT, like urban residents, have a duty to take reasonable care to prevent the spread of a fire from their property. Most rural landholders have a high level of awareness of the risks of ignition associated with machinery, equipment, and infrastructure, particularly during elevated fire danger conditions. Managing fire fuel load is a key component of bushfire management. [70]

Rural landholders are required to have a Bushfire Operational Plan (BOP) through the Farm FireWise program. The ACT Emergency Services Agency (ESA) supports rural landholders to prepare their Farm FireWise plans, which must be reviewed every five years and approved by the ESA Commissioner. The requirement to identify reasonable measures for managing bushfire risk and any fire management requirement is also established under Land Management Agreements (LMAs).

Drought adaptation actions relevant to fire management include:

- The use of targeted grazing to reduce biomass [70]
- Installing additional water storage tanks and sprinkler systems to protect key farm assets [A]
- Minimising fire risk at a landscape scale [A]
- Use of informal fire truck network among rural landholders. Some landholders have fire trucks and help each other out when needed. [A]

7.3.2.5 Management timing

Adaptations to manage the direct impacts of climate changes on management timing include:

- Changing breeding cycles to adapt to changing climate conditions (e.g., elect not to breed, avoid having lambs in frosts, match calving/lambing to fit with changed seasonal pattern of pasture growth) [B, 58]

These management decisions can be made in response to forecasts and climate indicators to ameliorate the impacts of drought.

Additionally, actions are required to manage the indirect impacts of climate change on management timing. Weed, pest, and disease management must adapt to shifting ranges and times of year (refer to **Section 7.3.2.6**).

7.3.2.6 Weed and pest management

Climate change will impact the timing and distribution of pests, weeds, and diseases. The effectiveness of natural enemies in controlling pests will decrease with pest distributions shifting into regions outside the distribution of their natural enemies. However, new communities of enemies may provide some level of control. [70] The effectiveness of natural enemies is altered through management strategies adopted by farmers to cope with climate change. Management strategies to discourage or encourage natural enemies (e.g. small bird species) of new pest species can impact pest reduction.

Because of the diverse and often indirect effects of climate change on natural enemies, predictions will be difficult. Drought adaptation actions relevant to weed and pest management include:

- Leasing land and agisting animals for weed control to buffer weedy areas [B]
- Continuing to manage weeds and being aware of, and planning for shifts in disease and pest ranges [D]

Common ways that weeds can be introduced are by supplementary feed, through livestock movements (i.e. when returning from agistment or restocking), through contaminated seed during sowing, or contaminated machinery, and though transmission by native and pest animals. [71] Actions that can be taken to mitigate these include:[71]

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[70] ACT Government. (2019). *Strategic bushfire Plan 2019 – 2024*. https://esa.act.gov.au/sites/default/files/2019-09/ESA%20Strategic%20Bushfire%20Management%20Plan2019-2024_ACCESSIBLE.pdf
[71] Tounce, B., & et al. *Weeds and drought*. https://www.lls.nsw.gov.au/__data/assets/pdf_file/0008/803294/A3-weeds-and-drought-factsheetfinal.pdf

- Restricting areas where grain and fodder are to be fed, and carefully monitoring these areas, particularly after rains, for up to two years after a drought.
- Restricting/excluding livestock movement within catchment areas of farm dams, as manure and weed seeds can contaminate water storage systems.
- Monitor riparian areas and water points, as these are often accessed by native and feral animals which can vector seeds and pests
- Control weeds quickly after germination, and well before they set seed.

In addition to reducing stocking rates, actions to manage the increased risk of infectious diseases to drought-affected stock can include:

- Ensure ready access to sufficient supplies of suitable water. [72]
- Check stock regularly to minimise stock injuries and death. [72]
- Carefully consider using commercial lick blocks – these can be a costly form of supplementation and can be toxic to hungry stock if they contain grain or urea. [72]
- Segregate animals based on size and strength to minimise competition for supplements [73]
- Minimise handling, and the distances stock need to walk for food and water to limit the loss of body condition. [72]
- Get advice and be careful when feeding novel feedstuffs. Chemical residues may be present which may cause poisoning or contaminate meat. [72]
- Make dietary changes slowly. Feedstuffs such as fruit, bread, urea mixes, fat, milk products and grain can cause illness in stock if fed too much too quickly. [72]
- Never release hungry stock onto green pasture or crops. [72]
- Create stock containment areas (also known as drought lot feeding facilities or sacrifice paddocks) for feeding, watering, and monitoring stock. Containment areas protect paddocks from erosion, minimise walking for stock and can save labour. [72]

7.3.2.7 Land management tools

Online media and web-based tools can be used to drive informed decision-making and the adoption of new practices. Studies into knowledge-sharing around soil management noted that a multidimensional approach to education and outreach is needed that balances familiar models with new online tools and forums, to create an active learning environment that facilitates change.[74] They noted that information provision, especially via online portals, will not necessarily result in knowledge acquisition, nor provide a dynamic learning environment that builds trust in the information and increases social capital to effect change.

There are many land-management tools to provide data and assist rural landholders in decision-making. Tools which were used and recommended by ACT rural landholders included: [A]

- Farming forecaster
- Meat and Livestock Australia (MLA) feed demand calculator
- Weatherzone and BOM apps
- RCS, MAIA and other regenerative farming pasture assessment and management tools

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[72] Agriculture Victoria. (2022). *Animal health in a drought*. https://agriculture.vic.gov.au/livestock-and-animals/livestock-health-and-welfare/animal-health-in-a-drought
[73] Business Queensland. (2022). *Protecting your livestock in drought | Business Queensland*. https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/disaster/drought/during/animal-welfare/protect
[74] Lobry de Bruyn, L., Jenkins, A., & Samson-Liebig, S. (2017). *Lessons learnt: Sharing soil knowledge to improve land management and sustainable soil use.* Soil Science Society of America Journal, 81(3), 427-438.

Social media and web-based tools can start conversations, in many cases. However, these should be followed by the face-to-face conversations, training, field tours, and hands-on demonstrations.[74]

7.3.2.8 Marketing

In Australia, there is increased focus on food experiences and festivals, with State and Territory Governments developing strategies based on food tourism and artisan agriculture. Sustainable tourism experiences or events are increasingly playing an important role in the business models of artisan producers, allowing them to sell directly to consumers and often add value through tourism experiences. [75]

From an economic welfare perspective, mechanisms that directly link consumers and producers are likely to improve consumer knowledge and satisfaction with foods and encourage higher-quality production techniques.[75] However, this can also play a role in fostering drought-resilient food systems.

Drought adaptation actions relevant to marketing include promoting sustainable local food to local consumers. Farmers noted that they are subject to consumer demand for certain breeds or enterprises which often do not match the breeds and enterprises that are most suited to the landscape[A]. As a result, there is a perceived pressure on farmers to conduct agricultural enterprises to fit consumer demand rather than selecting enterprises and breeds which are resilient on the ACT landscape, in the face of a changing climate. Educating consumers and promoting local, drought resilient food can assist farmers in economically benefiting from drought resilience.

7.3.2.9 On-farm biodiversity management

Native vegetation is well adapted to the harsh Australian environment and provides essential ecosystem services such as integrated pest management, healthy soils, and landscapes. Striving towards ecologically healthy and diverse farming systems provides more resilience to climate change and can improve both farm profitability and on-farm biodiversity values.

- Increasing the ground cover and abundance of native perennial grasses and forbs (herbaceous flowering plants that are not a grass, sedge, or rush) using rotational grazing can, allow natural regeneration of shrubs and trees for shelter.[76] Native pasture and species regeneration benefits the soil food web and nutrient cycling process by enhancing the abundance of beneficial fungi and bacteria. These benefits are the result of the increased availability of suitable habitat structure and niches for native fauna and flora species in which they find shelter from competition, protection from predators and increased availability of food and nutrients.
- Enhancing farm dams can lead to improvements in water quality and provide habitat for a wide variety of native wildlife. [77] Enhanced dams can be fenced to manage the impact of stock on the dam and have native vegetation in and around the dam. As a result of stock exclusion and vegetation, the water is cleaner. An enhanced dam may also have other features such as a hardened access point for stock, variable depths, islands, or snags. Enhanced dams can provide better quality drinking water, retain water for longer, support native plants and animals, and provide ecosystem services to the surrounding landscape.
- Kangaroo densities are above pre-European densities in many areas, despite most Australian states (except Tasmania and the ACT) having a commercial harvest of kangaroos, all states and territories allowing licensed shooters to cull kangaroos on their properties to reduce total grazing pressure, and some jurisdictions allowing conservation culls. [78] The Australian Capital Territory (ACT) Government undertakes an annual ‘conservation cull’ of kangaroos within the urban reserves comprising Canberra Nature Park[78]. However, the management of kangaroo grazing pressure in agricultural settings is a contentious matter

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[75] Star, M., Rolfe, J., & Brown, J. (2020). *From farm to fork: Is food tourism a sustainable form of economic development?*. Economic Analysis and Policy, 66, 325-334.
[76] Agriculture Victoria (2021) *Managing for biodiversity*. https://agriculture.vic.gov.au/farm-management/land-and-pasture-management/native-pasture-management/managing-for-biodiversity
[77] Sustainable Farms (2022) *Ways to improve natural assets on a farm: Enhance farm dams* https://www.sustainablefarms.org.au/on-the-farm/farm-dams/
[78] Iain Gordon, et al., (2021), *Herbivore management for biodiversity conservation: A case study of kangaroos in the Australian Capital Territory (ACT*). https://onlinelibrary.wiley.com/doi/full/10.1111/emr.12443

7.4 Economic adaptation actions

7.4.1 Focus actions

During stakeholder engagement, the most frequently mentioned category of economic adaptation actions was *enterprise selection*, followed by *planning and regulations*, and *infrastructure*. Collectively, actions related to these categories comprise over three-quarters of economic adaptation measures identified by ACT landholders.

7.4.1.1 Enterprise selection

"Our farm is considering changing towards an enterprise that relies on less rainfall"

Category: Enterprise selection

Context

Farming enterprises remain exposed to significant climate and price risk.

Drawing on extensive meteorological data collected and analysed by government agencies, and based on on-farm experiences and observation, farmers adjust their longer-term choices of farming enterprise, modifying choice of species/breed produced based on the local climate, stocking rates, fodder storage, tillage methods, and so forth for the purpose of income smoothing.[53] Australian farmers have altered their mix of enterprises, adopted lower-cost methods (i.e. practices with reduced inputs, such as organic agricultural systems), and where possible, purchased or leased additional land to increase farm size in response to drought.[53]

Two key economic ways farmers manage climate and price risk are by keeping debt low and maintaining sources of off-farm income. For many farms, these strategies are vital both to ensure the long-term survival of the farm business and to minimise variation in household income. [40] Diversification of enterprises is known to improve the resilience of food systems and farm enterprises. [53] Economic diversification options can include both agricultural and non-agricultural enterprises. Farmers also use income smoothing strategies such as the farm management deposit scheme offered by the Australian Taxation Office.

Adaptation actions

Enterprise selection should consider physical factors such as land, climate, irrigation water, farm structures and machinery as well as financial and management factors [D]. Examples include:

- Selecting and diversifying toward enterprises which rely on less rainfall [A B, C] These can include agricultural (i.e. varieties of food production and methods of production) and non-agricultural (i.e. farm tourism) based production.

Agricultural-based diversification options:

  - Greenhouse/glasshouse production (utilising wastewater and circular bioeconomy – such as in composting food waste to use the nutrients to grow more food crops)
  - Emerging crops, produce and practices (e.g. saffron, aquaculture, tree crops, mushrooms)
  - Value adding products (e.g. supplying locally sourced meat to consumers)

Other diversification options:

  - Farm tourism and accommodation (e.g. Airbnb) [A]
  - Leasing land for other uses (e.g. solar farms, agistment) [A]
  - Having a sub-brand to buy in fruit and sell wine, in addition to growing own fruit [B]
  - Selling credits and offsets for ecosystem services (through market based and/or government-based mechanisms)

- Enterprise management strategies which use weather and commodity price forecasts which predict when drought conditions or poor output prices are likely. Management can then be adapted to minimise losses, for example to reduce crop area planted and inputs applied (such as fertiliser).[D]

Impacts addressed

- Reduced carrying capacity of land
- Reduced water availability

Relevant agricultural enterprise

All

Legend: * *priority adaptation actions based on frequency of impact being cited by stakeholders and in literature.* [A] *identified through workshops.* [B] *identified through interviews.* [C] *identified by survey.* [D] *literature review.*

7.4.1.2 Planning and regulations

"we need to consider subdividing and selling land"

Category: Planning and regulations
Context
The planning and regulatory context of agriculture in the ACT is unique. The barriers and enablers presented in this context are summarised in **Section 11.**
Adaptation actions
Planning and regulations in agriculture aim to support healthy farm ecosystems and improve productivity and farm income while ensuring the land is fit for future use. Economic adaptations to drought which involve planning and regulations include: • Subdividing and selling land • Varying leases to facilitate succession planning and construct secondary residences for the next generation • Varying leases to allow diversification of enterprises (refer to **Section 7.4.1.1**)
Impacts addressed
• Financial vulnerability • Employment
Relevant agricultural enterprise
All

Legend: * *priority adaptation actions based on frequency of impact being cited by stakeholders and in literature.* [A] *identified through workshops.* [B] *identified through interviews.* [C] *identified by survey.* [D] *literature review.*

7.4.1.3 Infrastructure

"We use grants available to use to upgrade existing infrastructure"

Category: Infrastructure
Context
Infrastructure can improve drought preparedness by increasing farmers' capacity to store water and feed. This can reduce the need to buy resources during drought when availability is low, and prices are high.
Adaptation actions
Management of on-farm infrastructure can include: • Use of contractors instead of buying machinery to minimise machinery costs and get high-quality machinery that is well-suited to tasks [B] This can reduce debt and ameliorate the economic stress of drought. However, such strategies should be assessed on an individual farm level. • Using financial assistance (loans and grants) to upgrade existing infrastructure [A]
Impacts addressed
• Reduced water availability • Heat stress on livestock • Bushfire damage
Relevant agricultural enterprise
All

***Legend:* * *priority adaptation actions based on frequency of impact being cited by stakeholders and in literature.* [A] *identified through workshops.* [B] *identified through interviews.* [C] *identified by survey.* [D] *literature review.*

7.4.2 Other actions

7.4.2.1 Sale of stock

Drought adaptation actions relevant to the sale of stock include selling stock direct and avoiding feedlots and saleyards [B]. When destocking going into a drought, weaners can be sold to feedlots. Adaptation actions around destocking to manage drought are explored further in Section 7.3.1.4

7.4.2.2 Use of government financial support

Box 3 describes the availability and adoption of government support by farmers in the ACT

Box 3 Case study: government support for ACT farms

The ACT Government provided ACT Rural Resilience Grants during 2018-2019, 2019-2020 and 2020-2021 and administered a range of rebates for farmers to support landholders build resilience to drought conditions[79]. Conversations with farmers on their experience on receiving this government support during this time provided positive feedback regarding this approach and participants shared that they felt more inclined to act on building farm resilience.

Initiatives that were highlighted by farms to be successful included[79]:

- **Transport subsidy** where farmers bought fodder and/or water to a property, stock to/from agistment, stock to sale or slaughter, chemicals, fertiliser, and seed to farms and government covered up to 50% of the total freight cost.
- **National On-Farm Emergency Water Infrastructure Rebate** where a 25% rebate was offered for the costs associated with the purchase and installation of on-farm stock water infrastructure and infrastructure for permanent horticultural crops (grapes, olives, orchards) to improve farm resilience to drought.
- **Rural Resilience Grants** have been provided for 2018-2019, 2019-2020 and 2020-2021 to support landholders to build farm resilience. During conversations with landholders, it was noted that these grants were used to build drought lots, install siloes, construct fodder storage sheds and install a range of farm stock water infrastructure, as well as undertake post-drought weed and pest animal control
- **The Future Drought Fund Farm Business Resilience program** which is offering training to farmers in financial management and natural resource management in preparation for drought. Under the pilot year of the program, 10 ACT farmers undertook Meat and Livestock Australia's Business Edge Training; 14 landholders have been part-sponsored to attend a range of different natural resource management training courses; 4 farm families are receiving farm business coaching; and ACT NRM has offered 3 farm business webinars.
- **ACT Environment Grants** are offered every year and provide farmers with the opportunity to seek support to protect environmental assets on their farms.

Other support offered included relief grazing, requirements for fodder purchased from interstate and financial and mental health services.

The Australian Government also provided a variety of assistance measures including[80]:

- **Farm household allowance** to provide assistance to farming families experiencing financial hardship
- **Rural financial counselling service** help farmers find and apply for funds
- **Drought Communities Programme** to support local infrastructure projects, to create new opportunities in drought-affected communities.

[79] ACT Government, ACT Farmers Support Package, https://www.environment.act.gov.au/act-nrm/grants-and-support-packages/act-farmers-support-package#:~:text=The%20%245%20billion%20Future%20Drought,to%2C%20the%20impacts%20of%20drought.
[80] Australian Government Department of Agriculture, Fisheries and Forestry, 2020,Assistance measures, https://www.agriculture.gov.au/agriculture-land/farm-food-drought/drought/assistance

Barriers to receiving government support
Despite federal government support being available, a number of farmers in the ACT were not able to qualify for some of the rebates due to receiving off farm income or due to their agricultural practise not being eligible to apply. Criteria that excluded several farmers from being eligible included: • "You are a sole trader, partnership, trust or private company and trade agricultural products" *(Transport subsidy[81])* • "As owners and operators of the business you earn more than 50% of your gross income from the primary production enterprise under normal seasonal circumstances" (Transport subsidy[81]) • "As owners and operators of the business you do not have gross off-farm assets exceeding $5,000,000" *(Transport subsidy[81])* Overall, the main limitation for eligibility was due to off-farm income. The Australian Government amended the Farm Household Allowance to lift the off-farm income threshold to $100,000 and allow anyone running at a loss to access the offset[82]. Through conversations with farmers it was also noted that there was opportunity to streamline and simplify the grant systems, access, and applications. E.g. it takes two weeks to put together a $5,000 grant.

7.5 Social adaptation actions

7.5.1 Focus actions

During stakeholder engagement, the most frequently mentioned category of social adaptation actions was well-being, and knowledge sharing and information provision. Collectively actions related to these categories comprise over three-quarters of adaptation categories within the social domain identified by ACT landholders.

7.5.1.1 Wellbeing

"[ACT farmers need] a regular get-together to share info and experiences."

Category: Wellbeing
Context
Natural disasters, including drought, have long-term effects on the mental health of affected individuals and communities. [83] Community-led solutions that promote stress reduction, physical protection, and community cohesion can bolster resilience in crisis.[84] Educational programs including mental health-related events (for example mental health first aid training targeted at Aboriginal communities, teachers, general practice staff, youth workers, rural service providers, BBQ breakfasts at mental health service provider locations, activities, and mental health information days for young people to talk about mental health issues in a youth-focused format) and telephone crisis support have been implemented in NSW. This was considered effective in helping communities build capacity and resilience in the face of chronic drought-related hardship.[85]
Adaptation actions
There is evidence that the well-being of many farmers and farming families across Australia has decreased because of drought, fire and most recently floods as well as broader concerns about

[81] ACT Government, Transport Subsidy Application Guideline (Round Two)
[82] Australian Government Department of Agriculture, Fisheries and Forestry, 2022, Farm Household Allowance, Farm Household Allowance - DAFF (agriculture.gov.au)
Black Dog Institute. (2020). *Mental Health Interventions Following Disasters*. Randwick, NSW, Australia: Black Dog Institute.
[84] Humphreys, A., Walker, E., Bratman, G., & Errett, N. (2022). What can we do when the smoke rolls in? An exploratory qualitative analysis of the impacts of rural wildfire smoke on mental health and wellbeing, and opportunities for adaptation. https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-021-12411-2
[85] Hart, C. R., Berry, H. L., & Tonna, A. M. (2011). *Improving the mental health of rural New South Wales communities facing drought and other adversities. The Australian journal of rural health*, 19(5), 231–238. https://doi.org/10.1111/j.1440-1584.2011.01225.x

climate change. However, there are lots of different strategies that can support improved well-being in farming communities, including: • Creation of opportunities (formal and informal) to bring the farming community together to share experiences and knowledge [A]. • Building and supporting more formalised networks such as the ACT Rural Landholders Association and the ACT Grazing Group. • Providing support and training in succession planning and other key farm decision-making processes • Sharing information about a range of new opportunities including carbon farming and alternative markets for biodiversity conservation [A]. • Provision and promotion of mental health support services such as telephone counselling, financial counselling information and other services.
Impacts addressed
• Reduced wellbeing
Relevant agricultural enterprise
All

Legend: *[*] priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

7.5.1.2 Knowledge sharing and information provision

"Having sufficient forecast information is needed to be [a] sustainable farmer in 'good and bad' years. Information, if inaccurate or insufficient, means farming is high risk and can end badly for people and places."

"Mentoring, community support"

Category: Knowledge sharing and information provision
Context
Effective individual farms' responses to climate change require the farmers to have information about the different dimensions of climate change that affect them at the individual farm level, the broader industry level and nationally and internationally. State/Territorygovernments, industry bodies, businesses, science organisations, community-based organisations, the mass media, and social media can all play an important role in connecting key sectors of the community and sharing knowledge[86]. It was noted by ACT landholders that this function is performed to some extent by ACT NRM [A]. Farmers find community groups such as the RLA great ways to actively learn and share. There is a sense that more informal groups/ mentoring programs could exist. Although some landholders identified that this role was fulfilled for them by specific community groups relevant to their enterprise. [A] Complementary support by the government to provide information and facilitate knowledge sharing can include the provision of climate change and weather forecast information, help to evaluate the pros and cons of choices, and provision of a social safety net for those unable to adapt.[87]
Adaptation actions
Knowledge sharing and information provision is a key social component to adaptive, sustainable agricultural systems. Knowledge sharing and information provision actions include: • Ongoing farmer training and capacity building (field days, workshops, farm walks, newsletters, web-based information and more) • Support for different types of farming and farm diversification

[86] Harman, B.P, Cunningham, R., Jacobs B., Measham, T. and Cvitanovic, C. (2015), *Engaging local communities in climate adaptation: a social network perspective from Bega Valley, New South Wales, Australia*, CSIRO, Australia.
[87] Freebairn, J. (2021). *Adaptation to Climate Change by Australian Farmers*. https://www.mdpi.com/2225-1154/9/9/141

• Facilitating communication between farmers to share knowledge and experiences and support improved mental health and well-being. • Developing community leadership and supporting groups to build supportive social networks and resilience (such as the ACT Grazing Group, which provides a forum to share problems solutions and experience) • Farm preparedness can be improved by providing weather and climate projections which inform on-farm management and provide climate information at scales relevant to the decisions being made and combining information on both climate variability and trends in seasonal and medium-term (decadal) forecasts.[88]
Impacts addressed
• Reduced wellbeing
Relevant agricultural enterprise
All

Legend: *[*] priority adaptation actions based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

7.6 Governance adaptation actions

Common themes that came out of the rural landholders' workshop, the one-on-one meetings and the survey include the 'place' of rural land within the ACT as a region; the need to protect rural lands from development; the important role rural land plays in supporting biodiversity and providing a buffer zone for managing bushfire risk; and the need for a clear agriculture policy that articulates these themes and acknowledges the importance of rural land. The role of local agriculture as a source of food and fibre and as a reservoir of habitat connectivity for protection of flora and fauna within the Territory was also queried.

It was noted that the ACT Government's key role is within planning and land use, and that identifying, valuing, and protecting rural land within the ACT has implications for the capacity of rural landholders to prepare for drought and invest in drought preparedness. Considerations raised by rural landholders included:

- Having an appreciation for:
  - Support provided by the government to farming groups in the ACT such as the Rural Lands Association
  - Opportunities to review conditions on rural leases and the types of rural land uses permitted in association with these leases
  - Maintaining strong relationships with key agricultural extension and research organisations and consultants in the region.
- Having a desire for:
  - Greater acknowledgement of the social, economic, and environmental benefits provided to the ACT associated with current rural land use
  - Stronger alignment with NSW drought measures (incl. drought declarations, financial assistance) to aid planning
  - Investigation of opportunities to increase investment in resilience measures like NSW Government's Farm Innovation Fund, the Regional Investment Corporation's low interest loans.
  - Opening permits and approvals for certain types of rural land uses and providing support for farmers seeking to transition enterprises
  - Reviewing water and irrigation permits for rural land with consideration which end uses provide the greatest benefits and outcomes

[88] CSIRO, (2011) *Adapting agriculture to climate change* https://www.publish.csiro.au/ebook/chapter/CSIRO_CC_Chapter%207

- Providing support for the establishment of a new farming systems group for graziers in the ACT and border regions, and to continue sharing information

8.0 Case studies

Throughout stakeholder engagement activities farmers shared innovative farming techniques, financial barriers to adaptation, and the multitude of responses that they are making to build resilience to drought. The following section presents three case studies including:

- Data to support rotational regenerative agriculture
- Drought preparedness for graziers
- Adaptation in viticulture
- Government support.

8.1 Case study – data to support rotational regenerative agriculture

Callum Brae is a 150ha sheep farm (typically 300 head) in Symington which has seen continuous management by the same farming family for multiple generations. Over this time, droughts have been a recurring challenge and have had a significant impact on pasture and livestock production, leading to reduced income and increased costs for the family. Over the last 40 years, the family have experienced firsthand the challenges that drought can bring.

Sustainability is a key ambition driving their farm management techniques, with a very strong desire to enhance endangered grasslands and woodlands and the many endangered species that are present. Rotational regenerative processes are the centrepiece to achieving these ambitions.

Rotational regenerative agriculture is a holistic approach that takes into account the interconnections between soil, plants, animals, and the environment, and seeks to create a sustainable and regenerative farming system. It focusses on regenerating and enhancing the health of the soil through rotating crops, planting cover crops, minimising the use of synthetic fertilisers and pesticides, and incorporating animal manure and other natural amendments into the soil.

One of the main benefits of rotational regenerative agriculture is that it helps to improve the fertility and structure of the soil over time. By rotating crops and grazing, Callum Brae has been able to add nutrients back into the soil and break up compaction, which can improve water retention and increase the soil's ability to support healthy pasture growth during periods of low rainfall. In addition to improving soil health, rotational regenerative agriculture has also led to other benefits for Callum Brae, including:

- Increasing the efficiency and sustainability of farming operations
- Reducing the need for synthetic inputs, such as fertilizers and pesticides
- Enhancing the health, productivity, and quality of animals raised on the farm
- Providing habitat and food for beneficial insects and other wildlife.

Developing a detailed understanding of the carrying capacity of the land and pastures has been key in implementing and maintaining this approach.

Rotational regenerative agriculture can be supported by collecting data and using software in several ways. Here are a few examples:

- **Tracking and analysing pasture performance:** By collecting data on the performance of different pastures/grasses, the farm has been successful in identifying which ones are most successful for their particular soil and climatic condition to make informed decisions about which crops to plant in the future. This has helped to optimise pasture yields and improve the efficiency of the farm.
- **Monitoring soil health:** By collecting data on soil health indicators such as pH, nutrient levels, and moisture content, farmers can get a better understanding of the health of their soil and

identify any areas that may need improvement. This can help to optimise the use of natural amendments and reduce the need for synthetic inputs.

- **Analysing weather patterns and forecasting:** By collecting data on weather patterns and using software to forecast future conditions, farmers can make more informed decisions about when to plant and harvest crops, and how to allocate resources. For example, if a forecast indicates that a drought is likely, farmers may choose to encourage plant drought-resistant pasture species or implement water storage systems to prepare for the dry conditions.
- **Managing and optimising irrigation systems:** By collecting data on soil moisture levels and weather patterns, farmers can use software to optimise their irrigation systems and reduce water waste. This can help to conserve water resources and improve the efficiency of the farm.

There is a growing availability of climate-related data Callum Brae has been reviewing and using, adopting software to inform their decision-making to support these efforts. Below is a collection of tools cited as useful in their strategic planning and monitoring of conditions for better drought preparation and management outcomes. Examples are outlined in the table below.

Purpose	Tool
Drought resilience planning	• Department of Agriculture, Fisheries and Forestry's DR.SAT
Monitoring climate conditions	• Davis' Weatherlink community-driven weather station monitoring and reporting • The Commonwealth Government's CliMate tool which collates historical climate analyses relating to water variables • Department of Agriculture, Fisheries and Forestry's Climate Services for Agriculture to review climate projections and historical data • Use of Climate Atlas developed for the viticulture industry
Bushfire monitoring	• Bushfire.io and Fires Near Me to set alerts for fires within designated perimeters, data on weather and fire activity
Soil moisture monitoring	• SoilWater models plant available water using the app and farmers' own rainfall data • Farming Forecaster also models plant available water analysed from multiple grassland sites in nearby regions from soil probes • APSoil/Soil Mapp provides analysis of soil water content and other items for designated soil type, provides base data
Pasture monitoring	• Farm Carbon Calculator; FarmGas; Cool Farm Tool – detailed emission data, validation for enteric fermentation output • Sequestration tools including FullCam; LOOC-C (calculate sequestration potential) • Farming Forecaster to calculate projected green herbage, daily growth rates, ground cover, condition scores • OneSoil; Data Farming; Biomass MDA for pasture monitoring, reviewing Normalized Difference Vegetation Index • CSIRO's SoilMapp and NSW Department of Primary Industry's eSpade for soil profile data • DataFarming to identify vegetation index across properties • CSIRO's AusFarm, GrazFeed, and GrassGro • NSW Department of Primary Industry's Drought and Supplementary Feed Calculator to help develop rations in dry periods as well periods leading into and out of drought • Meat and Livestock Australia's Feed Demand Calculator to understand feed requirements over a 12-month period
On farm data collection and database recording	• Soil compaction measurements using a cone penetrometer (Agreto), recording pressure at 10cm intervals and relationship to bulk data • Soil health testing – assisted using Rapid Assessment of Soil Health (RASH) tool to develop a database aiding analysis • Documenting all native and exotic species on-farm to monitor for changes to biodiversity, species dominance, etc over time.

8.2 Case study – drought preparedness for graziers

Introduction
Drought and climate change are significant challenges facing many farmers in Australia, particularly in arid and semi-arid regions. These challenges can have a significant impact on livestock production, leading to reduced income and increased costs for farmers. This case study explores how one sheep and beef farmer in the ACT is adapting his farm to the impacts of drought and climate change.

Background
Michael has held his property for 33 years and has seen firsthand the impacts that drought and climate change can have on his operations. In the past, he has struggled to keep his livestock healthy and well-fed during dry periods, leading to reduced income and increased costs for supplementary feeding. Typically during good climatic conditions, the farm will have up to 25,000 sheep and 1,000 cattle; whereas during drought periods this has dropped to 7,000 sheep and 150 cattle.
For his farm, the drought of 2017 to 2020 was the longest that's been experienced, and the most difficult to manage in terms of water availability despite applying learnings from previous drought events (notably 2006). There is a history of improvement still, with the millennium drought seeing better outcomes following further lessons learned during the 1982 drought event.

Current solutions
To address these challenges, Michael has continued to implement strategies on his farm to adapt to the impacts of drought and climate change. Strategies that Michael has implemented include:
- The use of native grasses (which typically perform the best in average conditions), using fertilisers to manage the composition across species, manipulating native grasses to achieve desired outcomes at the time. However, there has been a need to introduce different, non-native drought tolerant species during droughts which are more resilient to dry conditions.
- Implementation of rotational grazing practices, which involve moving cattle to different paddocks regularly to allow the grasses to regenerate and improve the health of the soil.
- Reviewing 3-month outlooks from BOM – particularly ENSO indicators. This enables medium-term planning of stock numbers, whereby stock are sold down ahead of drought conditions which reduces future feed costs and provides capital to aid operations.
- Adoption of government support through freight subsidies when importing feed, water rebates to improve on-farm water infrastructure, and grants to help build drought lots.
- In addition to improving his pasture management practices, Michael has also implemented an irrigation system that uses weather data and soil moisture sensors to optimise water use and minimise waste. The system has helped him to better manage his water resources and ensure that his cattle have access to enough water to stay healthy and hydrated during dry periods.
- The scale of Michael's farming activities still means that during drought all feed is purchased for sheep. Cattle, however, are generally able to be spread across paddocks and remain pasture-fed.

Future actions
In the coming years, Michael intends to further invest in improving the farm's drought resilience. High priority actions include:
- Improving water infrastructure: investigating the installation of a water bore, and if unavailable will build a new dam, to improve water security.
- Planting shelter belts of trees and increasing paddock trees to increase shading for stock and reduce erosion/impacts of wind.
- Improving feed storage: looking at underground storage of silage and building grain storage facilities.
- Improving capital stores: saving more cash in the bank would aid farm operations during drought and improve opportunities to invest in rebuilding stock levels following drought.

- Investigating management tools: for example, Michael is seeking cost/benefit analysis tools to understand what the cost of 100% destocking and restocking is, compared to reducing stock numbers and purchasing feed.

Conclusion
Drought and climate change are significant challenges facing many farmers, but with the right strategies and technologies, it is possible to adapt and mitigate their impacts. Key outcomes include:

- The broader implications of Michael's strategies: The strategies that Michael has implemented on his farm not only benefit his operation but also have broader implications for the environment and the community. For example, the use of drought-tolerant grasses and rotational grazing practices can help to improve the health of the soil and reduce erosion, which can benefit the local ecosystem and water quality.
- The importance of adapting to drought and climate change: The challenges of drought and climate change are likely to become more severe in the future, making it increasingly important for farmers to adapt and find ways to mitigate their impacts. Michael's farm serves as a model for other farmers looking to adapt to these challenges and find ways to build resilience and sustainability into their operations.
- The role of technology and innovation: Technology and innovation can play a critical role in helping farmers to adapt to drought and climate change. The improvements in data interrogation and the adoption of further financial modelling software help farmers to be more efficient and sustainable in their practices.

8.3 Case study – adaptation in viticulture

The ACT is home to a small but vibrant viticulture community, with several wineries and vineyards located in the region. They are typically small to medium-sized operations, with many being family-owned and operated. The ACT has a long history of viticulture, with the first grapevines planted in the region in the late 19th century. Today, the region is known for producing high-quality wines, particularly cool-climate varieties such as Pinot Noir, Chardonnay, Riesling, and Pinot Gris.

The ACT's viticulture industry is supported by a number of organisations, including the Canberra District Wine Industry Association, which represents the interests of winemakers and grape growers in the region. The association works to promote the region's wines and support the development of the industry. The industry is also supported by several research and education organisations, including the Australian National University's Research School of Biology and the University of Canberra's School of Science, Health and Engineering. These institutions research topics such as grape and wine production, viticulture practices, and the impacts of climate change on the industry.

In addition to its wineries and vineyards, the ACT is also home to some winery restaurants and tasting rooms, which provide visitors with an opportunity to sample the region's wines and learn about the local viticulture industry.

Mount Majura Vineyard
Mount Majura Vineyard is at the top of the Majura Valley, just outside the city of Canberra. All wines are sourced from the single vineyard site, which also features a restaurant, cellar door, and vineyard tours. Water has been noted as the single most important resource for the vineyard, and concerns about the impacts of climate change are driving many changes on the property. The vineyard's water supply consists of a water bore licence which is used to its full capacity, an on-farm dam approx. two to three megalitres in size, and town water connection for domestic supply.

Impacts of climate change
The vineyard and winery are already experiencing several impacts associated with climate change:

- Vintage advancement describes the shift in the timing of grape harvests as a result of climate change. In many regions, grape harvests are occurring earlier than they did in the past due to warmer temperatures and changing weather patterns. For example, Mount Majura Vineyard has observed that on average, chardonnay grapes advance 1.5 days each year. That is, in the

30 years since the inception of the vineyard, Chardonnay now ripens 45 days earlier than it once did.

- Similarly, vintage compression is the term used to describe the shortening of the grape-growing season due to warmer temperatures. Mount Majura Vineyard has also experienced this compression, where some varieties that used to take six to eight weeks, now only take four weeks.
- This has had several implications for the organisation, including:
  - Changes in grape quality: Shorter growing seasons can lead to grapes that are less ripe and have a different balance of flavours compared to grapes grown in a longer season. This can affect the quality and flavour of the final wine.
  - Changes in the timing of winemaking: The shorter growing season can also affect the timing of winemaking and has required Mount Majura Vineyard to adjust their schedules to accommodate the earlier or later arrival of grapes. This can be particularly challenging for the winery which doesn't have the capacity to process the grapes within shorter or overlapping timeframes. This has flow on impacts to the availability of staff who work across multiple vineyards in the region – "*we have contract pickers and it's already tough to get staff*"
  - Changes in the economic viability of certain grape varieties: Some grape varieties may become less economically viable because of vintage advancement/compression, as they may not be well-suited to the changing growing season. This can lead to a shift in the types of grapes that are planted in a region and adds additional challenges around the marketing of new grape varieties – *"there is conservatism in the market. A new grape variety is hard to sell if people don't recognise it"*
- Scale insects are a type of pest that can be a problem for vineyards, as they feed on the sap of grapevines and can damage the plants. Mount Majura is concerned that climate change is likely to exacerbate the problem of scale insects in vineyards, with studies showing they become more resistant under warmer conditions. Climate change can also lead to changes in the prevalence of other pests and diseases, which can affect the overall health of grapevines and make them more susceptible to scale insects. For example, if Mount Majura Vineyard is dealing with a disease outbreak, the vines may be weaker and more prone to damage from scale insects. Similarly, there are fears that vintage advancement may also affect the prevalence of scale insects. For example, if grapes are harvested earlier than usual, the vines may be more vulnerable to scale insects as they may not have reached their full maturity. Pierces Disease is of similar concern, among others.
- Bushfire smoke has been a serious problem, as it can affect the quality and flavour of grapes and wine. In 2020 Mount Majura Vineyard lost the entire crop as a result of bushfire smoke damage. While this instance was manageable as a once-off event, consecutive events would be catastrophic for the business.

Adaptation activities

Mount Majura Vineyard is taking a variety of actions to adapt to climate change. Some of these actions include:

- Changing grape varieties to counter winery and staff capacity concerns associated with vintage advancement/compression: replacing Pinot that is picked in March with a new variety that is instead picked in February.
- Planting grape varieties that are more resistant to extreme weather conditions: Some grape varieties are more resistant to heat and drought than others, so Mount Majura are investigating alternative varieties.
- Modernising irrigation systems: installation of temperature and soil moisture sensors to automatically activate water pumps under certain conditions to optimise irrigation and maximise water efficiency.
- Implementing cover cropping: for Mount Majura, cover cropping means allowing grass to grow between rows of grapevines to help improve soil health and reduce erosion – although this does require additional maintenance to ensure this doesn't interfere with grape growing it's been beneficial in the long term.
- Using weather forecasting and monitoring systems: Using wine-making specific resources such as Wine Australia's Climate Atlas, as well as near and medium-term forecasting and monitoring systems to better understand and predict the impacts of climate change on their crops, and to

make more informed decisions about irrigation, pest management, and other aspects of vineyard management.

- Data collection and analysis: there has been a strong culture of keeping weather records on the property to understand longer-term trends. Key indicators include growing degree days; winter rainfall; Brandis Index.
- Collaborating with researchers and industry groups: working with researchers and industry groups to develop and test new approaches to adapting to climate change.
- Managing wine inventories: to cater for years that see significant drop loss (e.g. following 2020 bushfires), there is a concerted effort to build up stock inventories during good years – “*we want to have a year’s worth of stock in the cellar to get us through”.*
- Diversifying land use: a portion of land is leased to a solar PV farm, helping create climate-independent income streams for the business from what was previously unused land unsuitable for grape growing.

9.0 Discussion

9.1 Key findings

Drought will continue to be a challenge for rural landholders and farmers in the ACT. Investment in adaptation measures to build resilience to drought will be essential to preserve rural land and farming activities within the ACT. Based on the observed climate, future drought scenarios, stakeholder engagement, review of climate change impacts and identifying adaptation actions, the following findings regarding resilience to drought in ACT have been developed.

- **Diversity of agricultural enterprises within the ACT.** While sheep and cattle farming represents a large proportion of ACT’s agricultural enterprises, there is a long ‘tail’ of diverse agricultural products produced at a smaller scale.
    - Many federal government programs which focus on improving drought resilience are targeted at either larger-scale operations, generally larger than those of the ACT farming community; or industries that have only a small representation in the ACT such as cropping and horticulture.
    - Farming practices across the ACT generally require less water (i.e., few enterprises exist that require irrigation). Cropping, for example, which is subject to relatively higher drought risk due to the high need for irrigation is not prevalent in the ACT. This has likely shielded ACT farmers from some of the more severe financial impacts seen in other regions, as well as the tendency for farm profits to become more sensitive to drought impacts over the years. At the same time maintaining stock water, stock feed and animal health during drought has incurred considerable expenditure.
    - Other enterprises, such as vineyards, need longer lead times to adapt due to the high costs in switching grape varieties and the lengthy transition times from plant/grafting new varieties and harvesting grapes from the new varieties. For example, growing and marketing new grape varieties (that may perform better under different future climate conditions) takes more time and financial investment. These expenses are also incurred by grazing enterprises that shift cattle or sheep breeds and can take years for a transition to fully occur.
- **Lack of government progress in planning for droughts.** Stakeholder feedback indicated that participants felt that the policy context to support planning for, managing, and recovering from droughts is limited with limited representation for the farming community within the ACT Government.
- **There is broader exposure to multiple climate hazards.** Whilst this report focusses on the impacts of drought, the ACT’s exposure to bushfire risk was highlighted throughout stakeholder engagement (e.g., refer to Section 6.2 for the impact of drought on bushfires). There may be a need to do additional work to support farmer preparedness for bushfires in the future, given the growing frequency and intensity of bushfires in the ACT.

- **Adoption of farm management software and the availability of farm-relevant data is increasing.**
  - Farm sizes are typically small and as such have smaller revenues and expenditure budgets. As such, small farms are less likely to have digestible climate data available to them (e.g., destocking triggers), nor access to farm management software which is generally considered cost prohibitive. However, investment by the ACT Government and others in new data provision (e.g., soil moisture probes) and training (e.g., ACT Government's sponsoring of farmers to receive interstate training) is increasing farmers' engagement with new data sources.
  - Studies of national scope reviewed in the context of this report often entirely omit discussion of ACT as a farming region[89]
  - The lack of accurate production and consumption data is a significant impediment to the development of sustainable food production strategies by the government and the private sector to assess diversification options that generate increased availability of locally sourced food in the ACT. The ACT Food and Fibre Strategy is a good initiative that may help answer some of these questions.
  - Existing and emerging free tools such as Farming Forecaster appear to have good uptake, demonstrating an appetite for receiving and utilising more information to assist planning.
- **Strong ability to adapt to climate change**. Rural landholders in the ACT are generally well positioned to prepare for future drought, reasons that support this include:
  - It was identified that some rural landholders expressed that they felt confident that they would be able to introduce adaptation measures sufficient to manage the scale of changes expected. Adaptation measures such as changing stocking rates, changing breeds or species selection and diversification of farm income were identified as key measures to support adaptation and drought preparation.
  - Despite this confidence, climate change projections and scenarios indicate that future drought conditions will increase in severity and frequency which may overwhelm the levels of drought preparedness able to be achieved by individual farmers. A key factor identified by stakeholders that mitigated the impacts of the 2017 – 2020 drought was beef and lamb prices and demand remaining high. In times of future drought, global and local political, economic, and social trends may not provide the same protections.
- **Access to alternative water supplies.** Landholders have cited reliance on a range of sources including farm collection (e.g., tanks and dams), extraction of surface water, extraction of groundwater, and use of mains water.
  - The relatively short distance between rural properties and urban areas means many farms have access to mains-supplied water. While there is a higher cost associated with its use, it has meant these farmers have had security to water their core stock in times of drought.
  - Several landowners interviewed have invested in bore water extraction infrastructure; however, this is not an option for all properties. Key barriers to their use include high administration fees for bores that are not in use, difficulty in getting approved where catchment allocations have been exhausted, or unsuitable geology. Existing bore water users noted that there are inefficiencies in the way water allocations are distributed, with those establishing a bore first receiving first rights to water. Where users do not use their full allocation, it means other users within the catchment lose out.
  - The current use of wastewater recycling for agricultural production and other purposes in the ACT is minimal (if at all), though some farms benefit from releases by the Lower Molonglo Water Quality Control Centre.
- **A high proportion of farming families receive off-farm income.** This is considered to greatly reduce the financial vulnerability of many farming enterprises as the financial pressures of drought

[89] https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1030903/0

are reduced. However, this can also affect their eligibility for grants or subsidies which have expectations that recipients derive a higher level of total income from the agricultural enterprise.

- **Crown leasing arrangements introduce multiple challenges to adaptation.**
  - Each rural lease has a land management agreement in place specifying the type and number of stock to be held. This presents challenges to landowners looking to adaptively manage their stock based on conditions at the time or move towards different enterprises entirely.
  - Restrictions on the ability of landholders to construct a secondary dwelling presents challenges to farm succession planning. Many landholders noted that to support their next generation of farmers, enabling them to live on-farm before takeover is a key step.
  - The current duration of tenure for agricultural leaseholders in the ACT ranges from 99 years 3 months, and in some cases, some landholders have no active lease. For some landholders with expired leases, tenure is a monthly or weekly consideration. In addition, most lease agreements contain withdrawal clauses allowing government to terminate short-term leases albeit with a requirement to recognise the value of some improvements. Landholders on short-term arrangements are discouraged to make any substantial investment towards long-term adaptation for their properties. The lack of extended tenure for some leaseholders also significantly impacts their capacity to access finance for farm operations and diversification with banks reluctant to make loans for improvements that may not realise a return if leases are withdrawn or not renewed.
  - The duration of leases is intended to reflect future strategic land uses and planning intentions with an emphasis on maintaining flexibility for urban development. A lack of clarity in planning strategy is a particular disincentive on diversification options involving horticulture and other permanent plantings where large initial capital expenses are only recouped over an extended period as trees mature and production increases.
- **A lack of local agricultural infrastructure and skills.**
  - The small agricultural market means there is limited access to key supporting infrastructure such as abattoirs and veterinary services. This raises costs associated with transport, raises food miles, and contributes to the financial viability concerns of smaller farms.
  - Access to skilled agriculture labour is likely to be more constrained, with the small size of the ACT farming sector unlikely to attract career agricultural managers in the long term. Casual labour is particularly important in the context of diversification where out-sourcing of relatively unskilled activities allows landholders to devote more time and focus on diversification efforts.
- **Government engagement with adaptation activities in the ACT has the potential to deliver effective action, compared to other jurisdictions in Australia.** With its single level of government structure, relatively small geographical area and small rural population, opportunities to invoke transformational change are numerous.
  - Single-level government means decision-making is simplified and the community has direct access to key decision-makers.
  - The government has the opportunity to gather good on-ground information given the small size of the community.
- **Other triggers for reviewing farm practices may also enable the consideration of climate change planning** e.g., review of farm practices or other reasons such as the potential to work towards biodiversity credits.
- The ACT Government's **management of pests and weeds on crown lands is important in alleviating their spread into agricultural land**, easing the pressure of invasive species on farm boundaries. Continued investment in providing guidance to landholders around drought recovery actions such as managing fodder, weeds etc. is appreciated.
- **A high proportion of farms receive off-farm income.** This typically implies that these landholders are more financially resilient compared to others that are entirely reliant on their farm outputs.

- A 2020 survey by ACT NRM indicates that almost 80% of landholders surveyed (approximately 48 responses) derived at least 50% of their income from activities not related to their rural holdings. These properties most likely have a higher degree of economic security and consequently have an increased capacity to trial and adopt new systems, technologies, and other diversification opportunities.
- Growers with part-time or full-time employment off-farm may therefore find it difficult to allocate sufficient time-resources to maximise the probability of successful diversification. A balance of capital generation and time commitment is needed.
- Household income amongst the broader ACT community is high in comparison to the Australian average – for example, in 2021, 38.3% of households in the ACT had an income of more than $3,000 per week[90] (the Australian average was 24.3% of households). There is a sense among stakeholders that ACT residents have a higher propensity to support the purchase of premium sustainable products such as that grown in the ACT region.

- **Improvements to farm management practices that are not specifically associated with drought are ongoing**. Technology already being adopted such as minimal tillage principles, water infrastructure improvements, and investment in more advanced machinery and equipment lead to multiple improved farm outcomes, but also tend to improve the ability of farms to manage droughts when they do occur

9.2 Recommendations

Recommendations across five themes are provided in Table 11. These themes include:

- Enhance water security
- Data provision and engagement
- Land use planning
- Supporting education
- Collaboration and awareness

Table 11 Recommendations

Action	Outcome	Action owner
Enhance water security		
Identify opportunities to review farmers' access to alternative water sources to improve water security • Investigate Inefficient allocation of water allocations • Review water licence allocation mechanisms to enable better sharing of water within catchments. For example, there may be opportunities to allow existing water license holders that do not efficiently use their existing allocation to trade water with others in need elsewhere in their catchment. - Review water licencing arrangements to acknowledge higher value end uses. For example, water licences could be prioritised for enterprises in line with the Capital Food and Fibre Strategy. • Investigate opportunities and understand barriers to greater adoption of wastewater reuse e.g. Lower Molonglo Water Quality Control Centre effluent reuse scheme which	• Provision of sufficient affordable water for agriculture in the ACT's water allowance (within bounds of MDB Agreement) to be able to grow food • Improvements to water security for the agriculture community	• ACT Government • Icon Water

[90] https://www.abs.gov.au/census/find-census-data/quickstats/2021/8

Action	Outcome	Action owner
supplies water to the nearby golf course, and previously supplied to local vineyards		
Data provision and engagement		
Stakeholder engagement indicated that very few farmers had engaged previously with future projections of climate change. In addition, few saw that transformative changes in their practices were needed (e.g. shifting to produce different agricultural products). To improve the engagement landholders have with climate projections, there is a need to improve scales relevant to drought planning. It was identified that the use of long-term climate projections is not strongly resonating with landowners therefore there is opportunity for improving drought monitoring and early warning systems.	• Improved landholder engagement with projections of climate to enhance planning and demonstrate what sufficient preparedness looks like. • Continued investment in making climate data accessible and available	• Providers of climate projection data such as the NARCliM project team, the CSIRO/Bureau of Meteorology, and others
Engage with projects of national scope to ensure ACT is well represented within data sets and reporting outputs. E.g. enhanced inclusion of ACT's farming community within ABARES data (noting privacy concerns), ACT's inclusion within Droughthub[91] mapping and advice.	• Improved representation of ACT data within national data sets, enabling comparison with other regions	• ACT Government to engage with data providers
Recognising that droughts and bushfires are driven by many of the same changes in climate variables, it is recommended that the relationship between drought and bushfire risk is acknowledged in the RDRP, specifically the cascading impacts of drought and bushfire on rural landholders in the ACT and the wider community.	• Improved resilience to wider climate-related shocks and stresses	• All ACT Government agencies
Land use planning		
In the long term, climate futures may increase pressure for more transformative change for certain farms. This could include the emergence of new land use activities such as carbon abatement, biodiversity conservation, or renewable energy generation as complements to traditional farming. Defining ACT Government's ambitions and developing policies in programs in such spaces would aid existing landholders to plan long-term farm improvement measures.	• Improve farmers' abilities to undertake long-term planning and investment	• ACT Government
Review land use zone development controls in the Territory to seek the protection of areas of important landscape setting, or nature conservation corridors	• Improving	• ACT Government
Review change of use charges to NUZ1 and NUZ2 (rural and broadacre) zoned land where the main activity is to produce food or fibre i.e. allow ancillary uses without lease purpose change process and	• Enable farmers to adaptively manage their land and enterprises	• ACT Government

[91] https://www.droughthub.nsw.gov.au/

Action	Outcome	Action owner
costs (provided there is adequate consultation and investigation of impacts of the changes)		
Remove current lease and land use restrictions to enable flexibility in farming enterprise selection (e.g. switching from sheep to goats) and timing (e.g. removing minimum stock requirements during times of drought)	• Enable farmers to adaptively manage their land and enterprises	• ACT Government
Introduce payments where the conservation of important landscape setting or nature corridors restricts agricultural use	• Recognition of farmers' land stewardship	• ACT Government
Review the scope of land management agreements to only capture big picture data that the Territory needs to have info on (e.g. biosecurity, soils, water, landscape-scale wildlife links) and make clear the purpose and use of data	• Land management agreements are an enabler to climate adaptation	• ACT Government
Supporting education		
The support ACT Government has been providing to the agricultural community is well received, and it is recommended that these activities continue. Suggested topics include: • Alternative climate-resilient enterprises that may be viable in the ACT • Farm financial management principles to support drought preparedness • Implementing a farm-scale drought management plan including identification of trigger points for action.	• Improved landholder drought preparedness and engagement with climate change projections.	• ACT Government • Existing farm community forums (e.g. RLA)
Partner with education providers to highlight climate change adaptation and opportunities in agriculture within school curriculums e.g. farm demonstrations/visits	• Increased youth engagement and recognition of ACT's agricultural community	• ACT Government, education providers (e.g. Education Directorate)
Collaboration and awareness		
Encourage the Commonwealth's development of a food security plan to identify and protect farming regions that can continue to produce food under future conditions, including the ACT and its border regions.	• Recognition of ACT as a producing region • Further support and data for ACT's farmers	• Commonwealth Government (i.e. DAFF)
Support communication and marketing of produce that is more drought resilient e.g. helping to shift consumer preference to local products or away from meat breeds not suitable for ACT's climate	• Improve economic viability of switching varieties, species, breeds (increased consumer demand for resilient enterprises)	• ACT Government in partnership with local media; education providers

Appendix A

Climate projections – Scenario selection

Appendix A Climate projections – Scenario selection

Please note that this section is an extension of Section 5.0 in the main body of the report and therefore will include duplications between the text.

Scenario selection

Climate change is a significant challenge face the agriculture sector. Impacts are already being felt, in the form of drought, increasing temperatures, increasing extreme rainfall, and flooding and more frequent extreme weather events. Adaptation within the agricultural sector will play a crucial role in building resilience and mitigating these physical impacts.

Climate scenarios refer to the emissions scenarios which underpin projections of future climate and provide an indication of possible future impacts. Each climate scenario is underpinned by a range of different climate projections. Plausible physical pathways have been developed by industry and scientific groups including the NSW Government and the CSIRO and Bureau of Meteorology (BoM), based on robust scientific data and climate modelling provided by the Intergovernmental Panel on Climate Change (IPCC), to outline projected changes to the climate and anticipated responses across the public and private sector.

The purpose of this chapter is to present the rationale for proposing the climate change scenarios that will be used to assess physical risks for the ACT farming community. The scope of this chapter includes:

- Analysis and recommendation of climate (emissions) scenarios that allow for the identification of physical risks to ACT farming community.
- Analysis and recommendation of multiple time horizons to consider in developing climate scenarios and understanding future projections which are appropriate to the planning, design, and operational lives of the ACT farming community.
- Selection and understanding of the climate variables (hazards) that may result in physical risks to the ACT's agricultural sector.

This report does not cover the identification or assessment of transition risks and opportunities.

Context setting

Natural variations have always played a part in ACT's climate and will continue to do so; but climate change is expected to shift the range and the pattern of this variability.

The Territory is observing gradual changes, such as higher average and extreme temperatures, and more frequent and severe events such as heatwaves and bushfires. Climate change poses significant additional risks to ACT's communities and environment and will require adaptive responses that increase resilience to its impacts.

Droughts will change in frequency and intensity and therefore it is essential that farming communities and government acts now to strengthen resilience. The following section will unpack the complexity of drought hazards across north-east ACT and what future climate projections look like.

Climate scenario selection considerations

Scenario analysis is an important tool for understanding and exploring the strategic implications of climate-related physical risks and opportunities. It provides an understanding of how resilient organisations are to a range of plausible climate-related scenarios, and how sensitive an organisations' assets and operations are to the differences between these scenarios. Scenarios are also a useful mechanism for informing stakeholders about how an organisation is considering physical risks and opportunities, and presenting forward-looking information to partners and other stakeholders.

Box 4 Understanding scenarios

A scenario describes a path of development leading to a particular outcome. Scenarios are not intended to represent a full description of the future, but rather highlight central elements of a possible future to draw attention to the key factors that will drive future developments. Scenarios are hypothetical constructs; they are not forecasts or predictions[92].

Selecting climate scenarios requires careful consideration of:

- **The underlying greenhouse gas emissions scenario** – accelerated action by governments globally to reduce greenhouse gas emissions in the next ten years could mean we reduce the risks associated with future climate change, however conversely, in the absence of action, we may experience worsening climate risks.
- **Data confidence** – there remains significant uncertainty in determining the likely impacts associated with each emission scenario. Data confidence in climate projections can be discussed in terms of model 'mean', where the ensemble of different model runs (or simulations) are averaged to determine a 'likely' projection while the spread of the individual model runs give the range of possible futures. For example, NARCliM 1.0 ran models across twelve simulations, while NARCliM 1.5 provides data across six simulations, each of which presents different results for climate variable projections.
- **The climate hazards likely to affect the organisation and its assets –** a range of climate hazards are likely to affect the ACT Government's assets and operations, and different climate hazards will begin to impact at different times depending on emissions pathways.
- **The year of interest** – for example, there is little difference between maximum temperature projections between 2030 and 2045, whereas there is significant difference approaching 2070 and 2090. As such, the choice of RCP for short term planning horizons has lower importance compared to those adopted for long term planning horizons (i.e. the end of the century).
- **Avoiding 'path dependence'** – where future adaptation outcomes have a dependence on adaptation decisions (such as RCPs and the confidence interval of climate projections) made today. Some decisions create lock-in to a determined future pathway, which may be difficult to undo without significant expense and effort. For example, designing drainage infrastructure using rainfall projections from a lower RCP may mean the need to add additional capacity or replace existing drainage in the future to adapt to higher water volumes if greenhouse gas emissions continue to increase on their current trajectory (i.e. a higher RCP).

Climate projections and data availability

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment report published in 2014, outlines a range of Representative Concentration Pathways (RCPs) designed to be 'representative' of possible future emissions and greenhouse gas (GHG) concentration scenarios to the year 2100. The pathways are based on global research and existing literature and comprise four scenarios: RCP8.5, RCP6.0, RCP4.5 and RCP2.6, each of which comprises a consistent set of projections for radiative forcing (the net balance between energy (sunlight) absorbed by the Earth and energy radiated back into space, measured in watts per square metre (W/m^2)). Each RCP reflects a different concentration of global GHG emissions reached by 2100, based on assumptions of different combinations of possible future economic, technological, demographic, policy, and institutional trajectories[93] -

In 2014, the NSW Government (through the NSW and ACT Regional Climate Modelling (NARCliM 1.0)) released a suite of climate change projections, based on models used to inform the IPCC 4th Assessment Report and downscaled to provide higher resolution data for 12 regions across NSW (including the ACT). These projections used the SRES-A2 emissions scenario, which most closely aligns with the RCP8.5 scenario used in the IPCC 5th Assessment Report and used in subsequent more recent in climate change projections such as those provided by the CSIRO and BoM. The projections do not however provide for sensitivity testing between two different scenarios as the SRES-A2 was the only modelled scenario.

[92] TCFD, 2017, *Technical Supplement - The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities.* Page 10. https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Technical-Supplement-062917.pdf
[93] *Representative Concentration Pathways (RCPs) Fact Sheet*, Australian Government, Department of Environment

In 2021 NARCliM released an improved iteration of simulations (NARCliM 1.5) which better captures the seasonal patterns and magnitudes of precipitation as well as the potential hotter and drier futures that are currently being experienced. NARCliM 1.5 also provides the added benefit of future projections for two scenarios (being RCP4.5 and RCP8.5) to allow for a greater interrogation and understanding of future changes in climate in lines with other modelling datasets.

In 2015 the CSIRO and the Australian BoM released a suite of climate change projections for the entirety of Australia (broken into eight natural resource management regions) through the *Climate Change in Australia Portal*, based on the IPCC RCPs (RCP 2.6, 4.5 and 8.5) as provided through the 5th Assessment Report and downscaled to provide higher resolution data for Australia's natural resource management regions. By providing a range of scenarios, climate projections provided by CSIRO and BoM allow for comparison and sensitivity testing across both multiple emissions pathways and multiple time horizons. CSIRO has developed projection tools including climate analogues that matches the proposed future climate of a region of interest with the current climate experienced in another region using annual average rainfall and maximum temperature[94]. The CSIRO cluster reports also provide key climate change projections across a range of variables including drought.[95]

It is noted that with the release of the IPCCs 6th Assessment Report – Working Group I[96], a set of new illustrative emissions scenarios (called Shared Socioeconomic Pathways) have been considered to explore a range of future scenarios accounting for a broader range of greenhouse gas, land use and air pollution futures. The five Shared Socioeconomic Pathways (SSPs) and respective future annual CO2 emissions are highlighted in Table 12 In addition to the release of the 6th Assessment Report – Working Group 1, an Interactive Atlas has been prepared allowing a spatial and temporal analysis of the climate change information presented in the report at a regional level including Australasia.

[94] CSIRO. (2020). *Climate analogues.* https://www.climatechangeinaustralia.gov.au/en/projections-tools/climate-analogues/
[95] CSIRO. (2015). *Murray Basin Cluster Report.* https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/168/MURRAY_BASIN_CLUSTER_REPORT_1.pdf
[96] IPCC, 2021: *Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis*. Contribution of Working Group Ito the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

Table 12 Comparison of Representative Concentration Pathways for Australia

Scenario	Atmospheric CO2 concentration	Average temperature increase (to 2090) *	Range of temperature increase (to 2090)*	Description of scenario[97]
RCP 2.6 **(Aggressive mitigation)**	421 ppm	1.6ºC	0.9 to 2.3ºC	Assumes strong mitigation efforts, with early participation from all emitters followed by active removal of atmospheric carbon dioxide. It is anticipated that emissions will peak by approximately 2030 and then reduce resulting in zero net emissions by about 2050. This scenario is marked by a considerable change in technologies predicated on the widespread uptake of renewable energy, energy and emissions capture and storage and changes to transport fuels and modes. As a result, it is anticipated that temperature increases can be limited to 1°C by the end of the century (based on a 1985 – 2005 baseline) and while there will be some increase to extreme weather events due to historical climate change, these will result in low level adaptation costs to mitigate risk.
RCP 4.5 **(Strong mitigation)**	538 ppm	2.4ºC	1.7 to 3.2ºC	Assumes a high level of mitigation with no active removal of atmospheric carbon dioxide. Emissions are anticipated to peak around 2070 and then remain consistent until 2100. This scenario assumes full uptake of renewable energy however no carbon capture to help reduce the levels of carbon dioxide. As a result, it is anticipated that temperature increases can be limited to 1.8°C by the end of the century (based on a 1985 – 2005 baseline) and while there will be some increase to extreme weather events due to historical climate change, these will result in medium level adaptation costs to mitigate risk.
RCP 6.0 **(Some mitigation)**	670 ppm	2.8ºC	2.0 to 3.7ºC	Assumes a low to medium level of mitigation with no active removal of atmospheric carbon dioxide. Emissions are anticipated to slow, however continue through 2100. This scenario a mix of coal-fired and renewable energy with no carbon capture. As a result, it is anticipated that temperature increases can be limited to 2.2°C by the end of the century (based on a 1985 – 2005 baseline) and while there will be a moderate increase to extreme weather events due to historical climate change, these will result in medium level adaptation costs to mitigate risk.
RCP 8.5 **(Business as usual)**	936 ppm	4.3ºC	3.2 to 5.4ºC	Assumes emissions minimal effort to reduce emissions. Emissions will continue to grow unchecked, marked by the continued use of conventional fossil fuel energy to power cities homes and businesses. Without sizeable intervention this scenario assumes an average temperature increase of up to 4°C by the end of the century (based on a 1986 – 2005 baseline). It will require costly adaptation to minimise the impact extreme weather events which have continued to increase dramatically over the past century.

* Assumes a pre-industrial baseline period of 1850-1900

[97] Australian Govt. Department of the Environment and Energy, (n.d.). *What are the RCPs?.* https://coastadapt.com.au/sites/default/files/infographics/15-117-NCCARFINFOGRAPHICS-01-UPLOADED-WEB%2827Feb%29.pdf

Time horizons

To consider risks appropriately and adequately to assets, operations and services, a series of time horizons are needed to understand how risks may change over time as well as identified intervention points for adaptation measures. Scientific data (including climate projections) from NARCliM and the CSIRO and BoM sources generally include 20-year time horizons centred on a ‘fixed year’, for example, 2070 accounts for the period 2060-2079. The time horizons include:

- A baseline period of 1990-2009, as well as future time horizons of 2030, 2045, 2070 and 2090 for the NARCliM1.5 data projections.

Observed climate

Historical SPI for the ACT

Figure 14 supports The Standard Precipitation Index (SPI) discussion in Section 3.1

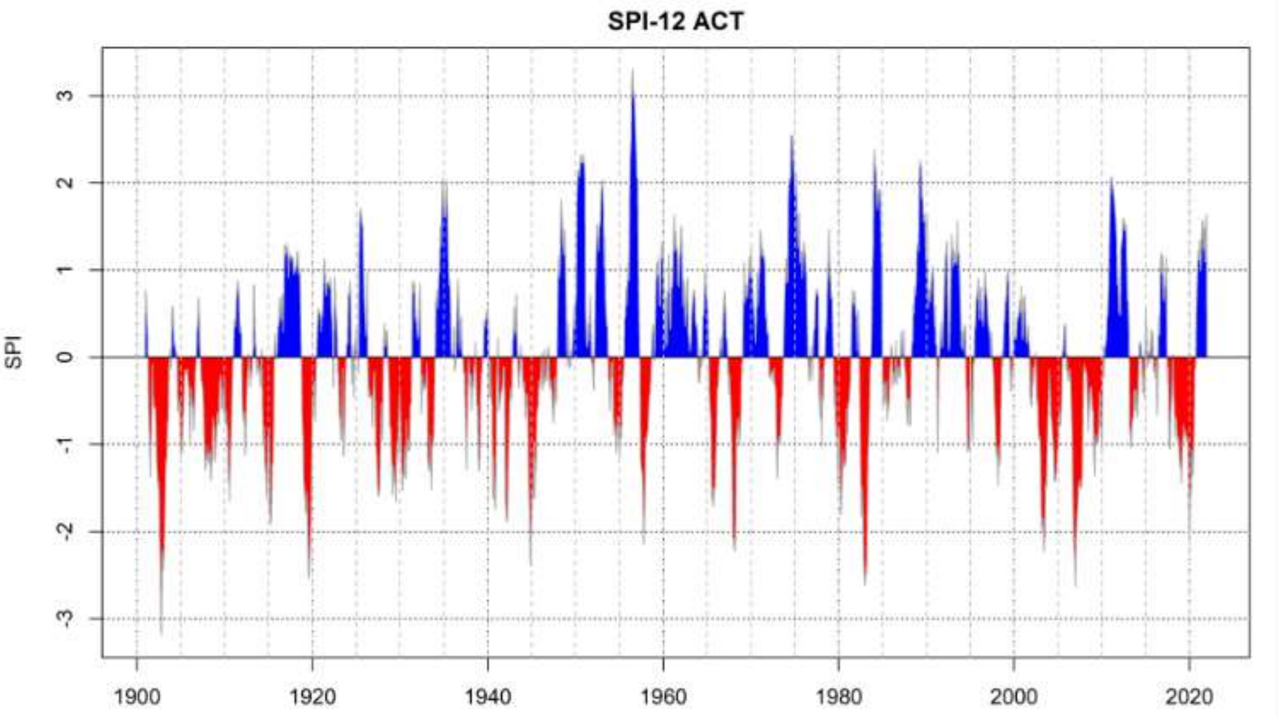


Figure 14 Historical (1900-2020) Standard Precipitation Index (SPI) 12-month scale for ACT. Mildly dry (0>SPI>-0.99), moderately dry (-1.0>SPI>-1.49), severely dry (-1.5>SPI>-1.99) and extremely dry conditions (SPI less than -2.0).[98]

SPI and average maximum temperature

Figure 15 supports The Standard Precipitation Index (SPI) discussion in Section 3.1

[98] Agricultural and Meteorological Software. (2020). What is SPI(Standardized Precipitation Index). https://agrimetsoft.com/faq/What%20is%20SPI(Standardized%20Precipitation%20Index)

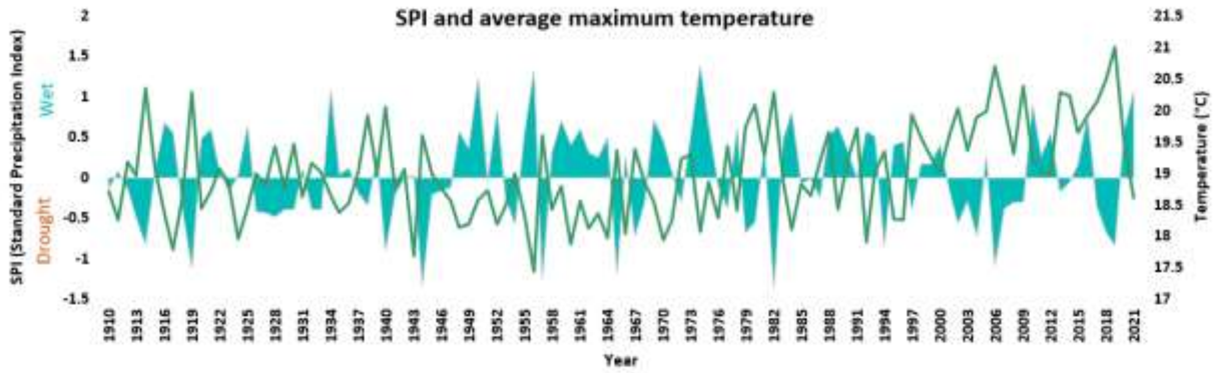


Figure 15 Observed SPI and higher temperatures for North-eastern ACT. Mildly dry (0>SPI>-0.99), moderately dry (-1.0>SPI>-1.49), severely dry (-1.5>SPI>-1.99) and extremely dry conditions (SPI less than -2.0).

Temperature

Periods of drought are often accompanied by higher-than-average surface air temperatures. Temperature variables that are indicators of drought include:

- Higher maximum temperatures,
- More days with maximum temperatures exceeding 35°C.

Both maximum and minimum average temperatures have been increasing annually.

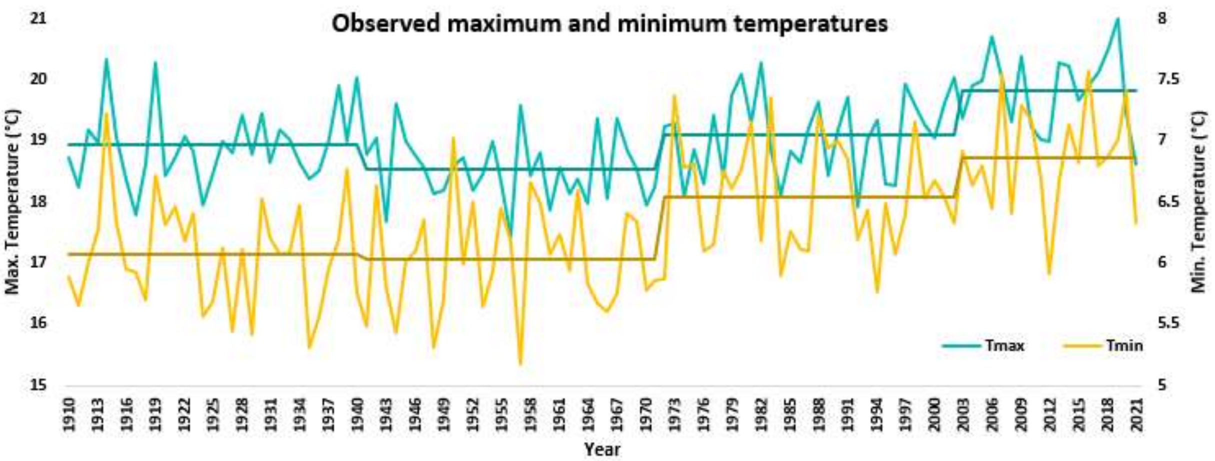


Figure 16 Observed maximum and minimum temperatures for North-East ACT

Similarly, there appears to be a relationship between above-average temperatures and a reduction in soil moisture through reduced rainfall and increased surface evaporation (Figure 19). Heat can exacerbate drought, enhancing evaporation, reducing surface water, and drying out soils and vegetation. Figure 17 shows an increase in the frequency of days experiencing maximum temperatures above 35°C in the recent two decades compared to the previous period of record. Of note, in 2019 there was a recorded 86% increase in the number of days over 35°C compared to the 1990-2021 baseline average. January 2019 recorded 12 days over 35°C compared to the 1990-2021 baseline average of 1.8 days.

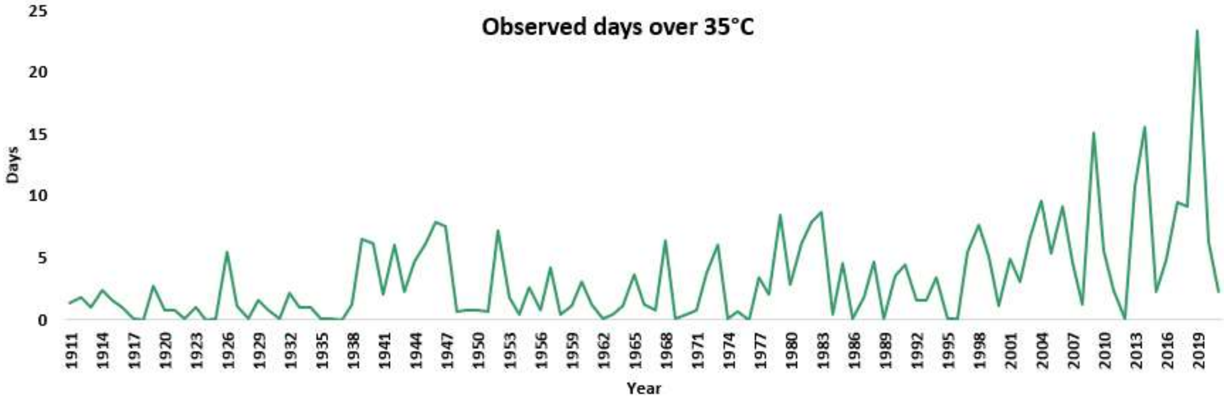


Figure 17 Observed days over 35°C 1910-2020 for North-East ACT

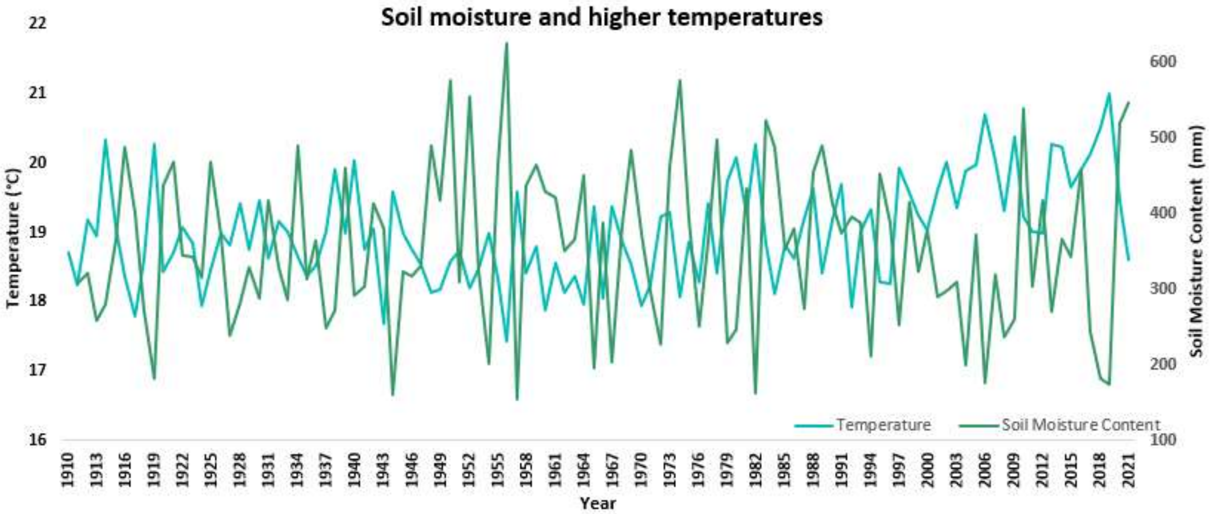


Figure 18 Soil moisture and increasing temperatures for North-East ACT

The number of days with minimum temperatures below 2°C has also steadily decreased. Agricultural enterprises sensitive to frost risk (e.g. growing of pastures, horticulture, and viticulture) may benefit from this reduced frequency and associated damage.

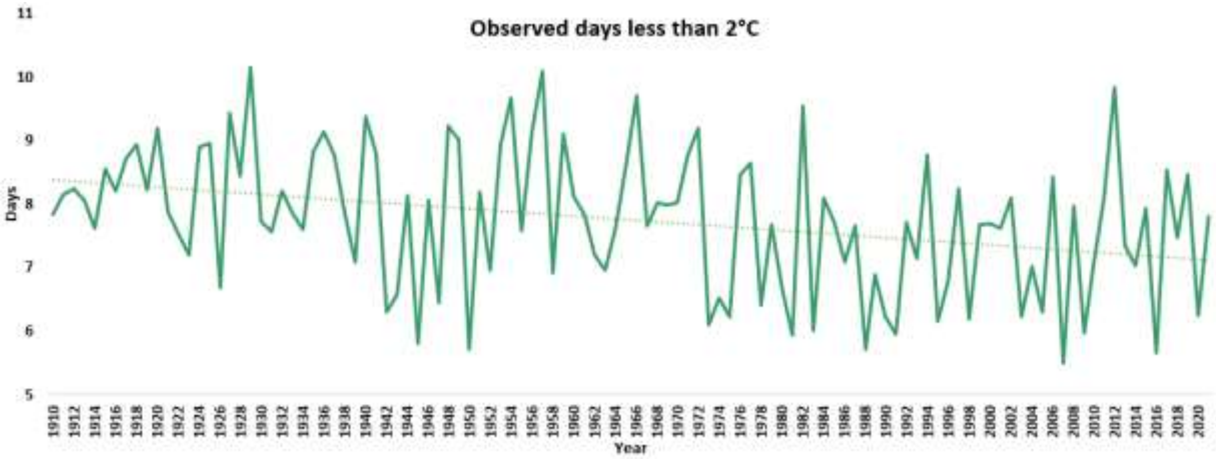


Figure 19 Observed days less than 2°C for North-East ACT

Rainfall

The frequency and intensity of extreme rainfall events have increased over the observed record. Large-scale climate drivers have had a strong influence over rainfall in the ACT. Based on rainfall data retrieved from the Bureau of Metrology's data for the North-Eastern region, annual rainfall in the region has varied anywhere between 315 mm to 1172 mm from 1900 to present (Figure 20).

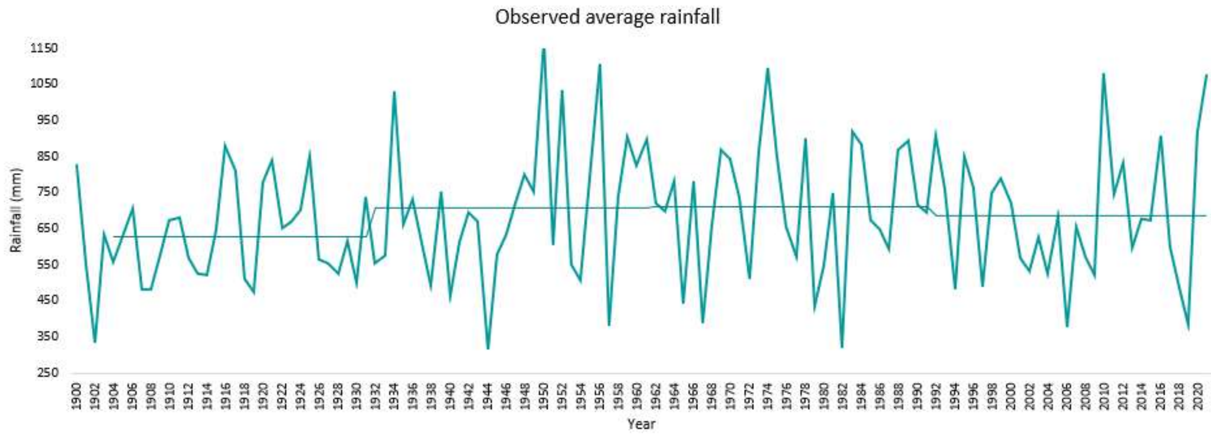


Figure 20 Observed average rainfall 1900-2020 for North-East ACT

Since 1900 Canberra has only twice experienced flooding events with an Annual Exceedance Probability (AEP)[99]. These events include the flooding in Yarralumla Creek catchment in January 1971 and the flooding in the Sullivan's Creek and Woolshed Creek catchments in February of 2018 in which Canberra received more than the expected total rainfall for February in a 6-hr period.

Mainly due to the 2021-2022 La Niña event, the ACT has more recently experienced increased monthly rainfall. 2021 was the wettest year on record for the ACT, with North-Eastern ACT recording its wettest November on record in 2021 receiving 191.6 mm.

Rainfall is the main source of soil moisture, with the two having a strong correlation with each other. For example, a period of reduced rainfall may reduce soil moisture and stress crops. Figure 21 shows the observed soil moisture content and rainfall for North-East ACT where there appears to be a relationship between both variables.

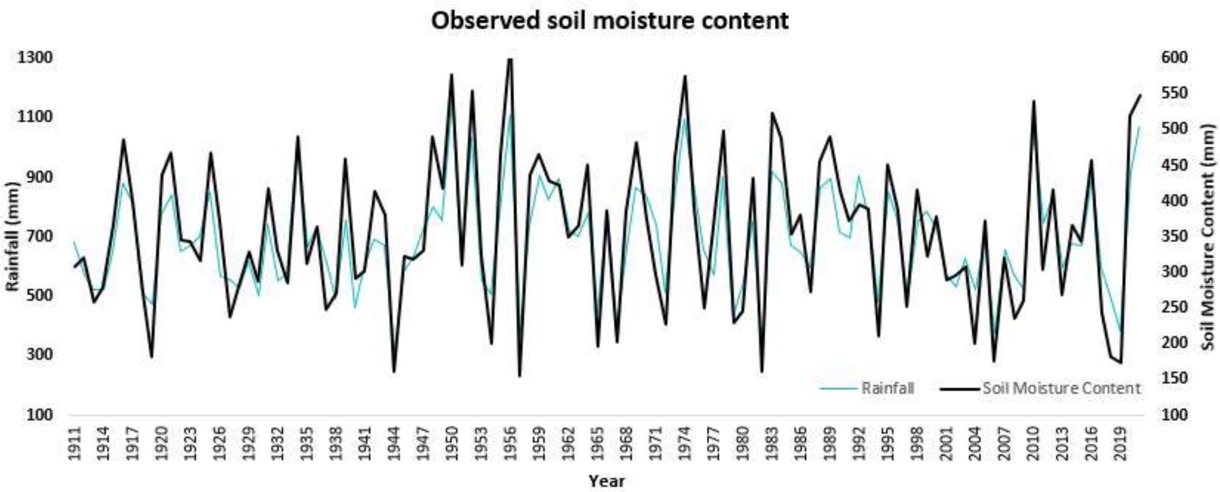


Figure 21 Observed soil moisture content and rainfall for North-East ACT

[99] defined as the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year greater than 1%.

Table 13 Climate hazards and corresponding NARCliM climate projections source and their relevance to agriculture

Climate hazard	Hazard definition	Relevance to agriculture
Consecutive dry days (cdd)	Maximum number of consecutive days with precipitation < 1mm	Effective indicator and projector of periods of drought
Cooling degree days (cddcoldn)	Number of degrees that a day's average temperature is above 18°C	It is a measurement designed to quantify the demand for energy needed to cool buildings
Cold spell duration index (csdi)	Annual count of days with at least 6 consecutive days when daily minimum temperature < 10th percentile	Prolonged cold spells can damage pasture growth and is harmful towards animal health particularly in early or late growing seasons
Consecutive wet days (cwd)	Maximum number of consecutive days with precipitation ≥ 1mm	Indicator of waterlogging and increased fungal disease risk
Frost days (fd)	Annual count of days when TN (daily minimum temperature) < 0°C	Damage to pastures can occur with desiccation damage occurring at temperatures between 0 °C to -2 °C and frost damage below -2 °C
Growing degree days (gddgrow)	Measure of heat accumulation	Used to estimate the growth and development of plants and insects.
Growing season length (gsl)	Annual count between the first span of at least 6 days with daily mean temperature > 5°C and the first span after July 1st of 6 days with daily mean temperature < 5°C.	Period of time where pastures can come to maturity without the risk of killing frost
Relative humidity (hurs)	Relative humidity at 2 m above the surface	Increased humidity slows down the process of evaporation allowing water to condense on the pastures providing a good environment for pathogens
Specific humidity (huss)	Specific humidity 2 m above the surface	Increased humidity slows down the process of evaporation allowing water to condense on the pastures providing a good environment for pathogens
Total soil moisture content (mrso)	Amount of water in the top 2 m of soil measured in millimetres	Vital to ensuring fertile soil for plants and soil forming processes and weathering is dependent on water
Bias corrected precipitation (pr_bc)	Average monthly precipitation corrected against any erroneous data	Grazable land and requirement for irrigation is dependent on precipitation
Number of heavy rain days (r20mm)	The number of projected days per month with precipitation above 20 mm	Indicator of waterlogging and increased fungal disease risk
Total annual PR from heavy rain days (r95p)	Number of days with precipitation above 95th percentile	Indicator of waterlogging and increased fungal disease risk

Climate hazard	Hazard definition	Relevance to agriculture
Maximum consecutive 5-day precipitation (rx5day)	Maximum rainfall over 5 consecutive days in a month	Indicator of waterlogging and increased fungal disease risk
Simple precipitation intensity index (sdii)	Mean precipitation on wet days	Grazable land, requirement for irrigation, indicator of waterlogging and increased fungal disease risk is dependent on precipitation
Standardised precipitation index (spi)	Measure of drought and extremely wet weather; mildly dry (0>SPI>-0.99), moderately dry (-1.0>SPI>-1.49), severely dry (-1.5>SPI>-1.99) and extremely dry conditions (SPI less then -2.0)	Grazable land, requirement for irrigation, indicator of waterlogging and increased fungal disease risk is dependent on precipitation
Daily maximum temperature (tasmax)	Monthly mean daily maximum air temperature	Higher temperatures reduce pasture growth
Daily minimum temperature (tasmin)	Monthly mean daily minimum air temperature	Damage to pastures can occur with cold damage occurring at temperatures below 5 °C desiccation damage occurring at temperatures between 0 °C to -2 °C and frost damage below -2 °C
Mean temperature of 5°C or lower (tmlt5)	Count of days with mean temperatures of 5 °C or lower	
Count of days when minimum temperature is below 2°C (tntl2)	Average number of days a year with minimum temperatures below 2°C.	
Mean daily temperature (tnm)	Projected monthly daily minimum temperature	Higher temperatures reduce pasture growth with extreme temperatures harmful to animal welfare
Percentage of days with a daily maximum temperature above the 90^{th} percentile (tx90p)	Percentage of days when daily maximum temperatures > 90^{th} percentile	
Daily maximum temperature of at least 35°C (txge35)	Projected no. of days per month with maximum temperatures greater than 35°C	
Mean daily maximum temperature (txm)	The mean daily maximum temperature	
Monthly maximum daily temperature (txx)	Projected daily maximum temperature in each month	
Warm spell duration index (wsdi)	Annual count of days with at least 6 consecutive days when daily maximum temperature > 90^{th} percentile	

Visualisation of future projections

The following section presents visualisations of future projections for the identified climate variables using NARCLiM 1.5 projections for the North-East region of the ACT under RCP8.5.

Temperature – Maximum and Minimum

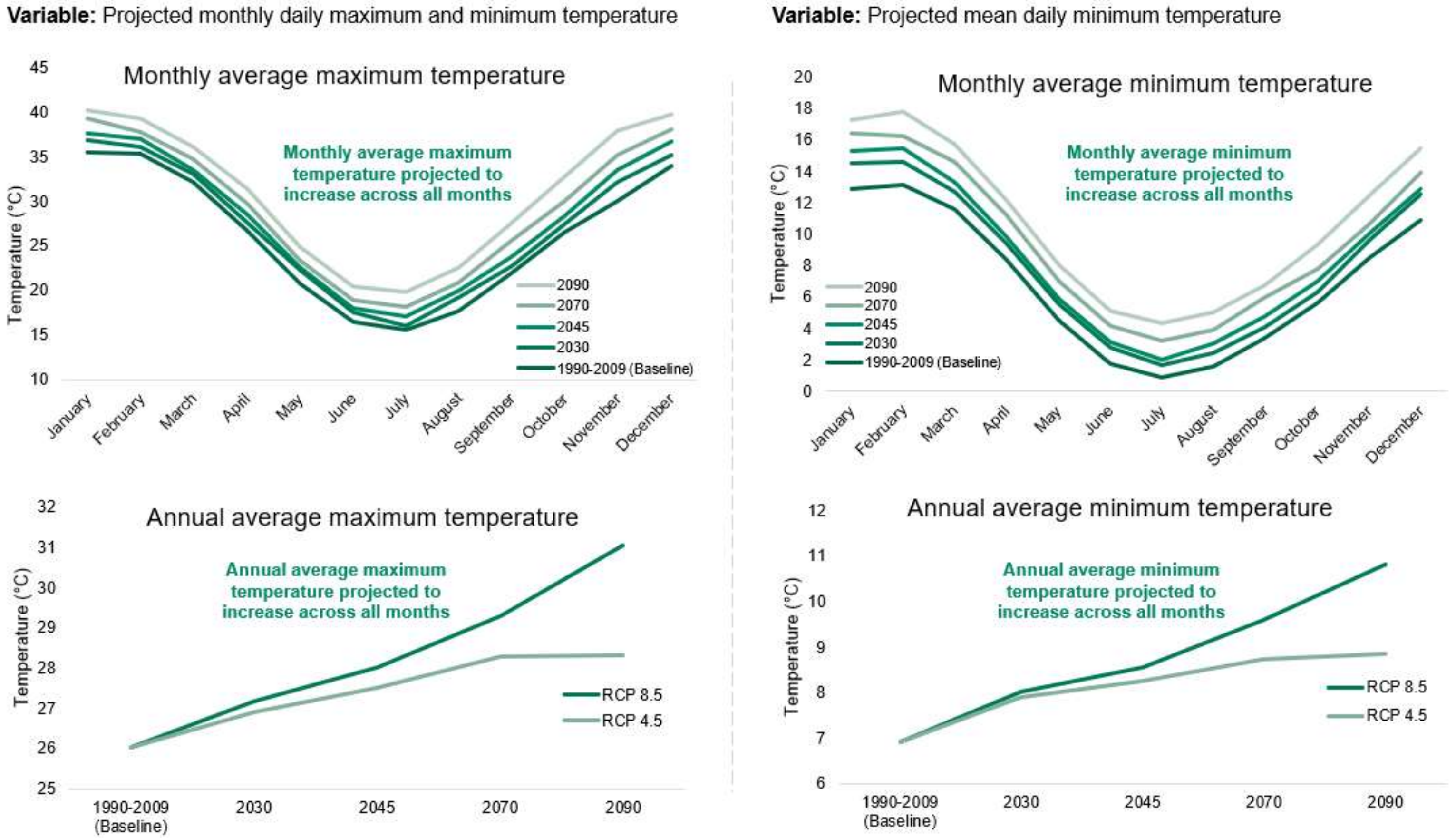


Figure 22 Future projections for temperature variables, average maximum, and minimum temperature, under an RCP 8.5 scenario for North-East ACT

Temperature – Lows and Extremes

Variable: Number of days when daily minimum temperature <2°C

Variable: Number of days with maximum temperatures > 35°C

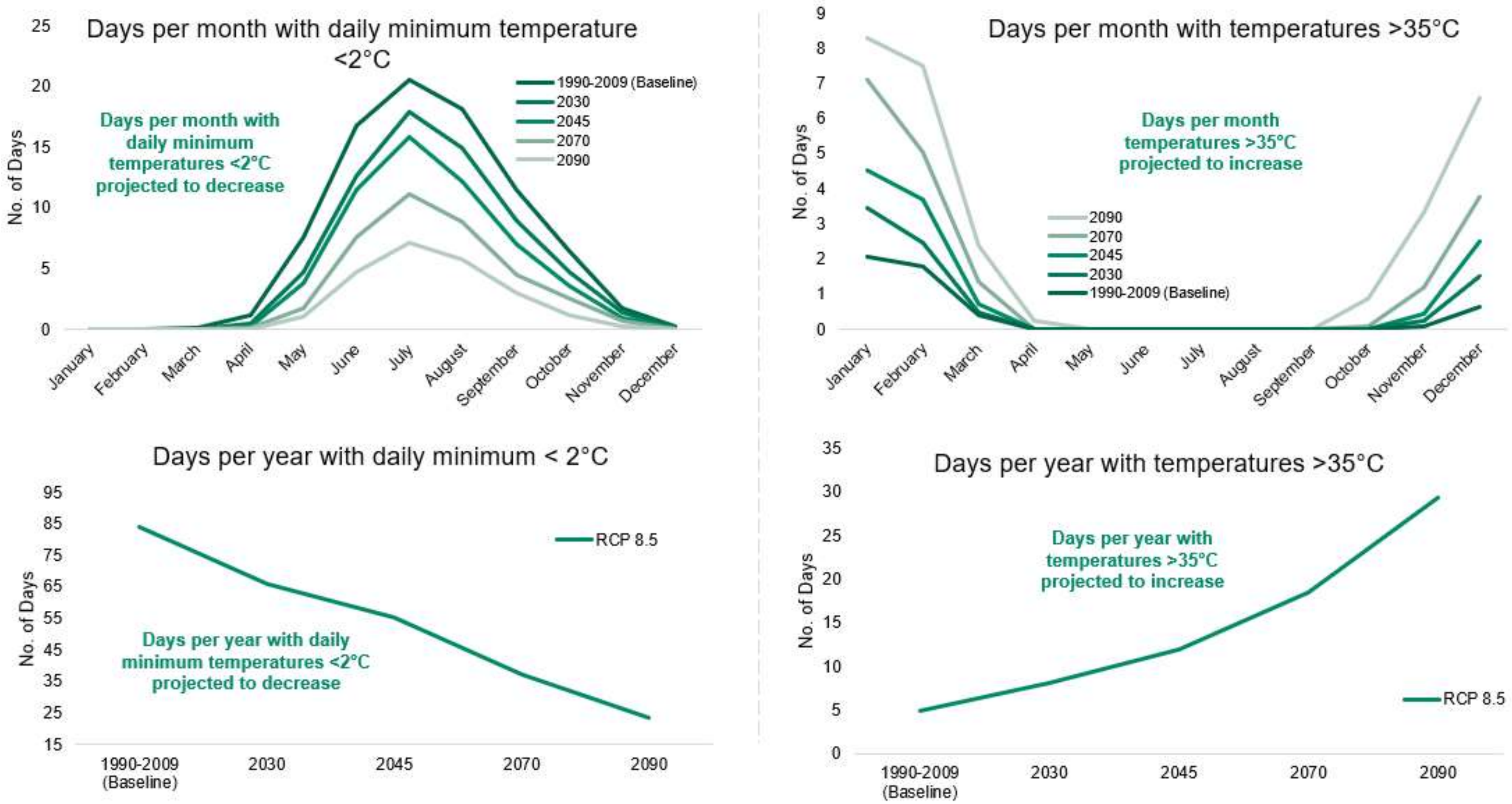


Figure 23 Future projections for temperature variables, lows, and extremes, under an RCP 8.5 scenario for North-East ACT

Rainfall – average precipitation and consecutive 5-day precipitation

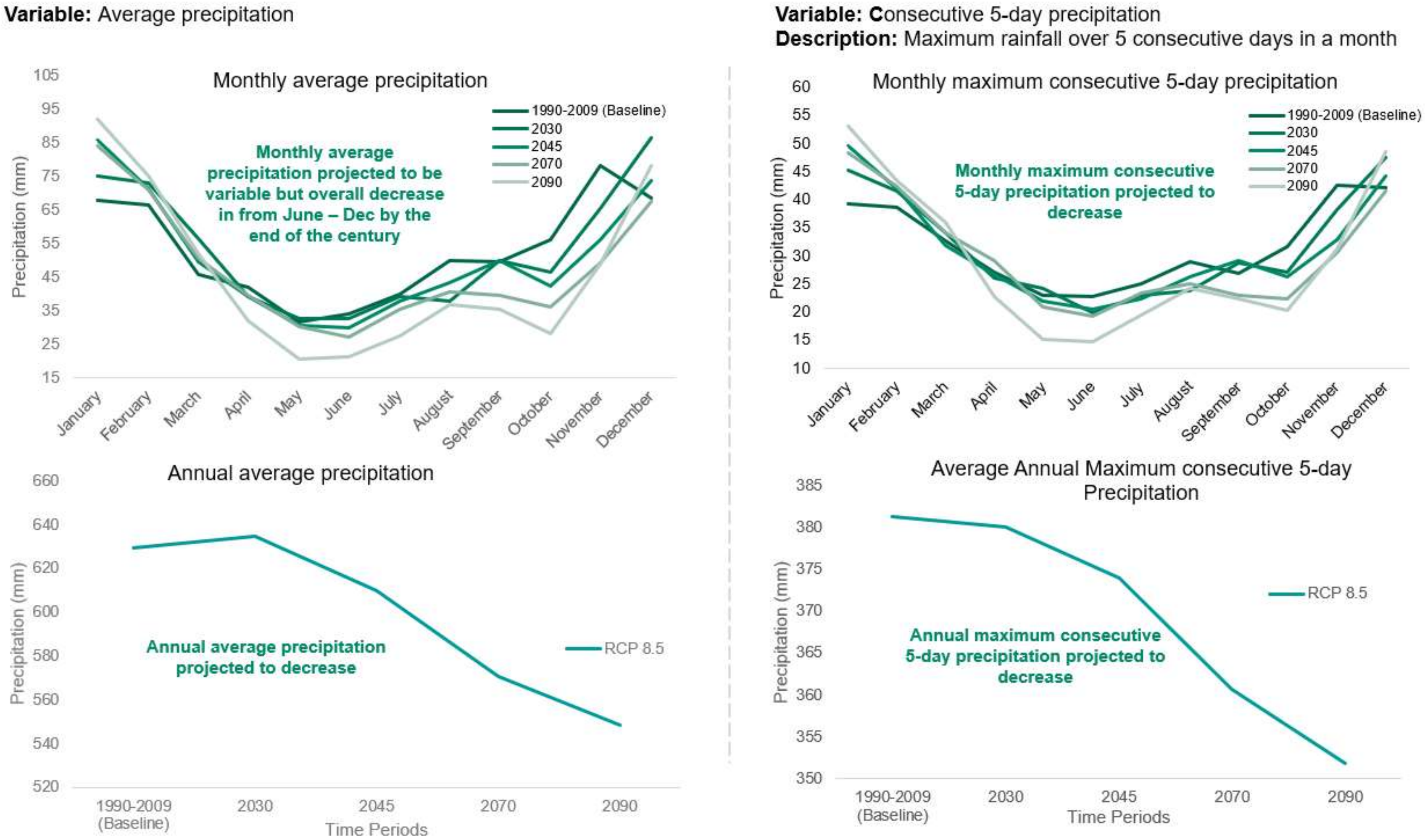


Figure 24 Future Projections for rainfall and consecutive 5-day precipitation, under an RCP 8.5 scenario for North-East ACT

Soil Moisture and Standard Precipitation Index (SPI)

Variable: Total soil moisture content
Description: Amount of water in first 2m of soil

Variable: SPI (3 month)
Description: Measure of drought and extremely wet weather

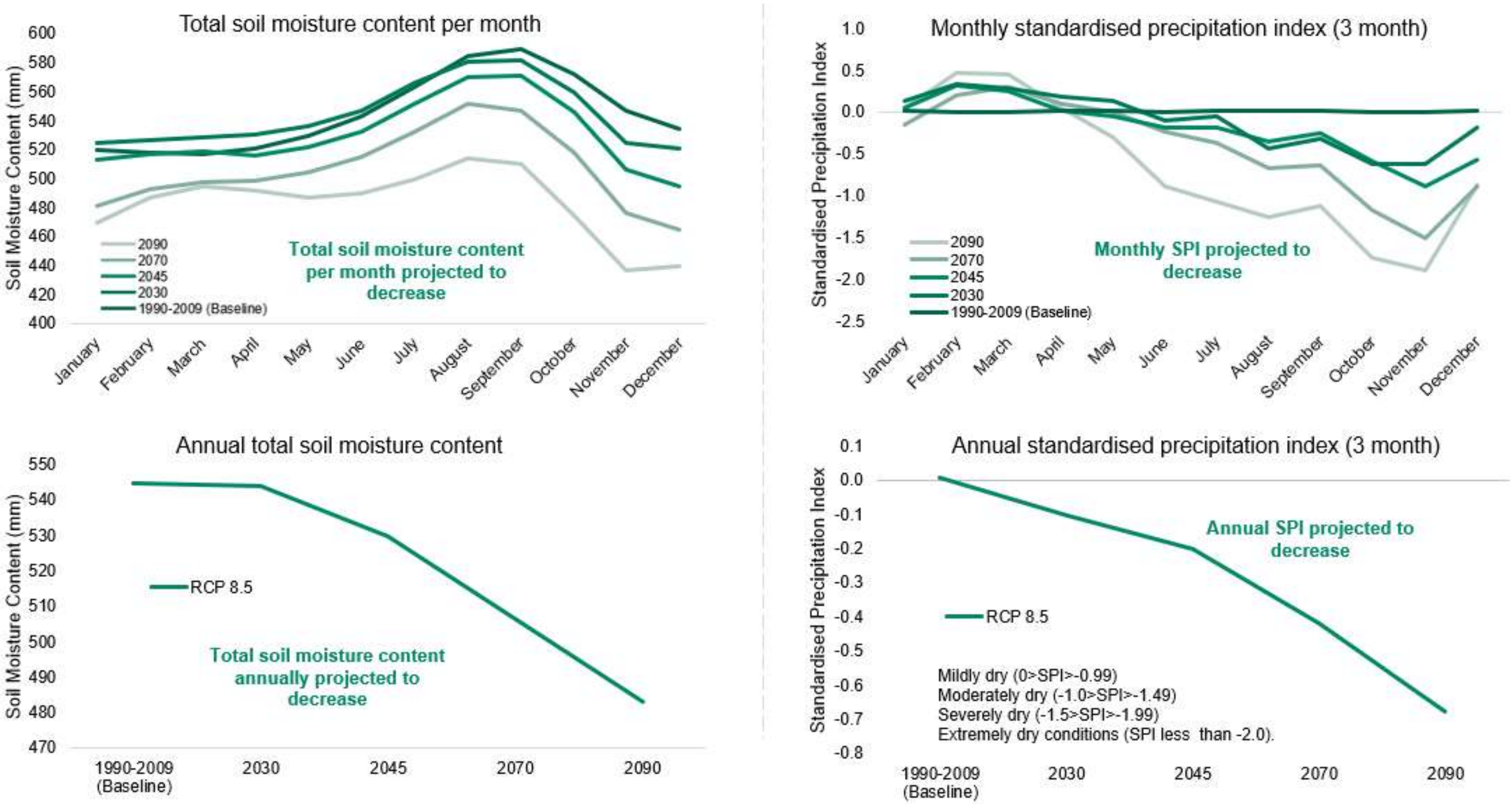


Figure 25 Future projections for soil moisture and standard precipitation index, under an RCP 8.5 scenario for North-East ACT

Box 5 Vapour Pressure Deficit

- Plants have an increased potential to transpire and an increased risk of drying out due to the greater potential difference between the leaf and the air
- Carbon dioxide uptake from plant is reduced, the nutrient intake from the roots is increased and concurrently, due to all these factors, plants experience greater levels of stress.[102]

Increased average temperatures and a decrease in relative humidity are projected across the ACT. The consequence of these projections is a sharp increase to VPD. A projection by Yuan et al. for global VPD is shown in Figure 26 below. The projected increase to VPD will cause increased evaporation thus increasing the risk of crops drying out. The likely consequences of this includes decreased yields and an increase in dry vegetation available for fires consequently increasing the intensity of potential bushfires. Increasing VPD is considered to have been an important driver in the severity of the droughts and fires of 2017-2020 in the ACT. Moreover, increased evaporation will also reduce water availability, soil moisture and pastures available for grazing. The resulting effect on the ACT agriculture industry includes an increase in water demand with reduced water availability, decreased yields and increased risk of fire damage.

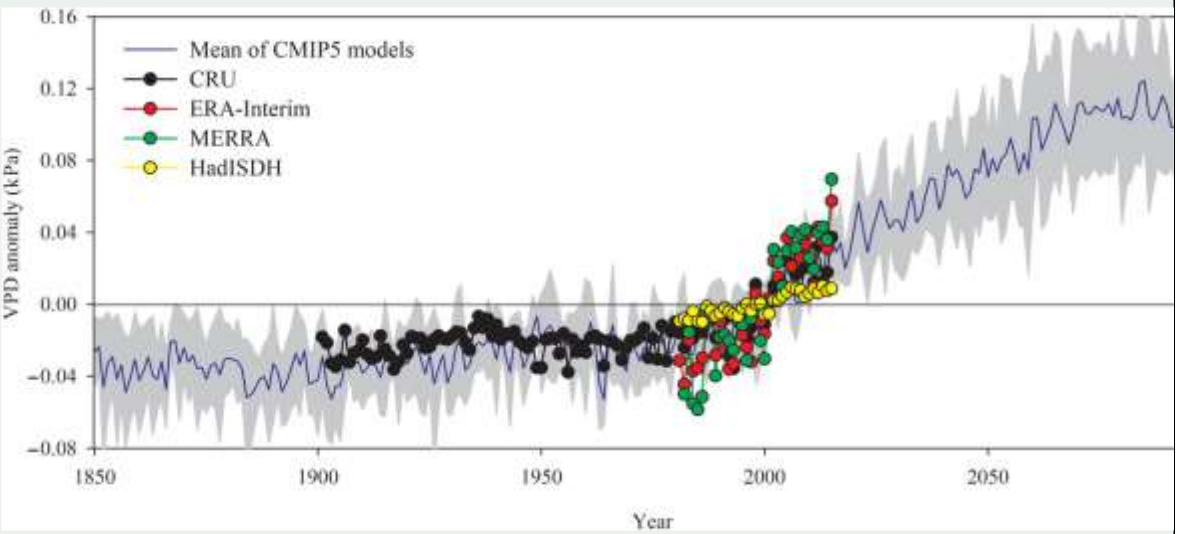


Figure 26 VPD Projection [100]

Future drought scenario

Table 13 presents a comparison of trends across the three future drought scenarios.

Table 14 Comparison of trends across the three future drought scenarios

Future drought scenario	Description
Low emissions scenario (RCP 4.5 model ensemble mean)	Under a low emissions scenario (RCP 4.5 model ensemble mean), it is projected that temperature will continue to increase, in line with a high emissions scenario (RCP 8.5 model ensemble mean), until 2045, after this timeframe temperature increase is projected to plateau. Rainfall is projected to continue to decrease however not as significantly as under a high emissions scenario (RCP 8.5 model ensemble mean). Soil moisture content follows a like trend to high emissions scenario (RCP 8.5 model ensemble mean) where it is projected to decrease, however after 2070 it is projected to plateau. Overall, a low emissions scenario (RCP 4.5 model ensemble mean) and high emissions scenario (RCP 8.5 model ensemble mean). follow similar trends in the near future.

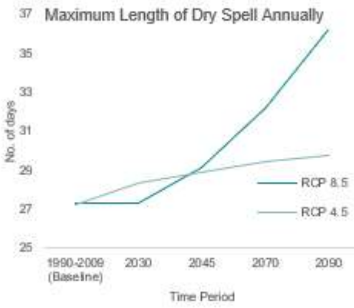
[100] Yuan, W., et al. (2019). *Increased atmospheric vapor pressure deficit reduces global vegetation growth.* https://www.science.org/doi/10.1126/sciadv.aax1396
[101] Wollaeger, H., & Runkle, E. *VPD vs. Relative Humidity*. https://www.canr.msu.edu/uploads/resources/pdfs/vpd-vs-rh.pdf
[102] Koverda, P. (2020). *The Ultimate Vapor Pressure Deficit (VPD) Guide - Pulse Grow.* https://pulsegrow.com/blogs/learn/vpd

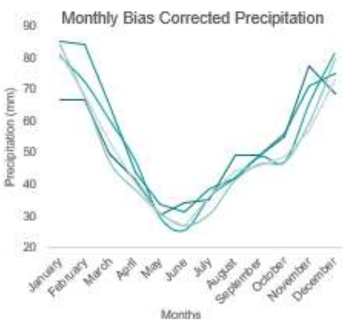
Future drought scenario	Description
High emissions scenario (RCP 8.5 model ensemble mean)	Under a high emissions scenario (RCP 8.5 model ensemble mean), it is projected that temperature will continue to increase, particularly over summer months, with a significant increase occurring towards the end of the century. Rainfall is projected to decrease annually however there will be increasing intensity of extreme rainfall events. It is also projected that consecutive days without rainfall will increase. Soil moisture is projected to decrease, particularly during August – December months, with a more significant decrease expected by the end of century. In comparison to a low emissions scenario (RCP 4.5 model ensemble mean), projections are generally more significant, whilst milder in comparison to hotter/drier scenario (RCP 8.5 hotter and drier model).
Hotter/drier scenario (RCP 8.5 hotter and drier model)	Under a hotter/drier scenario (RCP 8.5 hotter and drier model), it is projected that temperature will continue to increase at a more significant rate than under a high emissions scenario (RCP 8.5 model ensemble mean). Rainfall is projected to decrease annually with increasing intensity of extreme rainfall days. Under a hotter/drier scenario, rainfall is much more variable per month than under a high emissions scenario; annually the maximum length of consecutive days without rainfall is significantly higher under an upper mean scenario. Decreases in soil moisture are also significantly greater however follow a similar trend to that of a high emissions scenario.

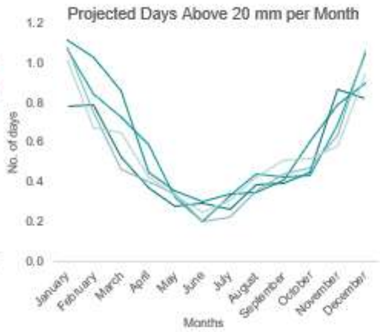
Drought Scenario – Low emissions scenario

Under a low emissions scenario (RCP 4.5 model ensemble mean), it is projected that temperature will continue to increase, in line with a high emissions scenario (RCP 8.5 model ensemble mean), until 2045, after this timeframe temperature increase is projected to plateau. Rainfall is projected to continue to decrease however not as significantly as under a high emissions scenario (RCP 8.5 model ensemble mean). Soil moisture content follows a similar to trend to high emissions scenario (RCP 8.5 model ensemble mean) where it is projected to decrease, however after 2070 it is projected to plateau. Overall, a low emissions scenario (RCP 4.5 model ensemble mean) and high emissions scenario (RCP 8.5 model ensemble mean). follow similar trends in the near future.

Rainfall = *decrease annually, increase in intensity*

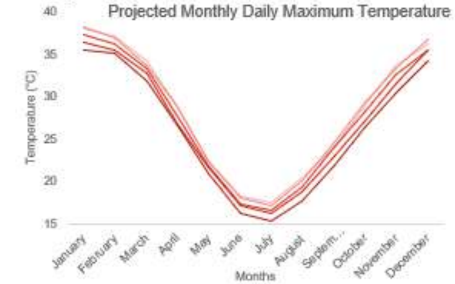


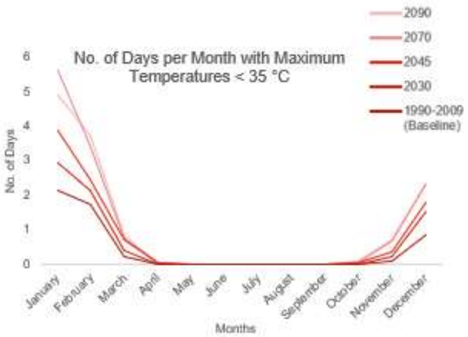


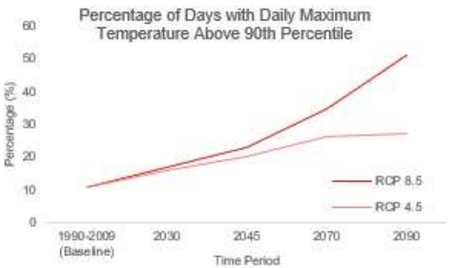


Rainfall is projected to decrease annually and increase in intensity however not as significantly as under a high emissions scenario (RCP 8.5)

Temperature = *increase*

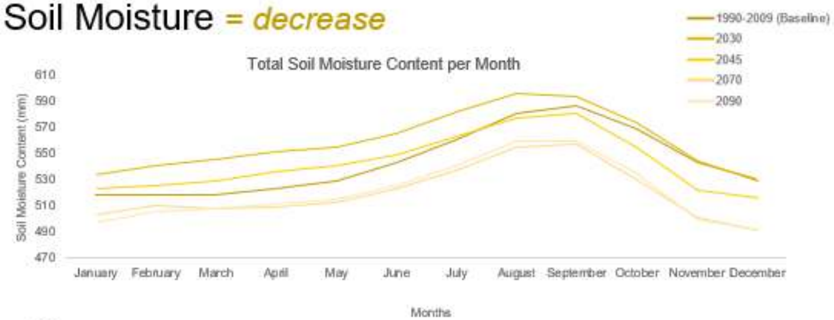


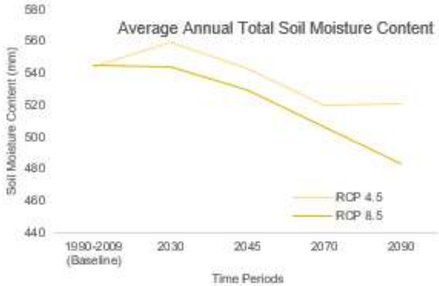




Temperatures are projected to increase however not as significantly as under a high emissions scenario (RCP 8.5). After 2045, temperature increase is projected to plateau.

Soil Moisture = *decrease*



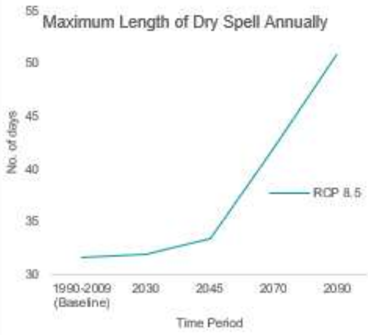


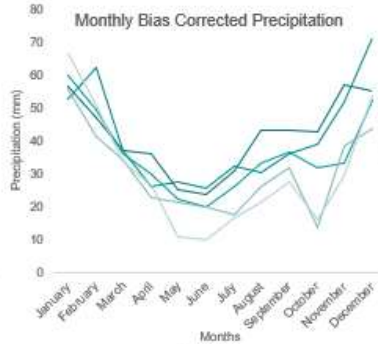
Soil moisture content is projected to decrease however not as significantly as under a high emissions scenario (RCP 8.5).

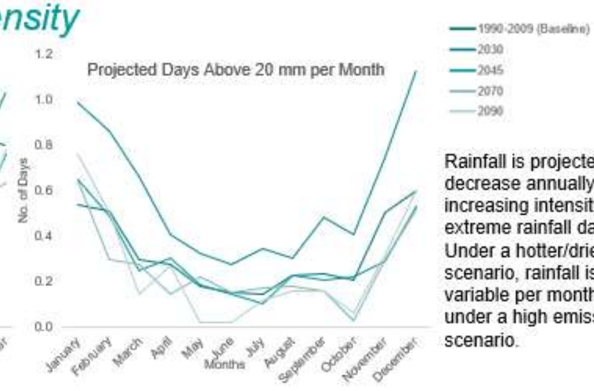
Drought Scenario – Hotter/ drier scenario

Under a hotter/drier scenario (RCP 8.5 hotter and drier model), it is projected that temperature will continue to increase at a more significant rate than under a high emissions scenario (RCP 8.5 model ensemble mean). Rainfall is projected to decrease annually with increasing intensity of extreme rainfall days. Under a hotter/drier scenario, rainfall is much more variable per month than under a high emissions scenario; annually the maximum length of consecutive days is significantly higher under an upper mean scenario. Decreases in soil moisture are also significantly greater however follow a similar trend to that of a high emissions scenario.

Rainfall = *decrease annually, increase in intensity*

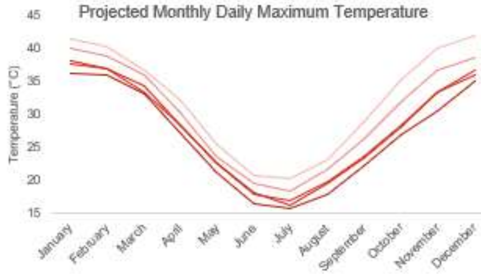


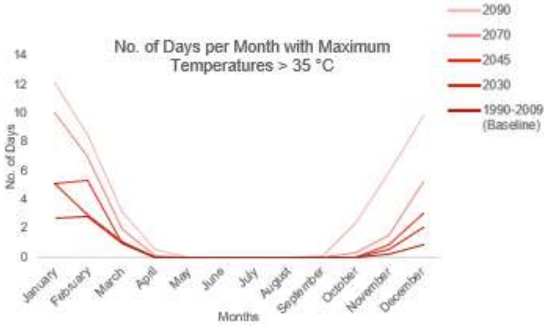


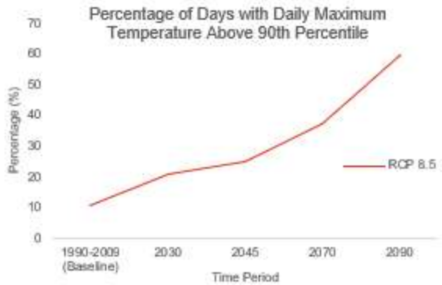


Rainfall is projected to decrease annually with increasing intensity of extreme rainfall days. Under a hotter/drier scenario, rainfall is more variable per month than under a high emissions scenario.

Temperature = *increase*

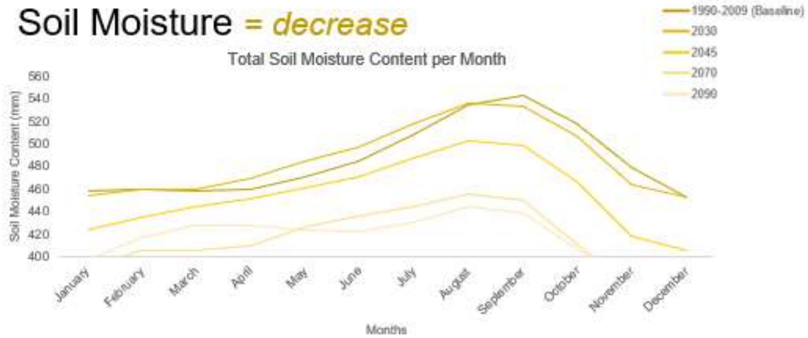


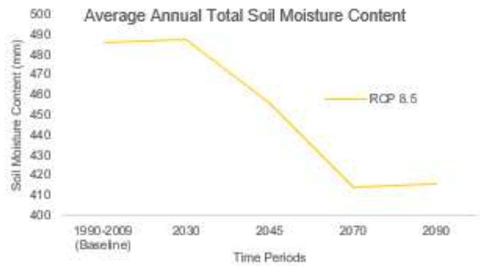




Temperatures are projected to increase more significantly than under a high emissions scenario

Soil Moisture = *decrease*





Soil moisture content is projected to decrease significantly lower than under a high emissions scenario

Appendix B

BOM Observed Data

Appendix B BOM Observed Data

Please refer to the Bureau of Meteorology Data Excel workbook provided under separate copy.

Appendix C

Climate Change Projections (NARCliM)

Appendix C Climate Change Projections (NARCliM)

Table 15 presents the trends in both regions of the ACT (northeast and southwest) under two emission scenarios (RCP 4.5 and RCP 8.5).

Table 15 NARCliM climate change projections for Northeast and Southwest ACT

Variable	Definition	Northeast RCP 4.5	Northeast RCP 8.5	Southwest RCP 4.5	Southwest RCP 8.5	Overall observations
Cdd	Consecutive dry days: maximum number of consecutive days with precipitation < 1mm	• Increase in the number of consecutive dry days (growth rate of ~1 day per 20 years, compared to ~3 days per 20 years under RCP 8.5)	• Increase in the number of consecutive dry days (growth rate of ~3 days per 20 years, compared to ~1 day per 20 years under RCP4.5). • Greatest increase in consecutive dry days occurs between 2070 and 2090 timeframe (36.26 days in 2090 compared to 27.30 days baseline) • Upper end of 50.93 cdd in 2090 (compared to 31.70 baseline)	• Decrease in the number of cdd between 2030 and baseline (~1 day decrease). Increases in cdd after 2050 timeframe. • Overall, cdd does not vary much from the baseline over all time periods	• Increase in the number of cdd not as significant as in the northeast region, e.g. baseline – 23.19; 2070 – 25.83 (~2 day increase, compared to ~5 day increase in northeast). • Greatest increase between timeframes occurs between 2070 and 2090 (~5-day increase)	• RCP 8.5 increases the maximum length of a dry spell across both regions, but the effects are worse in the Northeast region • RCP 4.5 minimizes the effects in both regions but an increase in length of the maximum dry spell is expected in the northeast region while the effects are close to negligible in the Southwest region with only a small upward trend predicted
cddcoldn	Average demand for energy to cool a building	• In the northeast region, the cddcoldn is projected to steadily increase towards 2090 with an overall increased energy demand of 75%	• Under RCP 8.5, cddcoldn is projected to nearly triple by 2090 in the northeast region	• Under RCP 4.5, cddcoldn is projected to nearly double by 2090 in the southwest region	• Under RCP 4.5, cddcoldn is projected to nearly quadruple by 2090 in the southwest region •	• The average energy demand is projected to raise quite significantly und scenarios and in both regions. • Southwest ACT is expected to increase in energy demand more considerably than the North west • In both regions, RCP 8.5 sees an increase of more than double when compared to the RCP 4.5 scenario
csdi	Cold spell duration index: annual count of days with at least 6 consecutive days when daily minimum temperature < 10th percentile	• The baseline index is quite low at 0.25. It is expected that cold spells of duration 6 days or more will cease to exist in North-eastern ACT by 2040 under RCP 4.5	• The baseline index is quite low at 0.29. It is expected that cold spells of duration 6 days or more will cease to exist in North-eastern ACT by 2060 under RCP 8.5	• The baseline index is quite low at 0.17. It is expected that cold spells of duration 6 days or more will cease to exist in South-western ACT by 2060 under RCP 4.5	• The baseline index is quite low at 0.19. It is expected that cold spells of duration 6 days or more will cease to exist in South-western ACT by 2040 under RCP 8.5	• Cold spells of at least 6 days are already quite unlikely in both regions of the ACT. It is expected under both RCP 4.5 and RCP 8.5 that the likelihood of cold spells will reduce to zero by 2060 in both regions.
cwd	Consecutive wet days: maximum number of consecutive days with precipitation ≥ 1mm	• Decrease in the max. length of wet spell days between 2030-2070. Slight increases seen after 2070 • Less than one day difference	• Decrease in the max. length of wet spell days after 2030. • Less than one day difference • Maximum wet spell length is expected to be lower when compared to RCP 4.5	• Max. length of wet spells fluctuates across 2030-2090 timeframes. Greatest decrease occurs from 2050 to 2070 • Wet spell length longer when compared to RCP 8.5	• Gradual decrease in max. length of wet spells starting at 6.82 days in 2030 decreasing to 6.17 in 2090.	• In both regions and scenarios, the maximum length of wet spells is expected to shorten. • Additionally, in both regions, maximum wet spell length are expected to be reduced further if the RCP 8.5 scenario is experienced instead of the RCP 4.5 scenario.
fd	Number of frost days: Annual count of days when TN (daily minimum temperature) < 0°C.	• Decrease in the number of frost days across timeframes. E.g. 12 days in July baseline, 9 days in July 2090. Consistent decrease across all frost months. • Same trend in terms of the occurrence of frost days across months • Decrease across timeframes is not as significant as during RCP8.5 e.g. ~2 days decrease from 2030 – 2090 in July compared to ~8 days decrease under RCP8.5	• Decrease in the number of frost days across timeframes. E.g. 12 days in July baseline, 4 days in July 2090. Consistent decrease across all frost months. • Same trend in terms of the occurrence of frost days across months	• Decrease in the number of frost days across timeframes. E.g. 23 days in July baseline, 15 days in July 2090. Consistent decrease across all frost months. • Same trend in terms of the occurrence of frost days across months • This region experiences more frost days than the north-east region (therefore the variable might be more significant to southwest region).	• Decrease in the number of frost days across timeframes. E.g. 23 days in July baseline, 7 days in July 2090.Steady consistent decrease across all frost months. • Same trend in terms of the occurrence of frost days across months • Decrease across timeframes is more significant during RCP8.5, reduction of ~16 frost days compared to ~8 days in the RCP 4.5 scenario	• In both regions, a decrease in frost days is expected under both RCP 4.5 and RCP 8.5 scenarios. • Moreover, both regions will experience a greater reduction in frost days per year if the RCP 8.5 scenario occurs.
gddgrow	Measure of heat accumulation	• Heat accumulation is expected to steadily raise under emissions scenario RCP 4.5	• The Northeast region is expected to see a sharper heat accumulation under emissions scenario RCP 8.5 of approx. 300 per timeframe	• Heat accumulation is expected to steadily raise under emissions scenario RCP 4.5 approx. energy demand increase of 200 per time frame	• The southwest region is expected to see a sharper heat accumulation under emissions scenario RCP 8.5 of approx. 250 per timeframe	• Both regions are projected to see a similar increase of heat accumulation under both emission scenarios

Variable	Definition	Northeast RCP 4.5	Northeast RCP 8.5	Southwest RCP 4.5	Southwest RCP 8.5	Overall observations
		approx. energy demand increase of 200 per time frame				
gsl	Growing season length: Annual count between the first span of at least 6 days with daily mean temperature >5°C and the first span after July 1st of 6 days with daily mean temperature <5 °C.[103]	• Increases to the growing season length across all timeframes. • Minimal differences between RCP4.5 and 8.5	• Increases to the growing season length across all timeframes. • Minimal differences between RCP4.5 and 8.5	• Increases to the growing season length across all timeframes. More significant increase for RCP8.5 after 2050	• Increases to the growing season length across all timeframes. Less significant increase when compared to RCP8.5 after 2050	• Increases to the growing season length in expected in both scenarios and regions. • The increase is predicted to be quite steady expect for a sharp increase in south-western ACT after 2050
hurs	Relative humidity at 2 m above the surface	• Across the time periods, there is a slight downward trend for the relative humidity which is mainly experienced in summer. • By 2090, it is expected that the average annual relative humidity will reduce by ~1%	• Across the time periods, there is a slight downward trend for the relative humidity which is mainly experienced in summer. This reduction is greater in the RCP 8.5 scenario • By 2090, it is expected that the average annual relative humidity will reduce by ~3%, a greater reduction than RCP 4.5	• Across the time periods, there is a slight downward trend for the relative humidity which is mainly experienced in summer • By 2090, it is expected that the average annual relative humidity will reduce by ~1%	• Across the time periods, there is a slight downward trend for the relative humidity which is mainly experienced in summer. This reduction is greater in the RCP 8.5 scenario • By 2090, it is expected that the average annual relative humidity will reduce by ~3%, a greater reduction than RCP 4.5	• A reduction in relative humidity should be expected in both regions and scenarios. • In both regions, it should be expected that the annual average relative humidity will reduce by ~1% by 2090 for RCP 4.5 and ~3% for RCP 8.5
huss	Near-Surface Specific Humidity	• Steady slight increase in specific humidity. E.g., the baseline for January is 0.0082 which increases to 0.0093 in 2090	• Steady more dramatic increases in specific humidity compared to RCP 4.5. E.g., the baseline for January is 0.0082 which increases to 0.0105 in 2090	• Steady slight increase in specific humidity. E.g., the baseline for January is 0.008 which increases to 0.0091 in 2090	• Steady more dramatic increase in specific humidity compared to RCP 4.5. E.g., the baseline for January is 0.008 which increases to 0.0102 in 2090	• Specific humidity is projected to only increase slightly in all scenarios to 2090 • In both regions, RCP 8.5 caused a greater increase in specific humidity by ~0.0011 when compared to RCP 4.5
mrso	Total Soil Moisture Content	• Less significant decreases in soil moisture content than under RCP 8.5 e.g. decrease is ~100mm under RCP8.5 between baseline and 2090 compared to ~40mm under RCP 4.5	• Decrease in total soil moisture content across timeframes, e.g. 546mm in Nov baseline compared to 436mm in Nov 2090. • Most significant decrease seen in months of Nov, Dec & Jan	• Less significant decreases in soil moisture content than under RCP 8.5 e.g. decrease is ~100mm under RCP 8.5 between baseline and 2090 compared to ~30mm under RCP4.5	• Decrease in total soil moisture content across timeframes, e.g. 627mm in Nov baseline compared to 481mm in Nov 2090. • Most significant decrease seen in months of Nov, Dec & Jan.	• RCP 4.5 & RCP 8.5 scenarios have a similar effect on both regions. • The soil moisture content in both regions is projected to decrease for each time period with the months of Nov-Jan most effected. • In North-eastern ACT, by 2090, if scenario RCP 4.5 is experienced instead of RCP 8.5, soil moisture content will be projected to be ~40 mm better off.
pr_bc_	Bias corrected precipitation	• Apart from the month of January, there is a slight downward trend on the amount of precipitation per month	• Apart from the month of January, there is a slight downward trend on the amount of precipitation per month • When comparing RCP 8.5 to RCP 4.5, the RCP 8.5 scenario experiences slightly less precipitation in every month by 2090	• Apart from the month of January, there is a slight downward trend on the amount of precipitation per month	• Apart from the month of January, there is a slight downward trend on the amount of precipitation per month • When comparing RCP 8.5 to RCP 4.5, the RCP 8.5 scenario experiences slightly less precipitation in every month by 2090	• A slight downward trend of precipitation per month is projected. This downward trend is exacerbated in the RCP 8.5 scenario compared to the RCP 4.5 scenario in both regions
r20mm	Annual count of days when daily precipitation amount on day ≥ 20 mm	• Projected days above 20 mm of rain is projected to increase in summer and decrease in winter by 2080-99 compared to 1990-2009	• Projected days above 20 mm of rain is projected to increase in summer and decrease in winter by 2080-99 compared to 1990-2009 • When compared to RCP 4.5, winter months will experience less days above 20mm and summer months will experience more days above 20mm	• Projected days above 20 mm of rain is projected to increase in summer and decrease in winter by 2080-99 compared to 1990-2009	• Projected days above 20 mm of rain is projected to increase in summer and decrease in winter by 2080-99 compared to 1990-2009 • When compared to RCP 4.5, winter months will experience less days above 20mm and summer months will experience more days above 20mm	• Both regions are projected to experience more days above 20 mm in summer and less days above 20 mm in winter. • When comparing RCP 4.5 and RCP 8.5 scenarios, the effects are heighten will drier winters and wetter summers likely
r95p	Very wet days rainfall: Annual total precipitation when daily rainfall > 95th percentile.	• Increase in the annual no. of days with precipitation above 95th percentile in 2030 timeframe compared to baseline (and greater increase than under RCP8.5), then decreases are seen until 2090 where it starts to increase again.	• Increase in the annual no. of days with precipitation above 95th percentile in 2030 timeframe compared to baseline, however after 2030, no. of days fluctuates with both decreases and	• Increase in the annual no. of days with precipitation above 95th percentile in 2030 timeframe compared to baseline and then decreases after 2030 in subsequent timeframes	• Fluctuations in no. of days with precipitation above 95th percentile. No. of days increases by 30 days in 2030 compared to baseline however then decreases by 81 days in 2050 before	• North-eastern is projected to have a steadier increase while southwest is projected to have significant fluctuations across timeframes

[103] US EPA. (2022). *Climate Change Indicators: Length of Growing Season.* https://www.epa.gov/climate-indicators/climate-change-indicators-length-growing-season

Variable	Definition	Northeast RCP 4.5	Northeast RCP 8.5	Southwest RCP 4.5	Southwest RCP 8.5	Overall observations
			increases of approx. 2-4 day from 2030-2090		increasing and decreases again in the subsequent timeframes.	
rx5day	Monthly maximum consecutive 5-day precipitation	• **Annual trend =** fluctuations across timeframes. Increases are projected in 2030 timeframe followed by decreases and then increases again in 2090 timeframe. • **Monthly trend =** overall trend similar to baseline, more significant differences are seen under RCP8.5	• **Annual trend =** Steady decrease across timeframes (compared to RCP4.5 where fluctuations across timeframes occur). • **Monthly trend =** overall trend of precipitation is similar to baseline. Differences include: • Higher precipitation in January across all timeframes when compared to the baseline. • Lower precipitation in June – August, particularly for 2090 timeframe. • Lower precipitation in Oct – Nov across all timeframes.	• **Annual trend =** fluctuations across timeframes. Increases are projected in 2030 timeframe followed by decreases and then increases again in 2090 timeframe. • **Monthly trend =** overall trend similar to baseline except for December & January where increased precipitation is projected.	• **Annual trend =** decrease across timeframes (compared to RCP4.5 where fluctuations across timeframes occur). No changes between 2070 to 2090 timeframes. • **Monthly trend =** overall trend of precipitation is similar to baseline. Differences include: • Higher precipitation in January and December across all timeframes when compared to the baseline. • Lower precipitation in June – August, across all timeframes. • Lower precipitation in Oct – Nov across all timeframes	• Higher precipitation projected in January and December across all timeframes when compared to the baseline. • Relatively similar trend across other months. • No significant differences between regions in terms of annual and monthly trends • Significant fluctuations across timelines under RCP4.5
sdii	Simple precipitation intensity index = mean precipitation in wet days	• Fluctuations across timeframes. sdii projected to increase in 2030, decrease in 2050 and 2070 and increase again in 2090.	• Overall projected increases (except for between 2030 and 2050 timeframe where sdii is not projected to change). • Very different to southwest region	• Significant fluctuations across timeframes. sdii projected to increase significantly in 2030, decrease slightly in 2050, decrease significant in 2070 and then increase significantly in 2090.	• Fluctuations across timeframes. sdii projected to increase in 2030, decrease in 2050 and 2070 and increase again in 2090. • Very different to northwest region	• Under RCP8.5 northeast, there are projected increases in sdii (except for between 2030 and 2050 timeframe where sdii is not projected to change). • Under RCP4.5 northeast and both scenarios under southwest, there are fluctuations projected for sdii.
spi	Standardised Precipitation Index: mildly dry (0>SPI>-0.99), moderately dry (-1.0>SPI>-1.49), severely dry (-1.5>SPI>-1.99) and extremely dry conditions (SPI less than -2.0).	• SPI is expected to trend towards drier conditions from 2020 onwards. From the baseline of approximately 0.3 to an SPI of approximately -0.2 (mildly dry) across the year	• Under the RCP 8.5 scenario, a dramatic decrease in SPI between all timeframes should be expected. • Between 2050 and 2070 the SPI is expected to drop from roughly -0.1 across the year to approximately -0.4 • By 2080, it is expected that the SPI will be approximately -0.6 across the year (mildly dry)	• SPI is expected to trend towards drier conditions from 2020 onwards. From the baseline of approximately 0.2 to an SPI of approximately -0.4 (mildly dry) by 2060 across the year	• Under the RCP 8.5 scenario, a dramatic decrease in SPI between all timeframes should be expected. • By 2080, it is expected that the SPI will be approximately -1 across the year (mildly dry)	• SPI is expected to decrease more substantially in the South-western region compared to the North-eastern region • If RCP 4.5 scenario can be followed, SPI is expected to improve by roughly 0.6 in Southwestern ACT and 0.4 in North-eastern ACT
tasmax	Daily Maximum Near-Surface Air Temperature	• **Monthly =** Projected increases across all timeframes and months. Increases are by approx. 0.5°C between timeframes. • **Annual =** projected increases across all timeframes. Almost ~2.5°C increase between 2090 and baseline.	• **Monthly =** Projected increases across all timeframes and months. Increases are by approx..1°C between timeframes. • **Annual =** projected increases across all timeframes. Almost ~5°C increase between 2090 and baseline. Similar trend to RCP 4.5	• **Monthly =** Projected increases across all timeframes and months. Increases are by approx. 0.5°C between timeframes. • **Annual =** projected increases across all timeframes. Almost ~2.5°C increase between 2090 and baseline.	• **Monthly =** Projected increases across all timeframes and months. Increases are by approx.1°C between timeframes. • **Annual =** projected increases across all timeframes. Almost ~5°C increase between 2090 and baseline. Similar trend to RCP 4.5	• Observations between regions are very similar • **Monthly =** Projected increases across all timeframes and months. Increases are by approx..1°C between timeframes. • **Annual =** projected increases across all timeframes. Almost ~5°C increase between 2090 and baseline.
tasmin	Daily Minimum Near-Surface Air Temperature	• **Monthly =** Projected increases across all timeframes and months. Increases are by approx. 0.5°C between timeframes, however greatest increases occur during Jan & Feb with approx. 1-2°C differences. • **Annual =** projected increases across all timeframes. Approx. ~3°C increase between 2090 and baseline. Less significant increase under RCP 4.5 when compared to RCP 8.5	• **Monthly =** Projected increases across all timeframes and months. Increases are by approx..1°C between timeframes. • **Annual =** projected increases across all timeframes. Approx. ~4°C increase between 2090 and baseline. More significant increase under RCP 8.5	• **Monthly =** Projected increases across all timeframes and months. Increases are by approx..0.5°C between timeframes, however greatest increases occur during Jan & Feb with approx. 1-2°C differences. • **Annual =** projected increases across all timeframes. Approx. ~2°C increase between 2090 and baseline. Less significant increase under RCP 4.5 when compared to RCP 8.5	• **Monthly =** Projected increases across all timeframes and months. Increases are by approx..1°C between timeframes, however greatest increases occur during Jan & Feb with approx. 2°C differences. More significant increase under RCP 8.5 • **Annual =** projected increases across all timeframes. Approx. ~4°C increase between 2090 and baseline. More significant increase under RCP 8.5	• Observations between regions are very similar • **Monthly =** Projected increases across all timeframes and months. Increases are by approx. 0.5-1°C between timeframes. • **Annual =** projected increases across all timeframes. Approx. ~4°C increase between 2090 and baseline for both regions.
tmlt5	mean temperature of at least 5 °C: (Number of days	• **Monthly =** Projected decreases across all timeframes.	• **Monthly =** Projected decreases across all timeframes.	• **Monthly =** Projected decreases across all timeframes however after 2050,	• **Monthly =** Projected decreases across all timeframes.	• Projected decreases across all timeframes and regions.

Variable	Definition	Northeast RCP 4.5	Northeast RCP 8.5	Southwest RCP 4.5	Southwest RCP 8.5	Overall observations
	when daily mean temperature < 5 °C.)	• Most significant decrease between timeframes to occur is at the 2030 timeframe (10 days at baseline, 7 days in 2030), for the month of July • After 2050, decrease plateaus whereas under RCP 8.5 decrease continues until almost no days per month under 5°C under 2090. • **Annual =** projected decrease across each timeframe however not as significant as under RCP 8.5 after 2050 timeframe.	• Most significant decrease between timeframes to occur is at the 2030 timeframe (10 days at baseline, 6 days in 2030), for the month of July • By 2090, almost no days per month with mean temperatures lower than 5°C expected. • **Annual =** projected decrease by ~10C across each timeframe. By 2090, almost no days per month with mean temperatures lower than 5°C expected.	decrease plateaus whereas under RCP 8.5 decrease continues significantly • **Annual =** projected decrease across timeframes however plateaus after 2070.	• Decreases not as significant as northeast region. • Northeast region projections suggest almost no days per month with mean temperatures lower than 5°C however for southwest region this is not the case – 5 days expected in 2090 (compared to 25 days at baseline), for the month of July • **Annual =** projected decrease by ~20°C across each timeframe. By 2090, approx. ~20 days per month with mean temperatures lower than 5°C expected compared to ~80°C at baseline.	• Most significant decrease is for the northeast region for 2030 timeframe (10 days at baseline, 6 days in 2030), for the month of July. By 2090, almost no days per month with mean temperatures below 5°C
tnlt2	The number of days when minimum temperature is < 2 °C.	• Projected decreases across all timeframes however not as significant as under RCP 8.5 • Average Number of Days when TN < 2 °C is projected to be 47 days in 2090 compared to 84 days at baseline. • Very similar trend to southwest region	• Projected decreases across all timeframes by approx.. 10-20 days. • Average Number of Days when TN < 2 °C is projected to be 23 days in 2090 compared to 84 days at baseline. • Very similar trend to southwest region	• Projected decreases across all timeframes by approx.. 10-20 days. • Average Number of Days when TN < 2 °C is projected to be 104 days in 2090 compared to 149 days at baseline. • Very similar trend to northeast region	• Projected decreases across all timeframes by approx.. 10-30 days. • Average Number of Days when TN < 2°C is projected to be 60 days in 2090 compared to 149 days at baseline. • Very similar trend to northeast region	• Projected decreases across all timeframes • Very similar trend between regions
tnm	The mean daily minimum temperature.	• **Monthly =** projected increase in mean daily temperatures across all months and timeframes however not as significant as under RCP 8.5 • **Annual =** projected increases across all timeframes however not as significant as under RCP 8.5 • Increase of 1.93°C between 2090 and baseline	• **Monthly =** projected increase in mean daily temperatures across all months and timeframes. • Increase of approx.~3°C between 2090 and baseline • **Annual =** projected increases across all timeframes. • Increase of 3.89°C between 2090 and baseline	• **Monthly =** projected increase in mean daily temperatures across all months and timeframes. • **Annual =** projected increases in all time periods • increase of 1.93°C from baseline to 2090	• **Monthly =** projected increase in mean daily temperatures across all months and timeframes. • Projected increase means that there will be no longer a mean daily min temp of 0°C during July under 2070 and 2090 timeframes (compared to baseline 1°C) • **Annual =** projected increases in all time periods • increase of 3.91°C from baseline to 2090	• Similar increases are expected in both regions. • If the RCP 8.5 scenario is followed, an increase of approximately 3.9°C to the minimum should is projected • If the RCP 4.5 scenario is followed, an increase of approximately 1.9°C to the minimum should is projected. A reduction of 2°C when comparing to the expected increase from the RCP 8.5 scenario
tx90p	Percentage of days when daily maximum temperature > 90th percentile	• Projected increase of percentage of days with daily max temp above 90th percentile. 25% in 2090 compared to baseline of 10%	• Significant projected increase of percentage of days with daily max temp above 90th percentile. 50% in 2090 compared to baseline of 10%	• Projected increase of percentage of days with daily max temp above 90th percentile. ~25% in 2090 compared to baseline of 10%	• Significant projected increase of percentage of days with daily max temp above 90th percentile. 50% in 2090 compared to baseline of 10% • Upper end = in 2090 upper end is 60% compared to baseline of 10%	• Similar trend between regions • Significant projected increase of percentage of days with daily max temp above 90th percentile.
txge35	daily maximum temperature of at least 35 °C	• Projected annual increases to occur however after 2070 plateaus.	• **Monthly =** Projected increases across all timeframes. Greatest increases to occur in month of January. ~4.5 days in January with max temp greater than 35°C in 2050 compared to baseline of 2 days. • **Annual =** Projected annual increases to occur. More than doubling in 2050 where ~11 days per year with max temp greater than 35°C C to occur compared to baseline of 5 days.	• Steady increases projected for RCP 4.5, compared to significant increases under RCP 8.5. Plateaus after 2070.	• **Monthly =** Projected increases across all timeframes. Greatest increases to occur in month of December and January. ~2.5 days in January with max temp greater than 35°C in 2050 compared to baseline of <0.5 days • **Annual =** Projected annual increases to occur. ~8 days per year with max temp greater than 35°C to occur compared to baseline of 1 day.	• Similar trends observed between regions. Greatest increases to occur in months Jan & Dec.
txm	The mean daily maximum temperature.	• Projected increases across all timeframes and months. Increases are less significant than under RCP 8.5	• Projected increases across all timeframes and months. Increases are approx. 1°C between timeframes	• Projected increases across all timeframes and months. Increases are less significant than under RCP 8.5	• Projected increases across all timeframes and months. Increases are approx. 1°C between timeframes	• Similar trends observed between regions. • Projected increases across all timeframes and months.

Variable	Definition	Northeast RCP 4.5	Northeast RCP 8.5	Southwest RCP 4.5	Southwest RCP 8.5	Overall observations
						• Increases under RCP 4.5 are less significant than under RCP 8.5
txx	Monthly maximum value of daily maximum temperature	• Projected increases across all timeframes and months. Increases are approx. 0.5°C between timeframes • An increase of approximately 2.3 °C is expected from the baseline to 2090	• Projected increases across all timeframes and months. Increases are approx. 1°C between timeframes • An increase of approximately 5 °C is expected from the baseline to 2090	• Projected increases across all timeframes and months. Increases are approx. 0.5°C between timeframes • An increase of approximately 5 °C is expected from the baseline to 2090	• Projected increases across all timeframes and months. Increases are approx. 1°C between timeframes • An increase of approximately 2.3 °C is expected from the baseline to 2090	• The daily maximums are expected to increase roughly similarly between both regions • When comparing the RCP 4.5 and 8.5 scenarios, the increase between time periods is nearly double. By 2090, this results in an increased average daily maximum of approx. 2.7 °C if RCP 8.5 is followed rather than RCP 4.5
wsdi	Warm spell duration index: annual count of days with at least 6 consecutive days when daily maximum temperature > 90th percentile	• A steady increase in warm spell duration is projected from the baseline to 2090 from a baseline of 3.7 to 24.4 by 2090	• A steady increase in warm spell duration is projected from the baseline to 2050. • From 2050, it should be expected that the warm spell duration increases more significantly. From approx. 41.4 to 98.04 between 2070 and 2090	• A steady increase in warm spell duration is projected from the baseline to 2090 from a baseline of 3.9 to 28.72 by 2090	• A steady increase in warm spell duration is projected from the baseline to 2050. • From 2050, it should be expected that the warm spell duration increases more significantly. From approx. 42.8 to 99.9 between 2070 and 2090	• Both regions experience similar conditions under both scenarios. However, warm spell duration is expected to increase slightly more in the southwest region in an RCP 4.5 scenario • In both regions, in the RCP 8.5 scenarios, an increased growth in warm spell duration is expected from 2050 onwards

Appendix D

NARCliM Data

Please refer to the NARCliM Data Excel workbook under separate copy.

Appendix E

Desktop review – Climate change impacts and adaptation responses

Appendix E Climate change impacts and adaptations desktop reviews

Climate change impacts: desktop review summary

Environmental

Drought has huge impacts on Australia's environment and agriculture industry, causing damage to arable land, including erosion and loss of topsoil and reduced food and fibre production. Environmental impacts identified in the literature include:

- Reduced crop, horticulture, pastures and fibre production
- Reduced groundcover and increased soil erosion and loss of nutrients during rainfall during and after droughts
- Increased flammability of vegetation (native vegetation, crops, pastures) and landscapes
- Increased frequency and intensity of bushfires, increased length of bush fire seasons, increased prevalence of extreme and uncontrolled bushfires, increased overnight temperatures which hamper firefighting efforts
- Decreased surface and ground water availability and quality
- Reduced soil moisture, increased vapour pressure deficit and increased aridity leading to greater demand for surface and ground water for stock and domestic purposes and by native fauna
- Loss of terrestrial, riparian and in-stream habitat for native fauna and flora due to drying
- Loss of native fauna and flora due to loss of food sources, available water, habitat and safe harbour from predators and temperatures (minimum and maximum and heatwaves) to allow recovery from heat.[104]
- Narrower windows for planting pasture and crop species and native vegetation for environmental restoration and shade
- Reduced predictability of key planting and harvesting times, with less room for error
- Reduced average returns and increased variability of returns (assuming no changes of practice)
- Reduction in soil health, including reduced soil carbon, which reduces water holding capacity of soils
- Potentially reduced livestock herds, and reduced hay and grain stocks
- Reduction in livestock health
- Altered weed, pest, and disease ranges resulting in loss of agricultural produce. [105]
- Stress on biodiversity – during the Millennium Drought, numbers of waterbirds, fish and aquatic plants declined across the Murray–Darling Basin. Established drought-tolerant trees such as the river red gum were stressed by the prolonged dry period.[106]
- Reduction in water availability for irrigation and access to irrigation water,

Economic

[104] Climate Council, (2019). *The Facts About Bushfires and Climate Change*, https://www.climatecouncil.org.au/not-normal-climate-change-bushfire-web/
[105] Department of Agriculture, Fisheries and Forestry. (2008). *Climate change impacts on pest animals and weeds.* https://www.climatekelpie.com.au/Files/FactSheet12.pdf
[106] AdaptNSW (2022) *Climate change impacts on drought.* https://www.climatechange.environment.nsw.gov.au/drought#:~:text=Drought%20has%20huge%20impacts%20on%20Australia's%20agriculture%20industry%2C%20causing%3A,leading%20to%20shortages%20in%20supply

Drought has national negative economic impacts. Prolonged drought pushed national real Gross Domestic Product (GDP) to 0.7 per cent or more below base in 2018–2019 and 2019–2020.[107] Drought also has a substantial negative economic impact on farmers and others employed in the agricultural sector through reduced income and increased costs. [108]

Due to the reduced carrying capacity of land in drought, farmers must sell stock to conserve the natural assets of the farm (i.e. maintaining soil health, waterways, groundcover), or purchase fodder to feed stock. The reduction in stock leads to lower income, as farmers are often selling when prices are low at the beginning of drought. Fodder prices are often high, because of drought and shortages of fodder. Farmers often need to source feed from SA, WA or Victoria.

During the 2017-2020 drought, stock prices remained high, ameliorating the economic impact of needing to sell stock going into a drought. However, the stock prices also remained high during drought, meaning that when the carrying capacity of land increased after drought, and farmers were able to support more stock on their lands, buying back stock was expensive.

Other farm costs impacted by drought and fires include higher costs of fertilisers, farm chemicals such as herbicides, machinery parts for farm machinery, and fencing supplies etc. Supply chains of these products are affected by drought and fires. Additionally, tradespeople to undertake work on farms can become more expensive during and after the drought.

Across Australia, farm profitability and incomes of larger farms are typically less sensitive to drought than small farms. Similarly, farms with younger (less than 50 years of age) managers are also generally less sensitive to drought For smaller farms, profits are highly sensitive to drought, but household income is relatively stable due to their relatively high off-farm incomes.

Social

Drought causes negative mental health impacts, and those who are most impacted are farmers and farm workers. More severe impacts on agricultural due to drought result in greater mental health impacts. [109]

There is also evidence that groups that are not employed in agriculture are adversely affected, with a widespread loss of services in drought-affected areas, and some marginal labour market groups experiencing poor employment outcomes in a drought-affected local economy[108]. These impacts are ameliorated to some extent, due to the proximity of Canberra, and the prevalence of off-farm income amongst ACT rural landholders. [A]

Governance

With increased incidence of extreme events, there is an increased reliance on the support systems provided by governments in times of hardship. In some cases, well-intentioned policies can disadvantage farmers who have been better prepared—or luckier—than farmers who are provided assistance and relief, diluting management incentives and raising difficult equity issues[110].

In the ACT, many rural landholders are not considered as having viable farming operations by ABARES and the ATO and are therefore not eligible for benefits targeted at farmers.

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[107] Wittwer, G., & Waschik, R. (2021). *Estimating the economic impacts of the 2017–2019 drought and 2019–2020 bushfires on regional NSW and the rest of Australia.* https://onlinelibrary.wiley.com/doi/abs/10.1111/1467-8489.12441
[108] Edwards, B., Gray, M., & Hunter, B. (2018). *The social and economic impacts of drought.* https://onlinelibrary.wiley.com/doi/abs/10.1002/ajs4.52
[109] Edwards, B., Gray, M., & Hunter, B. (2014*). The Impact of Drought on Mental Health in Rural and Regional Australia.* https://link.springer.com/article/10.1007/s11205-014-0638-2
[110] Intergovernmental Panel on Climate Change, 2014. *Climate Change 2014: Impacts, Adaptation and Vulnerability.* Page 5. https://www.ipcc.ch/site/assets/uploads/2018/03/ar5_wgII_spm_en-1.pdf

Impact summary table

Table 17 summarises the impacts identified by both stakeholder engagement (workshops, interviews and the survey) and the desktop literature review. Priority impacts were determined based on their exposure and sensitivity.

Table 16 Exposure and sensitivity legend

Exposure		Sensitivity	
High	High degree of exposure e.g. impact will affect a very large proportion of enterprises and communities and have a significant impact on most impacted farm households.	**High**	High degree of sensitivity e.g. high financial and productivity impacts (for example if the farming practice has high reliance on what is being impacted).
Medium	Medium degree of exposure e.g. impact will affect multiple (and different) farming systems and communities, and the impact will be moderately significant.	**Medium**	Medium degree of sensitivity e.g. medium financial and productivity impacts (for example if the farming practice has moderate reliance on what is being impacted).
Low	Low degree of exposure e.g. impact will affect only a few farming systems and communities and the impact won't be significant.	**Low**	Low degree of sensitivity e.g. low financial and productivity impacts (for example if the farming practice has low reliance on what is being impacted).

Exposure	Sensitivity
High	High

Exposure	Sensitivity
High	High

Table 17 Impact summary table

Domain	Impact	Climate variable and future projections	Impact description/examples	Prioritisation justification	
Envi				Exposure	Sensitivity

Domain	Impact	Climate variable and future projections	Impact description/examples	Prioritisation justification
	Reduced water availability [A, B, D]	Decreased rainfall, increased temperatures, reduced soil moisture and a decreasing SPI are all driving this impact. Future trends include: • Rainfall will likely decrease in winter and spring, but increase in summer • Decreasing average annual rainfall • Increased consecutive days without rainfall	• Reduced water availability for livestock water and irrigation [A, B, D] • Poor water quality and challenges maintaining the quality of water resources [A] • Depletion of on-farm water storage (e.g. dams, water tanks) [B] • Transition to alternative water sources e.g. town water, and bore water [B] • Reduction in production and yield for irrigated crops [D] • Reduced water quality affecting quality of food crops [D] • Reduction in quality of water stored on-farm [B]	**High** | **High** Reduced water availability because of a changing climate will have far-reaching impacts across both grazing enterprises and other agricultural sectors, in the ACT such as horticulture. A decrease in available water can cause production and yield to decrease impacting high value farms. Given that all farms are likely to be affected by this impact (high exposure) and all farms are sensitive to this impact (high sensitivity), this is categorised as a priority impact.
Environment ★	**Increased weeds and pests**	Increased temperatures are driving this impact. Future trends include: • Decreasing average annual rainfall and changing seasonality of rainfall • Increases to both average minimum and maximum daily temperatures	• Greater occurrence and incidence of weeds and pests during period of droughts [A, D] • Weed infestations in recovery phase following periods of drought [A] • Increased weed spreading events (e.g. flooding, bushfire, winds, native and pest animals) [D] • Increased costs of weed management (weeds are one of the most costly agricultural pests [D]) • Reduction in agricultural productivity and damage to the environment and natural resources [D]	**Exposure** | **Sensitivity** **High** | **High** Climate change will affect the spread and competitiveness of weeds and pests in the ACT. Both primary production industries and other agricultural enterprises are subject to these infestations and with greater climatic variations, pest management will become more important. Producers may need to increase pest surveillance, especially as pest life cycles change and response to climate change. The exposure and sensitivity are high due to the significant financial impact weed have, both in terms of control and lost productivity.
Economic *	**Reduced carrying**	Increased temperatures, reduced soil moisture and a	• Reduced pasture and native grass productivity; reduced groundcover	**Exposure** | **Sensitivity** **High** | **High**

Domain	Impact	Climate variable and future projections	Impact description/examples	Prioritisation justification
	capacity of land	decreasing SPI are all driving this impact. Future trends include: • Increases to both average minimum and maximum daily temperatures • Decreasing soil moisture content	• Reduced stocking rates [A] • Long recovery times from destocking [A] • Increased costs to buy-in feed where pastures are unable to produce enough biomass (compounded by increased costs of feed during drought periods) [B]	Primary production industries in the ACT have both high exposure and high sensitivity to managing appropriate stock levels due to impacts of drought making it challenging to recover from times of destocking and the increasing costs to buy-in feed.
Environment ★	**Reduced on-farm biodiversity**	Increased temperatures, increased extreme heat days, reduced soil moisture and a decreasing SPI are all driving this impact. Future trends include: • Increases to both average minimum and maximum daily temperatures • Increasing number of days above 35°C • Decreasing soil moisture content	• Increase in total grazing pressure from a combination of native herbivores and farm stock which impacts on negatively on other native species and their habitat and food sources [A] • Added pressures to support native wildlife during periods of drought [A] • Damage to ecosystem functioning can have flow-on affects to farm health and productivity. Healthy ecosystems benefit farms by controlling soil erosion and maintaining the quality of water for farm use [B, D]	**Exposure**: **High** / **Sensitivity**: **High** Reduced biodiversity loss leaves agricultural systems more vulnerable to threats such as pests, pathogens continued impacts from climate change. The exposure and sensitivity are high due to biodiversity loss reducing ecosystem functioning, resulting in less productive farms and added pressure for farmers to support native wildlife.
Social *	**Reduced wellbeing of farming community**	Decreased rainfall, increased temperatures, increased extreme heat days, reduced soil moisture and a decreasing SPI are all driving this impact. Future trends include: • Increases to both average minimum and maximum daily temperatures • Increasing number of days above 35°C	• Reduced health and mental wellbeing from recent pressures in the form of climate change, drought, pest and disease outbreaks and economic rationalisation [D] • Reduced wellbeing due to working long hours, having physically demanding work and often being isolated socially and geographically from services [D] • Increased concerns about bushfires, poor experience with evacuations [A]	**Exposure**: **High** / **Sensitivity**: **High** Climate change may increase the risk of mental health impacts among farmers as they face the hardships of practising agriculture along the ongoing impacts of greater climatic variations. The sensitivity and exposure are high as these impacts are making farmers and their agricultural systems more vulnerable.

Domain	Impact	Climate variable and future projections	Impact description/examples	Prioritisation justification	
		• Decreasing soil moisture content	• Increased exposure to challenging working conditions (e.g. days with temps exceeding 35°C) • Financial management pressures during periods of lower revenues and/or increased capital expenditure and operational expenditure.		
Environment ✶	**Increased occurrence of natural disasters**	Decreased rainfall and increased temperatures are driving this impact. Future trends include: • Increases to both average minimum and maximum daily temperatures Decreasing average annual rainfall and changing seasonality of rainfall	• Extreme events, especially floods and droughts, can harm crops and reduce yields [D] • Loss of biodiversity in drought induced bushfires [D] • Erosion following bushfires, due to loss of stabilising soil features. This can result in reduced water quality, and impact riparian habitat. [D] • More occurrence of fluctuating and compounding extremes e.g. bushfire events followed by flood events [A]	**Exposure** **High** The frequency, intensity, spatial extent, duration and timing of extreme weather events is expected to increase. The impact of this changing climate is already being felt by the agricultural sector and events including periods of drought are expected to increase.	**Sensitivity** **High**
Environment and Economic	**Shifts in timing of farm activities/operations**	Decreased rainfall, increased temperatures, increased extreme heat days, reduced soil moisture and a decreasing SPI are all driving this impact. Future trends include: • Increases to both average minimum and maximum daily temperatures • Increasing number of days above 35°C Decreasing soil moisture content	• Compressed timing for picking [B] • Increasing constraints with staff availability [B] • Change in joining, weaning, sale and other stock management decisions to avoid projected feed gaps Winter, Spring	**Exposure** **Medium**	**Sensitivity** **Medium**

Domain	Impact	Climate variable and future projections	Impact description/examples	Prioritisation justification	
Environment	**Damage to assets and infrastructure**	Increased temperatures and increased extreme heat days are driving this impact. Future trends include: • Increases to both average minimum and maximum daily temperatures • Increasing number of days above 35°C	• Loss of stock, crops, and infrastructure (e.g. fences due to increased fire risk) [D] • Bushfires can reduce water availability through damage to water infrastructure [D] • Reduced soil health from soils becoming increasingly hydrophobic after fires which can take 6–7-years to recover post bushfire events [B]	**Exposure** **Medium**	**Sensitivity** **Medium**
Environment	**Increased crop sensitivity**	Reduced soil moisture and a decreasing SPI are driving this impact. Future trends include: • Decreasing soil moisture content	• Cropping farms are more sensitive to drought than livestock farms [D] • Cropping farms are experiencing large, immediate declines in revenue during drought years due to crop yields being directly linked to weather conditions [D] • Cropping trends are expected to be similar for landholders growing fodder for livestock feed	**Exposure** **Medium**	**Sensitivity** **Medium**
Environment	**Heat stress on livestock**	Increased temperatures and increased extreme heat days are driving this impact. Future trends include: • Increases to both average minimum and maximum daily temperatures • Increasing number of days above 35°C	• Livestock experience heat stress resulting in reduced appetites, less desire to breed, increased animal stress and significant productivity loss for the livestock industry [A, D] • Heat stress can be compounded by poor stock water quality	**Exposure** **High**	**Sensitivity** **Medium**
Environ ment	**Erosion of soil and crop damage**	Changing rainfall is driving this impact. Future trends include:	• Extreme rainfall events leading to erosion of soil and damage to crops [D]	**Exposure**	**Sensitivity**

Domain	Impact	Climate variable and future projections	Impact description/examples	Prioritisation justification	
		• Decreasing average annual rainfall and changing seasonality of rainfall • Increasing intense rainfall events post drought	• Bushfire smoke can taint fruit and vegetable crops, with wine grapes being particularly susceptible [B,D] • Despite rain events, the soil may remain dry due to its inability to soak up as much water during an extreme rainfall event [D]	**High**	**Medium**
Environment	**Unsuitable land for agricultural enterprises**	Decreased rainfall and increasing temperatures are driving this impact. Future trends include: • Rainfall will likely decrease in winter and spring, but increase in summer • Decreasing average annual rainfall • Increased consecutive days without rainfall • Increases to both average minimum and maximum daily temperatures • Increasing number of days above 35°C	• Longer droughts and harsher fire weather causing crop stress and attracting new pests that thrive in warmer temperatures can result in land becoming unsuitable for certain agricultural enterprises [D]	**Exposure** **Medium**	**Sensitivity** **High**
Economic	**Increased need to import feed**	Reduced soil moisture is driving this impact. Future trends include: • Decreasing soil moisture content	• Increased need to import stock feed leading to increased feed and freight costs and greater requirements to source feed from Western Australia or Tasmania [A]	**Exposure** **Medium**	**Sensitivity** **Low**
Economic and Governanc	**Financial vulnerability**	All climate hazards including decreased rainfall and increasing temperatures are driving this impact. Future trends include:	• Greater need for financial assistance leading to increased need to access grants and increase off-farm income [A]	**Exposure**	**Sensitivity**

Domain	Impact	Climate variable and future projections	Impact description/examples	Prioritisation justification	
		• Decreasing average annual rainfall • Increases to both average minimum and maximum daily temperatures • Increasing number of days above 35°C	• The least profitable years for farmers tend to be drought years with unfavourable prices such as in 2016-17. Nationally, average farm returns decreased in 2018-19 in drought-affected regions [D] • Increased costs for feed, fuel and fertilisers [C]	**Medium**	**Medium**
Social	**Safety and reduced employment**	Increased temperatures and increased extreme heat days are driving this impact. Future trends include: • Increases to both average minimum and maximum daily temperatures • Increasing number of days above 35°C	• Heat stress can reduce labour capacity in agriculture [D] • Heat related staff safety concerns [B] • Heat stress can reduce labour capacity in agriculture [D]	**Exposure** **Medium**	**Sensitivity** **Medium**

*Legend: * priority impacts based on frequency of impact being cited by stakeholders and in literature. [A] identified through workshops. [B] identified through interviews. [C] identified by survey. [D] literature review.*

Climate change adaptation actions: summary of adaptation actions

Table 18 shows how the actions identified address the impacts identified in this work. By mapping the actions against the impacts, it highlights areas where ACT landholder communities can expect to see the greatest effect and opportunity to build resilience to climate change. The dot represents where there is a relationship between the action and impact, e.g. land management can be seen to address ten impacts. Overall , land management, enterprise selection, water management and stock management can be observed to address the greatest number of impacts.

Table 18 Applicability of action to address impacts

	Impacts														
Actions	Reduced water availability	Increased weeds and pests	On-farm biodiversity	Stock management	Increased occurrence of natural disasters	Damage to assets and infrastructure	Unsuitable land for agricultural enterprises	Shifts in timing of farm activities/operations	Heat stress on livestock	Erosion of soil and crop damage	Reduced carrying capacity	Increased need to import feed	Financial vulnerability	Reduced wellbeing	Safety and reduced employment
Land management	•	•	•	•			•	•	•	•	•	•			
Enterprise selection			•		•		•	•		•	•	•	•		
Water management	•		•						•	•	•	•	•	•	
Stock management	•		•	•			•	•	•		•	•	•	•	
Infrastructure	•			•	•	•			•	•					•
Planning and regulations	•			•				•				•	•	•	•
Knowledge sharing and information provision	•		•	•		•	•		•					•	
Wellbeing	•	•		•					•				•	•	•
Monitoring	•			•					•	•		•	•		
Fire management					•	•				•			•	•	•
Management timing	•							•			•				
Weed and pest management		•	•							•	•				

Land management tools	•		•	•			•	•		•					
Marketing	•												•		•
Crop management	•	•	•					•		•	•				
On farm biodiversity management	•	•	•							•					
Sale of Stock				•					•		•	•			

Climate change adaptation actions: desktop review summary

In accordance with findings from the literature review and stakeholder engagement, adaptation actions were categorised into four thematic areas or domains:

Environmental	Economic	Social	Governance
• The environmental domain covers environmental and biophysical adaptations to drought, for example, the introduction of different breeds, species or enterprises, methods of moving stock around to encourage groundcover and soil health.	• The economic domain covers financial adaptations to drought, for example, selling stock early when prices are high.	• The social domain covers drought adaptations involving people and social networks, including social capital and wellbeing initiatives.	• The governance domain covers drought adaptations related to policy and government reforms. The adaptations relevant to each of these four domains are discussed in detail below.

The ability for these actions to be implemented, and the extent to which they are already implemented is influenced by the unique context of the ACT agricultural system, including barriers and enablers to uptake of these practices in the ACT.

Environmental

Much of the effort on farms to adapt to climate change has been directed towards improving productivity under dry conditions. For short term decisions to improve their returns, farmers use climate and weather forecasts of the climate to adjust their times of planting and harvesting, irrigation and destocking . [111] However, adaptation oriented toward short time scale changes in the farming environment (droughts, market fluctuations) can have limited efficacy due to broad changes in the soil/water base and economic environment occurring over longer time scales.[112]

Actions are already being taken by farmers to make landscapes more resilient to Australia's highly variable climate. Existing systems which successfully navigate this variability can inform more widespread uptake of effective agricultural management. These include:

- Adjusting stocking rates to prioritise maintaining groundcover[113]
- Creating shelter belts of trees for shade and habitat for biodiversity and to reduce evaporation from the soil surface[113]
- Strategies to preserve soil moisture such as conservation tillage[111]
- Composting and cultivating soil biology[113]

Actions which can be taken to further cultivate resilience in Australian agriculture include:[114]

- Biotechnology and traditional plant and animal breeding have the potential to develop new 'climate-ready' varieties and new breeds, crops or pastures pre-adapted to future climates.

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[111] Freebairn, J. (2021). *Adaptation to Climate Change by Australian Farmers.* https://www.mdpi.com/2225-1154/9/9/141/htm
[112] Risbey, J., Kandlikar, M., Dowlatabadi, H., & Graetz, D. (1999*). Scale, context, and decision making in agricultural adaptation to climate variability and change*. https://link.springer.com/article/10.1023/A:1009636607038
[113] Soils for Life. (2022). *Case Studies*. https://soilsforlife.org.au/case-studies/
[114] Stokes, C., & Howden, M. (2011). *Adapting agriculture to climate change.* https://www.publish.csiro.au/ebook/chapter/CSIRO_CC_Chapter%207

- Plant nutrition can be adjusted by measures such as precision fertiliser use, legume rotations, and varietal selection to maintain the quality of grain, fruit, fibre, and forage sources.
- Efficiency of water provision, including irrigation will become critical as water resources become more constrained. This can be assisted by identifying less water intensive production options, by developing better water delivery technologies, and by implementing water markets and water-sharing arrangements.
- Biosecurity, quarantine, monitoring, and control measures can be strengthened to control the spread of pests, weeds, and diseases under a warming climate.
- Better models of agricultural systems can assess climate change impacts and more reliably explore and improve adaptation options.
- Monitoring and evaluation systems are needed to track changes in climate, impacts on agriculture, and the effectiveness of adaptation measures, to help decide when to implement particular options and to refine them over time
- Soil and water conservation methods and new systems become even more important as climates fluctuate more and extreme events become more frequent.

While it remains difficult to quantify the long-term consequences of climate change for Australian agriculture, recent trends suggest that a number of structural changes are possible. Elsewhere in the country there could be a shift away from cropping towards livestock and mixed farming, particularly in lower rainfall areas. Given the low prevalence of cropping industries in the ACT these structural changes are not an issue in the short to medium term. Economic

There is already evidence of strong farm adaptation responses to the recent climate shifts with improvements in technology and management practices helping to increase farm productivity and profits. Despite these improvements Australian farm profits have become more sensitive to drought impacts over time. ABARES found that the decline in rainfall from 2001 to 2021, compared to 1950-2000, saw farm profits reduced, on average, by 23 per cent, or $29,200.[115] That is, while average farm productivity and profits have increased, the difference between profits in normal years and drought years has widened.[116]

As part of the strategy for adaptation to the variability of farm decision-making circumstances, some farmers have diversified their sources of income with inclusion of off-farm employment and capital income to cover variations in seasonal conditions and the likelihood of natural disasters[111].

Climate change could also lead to continued amalgamations of farms, increasing average farm size as an adaptive response, and consequent reductions in farm business numbers. Farm survey data consistently show higher productivity and profit levels among larger farm businesses, while larger farms are also less sensitive to drought risk. Given their lower profit margins, smaller farms are likely to face greater pressure from climate change which could hasten farm consolidation trends[117].

Social

The stressors affecting farming communities during times of drought are likely to lead to increased risk of mental health problems.[118] Community-led solutions that promote stress reduction, physical protection (such as access to clean air spaces or air filtration), and community cohesion have the opportunity to bolster resilience during crises. [119]

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[115] Sullivan, K. (2021) *ABARES says changing climate is costing every farm, on average, $30,000 every year*. https://www.abc.net.au/news/rural/2021-07-29/abares-climate-change-costs-30k-per-farm/100331680
[116] Hughes, N., & Gooday, P. (2022). *Climate change impacts and adaptation on Australian farms* https://www.agriculture.gov.au/abares/products/insights/climate-change-impacts-and-adaptation
[117] [117] Hughes, N., & Gooday, P. (2022). *Climate change impacts and adaptation on Australian farms* https://www.agriculture.gov.au/abares/products/insights/climate-change-impacts-and-adaptation
[118] Sartore, G., Kelly, B., Stain, H., Albrecht, G., & Higginbotham, N. (2008). *Control, uncertainty, and expectations for the future: A qualitative study of the impact of drought on a rural Australian community.* https://search.informit.org/doi/abs/10.3316/INFORMIT.471246494717588
[119] Humphreys, A., Walker, E., Bratman, G., & Errett, N. (2022). *What can we do when the smoke rolls in? An exploratory qualitative analysis of the impacts of rural wildfire smoke on mental health and wellbeing, and opportunities for adaptation.* https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-021-12411-2

Additionally, knowledge sharing and information provision is an important social component of resilience and adaptive management. Information delivery to farmers can be enhanced by providing management- and policy-relevant weather and climate metrics (e.g. cold indices for stone fruit), at scales relevant to the decisions being made, and combining information on both climate variability and trends in seasonal and medium-term (decadal) forecasts[68].

Governance

Policy and management decisions require timely inclusion of climate information as it becomes available, as well as closer collaboration between policy makers, managers, researchers, extension agencies, and farmers.

Complementary support by the government includes the provision of climate change and weather forecast information, support for research into new technology, help to evaluate the pros and cons of alternative choices, and provision of a social safety net for those unable to adapt[87].

Appendix F

Workshop slides and factsheet

Appendix F Workshop slides and factsheet

Appendix G

Survey Questions

Appendix G Survey Questions

Following the workshop and additional community engagement activities, a survey, “Have Your Say – ACT’s Regional Drought Resilience Plan”, was sent out to attendees. The survey aimed to seek input from ACT’s agricultural community with regard to experiences of the past drought, the challenges that were faces, and any ideas that will help build resilience to future droughts. Questions that made up the survey are as follows:

- What is your primary agricultural enterprise(s)?
- What is the size of your landholding/how large is your farm?
- Did you introduce new farm management measures during the last drought, or as a result of the drought and other climate events such as fire and flood?
- What did you observe about the 2017-2020 drought and how did the drought impact you and your farm?
- What measures did you have in place that helped you to manage the impact of the drought?
- Noting these projected changes in climate, what additional measures are you considering to help manage future drought, now or in the future?
- Given the projected changes in climate, is there a point at which you are concerned your current farm practices will no longer be feasible?
- What information do you need going forward to help you make decisions about how you manage your farm under projected climate change?
- What other support do ACT farmers need in preparing for and responding to droughts?
- What do you see as the role of state and federal government and other organisations in preparing for and responding to droughts?
- What are the roles and responsibilities for farmers?
- Are there specific policy or legislative measures you would like to see being introduced or changed that would help you and other ACT farmers to prepare for and manage drought? Why?
- Climate variables - Depending on your agricultural enterprise, there may be certain climate variables that are particularly influential on the success of your season, or drive risks. Please review the following climate variables and rate the importance of these as you plan for future drought. The climate variables listed below are available in data sets provided by the NSW and ACT Regional Climate Modelling (NARCliM).
  - [climate variables listed in survey]
  - Please describe why you've rated some variables higher than others.
- Are there any other climate indicators you use or regularly review?
- Please let us know if there's anything further you'd like to share about how you use climate variables to inform your drought planning.

Appendix H

Climate change analogues for Canberra

Appendix H Climate change analogues for Canberra

Climate analogues is a tool that matches the proposed future climate of a region of interest with the current climate experienced in another region using annual average rainfall and maximum temperature.

The following section is an extension of Section 5.3 where climate analogues for Canberra was explored. Please refer to that chapter for further context.

2030 Climate analogues

Australia has 54 natural resource management (NRM) regions, which are defined by catchments and bioregions. Statistics for each town are reported based on the 2022 agricultural data for the NRM region that the town sits within, unless otherwise referenced.[120]

Bairnsdale (NRM region: East Gippsland VIC)

Dominant agricultural enterprises

- Sheep and cattle grazing (wool, milk and meat)
- Cropping
- Vegetables (predominantly beans)

Specific to Bairnsdale and Dargo region

Cattle and sheep grazing is the most widespread form of agriculture although there are areas of horticulture on the Mitchell and Tambo River flats. Some cropping and irrigated horticulture using groundwater is carried out on the Red Gum Plains.[121]

Agricultural issues

Nitrate leaching and build-up of soil organic matter are the major causes of soil acidity under grazing systems.

The use of acid tolerant plants is widespread in the higher rainfall grazing areas. Many producers rely on moderate to highly tolerant pasture species (eg subterranean clover, perennial ryegrass and cocksfoot). Since the mid 1990s there has been a revival in the establishment of perennial systems (phalaris). This trend is reflected in increased lime usage. There is growing interest in low input native pastures for light textured, rocky or steep areas where it is difficult to apply lime (Hughes 2001).

Bathurst (NRM region: Central Tablelands NSW)

- Sheep and cattle grazing (wool, and meat)
- Cropping, specifically broadacre crops, predominantly wheat
- Crops for hay

Specific to Bathurst

In addition to the above, the below enterprises are specific to the Bathurst Local Government Area (LGA).

- Vegetables
- Nurseries and cut flowers[122]

Benalla (NRM region: Goulburn Broken Regional Catchment VIC)

- Cattle grazing (milk and meat)

[120] Australian Bureau of Statistics. (2022). *Value of Agricultural Commodities Produced, Australia, 2020-21 financial year.* https://www.abs.gov.au/statistics/industry/agriculture/value-agricultural-commodities-produced-australia/latest-release
[121] Agriculture Victoria. (2020). *Soils and landforms of the Bairnsdale and Dargo Region | VRO | Agriculture Victoria.* https://vro.agriculture.vic.gov.au/dpi/vro/egregn.nsf/pages/eg_soil_bairnsdale_dargo
[122] Bathurst Regional Council. (2016). *Agricultural industry statistics | Bathurst | economy.id.* https://economy.id.com.au/bathurst/value-of-agriculture

- Broadacre cropping (predominantly wheat)
- Fruit and nuts (excluding grapes, predominantly apples)

Specific to Benalla

- Broadacre cropping and crop-pasture (North west of Benalla)
- Pasture dryland (south east of Benalla) sheep and cattle grazing[123]

Agricultural enterprises in detail

Agriculture is predominantly dry land cropping and pastoral, with significant tracts of irrigation along the Broken River. Irrigated horticulture is a growing and valuable industry, particularly in the northern Warby Range area.

The stone fruit industry is developing, as are wine grape production and wine making. Tree production is featuring as a new enterprise.[124]

Agricultural issues

- Irrigated salinity
- Dryland salinity
- Erosion due to land clearing, salinity and rabbit plagues[123]

Albury Wodonga (NRM region: North East Catchment VIC, and Murray NSW)

- Broadacre cropping predominantly wheat, canola, and barley
- Sheep and cattle grazing (milk and meat)
- Pigs
- Poultry
- Fruit and nuts (excluding grapes), predominantly cherries
- Vegetables

Sale (NRM region: West Gippsland Catchment VIC)

- Sheep and cattle grazing (milk)
- Poultry
- Cropping
- Vegetables

Bendigo (NRM region: North Central Catchment VIC)

- Broadacre crops predominantly wheat
- Sheep and cattle grazing (milk)
- Pigs
- Crops for hay

Young (NRM region: Riverina NSW)

- Sheep and cattle grazing
- Broadacre crops predominantly wheat, canola and barley
- Fruit and nuts (excluding grapes)

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[123] Agriculture Victoria. (2020). *Landuse | VRO | Agriculture Victoria.* https://vro.agriculture.vic.gov.au/dpi/vro/gbbregn.nsf/pages/gbb_landuse_map
[124] About Benalla - Tomorrow Today Foundation. (n.d.) , https://tomorrowtoday.com.au/about-us/about-benalla/

Melbourne (NRM region: Port Philip and Westernport Catchment VIC)

- Nurseries, cut flowers or cultivated turf
- Vegetables
- Cropping
- Fruit and nuts (excluding grapes)
- Livestock, predominantly poultry

2050 Climate analogues

Wangaratta (NRM region: North East Catchment VIC)

- Livestock cattle and sheep (milk and meat)
- Broadacre crops
- Fruit and nuts, predominantly cherries

Mudgee (Central Tablelands NSW)

- Cattle and sheep grazing (wool and meat)
- Broadacre crops predominantly wheat
- Crops for hay

2090 Climate analogues

Dubbo (Central West NSW)

- Broadacre crops predominantly wheat, barley and canola
- Sheep and cattle grazing

Drought mitigation through farm diversification in the ACT

Australian Farm Institute

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Editor: Katie McRobert (AFI)

October 2022

Australian Farm Institute

New thinking about agriculture

ACT Government

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Terms of reference

The key objective of this project is to:

> *Identify opportunities for ACT and region farmers to diversify their on-farm income, so they maintain farm viability during drought and downturns in commodity prices.*

The project will contribute to improving the viability of farm businesses in the ACT by:

- Enhancing their capacity to diversify their business by taking advantage of the close proximity to urban markets, and
- Increasing demand for environmentally friendly and socially responsible agriculture as well as rural experiences.

The project specifically addresses opportunities for:

1. Increased income from existing farm practices
2. Improved farm diversification in the ACT
3. Barriers and opportunities to farm diversification in the ACT

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Executive summary

The 2017-19 drought tested the capacity of ACT farmers, rural landholders and land managers to sustain farm incomes. Maintaining a financially resilient and diverse business with alternative income sources provides the most consistently effective mitigation of risk across production, market and institutional risk categories for Australian farmers. However, many farms in the ACT run single enterprises that are vulnerable to drought and other impacts.

This report defines diversification as:

> *the development of resilient agricultural businesses and systems using rational, affordable strategies to maintain ecosystem function and protect livelihoods.*

Opportunities for the diversification of agricultural production are supported by several characteristics of the ACT region and population. Some characteristics are also evident elsewhere in Australia, but the ACT is one of the only regions where **all characteristics combine to provide a powerful opportunity for region-wide diversification approaches**.

The observations highlighted here and detailed in the report draw on interviews with a range of farmers in the ACT region across different production systems, farm sizes and farm business structures, as well as an extensive review of the literature.

Barriers

The range of diversification options available to ACT farm businesses are significantly impacted by several factors including farm size, human capital and variation in land capability and soil type. Other factors influencing diversification options include the risk appetite of the individuals involved, location and access to labour, life stage, family decision-making and ease of integration with current farm operations.

The major disincentive for diversifying production system or revenue generation on farms in the ACT region is associated with land planning and the requirement to maintain alignment with purpose clauses under lease agreements that often do not appear fit for purpose.

While there is significant variation across three principal soil types in the ACT region - including pockets of highly fertile soil - **most of the soils in the ACT are of low to poor quality** with respect to traditional production systems. While recent soil testing has found relatively high soil carbon across most paddocks, this has followed a very good series of seasons. Almost all the non-urban land in the ACT is classified as moderate-low (grade 5) to very low (grade 7) capability - meaning it is suited to a restricted number of uses (primarily grazing) and subject to a range of hazards that must be carefully managed. This has significant implications for diversification options.

Under the Territory Plan, agriculture is largely prohibited on NUZ5 land (mountains/bushland zone) land and restricted on NUZ4 (river corridor zone) through the application of precinct codes. Agricultural production is only a specific objective on land zoned NUZ2 (rural zone) or more generally NUZ1 (broadacre zone). Land use in the ACT is subject to Land Management Agreements (LMAs), i.e. agreements between the lessee and the ACT government. LMAs can be very detailed and extremely resource intensive, and are often cited as onerous by farmers. Importantly, permitted activities on NUZs 2 and 1 can be further restricted by specific lease purpose clauses in LMAs.

Lack of recognition of agriculture in strategic planning documents creates ongoing planning tension between rural and urban uses - driven on the one hand by the desire of the ACT Government to maintain maximum flexibility for future development, and on the other hand by leaseholders seeking greater certainty of tenure and clarity of allowable activities needed to generate the confidence to invest in land improvements and diversification options.

Net **water use** in the ACT is less than half (19GL in 2018/19) of the sustainable diversion limit (SDL) approved in the Murray-Darling Basin Plan. Of the water extracted in the ACT, less than 1% (233ML) is utilised for agriculture. In addition, **climate variability** is a major risk to agricultural production across Australia that is likely to increase under future climate scenarios.

Opportunities

Options in current farming systems resulting from practice change - such as improving the organic matter of soils, maintaining groundcover to improve water infiltration, utilisation of mixed farming system approaches and pasture improvements - have not been discussed in detail for this report. These are important technologies and practices for improving the productivity, resilience and profitability of farming businesses; however, they are either already being routinely implemented or validated in most production systems, so offer little *additional* benefit.

Rather, this report focusses on opportunities for non-traditional alternative production systems, value-adding, new markets and improving food distribution that align with the land capability and could potentially provide a market niche for the ACT and surrounding region.

These are presented in brief below:

Glasshouse / greenhouse production

Assuming planning approval could be gained, the success of any intensive glasshouse / greenhouse venture would be largely dependent on cost and access to irrigation water and power. The green electricity strategy of the ACT would contribute to the sustainability credentials of an intensive production facility, but the economic feasibility would require careful consideration. Irrigation issues could be mitigated if access to treated wastewater could be obtained. Currently, the majority of treated wastewater from the ACT is returned to the Murrumbidgee River but the opportunity for its use in production should not be dismissed, especially if coordinated with compost production from organic waste recycling in a closed circular bioeconomy.

Emerging industries

Snails

The small Australian snail industry is largely centred on the common brown garden snail (*Helix aspersa).* Despite a potential ready market, exports of snails from Australia in the past 5 years have been limited to 3,554kg (in 2019) compared with an import of almost 46,000kg (22,000kg in 2020 alone).

Insects

The Australian insect market consists primarily of crickets and grasshoppers, mealworms and black soldier flies utilising waste streams and low-quality feeds. Promising immediate markets appear to be in the provision of alternative proteins to stock feeds (aquaculture in particular) and the pet food industry, especially where production can be co-located with waste streams suitable as feed sources. Canberra-based insect waste management and production company Goterra is one of the case studies for this project.

Tree crops

Tree crops with production potential in the ACT are most likely to be suitable for production only on areas with land capability class 5 or better. Regardless of market potential, the establishment of tree crops in the ACT is hindered by a number of environmental and regulatory issues.

Mushrooms

The potential of alternative edible and medicinal mushroom market remains largely untested – however, this is explored in some detail in a 2018 AgriFutures emerging industries report[1].

Saffron

Saffron - the dried stigmas and styles of the crocus flower - is one of the most valuable spices in the world at about $30,000/kg gross value. Yields of 1-2kg/ha in Australia are usual but the higher summer temperatures and rainfall of the ACT region would probably require supplemental irrigation to achieve maximum yield. While there is potential for saffron production in the ACT, this opportunity would need to generate a premium product with specialist marketing to maximise the potential for viability.

Essential oils

Global growth in essential oils is predicted to be significant as the consumer focus on natural ingredients continues. Potential production suited to the ACT environment is most likely associated with lavender and an emerging essential oil derived from kunzea. Kunzea oil has been identified as a prospective emerging industry However, *Kunzea ambigua* or white tick bush, while native to the ACT, also has potential to be a problematic pest species.

Aquaculture

Aquaculture opportunities for the ACT include yabbies and finfish – however, zoning for intensive production may be a significant issue for these options. Aquaculture would need to align with the permitted uses zoning and would be subject to a development application.

Value-adding

One of the challenges for producers of commodity products is that they are generally price takers rather than price makers. Typically, larger commodity producers maintain and improve economic performance through adoption of scale economies (productivist approaches[2]), but product diversity and scope economies[3] can also make significant contributions to farm business performance. This is particularly pertinent for smaller-scale producers (typically highly represented in the ACT region), where scale efficiencies can be difficult to achieve.

Value-adding of product (for premium and non-premium markets) provides an opportunity to identify additional demand and increase prices received. However, diversification into value added products is not risk-free. Markets are often small and target a niche of consumers. In addition, the effort and expertise required for value-adding should not be underestimated. However, this option does represent a significant diversification opportunity for ACT producers, especially where products can be promoted as natural, local, traceable and sustainable.

One of the most direct forms of value-adding is the supply of locally sourced meat to consumers. This may appear to be a relatively simple, low-risk diversification option, but meat processing in Australia is a high-volume, low-margin business where costs are strictly controlled, and ongoing quality assurance is a necessity.

Marketing

Direct marketing of farm products has exploded, particularly online, with the use of social media as a marketing tool and the relative ease by which webpages and shop platforms can be generated by

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[1] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-041.pdf

[2] Productivism is a focus on measurable productivity and growth, i.e. more production is necessarily good.

[3] Scope economies: a proportionate saving gained by producing two or more distinct goods, when the cost of doing so is less than that of producing each separately.

individual sellers. The strategies employed differ with the needs and demands of the market and several different approaches may need to be tested to identify those most effective for the product being sold.

E-commerce platforms have become a feature of selling food and food products with the potential to increase profitability in agricultural markets by increasing sales while decreasing sourcing and transaction costs. However, the perishable nature of food products means that the relevance of e-commerce platforms for direct to customer marketing for small farm businesses can be challenging. For many smaller farm businesses, such as those in the ACT region, e-commerce is more likely to form part of a combination of marketing channels needed to maximise overall sales.

As well as online, there are two unique types of on-site selling: roadside stalls and attracting tourists to a location then on-selling product.

Farmers' markets and co-operatives are particularly important options for maintaining viability of small-holder farmers. Farmers' markets and other alternative market mechanisms, often collectively referred to as Alternative Agri-Food Networks (AAFNs), represent a realistic alternative retail opportunity for many growers that is complementary to other selling options.

Sustainability

Meeting the challenge of demonstrating sustainable production is a pillar of the Federal Government's $34m Agriculture Stewardship Package, supported by development of the Australian Agricultural Sustainability Framework[4]. Demonstrating the sustainability of production has moved from a value-adding activity embraced by the few, to an absolute requirement to maintain social licence and market access which underpins all farming businesses across multiple sectors.

Tourism

While all tourism in Australia has been impacted by the Covid-19 pandemic, tourism continues to be an important aspect of the ACT economy, with the gross value added to the ACT economy from tourism at $1.6bn in 2019/20. A 2018 survey of growers in the Cootamundra/Gundagai region indicated that agritourism has significant potential, yet remains niche and driven by farming family preference rather than a major market change. This may change significantly following the pandemic, which has resulted in far greater uptake of domestic travel and may provide a major opportunity for suitably inclined or positioned growers to diversify into tourism-based activities.

Lease and agistment

Horse riding is an extremely popular hobby in the ACT with more than 500 km of trails available to riders. Demand for equine service has been demonstrated to be more income elastic[5] than commodity production (in the UK) and thus represents potentially important benefit to land managers, especially as disposable income across the population grows. The sale of services as an income diversification strategy also extends to other forms of agistment, particularly the cattle and sheep industries that are well-established in the ACT and surrounding region. In particular, the harsh winters in the ACT make agistment an attractive alternative to breeding herds that require supplemental feeding over the winter months.

[4] https://www.farminstitute.org.au/the-australian-agricultural-sustainability-framework/

[5] Income elasticity refers to the sensitivity of change in the quantity demanded for a good or service, as consumer income changes. If a product or service is highly income elastic, demand for it increases as incomes rise, whereas inelastic goods do not see a rise in demand as incomes increase.

Ecosystem services

Farmers manage 55% of the total land area in Australia and up to 15% of the total land area in the ACT. Ecosystem services are those ecological functions which lead to desirable environmental outcomes, such as air and water purification, drought and flood mitigation, and climate stabilisation. Market-based mechanisms (often preferred by economists to regulatory intervention) can provide the financial incentive to minimise costs while delivering the desired environmental outcomes. Despite this, the approach in the ACT to date has been largely regulatory, with requirements to deliver ecosystem services included in LMAs - the costs of which are mostly borne by the leaseholder.

Carbon farming

The Emissions Reduction Fund (ERF) enables land managers to earn carbon credits by changing land use or management practices to store carbon or reduce greenhouse gas emissions. Soil carbon farming has been mooted as a key strategy for offsetting Australia's greenhouse gas emissions, with the ancillary benefit of improving farm productivity. However, several barriers restrict farmers from participating in schemes designed to monetise the production of carbon credits, e.g. what increase in soil carbon storage is achievable and whether credit income will exceed a project's cost.

Other opportunities

Improved linkage of waste streams throughout the ACT with reuse activities such as insect production and composting has the potential to generate a circular bioeconomy that minimises organic waste, increase productivity and soil health on agricultural lands, provides opportunities for diversification and makes a significant contribution to the ACT Waste Minimisation Strategy.

Greater clarity on potential access to water in the ACT and through water trading for agriculture would provide leaseholders with certainty when assessing diversification options that include the need for irrigation (most production options).

Time-limited biodiversity stewardship schemes could be employed within the ACT to protect biodiversity and maintain natural capital that is then utilised as environmental offsets for other developments, as is routinely practiced currently.

The ACT government could consider support for the construction and implementation of a database of growers, buyers and customers similar to MarketMaker. Such a database is part of the City-Region Food System developed by the Canberra Region Food Collaborative.

Conclusions

While biophysical limitations will always dictate the range of diversification options which can mitigate the vagaries of drought and other climate extremes, ACT farmers are resilient and innovative. The unique competitive advantage provided by co-location to consumers and potential labour, generation of off-farm income, and marketing of provenance attributes opens the door to diversification opportunities for the ACT. In particular, the opportunity to establish a world-leading agriculturally based circular bioeconomy should not be dismissed. With the cooperation of Government and industry to address and remove the barriers identified herein, opportunities aligned with land capability for non-traditional alternative production systems, value-adding, new markets and improved food distribution could potentially provide not only a market niche for ACT producers but also increased resilience to climate impacts.

1. Introduction

The 2017-19 drought tested the capacity of Australian Capital Territory (ACT) farmers, rural landholders and land managers (particularly those with livestock) to maintain farm incomes.

The Australian Farm Institute (Laurie et al., 2019) notes that maintaining a financially resilient and diverse business with alternative income sources provides the most consistently effective risk mitigation across production, market and institutional risk categories for Australian farmers (Figure 1). Many farms in the ACT run single enterprises that are vulnerable to drought and other impacts. By diversifying farm enterprise, farming in the ACT is likely to be more resilient to setbacks, disruptions and downturns.

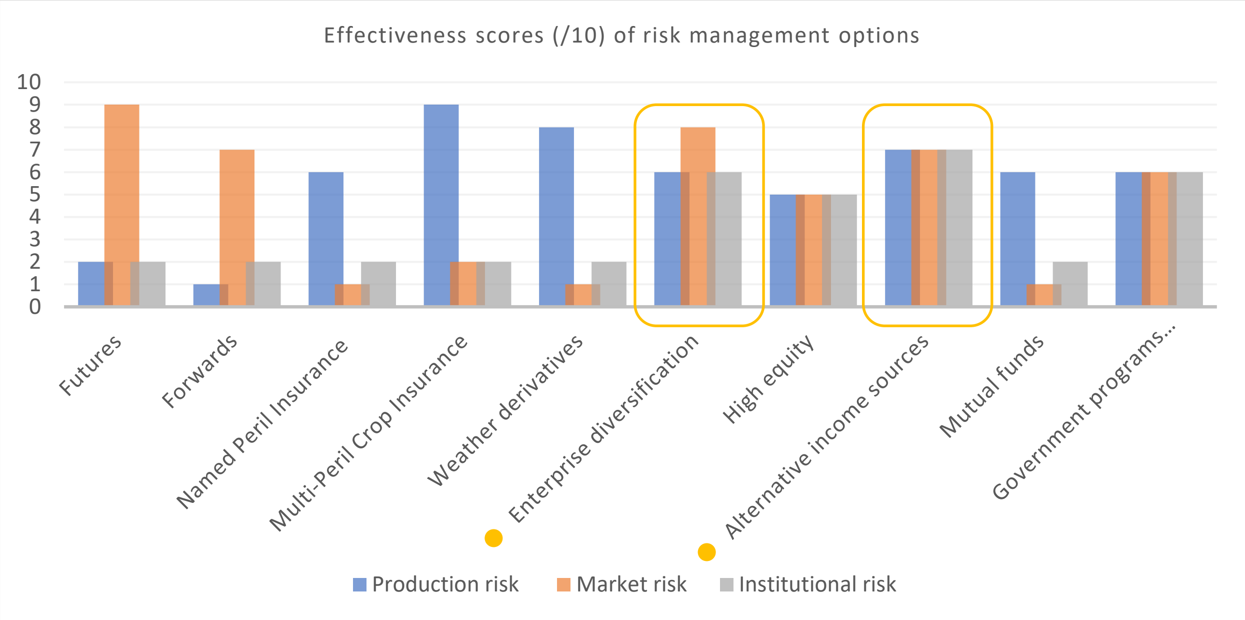


Figure 1: Comparative effectiveness scores of options in mitigating risk. Source: *(Laurie et al., 2019)*

Many single-enterprise ACT (and nearby NSW) farmers are not fully utilising the opportunity to grow and sell clean, green farm produce and products to a nearby wealthy and sophisticated consumer market (Institute for Sustainable Futures, 2016). This research therefore assesses options to increase income from existing farms, and identifies barriers and opportunities to farm diversification in the region.

The report provides an overview of agricultural production in the ACT (including the unique characteristics of the agro-ecological zone), sets out the concept of farm diversification, and considers the region's competitive advantage.

In discussing agricultural diversification in practice, interviews with growers and a workshop conducted for this project confirmed that the barriers identified in the research are reflected in the lived experience of ACT farmers and land managers (Figure 2). Primarily, the range of diversification options available to ACT farm businesses are significantly impacted by several factors including farm size, access to water, availability of human capital and variation in land capability and soil type.

Other factors influencing diversification options include the risk appetite of the individuals involved, location and access to labour, life stage, family decision-making and ease of integration with current farm operations.

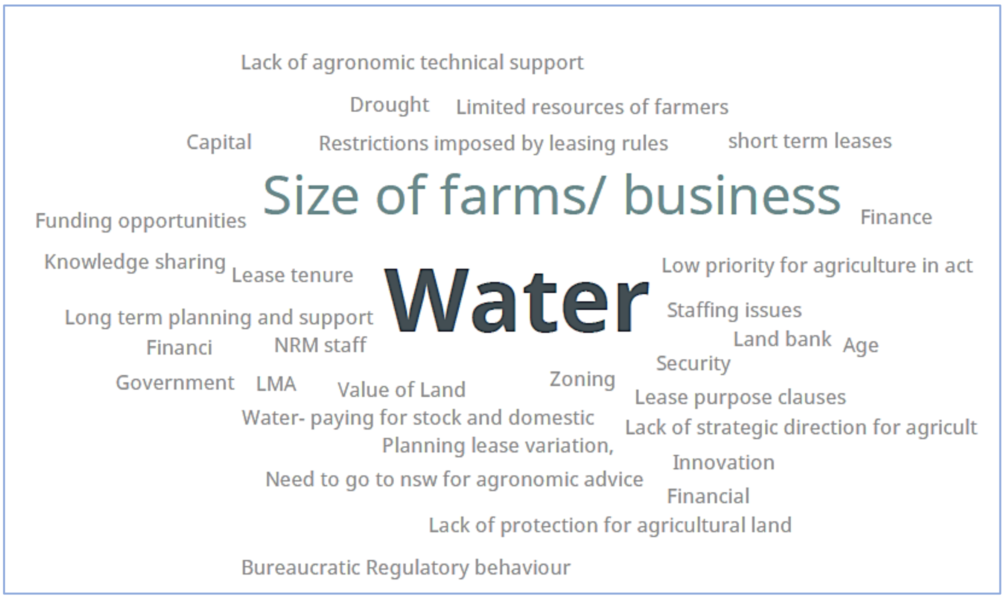


Figure 2: Workshop feedback on biggest barriers to building farm resilience in the ACT and surrounds

The term 'diversification' means different things to different stakeholders, with some workshop attendees highlighting environmental diversification via improved biodiversity as a drought mitigation strategy in their feedback.

In this report, diversification is taken to mean:

> ***the development of resilient agricultural businesses and systems using rational, affordable strategies to maintain ecosystem function and protect livelihoods.***

2. Agricultural production in the ACT and surrounds

The Australian Capital Territory (ACT) covers 2,358 square kilometres[6] in the upper Murrumbidgee catchment. The ACT encompasses the city of Canberra, a number of smaller townships, a large area of nature reserves and a much smaller, but significant area of land utilised for agricultural production.

2.1 Climate

The ACT has a temperate climate, with warm to hot summers and cool to cold winters. In Canberra, average maximum temperatures in January exceed 30°C and average minimum temperatures approach 0°C in July (Figure 3). The climate across the ACT displays significant variation, predominately associated with changes in elevation (from just under 600m in Canberra to more than 1900m in the southern alps). The north of the ACT is warmer and drier than the cooler and wetter regions in the south that merge with the northern part of the Australian Alps[7].

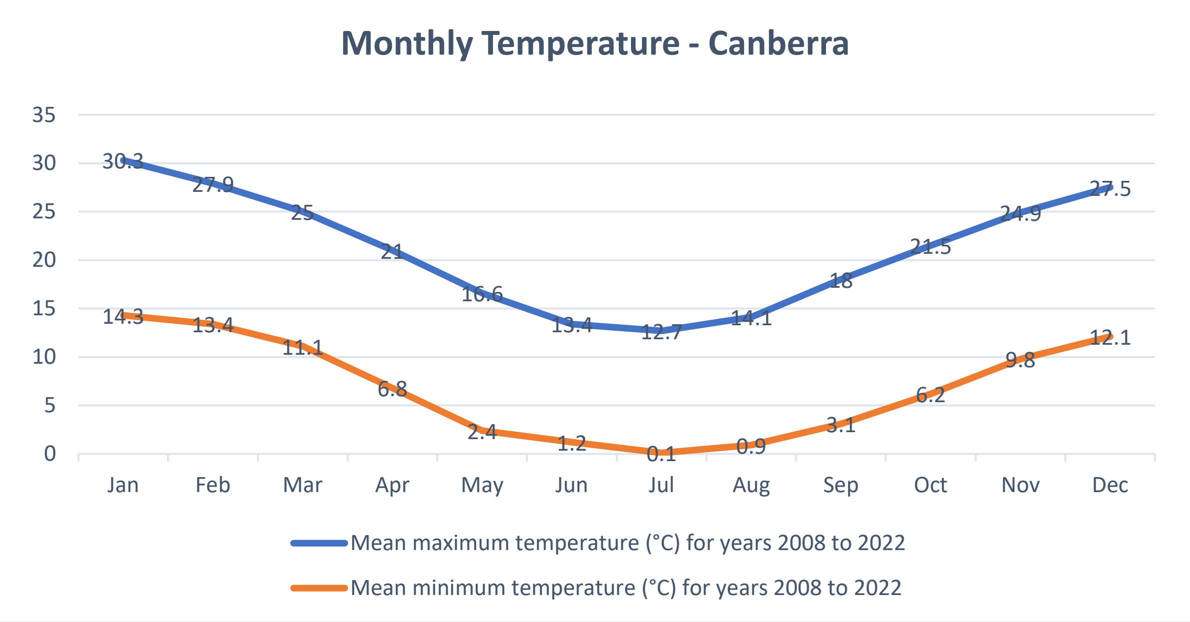


Figure 3: Average monthly maximum & minimum temperatures at Canberra airport 2008-22. Source: BOM Graphical climate statistics for Australian locations (bom.gov.au)

Average annual rainfall totals range from 400-800mm in the north (including Canberra) to 800-1200mm in the central and western region and greater than 1200mm in the southern alps.

Rainfall occurs relatively uniformly throughout the year and likewise, days of high rainfall are also uniformly distributed across the year (Figure 4). Regional evaporation data over 10 years (required to calculate longer-term averages) is not available, but national evaporation data indicates that the ACT experiences only moderate evaporation in comparison to other areas of Australia (Figure 5).

[6] Area of Australia - States and Territories | Geoscience Australia (ga.gov.au)
[7] Australian Capital Territory Climate Change snapshot (act.gov.au)

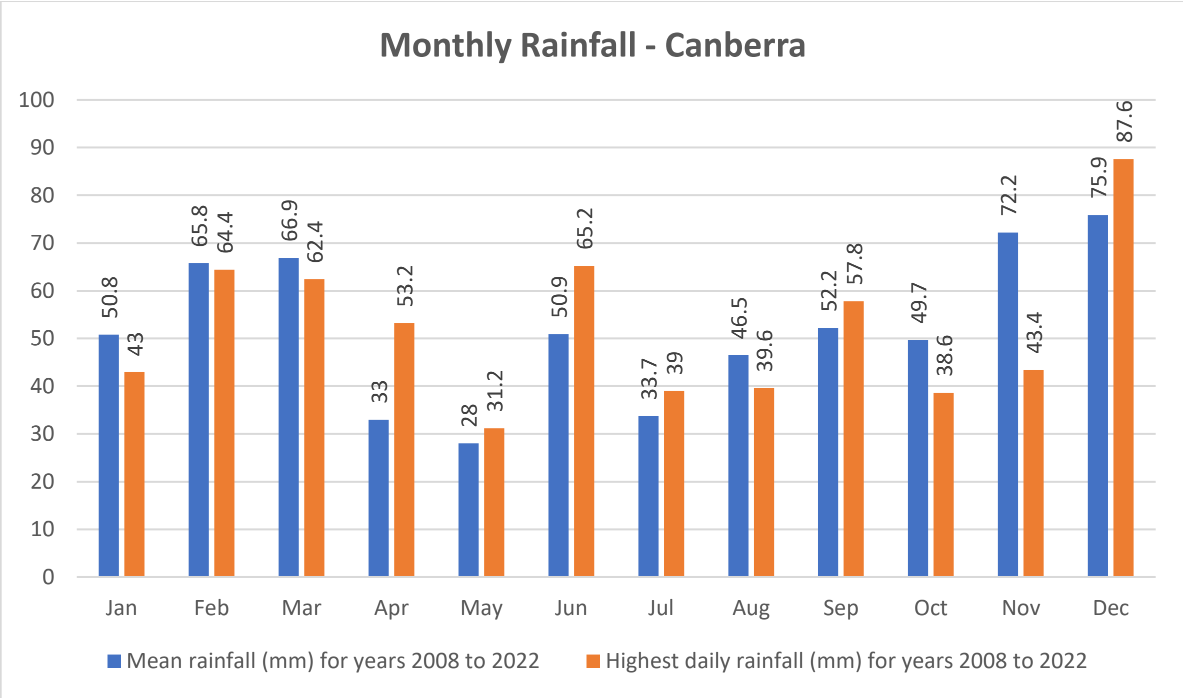


Figure 4: Average monthly rainfall and highest daily rainfall at Canberra airport 2008-21; Source: BOM [Graphical climate statistics for Australian locations (bom.gov.au)]

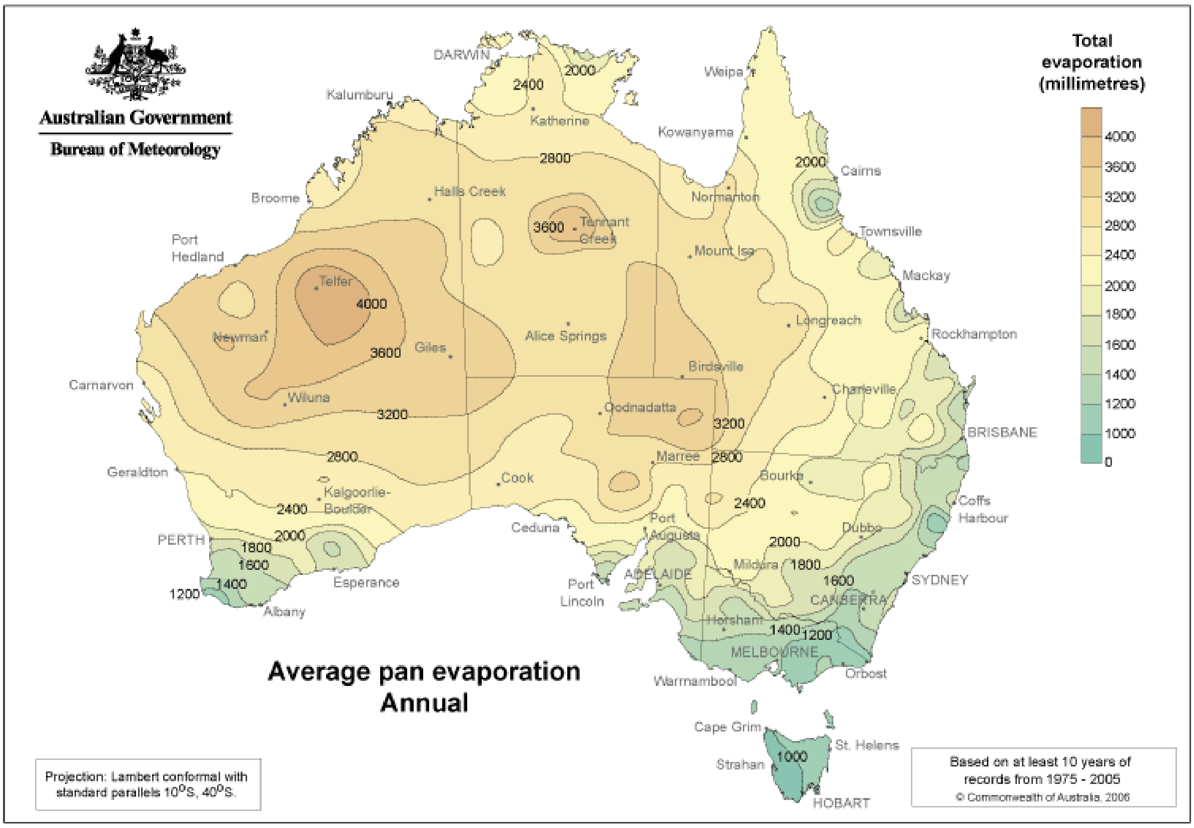


Figure 5: Average annual evaporation (based on at least 10 years data); Source: [BOM Water and the Land: Evaporation] (bom.gov.au)

2.2 Soils

In common with much of Australia, the soils of the ACT are old and generally infertile requiring significant inputs to increase traditional agricultural production capacity (Gunn et al., 1969; Sleeman and Walker, 1979) although there is significant variation across three principal soil types in the ACT region (Figure 6) including pockets of highly fertile soil (ABS, 2007[8]).

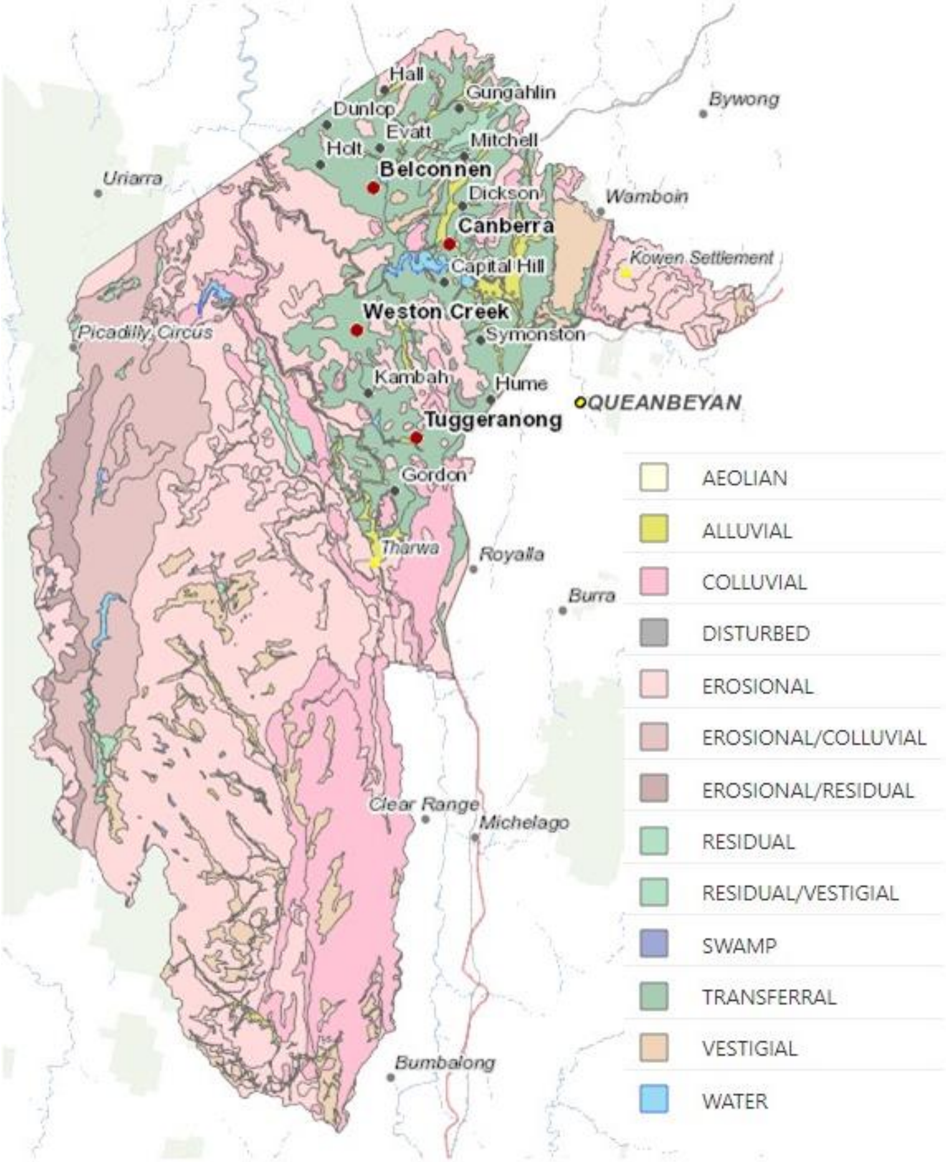
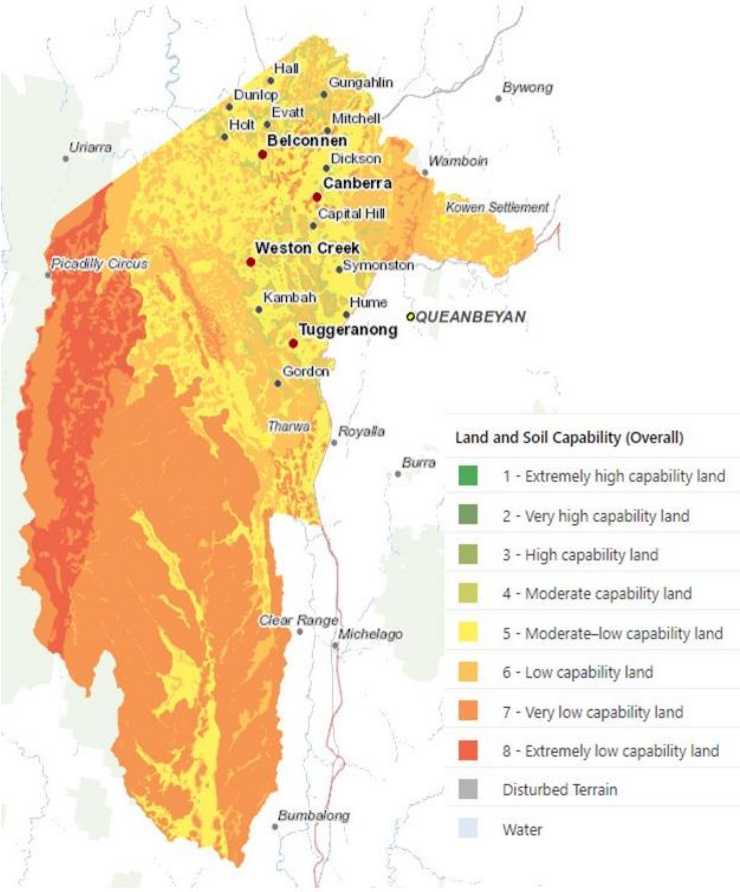


Figure 6: Soils of the ACT region; Source ACTmapi ©Australian Capital Territory.

[8] 1307.8 - Australian Capital Territory in Focus, 2007 (abs.gov.au)



Much of the non-urban land in the ACT is classified as moderate-low (grade 5) to very low (7) capability

Figure 7: Land Capability in the ACT; Source: ACTmapi ©Australian Capital Territory.

Lithosols occur mostly in the south and west, are nutritionally poor and are subject to erosion particularly where native vegetation has been removed from landscapes with steeper slopes. Gradational soils are characterised by a gradual increase in clay content with depth and are, relatively fertile. They are the principal soil types under the Limestone Plains associated with many of the waterways in the north of the ACT. Texture contrast (or duplex) soils are the dominant feature of most of the ACT. They are relatively infertile, are vulnerable to erosion on bare slopes, and have a fragile surface structure that can become hard setting and impermeable to water if they are not carefully managed. There is moderate to high retention of water in clay subsoils, but permeability and root penetration are issues that restrict productivity (Gunn et al., 1969).

Soils in the ACT are classified into land and soil capability (LSC) classes (Figure 7). LSC represents the physical capacity of land to sustain a range of land uses and management practices without long-term degradation to soil, land, air and water resources[9]. LSCs are calculated based on a range of variables including landform position, slope gradient, drainage, climate and soil characteristics that are used to derive detailed ratings for a range of land and soil hazards. Almost all the non-urban land in the ACT is classified as moderate-low (grade 5) to very low (grade 7) capability meaning it is suited to a restricted number of uses that consist primarily of grazing and are subject to a range of hazards that must be carefully managed (Table 1)[10]. This has significant implications for diversification options.

[9] Soil and Hydrogeological Landscapes Map (act.gov.au)
[10] Land and soil capability assessment scheme (nsw.gov.au)

Table 1: Land & Soil Capability Classes - General Definitions. Source: NSW Office of Environment and Heritage.

LSC CLASS	GENERAL DEFINITION
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)	
1	Extremely high capability land: Land has no limitations. No special land management practices required. Land capable of all rural land uses and land management practices.
2	Very high capability land: Land has slight limitations. These can be managed by readily available, easily implemented management practices. Land is capable of most land uses and land management practices, including intensive cropping with cultivation.
3	High capability land: Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)	
4	Moderate capability land: Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.
5	Moderate–low capability land: Land has high limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.
Land capable for a limited set of land uses (grazing, forestry and nature conservation, some horticulture)	
6	Low capability land: Land has very high limitations for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation
Land generally incapable of agricultural land use (selective forestry and nature conservation)	
7	Very low capability land: Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation.
8	Extremely low capability land: Limitations are so severe that the land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation.

2.3 Land planning and use

Zoning of land for different purposes in the ACT reflects a range of considerations, including environmental outcomes and aesthetics as well as current and future uses with a focus on the maintenance of access to land for urban expansion. Land planning objectives and regulations are set out in the Territory Plan[11] and the ACT Planning Strategy[12].

Agricultural production in the ACT is limited to the areas identified as non-urban zones under the Territory Plan (Figure *8*), as well as some production in the Majura Valley that is a 'Designated Area' and regulated under the National Capital Plan.

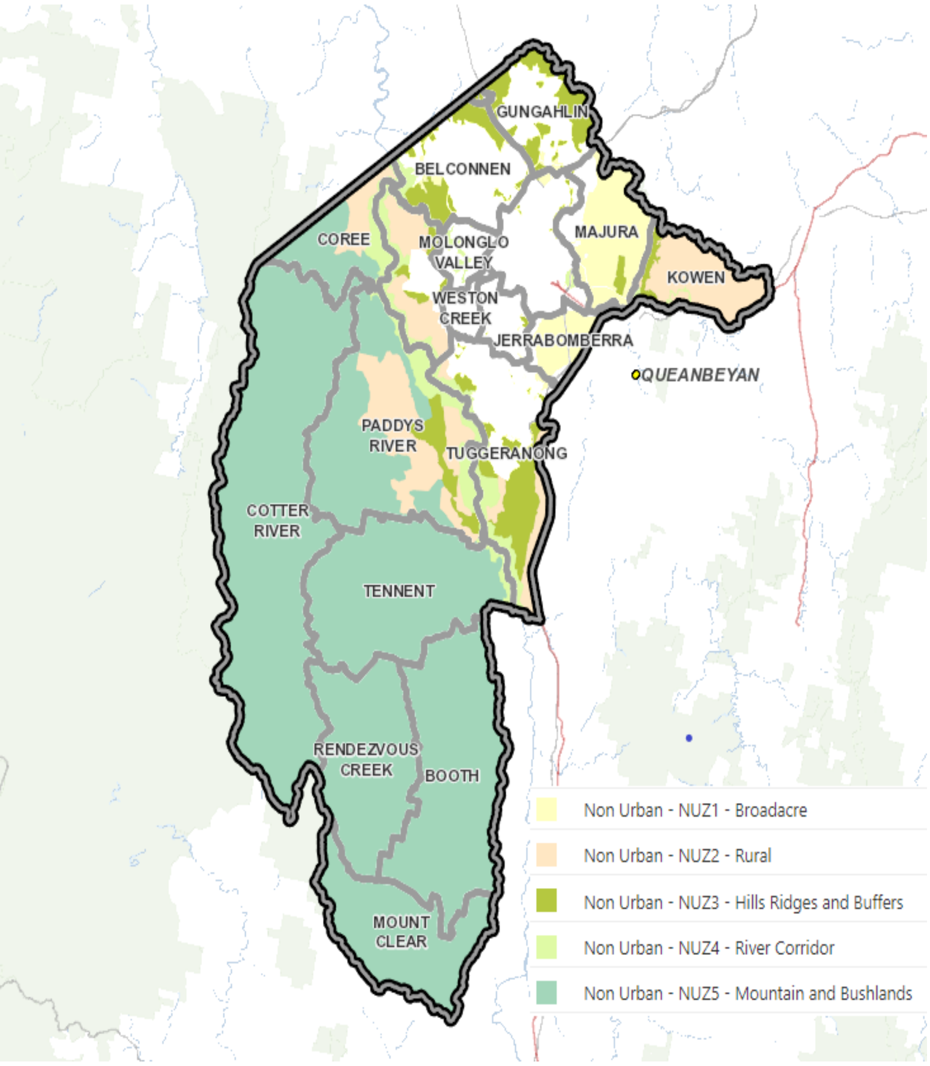


Figure 8: Non-urban land zoning the ACT; Source: ACTmapi ©Australian Capital Territory

[11] Territory Plan 2008 | Notifiable instruments (act.gov.au) provides a full description of the planning objectives, permitted activities and development requirements on different zones of non-urban land, subject to statutory approval. Under *the Australian Capital Territory (Planning and Management) Act 1988 Cwth*, the Territory Plan must not be inconsistent with the National Capital Plan.

[12] ACT Planning Strategy 2018

Agriculture is defined[13] in the Territory Plan as:

> *broadacre animal farming, crop and pasture production, and horticulture for commercial wholesale production, but does not include animal husbandry or any cultivation or animal farming carried out primarily for the personal enjoyment of, or consumption by, the owner(s) or occupant(s) of land*.

Horticulture is specifically included as a subcategory of agriculture as:

> *the use of land for intensive plant production such as fruit, vegetable or flower production (including berries and vines)*.

Intensive animal production is explicitly not captured under the definition of agriculture but is defined separately:

> *Animal husbandry means any form of animal production that either takes place within the confines of a building or buildings where livestock are reared in confined areas excluding any husbandry carried out mainly for the personal enjoyment of, or consumption by, the owner(s) or occupier(s) of the land.*

Under the Territory Plan, agriculture is largely prohibited on NUZ5 (mountains and bushland zone) land and restricted on NUZ4 (river corridor zone) land through the application of precinct codes.

For example, the Cotter River Precinct Code[14] specifically prohibits agriculture on NUZ5 land and the Coree District Precinct Code[15] limits production on NUZ4 land to plantation forestry where livestock grazing may be permitted subject to development assessment. Some agriculture is permitted on NUZ3 (hills, ridges and buffer zones) land but agricultural production is only a specific objective on land zoned NUZ2 (rural zone) or more generally NUZ1 (broadacre zone). Zone objectives, as they relate to planning and development are available publicly[16], and for NUZ1 and NUZ2 are provided in Table 2.

Importantly, permitted activities on rural and broadacre lands can be further restricted by specific purpose clauses in Crown lease agreements. General planning rules may allow for grazing in some regions, but lease purpose clauses may specify that this must be cattle or sheep grazing and that other grazing animals (e.g., goats, alpacas etc.) would require a change to the lease agreement. Changes to lease agreements are assessed in the same manner as development applications with similar associated costs, requirements to meet environmental and other regulations and application of general administrative processes.

[13] https://www.legislation.act.gov.au/DownloadFile/ni/2008-27/copy/141509/PDF/2008-27.PDF
[14] ibid.
[15] ibid.
[16] Territory Plan 2008 | Notifiable instruments (act.gov.au)

*Table **2**: Planning objectives of key agricultural production zones – NUZ1 (broadacre) and NUZ2 (rural).*

ZONE	OBJECTIVES
NUZ1 – Broadacre	
	Make provision in a predominantly rural landscape setting for a range of uses which require larger sites and/or a location outside urban areas.
	Make provision for activities requiring clearance zones or protection from conflicting development.
	Ensure that development does not adversely impact or visually intrude on the landscape and environmental quality of the locality.
	Ensure, where appropriate, that development and the use of land does not undermine the future use of land which may be required for urban and other purposes.
NUZ2 – Rural	
	Conserve the distinctive rural landscape setting of Canberra and maintain its ecological integrity
	Conserve sufficient wildlife habitats to adequately protect native plant and animal species
	Make provision for the productive and sustainable use of land for agriculture
	Make provision for other uses which are compatible with the use of the land for agriculture
	Ensure that land parcels are appropriate in size for their approved uses
	Offer leases for time periods which reflect planning intentions for the locality
	Reinforce a clear definition between urban and rural land

In both NUZ1 and NUZ2 areas, planning processes must accommodate the somewhat competing objectives of providing long-term security for food production and landscape management while maintaining capacity for urban development in areas that are subject to a Disallowable Instrument or identified in the ACT Planning Strategy.

The ACT Planning Strategy, 2018[17] specifically identifies the need to:

- Recognise and protect existing industrial, commercial and service trade areas as important elements of a diverse economy (Strategic Direction 2.4).
- Reduce vulnerability to natural hazard events and adapt to climate change (Strategic Direction 3.2).
- Plan for integrated water cycle management to support healthy waterways and a liveable city (Strategic Direction 3.4).
- Protect biodiversity and enhance habitat connectivity to improve landscape resilience (Strategic Direction 3.5).
- Reduce waste, improve resource efficiency and decrease our ecological footprint (Strategic Direction 3.6).

[17] ACT Planning Strategy 2018

Agriculture is not identified as a significant contributor to the liveability of Canberra in any current strategic planning approaches (i.e. the ACT Planning Strategy). This is surprising given these strategic directions either directly impact agricultural leaseholders or would benefit from alignment with agricultural and rural policy. The lack of recognition of the importance of agricultural production in the ACT is exacerbated when considering the commitment of Government to support sustainable urban growth by working towards delivering up to 70% of new housing within the existing urban footprint, and by concentrating development in areas located close to the city centre, town and group centres and along key transit corridors (Strategic Direction 1.1). While a target of 70% urban infill is laudable, 30% of future urban development will need to be furnished from greenfield sites, with consequent impacts on agricultural leaseholders and the capacity to diversify production and income.

Planning must accommodate the competing objectives of long-term security for food production and landscape management while maintaining capacity for urban development

This leads to an ongoing planning tension between rural and urban uses that is driven on the one hand by the desire of the ACT Government to maintain maximum flexibility for future development of land, and on the other hand by leaseholders seeking greater certainty of tenure and clarity of allowable activities needed to generate the confidence to invest in land improvements and diversification options. Despite conflicting interests, opportunities exist to explore collaborative strategic planning directions in water, biodiversity and waste management that could deliver benefits to leaseholders while meeting the objectives to maintain land availability for urban development. These are discussed later in this report and are currently being considered in the development of a dedicated agriculture policy for the ACT.

In addition to planning rules and lease purpose clause in crown leases, land use in the ACT is also subject to Land Management Agreements (LMAs)[18]. Unique to the ACT, all rural lessees are required to enter a LMA under the *Planning and Development Act, 2007*.

A LMA neither authorizes nor permits a particular use of the land. Rather, LMAs are an agreement between the lessee and the ACT government with the objective to "establish appropriate sustainable agricultural management practices and good farm biosecurity for the subject land while maintaining ecological and cultural values present on the land and protecting the environment from harm." LMAs are extremely detailed documents that describe:

- Details of existing rural enterprises conducted on the property and any additional approved activities planned for the future. This includes estimates of annual stocking levels encompassing both domestic and native/pest animals.
- Future management objectives with timetables, potential associated land management issues and proposed management practices.
- Identification of sites of significant environmental value and guidelines for their management.
- Identification of other native vegetation, an assessment of its health and associated specific management actions and timelines.
- An assessment of soil condition and a management action and timelines to address each issue identified (e.g., salinity, acidity etc.)

[18] LMA Guidelines and Agreement 2020.

- Identification and management of contaminated and hazardous materials sites
- Identification of the introduction and management of spoil
- Identification of surface and ground water sources and plans for their management.
- Identification of and management plans for riparian zones
- Identification of and management plans for erosion
- Drought risk management plans (with limited information on diversification options)
- Bushfire risk management plans
- Estimation of Eastern Grey Kangaroo numbers and any future plan to apply to cull.
- Identification of and management plans for pest plant populations
- Identification of and management plans for pest animal populations
- Identification of and management plans for heritage areas including those listed on the ACT Heritage Register and all Aboriginal places and objects.

The detail required in LMAs make them extremely resource-intensive and potentially even onerous agreements for both leaseholders and government. Their ongoing implementation has been the subject of considerable criticism, with both the Auditor General and leaseholders questioning the value of LMAs in the most recent audit.[19]. The latest audit report places significant emphasis on the variable quality and depth of information and assessment in LMAs that, together with a lack of ongoing compliance activities, compromises their ability to be used as active land management tools. For an approach to land management that is based on regulation and compliance, this is undoubtedly a significant issue.

However, perhaps the most informative aspect of the audit report is the acknowledgement of the lack of coordination of effort and cooperation between ACT Government business units and stakeholders such that there is no formal, regular and systematic opportunity to share knowledge and discuss potential system and process improvements. The current approach to lease management clearly hinders the Directorate's ability to implement and monitor jointly developed, agile approaches to lease management that meet the needs of the ACT government, rural leaseholders and wider society and are essential for the successful identification and implementation of diversification options.

2.4 Water

The ACT sits entirely within the Murrumbidgee catchment that is part of the wider Murray-Darling Basin (MDB). Water use is managed under the ACT Water Resources Act 2007 consistent with obligations placed on the ACT under the MDB Plan,[20] which establishes extraction limits and environmental water requirements.

Water extraction within the ACT is limited by the sustainable diversion limit (SDL) defined under the MDB Plan (2012). The SDL is the long-term average volume of water that can be taken – i.e., the amount of water extracted for household use, manufacturing, industry and agriculture. The ACT's SDL for surface water is 42.7 gigalitres (GL) and 3.16 GL for groundwater extraction (ACT Water Resource Plan).

Of the water extracted in the ACT during 2018-19, less than 1% was utilised for agriculture

[19] Report No. 01 of 2021 - Land Management Agreements (act.gov.au)
[20] A plan for the Murray–Darling Basin | Murray-Darling Basin Authority (mdba.gov.au)

The ACT extracted a total of 49.5GL in 2018/19 of which 30.5GL was returned to the environment, predominately as treated wastewater (ABS Water Account, Australia[21]). Water returned to the environment provides an offset in accounting for water use under the SDL.

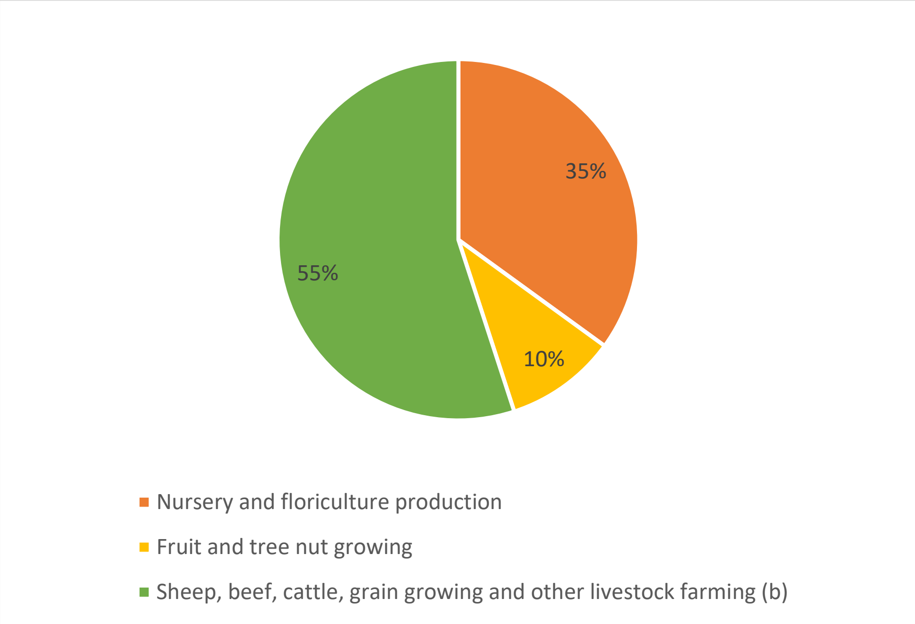


Figure 9: Agricultural water use in the ACT 2018/19; Source: Australian Bureau of Statistics. (2018-19). Water Account, Australia. ABS.

Of the water extracted in the ACT during 2018-19, less than 1% (233ML) is utilised for agriculture. The vast majority of water is used for domestic supply, sewerage and drainage services (48.5GL). Of the water utilised for agriculture, 35% is used for nursery and floriculture production, 10% for fruit and nut production and 55% for livestock farming or grain growing (Figure 9).

Groundwater resources in the ACT are very small in comparison to other areas in Australia. ACT Government policy is to limit extraction of groundwater to 10% of the volume of long-term recharge (ACT Water Resources (Water Available from Areas) Determination 2019[22]).

The current use of wastewater recycling for agricultural production and other purposes in the ACT is low. Some wastewater (approx. 250ML/year) from the Lower Molongolo Water Quality Control Centre (LMWQCC)[23] has been used for irrigation of nearby vineyards (100ha) and is currently supplying a golf course (30ha)[24]. The North Canberra Water Re-Use Scheme provides water to 70ha over seven sites. Figures from 2004-2009 indicate daily wastewater inflow to the LMWQCC of 80ML/day (from an average use of 164L per person per day) with outflows to the Murrumbidgee catchment between 1990 and 2008 averaging 81ML/day.

Outflow from LMWQCC is an important contributor to river flow in times of low rainfall and drought; however, the reuse of water from treatment plants provides an opportunity for water supply that is less dependent of climate factors and of a high-water quality. The reuse of treated wastewater is an important option in a new policy that is (at the time of writing) in draft, regarding management of point source pollution. It will also feature strongly in a future integrated water management plan.

[21] 46100DO010_201819.xls (live.com)
[22] Water Resources (Water Available from Areas) Determination 2019 | Disallowable instruments (act.gov.au)
[23] Sewage Reuse Projects | Icon Water
[24] Microsoft Word - cover page (act.gov.au)

Other opportunities for wastewater treatment facilities in (or that discharge into) the ACT are emergent, but are yet to be explored.

2.5 Production and consumption

Production and consumption data for the ACT is imprecise due to the low number of farm businesses and the minor contribution that the ACT makes toward national agricultural production statistics. The most recent ABS production data for the ACT (2019-20) shown in Table 3 should be interpreted with a degree of caution; for example, the ABS estimates only one egg production business whereas consultation identifies at least three (ACT NRM Rural Landholder Survey, 2020).

Of the 235,000ha of land in the ACT, ABS estimated approximately 21,500ha was utilised for agricultural production in 2019/20[25], supporting the operation of 40 agricultural businesses[26]. Grazing remains the most common form of agricultural production on either unimproved (approximately 7,000ha) or improved (approximately 14,000 ha) pasture. Grazing is focused on the production of sheep (meat and wool) and lambs (approximately 30,000 head across 13 businesses) as well as cattle (2,300 head across 26 businesses). Egg production is also a feature, with at least 2,600 layers producing 52,000 dozen eggs annually. Alternative animal production is focused mainly on the well-established horse and equestrian sector.

Broadacre cropping is insignificant with only marginal activity targeted toward production of animal feed. Horticultural production is dominated by orchards (4 businesses) with more than 2,200 trees, 1,500 of which are of bearing age. Almost all orchard production is focused on apples (1,452 mature trees bearing 14 tonnes of fruit) with lower production of pears (35 trees bearing 2t) and other fruits and nuts (45 trees) that includes olives as well as hazelnuts as a host for truffle production. There is a single viticulture business growing grapes for wine production on 9ha.

[25] NB: The actual area of agricultural production is estimated to be larger (i.e. closer to 40,000ha) but is comprised of agricultural enterprises that do not meet the ABS definition of agricultural businesses.
[26] 71210DO001_201920.xlsx (live.com)

*Table 3: Agricultural production in the ACT 2019-20. Source Australian Bureau of Statistics. ^estimate has a relative standard error of 10% to less than 25% and should be used with caution. * estimate has a relative standard error between 25% and 50% and should be used with caution. (a) Including hens in moult, (b) E.g. horses, goats, beehives, domesticated buffaloes.*

COMMODITY DESCRIPTION	ESTIMATED AREA (ha)	NUMBER OF BUSINESSES
Land use - Land mainly used for agricultural production - Total area (ha)	21,598^	40
Land use - Land mainly used for grazing - Total area (ha)	21,006^	35
Land use - Land mainly used for grazing - Grazing on improved pastures - Area (ha)	13,959^	27
Land use - Land mainly used for grazing - Grazing on other land - Area (ha)	7,048^	21
Livestock - Sheep and lambs - Total (no.)	30,703^	13
Livestock - Cattle - Total cattle (no.)	2,371	26
Livestock - Poultry and eggs - Live poultry - Layers (no.) (a)	2,675*	1*
Livestock - Poultry and eggs - Commercial hen egg production for human consumption - Total (dozens)	52,091*	1*
Livestock - All other livestock n.e.c. (no.) (b)	537^	15
Land use - Land mainly used for forestry (including plantation and native forest) - Area (ha)	13*	1*
Fruit and nuts - Orchard fruit and nuts - All orchard fruit (including nuts) - Total trees (no.)	2,208^	4^
Fruit and nuts - Orchard fruit and nuts - All orchard fruit (including nuts) - Total trees not yet of bearing age (no.)	676*	1*
Fruit and nuts - Orchard fruit and nuts - All orchard fruit (including nuts) - Total trees of bearing age (no.)	1,532^	3^
Fruit and nuts - Orchard fruit - Apples - Trees of bearing age (no.)	1,452*	3^
Fruit and nuts - Orchard fruit - Apples - Production (t)	14*	3^
Fruit and nuts - Orchard fruit - Pears (including Nashi) - Trees of bearing age (no.)	35*	1*
Fruit and nuts - Orchard fruit - Pears (including Nashi) - Production (t)	2*	1*
Fruit and nuts - Orchard fruit - All other orchard fruit n.e.c. - Total trees (no.)	45*	1*
Fruit and nuts - Grapes for wine production - Total area (ha)	9	1

Consumption data is even more sparse than production data. The most accurate source of consumption data is from the 2012 Food in the ACT study (Turner et al., 2012) but even these figures are based on 1988/89 data. **Error! Reference source not found.** summarises potential ACT c onsumption of key foodstuffs based on average per capita assumption as reported (Turner et al., 2012) adjusted for population growth to 431,500 as at December 2020[27]. The figures therefore do not account for changes in diet since 1988/89 (e.g., they do not capture the significant increase in the consumption of chicken meat over the last two decades) and are not directly comparable with the production figures above. They are included here to provide some context of the average food consumption in the ACT.

[27] https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/dec-2020

Table 4: Predicted food consumption in the ACT extrapolated from Turner et al., 2012 adjusted for increased population size

MAIN PRODUCT	SUB-CATEGORY	VOLUME P/C PER YEAR	INDICATIVE TOTAL ACT CONSUMPTION
Dairy	Butter	2.9kg	1,251t
	Cheese	10.7kg	4,617t
	Milk	102.4L	44,186 kL
Meat & meat products	Beef	36.4kg	15,707t
	Lamb & mutton	16.3kg	7,033t
	Pig (including ham and bacon)	28.3kg	12,211t
	Poultry	30.8kg	13,290t
Fresh Fruit (including juice)	Citrus	56.4kg	24,337t
	Other	55.4kg	23,905t
Vegetables	Potatoes	68.0kg	29,342t
	Other root and bulb vegetables	24.4kg	10,529t
	Tomatoes	24.9kg	10,744t
	Leafy and green vegetables	20.6kg	8,889t
	Other vegetables	25.1kg	10,831t
Eggs		137	4,926,292doz
Grain products	Flour	16.3kg	7,033t
	Rice	7.1kg	3,064t
	Bread	53.4kg	23,042t
Nuts	Tree nuts	4.8kg	2,071t
	Peanuts	2.3kg	992t

It is apparent that consumption in the ACT is highly reliant on food produced in other areas of Australia and, to a lesser degree, overseas. This introduces several potential risks to the ACT food supply chain but also highlights opportunities to replace or complement external food sources with local production of vegetables, fruit, eggs and meat.

Consumption in the ACT is highly reliant on food produced in other areas of Australia

The lack of accurate production and consumption data is a significant impediment to the development of sustainable food production strategies by government and the private sector to assess diversification options that generate increased availability of locally sourced food in the ACT. The data gap has previously been identified (Turner et al., 2012) as a serious barrier to food resilience in the ACT and action by the ACT government, together with the ABS, to develop a common approach to data generation is needed. In addition, the ability to capture willingness to pay data, based on food quality and regionality would contribute significantly to a more accurate picture of ACT consumption trends that reflect the relatively high level of disposable income and discerning nature of consumers.

2.6 Australian Capital Region

The attributes of farms in the ACT are unique because of the size of operations, the use of land in the ACT and the regulations imposed. However, the general production environment and the relationship with buyers and consumers should be considered on a wider basis. The Australian Capital Region (ACR) includes the ACT and 17 surrounding NSW Local Government Areas and is relevant to strategic planning decisions of both the ACT and NSW governments. It overlaps significantly with the NSW South-East Local Land Services[28] and Southern Inland RDA[29] areas.

Agricultural production in the South-East and Tablelands region of NSW area provides a good depiction of that in the ACT region more generally[30] as it includes the same focus on beef and sheep production. Unsurprisingly, broadacre cropping becomes more significant in the western part of the region while dairy and nursery industries are more prevalent in the eastern regions. Beef, sheep and wool production are core agricultural activities across the region.

The significant overlap of the ACT region with the SE Local Land Services and Southern Inland RDA provides significant opportunities for joint strategic planning and investment activities. In many areas, data sharing between ACT and NSW Government agencies is already in place (e.g., biosecurity and bushfire management). Effective collaboration for the delivery of some extension programs is also apparent, although often driven by officer-level interactions. There are further opportunities for more structured collaboration particularly as it relates to economic development in the region.

[28] South East - Website - Local Land Services (nsw.gov.au)
[29] About Us – RDA Southern Inland (rdasi.org.au)
[30] Agriculture Industry Snapshot for Planning South East and Tablelands Region (nsw.gov.au)

3. Farm Diversification

This report focusses on the options for diversification of production on farms in the ACT, the opportunities that can be explored and the constraints that may inhibit adoption. In doing so, it is first important to understand what is meant be diversification.

Diversification (is) the development of resilient agricultural businesses and systems using rational, affordable strategies to maintain ecosystem function and protect livelihoods

3.1 What is diversification?

Studies into farm diversification have been complicated by the lack of a generally agreed definition as to what diversification is. For the purposes of this report, a modification of the definition by Lin (2011) is used with diversification being the development of resilient agricultural businesses and systems using rational, affordable strategies to maintain ecosystem function and protect livelihoods. Consistent with the terms of reference, off-farm diversification options such as off-farm employment and leasing of land/buildings are not directly considered in this report but are important contributors to grower wealth, as well as impacting the success of other diversification activities.

3.2 Why is diversification required?

Numerous studies have explored the drivers for diversification in Australia (RIRDC, 2002; Ollenburg and Buckley 2007; Mooney et al., 2010; Medhurst and Seagrave, 2007) and internationally (Bowler et al., 1996; Barbieri et al., 2008; Barbieri and Mahoney, 2009). While most have focused on the need for diversification in more traditional farming businesses that are not widely represented in the ACT, some common reasons for diversification include:

- Addressing economic constraints to the farm business (e.g., increasing income)
- Decreasing risk associated with variation in climate, environment and markets.
- Providing an opportunity for family members to remain in the farm business (through succession planning and economic expansion).
- Capturing new market opportunities.
- Capitalising on an interest or hobby
- Better use of farm resources
- Other individual aspirations (e.g., learn new skills and provide a new challenge, desire to interact with community, enhancement of quality of life etc.).

Primary producers in Australia have historically been exposed to a range of risks associated with markets, variable climate and environment. More recently, other risks to farm businesses have become more prominent including those associated with changes in competition and supply chain dynamics as well as the need to meet community expectations for social license, animal welfare, sustainability, provenance, and trust (Lockie, 2015; Laurie et al., 2019).

Governments have increasingly viewed farm diversification as an economic lifeline for farm businesses (Ollenburg and Buckley, 2009) and an effective method to address many economic and environmental risks. However, it is not a panacea to all the risks associated with primary production. Indeed, despite anecdotal evidence that diversification has been increasing, there is little statistical supporting data (Medhurst and Seagrave, 2007). Regardless, there are some compelling reasons for diversification to be examined closely in the ACT and surrounding regions.

3.2.1 Predicted climate

Climate variability is a major risk to agricultural production across Australia that is likely to increase under future climate scenarios (Lock et al., 2012). National climate trends[31] and ACT specific trends[32] are shown in Table 5.

*Table **5**: Modelled climate variability trends for Australia and the ACT*

NATIONAL CLIMATE TREND	ACT CLIMATE TREND
Australia's climate has warmed by 1.44 ± 0.24°C since national records began in 1910.	ACT's annual mean maximum temperature has increased by over 1.5°C since records began in 1926. Annual mean minimum temperatures have warmed 2°C in the same period.
In SE Australia, rainfall between April and October has declined by approximately 12% since the late 1990s.	Rain is variable in the ACT region, but recent years have been drier than average (with the exception of 2016).
There has been a decrease in streamflow in the majority of waterways (where gauges are present) across southern Australia since 1975.	There have been reduced inflows to water storages, with the majority of years between 2001–2002 and 2018–2019 below the long-term average.
Extreme fire weather and the length of the fire season has increased since the 1950s, especially in southern Australia.	Increase in the average and maximum Fire Danger Index and an increase in the number of days with a very high Fire Danger Rating.

Climate modelling, conducted with NSW (NSW and ACT Regional Climate Modelling project[33]), indicates a continued future drying and warming climate. Spring rainfall is predicted to decrease while rainfall in summer and autumn is expected to increase. Variability in the reliability of rainfall is a major source of farm production and viability risk (Kimura and Antón, 2011). Temperatures are expected to increase in the near future (maximum increase 0.6-0.9°C; minimum 0.4-0.7°C between 2020 and 2039) and continue rising (maximum and minimum temperatures increase by 1.4-2.3°C by 2079). In addition, the number of severe fire weather days in spring and summer is expected to increase.

[31] State-of-the-Climate-2020.pdf
[32] Office for the Commissioner for Sustainability and the Environment – An independent voice for sustainability and the environment in the ACT
[33] Australian Capital Territory Climate Change snapshot (act.gov.au)

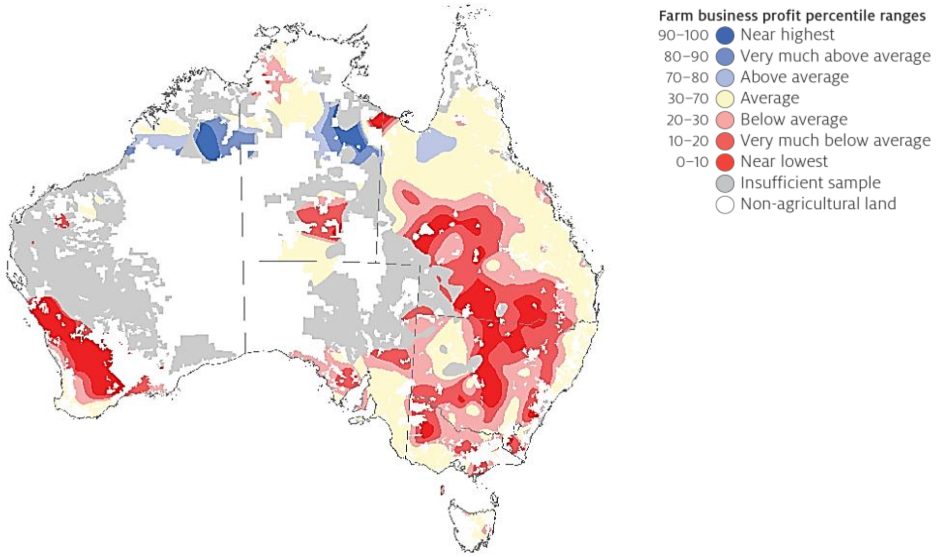


Figure 10: Simulation of percentage change in farm profits under the Recent (1999-2019) scenario, relative to Historical (1949 to 2019); Source Hughes et al., 2019.

Modelling of the potential impact of climate variability on farm profit is not precise, but the most recent simulation modelling by ABARES indicates that changes in average farm profits are already occurring based on a comparison of the 50 years between 1949 and 2019 and observations over the last 20 years (Figure 10) (Hughes et al., 2019). Future changes to profit may range from -2% to -50% depending on assumptions regarding global emissions scenarios (Table 6) (Hughes and Gooday, 2021; Hughes et al., 2021). Importantly, the results do not account for the positive effects of long-run adaptation, technological advances and carbon dioxide fertilisation.

Table 6: Percentage change in farm profits relative to Historical (1950 to 2000). Source Hughes and Gooday, 2021.

Industry	**Historical Profit ($)**	Recent (1999-2019) Change	Future Modelled Change to 2050 with action to limit global emissions (Rcp 4.5, 2050)			Future Modelled Change to 2050 with minimal action to limit global emissions (Rcp 8.5, 2050)		
			min	mean	max	min	mean	max
Beef – Northern	152,815	-3.1	-22.1	-11.7	-3.0	-54.5	-27.6	-16.3
Beef – Southern	20,968	-22.5	-26.6	+0.5	+10.3	-63.8	-18.0	-2.7
Sheep – lamb	108,234	-14.9	-16.6	-5.8	-0.1	-31.6	-12.9	-5.6
Sheep – mixed	58,817	-26.7	-37.3	-13.2	-6.3	-66.3	-28.1	-15.9
Cropping – Northern	212,491	-36.2	-23.7	-9.8	-3.6	-43.1	-20.1	-4.8
Cropping – Southern	179,423	-21.7	-27.7	-3.3	+11.5	-30.8	-8.5	+4.1
Cropping – Western	437,227	-26.8	-55.9	-31.6	-5.1	-68.1	-50.5	-7.3
All Farms	129,187	-22.6	-31.9	-13.1	-2.0	-49.9	-25.6	-10.7

Note: RCP4.5 - global emissions peak by 2040, and CO2 concentrations reach around 485 ppm by 2050. RCP8.5 - limited curbing of global emissions, such that CO2 concentrations reach around 540 ppm by 2050.

The Canberra region is classified as part of the southern beef production system but has more recently been included as part of the northern cropping region. The potential impact of climate change on beef and sheep production systems is significant while impacts on broadacre cropping is of lower relevance in the ACT.

While there are limits to the predictability of global climate systems (Nelson et al., 2010), climate variability over the past 20 years has increased the riskiness of farming in Australia (particularly south-western and south-eastern areas), with the risk of very low returns in any one year increasing from 1 in 10 in the period 1950-2000 to 1 in 5 (Hughes et al., 2019).

One of the major risks associated with an increasingly variable climate is the increased likelihood of drought (Lock et al., 2012). Australia has a unique approach to drought policy amongst developed nations, having moved from the treatment of drought as a natural disaster up to 1992 (triggering subsidies, low interest loans and cash grants) to one that focusses on managing drought as an integral aspect of farming in Australia. Farmers are now expected to assume greater responsibility for preparedness and proactively manage the risks associated with increasing climate variability (Quiggin and Chambers, 2004; Botterill and Hayes, 2012; Kiem and Austin, 2013). The effectiveness of this approach is evident in recent analysis of the drought risk associated with wheat production, where the adoption of new technologies and practices since 2007–08 have resulted in wheat yields under dry conditions increasing by 14% (Hughes and Gooday, 2021).

Some government support is required to address the social and economic impacts of a more variable climate, but most commentators agree that it should focus on adaptive capacity generated through resilience in preference to short-term responses (Kiem et al., 2010 and Goucher, 2020) This principle is clear in the Future Drought Fund, the key Federal investment to build drought resilience in Australia's agriculture sector, the agricultural landscape, and communities[34]. The $5 billion fund[35] generates approximately $100m per annum invested to build drought resilience through:

- Harnessing innovation - driving adoption of new drought resilient technologies and practices
- Better risk management - helping farmers and regions plan for drought
- Better climate information - making climate information accessible and useful
- More resilient communities - building social capital to drive change and support resilient communities
- Better land management - trial and adoption of land management practices that support landscape resilience

While the lack of certainty regarding the precise impact of climate variability makes it difficult to assess the long-term viability of many diversification options (Kandulu et al., 2012) that form part of the Federal Drought Fund and other regional initiatives, diversification remains an important tool for managing predicted climate variability in the ACT, including periods of drought (Figure 1)(Laurie et al., 2019).

3.2.2 Meeting sustainability objectives

Urban transport and electricity generation have been the largest contributors to greenhouse gas emissions in the ACT and are specifically targeted in the ACT Climate Strategy[36]. The *Climate Change and Greenhouse Gas Reduction Act 2010*[37], adopted by the ACT Government sets targets for:

- Zero net greenhouse gas emissions by 2060;
- 80% below 1990 levels by 2050; and

[34] Future Drought Fund - DAWE
[35] Future Drought Fund Annual Report 2020–21 (awe.gov.au)
[36] ACT Climate Change Strategy to a Net Zero Emission Territory (amazonaws.com)
[37] Climate Change and Greenhouse Gas Reduction Act 2010 | PDF

- 40% below 1990 levels by 2020.

An important but often overlooked contributor to greenhouse gas emissions in the ACT are emissions associated with the transport of food and other materials to the ACT from elsewhere in Australia. For example, it is estimated that 90% of Canberra's leafy greens and fruits come from the Sydney Markets[38].

It's estimated that 90% of Canberra's leafy greens and fruits come from the Sydney Markets

Initiatives to limit food transport miles by increasing the availability of local produce have the potential to increase freshness as well as contribute to ACT sustainability targets. Despite this, it is unrealistic to believe that the ACT could or should achieve 100% food sustainability from the ACT region. The reality is that some foods are more economically produced in other areas of Australia (or internationally) or can only be produced in other areas (e.g., tropical foods such as mango, banana, sugar etc.). There are opportunities, however, to produce and market some foods in the ACT that are currently transported from elsewhere - even if that incurs higher costs. This concept is explored in detail by Regional Development Australia (ACT and Southern Inland) and is the basis for its recently released Proposal for Sustainable Urban Food in the ACT. Importantly, the proposal recognises that a sustainable city must be fully integrated with the region which surrounds it and that regional food producers can be better engaged in closer collaboration to deliver desired sustainability outcomes.

Agricultural production can also contribute to sustainability and the reduction of greenhouse gas emissions through sequestration of carbon in natural woodlands, grass lands and forestry plantations as well as managing emission from ruminant animals. Carbon sequestration opportunities in the ACT are limited as discussed later in this document. Management of animal emissions is most likely dependent on technology breakthroughs. For example, seaweed additives developed by CSIRO in their FutureFeed program which have been shown to reduce enteric methane emissions by more than 80%[39]. Given the close location with CSIRO and the University sector, ACT graziers are well placed to participate in exploring these opportunities to reduce methane generation as well as increasing profitability and sustainability of production.

While there are opportunities for agriculture in the ACT region to contribute to meeting the ACT Government's sustainability objectives, to make a meaningful contribution farmers must first be profitable in their own right. A sound financial base supports active participation in the sustainability debate, valued contributions to agricultural policy settings and engagement in the R&D required for innovative solutions to what are complex problems.

3.2.3 Addressing waste management

Waste minimisation and reuse schemes have been in place in Australia for decades and were originally targeted toward achieving human health, environmental and aesthetic outcomes. Over the past several decades, waste management has become a critical aspect of sustainability programs, with increasing recognition of the contribution that organic waste in landfill makes to greenhouse gases through the release of methane. Waste management in the ACT, and in particular the

[38] ACT sustainable urban food proposal - RDA ACT Aug 2019 | PDF (scribd.com)

[39] FutureFeed - CSIRO

management of organic waste, is therefore an essential component of meeting sustainability goals and in meeting obligations of the Climate Change and Greenhouse Gas Reduction Act 2010[40].

The re-purposing and reuse of organic waste - often referred to as the circular bioeconomy - is an important focus of the National Food Waste Strategy[41]. The size and connectedness of businesses in the ACT mean that the region is well placed to implement many principles of the circular bioeconomy. Waste accounts for 3% of ACT greenhouse gas emissions[42]. There are significant opportunities for the innovative management of organic waste to reduce the ACT's emissions profile while also contributing to agricultural productivity and sustainability through diversification and new business models.

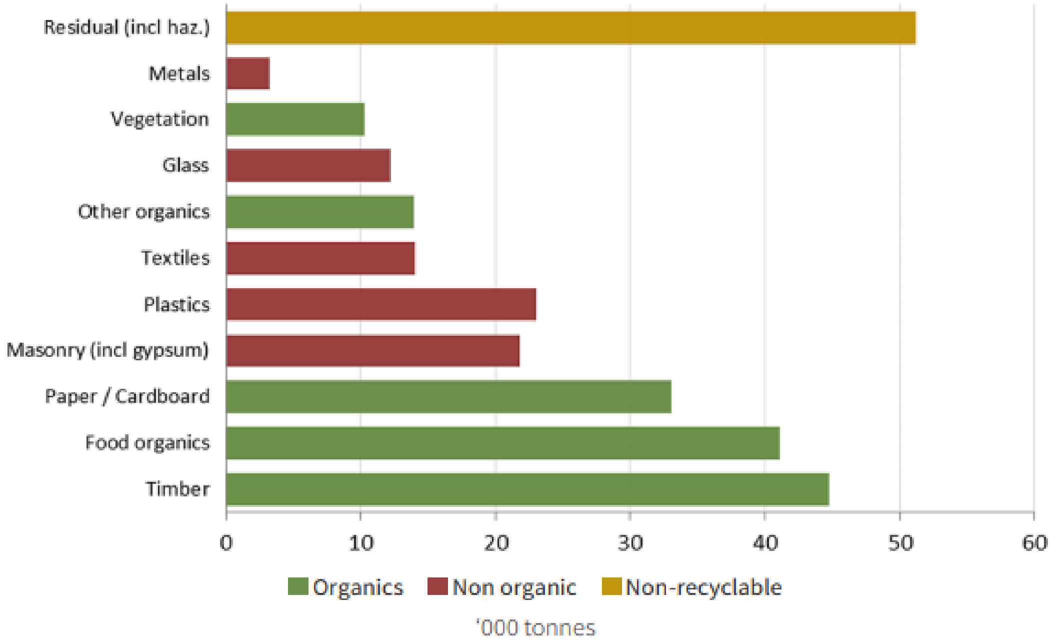


Figure 11: ACT waste going to landfill; Source: ACT Waste Feasibility Study

More than 200,000 tonnes of green waste (over 90% of ACT's total garden waste) per annum is recovered, processed, and reused[43]. However, the amount of food and other organic waste that is transferred to landfill (approximately 40-50% of 61,000t of annual household waste, Figure 11)[44] remains high.

Commercial composting (as opposed to home composting, which is also important) provides the opportunity to combine food waste, biosolids and green waste to generate soil improvement products at scale. Given the low capacity of most soils in the ACT, the addition of organic matter to stimulate soil biology, increase water retention and improve soil nutrition could be part of numerous diversification strategies that not only increase productivity but also contribute to managing ACT organic waste streams.

[40] https://www.legislation.act.gov.au/DownloadFile/a/2010-41/current/PDF/2010-41.PDF
[41] National Food Waste Strategy: Halving Australia's Food Waste by 2030 (awe.gov.au)
[42] ACT Waste Management Strategy
[43] ACT Waste Management Strategy
[44] Waste Feasibility Study - Roadmap and Recommendations (amazonaws.com)

3.2.4 Economics and employment

Given that Canberra was specifically established as a location for Federal Government, it is not surprising that the ACT has a high reliance on central government administration as a driver of economic activity.

A cursory examination of the ACT employment figures shows that 18.4% of employed people in the Territory worked in Central Government Administration (compared with 1.2% Australia wide). Other major industries of employment included defence (5.2%), hospitals (except psychiatric hospitals) (3.2%), State Government administration (3.1%) and higher education (3.0%)[45]. As noted in other regional areas, the dominance of a few large employers can leave a region susceptible to changes in employment environment (RAI, 2013). The ACT economy is significantly exposed to government decisions and policies that impact public service numbers. For example, the Federal Government's approach to decentralisation of public service positions to regional Australia is designed to support regional economies but, given that 37.9% of the 152,000 public servants in Australia were located in the ACT when the decentralisation approach was first implemented in 2017[46], the policy has a significantly larger impact on employment in the ACT region than other capital cities.

While the high level of public service employment in the ACT provides a sound and stable economic base, such a narrow economic focus, that is highly reliant on successive government policies, is also a substantial economic risk. Diversification of economic activity in the ACT beyond the public service and higher education is therefore a critically important goal to which agriculture can make a significant contribution.

The Department of Agriculture, Fisheries and Forestry maintains an interactive portal of information regarding production, land use, employment and value of commodities[47]. Gross value of agricultural production in the ACT in 2020-2021 was $9 million, dominated by cattle and sheep production. It is apparent that, while agriculture in the ACT is minor contributor to the national gross value of agricultural production (estimated at $61 billion in 2019-20[48]) it is an important contributor to the ACT economy.

ABARES estimates that agriculture directly contributes approximately 2.6% to regional employment[49]. As a thumbnail sketch, applying that same percentage to the 215,833 people employed either part time or full time in the ACT at the last census[50] indicates that agriculture could – at least in theory – support up to 5,600 jobs. Actual employment in the agriculture and fisheries industries in the ACT is estimated at 500 jobs or less[51]. Agricultural production in the ACT and the surrounding region therefore has the potential to make a more significant contribution to employment, even if only at a level of employment already achieved in agriculture in other areas of regional Australia.

3.2.5 The "Bush Capital" aesthetic

As one of only a few greenfield designed cities in the world, the planning of Canberra (and the ACT as a whole) is based on the principles of productivity, sustainability, liveability and accessibility.

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[45] 2016 Census QuickStats: Australian Capital Territory (abs.gov.au)
[46] Decentralisation of Commonwealth Entities – Parliament of Australia (aph.gov.au)
[47] About my region dashboard | Tableau Public
[48] Value of Agricultural Commodities Produced, Australia, 2019-20 financial year | Australian Bureau of Statistics (abs.gov.au)
[49] Snapshot of Australian Agriculture 2021 (sirsidynix.net.au)
[50] 2016 Census QuickStats: Australian Capital Territory (abs.gov.au)
[51] About my region - Australian Capital Territory - DAWE

Indeed, the rural and natural setting of Canberra has earned it the nickname of the "Bush Capital." The desire to maintain the rural and natural setting of Canberra is captured in Part 2.3 of the National Capital Plan which specifies that:

> *Urban expansion should be contained to minimise impacts on valuable natural and rural areas.*[52]

The Territory Plan Principles for Sustainable Development[53] also note the importance of rural lands such that:

> *Planning policies will provide for the sustainable management of rural areas, ensuring that rural lands nominated for future urban development or other purposes can be retained in productive use and properly managed for the time being.*

It could be suggested that the maintenance of the desired "Bush Capital" aesthetic requires that urban encroachment be given greater scrutiny while rural lands are managed in a productive and sustainable manner that maintains the visual and environmental quality of the landscape. Farm diversification remains an important tool to maintaining the sustainability of farms that contribute to the rural aesthetic of the ACT and the surrounding landscape.

3.2.6 Bushfire Management

The ACT is predicted to experience increases in both average and severe fire weather in the immediate (next 10-20 years) and far (next 50 years) future[54] principally in Spring and Summer. With more than 50% of the ACT maintained as national or territory conservation reserves[55], the potential for dramatic fire events, as seen in 2003 and again in 2020, is high. The fires in 2003 resulted in five fatalities as well as extensive damage to buildings (insured losses estimated at $660m), livestock (13,000 sheep and 4,000 cattle died or were euthanised) and forestry (almost $1.5bn in losses and only 39% of impacted plantation salvageable)[56].

While the maintenance of significant areas of natural bushland contributes to the Bush Capital aesthetic, diversified agricultural production on rural and broadacre land provides an important buffer protecting urban areas. This is reflected it the ACT Strategic Bushfire Management Plan 2019-24 which identifies that the people occupying and managing rural properties are an important part of bushfire response and management[57]. Maintaining their presence and collaboration through diversification programs that support resilience are important aspects of the ACT fire management strategy.

3.3 Farm diversification options

The range of diversification options available to farm businesses is significantly impacted by several factors (Figure 12) including farm size, human capital and variation in land capability and soil type (Anosike and Coughenour, 1990). Other factors influencing diversification options include the risk appetite of the individuals involved (RIRDC, 2002), location and access to labour (Culas, 2006), life stage, family decision-making and ease of integration with current farm operations (Medhurst and Seagrave, 2007).

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[52] Part Two – Statement Of Planning Principles | National Capital Authority (nca.gov.au)
[53] https://www.legislation.act.gov.au/DownloadFile/ni/2008-27/copy/118748/PDF/2008-27.PDF
[54] Australian Capital Territory Climate Change snapshot (act.gov.au)
[55] ACT Nature Conservation Strategy 2012-23
[56] a56c563caa5bb336050ed88c60dba7e4.pdf (climatecouncil.org.au)
[57] Strategic Bushfire Management Plan 2019–2024 (act.gov.au)

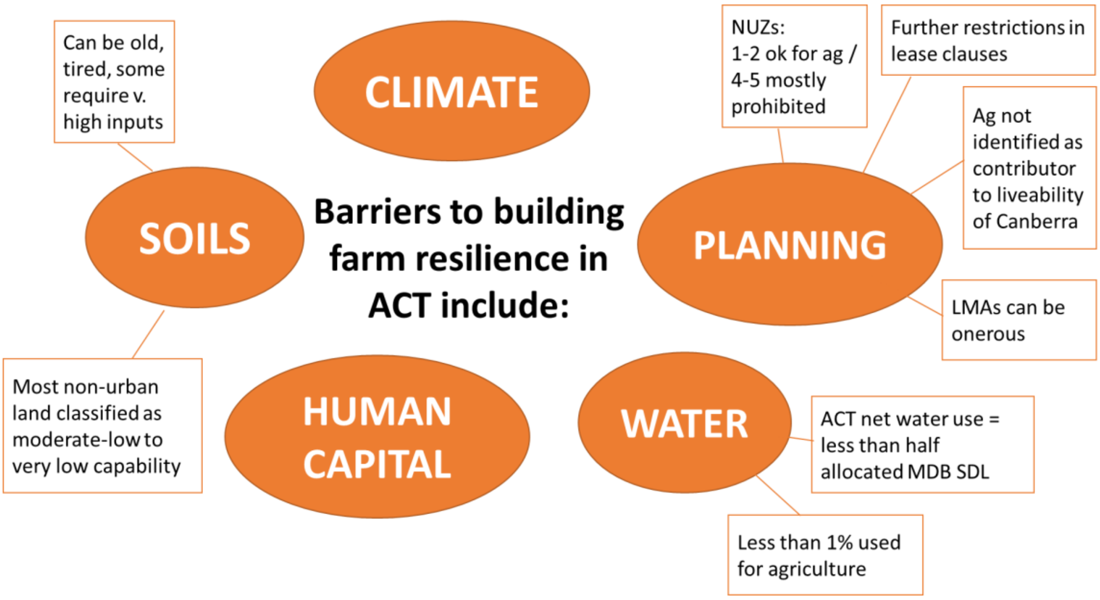

Figure 12: Barriers to building farm resilience to drought in the ACT

Considering these and other factors, eight general categories of diversification have been identified (Barbieri and Mahoney, 2009):

1. Non-traditional crops, livestock and practices
2. Value-adding to existing products
3. New marketing and distribution
4. Recreation, tourism and hospitality
5. Historic preservation and adaptive re-use
6. Leases, easements and timeshare
7. Contracts and services
8. Education, expertise and consulting

Contracts and services, together with education and consulting (options 7-8) are largely off-farm income streams and, consistent with the terms of reference, are not considered further here. The remaining options can be further grouped into those associated with current or future production (options 1-3) and non-production options (4-6). These options have formed the basis for examining a range of diversification activities in Australia and overseas[58] and are explored further below.

3.3.1 Production-based options

The relatively poor land capability in the ACT limits production-based diversification options that require more fertile soil and/or pose unacceptable hazards of environmental damage associated with production activities. Options in current farming systems such as improving the organic matter of soils, maintaining groundcover to improve water infiltration, utilisation of mixed farming system approaches and pasture improvements have not been discussed in detail here. While they are important technologies and practices for improving the productivity, resilience and profitability of farming businesses, they are either already being routinely implemented or validated in most production systems. This report focusses on non-traditional alternative production systems as well as opportunities for value-adding, new markets and improving food distribution that align with the land capability and potentially provide a market niche for the ACT and surrounding region.

[58] List of Alternative Crops and Enterprises for Small Farm Diversification | Alternative Farming Systems Information Center | NAL | USDA

Intensive glasshouse/greenhouse production

The reliance of the ACT on production and markets in Sydney for the bulk of its fruit and vegetables is a potential food security risk but is better explored as an opportunity for the diversification of production, in particular intensive greenhouse production. Under the Territory Plan, horticulture (including intensive production) is included as a sub-category of agriculture and is presumably permitted in zones acceptable for agricultural production, subject to the assessment of a relevant development application. The success of any application is likely to be highly dependent on the probability that greenhouse/glasshouse infrastructure can be accommodated within the aesthetic of the region and, in the case of lit glasshouses, the degree to which any light pollution can be managed to meet relevant standards.

Assuming planning approval could be gained, the success of any intensive venture would be largely dependent on cost and access to irrigation water and power. The green electricity strategy of the ACT would contribute to the sustainability credentials of an intensive production facility, but the economic feasibility would require careful consideration especially given recent increases (and expected future increases) in retail electricity charges of 11.95% in 2021-2022 that would equate to an increase in the weekly bill of around $14.45 for an average non-residential customer consuming 25,000kWh[59]. The electricity use of greenhouse complexes is likely to be significantly higher than this for supplementary lighting on overcast days and especially during winter when heating will also be essential.

Irrigation may potentially be less of an issue if access to treated wastewater can be obtained. Currently, the majority of treated wastewater from the ACT is returned to the Murrumbidgee River but the opportunity for its use in production should not be dismissed, especially if coordinated with compost production from organic waste recycling in a closed circular bioeconomy.

Only 3% of treated wastewater is utilised in agricultural production in Australia (Radcliffe, 2022) predominately for fodder production. Depending on the quality of water exiting treatment plants, a range of production opportunities exist from non-food options such as flowers and forestry to production of foods that are cooked before consumption and those that are eaten raw (highest quality water required). Many of the current integrated uses of wastewater have been developed to address concerns regarding the high nutrient load of treated water and several examples of utilising treated water for agricultural production exist in capital cities and larger regional towns (Table 7Table 7). Costs vary widely depending on how much treatment infrastructure is also required.

[59] Retail electricity price recalibration 2021–22: standing offer prices for the supply of electricity to small customers (act.gov.au)

Table 7: Treated wastewater production schemes - adapted from Radcliffe, 2022

Location	Year	Quality	Volume (GL p.a.)	Cost ($)	Cost ($/kL)	Distance (kms)	Use
South Australia							
North Adelaide	1999	A	15	$55m	$0.05 - $0.09	N/A	Spray irrigation salad and other crops
North Adelaide	2017	A	12	$155.6m	$0.27*	N/A	Spray irrigation salad and other crops
South Adelaide	2002	B/C	8	$7m	$0.95 - $1.25**	13	Viticulture
Victoria							
Werribee	2019	C	13	N/A	N/A	<5	Pasture
Werribee	2005	A	8.5	>$20m	$0.36	N/A	Vegetables and salad
Melbourne	2014	A	5#	N/A	N/A	N/A	Vegetables and salad
Melbourne	Current	C	Up to 19	$116m	N/A	59	Dryland farms
Ararat-Grampians	1995	C	0.65	$4.1m	$0.205	N/A	Viticulture
NSW							
Gerringong	2002	N/A	>1.8	N/A	N/A	<5	Dairy pasture
Tamworth	N/A	N/A	6	$35m	50% OPEX	N/A	Fodder (lucerne)
Dubbo	N/A	N/A	2.8	$6.8m	N/A	<5	Fodder (lucerne)
Narrabri	N/A	N/A	0.65	N/A	N/A	14	Cotton & other crops
Shoalhaven	2003	A	5	$34m	N/A	N/A	Dairy pasture
Queensland							
Hervey Bay	2007	A/B	5	$30m	$0.035	N/A	Sugarcane & forestry
Mackay	2008	A	N/A	$154m	$0.05	N/A	Numerous
Bundaberg	2018	A	1	$71m	N/A	<5	Sugarcane

* Growers also pay a one-off $3.16/kL capital contribution and annual $0.26/kL availability fee
** Growers also pay a one-off $7260/GL capital contribution
\# A further 100Gl/year of class A water discharged to ocean that could be diverted.

Most successful examples of the use of treated water are observed when the treatment plant is situated within 15km of production (to minimise capital and operating costs). Applying a similar radius in the ACT highlights the potential for intensive horticulture in the west of the ACT assuming that integration with potential urban development in the Western Edge Investigation Area and adjacent greenfield sites[60] can be achieved.

Emerging crops, livestock and practices

AgriFutures has previously commissioned extensive review of emerging industries in 2018 (Decker and Kurnik, 2018[61]) and again in 2021 (Coriolis, 2020[62]; Wilkinson et al., 2021[63]).

The initial review in 2018 (Decker and Kurnik, 2018) identified 50 potential emerging industries, of which 10 were selected for further investigation. Of the 10 industries investigated, only four (snails, insects, jujube[64] and medicinal mushrooms) are considered suitable for potential production in the ACT regional climate (most others are tropical plants e.g., cocoa, sesame, turmeric or are regarded

[60] ACT Planning Strategy 2018
[61] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf
[62] https://www.agrifutures.com.au/wp-content/uploads/2021/05/21-052a.pdf
[63] https://www.agrifutures.com.au/wp-content/uploads/2021/05/21-052.pdf
[64] Jujube is a Chinese plum.

as weeds in Australia, e.g., tiger nut is a declared weed in NSW[65]). The 2021 review (Coriolis, 2020; Wilkinson et al., 2021) focused on emerging industries with the potential to generate $10m per annum turnover or more (based on qualitative assessment of fit with Australian capabilities and conditions, and the potential size of the industry) that were not the focus of the 2018 review.

The following section provides a brief overview and summarization of potential new production opportunities and constraints with potential relevance to the ACT as identified in the AgriFutures reports (including further production details in some cases) and a range of other sources. This represents the potential of new industries, which is general in nature. It is not a definitive list, and, in most cases, there are likely to be significant variations in figures depending on farm type, market and season. No reliance on the data must be made without seeking prior expert professional advice. More detailed information is available in the AgriFutures reports (Decker and Kurnik, 2018; Coriolis, 2020; Wilkinson et al., 2021) and on the AgriFutures farm diversity webpage[66].

Snails[67] [68]

The small Australian snail industry is largely centred on the common brown garden snail (*Helix aspersa)*, a species thought to have been introduced in Australia in about 1890 and the only species permitted for farming in Australia[69]. Internationally, snail consumption is dominated by France and Spain with French consumption outstripping domestic supply. Despite a potential ready market, exports of snails from Australia in the past five years have been limited to 3,554kg in 2019 compared with an import of almost 46,000kg of which more than 22,000kg was imported in 2020 (UN Comtrade Database[70]).

Snail production is relatively straightforward and has been described in detail (Murphy, 2001) with most production occurring in pens and crates. Snails can endure a wide range of environments including temperatures down to -4°C and up to 30°C but will enter dormancy when exposed to extreme cold or hot temperatures[71].

Snail farms have been established in most states including WA, Queensland, Victoria, Tasmania and NSW. Snails can be sold domestically live or processed on-farm, although this would require the construction of facilities that meet associated food standards. Under the Territory Plan, snail farming is presumably a type of animal husbandry and therefore would be prohibited in NUZ2 but may be permitted in NUZ1 subject to development approval.

As snail production is labour-intensive, it is expected that international markets will most likely be serviced by countries where labour cost structures provide a competitive advantage. In Australia, an opportunity for import replacement is possible although the domestic market is currently limited to growing snails for restaurants where supply relationships have already been established[72].

Other potential uses of snails include snail slime, which is finding a growing use in skin creams for wrinkles, dry skin, and acne. Snail secretion filtrate is widely used in Korean beauty products such as

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[65] Cyperus esculentus | WEEDS AUSTRALIA - profiles (ala.org.au)
[66] Farm Diversity Search | AgriFutures Australia
[67] Snails | AgriFutures Australia
[68] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf
[69] Snails | AgriFutures Australia
[70] Download trade data | UN Comtrade: International Trade Statistics
[71] Snails | AgriFutures Australia
[72] *Ibid*.

serums, facial masks, moisturisers, and fading creams. Demand for snail caviar in international markets has also been increasing steadily[73].

Insects[74]

Insects have been a significant part of many human diets for centuries. As global demand for protein continues to increase, the global edible insect market is expected to grow to $1.3bn in 2025 with expected annual growth of 44% (FIAL, 2019). The global export trade is dominated by Belgium ($US52m trade value), the Netherlands ($US19m), United Kingdom ($US18m), Israel ($US16m) and the USA ($US8m) (UN Comtrade Database[75]).

The Australian insect market consists primarily of crickets and grasshoppers, mealworms and black soldier flies utilising waste streams and low-quality feeds. Several insect production companies are established in Australia and the Insect Protein Association of Australia (IPAA) advocates to promote the use and role of Insects within the Australian food and feed ecosystem[76]. Goterra, a startup insect business located in the ACT and founding partner of IPAA has recently completed a $5.5m capital raising co-led by Tenacious Ventures and Grok[77] (see case study in Section 3.5).

Promising immediate markets appear to be in the provision of alternative proteins to stock feeds (aquaculture in particular) and the pet food industry, especially where production can be located with waste streams suitable as feed sources[78]. The slow development of the insect market is associated with unclear regulatory requirements in different countries, the need to overcome customer aversion to insect consumption and a lack of scale that makes supply difficult even when demand is established[79]. Interestingly, there is relatively little publicly available information on the rearing and processing of insects in Australia despite its potential.

As with snail farming, under the Territory Plan, insect rearing is presumably a type of animal husbandry and therefore would be prohibited in NUZ2 but may be permitted in NUZ1 subject to development approval.

Tree crops

Tree crops with production potential in ACT include hazelnuts, walnuts, and jujube[80]. They are most likely to be suitable for production only on areas with land capability class five or better. Regardless of market potential, the establishment of tree crops in the majority of the ACT is hindered by a number of environmental and regulatory issues that include:

1. The lack of land with suitable capability.
2. The requirement for irrigation infrastructure and water (8-10ML/ha/annum) to achieve consistent yields.
3. The high cost of initial capital investment and long pay back periods (trees maturing in 10-15 years) is not attractive to most potential investors/growers.

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[73] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf
[74] *ibid*
[75] Download trade data | UN Comtrade: International Trade Statistics
[76] Insect Protein Association of Australia
[77] Tenacious co-leads Goterra's $6m Series A to launch Australia's first agrifoodtech VC - AFN (agfundernews.com)
[78] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf
[79] Edible insects (csiro.au)
[80] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf

4. The long time to maturity is not compatible with the ACT zoning and planning regulations that limit the length and stability of some leasing arrangements, in particular the potential to exercise termination clauses.

Hazelnut[81]

Hazelnuts represent an opportunity for import replacement with Australia importing more than 3,200t of shelled product annually and exporting less than 8t(UN Comtrade Database[82]). Approximately 60% of Australian production is utilised domestically (either in direct retail or through food service industries) with under 40% of production exported. A single company (Ferrero) planted more than one million trees in 2013, which will mature in the next five years and can be expected to significantly impact market dynamics[83]. Indeed, in 2020 approximately 350t of in-shell nuts were produced and this is predicted to grow to 5,500t in 2021 as newer plantings begin to mature[84]. Current hazelnut production in the ACT region is more closely associated with truffle production for which the trees are a host.

Walnut[85]

Australian walnut production and consumption is largely self-sufficient but is characterised by export of approximately 4,400t of in-shell product and import of 4,900t of shelled product (UN Comtrade Database[86]) reflective of the opportunity for Australia to meet contra-season demand for fresh product in the northern hemisphere. Almost all demand for fresh, whole walnuts in the domestic market is expected to be met by domestic production while product to meet demand for kernel is expected to continue to be sourced from imports[87]. Market opportunities for new growers are influenced by scale of production and ability to meet market demand, with export markets requiring significant volumes and domestic markets seeking fresh 'direct from the grower' product[88]. Walnut trees reach mature production levels in 10-15 years and production from extensive commercial plantings in the 2010's can be expected to come on-line in the next few years limiting opportunities for small producers to local markets where a lack of scale can be more easily accommodated[89].

Jujube[90]

Jujubes (Chinese dates) are hardy trees that tolerate poor growing conditions and extremes of temperature[91]. They prefer a cold winter and hot, dry summer and would be suitable for production in the ACT. Jujubes are an emerging industry in Australia principally located in the south-west of Western Australia where 10,000 trees are planted on 20ha. Jujubes from this source are sold domestically through specialist supermarkets and farmers markets. Domestic demand exceeds supply[92]. China is the largest producer (over 8 million tonnes in 2015) and, as of 2015, was the only exporter of jujube fruit. There is some potential for export to China from Australia, but China maintains high inventories and given its large production base and regulated market, can exert

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81 Hazelnuts | AgriFutures Australia
82 Download trade data | UN Comtrade: International Trade Statistics.
83 Hazelnut industry snapshot - Hazelnut Growers of Australia Inc. (hazelnutgrowersaustralia.org.au)
84 *Ibid*.
85 Walnuts | AgriFutures Australia.
86 Download trade data | UN Comtrade: International Trade Statistics.
87 Walnuts | AgriFutures Australia.
88 *Ibid.*
89 *Ibid*.
90 https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf.
91 *Ibid*.
92 20131129 PRJ_005304 Final Report _ for edits (agrifutures.com.au)

significant price control. Indeed, some Chinese growers have left the market in the last five years due to low prices and lack of return on investment[93].

Medicinal mushrooms[94]

Several mushroom producers operate in the ACT region with most focused on the production of edible white and brown mushrooms (*Agaricus*) for the domestic market. Australia-wide other edible mushrooms are also produced including shitake, enoki and oyster mushrooms[95]. Australia imported only 40t of *Agaricus* mushrooms in 2020 but almost 4,000t of other mushrooms (UN Comtrade Database[96]).

The potential of alternative edible and medicinal mushroom market remains largely untested but is explored in some detail in the AgriFutures emerging industries report[97]. A number of edible mushrooms with medicinal properties were identified including Reishi and Maitake, used in Chinese traditional medicine, as well as Chaga that potentially has anti-cancer properties. Most recently, researchers at University of Queensland have been given approval to collect and catalogue native 'magic' mushrooms in Australia[98]. The Federal Government is investing $15 million in grants to support research into the use of mushrooms amongst other treatments to combat illnesses such as PTSD, major depressive disorders, addiction and eating disorders[99]. The edible medicinal mushroom industry remains in its infancy with some serious barriers to expansion associated with regulation (it is currently illegal to cultivate, possess or supply psychedelic mushrooms in Australia) standard identification and the detection of potential side effects associated with their use or consumption[100].

Spices and herbs

Saffron[101]

Saffron is the dried stigmas and styles of the crocus flower (*Crocus sativus*) and is one of the most valuable spices in the world (about $30,000/kg gross value)[102]. *Crocus* is well suited to growing in the ACT region requiring slightly acidic soils that are not too fertile. *Crocus* thrives at low temperatures and requires a cold shock to initiate flowering. Flowering occurs over a 15-day period in autumn and about 150–200 flowers are needed to obtain one gram of dry stigmas[103]. Yields of 1-2kg/ha in Australia are usual[104] but the higher summer temperatures and rainfall of the ACT region would probably require supplemental irrigation (Crocus requires 800-1,200mm rainfall per annum) to achieve maximum yield. Saffron production is highly labour intensive with flowers being picked by hand and subsequent processing also requiring manual labour.

Australian production of saffron has varied greatly over the last decade as have exports, from a high of over 2t in 2017 to the current 178kg (UN Comtrade Database[105]). Imports regularly exceed 8t per annum and a strong domestic industry was established supplying Australian saffron to Coles and

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[93] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf
[94] *ibid*
[95] Mushroom Varieties - Australian Mushroom Growers
[96] Download trade data | UN Comtrade: International Trade Statistics
[97] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf
[98] A trip into the therapeutic potential of Australia's native magic mushrooms - UQ News - The University of Queensland, Australia
[99] Psychedelic renaissance' sees first legal collection of Australia's medicinal magic mushrooms - ABC News
[100] https://www.agrifutures.com.au/wp-content/uploads/2018/10/18-040.pdf
[101] Saffron | AgriFutures Australia
[102] *ibid*
[103] *ibid*
[104] *ibid*
[105] Download trade data | UN Comtrade: International Trade Statistics

Woolworths supermarkets. However, Australian saffron is not price-competitive with international production (on a price basis), that is dominated by Iran[106].. Australian saffron production is dominated by Tasmania (Tas-Saff[107]) with product distributed through some wholesalers as well as directly marketed to restaurants and boutique retailers and being sold online. There is potential for saffron production in the ACT, but it would need to generate a premium product with specialist marketing to maximise the potential for viability.

Essential oils

Global growth in essential oils is predicted to be significant as the consumer focus on natural ingredients continues. Capital annual growth between 2019 and 2026 of almost 10% is likely ((Coriolis, 2020[108]). Several essential oils are produced on a commercial scale in Australia[109] including eucalyptus oil, tea tree oil, Western Australian sandalwood oil, lemon myrtle oil, lemon-scented tea tree oil, lavender oil, peppermint oil, bitter fennel oil, parsley oil, boronia absolute, orange oil, lemon oil and *Santalum album*. Potential production suited to the ACT environment is most likely associated with lavender and potentially an emerging essential oil derived from kunzea.

Lavender[110]

Despite the current small size of the domestic lavender industry, it is predicted to grow to \$5m-\$10m by 2030[111]. Lavender is quite suited to the ACT region environment, being frost hardy and drought tolerant but it does prefer free draining soils with a pH of 6.0-8.0[112] which are difficult to identify in the ACT. Lavender is grown commercially in the ACT region and surrounds at Laggan (Crystal Brook Farm), Coolagolite (Maryvale Farm), Wagga Wagga (Rustique), most often in conjunction with some form of agritourism, ecommerce and/or farm gate sales.

Lavender is propagated by cutting and can take up to four years to reach mature oil and flower production (about 5t flowers/ha)[113]. The scale of production differs between those farms where lavender is one of a number of income streams to larger, specialist producers utilising mechanised harvesting and irrigation as well as distillation of the oil on farm. Growing for wholesale selling (e.g., supplying a third-party oil distillery) is unlikely to be profitable with some growers acknowledging that the high costs of production (mainly water and labour) require value adding in the form of on-farm production of oil or other products[114].

Crystal Brook Farm, Larkman Nurseries, Golden Grove Naturals and La Trobe University are undertaking research into lavender agronomy, variety selection and essential oil production[115] that may assist the further growth of the industry.

Kunzea

Kunzea ambigua or white tick bush is a native species belonging to the Myrtaceae that is found from NE Tasmania to NSW[116]. Kunzea oil has been identified as a prospective emerging industry with the

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[106] Saffron | AgriFutures Australia
[107] Tas-Saff | Saffron. From Only the Finest Flowers
[108] https://www.agrifutures.com.au/wp-content/uploads/2021/05/21-052a.pdf
[109] The Essential Oils Industry in Australia | EOPAA.
[110] Lavender Oil | AgriFutures Australia
[111] https://www.agrifutures.com.au/wp-content/uploads/2021/05/21-052a.pdf
[112] Lavender Oil | AgriFutures Australia
[113] *ibid*.
[114] High Tasmanian lavender production costs a barrier to a booming industry - ABC News
[115] Could lavender be Australia's next \$10 million rural industry? | About Regional
[116] Kunzea ambigua - Growing Native Plants (anbg.gov.au)

possibility of growing from $2m in 2019 to $5m-$10m by 2030[117]. Current production is focused on Tasmania and the oil market is dominated by a single company, Zea Relief[118]. Zea Relief estimates current domestic production at 2-3t with most derived from material harvested from the wild.

K. ambigua is native to the ACT but it, together with other species in the genus (e.g., *K. ericoides*) also have the potential to be a problematic pest species if changed production and/or environmental situations allow it to assume dominance in vegetation communities. Kunzea can form dense stands of growth that severely impact other plant and animal species. The invasiveness of *K. ambigua* and its potential to have severe to catastrophic effects on the environment has resulted in it being identified as a plant of concern in Victoria (Carr, 2001). Anecdotal evidence suggests that *K. ericoides* is similarly invasive in the ACT where environmental disturbance can result in significant stands that dominate the local flora.

There is an opportunity to develop Kunzea into a commercially grown crop similar to that of tea tree (4000ha under production generating 900 tonnes of oil with a value of $35.32 million[119]) with the added benefit of addressing a potentially significant environmental issue of invasive weediness. Development of the Kunzea industry in the ACT would require confirmation that the subspecies present contains sufficiently high levels of oil to make extraction viable. It may also need to address freedom to operate, with patents granted for the use of Kunzea oil in the internal treatment of a range of diseases, pests and other ailments[120].

Aquaculture

In common with insect and snail production, if aquaculture is classified as animal husbandry under the Territory Plan, it would be prohibited in NUZ2 but may be allowed in NUZ1 subject to a development application.

Yabbies[121]

Of the freshwater crayfish that are commercially produced in Australia, the yabby (*Cerax destructor*) possibly represents the greatest potential for the ACT as they can withstand water temperatures from near freezing to above 35°C. Growth is fastest when water temperatures are between 23°C and 25°C with limited growth when water temperatures are below 15°C or exceed 28°C[122].

Total yabby production in NSW for human consumption has declined in the last two to three years (due to drought and climatic conditions), compared with the growth in production of yabbies for bait (where they are sought after by Murray Cod and trout fishers) (Figure 13)[123]. Production volumes and prices are highly volatile, and it is assumed that in years of excess production for the human consumption market product is re-directed to the bait sector with a commensurate impact on price.

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[117] https://www.agrifutures.com.au/wp-content/uploads/2021/05/21-052a.pdf
[118] Zea | Australian Kunzea Products for Health and Wellness
[119] Tea Tree Oil | AgriFutures Australia
[120] http://pericles.ipaustralia.gov.au/ols/auspat/applicationDetails.do?applicationNo=2008241370
[121] Freshwater crayfish (Redclaw) | AgriFutures Australia
[122] *ibid.*
[123] Aquaculture production reports (nsw.gov.au)

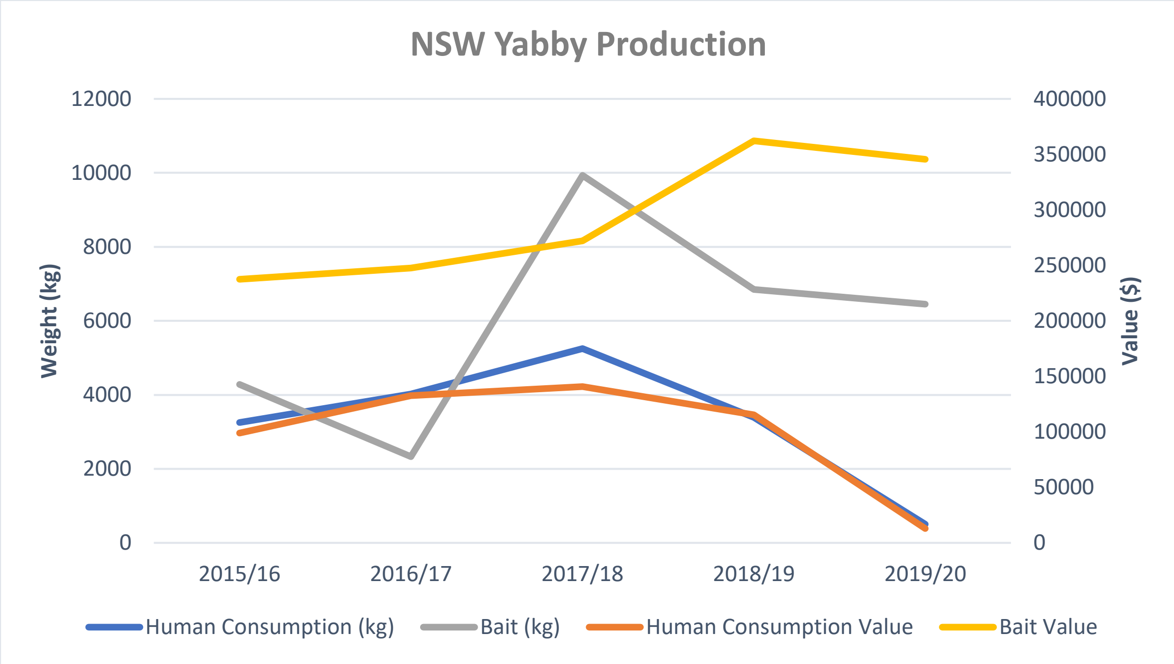

Figure 13: NSW yabby production (kgs and value) for human consumption and bait; Source: NSWDPI aquaculture production reports

Yabbies consume a range of foodstuffs (both vegetation and scavenging animal carcasses) and are adaptable across a range of environments. Consequently, they have been a target of numerous attempts to culture them but, despite some success, the main Sydney market is still supplied mainly with wild caught yabbies from the west of NSW[124].

Yabbies are sold domestically and in some export markets in Europe and Asia although marron are the preferred freshwater crayfish in many export markets. However, the risks associated with yabby production are significantly lower than those for marron principally because marron can take between three and five years to grow to a marketable size[125].

Prices between AU$8 and AU$18 per kilogram have been recorded with larger yabbies commanding higher prices especially in domestic restaurants[126]. Yabby production is most extensive in farm dams with little intervention, but the potential of the species for semi-intensive production is significant[127].

Finfish

Finfish suited to the ACT environment include trout and Murray cod. Trout are already extensively produced at Eucumbene trout farm, which also integrates a café, accommodation and fishing options[128]. Rainbow trout are the most commonly farmed of the trout species due to the ease of production and 207t was produced in NSW alone in 2019/2020[129]. Exports of fresh or chilled whole trout from Australia have averaged 80-90t over the past five years, while imports of chilled trout have declined from a similar figure to just 26t in 2019. Imports are instead dominated by the import of frozen fillets with quantities ranging from 416t in 2019 to 299t in 2020, and smoked products

124 Yabby - aquaculture prospects (nsw.gov.au).
125 Freshwater crayfish (Redclaw) | AgriFutures Australia
126 *ibid*
127 Yabby - industry profile (nsw.gov.au).
128 Experience trout fishing the way it was meant to be - Eucumbene Trout Farm
129 Aquaculture Production Report 2019-2020 (nsw.gov.au)

(457t in 2020 - UN Comtrade Database [130]). Given the production requirements, especially the need to completely circulate water every hour[131], establishment of a viable, artificial trout farm in the ACT seems optimistic.

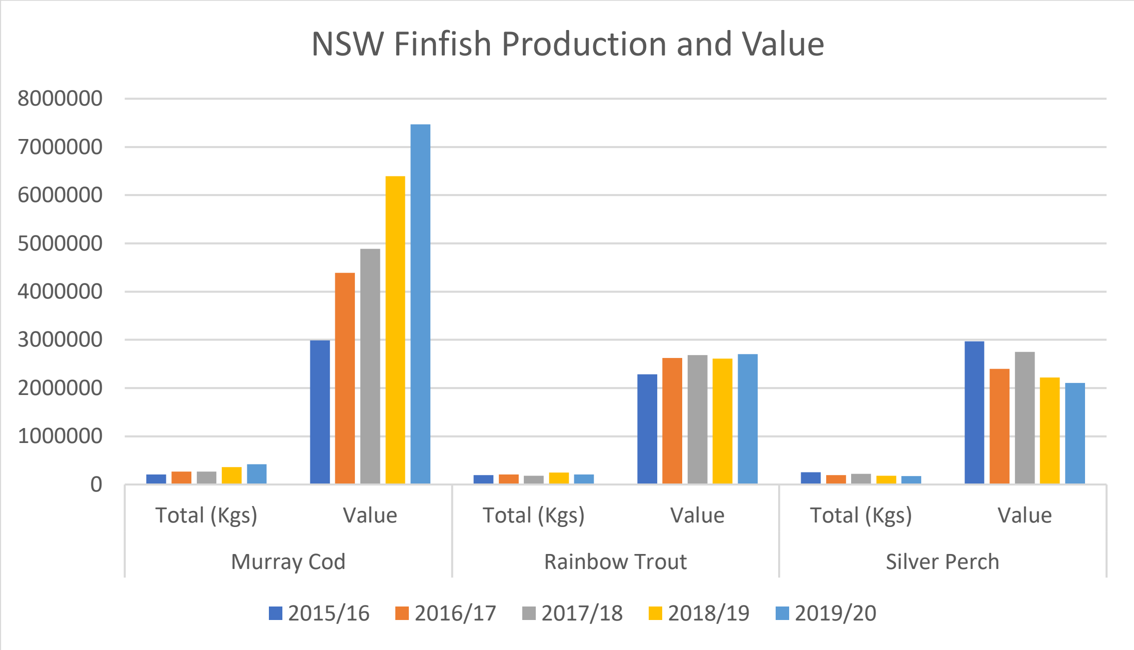

Figure 14: Value of NSW fin fish aquaculture (selected species). Source: NSWDPI Aquaculture Production Reports

Murray cod production has experienced a period of accelerated development over the past four years (Figure 14). Industry value in 2019 was between $7m and $10m and estimated to grow to between $30m and $50m by 2030[132]. Production has previously been based on fish in farm dams (stocked at about 200 fish/ha)[133] but is now undertaken by several commercial entities including Aquna and Uarah fisheries, both in the Riverina. Original assessments of Murray cod for aquaculture were not favourable with many believing the highly territorial nature of the fish would make it unsuitable for intensive raising. On the contrary, Murray cod has proven to be quite suitable for intensive production in recirculation tanks and hybrid systems where grow out is managed in pond systems[134]. Intensively-raised Murray cod require high protein diets and while conversion ratios of less than 1 have been reported, it is more likely that ratios in the order of 1.5-2:1 are achievable (e.g., 1.5kg feed for every 1kg body weight achieved). Water temperature of about 25°C has been shown to be optimal and water quality must be high[135].

The NSW DPI has identified the potential for both filleted and live fish in the domestic and export markets and has extensive material available to assess the economic viability of Murray cod farming, although most is somewhat dated[136]. Production information, including development of a genetic selection program is also available from the Victorian fisheries authority[137].

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[130] Download trade data | UN Comtrade: International Trade Statistics.
[131] Trout farming in NSW
[132] https://www.agrifutures.com.au/wp-content/uploads/2021/05/21-052.pdf
[133] Murray cod - aquaculture prospects (nsw.gov.au)
[134] *ibid*.
[135] *ibid*.
[136] Murray cod - industry profile (nsw.gov.au).
[137] Murray Cod aquaculture - VFA

Bio-active Honey

Bio-active honey, also known as Manuka honey, is produced by bees that feed on species of *Leptospermum*. Australian bio-active honey producers are currently actively participating in legal action against certification of the trademark Manuka honey by producers in New Zealand[138] which has recently seen the New Zealand application for trademark in the United Kingdom rejected[139].

Different species of *Leptospermum* confer different levels and types of compounds with anti-microbial activity in the honey derived from them. Recent research (Cokcetin et al., 2019) has identified that honey produced from bees feeding on seven key species of *Leptospermum* has very high anti-bacterial activity associated with elevated levels of methylglyoxal. The antifungal activity of some honey is more closely associated with the level of peroxide-type activity with honey derived from *Leptospermum* generally exhibiting non-peroxide activity (Cokcetin et al., 2019). Of the seven *Leptospermum* species generating honey with high levels of anti-bacterial activity, none are identified as endemic to the ACT region (Table 8).

Table 8: Key Leptospermum species for bioactive honey production.

***LEPTOSPERMUM* SPECIES**	**STATES FOUND**
L. lanigerum	NSW, Vic, SA, Tas
L. liversidgei	Qld, NSW
L. nitens	WA
L. polygalifolium	Qld, NSW, Vic
L. scarposium	Vic, Tas
L. speciosum	Qld, NSW
L. whitei	Qld, NSW

Leptospermum lanigerum can be grown in the ACT - indeed it is listed as a native species of the region by the Australian Native Plants Society[140] - but would likely require the establishment of controlled plantings to support bio-active honey production.

Global trade statistics do not differentiate between bio-active honey and honey in general. However, imports of honey into Australia have, on average, exceeded exports by approximately 2:1 over the past five years (UN Comtrade Database[141]).

A range of other production-based diversification options exist including alpacas, dairy goats and sheep, gamebirds, other essential oils and truffles. Some of the intensive animal industries may be prohibited developments on some land in the ACT while other industries have already been established in the ACT region. For all, the production requirements are well established, and the benefits and risks of diversification largely are associated with individual's circumstances. They are therefore not discussed here but further information on some of the more common options, as well as case studies of individual growers, can be obtained from the AgriFutures website[142].

[138] Time is Running Out: Australian Manuka Honey Industry in David vs Goliath Battle for Survival - Australian Manuka Honey Association (manukaaustralia.org.au).

[139] Australia emerges victorious in British manuka honey trademark battle with New Zealand - ABC News

[140] brochure-native-plants-canberra-region.pdf (nativeplantscbr.com.au)

[141] Download trade data | UN Comtrade: International Trade Statistics.

[142] Farm Diversity Search | AgriFutures Australia

3.3.2 Value-adding to existing products

One of the challenges for producers of commodity products is that they are generally price takers rather than price makers. Typically, larger commodity producers maintain and improve economic performance through adoption of scale economies (productivist approaches), but product diversity and scope economies can also make significant contributions to farm business performance (Paul and Nehring, 2005). This is particularly pertinent for smaller scale producers (that are typically highly represented in the ACT region) where scale efficiencies are more difficult to achieve. Value adding of product (for premium and non-premium markets) provides an opportunity to identify additional demand and increase prices received. Indeed, the EU has previously administered dedicated programs to support on-farm processing opportunities as part of their farm assistance packages (Gellynck and Viaene, 2002).

However, diversification into value added products is not risk-free. Markets are often small and target a niche of consumers looking to access farm food as an alternative to industrialised processes and/or are seeking access to fresher food of known quality and origin (Gellynck and Viaene, 2002). The effort and expertise required for value-adding should not be underestimated but it does represent a significant diversification opportunity especially where products can be promoted as natural, local, traceable and sustainable.

One of the most direct forms of value adding is the supply of locally sourced meat to consumers as an alternative to the sale of animals either through saleyards (the nearest to the ACT are the yards at Yass) or over the hooks where animals are marketed directly to an abattoir. Under a “locally sourced” approach, locally raised animals (mostly cattle or sheep in the ACT, but could also be goats, poultry or game birds) are processed at certified abattoirs capable of maintaining traceability of the carcass from slaughter to butchery that ensures provenance of the product. The resulting meat is sold either directly to the consumer or via a specialist butcher.

While this may appear to be a relatively simple and low risk diversification option, the reality is that meat processing in Australia is a high-volume, low-margin business where costs are strictly controlled, and ongoing quality assurance is a necessity. As such, most facilities are geared toward specific, high-volume markets. For example, Frews at Stawell, Victoria, is slaughtering 4,500 lambs/day but with capacity for 6,000[143]. On this scale, the entire ACT sheep flock could be processed by a single abattoir in under a week.

There is little capacity in most major abattoirs for processing small numbers of animals, which is a requirement for the value-added operations described above. Consequently, growers exploring these opportunities have been required to either establish their own processing facilities (e.g., Tablelands Premier Meats at Canowindra[144]) or transport animals to the nearest abattoir that processes limited numbers (e.g., Moruya) with commensurate increases in costs. Some mobile abattoir options exist, but most are dissuaded from operating in the ACT by the small numbers of animals, the lack of a suitable site for operations and the high cost and difficulty associated with the disposal of offal.

The opportunities and constraints for value-adding in other sectors differ with product. Alpaca growers may use wool to produce garments or toys, but the nearest mills for processing alpaca fleece are either in Victoria, Orange[145] or Burra[146]. Apple and pear growers may use fruit for cider

[143] Thomas Foods International buys 50pc stake in Frew Group - Sheep Central
[144] https://tablelandspremiermeats.com/about
[145] Adagio Mills
[146] Processing | Bostonfinefibres

making provided the varieties are suitable. Indeed 3 Sons Cider is an ACT cider making business based in Aranda that utilises apples from the local region, Batlow and their own grown trees to make a range of English ciders that are available from the Cook Friendly Grocer, Hop & Vine and Plonk[147]. Sully's Cider is also made in the region, at Reidsdale, and sold via some local shops as well as through the Braidwood Farmers' Market[148]. The higher rainfall areas east of the ACT and down to the coast have a long history of dairying and still accommodate a range of cheese making enterprises from the boutique to large, national producers, including Bodalla, ABC Cheese Factory and Bega[149]. It is therefore somewhat surprising that there is only a single cheese making enterprise in Canberra, Gypsy Cheese Company, which uses milk sourced within 300km of Canberra and sells product at local markets[150].

Clearly, a range of value adding opportunities exist in Canberra, some on-farm and others through collaboration with other entities. Regardless of the value-adding opportunity, success is a factor of the capacity to meet the demands of maintaining current production while developing value-added opportunities. For some, the effort required to undertake value-adding is part of the lifestyle they seek. For others though, product development, innovation and marketing are additional tasks to be completed in addition to the production focus of the farm enterprise.

3.3.3 New marketing and distribution

Direct marketing of farm products has exploded, particularly online, with the use of social media as a marketing tool and the ease in which webpages and shop platforms can be generated by individuals. The strategies employed differ with the needs and demands of the market and several different approaches may need to be tested to identify those most effective for the product being sold. Both online and on-site options are canvassed here.

On-site selling

There are two unique types of on-site selling:

1. **Roadside stalls** – In areas with high through-traffic, selling methods as simple as a road-side stall with an honesty box have been successfully utilised in many areas of Australia. In the Riverland, roadside stalls of citrus, vegetables and other fruit are common with almost all operating on an honesty system. In almost all cases, revenue from the roadside supplements the major farm operation that is selling product via other mechanisms. The roadside stall must therefore be inexpensive to establish and does not warrant the diversion of labour that could be better used elsewhere on the farm. The same principles are applied to roadside stalls in the ACT in the Majura Valley (e.g., Majura Valley Free Range Eggs[151]) and Pialligo, both of which have very high levels of through traffic. It also applies to a lesser extent in other areas but still principally on thoroughfares with high traffic loads (e.g., Amberley Farms Free Range Eggs[152]).

2. **Attracting tourists to a location then on-selling product** – like roadside stalls, this involves direct sales to the consumer. However, rather than relying on through-traffic, the consumer is provided a separate reason to visit the farm then provided the opportunity to purchase

[147] 3 Sons Cider
[148] Braidwoodmade - championing local produce and cultural distinctiveness
[149] Food & Wine - Canberra Region
[150] https://www.instagram.com/gypsy_cheese_co/.
[151] Eggs — Majura Valley Free Range Eggs (mveggs.com)
[152] Adam never thought he would be a chicken farmer but now he won't turn back | The Canberra Times | Canberra, ACT

farm products. Cellar door sales are a prime example and in the ACT Mt Majura Vineyards[153] hosts events which attract potential customers (e.g., the RIEDEL sensory workshop[154]). These ventures require a greater outlay of capital in establishing a destination for people to visit and are therefore higher risk, but also provide greater opportunities for collaboration with others to make multiple offerings to visitors - thus sharing the risk as well as benefits.

Online sales - ecommerce

E-commerce platforms have become commonplace for purchasing everything from clothing and jewellery to properties and stocks. It is therefore unsurprising that e-commerce is also a feature of selling food and food products with the potential to increase profitability in agricultural markets by increasing sales while decreasing sourcing and transaction costs (Carpio et al., 2013).

Data from U-box, the largest direct to customer agri-food platform in Taiwan, has shown that the Covid-19 pandemic has resulted in significant increases in demand (5.7% increase in sales) and customers (4.9% increase) for fruit, vegetables, and other agricultural products (Chang and Meyerhoefer, 2021).

However, the perishable nature of food products means that the relevance of e-commerce platforms for direct to customer marketing for small farm businesses can be challenging. For many smaller farm businesses, such as those in the ACT region, e-commerce is more likely to form part of a combination of marketing channels needed to maximise overall sales (LeRoux et al., 2009). Often this occurs through the use of e-commerce as a platform to coordinate product offerings across multiple producers to meet demand or as an offering from a single producer that may also use other sales channels such as wholesale and/or farmers' markets.

Perhaps one of the most successful uses of e-commerce in small producer marketing is the MarketMaker[155] platform developed in 2000 by extension staff at the University of Illinois to connect Illinois food producers with new markets. MarketMaker is now a multi-state, national network covering more than 18,000 food related enterprises in an electronic farm directory/food marketing/educational tool providing information about products, availability, affiliations, attributes, certifications and more.

MarketMaker does not have a sales feature, meaning that consumers and buyers cannot make direct purchases via the website. The directory instead focusses on the development of relationships between producers and buyers. Producers, that might otherwise find it difficult to promote their product, register their businesses in MarketMaker to efficiently communicate their products or services, reach a larger number of potential buyers and develop profitable business relationships. Buyers register with MarketMaker to connect with food producers that are growing or looking to grow produce with the buyer's preferred product attributes. Likewise, consumers use the database to locate suppliers of a desired product or to find local farmers markets, co-op grocers, agritourism sites, and restaurants using local produce. MarketMaker also allows producers to match their products more effectively with the needs of buyers and consumers and promotes the production of differentiated, high-quality products that are efficiently sourced and generate higher margins.

MarketMaker is only one of a range of similar directories offered by private suppliers, local grower organisations and government entities. A similar platform is being developed within the Canberra Region Food Collaborative (CRFC) a collaboration of the ACT and Southern Inland RDAs. The CRFC is

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[153] Mount Majura Vineyard | Canberra District Wine
[154] Mount Majura Vineyard | RIEDEL Sensory Workshop
[155] MarketMakerWebsite (foodmarketmaker.com)

envisaged to be an independent information broker and coordinating body that, through a range of R&D, training initiatives, data platforms and other assistance, will encourage producers and retailers to shorten the food supply chain and deliver better food options in the ACT region[156]. The CRFC has an ambitious agenda that will require strong government and private sector support to be successfully implemented. If successful, it provides the opportunity to bring together participants from across the ACT region food supply chain to make transformational changes to food production and consumption that can support diversification at the grower level while providing fresh, high-quality product to consumers and contributes to the ACT targets for greater sustainability.

Alternative Agri-Food Networks

Farmers' markets

Farmers' markets and co-operatives are particularly important options for maintaining the viability of small-holder farmers. Productivist policy settings[157] (based on ongoing improvements in production efficiency) require farmers to continually increase productivity to remain viable but small-scale farmers are not always able to adapt (Fielke and Bardsley, 2013). Farmers' markets and other alternative market mechanisms, often collectively referred to as Alternative Agri-Food Networks or AAFNs (Andree et al., 2010), provide complementary options or an alternative to conventional supply chains with an emphasis on quality, locality and sustainability. Hybrids can and do exist, with producers diversifying risk by selling some product through conventional wholesalers and retaining some product for sale through AAFNs (Ilbery and Maye, 2005; Fielke and Bardsley, 2013).

Farmers' markets are the more visible AAFN model and have been popular for many years. As defined by the Australian Farmers' Market Association,[158] farmers' markets are predominately a fresh food market operating regularly within a community at a public location providing a suitable environment for farmers and specialty food producers to sell farm-origin and associated value-added specialty foods for human consumption (and plant products) directly to customers.

In the ACT, the major farmer's markets are the Capital Region Farmers' Market (CRFM) (located at EPIC on a Saturday) and Southside Farmers' Market at Phillip (held on Sunday) as well as smaller markets at the Bus Depot and Hall. Taking the CRFM as an example, rules[159] for stallholders are in place that maintain the authenticity of regional produce and maintains consumer trust. Stall fees[160] are modest, $150 registration fee, $75 for a small site and $5 each for power and advertising. Nearly 80% of farmer respondents to a survey in 2014 indicated that they made a profit from their farmers' market stall (Woodburn, 2014) but most growers acknowledged the need to be regular stallholders to maximise impact. To overcome the need for a continual presence, some smaller producers will utilise an agent to sell their product. Agents are permitted at CFRM but are required to pay an agents' fee and must indicate who grew the produce they are selling and where it was grown.

Farmers' markets represent a realistic alternative retail opportunity for many growers that is complementary to other selling options. Very few growers use farmers' markets as the sole sales point (only 7% in the 2014 survey) with most using a range of distribution channels to sell their

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[156] CANBERRA REGION FOOD COLLABORATIVE - Home (agrifood-hub.com)
[157] i.e. the tenet that measurable growth is the primary purpose of an endeavour, such that *more production* is inherently good.
[158] Australian Farmers' Markets Association (farmersmarkets.org.au)
[159] Capital Region Farmers and Food Producers Market Rules (capitalregionfarmersmarket.com.au)
[160] Provisional Rotary Club of Mitchell—Gungahlin (capitalregionfarmersmarket.com.au)
https://capitalregionfarmersmarket.com.au/wp-content/uploads/2020/03/Stall-Fees-January-2017.pdf

produce. The most frequent alternative market options were local shops and restaurants and direct to the food service sector (Woodburn, 2014). The strengths and weaknesses of farmers' markets, from the perspective of growers, consumers and local communities have been well established (Woodburn, 2014) and are summarised below (Table 9).

Table 9: SWOT analysis of farmers' markets for growers, consumers and community; Source Woodburn (2014)

GROWER STRENGTHS & OPPORTUNITIES	GROWER WEAKNESSES & THREATS
• Reliable distribution channel • Ease of incorporation into a broader mix of selling options • Positive economic outcomes • Low risk environment to grow a business, test products and develop a brand • Opportunity to meet with and learn from like-minded people. • Increased control of business outcomes and outputs compared to other distribution options.	• High time requirement that may not fit with other parts of the business or lifestyle • Customer numbers can vary with weather, other events, holidays etc. • Highly reliant on the skill of market management to attract customers and suitable stall holders. • Limited ability to influence the actions of other stallholders that can impact on market reputation. • Some rural and regional markets may not offer adequate returns for stallholder participation especially when compared with metro markets that have consumers demanding and willing to pay for particular types of food products (e.g., organic, local product). • In some cases, stall availability can be limited especially where others are already providing like products.
Consumer strengths & opportunities	**Consumer weaknesses & threats**
• Access to local, fresh produce • Range of new foods a food-related products • Direct support of local growers and food businesses • Sustainability advantages regarding food miles and packaging.	• Decreased convenience compared with supermarkets • Produce availability impacted by season/weather • Assumption that products are better for the environment and human health often with little supporting evidence. • Potential for misrepresentation of foods being local.
Community strengths & opportunities	**Community weaknesses & threats**
• Alternative avenue to access fresh and local produce. • Viable avenue for growers to sell their produce. • Enhance community economy, leadership, wellbeing and regional development. • Informal learning environment. • Mechanism for community organisations to fund raise.	• Reliance on public venues and facilities • High reliance on volunteers subject to burn out. • Must manage small risk of food safety. • May require ongoing support and investment especially for smaller markets and those at startup phase.

Overall, farmers' markets can be a useful selling option for some farmers and food businesses, but they are not suitable for every farm business.

Co-operatives and community-supported agriculture

Co-operatives are another form of socialised selling opportunity that, in contrast to farmers' markets, use more structured relationships to provide collective offerings to consumers that could not be viably offered by a single producer.

Numerous farm co-operatives operate in Australia many targeted toward increasing purchasing power of members for inputs. Examples of selling co-operatives also exist, some of which are large firms in their own right (e.g., CBH, Sunrice, Bega), but co-operatives at the local and regional level are more significant contributors to providing selling options for producers in the ACT region.

Southern Harvest (see section *3.5.2 Southern Harvest Association - multi-producer boxes*) is a not-for-profit association established to "foster the sustainable growth and availability of local produce within the Southern Harvest region".[161] The association is supported by membership contributions and volunteers and undertakes two activities of significance for ACT region producers. Southern Harvest coordinates the Bungendore Farmers' Market that supports local growers many of whom also maintain stalls at the ACT Farmer's Markets.

Southern Harvest also maintains an active producer box scheme that is based on a Community Supported Agriculture (CSA) model[162]. CSAs vary in detail but follow the same general principle of consumers buying a share of future grower products in advance for a set period and in return receive regular food deliveries (Coles, 2019). Consumers commit to supporting farmers through the season and share the ups and downs of food production. The Southern Harvest scheme asks subscribers to commit to a thirteen-week season to receive weekly deliveries of fruit, vegetables, herbs and nuts as they are harvested. Southern Harvest facilitates this by aggregating produce from a range of local growers such that consumers are provided a greater variety than a single farm could viably produce. A typical producer box contains 8-10 different vegetables and fruit from different producers. Recently, producer boxes have been expanded to include requested non-food items.

Southern Harvest coordinates aggregation and provides advice to producers on seasonal opportunities and what produce is likely to be demanded by consumers. Produce costs are paid direct to the farmer and Southern Harvest Association charges an administrative cost of 30%. As the association is not-for-profit it does not charge a margin and therefore is highly dependent on the contributions of benefactors and volunteers.

3.3.4 Sustainability options

The increasing demand for products that have been produced in a sustainable manner is a well-defined consumer and buyer need. As consumers in domestic and international markets have become wealthier, the influence of factors other than price is evident in purchasing decisions that reflect personal values relating to sustainability of production, climate change and social welfare outcomes.

International recognition of the need for sustainable development is captured in the 17 Sustainable Development Goals and 169 targets of the United Nations 2030 Agenda for Sustainable Development adopted in 2015[163]. Countries are implementing various approaches to achieve these goals with the EU one of the most progressed through its Farm to Fork Strategy[164] which outlines a transition to a sustainable food system that should:

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[161] Constitution-of-Southern-Harvest-Association.pdf (southernharvest.org.au)
[162] Produce Boxes – Southern Harvest
[163] United Nations Official Document
[164] Farm to Fork Strategy (europa.eu)

- have a neutral or positive environmental impact
- help to mitigate climate change and adapt to its impacts
- reverse the loss of biodiversity
- ensure food security, nutrition and public health, making sure that everyone has access to sufficient, safe, nutritious, sustainable food
- preserve affordability of food while generating fairer economic returns, fostering competitiveness of the EU supply sector and promoting fair trade

The sustainability policies of the EU extend beyond domestic production to other areas such as the requirement for certification of sustainable production of canola in Australia destined for the EU biodiesel market (approximately 50% of Australian canola production) under the EU Renewable Energy Directive[165].

Major Australian agriculture export markets in Asia are also demanding greater levels of transparency over the sustainability of production[166]. The demand for sustainable production also extends to the Australian domestic market particularly for millennial and 'Gen Z' consumers[167].

Meeting the challenge of demonstrating sustainable production is a pillar of the Australian Government's $34m Agriculture Stewardship Package, supported by the iterative establishment of the Australian Agricultural Sustainability Framework (AASF), coordinated by the National Farmers' Federation. Objectives identified in the Framework[168] include:

- Integrate productivity, sustainability and biodiversity on Australian farms to provide lasting benefits to farmers and the community.
- Ensure Australian farmers can showcase best practice sustainability and biodiversity management of natural resources – and ensure these actions are recognisable by supply chains, markets, investors, the community and other farmers.

The first and second phases of development of the Framework have been completed by the Australian Farm Institute. The AASF intends to "communicate the sustainability status and goals of the Australian agricultural industry to markets and to the community", and the supporting report identifies existing and emerging commodity-focused sustainability schemes in Australia and comparable international schemes[169]. As expected, some Australian agricultural sectors are further advanced in sustainability reporting and opportunity capture than others. The current iteration of the AASF identifies 17 overarching principles of sustainability (i.e., a desired outcome or ideal state) for the Australian agriculture industry under the themes of environmental stewardship; people, animals and community; and economic resilience (Figure 15).

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[165] EU_Canola_Certification_-_GRDC_Fact_Sheet.pdf (australianoilseeds.com)
[166] From Food Bowl to Health Food Store - Disruptive Asia (asiasociety.org)
[167] Getting acquainted with a more mindful Australian consumer | McKinsey
[168] Australian Agricultural Sustainability Framework - National Farmers' Federation (nff.org.au)
[169] The Australian Agricultural Sustainability Framework - Australian Farm Institute

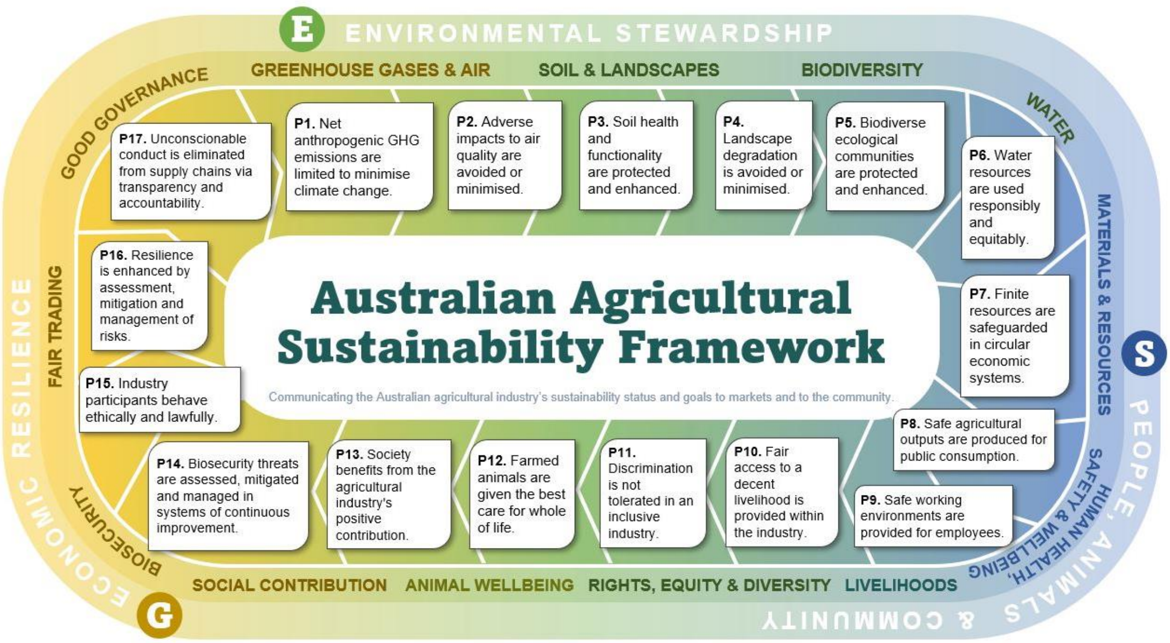

Figure 15: The Australian Agricultural Sustainability Framework. Source: Australian Farm Institute

Review of the commodity-specific frameworks confirm that demonstrating sustainability of production has moved from a value-adding activity embraced by the few, to an absolute requirement to maintain the social licence and market access which underpins all farming businesses across multiple sectors. As such, payments of premiums for sustainable production are less likely in future markets that will require demonstratable sustainable production as a pre-requisite to even participate.

3.3.5 Non-production based options

One of the notable features of agricultural production is that demand for food (especially commodity-based foods) is relatively income-inelastic; consumers demand a set volume and as incomes change, that volume remains the same (Anderson, 1987). Therefore, as incomes increase consumers tend to purchase other products such as luxury items, manufactured products and services. In effect, producers of core agricultural commodities cannot exploit the growing wealth of a population to sell more product. Subsequently, it has been demonstrated that diversification of agriculture into products and services with high income demand elasticity (e.g., demand increases with increasing consumer income) are more likely to generate long term benefits for farmers in comparison to traditional agricultural commodity production (Bailey et al., 2000). The diversification options below capture a range of non-production opportunities that may present benefits to farmers over the longer term.

Farm tourism

One of the most common on-farm, non-production options to diversify income is farm tourism. Tourism generally is an important aspect of the ACT economy and, while all tourism in Australia has been impacted by the Covid pandemic, the gross value-added to the ACT economy from tourism was $1.6bn in 2019/20[170].

Farm tourism is viewed as an important farm income diversification strategy in the northern hemisphere (Sharpley and Vass, 2005), particularly in the European Union where 10-20% of farms operate some form of tourism. In Australia only 0.2% of farms are engaged in tourism activities

[170] Australian Capital Territory tourism summary | Tourism Research Australia

(Ollenburg, 2007). A survey of growers in the Cootamundra/Gundagai region indicates that agritourism has significant potential but remains niche and driven by farming family preference rather than a major market change (Olsauskas et al., 2018). This may change significantly with the pandemic, which has resulted in far greater uptake of domestic travel and may provide a major opportunity for suitably inclined growers to diversify into tourism-based activities.

The motivation to undertake farm tourism includes both social and economic drivers, although economic outcomes remain the most important driver in most situations (Sharpley and Vass, 2005; Ollenburg and Buckley, 2007; Northcote and Alonso, 2010). The influence of these drivers is apparent in the four predominate farm types that undertake tourism activities (Ollenburg, 2007; Ollenburg and Buckley, 2007):

1. Full-time farmers utilise tourism as an option to manage economic risk – tourism activities are a direct trade off from farming and must generate significant income to warrant their pursuit.
2. Part-time farmers are broadly similar to full-time farmers but in general have already undertaken a level of income diversification, often through off-farm part time work.
3. Retirement farmers may use tourism to boost cash flow while residing on the property in semi-retirement and tend to place a greater value on social outcomes.
4. Lifestylers have often chosen farming because of the amenity and social aspects and for these people, tourism can be a primary source of income.

Farm tourism in the ACT region varies from conventional farm-stay arrangements (often advertised through hosting services such as Airbnb) to more sophisticated tourism operations for local, national and international visitors. Farm tourism, as defined in the Territory Plan[171] means operating a craft workshop, shop, guesthouse, outdoor recreation facility, overnight camping area or other activity for tourists that is secondary to the use of the land for the primary purpose authorised by the lease. Planning in the ACT specifically accounts for fostering tourism, including farm tourism, by permitting a variety of entertainment, leisure and accommodation facilities, including opportunities for ecotourism, in appropriate locations throughout the Territory (section 1.15 of the Territory Plan) although such activities also need to be consistent with land use clauses in lease agreements.

Farm stay accommodation is widespread with a cursory review of Airbnb identifying multiple farm stay options within an hour of Canberra with most highlighting either the opportunity to stay on a working farm, and/or the seclusion of accommodation away from the city. The value of these selling points depends on the clients being targeted and their promotion requires a marketing approach that clearly identifies the target audience and presents them options that appeal to their desired accommodation type. Platforms such as Airbnb and others provide a level of sophistication in their algorithms that allow users to search for farm stays, but further marketing via dedicated websites and advertising is also needed.

Ad hoc events (weddings, birthdays etc.) could also be important diversification options requiring relatively little capital input. Within the ACT there are numerous opportunities for *ad hoc* events on farming properties located in areas of natural beauty and especially when associated with historical events or buildings. For example, Lambrigg Station is the former home of William Farrer whose contributions to wheat breeding in Australia were commemorated by his portrait on the two-dollar note and would be of historical interest. The property itself is also stunning and has previously featured in *Country Style*[172] and other magazines.

[171] 2008-27 (40).PDF
[172] Historic Lambrigg garden in Tharwa, ACT | Country Style (homestolove.com.au)

The degree to which a*d hoc* agritourism events such as event hospitality aligns with ACT leasing requirements is unclear. Such events would potentially be ancillary to the use of the land for the primary production purposes but are aligned with the activities to foster tourism outlined in section 1.15 of the Territory Plan. They are however subject to ambiguity of what constitutes a tourist which is not defined in the Plan.

At the other end of the scale of farm tourism sophistication are the properties that maintain dedicated tourism offerings as an important part of adding value to the primary farm operations. These operations clearly fall within the definition of farm tourism under the Territory Plan and are important income diversification options requiring significant investment of capital and time to be effective. They are often associated with dedicated national tour operator companies such as Contiki, Adventure Tours Australia, Trafalgar and AAT Kings. As such, they must be able to offer standardised tours of a consistent quality while also offering diverse experiences associated with the facilities and activities. Perhaps the most well-known of these operations in the ACT is Gold Creek Station[173] (see section *3.5.3 Gold Creek Station*) which works with tour operators to demonstrate sheep farm operations.

The focus and drive for different approaches to farm tourism are clearly defined by individual circumstance but the basis for successful farm tourism (Sharpley and Vass, 2005) is common across farm types and includes:

1. Location – not all areas are equally attractive. In Australia, as elsewhere, most farm tourism operations are located close to major population centres (Ollenburg, 2007).
2. Investment – like other forms of diversification, farm tourism requires significant investment. Of the diversification case studies assessed by Campbell White & associates and Black for RIRDC in 2002 (RIRDC, 2002), the two that involved farm tourism both required substantial investment ($1.2m and $500,000 in 2002 dollars) with break-even periods of 15 and 10 years. Both had cost: benefit ratios less than one.
3. Marketing – unsurprisingly, most individual farm businesses possess neither the skills nor the resourcing for effective marketing.
4. Quality – the standard of farm tourism must meet the expectations of clients.

Agritourism activities require time and effort that must be diverted from other farm activities and entail an entirely new skill set that many current growers would need to acquire via additional training. Greater clarity of how and which agritourism events can be hosted on farming properties would provide certainty to leaseholders required to devote the time and capital toward realising such options to diversify income.

Lease and agistment

Horse riding is an extremely popular hobby in the ACT with more than 500 km of trails available to riders[174]. Canberra is characterised by the wide availability of private and public horse agistment facilities within the urban fringes as well as more broadly across the rural and broadacre zones. The ABS estimates that there were approximately 15 businesses in the ACT offering agistment and grazing for more than 500 horses (although the exact number may vary considerably).

Demand for equine service in the United Kingdom has been demonstrated to be more income elastic than commodity production and thus represents potentially greater benefit to growers especially as disposable income across the population grows (Bailey et al., 2000). The relatively high income of

[173] Blog — Gold Creek Station
[174] Horses - City Services (act.gov.au)

ACT residents and large number of horses suggest a similar benefit for the providers of equine services in the ACT. In addition, the provision of such services has the potential to generate demand in other parts of the rural economy particularly in the provision of high-quality horse feed.

The sale of services as an income diversification strategy also extends to other forms of agistment, particularly the cattle and sheep industries that are well-established in the ACT and surrounding region. In particular, the harsh winters in the ACT make agistment an attractive alternative to breeding herds that require supplemental feeding over the winter months from reserves of hay and silage or feed imported from outside the ACT region. For landowners in the ACT, that are often earning off-farm income and can be time-poor, the agistment of stock can be a profitable enterprise that maintains a rural lifestyle without a large time commitment. Agistment of livestock as an income diversification option has the additional advantage that contracts can be made on a seasonal or annual basis or on an agreed set period that aligns with lease tenure and use requirements. Multiple agencies provide access to generic agistment agreements and background information on key clauses and requirements that should be considered[175,176].

Ecosystem services

Farmers manage 55% of the total land area in Australia[177] and up to 15% of the total land area in the ACT[178]. Growers are therefore important custodians that manage their lands in a sustainable manner to deliver economic and environmental benefits to their businesses and the wider community. While the direct farm benefits of sustainable production are obvious and rewarded by market access and potential economic return, the rewards for ecosystem services have, up to now, been largely undefined.

Ecosystem services are the ecological functions that lead to desirable environmental outcomes, such as air and water purification, drought and flood mitigation, and climate stabilisation (Murtough et al., 2002). Ecosystem services benefits include provisioning services such as food and water; regulating services such as flood, fire and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling.

Markets for ecosystem services have historically been rare and numerous governments, including Australia, have explored mechanisms to create markets by defining a new property right that is linked to the ecosystem service that can be exchanged for reward (Murtough et al., 2002). Alternatively, the absence of a market can be addressed via regulation that imposes certain ecosystem service duties on landholders. Market-based mechanisms are generally preferable as they provide the incentive to minimise costs while delivering the desired environmental outcome. Despite this, the approach in the ACT to date has been largely regulatory with requirements to deliver ecosystem services included in land management agreements, the costs of which are mostly borne by the leaseholder, with a degree of subsidisation for agreed ecosystem improvement activities. Indeed, while the recent Auditor General's report into Land Management Agreements concluded that they were of questionable value, the criticism was focused mainly on the lack of process for regulatory and compliance oversight rather than their effectiveness as instruments to deliver ecological and cultural outcomes.[179]

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[175] Agistment guidelines (nsw.gov.au).
[176] Horse agistment contracts | Agistment for horses | Horses | Livestock and animals | Agriculture Victoria
[177] Snapshot of Australian Agriculture 2022 - DAFF
[178] 71210DO001_201920.xlsx (live.com)
[179] Report No. 01 of 2021 - Land Management Agreements (act.gov.au) f

Prominent reasons why markets for ecosystem services have been difficult to establish are uncertainty about ecosystem processes and how they can be valued[180] and an inability to define and enforce ownership (Murtough et al., 2012). Valuations are critical to the development of market mechanisms that deliver desired environmental, social, cultural and financial benefits to the broader public while also providing the financial incentive for farming businesses to adopt approaches that build greater resilience and generate income diversity through the provision of improved ecosystem services. Admassu et al., (2019) discussed lessons to be learnt from the UK, where payment for ecosystem services models are more established, noting that provision of robust data a clear value proposition for both buyer and seller of the services are vital for success[181].

Despite these difficulties, the provision of ecosystem services remains an important objective of the NFF's strategy to deliver $100 billion in farm gate value by 2030. Specifically, the NFF Roadmap calls for the establishment of payment for ecosystem services like that already in place in EU, UK, US, Canada and New Zealand generating a net benefit equal to 5% of farm revenue ($5 billion)[182]. NFF has worked with KPMG to explore models that could allow Australian growers to utilise commitments to sustainably managing their land to access payments for ecosystem services and/or access to sustainable finance[183] via market-based mechanisms. Access to sustainable finance is already a reality, with Queensland beef producer Stockyard Group entering into a sustainability-linked loan with Commonwealth Bank in 2021[184].

Other private and public sector approaches to generating ecosystem services have also emerged. The most developed approaches in Australia are the programs administered by the NSW Biodiversity Conservation Trust (BCT)[185] and the Reef Credit Scheme[186]. Agreements administered by the BCT are relevant examples of the opportunities to establish ecosystem services in the ACT. Under the Conservation Management Plan, landholders can apply for agreements with ongoing annual payments under conservation tenders or fixed price agreements. The budget for the Conservation Management Plan in 2020-21 is approximately $47 million.

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[180] A Return on Nature (assets.kpmg)
[181] Admassu, S, Fox, T & McRobert, K, (2019) Lessons from the UK on ecosystem services models, Farm Policy Journal (16)3, 24-34.
[182] NFF_Roadmap_2030_FINAL.pdf.
[183] A Return on Nature (assets.kpmg)
[184] CBA seals Australia's first sustainability-linked loan for agriculture (finextra.com).
[185] Home | BCT (nsw.gov.au)
[186] Reef Credit as Market-Based Incentive Mechanism - Eco-Markets Australia

Figure 16: Target area for expressions of interest in the conservation agreements for the management of Snow Gum woodlands and grasslands; Source NSW Biodiversity Trust

Fixed price offers are made by the BCT through expressions of interest to protect high priority landscapes that provide habitat for threatened species, threatened ecological communities and/or important wetlands. Landholders with land that meets the specifications for a minimum size of high priority landscapes can apply for a Fixed Price Agreement under which the Trust pays an annual fee for the land to be managed to protect its biodiversity[187]. Fees differ across the state with high value areas in the Snowy Valley currently attracting payments of $106.74/ha/year. Landholders may also be eligible to access further funding if fencing of the conservation area is required. Fixed Price Agreements are made in perpetuity and are recorded on the land title.

Conservation Tenders under the Conservation Management Plan allow landholders to put forward a package for consideration in which they specify the area of land, price for management and timeframe (15 years or in perpetuity) in response to BCT calls for expressions of interest targeted at

[187] BCT-FS-CMP-FPO5-Central Eastern-WEB.pdf (nsw.gov.au).

distinct ecological zones. For example, the BCT completed the EOI for conservation agreements in the Snow Gum Woodlands and Grasslands in 2020[188]. The defined area surrounds the ACT (Figure 16) and is one of several calls made each year. Conservation agreements are recorded on the land title.

Finally, landholders can enter a Biodiversity Stewardship Agreement to generate biodiversity credits from all or part of their land for sale to public and private entities that may include developers (to offset other biodiversity impacts) the BCT or other entity. The operation of the scheme including costs and benefits as well as potential financial and tax implications of a BSA are set out in the landholders' guide[189] and landholders are advised to contact an accredited assessor to guide them through the BSA process. BSAs are in perpetuity and are recorded on the land title with payments and liabilities transferring with ownership of the land.

More recently, in June 2022 the NSW Government announced a Sustainable Farming Program[190] to improve both the state's natural assets and agriculture sector's productivity. Under the nascent program, farmers who voluntarily want to manage biodiversity and carbon while enhancing their land for productive use could achieve certification through agreed sustainability actions, including farm planning; grazing and land management; improvement and restoration.

Carbon farming

The Carbon Farming Initiative (CFI) was a voluntary carbon offsets scheme, integrated into the Emissions Reduction Fund (ERF) in 2014. Carbon credits markets in Australia are still often referred to by the previous descriptor (CFI). The ERF enables land managers to earn carbon credits by changing land use or management practices to store carbon or reduce greenhouse gas emissions.

In the carbon market, Australian carbon credit units (ACCUs) represent one tonne of carbon dioxide-equivalent (CO2-e) which has been sequestered or removed from the atmosphere. ACCUs are a financial product that are regulated and issued by the Australian Government to project developers, generated primarily from land restoration projects. Offsetting carbon via the purchase of ACCUs (i.e., funding an activity for emissions reduction to compensate for emissions generated elsewhere) is driven by a combination of compliance and voluntary demand. While offsetting creates income for the producers of the ACCUs, this also means the carbon sequestered or removed no longer 'belongs' to the accounts of that enterprise; e.g. if a farm business is claiming to be carbon neutral due to carbon sequestration activities, but then sells ACCUs beyond the emissions neutrality threshold, it could lose carbon neutral status. However, carbon negative (or 'climate positive') enterprises may choose to sell excess credits for income and retain carbon neutrality.

Soil carbon farming has been mooted as one of the key strategies for offsetting Australia's greenhouse gas emissions, with the ancillary benefit of improving soil health and farm productivity. However, several barriers restrict farmers from participating in schemes designed to monetise the production of carbon credits (e.g., differing perceptions of what increase in soil carbon storage is achievable and whether credit income will exceed a project's cost).

For example, a paper by White et al., (2021)[191] compared soil carbon project compliance costs, which are variable, with the possible income from carbon credits. The overriding metric determining

[188] Conservation Tender Landholder Guide - Snow Gum Woodlands and Grasslands_14.09.20.pdf (nsw.gov.au)
[189] Biodiversity Stewardship Agreement Landholder Guide | BCT (nsw.gov.au).
[190] Sustainable Farming Program | NSW Environment and Heritage
[191] OCCASIONAL PAPER: A landholder's guide to participate in soil carbon farming in Australia - Australian Farm Institute

whether a project is financially viable is the *opportunity cost* of changing the land management practice, which generally far exceeds the net income from carbon credits. However, the authors note the benefit-cost ratio could become more favourable if the value of ecosystem services provided by an improved soil condition could also be realised.

Although there is no guarantee that soil carbon projects aimed at earning and selling carbon credits through the ERF will be profitable given current compliance costs and the price of ACCUs, there are many other co-benefits of increasing farm soil carbon, e.g. improvements to soil health and functionality in the form of enhanced structure, water holding capacity, biological function and cation exchange capacity. These benefits also extend to broader ecosystems through reduced erosion from more stable soils and flow-on beneficial impacts of improved water quality. Increasing soil carbon on-farm can lead to productivity improvements on farm which may be of greater value than participation in carbon markets. While these benefits are not direct financial rewards for diversification, they are clear drought resilience improvement measures.

An emerging area of payment for ecosystem services is the Carbon + Biodiversity pilot[192] developed by the Federal Government. The proposed scheme aims to allow farmers to stack carbon credits with biodiversity credits and be paid for biodiversity improvements on farm (namely through planting trees). There is little information available about the scheme at the time of this research, but this emerging area of ecosystem payments could be an option for farmers in the ACT to diversify their income streams.

[192] https://www.agriculture.gov.au/agriculture-land/farm-food-drought/natural-resources/landcare/sustaining-future-australian-farming/carbon-biodiversity-pilot

3.5 Case studies

3.5.1 Goterra

It's hard to love baby black soldier flies. They aren't cute or cuddly and they certainly don't have the appeal of a lamb or calf. Yet the rearing of these ravenous insects, which consume a range of food and other wastes, requires the same level of care. Finding employees with an affinity for insects to tend to their needs has been one of the more unusual challenges faced by Olympia Yarger as she established Goterra, an insect production enterprise with facilities in Canberra, Albury and Sydney.

Olympia and her family have strong ties to the land having worked on a range of rural properties. Ultimately, this led to purchase of 120Ac on the Monaro. Like many other small landholders, the consideration of production options on limited land needed to be compatible with employment off-farm. This resulted in an initial focus on poultry production. The interest in insect rearing began as Olympia researched alternative options for poultry feed that matched the nutritional components of commercial pellets. Black soldier flies were identified as a good option and so the beginnings of Goterra were set in motion. Today, Goterra is a leading example of insect production in Australia, an industry that CSIRO estimates to be worth more than $10 million per annum in the next five years.

Principles

The growing world population continues to drive increased demand for food that has contributed to the soaring prices of farming land Australia and abroad. In this environment, entering farming requires intergenerational land ownership or the deep pockets of corporate agriculture. For those wanting to enter farming with more limited budgets, the options are limited and must focus on avoiding the big capital outlays associated with land purchases.

Goterra is based on the principle of modular agriculture where production systems minimise the need for large areas of land, can be scaled to be compatible with feed stocks and demand, and can be integrated into urban environments. The capacity to integrate modular insect rearing in an urban environment is a key principle that allows the establishment of facilities close to where food and commercial waste streams are available as feedstocks. This simplifies logistics, minimises transport costs and provides options for integration at scales ranging from regional production, exemplified by the facilities servicing Canberra at Hume, to individual commercial premises as seen in the more recent co-establishment of facilities with Lend Lease at their Barangaroo site. Simply put, the modular production system and deep technology employed by Goterra allows a re-imaging of the food system that supports the principles of a circular bioeconomy and provides the resilience needed to adjust to changing environments.

Challenges

Being a non-traditional production enterprise, the challenges associated with the development of insect production have been wide and varied. Some challenges, such as ensuring access to feedstuffs and developing commercial channels for demand, were identified early. Close collaboration with the stockfeed industry was quickly identified as a necessity that was met with a willingness of manufacturers to embrace insects as a sustainable source of protein, energy and essential nutrients.

Production challenges included finding information on techniques and environmental requirements (there aren't any brochures) for insect rearing as well as less obvious factors such as a lack of brood stock in Australia that required the collection of insects from the wild and trial and error to establish and grow a colony. One of the greatest challenges that remains is the indifference of the Australian population to most insects that means that the use of insects in food and feed in Australia does not match that in other countries in the region and worldwide.

Common challenges of planning and zoning are also identified by Goterra. However, in an example of the need for management of planning on an individual basis, the challenges facing Goterra are not associated with a lack of planning permission, as highlighted in other diversification options, but rather identify the need to maintain zoning support for industrial operations close to the city in the face of increasing urban development as currently observed in Fyshwick.

Drivers of Success

A recurring theme across many diversification efforts has been the focus required for success and Goterra is no exception. Olympia highlights the need to do your homework on the options available and not be afraid to seek help. Indeed, Olympia readily admits that in hindsight, she would have hired an experienced person earlier that would have made the initial development of the business simpler.

Access to resources in NSW Department of Primary Industries as well as grant support from the ACT government (ICON) was critical to establishing proof of concept that has subsequently allowed Goterra to access funding from venture capital that will support the expansion of Goterra's operations targeting the management of 45,000 tonnes of waste.

Lastly, but certainly not least, Olympia highlights the need to talk to as many people as possible. This means everyone up and down the supply chain as well as those associated with the wider value chain. It is important to understand their views, how this impacts the business model and how the business can add value to their enterprises.

KEY MESSAGES

- Diversification does not necessarily require large capital investment in land. Modular agriculture supports opportunities for scale appropriate diversification that can integrate in rural and urban environments to support a circular bioeconomy. Modular agriculture has a number of differences to traditional production, it is more reliant on deep technology to develop new products and deliver new service capacity. In addition, the financing of modular agriculture is more aligned with venture capital. Mentoring as well as grant programs for startups are therefore critical components of success.

- Zoning of land and planning can have a big impact on diversification. Clear planning and land use requirements provide the confidence for business investment that, once established in the ACT, is likely to remain.

- Most importantly, having identified the desired diversification option, commit to it 100%. Success requires focus and hard work. Gather and analyse as much information as possible, seek help where available and talk to as many people as possible.

3.5.2 Southern Harvest Association - multi-producer boxes

Packing boxes with locally grown fruit and vegetables is a long way from the original vision of Southern Harvest Association (SHA) when it launched in 2011 under the auspices of Regional Development Southern Inland with a focus on attracting food tourism to the region. However, from humble beginnings, SHA has developed into an innovative, farmer and volunteer led, not-for-profit organisation working to foster the sustainable growth and availability of local produce. Today, SHA supports producers, retailers and consumers across the Southern region including the ACT extending north to the Boorowa shire, west to Temora, Junee and Tumut, east to the coast and south to the Victorian border.

Research workshops and meetings conducted early in the establishment of SHA highlighted a consumer desire to access local food through retailers, food boxes and farmer markets that was frustrated by the inability to identify locally produced food. Southern Harvest Produce Boxes commenced in 2016 instigated by Canberra City Farm (CCF) with a single event of producers and consumers coming together at the farm site in Fyshwick. Following this promising trial, further development and implementation of the produce boxes transitioned to SHA, with CCF remaining an important part of the scheme. The produce box scheme has since grown dramatically to now include more than twenty producers, 147 subscribers , and fourteen collection points on a weekly basis, as well as a delivery option.

Principles

The SHA produce box scheme follows the Community Supported Agriculture model that promotes the connection of consumers and producers through a subscription approach. Under the SHA scheme, subscribers share the risk of production by committing to a thirteen-week season, purchasing a share of produce that includes fruit, vegetables, herbs and nuts as they are harvested. SHA facilitates the link between growers and consumers by aggregating produce from multiple growers to provide a greater variety of food than can be offered by a single grower.

Originally, produce boxes were focused on providing a market for growers to sell excess product to consumers seeking fresh, local food. The success of the scheme, as is evident in the growing number of subscribers and the expanding market opportunities for growers, supports more coordinated production to meet consumer demands while producers continue receiving fair retail prices for premium food.

Challenges

The viability of the scheme has historically been highly reliant on volunteers for packaging boxes, distribution and administration. Establishment of new drop-off points requires both a minimum number of subscribers and volunteers for box distribution. While volunteers remain an important feature of the scheme, the implementation of a 30% surcharge directly covers the costs of administration and volunteer support while maintaining the not-for-profit nature of SHA. The scheme is now viable in its own right.

A key challenge to the scheme and other activities undertaken by SHA is the lack of consistent and scale-appropriate regulation across the NSW-ACT governments. For example, under ACT Food Safety regulations, most value-added products prepared in domestic kitchens cannot be offered for sale in the ACT or included in food boxes. In contrast, regulation is administered by local councils in NSW and adopts a more flexible approach to identifying and managing potential food safety risks.

Differences between NSW and ACT are also apparent in the level of support that SHA has attracted. As an NSW-based organisation, it is unsurprising that successful applications for support of SHA have come from the NSW government. However, the produce box scheme clearly benefits consumers in the ACT and has the potential to provide greater support to ACT producers.

Bringing producers and consumers together requires continual effort. SHA has developed a new local food directory on its website in response to industry and consumer demand for information about regional food. In addition, SHA continues to operate the Bungendore Farmers' Markets that were established in 2015 and continue to this day.

Drivers of Success

Undoubtedly, a key driver of success is the engagement of community across the entire value chain from producers to consumers, not only in bringing people together but in shared decision making and vision. Models for operations, finances and infrastructure are developed with input from the whole of the value chain and therefore enjoy considerable support for adoption.

In common with other start-ups in the not-for-profit and commercial sectors, the importance of individuals with the passion and tenacity to drive activity and impact cannot be under-estimated. A succession of passionate people has been involved in the establishment and success of SHA and the produce box scheme in particular. The vision of SHA is important to identifying and supporting the next generation of champions that volunteer their time, skills and resources to achieve a shared goal.

KEY MESSAGES

- Approaches that bring like-minded groups together can benefit all members of the value chain from producers to consumers.
- Alternative market mechanisms such as community supported agriculture require dedicated people with a shared vision to make it work.
- Government support for these types of initiatives does not necessarily need to be financial. Consistency of regulation would generate significant value at low cost.

3.5.3 Gold Creek Station

Gold Creek Station is a popular stopover for tourists on guided holidays travelling between Sydney and Melbourne. Group tours of between 30-200 people are conducted at the property. At the woolshed, tourists can see shearing, fleeces being thrown, classed and prepared for baling and the famous Kelpie dogs mustering sheep. Add a steak for lunch at the homestead and it is easy to see why the Gold Creek stopover is so popular.

These are the results of the efforts of the Starr family over more than three decades. John Starr grew up in the Central West of NSW and worked as a shearer and wool classer before moving to the outskirts of Hall in the ACT in 1970 to manage the Gold Creek Station sheep and cattle property. Like other leaseholders in the ACT, when the lease withdrawal clause was enacted in 1974, the owner of Gold Creek Station decided it was time to move on. Fortunately for John some years later the opportunity to acquire part of the property on a 99-year lease arose and so Gold Creek Station continued albeit on a more modest scale and with a need to diversify farm income.

Principles

Gold Creek Station has always been synonymous with wool production with up to 7,000 head shorn on the property in boom years. It is not surprising then, that the potential to provide shearing and sheepdog demonstrations to tourists arose early in John Starr's employment as manager and later as owner of the property. However, while diversification into tourism has provided additional income as well as maintaining an active woolshed, a focused approach has been required to ensure the viability of the tourism business.

According to John, the single most important principle of farm tourism is credibility. Inbound tour operators (ITOs) must be sure that the experience being offered is authentic, repeatable, cost effective and reliable with backup in the event of illness or disaster. It is most difficult to gain the trust and confidence of an ITO to have your business included in their brochure. A failure in any of these has a direct impact on credibility and an unwillingness of tour operators to include a stopover on the itinerary.

Challenges

One of the most challenging aspects of establishing and maintaining the farm tourism business is in ensuring that the tourism activities are compliant with the terms of the land use agreement for the lease especially when the interpretation and regulation of those agreements can vary. A lack of consistency in the application of regulations and the difficulty in seeking any adjustment has been the major disincentive to pursuing farm diversification opportunities.

In addition, early Government support of tourism lacked scale appropriateness. Programs were designed to encourage tourism regardless of scale such that the needs and efforts of Gold Creek Station were considered in the same way as those of national entities such as the War Memorial or Questacon. The lack of scale-appropriate support resulted in the need to self-resource most tourism activities at Gold Creek including infrastructure improvements as well as training in computer systems and operator logistics.

Interestingly, when support for smaller tourism start-ups was eventually provided, a number of unforeseen, perverse outcomes occurred. Not least, the support of under-prepared farm-tourism start-up companies resulted in failures of authenticity and reliability that damaged not only the credibility of individual businesses but the credibility and viability of farm tourism and established coach operators in the ACT region.

Most recently, the bushfires of 2019-2020 and the ongoing Covid pandemic have contributed to a sharp decline in tourism. The effort required to re-establish the guided tourism sector will be significant as Australia again welcomes incoming visitors, but it remains a key to the viability of farm tourism at Gold Creek Station and at other destinations in the ACT and across the country.

Drivers of Success

John puts the success of Gold Creek Station down to the commitment to the principle of credibility. Entering guided farm tourism requires a 100 percent commitment, it is not a hobby and can't be treated like one. Credibility takes years to establish and only a moment to lose.

In addition to credibility, Gold Creek Station also benefits from its reputation to be agile, often filling vacancies with clients or supporting special needs of operators to ensure the farm tourism experience is the best that can be delivered. In particular, the capacity of John's wife Beverly to host those people without the desire to see sheep farm operations ensures that all tourists enjoy the Gold Creek Station stop-off, regardless of their preference for different experiences.

KEY MESSAGES

- Greater clarification of terms and requirements in land use agreements and a working relationship with leaseholders would be a major contributor to a successful and diverse agriculture landscape in the ACT.

- Targeted scale-appropriate support for tourism operator skills development and marketing are preferable to a blanket granting process.

- If you are entering the farm tourism sector do not underestimate the commitment in time and resources required to establish the credibility in the industry needed to be viable. It seems easy but do the homework and understand what is necessary before jumping to action.

4. ACT region competitive advantage

Opportunities for the diversification of agricultural production are supported by several characteristics of the ACT region and population. Some characteristics are also evident elsewhere in Australia, but the ACT is one of the only areas where all characteristics combine to provide a powerful opportunity for region-wide diversification approaches.

4.1 Off-farm income

One of the major disincentives for diversification of agricultural production worldwide is the requirement for significant capital input and associated risk to the current farm business (RIRDC, 2002). Not surprisingly then, the capacity to generate off-farm income is a significant driver of diversification (Barbieri et al., 2008).

A 2020 survey by ACT NRM indicates that almost 80% of landholders surveyed (approximately 48 responses) derived at least 50% of their income from activities not related to their rural holding. These properties most likely have a higher degree of economic security and consequently have an increased capacity to trial and adopt new systems, technologies and other diversification opportunities. However, reliance on off-farm income also has some drawbacks. The success of diversification activities is highly correlated not only with the amount of capital available but also the time and commitment required to develop business plans, relationships and marketing strategies (RIRDC, 2002). Growers with part-time or full-time employment off-farm may therefore find it difficult to allocate sufficient time-resources to maximise the probability of successful diversification. A balance of capital generation and time commitment is needed.

4.2 Consumer disposable income

While most consumers are aware of the benefits of eating a healthy diet and prefer purchasing products that are sustainably grown, the price of doing so comes with a premium (Barosh et al., 2014). There is significant inequity in disposable income across households with those in the lowest income quintile spending 40% of their weekly income to purchase food compared with those in the highest quintile spending just 9% of their weekly income (Barosh et al., 2014). Households with higher incomes have greater capacity to purchase premium generating sustainable and healthy foods.

Household income in the ACT is high in comparison to the Australian average. In 2016, 28.4% of households in the ACT had an income of more than $3,000 per week (Australian average was 16.4% of households[193]) and, while costs of living in the ACT are also relatively high, there is little doubt that ACT residents enjoy a level of disposable income exceeding most other regions that can support the purchase of premium sustainably produced, healthy foods such as those grown in the ACT region.

4.3 Access to labour

Despite a low level of unemployment in the ACT (4.7% c.f. Australian average of 6.9% in 2016[194]), there is a significant casual workforce available principally associated with the large number of students attending one of the universities in Canberra. Access to skilled agriculture labour is likely to be more constrained, with the small size of the ACT farming sector unlikely to attract career agricultural managers in the long term. Casual labour is particularly important in the context of

[193] 2016 Census QuickStats: Australian Capital Territory (abs.gov.au)
[194] *ibid.*

diversification where outsourcing of relatively unskilled activities allows landholders to devote more time and focus on diversification efforts.

4.4 Provenance

A range of studies indicate that consumers are willing to pay some form of premium for locally produced food (for example, Giraud et al., 2005) dependent on several consumer factors including product, age, income and education. Anecdotal evidence suggests that ACT consumers have a great deal of interest in the provenance of the food they purchase, an observation that is supported by the large numbers of shoppers making food purchases at farmer markets. The high demand and willingness to pay for locally sourced products in the ACT presents opportunities for diversification as products are more likely to find ready local markets if supply and quality can be maintained.

Data to support these anecdotal observations is limited and should be the target of focused surveys to determine ACT region consumer demands and willingness to pay for locally grown, healthy and sustainable food.

4.5 Location

The planned location of the ACT between Sydney and Melbourne places it in ideal position to access two major markets with very large populations. Distance to the Sydney market (population 5.3m[195]) is less than 250kms from Canberra and Melbourne (population 5.1m[196]) is less than 500kms. The populations of both Sydney and Melbourne are projected to exceed six million by 2030[197].

The Hume highway, the major road transport route between Sydney and Melbourne passes close to Canberra and is linked to it via the Barton Highway. The ACT is not directly located on the inland rail passage being constructed between Melbourne and Brisbane but is expected to be linked to it via the line between Sydney and Stockingbingal. Freight logistics could therefore be expected to be well supported although anecdotal evidence suggests that the limited size of the ACT contributes to higher-than-expected transport costs.

Canberra as a tourist destination and tourist thoroughfare, also provides market advantages that can support production diversification options. 6.13 million people visited Canberra in 2019 staying for more than 14 million nights and spending $2.82 billion[198]. This is a sizeable target for diversification options such as agri-tourism and farm stays and does not include through-traffic that may also purchase local produce. For example, pre-Covid, the NSW ski fields attracted almost 1 million visitors (year ending December 2019), with the majority (almost 40%) travelling from Sydney[199] and transiting through Canberra.

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[195] Centre for Population Annual Population Statement 2021
[196] *ibid.*
[197] *ibid.*
[198] Research – VisitCanberra Corporate (act.gov.au)
[199] Snowy Mountains Visitor Profile Factsheet - Year ending December 2019 (destinationnsw.com.au)

5. Lived experience of agricultural diversification in the ACT

The lived experience of farmers in the ACT provides insights to the opportunities and barriers for diversification. The following observations draw on interviews with a range of farmers in the ACT region across different production systems, farm sizes and farm business structures.

5.1 Land planning and lease agreements

The major disincentive for diversifying production system or revenue generation on farms in the ACT region is associated with land planning and the requirement to maintain alignment with purpose clauses under lease agreements that can appear to be outdated and ill-informed. While the specifics differ across leaseholders, all had significant issues understanding the multitude of rules, regulations and guidelines as well as the difficulties, costs and lack of consistency across different agencies associated with applying for and assessment of development approval and/or changes to land management agreements.

The experience of many leaseholders is of a "command and control" approach from planning and lease management agencies

The need to maintain land for future urban expansion is a significant issue in planning recognised by all stakeholders. However, it is a widely held belief that broadacre and rural land leases are managed to protect future availability for urban expansion at the expense of objectives relating to agricultural production. The experience of many leaseholders is of a "command and control" approach from planning and lease management agencies that is not conducive to jointly exploring opportunities to diversify systems to achieve resilient farming businesses that also deliver natural resource management outcomes and provide flexibility in meeting future development needs.

Of particular concern is the apparent lack of consistency in interpretation of the Objectives of the Territory Plan across Strategic Planning Direction and the application of land use clauses in Land Management Agreements. While it may be interpreted that broadacre zoned land is available for permitted agricultural activities as defined in the Territory Plan, most activities are in fact further curtailed by the imposition of strict land management agreements that then limit "agriculture" to a subset of industries. For example, agricultural production on land suited to several different industries can be limited to grazing under purpose clauses in individual lease agreements and further limited to grazing of sheep and cattle under the same agreement. Diversification of production, even within the broad definition of agriculture as it stands in the Territory Plan then requires the leaseholder to apply for a change to the lease purpose clause. This is an onerous process that requires input from multiple agencies and is associated with costs that are prohibitively expensive to most leaseholders. Under such regulations, the incentive to diversify the production base is extremely limited.

Issues with planning and lease purpose clauses also extend to value-adding and non-production diversification options. In particular, confusion exists surrounding the definition and application of the term "ancillary use".

Under the Territory Plan, ancillary use is defined as "*the use of land for a purpose that is ancillary to the primary use of the land*". Ancillary is then defined as "*associated with and directly related to, but incidental and subordinate to the predominant use*". Ancillary uses of agricultural land could include diverse revenue generating activities that remain consistent with other aspects of the Territory Plan such as:

- Value adding through processing
- Waste stream diversification e.g., use of chicken manure to generate compost
- Agri-tourism consistent with the definition of tourist facility
- Event hosting – such as weddings, birthdays, open gardens etc.
- Leasing of buildings and other infrastructure

However, there remains considerable uncertainty regarding the variables that determine ancillary use. Is an activity 'incidental and subordinate' to agriculture if:

- the revenue generated from it is less than that derived from agriculture?
- the area of land use is less than that for agriculture?
- the use of labour is less than that from agriculture?
- operating costs exceed those for agriculture?

While the determinant of ancillary use remains unclear, the impact on efforts to diversify farm production and income are profound. As the focus of diversification is to maintain farm viability (including business viability and sustainability in the long term), it should be expected that in periods of downturn, caused by drought or commodity price drops, a diversification activity may become the dominant contributor to farm viability at least for a limited period.

The question is – do these remain ancillary if the intent is for them to be a major contributor to farm viability? The lack of clarity regarding how "ancillary use" is applied within the context of Territory planning results in high levels of confusion and distrust and is a major disincentive to investment in diversification opportunities.

The lack of clarity regarding the application of "ancillary use" activities may have an even greater impact on diversification approaches that require coordinated efforts across leaseholders. Given the limited size of most ACT farms, the economic feasibility of many value adding opportunities depends on capacity to source supply from several individual farms. If processing of produce from multiple farms occurs at a single agricultural property, it is unclear if the relevant planning authorities would interpret that value adding activity as ancillary to agriculture.

Furthermore, if the activity is not considered ancillary, there is the possibility that it could be classified as light industry and be prohibited on non-urban zoned land. A requirement to establish coordinated, value-added processing on industrial zoned land raises the economic feasibility given the high costs associated with accessing such a property in the ACT. The opportunity for farm income diversification under this scenario is limited.

Opportunity: The ACT Government should provide clarity to leaseholders regarding the interpretation of the Objectives for Broadacre and Rural lands and how these are currently applied in planning and lease management. The current development of an Agriculture Policy is a potentially significant contribution, but it must have an impact on how planning and lease management are implemented if it is to have any discernible effect on agricultural production and diversification.

Opportunity: The ACT government should work with leaseholders to better define and communicate the planning and approvals processes for non-urban zoned land with specific attention to diversification that requires change of use of the land to deliver business resilience and protection of natural capital while also maintaining flexibility for future development needs.

Opportunity: the ACT Government could consider the merit of changes to the Territory Plan to facilitate diversification options where these involve the development of light industry on non-urban zoned land associated with current agricultural production.

Opportunity: The ACT Government should review the process and costs structure for applications to change lease purpose clauses where the change relates specifically to a different form of agriculture as defined in the Territory Plan. Alternatively, the ACT Government could consider removing lease purpose clauses that apply further constraints beyond those of the general provisions of agriculture as defined in the Territory Plan.

5.2 Lease tenure

The current duration of tenure for agricultural leaseholders in the ACT ranges from 99 years to less than 10 years. For some landholders with expired leases, tenure is a monthly or weekly consideration. In addition, most lease agreements contain withdrawal clauses allowing the government to unilaterally terminate leases albeit with a requirement to recognise the value of some improvements. The duration of leases is intended to reflect future strategic land uses and planning intentions with an emphasis on maintaining flexibility for urban development that is a core aspect of a planned city such as Canberra.

Short term tenure can have a detrimental impact on adoption of farm diversification options that may deliver environmental benefits

Future planning strategy is therefore a key determinant of lease duration which in turn has a major impact on options for farm income diversification, particularly options that involve extended periods prior to payback. A lack of clarity in planning strategy is a particular disincentive on diversification options involving horticulture and other permanent plantings where large initial capital outlays are only recouped over an extended period as trees mature and production increases.

The lack of extended tenure for some leaseholders also significantly impacts their capacity to access finance for farm operations and diversification, with banks reluctant to make loans for improvements that may not realise a return if leases are withdrawn or not renewed.

Short term tenure and the potential to withdraw lease agreements can also have a detrimental impact on adoption of farm diversification options that may deliver environmental benefits (e.g., ecosystem services contracts that require long-term agreements) or require significant capital investment in infrastructure (e.g., covered cropping, glass house production, aquaculture).

Section 291 of the *Planning and Territory Act, 2007*[200] outlines the requirement of the ACT Planning Authority to make payments of market value for improvements made to land when a lease expires, is surrendered or terminates. Improvement, in relation to land, means:

a) a building or structure on or under the land; or

b) for land held under a rural lease;
(i) a building or structure on or under the land; or
(ii) any earthworks, planting or other work that affects the landscape of the land that is reasonably undertaken for rural purposes.

It is unclear what payment would be made for land improvement efforts such as increasing soil carbon or maintaining biodiversity. Indeed, it is not clear if the value of improvements to pasture

[200] Planning and Development Act 2007 | PDF

achieved through judicious agronomy and nutrition management would be recognised in the current compensation model.

Given that most options to receive payment for carbon storage or biodiversity conservation require agreements in perpetuity or up to 100 years, it is unclear how leaseholders in the ACT could enter such markets and generate natural resource and climate outcomes.

Opportunity: The ACT Government could work with leaseholders to identify land that is unlikely to be utilised for urban development and could be rezoned to rural and accompanied by extended lease tenures that provide a level of certainty required for diversification and the access to required capital.

Opportunity: The ACT Government could explore options to align lease tenure with the requirements of soil carbon and ecosystem services programs that would allow growers to participate in these emerging markets more easily.

Opportunity: The ACT Government could seek expert agronomic advice and provide clarity on improvements that contribute to market value based on improved production capacity in the event that land is acquired by the government following withdrawal or expiration.

5.3 Land Management Agreements

Farmers in the ACT have a strong connection with the land and are passionate about protecting the ecological and cultural value of the environment upon which they are reliant. It was not surprising therefore that ACT grower attitudes are aligned with the environmental outcomes sought under the *Planning and Development Act*. However, the support to achieve those environmental outcomes through the use of highly regulated and compliance driven Land Management Agreements (LMAs) is more ambiguous even accepting that many Agreements have not recently been actively enforced[201]. LMAs offer advantages to lifestyle leaseholders with limited acreages and experience. For these leaseholders, LMAs provide access to expertise within the ACT government to develop appropriate natural resource management plans, ensure farming systems are appropriate to the land capacity and provide a mechanism for coordinated action especially in the management of invasive weeds and pests. For more experienced leaseholders and those more reliant on the land to generate an income, LMAs are a complicated instrument that lacks production expertise and requires the application of scarce resources to develop, implement and monitor. In particular, the focus of LMAs on activities associated with reporting detailed assessment and management actions utilises resources that might be better directed to meeting production, conservation and diversification targets.

Leaseholders in general acknowledged the need to assess and manage their land. The argument is that the focus of government should be on the assessment of outcomes (e.g., how well the environmental and cultural values of the land are maintained or improved) rather than recording the specific actions required to achieve those outcomes. There will of course be exceptions, for example few would argue that agreement on specific activities is required to manage identified sites of significant environmental value. This should not, however, extend to other areas where the outcomes of land management should be the focus of attention rather than activities. The blunt

[201] Report No. 01 of 2021 - Land Management Agreements (act.gov.au)

application of LMAs in the absence of any risk framework to articulate the priorities for management on leased land was likewise noted as a significant issue in the recent LMA audit.[202]

Finally, the application of LMAs to achieve environmental and cultural outcomes may be a disincentive to leaseholders to undertake any activity beyond the minimum required to achieve compliance. Specifically, it prevents the adoption of market mechanisms to deliver biodiversity outcomes that are becoming common elsewhere in Australia and globally. As such, it removes a potential cost-effective and efficient diversification mechanism for achieving environmental outcomes that rewards pro-active management by leaseholders.

Opportunity: The ACT government should review the effectiveness of current LMA models to achieve desired environmental outcomes together with leaseholders. The current LMA approach may be appropriate, and indeed welcomed by some leaseholders, but may not be as effective when applied to larger leaseholders and those more closely engaged in production. There is an opportunity to develop a more nuanced approach that focusses on delivering desired outcomes with leaseholders determining their requirements for engagement with government experts at the activity level.

Opportunity: The ACT Government should consider the possibility of managing identified sites of environmental and cultural value via market mechanisms like those being adopted successfully for the delivery of biodiversity outcomes elsewhere.

5.4 Farm size

Farm size in the ACT is generally small and this impacts diversification in two ways. First, the small size of some holdings means that economies of scale in current systems cannot be achieved to an extent that time and resources can be dedicated to new ventures. Diversification then entails either a loss of efficiency in current activities and/or has sub-optimal resources allocated to it. In some situations, the physical farm size in the ACT is insufficient to accommodate more than one production enterprise.

Second, farm size has a major influence on capacity to generate supply. One of the main requirements of markets is that supply can be maintained to meet current and future demand. Meeting continual supply requirements is a challenge on small acreages in the ACT. Some growers are addressing this through cooperative schemes that generate supply across several farms, but the lack of a coordinating mechanism means that opportunities of cooperative supply are largely realised through arrangements based on pre-existing relationships between growers.

Opportunity: As there are few options for government to address the size of rural holdings, an effective action to address the need to maintain supply and encourage demand may be to facilitate the interaction between growers and buyers (local and elsewhere) where coordinated mechanisms of supply and demand can originate. This is one of the actions proposed in the Canberra Region Food Collaborative[203] regarding the establishment of databases and information linking producers with buyers and consumers similar to the MarketMaker program and the Producer Box scheme outlined earlier.

Opportunity: There is a need for resources to assist farmers and food businesses in determining if a farmers' market is the most suitable strategy for their business including the benefits that may be realised and the risks that must be managed. More broadly, government agencies at the local, state

[202] *ibid*.
[203] https://www.agrifood-hub.com/

and Commonwealth levels could focus greater expertise and resources on the potential for direct to customer business models to integrate into the broader community food dynamic with the realisation of commensurate social, economic and environmental benefits (Woodburn, 2014).

Opportunity: The Farm Cooperatives and Collaboration Pilot Program launched by the Commonwealth Government in 2016 was not continued beyond 2018[204] - yet made substantial contributions supporting farm collaboration under a model that could be further explored. In particular, support for farm cooperatives and access to farmers' markets should focus on innovative ways to ensure ongoing supply of some produce while educating consumers about the use of seasonal foods that are more likely to be fresh and available at certain times of the year. There are also opportunities to celebrate the seasonality of food such as occurs annually in the sale of the first box of mangoes in Brisbane[205], cherries in Sydney[206], and internationally in celebrations such as Spargelzeit (asparagus season) in Germany[207] that sees numerous stalls, festivities and special menus in restaurants dedicated to asparagus.

5.5 Labour

Several farming businesses in the ACT highlighted the difficulties in attracting and retaining labour. This may seem surprising given the large numbers of students attending university in Canberra that would be expected to be seeking part time work. However, the nature of agricultural employment is not conducive to attracting part time student employment with time demands during the day overlapping with study requirements. University students tend to favour more flexible work that can be managed in conjunction with study requirements.

Australian agriculture has a high reliance on the use of foreign workers especially for seasonal work. The Australian Government formed an Agricultural Labour Advisory Committee in December 2019 to develop a National Agriculture Workforce Strategy[208], and the current focus on labour shortages in agriculture has ensured the issue is front-of-mind for federal policy-makers and industry bodies.

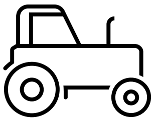
The difficulty in attracting labour in the ACT region is not significantly different to that encountered across multiple agriculture industries nationwide and has a direct impact on farm businesses especially in achieving time-critical operations such as fruit picking, egg collection etc. It also has a profound impact on the capacity to diversify. As noted, (RIRDC, 2002) successful diversification requires the commitment of resources, including time, in both planning and execution. A lack of casual labour to maintain current business activities prevents owners from devoting the time required to explore diversification opportunities.

Opportunity: ACT leaseholders should engage with the national Agricultural Labour Advisory Committee to ensure the specific agricultural labour needs of the ACT region are understood.

Opportunity: Growers in the ACT region could explore the availability of support from the Commonwealth AgATTRACT[209] program to attract young people to a career in agriculture.

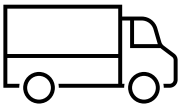
[204] Cooperative program Farming Together ends without further funding in budget - ABC News
[205] Brisbane Produce Market Mango Auction hits $1 million raised for charities | Good Fruit & Vegetables | Australia (goodfruitandvegetables.com.au)
[206] First box of cherries at the Sydney Markets' Cherry Auction sold for $20,000 | Good Fruit & Vegetables | Australia (goodfruitandvegetables.com.au)
[207] 10 facts about Spargelzeit AKA asparagus season (iamexpat.de)
[208] National Agricultural Workforce Strategy | Have Your Say - Agriculture, Water and the Environment (awe.gov.au)
[209] Agricultural Workforce - DAWE

5.6 Contractors



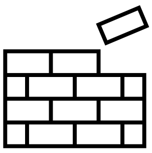
Reports on the availability of contractors for activities such as shearing, hay making, crop planting and spraying differed markedly across growers. Some had long-standing arrangements with providers in region while others had difficulties accessing contract services or reported the contract services were very expensive. From a service provider perspective, the size of ACT farms and enterprises is not attractive to maintaining the capacity to service a relatively small market. Similar to opportunities to maintain supply via coordinating production across farms, the opportunity exists to co-ordinate demand for contract services to increase the probability of attracting a suitable provider at a reasonable cost. It is debatable that there is a role for government with such coordination probably best delivered by growers or as a business offering from potential providers.

5.7 Transport



The ACT region is well situated to supply domestic markets in Sydney and Melbourne by road as well as international markets via air from the same cities and the Canberra airport. Given the proximity to the Hume highway and the provision of goods into Canberra from both Sydney and Melbourne, it might be expected that capacity for backloading would be high resulting in substantial discounts for freight out of the ACT region. However, this does not appear to be the reality with most growers reporting that freight is expensive, difficult to acquire (especially for small volumes of perishable food) and is therefore a significant limitation to accessing markets. A similar issue has been reported by producers in Central West NSW many of whom have reverted to using Australia Post for small deliveries, despite the cost, and/or are delivering perishable goods to customers in Sydney and Canberra themselves[210]. In addition, transport of inputs to the ACT (especially feedstocks) can also be expensive and a limitation on the operations and expansion of a number of ventures.

5.8 Infrastructure

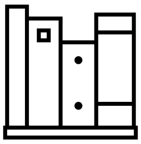


The size of the ACT farming sector, and even the ACT region, makes it difficult to attract required investment in infrastructure for localized processing and manufacture. This is particularly evident in the meat processing sector where the lack of abattoir infrastructure in the ACT, Southern Tablelands and Central West is an acknowledged block to the development of diversified animal production opportunities. In addition, the costs associated with travel to the ACT, meeting local regulations and disposing of waste (e.g., offal) in the ACT can be unattractive to mobile abattoir providers.

The lack of infrastructure is further complicated by ACTs planning regulations that classify most processing infrastructure as light industry and require it to be established on industrial sites that are both expensive and not necessarily easily accessible to growers. Despite this, some infrastructure does exist such as the Capitol Chilled Foods (owned by Bega) packaging plant at Fyshwick.

Opportunity: The development of processing infrastructure throughout the ACT is clearly not desirable. However, there is an opportunity for growers and government to work together to identify sites on broadacre and rural land where collaborative infrastructure that supports farm diversification could be developed without compromising the Territory Plan zoning objectives.

[210] FINAL-Value-Adding-to-Agriculture.pdf (rdacentralwest.org.au)



5.9 Access to Information

Some but not all growers related that accessing information on opportunities for diversification was difficult. Indeed, there is no single site to access information on multiple diversification topics, although it is hoped that this report provides some instruction on how such information can be obtained. In addition, the ACT and Southern Tablelands RDAs are good sources of information. However, it should be acknowledged that one of the most effective learning methodologies in agriculture entails growers learning from growers. This paradigm applies to exploring diversification opportunities.

Recommendation: The ACT government, RDAs and landholders should consider methods to facilitate grower-to-grower and grower-to-customer exchanges of information. Food in the Capital is a good start but more frequent events, each focused on a limited number of topics, would provide the forum for more effective learning experiences.

6. Other opportunities

6.1 The circular bioeconomy

Globally, approximately one third of all food produced (1.3 billion tonnes) is wasted with an annual direct cost of $1.75 trillion[211]. In Australia, food lost as waste is estimated to exceed 7.3 million tonnes per annum (2016/17) costing $20bn[212].

The ACT Government is aligned with the National Food Waste Strategy (FWS) targets[213] with the aim to halve food waste by 2030. The FWS outlines approaches to halve food waste by 2030, identifies some of the opportunities for innovation that are likely to arise and is consistent with the UN Sustainability Goals[214] that underpin growing consumer, producer and market demand for sustainably produced foods.

The Fight Food Waste CRC (FFWCRC), in which the ACT government participates[215], provides important leadership in the implementation of the FWS. The FFWCRC (together with KPMG) has developed a food recovery hierarchy[216] which highlights areas where different interventions can impact food waste. Preferred strategies include reducing the volume of food surplus generated that could add to wastage and the redistribution of additional food to those in need. The use of food scraps in animal feed, industrial uses (e.g., generation of fuel from cooking oil) and composting are also important. Unsurprisingly, disposal of food waste in landfill is not a preferred option.

Strategies of significant interest to diversification of primary production in the ACT region include:

- Source reduction and reuse – Linked to initiatives such as the Proposal for Sustainable Urban Food that would encourage greater alignment of local production and consumption to reduce the amount of food transported into the ACT that subsequently goes to waste,
- Feed animals – linked to opportunities to convert food waste and excess production to high value animal feed.
- Composting – linking opportunities to produce nutrient-rich soil ameliorants.

Opportunities associated with generating high value animal feed, particularly using insects, is well suited to the ACT. There are start-up companies (e.g. Goterra) already established, transport distances are manageable, and R&D via CSIRO and the universities is available.

Most recently, insect farming has gained growing attention because of its capacity to generate protein from low value, low quality food stuffs using a minimal amount of water. Data collated by CSIRO[217] in 2021 demonstrates the relative advantages of insect rearing compared to the main livestock production activity in the ACT of cattle grazing. Comparing cattle production with crickets as an example of insect production illustrates benefits in the proportion of edible protein (crickets have twice the amount of edible protein), land use (crickets use less than 10% of the land area required for cattle), greenhouse gas emissions (crickets generate less than 5% the CO_2 of cattle), water use (less than 1%) and feed (less than 10%). Crickets also have a far superior feed conversion efficiency, that is the amount of feed required to generate 1kg of cricket protein.

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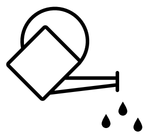
[211] Tackling the 1.6-Billion-Ton Food Loss and Waste Crisis (bcg.com)
[212] (PDF) Primary Production Food Losses: Turning losses into profit (researchgate.net)
[213] National Food Waste Strategy: Halving Australia's Food Waste by 2030 (awe.gov.au)
[214] Take Action for the Sustainable Development Goals - United Nations Sustainable Development
[215] OUR PARTICIPANTS | Fight Food Waste CRC
[216] Fighting food waste using the circular economy (assets.kpmg)
[217] Edible insects (csiro.au)

More generally, opportunities for composting are already being utilised by several individual businesses in the ACT (E.g., Two Before Ten's urban farm project[218]) and some growers have utilised sewerage ash for soil amelioration and nutrient input onto pastures in the past.

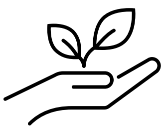
Opportunity: Greater linkage of waste streams throughout the ACT with reuse activities such as insect production and composting has the potential to generate a circular bioeconomy that minimizes organic waste, increases productivity and soil health on agricultural lands, provides opportunities for diversification and makes a significant contribution to the ACT Waste minimisation strategy.



6.2 Wastewater

A conservative estimate of the potential volume of wastewater from LMWQCC available for reuse is approximately 28GL/year and is expected to increase to 32.6GL/year by 2060[219]. Initial assessments of reusing wastewater for urban and agricultural uses indicated a negative impact on downstream irrigators beyond about 25%[220] although other modelling suggests the impact on downstream flows of increasing recycled water use in the ACT would be minimal due to increased overflows from the enlarged Cotter Dam[221]. The ACT Non-potable Water Master Plan study (2011) focuses on the provision of 13,750ML/year (with a reliability of 95%) for non-potable demands[222] that could include diversified agricultural production. The appetite for water recycling in the ACT is unclear such that, despite the potential for at least some use of wastewater, opportunities for irrigated agriculture have been limited to the Hardies vineyard in Belconnen. Indeed, Icon Water (the water supply company in the ACT) have considered the introduction of minor water restrictions at a time when Canberra's dams are all at 100% capacity[223].

Opportunity: Greater clarity on potential access to water in the ACT and through water trading for agriculture would provide leaseholders with certainty when assessing diversification options that include the need for irrigation (most production options).



6.3 Ecosystem services

Previous studies have identified that the supply of certain aspects of biodiversity conservation is hindered by rules for land tenure, competitive neutrality, and taxation (Productivity Commission 2001). The tenure of leases on rural land in the ACT makes it impractical to consider perpetual models of payment for ecosystem services. However, the ACT government could consider a model based on the 15-year conservation tenders utilised by the Biodiversity Conservation Trust (BCT) in NSW or indeed could adopt the same model to provide consistency across jurisdictions within the ACT region.

The ACT government might also consider the use of time-limited stewardship models to recognise the value of landholders maintaining biodiversity and managing natural capital. However, any such model would need to adopt a timeframe appropriate to the market in which biodiversity credits

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[218] Urban Farm | Two Before Ten
[219] https://www.environment.act.gov.au/__data/assets/pdf_file/0005/576077/ACT_Non-potable_Water_Master_Plan_Study.pdf
[220] https://www.environment.act.gov.au/__data/assets/pdf_file/0006/576078/Appendix_A.pdf
[221] https://www.icrc.act.gov.au/__data/assets/pdf_file/0004/1246585/Submission6_5_January_2012_ACTEW_Corporation_Ltd.pdf
[222] https://www.environment.act.gov.au/__data/assets/pdf_file/0005/576077/ACT_Non-potable_Water_Master_Plan_Study.pdf
[223] Water restrictions for Canberra considered despite full dam capacity | The Canberra Times | Canberra, ACT

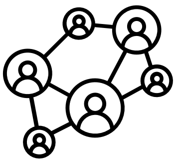
might be traded and, given that most current models are based on biodiversity outcomes in perpetuity, a fixed timeframe may not be attractive to buyers or sellers or indeed may not meet the requirements of current and future market-based mechanisms for payment.

Opportunity: The ACT Government could consider funding private on farm management of future biodiversity offset sites rather than the transfer of those sites into the public reserve system. Private management of the offset areas could provide a significant value proposition and enhance the overall farm viability and sustainability of adjacent on farm areas by undertaking more traditional farm practices.

Opportunity: Time limited biodiversity stewardship schemes could be employed within the ACT to protect biodiversity and maintain natural capital that is then utilised as environmental offsets for other developments, as is routinely practiced currently. The approach would circumvent the difficulties in participating in broader schemes that require longer timeframes or perpetual models of management of protection.

Regardless of timeframe, the adoption of a model to pay for ecosystem services that incentivises growers to manage natural capital for public and private benefit, generate an income stream and build resilience is an opportunity for diversification that has been adopted in other jurisdictions and is a significant opportunity in the ACT.

Opportunity: Establishment of appropriate training and information services for landholders in the ACT region to increase their awareness of ecosystem services programs and broader sustainability programs that are already available or may become available in the future.



6.4 Data sharing

The size of ACT farms, small volumes of production and high freight costs make it difficult to explore diversification opportunities that require consistent supply to distributed buyers to achieve viability. Mechanisms such as databases (e.g., MarketMaker in the USA) have been shown to be effective in bringing together growers, buyers and customers as have farmers markets and community co-operatives. In the ACT the case for supporting the linking of growers, buyers and customers is compelling given that the population in general has a high degree of wealth, a solid understanding of the principles of sustainability and a willingness to pay a premium for locally produced food if they can find it. The current farmers' markets and co-op schemes provide excellent support for growers to sell local products but could be supported through activities that support greater grower access.

Opportunity: The ACT government could consider support for the construction and implementation of a database of growers, buyers and customers similar to MarketMaker. Such a database is part of the City-Region Food System developed by the Canberra Region Food Collaborative.

Opportunity: For Community-based co-operatives, the high reliance on volunteers is a major risk to the business model that could be addressed through a small but targeted grant scheme.

7. Conclusion

The range of diversification options available to ACT farm businesses are impacted by several significant factors including farm size, human capital and variation in land capability and soil type, as well as individual risk appetite, location and access to labour, life stage, family decision-making and ease of integration with current farm operations.

The major disincentive for diversifying production system or revenue generation on farms in the ACT region is associated with land planning and the requirement to maintain alignment with purpose clauses under ill-fitting lease agreements. A lack of recognition of agriculture in strategic planning documents creates uncertainty for producers in their tenure and clarity of allowable activities for landholders needed to generate the confidence to invest in land improvements and diversification options.

While the biophysical limitations of soil quality and access to water (2022 notwithstanding) will always dictate the range of diversification options which can mitigate the vagaries of drought and other climate extremes, ACT farmers are resilient and innovative. The unique competitive advantage provided by co-location to consumers and potential labour, generation of off-farm income, and marketing of provenance attributes opens the door to diversification opportunities for the ACT (summarised in Figure 17).

In particular, the opportunity to establish a world-leading agriculturally based circular bioeconomy should not be dismissed as idealistic rhetoric. The fledgling Bega Circular Valley 2030 program[224] demonstrates that audacious change is possible, and the ACT region's agricultural economy is of a scale that makes such a project feasible.

With the cooperation of Government and industry to address and remove the barriers identified herein, opportunities aligned with land capability for non-traditional alternative production systems, value-adding, new markets and improved food distribution could potentially provide not only a market niche for ACT producers but also increased resilience to climate impacts.

[224] Projects - Bega Circular Valley

Figure 17: ACT farm diversification options overview

8. Recommendations

The following recommendations summarise opportunities identified throughout the report:

1. The ACT government should **establish a direct point of communication on agricultural issues**. While commendable that ACT NRM is so proactive on these issues, it is still very difficult for new entrants to know where to look or who to talk to regarding both opportunities for diversification and barriers.

2. **Leaseholder and Government interactions must be improved** to overcome barriers of land use planning, land tenure, lease agreements and land management agreements. It is recommended that the ACT Government:
    i. **provide greater clarity to leaseholders** regarding the interpretation of the objectives for broadacre and rural lands and how these are currently applied in planning and lease management.
    ii. work with leaseholders to **better define and communicate** the planning and approvals processes for non-urban zoned land with specific attention to diversification.
    iii. **consider the merit of changes to the Territory Plan to facilitate diversification** options where these involve the development of light industry on non-urban zoned land associated with current agricultural production.
    iv. **review the process and costs structure for applications to change lease purpose clauses** where the change relates specifically to a different form of agriculture as defined in the Territory Plan; or, consider removing lease purpose clauses that apply further constraints beyond those of the general provisions of agriculture as defined in the Territory Plan.
    v. work with leaseholders to **identify land that is unlikely to be utilised for urban development** and could be rezoned to rural and accompanied by extended lease tenures that provide a level of certainty required for diversification and the access to required capital.
    vi. **review the effectiveness of current LMA models** to achieve desired environmental outcomes together with leaseholders.
    vii. seek expert agronomic advice and provide clarity on improvements that contribute to market value based on improved production capacity in the event that land is acquired by the government following withdrawal or expiration.
    viii. provide greater clarity on **potential access to water in the ACT** and water trading for agriculture to assist leaseholders decision-making when assessing diversification options that include the need for irrigation (i.e. most production options).

3. The ACT Government and ACT NRM should consider **region-specific activities and initiatives which promote participation in ecosystem services programs**, which incentivise growers to manage natural capital for public and private benefit, generate additional income from land management and build drought resilience:
    i. Time limited biodiversity stewardship schemes could be employed within the ACT to protect biodiversity and maintain natural capital.
    ii. **Appropriate training and information services** should be established for landholders in the ACT region to increase ‘sustainability literacy’ and awareness of available ecosystem services programs and broader sustainability programs.

iii. Consider **aligning lease tenure with the requirements of soil carbon and ecosystem services program**s that would allow growers to participate in these emerging markets more easily.

4. ACT leaseholders must **engage with the national Agricultural Labour Advisory Committee** to ensure the agricultural labour needs of the ACT region are well understood, and explore options in the Commonwealth AgATTRACT program for workforce attraction assistance.

5. **Information exchanges:** The ACT government, RDAs and landholders should consider**:**
    i. additional methods to facilitate grower-to-grower and grower-to-customer exchanges of information. While 'Food in the Capital' is a good start, more frequent events, each focused on a limited number of topics would provide the forum for more effective learning experiences.
    ii. supporting the implementation of a database of growers, buyers and customers similar to MarketMaker.
    iii. lift efforts to provide information resources, initiatives and programs (such as the discontinued Farm Co-operatives and Collaboration Pilot Program) to identify direct-to-market opportunities for ACT farmers.

6. A **greater linkage of waste streams** throughout the ACT could generate a circular bioeconomy; this is a unique opportunity for the ACT given the co-location of businesses in a defined region with strong social support.

7. For **community-based co-operatives**, the high reliance on volunteers is a major risk to the business model that could be addressed through a **small, targeted grant scheme**.

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