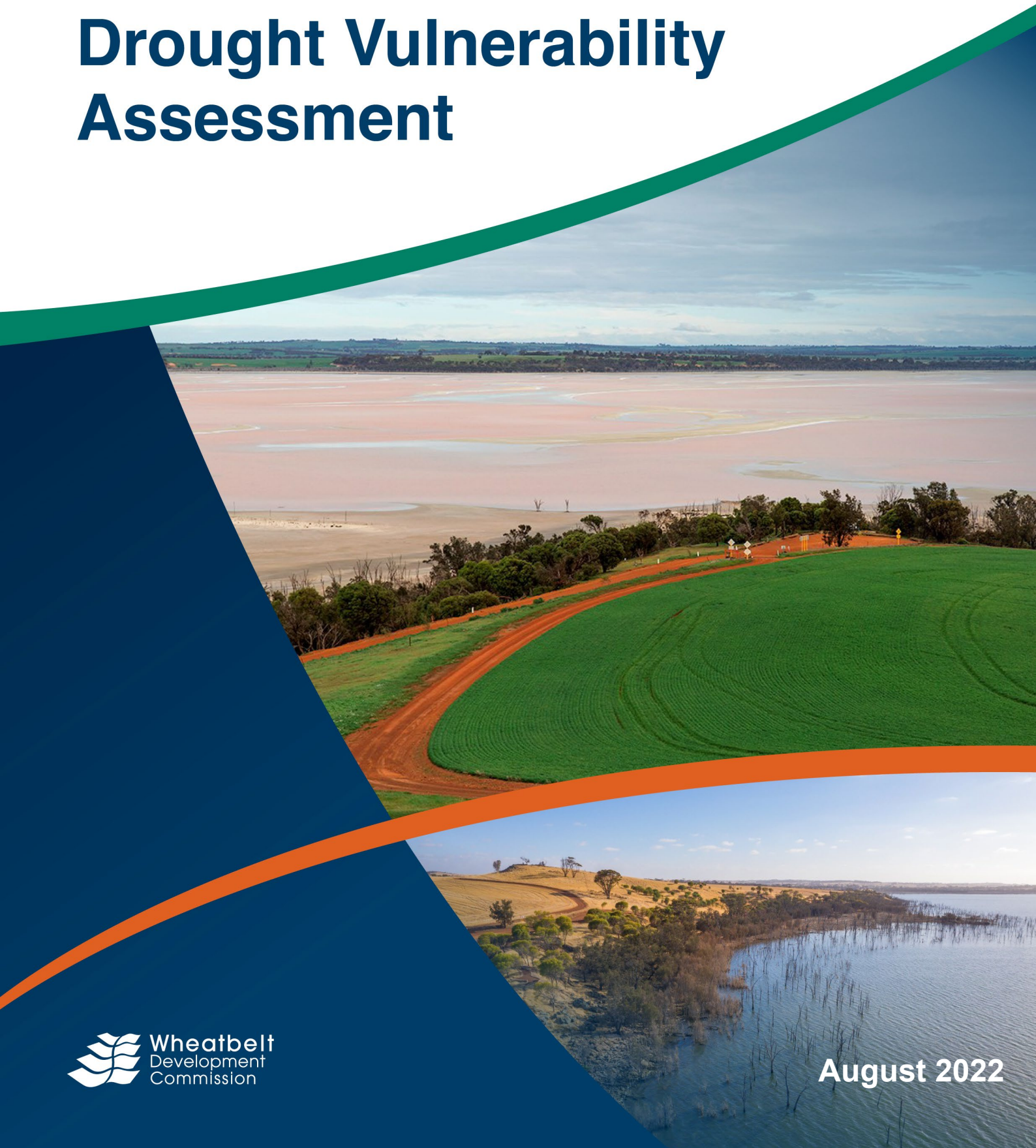
Australian Government
Department of Agriculture, Fisheries and Forestry

Future Drought Fund

Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

Southern Wheatbelt
Drought Vulnerability Assessment



Wheatbelt Development Commission

August 2022

Acknowledgement of Country

We respectfully acknowledge the Traditional Owners of the lands that we live and work on:

The family and clan groups of the Ballardong, Goreng, Gubrun, Kalamaia, Njaki-Njaki, Whadjuk, Wilman, Wudjari, Yued and Yamaji People, their Elders past, present and emerging.

We acknowledge their living culture and important role in the sustainable economic development and prosperity of the Wheatbelt region.

This page image credit: Wheatbelt Development Commission; Cover image credit: Shire of Dumbleyung

The Regional Drought Resilience Planning program (RDRP) is jointly funded through the Australian Government's Future Drought Fund and the Western Australian Government through the Department of Primary Industries and Regional Development (DPIRD).

The Southern Wheatbelt Regional Drought Resilience Plan is a locally led project that champions drought resilience and preparedness in the region. It has been supported by the Shires of Dumbleyung, Kondinin, Kulin, Lake Grace and Wagin.

We would like to thank the nearly 330 people representing 150 different organisations and businesses in the region who contributed to the development of this plan through participation in interviews, meetings and workshops.

The in-kind contribution of the Climate Science and Geographic Information Systems teams at DPIRD, and the work of the consultants who undertook literature reviews and data syntheses on our behalf were integral in the development of this document.

We thank the members of the Southern Wheatbelt Program Advisory Group, along with the Steering Committee and Technical Working Group that contributed to review and refinement of elements of this plan. We also acknowledge the partner agencies, organisations and stakeholders who have supported and contributed to this plan including:

- The Shires of Dumbleyung, Wagin, Kulin, Kondinin and Lake Grace
- The Wheatbelt, Mid West and Great Southern Development Commissions
- Wheatbelt NRM
- South-West WA Drought Resilience Adoption and Innovation Hub
- Grower Group Alliance
- Local community groups and business networks
- Indigenous groups
- Utility providers and research organisations.

Disclaimer

This document has been prepared using best available information and expert analyses to provide an evidence base for the Southern Wheatbelt Regional Drought Resilience Plan.

All information is provided to the best of our ability and within the limits of our knowledge and resources.

It is anticipated that elements of this inaugural Regional Drought Resilience Plan will require review and updating as new information and research become available.

The Chief Executive Officer of the Department of Primary Industries and Regional Development and the State of Western Australia accept no liability whatsoever by reason of negligence or otherwise arising from the use or release of this information or any part of it.

Version: 1.0; **Accessibility** This plan is available in alternative formats on request.

An electronic copy of this plan may be obtained at www.wheatbelt.wa.gov.au

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Preface

Australia has experienced significant drought events over the last decade, with widespread impacts on the agricultural sector and rural and regional communities. Climate variability is expected to continue, with research underway to understand the impacts of drought, informing policy and programs to support adaptation and mitigation efforts.

A vulnerability assessment is a form of risk analysis. This drought vulnerability assessment (DVA) provides the evidence base for the Regional Drought Resilience Plans (RDRPs) for the three consortia regions participating in the Australian Government's Future Drought Fund Regional Drought Resilience Planning Program.

Vulnerability is concerned with ways in which people or systems may be adversely affected by an event or hazard. Understanding vulnerability involves considering exposure to a hazard, sensitivity or susceptibility to harm resulting from exposure to the hazard and the adaptive capacity to cope and effectively respond to the hazard.

Responding to drought at a local or regional level requires a holistic approach that considers vulnerability in the context of complex ecological, economic and social systems. In this report, we present a summary of the likely economic, environmental and social impacts of future drought based on the latest available climate change scenarios, supported by the completion of comprehensive spatial analysis to identify target areas for drought resilience action.

We also report on results of engagement with stakeholders in the region about the ways in which drought has affected them in the past and identify opportunities to build drought resilience. This vulnerability assessment will inform the Southern Wheatbelt RDRP.

This program has strong alignment with National, State, Regional and Local policy and planning including the Australian Government's Future Drought Fund, Wheatbelt Development Commission's strategic priorities of Enabling Infrastructure, Diversifying the Economic Base and Sustainable Communities and Landscapes; the South West WA Drought Innovation and Adoption Hub and the Strategic Community Plans of the Shires of Dumbleyung, Wagin, Lake Grace, Kulin and Kondinin.

Extensive consultation and technical review informed the development of the maps within this report. As such, the maps produced should only be used in relation to the regions that participated in the WA RDRP Pilot.

Executive Summary

The Australian Government established the Future Drought Fund (FDF) to provide secure, continuous funding for drought resilience. Through the FDF, the Australian Government is supporting regions to develop Regional Drought Resilience Plans (RDRPs).

The South West of WA is particularly exposed to the impacts of climate change, with projections indicating increasing temperatures and reducing rainfall under multiple emissions scenarios. Dry spells and drought incidence are likely to increase, requiring a proactive approach to climate adaptation by agriculturally dependent regions.

Understanding vulnerability to drought, through the development of the Southern Wheatbelt Drought Vulnerability Assessment (DVA) is a key component in the delivery of the Southern Wheatbelt RDRP. This DVA is informed by a range of technical analyses, a comprehensive geospatial multicriteria analysis, extensive community and technical expert engagement.

Outcomes of the DVA process include:

- an excellent understanding of the impacts of drought in the region achieved through extensive stakeholder engagement;
- a synthesis of program and policy initiatives related to drought at a local, regional, State and Federal level;
- an investigation of alternative definitions of drought, based on growing season rainfall, better-suited to the broadacre cropping areas in the Southern Wheatbelt region;
- in depth analyses of the economic, environmental, social and water impacts of drought, including the impacts of drought on Aboriginal communities;
- development of a multi-criteria mapping methodology that synthesises many datasets into a single decision-support tool highlighting priority areas for investment in resilience building activities;
- an exploration of how readily measurable biophysical and socio-economic factors, often publicly available data, might serve as indicators of drought and be used to understand and / or predict the impacts of drought; and
- a drought vulnerability index using the data collected to create the drought risk priority areas map.

The impacts of drought in the Southern Wheatbelt are cross-cutting. Stakeholder engagement revealed drought impacts can be significant and wide ranging affecting the economic, social and environmental functioning of the Southern Wheatbelt community and industries.

Except for western parts of Wagin, the entire Southern Wheatbelt RDRP study region has high and very high likelihood of being impacted adversely by drought. Areas of most concern are the Shire of Kondinin, western and eastern Kulin, most of Dumbleyung, west and north east Lake Grace.

The main impacts of drought in Southern Wheatbelt region, identified through the stakeholder engagement and technical review process, are:

- **Economic:** Southern Wheatbelt stakeholders report experiencing financial stress because of failed production, with farming families selling or euthanising livestock, liquidating assets or increasing debt. It should be noted some farmers benefit from drought, through increases in farm size and becoming more crop dominant, increasing their wealth over time[1]. Non-farming families experience reduced throughout of business, reduced employment opportunities, inability to retain staff and reduced cash flows. Targeted research, development and extension to build on already water efficient farming systems and practices; investment in water infrastructure; businesses diversifying their clientele, value adding commodities; improved understanding and advocacy for regional enabling infrastructure needs to support economic functioning needs were opportunities identified to building drought and climate resilience. There are also opportunities to capture the opportunities of decarbonisation.

- **Environmental:** Drought can have serious, long-term consequences for soil health, vegetation cover and biodiversity. Reduced vegetation cover and drier soils increases the risk of erosion and invasion by weeds, pests and diseases Plant mortality becomes more pronounced in drought years impacting on biodiversity, ecosystem services and reduces the ability to sequester carbon. Environmental stewardship programs, informed participation in carbon farming and extension and adoption programs with a focus on peer to peer learning, were identified as opportunities to improve environmental resilience.

- **Social:** The uncertainty and financial stress associated with drought negatively affects mental health in regional areas. Drought contributes to failed businesses, causing people to move away and, in turn, reducing population, access to skills and services and the availability of community services and support networks in the region. The small communities that are a feature of the Southern Wheatbelt are particularly exposed to drought impacts, given the high dependence on agriculture and the high levels of volunteerism that support social connection.

- **Water:** The Southern Wheatbelt's potable water source is provided by externally sourced piped scheme water via the Goldfields Water Supply and Great Southern Town Water Supply schemes. During dry periods, scheme water resources are strained. Non-potable community and on farm supplies augment potable supplies, though are often unable to cope with more than two dry seasons. This results in increased draw on scheme water and emergency supplies, triggering water deficiency declarations. Water supply development occurs sporadically and is undertaken by multiple organisations. Improved planning and coordination of future water needs was identified as a key opportunity to augment existing water supplies for industry and community use, supporting ongoing growth and development.

- **Impact on Aboriginal communities**: Aboriginal communities are likely to be disproportionately affected by drought due to pre-existing health and social disadvantage. Aboriginal community members expressed concern about the impact of drought on vegetation, water and fire regimes in the region, as well as the impact of land transformation and climate change on the region's vulnerability to drought. Participation in landscape conservation and restoration activities such as seed collection to support revegetation and carbon farming projects were identified as economic opportunities for Aboriginal people. A Noongar led framework of action to

support improved engagement in land management was suggested as a way forward.

Following consultation with regional stakeholders and technical experts, a working definition of drought for the RDR Planning Program in WA was developed. Drought is defined as:

> *"a prolonged period of abnormally dry conditions that impacts negatively on water availability and agricultural production in a region and, consequently, impacts negatively on the economy and environment of the region and the health and well-being of its residents"*

Assessment of meteorological definitions of drought indicated a definition based on **growing season rainfall** (between April to October) is considered more appropriate for the Southern Wheatbelt region than a definition based on total annual rainfall. Growing season rainfall better represents agricultural drought in the region, where dryland cropping in autumn and winter is the primary land use.

Analyses of rainfall and temperature data highlighted a potentially concerning trend, with the composite hazard of **hot drought** beginning to occur in recent years.

Combined high temperatures and low rainfall can be devastating and are likely to occur more frequently and over larger areas in future given global climate trends. Appropriate steps must be taken to anticipate and mitigate the potentially devastating effects of hot droughts.

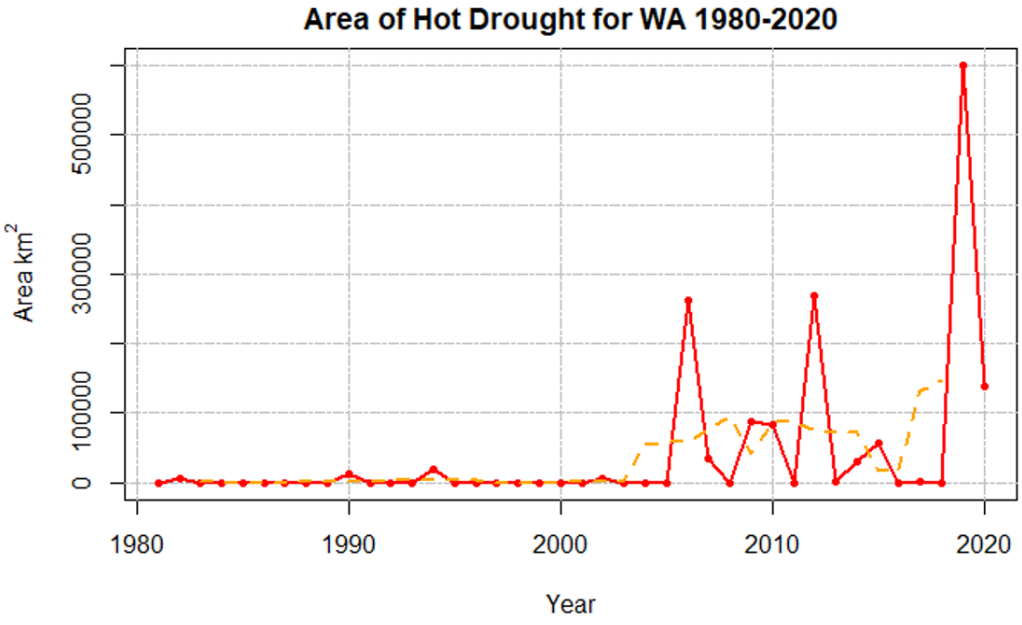

Figure 1 Hot droughts were relatively unknown in WA until 20 years ago. They are now increasingly common and severe, with potentially serious consequences for the agriculture sector.

Detailed, context-specific information is needed to guide local level drought resilience decision-making, planning and implementation. A spatial multi-criterion analysis of economic, environmental and social data relevant to drought was undertaken to create a drought risk priority areas map.

The priority areas map used LGA boundaries to directly inform local level political, administrative and operational decision-making. The final drought risk priority areas

map shows the areas in the Southern Wheatbelt region that are most vulnerable to drought. Drought vulnerability varies between moderate to very high vulnerability. Very high vulnerability in the Southern Wheatbelt region often correlates to proximity to water supplies – either scheme or non-potable supplies.

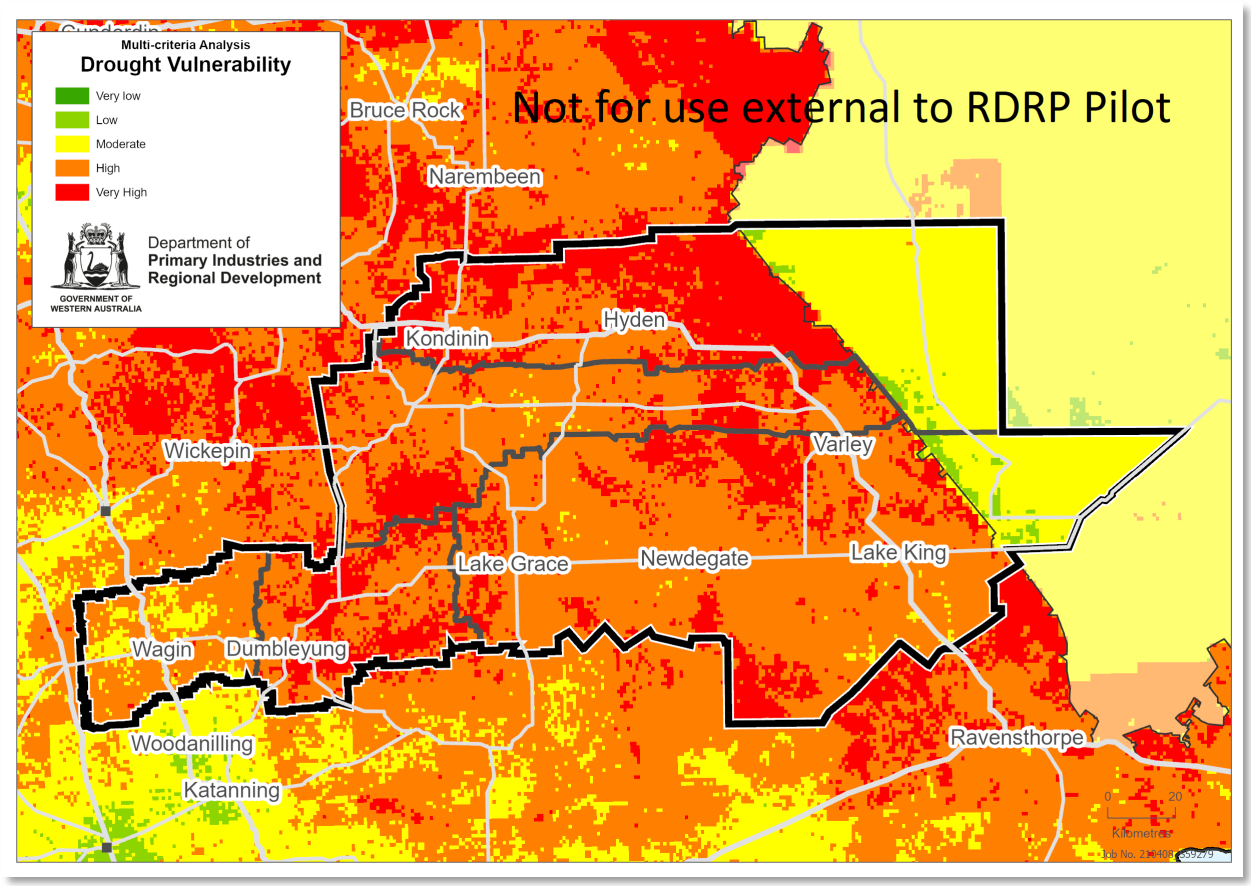

Figure 2 The composite drought vulnerability map highlights drought risk priority areas in the Southern Wheatbelt region based on temperature, rainfall and production data, access to infrastructure, population demographics and environmental characteristics. Red areas are considered most vulnerable to drought and should be treated as the highest priority for drought resilience interventions. Data for areas outside the southwest forecasting zone (i.e. pastoral areas to the east) are not reliable and should be ignored.

Despite high resilience in terms of agricultural production capability, the region is exposed to the impacts of climate change (increasing temperatures, decreasing rainfall, changes in the timing of rainfall and increasingly frequent drought) and faces several general resilience challenges including economic diversification and access to infrastructure, services and reliable, good quality water.

Improving our understanding of and responses to these challenges should be the focus of drought resilience action in the region.

1. Introduction

The Future Drought Fund (FDF) is an Australian Government initiative to help Australian farmers and regional communities become more prepared for, and resilient to, the impacts of drought[2]. The $5 billion fund invests $100 million a year in projects that will provide opportunities for farmers, allied industries and regional communities to adopt new technologies, improve their environmental and natural resource management, refine their drought resilience planning and decision-making abilities and participate in a range of community resilience activities. The Regional Drought Resilience Planning (RDRP) program is one of the foundational programs under the FDF in 2021-22, under the 'Better Risk Management' theme.

The RDRP program focuses on developing regional drought resilience plans, based on sound resilience planning principles and practices[3, 4, 5, 6]. These plans identify priority actions to build resilience to drought in agriculture and allied industries across different regions. In Western Australia, the program will deliver three Regional Drought Resilience Plans in the foundational year. The pilot regions are in the Great Southern, Mid West and Wheatbelt. This report focuses on the Southern Wheatbelt region, incorporating the Shires of Dumbleyung, Wagin, Kulin, Kondinin and Lake Grace.

Regional drought vulnerability assessments are an important part of building the evidence base underpinning the plans (Figure 3).

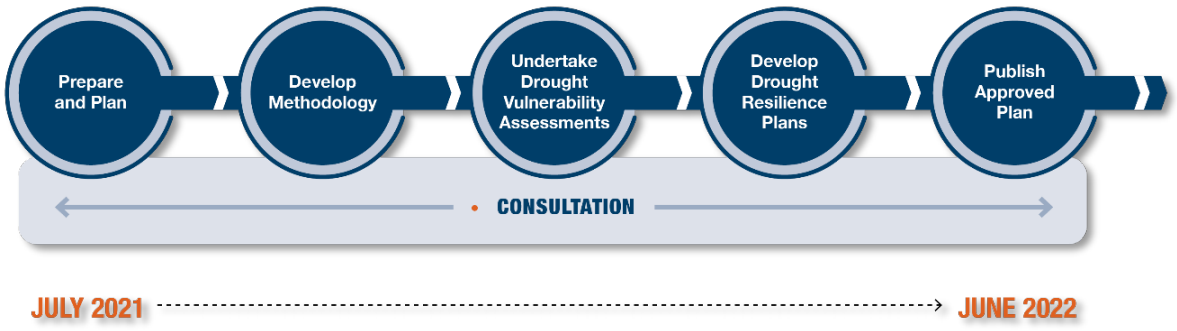

Figure 3 Project implementation plan for the Future Drought Fund Regional Drought Resilience Planning Program in Western Australia, showing where regional drought vulnerability assessments fit into the delivery of the program.

Vulnerability refers to the predisposition or propensity to be adversely affected[7]. Vulnerability encompasses a variety of concepts and elements including exposure to a hazard, sensitivity or susceptibility to harm because of exposure to the hazard and the adaptive capacity to cope and respond effectively to the hazard. Responding to drought at a local level requires a holistic approach that considers vulnerability in the context of complex economic, social and ecological systems.

A vulnerability assessment is a form of risk analysis involving identification, quantification and prioritisation amongst the vulnerabilities in a given system[8, 9, 10]. Consultation with stakeholders and reviewing existing data on drought impacts in the focus regions during the vulnerability assessment phase is an opportunity to better understand how the regions have been affected by drought in the past and how they are likely to be affected by drought in the future.

The vulnerability assessment is also an opportunity to review what has already been done to mitigate the impacts of future droughts and how effective these measures have been. Each regional vulnerability assessment will include a technical analysis of the likely social, economic and environmental impacts of future drought based on the latest available information, including climate change scenarios.

1.1 Drought Vulnerability assessment conceptual framework

Regional drought vulnerability assessments require consideration of both the potential impacts of drought and the adaptive capacities of the people and systems in each region. Drought impact includes the degree of exposure to drought in the regions and each region's inherent sensitivity to drought conditions. Adaptive capacity describes the internal features and characteristics of the regions that influence their ability to respond effectively to and withstand past and future droughts.

Resilience refers to the region's ability to absorb disturbance and to effectively maintain, reorganise or make changes to sustain lives and livelihoods [11]. The RDRP drought vulnerability assessment conceptual framework (Figure 4) draws on past studies in Australia [12, 13, 14, 15] and around the world [16, 17, 18] to ensure that sufficient attention is paid to all important aspects of drought vulnerability and resilience in the affected regions.

Definition of terms

Exposure: the extent to which a given system, community or region will be subjected to a particular hazard. For the RDRP, exposure is measured in terms of the extent to which a focus region will be exposed to drought and drought-related climate change processes such as increasing atmospheric temperatures and changes in rainfall patterns and soil moisture.

Sensitivity: the extent to which a given system, community or region will be affected by a particular hazard. For the RDRP, sensitivity is fundamentally about the ways in which regions are impacted by drought. It is measured in terms of the effect of drought on crop and animal production and the influence of regional characteristics such as soil types and farming systems on the effect that a drought has in the region.

Adaptive Capacity: the extent to which a system can exploit opportunities and resist or adjust to change. For the RDRP, adaptive capacity is measured in terms of historical response to droughts in the regions or estimated according to a set of vulnerability proxies such as income, education, community participation rates and drought resilience natural features (ground cover, topography).

Resilience: the capacity of a rural community and landscape as social-ecological system to absorb disturbance, reorganize, maintain or change functions and feedbacks to continue to deliver values. Planning for resilience is about building

- **Absorptive capacity** for maintaining the system;
- **Adaptive capacity** for modifying the systems when needed;
- **Transformative capacity** for systemic change when maintaining and modifying existing system are untenable; and
- Developing new configuration of **networks** and **institutions** to implement these capacities.

Our drought vulnerability assessment approach uses existing social, economic and environmental data representing current and historical conditions and contextualises these data within the latest available climate science for the regions. It is assumed, based on past research in Western Australia [19, 20], that existing vulnerabilities will be exacerbated by drought. The same level of drought will affect more and less vulnerable people and systems differently. A focus on known current social, economic and environmental vulnerability is less sensitive to uncertainties in climate projections than

modelled approaches and aligns more readily with Australian policy priorities around economic growth and production.

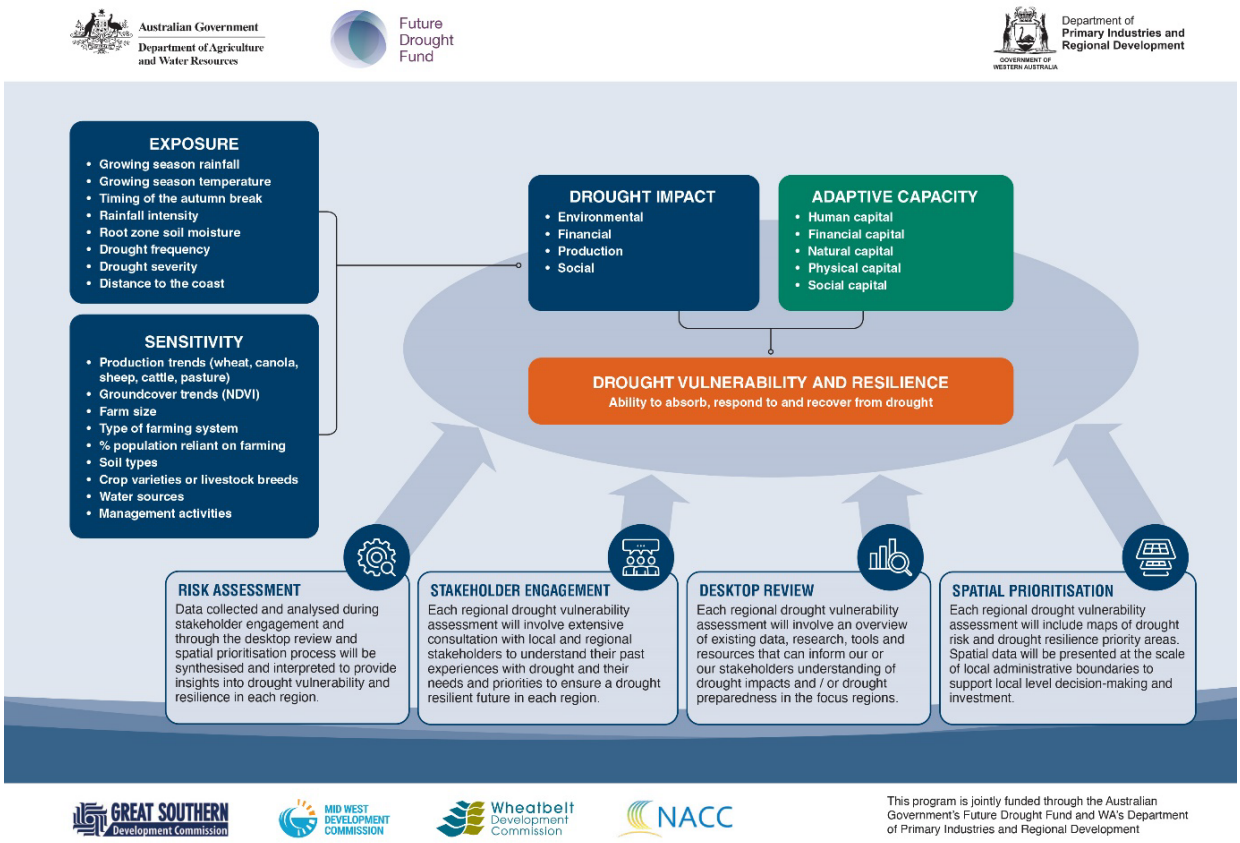

Figure 4 Conceptual framework for regional drought resilience vulnerability assessments

1.2 Components of a vulnerability assessment

1.2.1 Stakeholder Engagement

Stakeholder engagement is a critical component of any vulnerability assessment process. A stakeholder mapping process was undertaken for each region to identify groups and individuals to consult on the development of the regional drought resilience plans. Stakeholders identified through this process included local government authorities, farmers and their representative bodies, agribusiness, Traditional Owners, community groups and not for profit organisations, research institutions and the regional offices and technical teams of state and federal government agencies.

Consultation with stakeholders is critical in understanding how those living and working in the regions have experienced and responded to drought in the past, what they have undertaken to mitigate drought risk, how they perceive future drought risk and understanding priority actions they consider important in building resilience to drought in the future.

Strong stakeholder engagement generates buy-in from the community and stimulates interest in the project. It sets a level of accountability for the project team and builds and strengthens relationships across and within the region that will outlive this program.

In the Southern Wheatbelt region, stakeholder engagement occurred between October 2021 and June 2022. A range of methods were used to engage stakeholders across all levels of government, key agricultural and natural resource management groups, traditional owners, businesses and community organisations.

The formation of the Southern Wheatbelt Project Advisory Group, consisting of local government Executive and Elected Members from across the participating Shires assisted in targeting stakeholder engagement. Wheatbelt Natural Resource Management Inc were contracted to undertaken consultation with Agriculture, Natural Resource Management and Traditional Owners across the region using a range of methods. A community engagement consultant based in the Shire of Dumbleyung undertook consultation with a range of business and community organisations.

A Technical Working Group was established and provided opportunity for input and review of the key elements of the Drought Vulnerability Assessment model, including identification of important datasets to inform the assessment process. A high level Steering Committee provided high level support and direction to the project team.

Consultation sessions focused on reviewing emerging technical analyses, sharing the results of earlier consultation efforts and identifying drought resilience project ideas for inclusion in the regional drought resilience plan. More than 330 people representing over 150 separate organisations and businesses were consulted. The consultation was overseen by the Wheatbelt Development Commission, with support of a Project Manager and a consultant based in the Shire of Dumbleyung. The WDC Board was regularly updated on the project.

See **Appendix 1** for a snapshot of the stakeholder engagement activities. Consultation reports for Agriculture and Natural Resource Management Stakeholders, Aboriginal Stakeholders and Regional Businesses are available on request. See Section 10.

1.1.1 Desktop review

Desktop review is a critical component of any vulnerability assessment process. It involves identifying, summarising and interpreting what is already known about the impacts of the hazard of interest on a particular system, in this case drought. The desktop review followed the development of the RDRP conceptual framework, and investigated aspects of exposure, sensitivity, impact and adaptive capacity and the ways in which each of these relate to and inform vulnerability and resilience to drought in the regions.

The desktop review included an overview of existing data, research, tools and resources that informed our stakeholders' understanding of drought impacts and drought preparedness across the focus regions. It included a socio-economic and land-use profile of each region, describing the population, major land-uses and economic activities, the threatening processes they face and what that means in terms of drought resilience. The review identified those actively working to support drought resilience in the region with regards to drought, including their respective roles and relationships between them, and summarised existing and past drought resilience policies and plans across a range of levels, from local to international, and the suite of drought resilience programs currently operating in Western Australia and Australia as a whole.

1.2.2 Spatial Prioritisation

The spatial component of the RDRP regional drought vulnerability assessments used mapping software to visualize 1) drought risk and 2) drought resilience priority areas.

All spatial data was prepared and presented at the scale of local administrative boundaries, to best support local level decision-making and investment.

The first set of spatial products included a visualisation of drought risk in terms of historical and projected changes in rainfall (*Figure 5*), temperature, soil moisture and the frequency and severity of drought, and is intended to build local capacity to understand historical drought and work with a range of plausible future drought climate scenarios using climate projections to inform planning discussions.

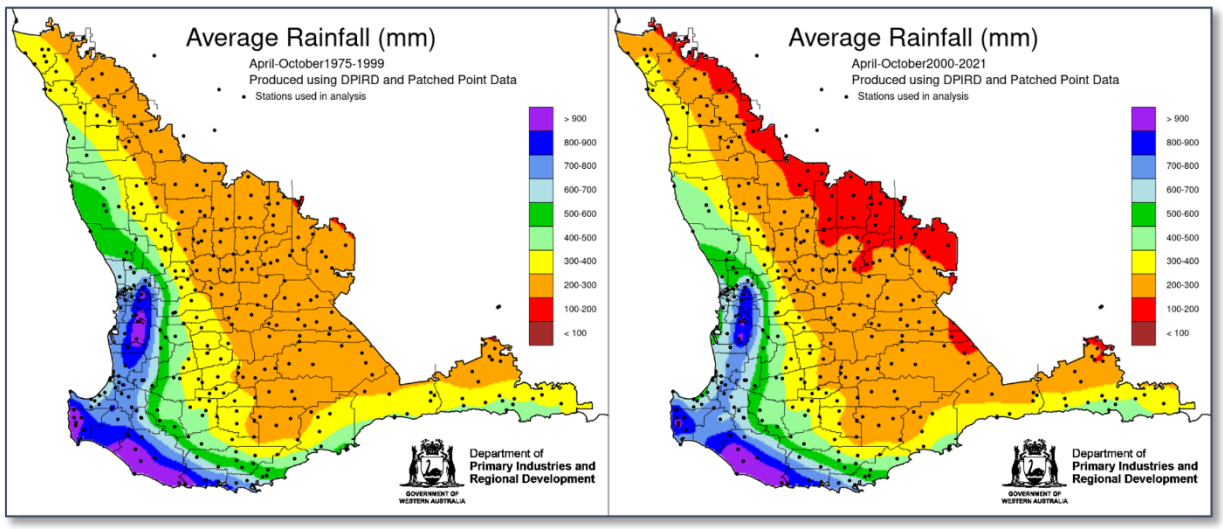

Figure 5: Change in growing season rainfall between 1975 and 1999 (left) and 2000 and 2020 (right) using data from the Future Drought Fund climate information program, Climate Services for Agriculture.

The second set of spatial products was a visualisation of drought resilience priority areas. This is intended to guide on-the-ground drought resilience implementation by identifying high priority sites and enabling decision-makers to visualise these priority sites for fine scale local level planning. Inputs into the multi-criteria analysis (MCA) were determined following the development of the RDRP conceptual framework, and include exposure, sensitivity, impact and adaptive capacity and the ways in which each of these relate to and inform vulnerability and resilience to drought in the regions.

Spatial data layers will include:

- climate data (historical and projected change in rainfall, temperature, soil moisture and drought frequency and severity)
- environmental data (soil type, topography, ground and surface water resources, native vegetation extent, ground cover, NDVI)
- production data (crop yields, animal production, type of farming system)
- financial data (household income, farm profitability, use of farm management deposit schemes)
- social data (population trends, access to services, community participation rates)
- infrastructure data (roads, water supplies).

Composite maps showing how different features of drought risk and resilience are overlaid in the regional landscapes are created using a standard multi-criterion GIS analysis (MCA)[21, 22, 23, 24, 25] (*Figure 6*). Priority areas for investment in drought resilience projects or programs are highlighted at the overlap between spatial datasets that highlight where drought is likely to occur, where there are features are likely to provide

resilience to the impacts of drought (e.g., high ground cover, lots of water resources, drought resilient farming systems) and where vulnerable communities of people are likely to be impacted by drought (e.g. remote communities with limited access to services).

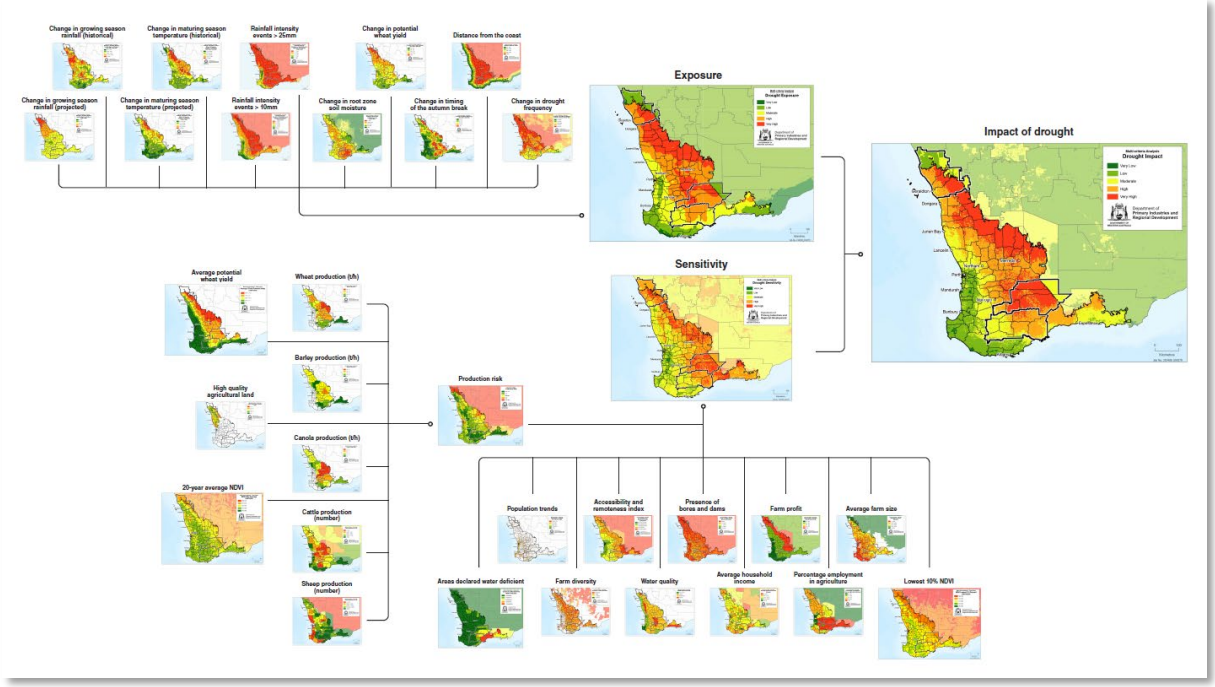

Figure 6: Multi-criterion GIS analysis works by standardising and overlaying spatial data to identify significant areas of overlap.

1.2.3 Risk Assessment

A drought risk assessment collates all the data collected and analysed from the stakeholder engagement, desktop review and spatial prioritisation components, and provides local decision-makers with a summary of vulnerability to drought in their region. Synthesis of the data into a risk assessment followed the development of the RDRP conceptual framework and investigated aspects of exposure, sensitivity, impact and adaptive capacity and the ways in which each of these relate to and inform vulnerability and resilience to drought in the regions.

The aim of a risk assessment summary is to assist local decision makers and managers in the rapid evaluation of drought vulnerability for the region and enable tracking of change over time. Data in each drought impact category (i.e. social, financial, production, environmental) can be scored along a sliding scale and assessed over medium and long term timeframes in terms of drought risk and resilience [26, 27]

1.3 Structure of this Report

This report is presented in four main sections as outlined below:

- Background and context. In this section we provide information about the region, including where it is located, why it was selected and the socio-economic, land use, institutional and policy context. This information can speak to vulnerability and resilience in general terms.
- An analysis of historical and project future drought. In this section, we provide a summary of the available historical climate data and the latest future climate

projections as sourced from Climate Services for Agriculture. This section focuses on exposure to drought in the region and on how we have defined drought for the planning purposes.

- An assessment of drought risk and the impacts of drought in the region. In this section, we summarise the economic, environmental social and production impacts of drought using a combination of stakeholder engagement, desktop review of the available data and GIS-based assessment of impacts. We present a drought resilience priority areas map to guide investment in the region.
- An assessment of some different ways in which drought impact, resilience and vulnerability could be measured. In this section, we discuss how all the above information could be synthesised into standardised indices to enable comparison with other regions and to allow for tracking change over time. We also present an index of drought vulnerability based on the data collected to generate the drought risk priority areas map.

2. Background and context

The 2021-2022 foundation year of the RDRP program is being piloted in the Great Southern, Mid West and Wheatbelt regions of WA (Figure 7)Figure 7: Map showing the geographic scope of the Future Drought Fund Regional Drought Resilience Planning Program in Australia during the foundation year.

Together, the three pilot regions cover over 82,000 km^2 of WA's grainbelt, the largest agricultural producing area in WA and a key contributor to the State economy. In addition to large scale broadacre cropping and livestock production, these regions support a diverse range of other primary production activities, with small and medium businesses servicing agricultural and mining, with government and population services prevalent in larger population centres.

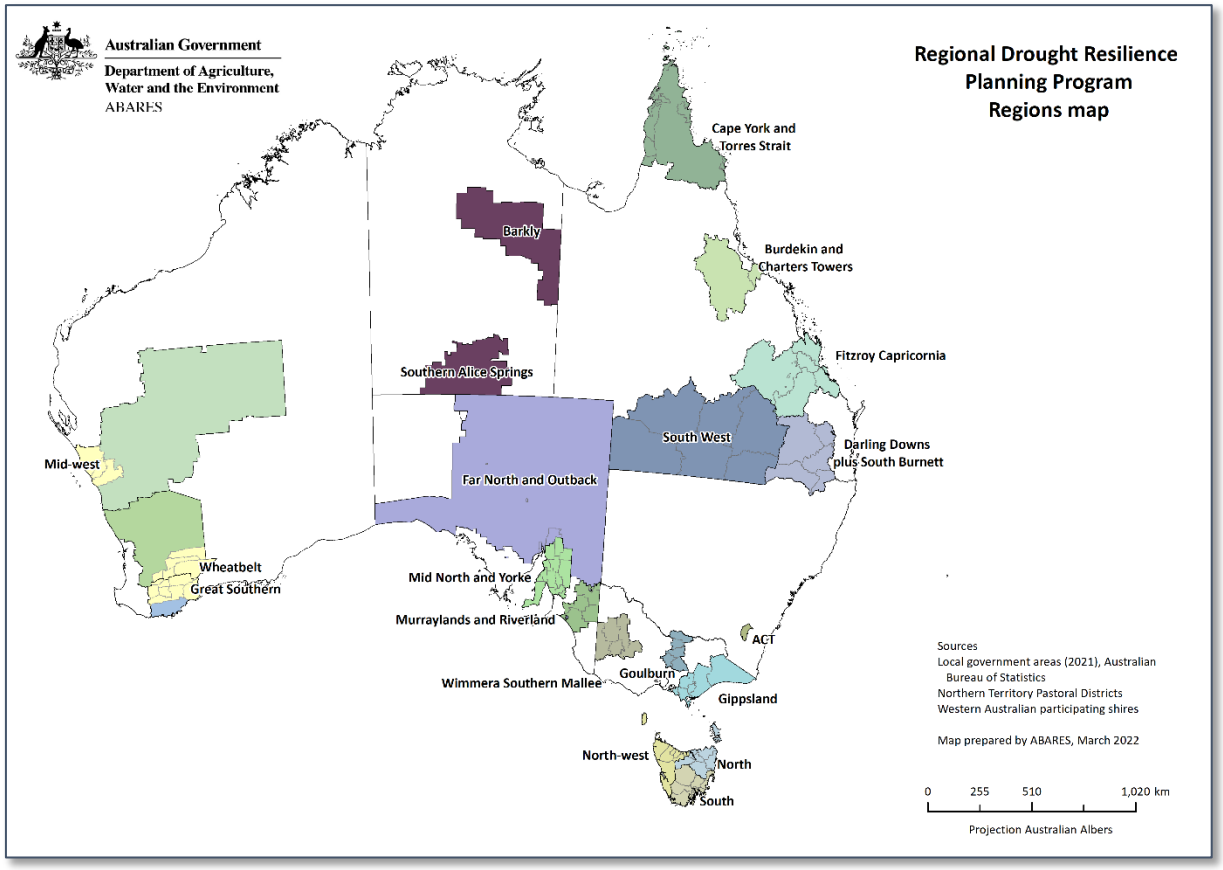

Figure 7: Map showing the geographic scope of the Future Drought Fund Regional Drought Resilience Planning Program in Australia during the foundation year.

The three pilot regions all fall within the Bureau of Meteorology's South West Land Division forecasting area. The South West Land Division is amongst the regions most impacted by climate change in Australia, experiencing consistent reduction in rainfall over the last several decades. Rainfall in South West WA continues to decline with projections showing a further decrease in annual rainfall of up to 15% by 2030.

2.1 The Southern Wheatbelt Region

In the Southern Wheatbelt region, the participating Local Government Areas (LGAs) are the Shires of Dumbleyung, Lake Grace, Wagin, Kulin and Kondinin (Figure 8), covering 28,512km^2. This region is located on Ballardong, Wagyl-Kaip and Gnaala

Karla Booja land, with the boundaries of the 3 Indigenous Land Use Agreements meeting in the Southern Wheatbelt study area [28].

The region covers the south-eastern portion of the Wheatbelt Development Commission region, bordering the Great Southern Development Commission's northern boundary, and Goldfields-Esperance Development Commission and Great Western Woodland western boundary. It includes the H4 (high rainfall south), M4 (medium rainfall south) and L4 (low rainfall south) agro-economic zones as identified by the Department of Agriculture and Food WA.

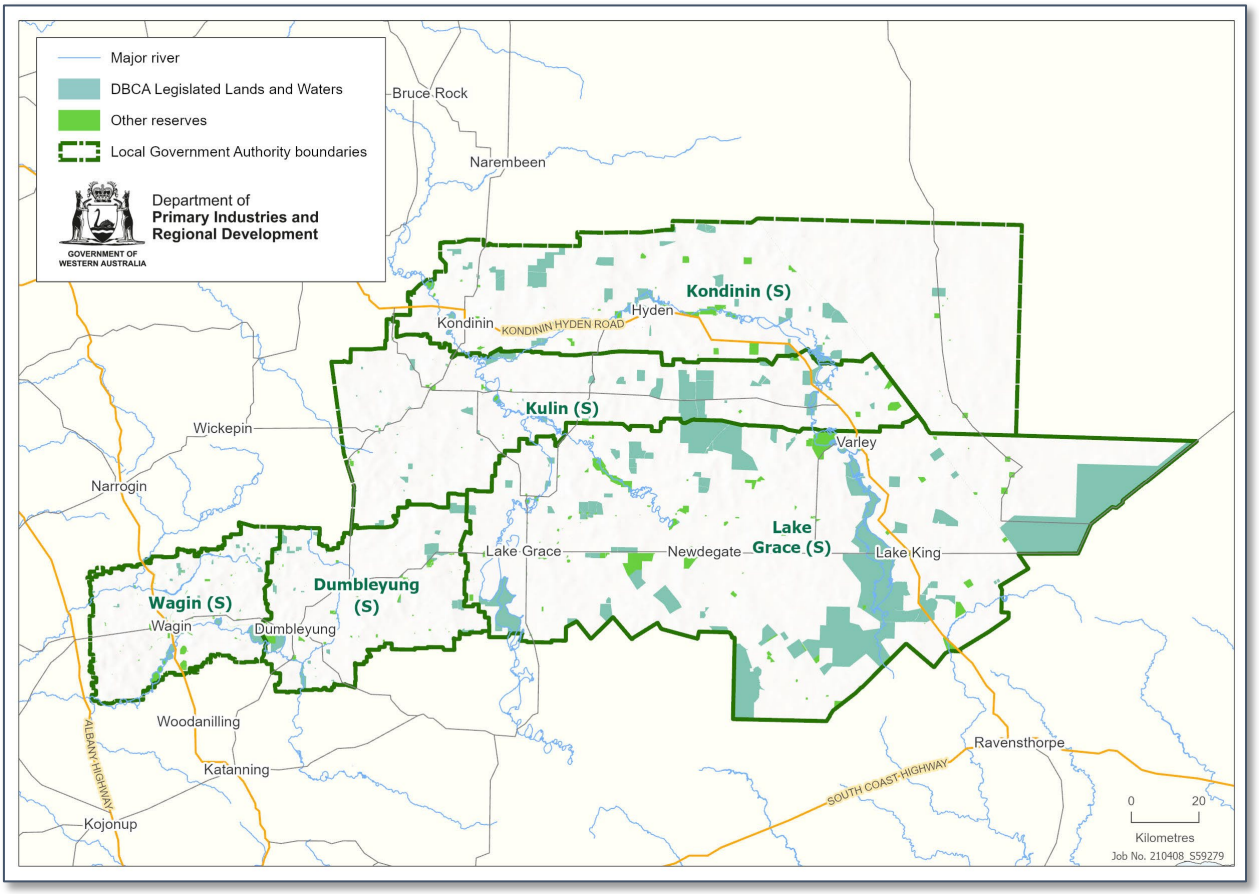

Figure 8 Map showing the geographic scope of the regional drought resilience plan in Southern Wheatbelt during the foundation year of the Future Drought Fund Regional Drought Resilience Planning Program.

Key characteristics of the Southern Wheatbelt Consortia include:

- The Shire of Wagin has the largest population, followed by Lake Grace.
- All areas have a median age above the WA median, with the largest variance in Wagin.
- Overall, most Shires had net out-migration, with a trend towards neutral in/out migration in 2020.
- The Shires of Wagin, Dumbleyung and Kondinin have more disadvantage than greater regional WA and WA, the Shires of Kulin and Lake Grace have more advantage.
- Agriculture accounts for over 50% of economic output and over 50% direct employment in the Shires' of Lake Grace, Dumbleyung and Kulin.

2.1.1 Demographic Summary

The Southern Wheatbelt Consortia is home to 5,323 people, and between 2017 and 2019 most Shires had net out-migration, with a trend towards neutral in / out migration in 2020. All Shires are above the WA median age of 36, being highest in the Shire of Wagin at 49, and in other Shires ranging from 40-44. Figure 9 highlights the concentration of population in major town centres.

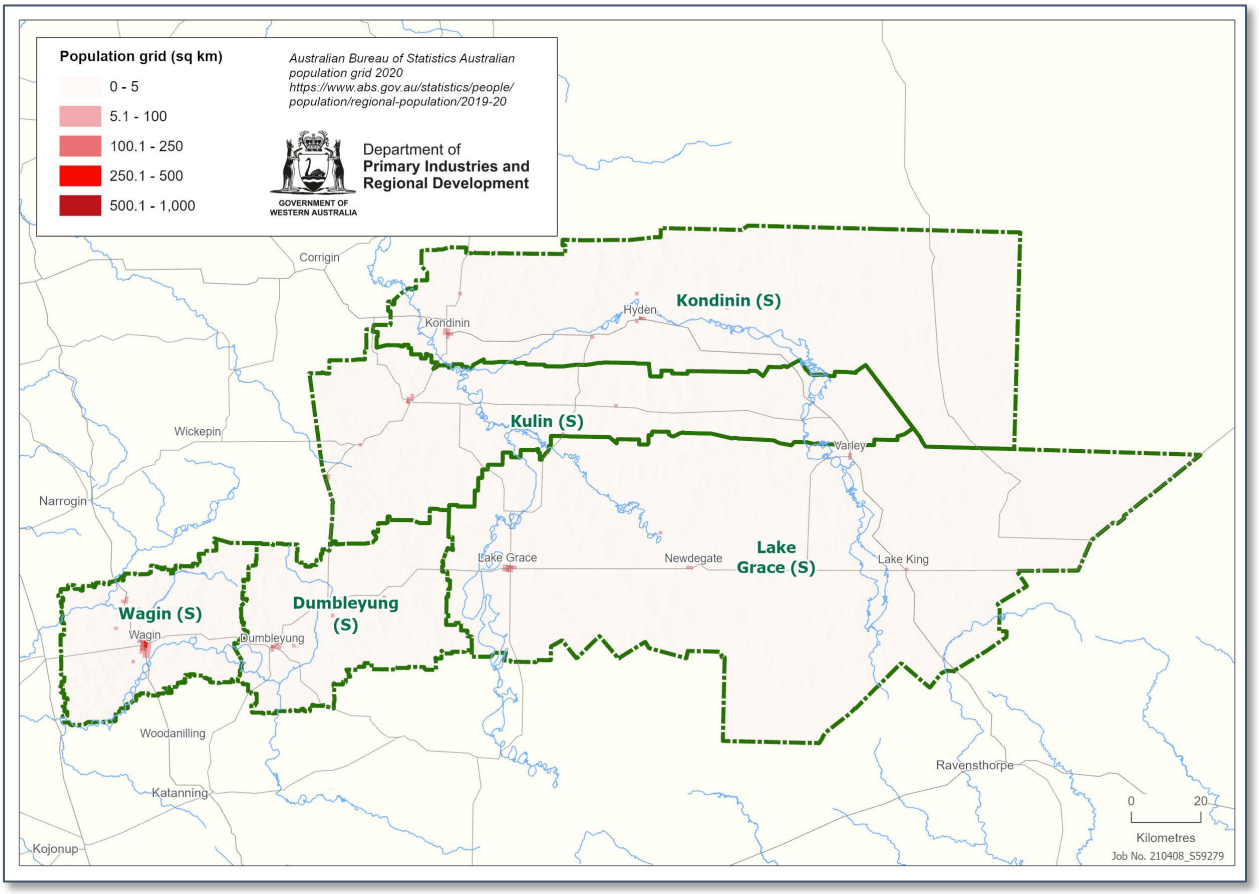

Figure 9: Population density in the Southern Wheatbelt region as number of people per km

2.1.2 Economy and employment

The Consortia area has an economic output of $1.5 billion, or 9.93% of total economic output for the Wheatbelt. Agriculture, forestry and fishing is the largest sector by economic output in the Consortia, with $643.16 million or 36.07% of total output[29]. This is followed by mining, with concentration of activity in the Shire of Kondinin. Dryland cropping is the dominant land use (Figure 11).

Across the Consortia there are 2,818 jobs, 9.53% of jobs for the Wheatbelt region. Agriculture, forestry and fishing is the largest employing sector with 1,264 or 44.85% of jobs (Figure 10).

Table 1 summarises the combined consortia and local government area statistics.

Table 1: A snapshot of the combined consortia and each local government area

	Consortia	Shire of Dumbleyung	Shire of Kondinin	Shire of Kulin	Shire of Lake Grace	Shire of Wagin
Area (km^2)	**28,512**	2,541	7,422	4,717	11,886	1,946
Population (ERP 2020)	**5,323**	681	847	769	1,265	1,761
Median age (years) - WA 36	-	44	46	44	41	49
SEIFA - greater regional WA 965; WA 1,015	-	996	979	1,021	1,017	929
DOTE Index (Score)	**2-3**	3	2	3	3	2
Annual economic output ($)	**$1.506 billion**	$130.74 million	$543.24 million	$166.26 million	$327.14 million	$338.96 million
Agriculture* (% of economic output)	**36.07%**	63.7%	17.10%	66%	52.60%	25.20%
Agriculture* (% of jobs)	**44.85%**	62.3%	31.5%	66.8%	53.7%	28.6%

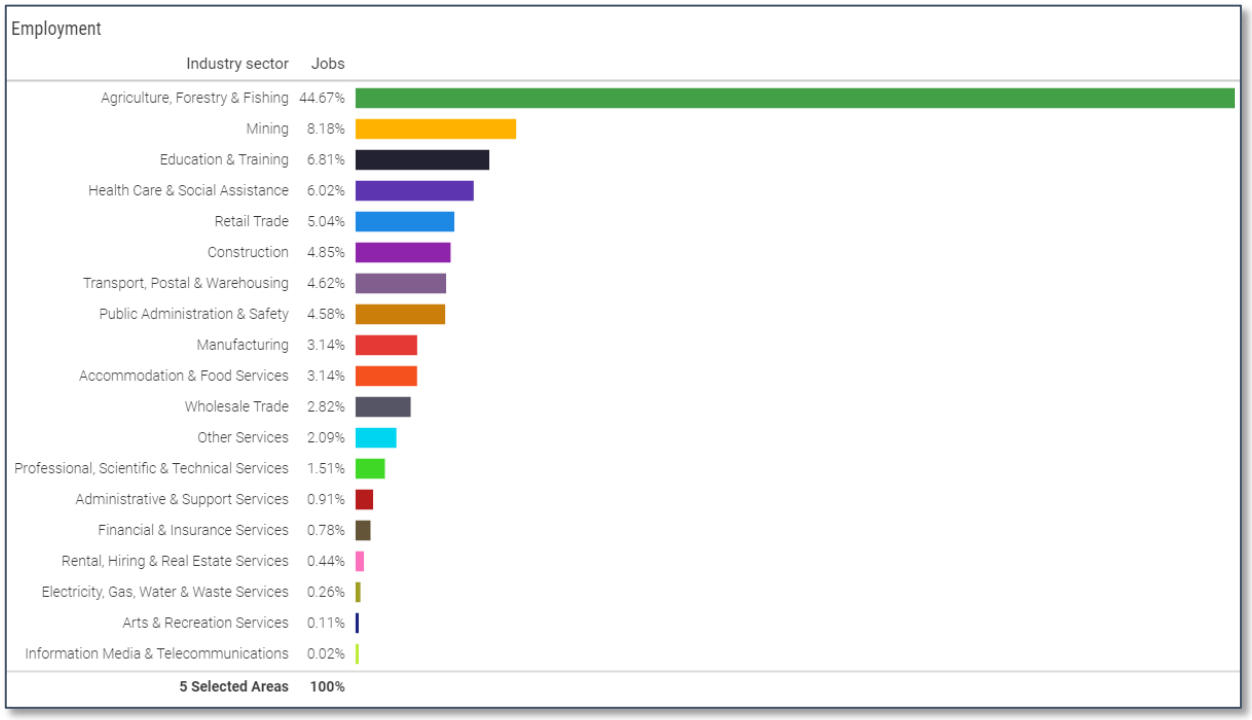

Figure 10: Employment by industry (%) in the Southern Wheatbelt Consortia

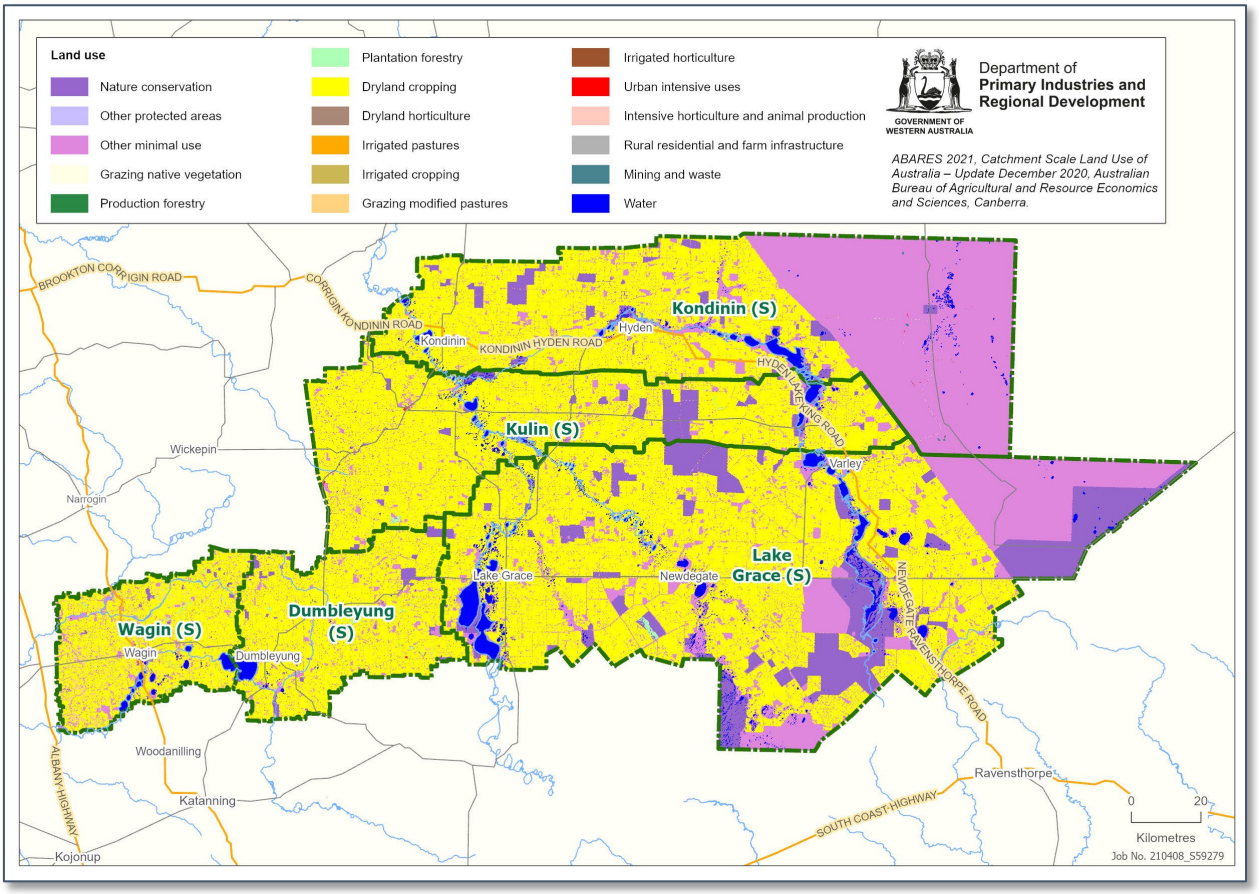

Figure 11: Land Uses in the Southern Wheatbelt region

The region is dependent on agriculture, with wheat production dominating the gross value of agricultural production across all Shires except Wagin. Wagin has a higher GVAP attributed to livestock production. There are shifts towards more diversity, with value adding and niche market development occurring, particularly in the agribusiness sector, and the increasing concentration and sophistication of health and aged care services being centred out of Narrogin[30]. Mining exploration is increasing across the region, with established nickel mining in the Shire of Kondinin and a new Kaolin mine due to commence production in nearby Wickepin. Planned renewable energy projects and development of a biodiesel production plant in Narrogin present further economic diversification opportunities based on the region's competitive advantages [30].

Agricultural businesses make up 636 of the 1098 in the region. Of those businesses, 160 (25%) have a turnover of less than $200,000; 114 (18%) have a turnover between $2 million and $5 million; with 3 having a turnover of more than $10 million (all located in Kondinin). Across all regional businesses, 28 have a turnover $5 million (including 15 over $10 million) across wholesale trade, manufacturing, retail trade, agriculture and professional, scientific and technical services. They are based in the Shires' of Lake Grace, Wagin and Kondinin. *Figure 12* and *Figure 13* illustrate percentage of businesses by turnover according to business sector, and businesses by turnover by sector and Shire.

With agriculture a key driver to the economy, there is an established local supply chain network with strong presence of transport, warehousing and mechanical repair services businesses. Agriculture is the primary occupation of employees in the region, though

the number employed has decreased over time due to increasing productivity and consolidation of farms, and shift of farming enterprises towards grain growing.

Lake Grace has the highest number of total businesses, with 218 of those agricultural businesses (*Figure 14*). This is due to its large physical size, larger population and strategic location. Wagin has slightly more diversity than other Shires (*Figure 14*) and the second highest number of businesses due to its western Wheatbelt location and proximity to major regional centres of Narrogin and Katanning.

Growth opportunities in the Wheatbelt South include those that build on existing strengths such as agricultural support and population services, and in the development of opportunity industries such as large scale biofuels and renewable energy projects, grain cereal product manufacturing, meat processing, tourism and niche agricultural products[30].

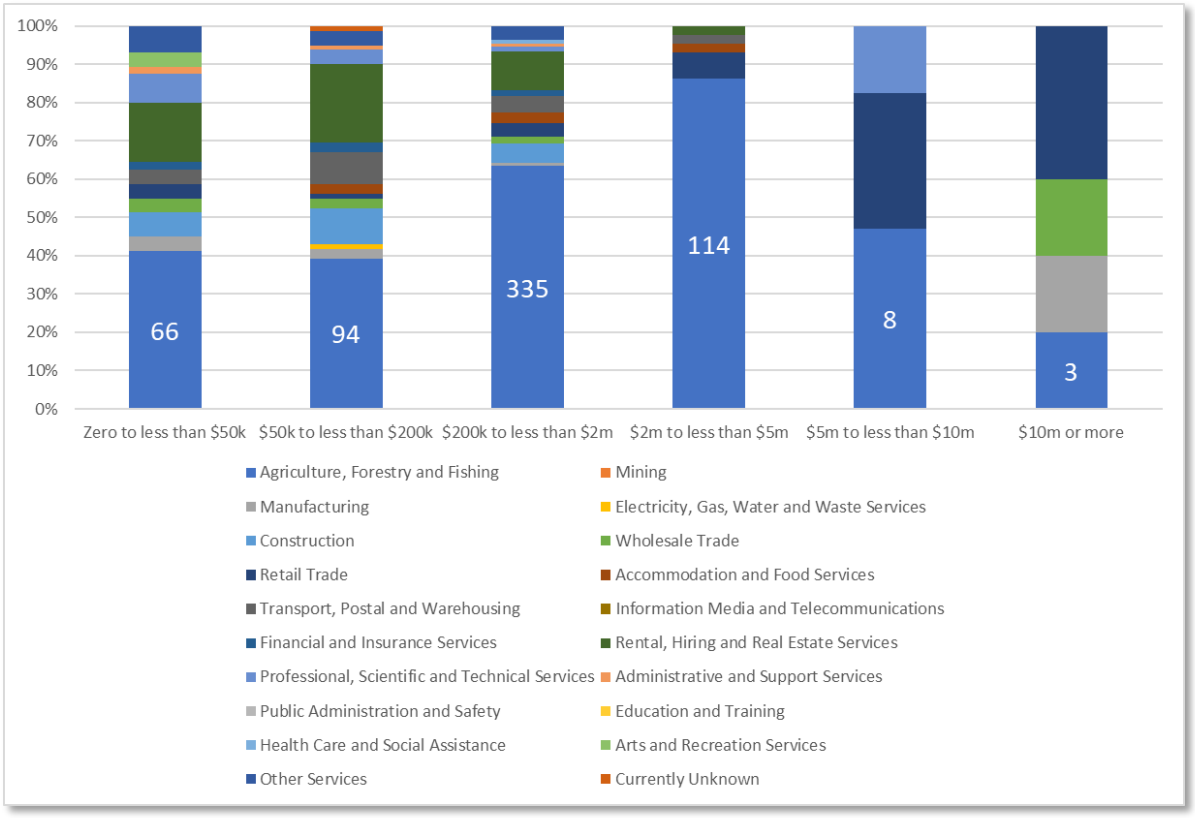

Figure 12 Business sector by turnover in the Southern Wheatbelt focus region

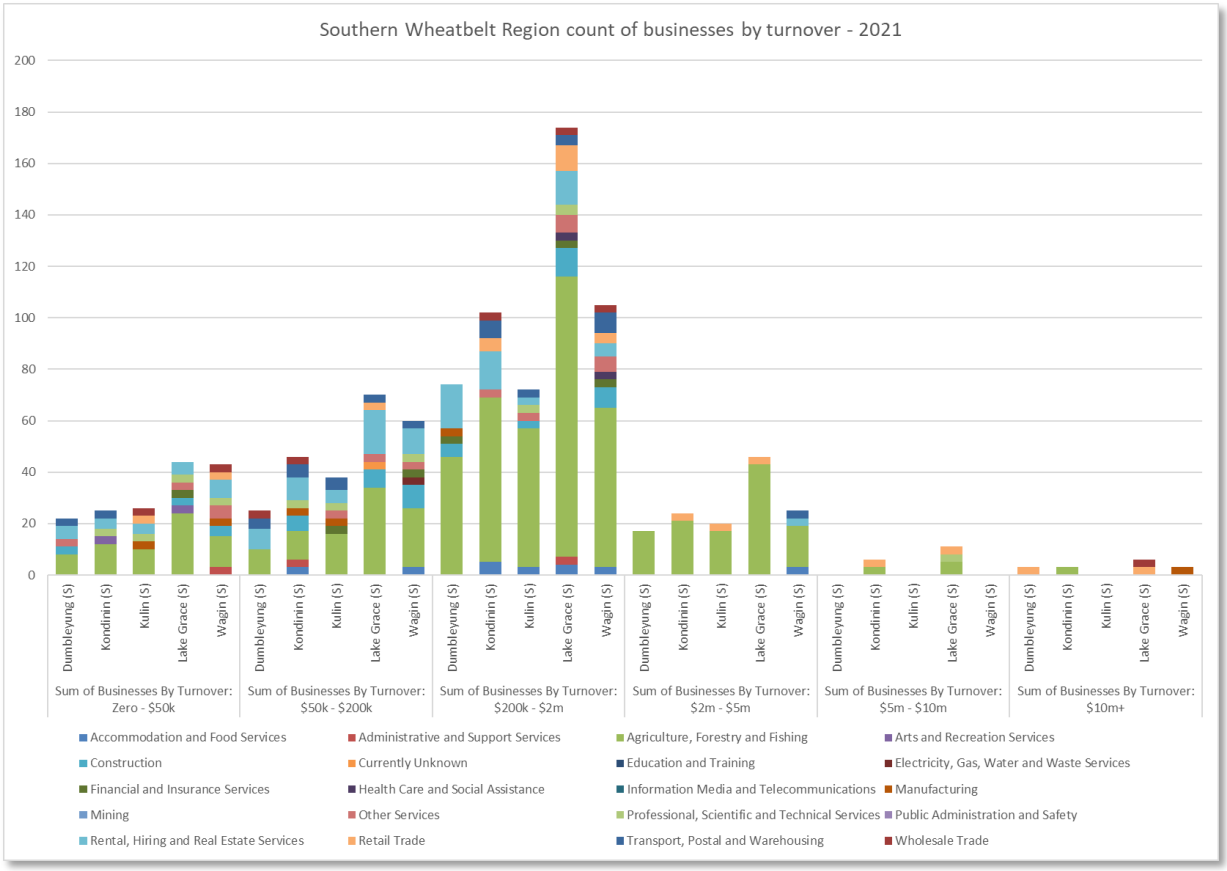

Figure 13 The number and type of businesses by turnover in the Southern Wheatbelt region and by Shire.

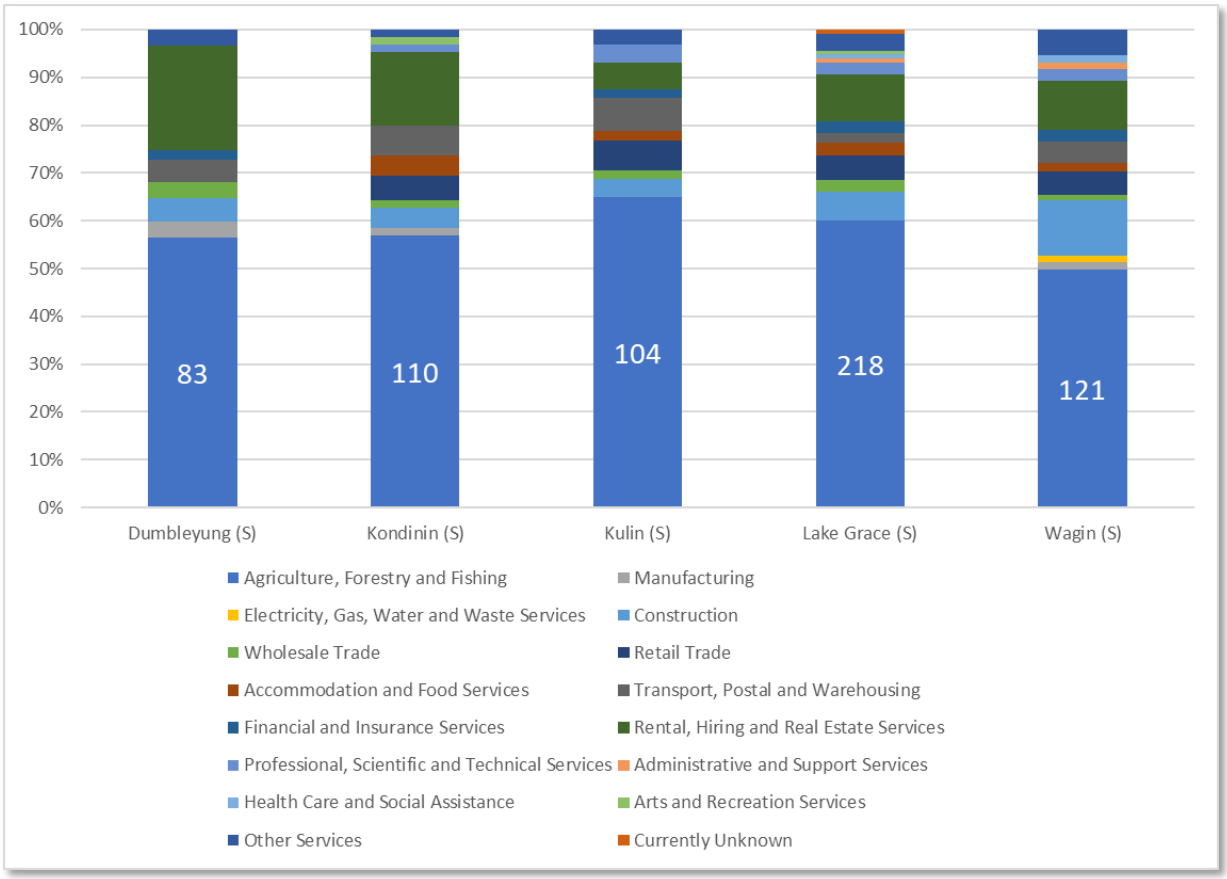

Figure 14 Number and type of businesses by Shire

The Curtin Bankwest Economic Centre identified Southern Wheatbelt industries of grain sheep and grain beef cattle farming as comparative strengths in the Wheatbelt, with Nickel ore mining a key industry in terms of comparative advantage [31]. High strategic advantages exist in the allied agricultural supply chain including agricultural machinery and equipment manufacturing and fabricated metal products and wholesaling of agricultural products[31].

2.1.3 Social determinants

Social determinants of health and wellbeing include socio-economic position, early life circumstances, social exclusion, social capital, employment and work, housing, welfare policies and the residential environment [32]. Between one third and one half of the differences in life expectancy are explained by differences in the social determinants of health [33]. Over the period 2001 to 2010, occupational groups with the highest rates of suicide in Australia were labourers, farmers, machine operators and technical and trade workers[27].

The Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) Socio-economic Index for Areas (SEIFA) score, which measures both advantage and disadvantage, show that the Shires of Wagin, Dumbleyung and Kondinin have more disadvantage than greater regional WA and WA, and the Shires of Kulin and Lake Grace have more advantage [34].

The Dropping off the Edge [35] index ranks locations from 1 to 5 across 37 indicators, with 1 the highest disadvantage and 5 the least. It uses SA2 boundaries which are different to local government areas, however it can give a useful macro view of issues.

The region had scores from 2-3, indicating high disadvantage and highlighting areas of vulnerability across the area including low family incomes, no internet at home, juvenile convictions, prison admissions, air quality and heat vulnerability (days over 38 degrees).

The full report on the population demographics, drought risk characteristics and strategic priorities for each participating local government authority is available on request – see Section 10.

2.1.4 Landscapes and natural resources

The landscape of the Southern Wheatbelt is diverse, from medium to high rainfall and more dissected landscapes in the west, to flatter landscapes, with extensive salt lake chains, dotted with granite exposures towards the east [36].

The region falls into two major catchment areas, the Blackwood and the Lockhart. The Blackwood Catchment drains towards the south west, downstream from Lake Dumbleyung. The Lakes sub-catchment of the Lockhart Catchment, in the Avon River Basin, drains to the north west.

The region forms part of the Great Plateau of WA, an ancient landform that has weathered variably to give way to its current gently undulating form with low-relief uplands and flat bottomed valleys. Remnant vegetation is fragmented across the landscape, with medium and open woodland and mallee scrub. Saline valley floors areas are dominated by succulent steppe vegetation such as saltbush, bluebush and samphire.

Soils vary across the region, though are primarily shallow sandy duplexes with low fertility. The region uses a mix of distantly derived potable and locally derived non-

potable water sources. These resources support the use of the land for broadacre cropping and livestock (sheep and cattle) across the region.

There is opportunity to utilise the regions abundant solar, wind and biomass resources for in situ bioenergy production.

2.2 Impact of Drought in the Southern Wheatbelt

Drought impacts can be significant and wide ranging, and impact regions, industries and communities economic, social and environmental functioning. Several studies rank drought first amongst natural hazards in terms of the seriousness of impacts, including loss of life and livelihoods, economic losses and adverse social, economic and ecological effects [37].

Reduction in household income, financial hardship and a drop in financial position are three major economic impacts experienced by those in drought across Australia [38]. Broader economic impacts on regional communities include job losses, worker relocation and a reduction in income for small local businesses, particularly in small towns with economies highly dependent on farm expenditure[22].

Environmental impacts of drought include irreversible damage to soil and vegetation, leading to dust storms and a loss of top soil, soil nutrients, organic matter and soil carbon [39, 40]. Social impacts of drought can be devastating and include permanent loss of services in regional areas, loss of employment opportunities, negative physical and mental health impacts and financial hardship [22, 41, 42]. Drought adds more weight to the existing personal and professional burdens of regional communities such as poor health, isolation and limited access to services and infrastructure [43, 44]. Drought resilience is strongly influenced by regional characteristics including wealth, infrastructure, policies and plans, the level of community cohesion and the extent to which regional economies depend directly on agriculture and/or water [45, 46, 47].

2.2.1 Impacts on water infrastructure

A range of impacts were identified during consultation. Key among these was the impact to on farm and community water supplies, with pressure applied to scheme water supplies provided by the Water Corporation.

Several localities in the region experienced water deficiencies, with deficiency declarations triggering State Government assistance to cart water for emergency use.

In this region, it is observed that water infrastructure is unable to keep up with demand, with the end of scheme pipelines vulnerable to drawdown across the whole system. Farm practices and enterprise mix changes occurred during drought periods, with livestock being sold or agisted due to lack of feed and water. This correlates with increases in cropping area, that requires different quality water.

2.2.2 Impacts on mental health and wellbeing

Mental health pressures are observed particularly in successive dry or damaging event seasons, with people withdrawing from social interaction, impacting on volunteering and philanthropy. The challenges to maintain green spaces in towns and desertification and decline in natural resource condition (soil erosion, water erosion, vegetation decline) adds to the mental health burden associated with drought. Stakeholders commented on the challenges of provision of regular visiting health services in small communities. Rural West has one Rural Financial Counsellor based in the region, who provides important support to farming families.

2.2.3 Business and economic impacts

There has been an observation of a decline in permanent worker populations, partly due to changing business practices (farmers and businesses employing seasonal or casual workers). In dry seasons, the “cheque book goes away”, with the reduction in spending impacting on cash flow to businesses in the region [48].

2.2.4 Impact on agricultural sector

The agriculture sector across the region have made major changes to their farm management practices to limit the impacts of drought on their businesses [49, 50]. These include managing their debt, accessing farm management and business support, de-stocking early and / or permanently, improving soil condition to influence water retention capability, increasing on-farm water storage and optimising pesticide and fertiliser use to assist with reducing costs.

They have a good track record in terms of capacity to adapt and respond to risks, with increasing levels of grain production occurring despite reduced growing season rainfall. There are still areas for further investigation to enable continued productive capacity and profitability in the face of a drying climate. The targeting and extension of research and development of climate resilient farming systems is considered essential. The South West Western Australia Drought Hub (the Hub) is actively working with Grower Groups and their consortia partners to develop and enhance to uptake of farmer-centred drought innovation and adoption practices in the region [51]. A draft situational analysis has identified a drop in growing season rainfall, a later traditional “break of season”, and increased warming during grain filling since the year 2000. The reduced frequency of intense rainfall events (10mm to 20mm) means many of the Wheatbelt’s 200,000 dams, designed to capture rainfall events over 10mm are not as reliable as they once were.

The Wheatbelt Regional Advisory Committee (RAC) has identified on-farm water supplies and efficiency gains in cropping and livestock systems as essential in coping with projected reductions in rainfall and temperature increases [52].

LA One’s Economic and Environmental Impact assessment technical supports provide further information on economic and environmental impact. This report is available on request. See Section 10.

2.2.5 Building resilience to drought in the region

Southern Wheatbelt stakeholders identified gaps in past drought responses that could be addressed through future drought resilience building activities. The number one priority for these communities is increasing their confidence in available water systems to ride out at least two successive drought years. This would ensure agricultural businesses can continue to function, through direct access to water and to enable critical road maintenance, to be undertaken. It would also maintain amenity of community spaces to support social wellbeing.

Supporting the diversification of the economy through encouraging business development in the region was also considered important in enhancing economic and community resilience.

Gaps in past drought responses were identified, including a need for drought relief systems (financial assistance to drought affected families and businesses) that are more understandable, easier to access and quicker to mobilise during drought. Opportunities to enhance drought response included well-informed farm business

planning, earlier identification of drought impacts and interventions to support community groups and local governments, and continued investment in research and development into farming practices to maximise drought resilience. Stakeholders called for an improved definition of drought, more relevant to regional farming systems and the local climate, as well as for improvements in long-range weather forecasting to support decision-making.

3. Institutional & Policy Context

Crisis management and financial assistance policies focused on drought response and recovery are commonly used around the world and have largely been assessed as ineffective. Drought relief packages are a source of tension, typically viewed by recipients as 'too little, too late' or as over-complicated and difficult to access. Measures that promote self-reliance and preparedness are preferred by farmers, industry and government agencies. Globally, and in Australia, policies have shifted towards developing early warning systems and proactive risk management strategies that build resilience to drought (Figure 15) [53, 54, 55].

Under the current National Drought Agreement[35], the role of states and territories includes:

- Encouraging the delivery and uptake of programs to improve farm businesses' skills and decision-making; and
- Ensuring animal welfare and land management issues are managed during drought

The Commonwealth, states and territories also have several shared roles and responsibilities:

- Drought preparedness, response and recovery programs;
- Capability building programs;
- Tools and technologies;
- Rural financial counselling services;
- Health and wellbeing support;
- Sharing relevant drought policy information;
- Making available drought assistance information;
- Contributing to the development of quality data; and
- Having input into drought policy and programs.

The Drought Response, Resilience and Preparedness Plan [56] describes the Australian Government's strategies for helping farming communities prepare for and manage drought and has three key focus areas:

- Immediate action for those in drought;
- Support for the wider communities affected by drought; and
- Long term resilience and preparedness.

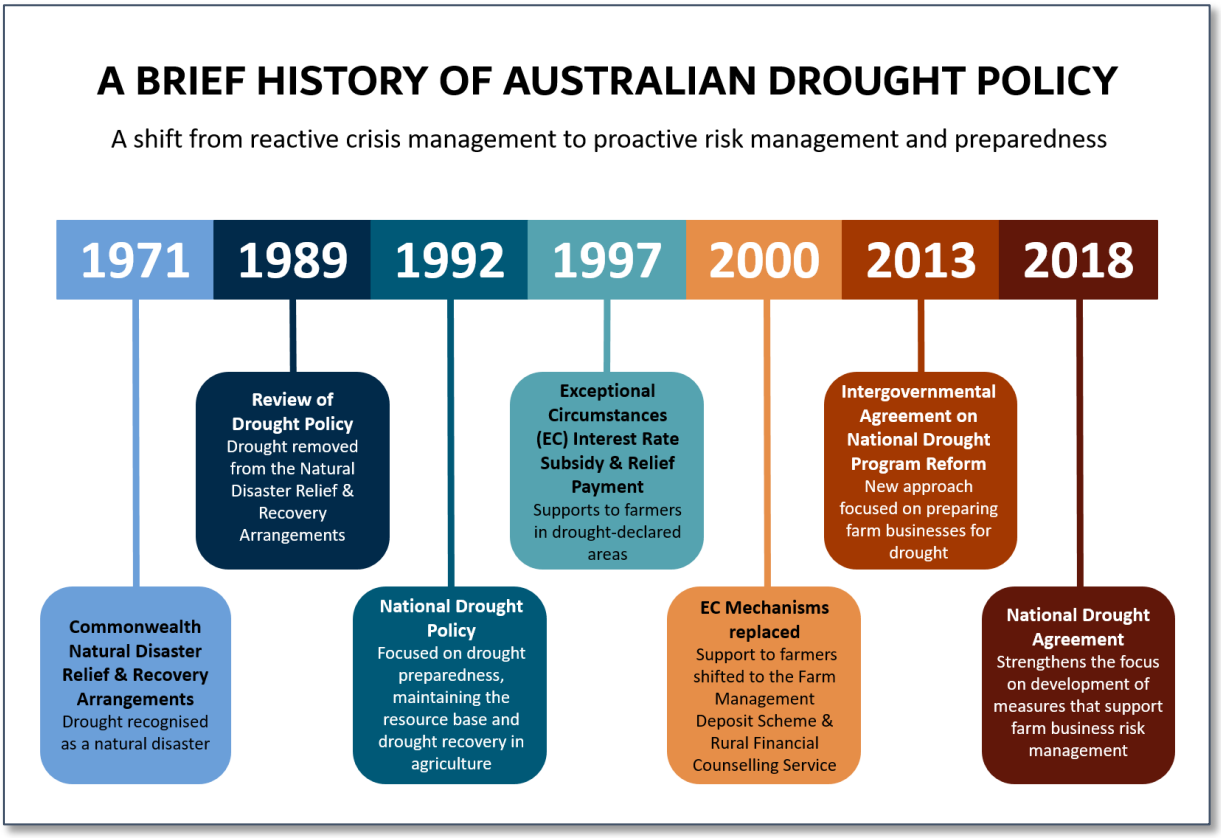

Figure 15: A brief history of the evolution of drought policy in Australia

Many international, national and local agencies are involved in drought research, preparedness, response and recovery. These agencies undertake programs to support communities to plan and prepare for, respond effectively to and recover from drought.

The most directly relevant agencies and programs related to building drought resilience in the Southern Wheatbelt are outlined in Table 2:

Table 1:Organisations and programs with an interest in Drought resilience

[57]Actor	Scale
Australian Export Grains Innovation Centre (AEGIC)	National
Australian Institute for Disaster Resilience (AIDR)	National
Australian Red Cross	National
Australian Research Council (ARC)	National
Australian Wool Innovation	National
Bureau of Meteorology (BoM)	National
Centre for Australian Weather and Climate Research (CAWCR)	National
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	National
Curtin University Centre for Crop and Disease Management	National
Department of Agriculture, Water and the Environment (DAWE)	National
Grains Research and Development Corporation (GRDC)	National
Meat and Livestock Australia (MLA)	National
Monash University Climate Works Australia; Monash Sustainable Development Institute; Monash Climate Change Communication Research Hub	National
National Climate Change Adaptation Research Facility (NCCARF)	National
National Drought and North Queensland Flood Response and Recovery Agency (NDNQFRRA)	National
National Recovery and Resilience Agency	National

Natural Resource Management Regions Australia (NRMA)	National
Regional Development Australia (RDA)	National
Drought Research and Adoption Innovation Hubs (RAIH)	National
The Australian Research Council's Centre of Excellence for Climate System Science (CECSS)	National
The Future Farm Industries CRC (Cooperative Research Centre)	National
University of Western Australia Institute of Agriculture; International Centre for Plant Breeding; Centre for Legumes in Mediterranean Agriculture; Centre for Environmental Economics and Policy; Western Australian Centre for Rural Health; Centre for Social Impacts	National
Murdoch University Harry Butler Institute	State
Australian Association of Agricultural Consultants WA	State
Department of Biodiversity, Conservation and Attractions (DBCA)	State
Department of Planning, Lands and Heritage (DPLH)	State
Department of Primary Industries and Regional Development (DPIRD)	State
Department of Water and Environmental Regulation (DWER)	State
Edith Cowan University Centre for Ecosystem Management; Climate Initiative Taskforce	State
Grain Industry Association of Western Australia (GIWA)	State
Grower Group Alliance (GGA)	State
Pastoralists and Graziers Association	State
Regional Men's Health Initiative	State
Rural Business Development Corporation	State
Rural West	State
Sheep Alliance of Western Australia	State
South West WA Adoption and Innovation Hub	State
State NRM	State
Water Corporation	State
Western Australian (WA) Farmers Federation	State
WA Landcare Network	State
WA No-Tillage Farmers Association	State
WA Biodiversity Science Institute (WABSI)	State
Wheatbelt Development Commission (WDC)	State
Wheatbelt Natural Resource Management Inc (WNRM)	Local
Central Regional TAFE	Local
Corrigin Farm Improvement Group	Local
Dumbleyung Land Conservation District Committee	Local
Facey Group	Local
Lakes Information and Farming Technology	Local
Holt Rock Production Group	Local
Women in Farming	Local
Wagin Woodanilling Landcare Zone (Wagin)	Local
Bugs and Biology (Wagin)	Local
Wheatbelt Integrity Group (Newdegate)	Local
East Wagin Top Crop Group (Wagin)	Local
Rural Edge	State

Programs, including data platform and on-ground assistance with drought planning, preparation, response and recovery of relevance are outlined in Table 3:

Table 2: List of programs and policies related to drought resilience

Program	Scope	Description
ABARES New Insurance Markets	Australia	Research into parametric insurance, where payouts are based on weather conditions rather than damages.
Australian Climate Service – BOM, Geoscience Australia, CSIRO, Australian Bureau of Statistics	Australia	Increasing customer understanding of threats posed by climate change and natural hazards to limit their impacts. ACS Public
Australian Combined Drought Indicator (CDI)	Australia	Drought early warning system based on the US Drought Monitor.
Building Better Regions Fund – Drought Round	Australia	Creating jobs, driving economic growth and building stronger regional communities in drought-affected areas.
Bureau of Meteorology (BoM) Regional Climate Guides	Australia	Climate summaries for each of Australia's 56 Natural Resource Management regions.
BoM Climate Resilience Water Sources	Australia	Information on public and private desalination and water recycling plants across Australia.
BoM Australian Water Resources Assessment; National Water Account; Urban National Performance	Australia	Information on surface water, groundwater and alternative water resources to support policy and planning.
Communities Combating Pests and Weed Impacts During Drought Program	Australia	Grants to help to manage wild dogs and other established pests and weeds during drought.
Community Childcare Fund	Australia	Supports continuity of childcare when services are impacted by extreme events.
Country Women's Association of Australian Drought Grants	Australia	Up to $3,000 to farmers and farming families experiencing hardship due to drought.
DAWE Climate Systems Hub	Australia	Research to advance the understanding of Australia's climate and inform adaptation.
Drought Community Outreach Program – National Resilience and Recovery Agency, Rotary	Australia	Events in drought-affected communities; information about accessing support during drought; $500 household vouchers.
Drought Communities Extension Program	Australia	Economic stimulus in drought-affected areas through infrastructure projects and drought relief e.g., Roads to Recovery.
Drought Communities Small Business Support Program	Australia	Helps drought-affected small regional businesses to understand their financial position, identify options and implement plans to improve their situation.
Drought Community Support Initiative	Australia	Up to $3,000 per household to support farmers, farm workers and contractors who are facing hardship due to drought.
Farm Household Allowance	Australia	Time-limited income support, supplements and case management resources.
FarmHub	Australia	Information on the support available for risk management, farmer assistance and drought.
Foundation for Rural and Regional Renewal Tackling Tough Times Together	Australia	Grants aimed at community-led economic renewal, reducing volunteer fatigue, bolstering local leadership and funding community

		infrastructure
Future Drought Fund	Australia	$5 billion federal fund to resource drought resilience activities. Current programs are: Adoption and Innovation Hubs Drought Innovation Grants Farm Business Resilience Planning Regional Drought Resilience Planning Climate Services for Agriculture Drought Resilience Self-Assessment Tool Drought Resilient Leaders Program Networks to Build Drought Resilience Drought Resilient Soils and Landscapes NRM Drought Resilience Program
Mental and Community Health Program	Australia	ReachOut Connecting the Youth Awareness-raising initiative Empowering our Communities Program Better Access Telehealth Trusted Advocates Mental Health First Aid Program
National Drought Map	Australia	Online interactive tool making data available to improve decision making.
National Environmental Information Infrastructure (NEII) Platform	Australia	Information platform designed to improve access to and re-use of nationally significant environmental data.
National Resilience and Recovery Agency Support Officers	Australia	People located in regional areas to provide support to drought affected communities.
National Water Grid Authority National Water Infrastructure Development Fund	Australia	Funding for construction of water infrastructure projects and feasibility studies.
On-farm Emergency Water Infrastructure Rebate Scheme	Australia	Rebates up to $25,000 for purchase and installation of on-farm water infrastructure.
Red Cross Drought Resilience Program	Australia	Offers psychological first aid and farm first aid training, a mentor program and practical assistance during drought.
Recovery Connect – Service Australia	Australia	A proposed recovery assistance locator application to connect people with drought assistance available in their area.
Regional Investment Corporation Loans	Australia	Concessional drought loans for farmers and drought loans for small businesses.
Rural Financial Counselling Service Program	Australia	Help eligible clients to understand their financial position, identify options and implement plans to improve their situation.
Taxation measures	Australia	Taxation concessions during drought, e.g. Farm Management Deposits Scheme, accelerated depreciation arrangements.
Western Australian Agricultural Research Collaboration	Western Australia	WA collaboration of State, GRDC and research organisations, with focus initially on Grains Transformation, Northern Agriculture and Climate Resilience
Western Australian Climate Science Initiative	Western Australia	Making the latest climate science available for decision-making in WA
Western Australian Farming Systems Project	Western Australia	DPIRD and GRDC collaboration focused on improving farming systems in low and medium rainfall zones of WA

CliMate weather app	Australia	Climate trends and forecasting app climateapp.net.au
DPIRD Climate and Weather Tools	Western Australia	Range on online tools including extreme weather, potential yield tools, rainfall to date, seasonal weather outlook, weather stations Dry season resources | Agriculture and Food
DPIRD Dry Seasons Information Webpage	Western Australia	Updated information on seasonal conditions and resources to support management of the season Dry season resources | Agriculture and Food
Drought Resilience Self-Assessment Tool (DRSAT)	Australia	Online resource to support farmers to assess drought resilience https://www.drsat.com.au/

3.1 Drought Policies, Plans and Priorities

This section outlines the relevant policies and plans, and priorities at a Federal, State, Regional and Local level that can influence drought resilience in the region.

3.1.1 Federal

Drought assistance measures in Western Australia (WA) are guided by the National Drought Agreement[40] and lessons learned from the WA Drought Pilot Programs[58]. The focus is on improving drought preparedness through business training, risk management and improved social support for farming families[59]. Specific assistance measures available in WA currently include farm household payments, farm finance concessional loans, support for farm business training, rural financial counselling, access to farm management deposit schemes and funding for social support.

The Future Drought Fund's suite of programs are targeted at building resilience across social, economic and environmental dimensions. The Drought Resilience, Innovation and Adoption Hub program is focused on supporting uptake of best practice drought resilience research across select regions of Australia, including the South West of WA.

3.1.2 State

The WA Climate Policy[60] outlines the state government's commitment to climate change adaptation and achieving net zero greenhouse gas emissions by 2050. Several climate resilience initiatives are identified as part of this policy, including the Climate Resilience Action Plan 2022-25, Climate Science Initiative, Climate Risk Framework and Pilot Sectoral Adaptation Plans. The Climate Science Initiative is aimed at understanding how future global emissions will affect WA's climate. As part of this initiative, climate projections will be provided along with communications material that support agribusinesses and government with interpreting the projections.

3.1.3 Regional

The Wheatbelt Development Commission's Strategic Plan 2020-2023, identifies the following strategic priorities that are relevant to drought resilience:

- Enabling infrastructure - Goal 1: Advocate for alternative water and energy solutions suitable for the Wheatbelt; Goal 2: Improve digital connectivity across the region;
- Diversify the economic base - Goal 1: Support economic diversification opportunities; Goal 2: Support economic diversification opportunities, facilitate regional collaboration, skills building and shared learning;
- Sustainable landscapes and communities - Goal 1: Facilitate environmental entrepreneurship, build environmental social and economic resilience, facilitate new industry opportunities; and

- Entrepreneurships and innovation: Goal 1: Facilitate future focused economic opportunities to support local entrepreneurs, business leaders and key industries to collaborate and harness innovation [61].

The Regional Investment Blueprint 2015 for the Wheatbelt outlines a range of strategies to achieve an ambitious target of doubling its population by 2050, including key economic insights and evidence-based guidance to support regional investment and decision making. This blueprint highlights key economic opportunities for the Wheatbelt south economy as agriculture, livestock and food supply chains and describes the region has having 'comparative climate resilience.' [62]

A recent analysis of the Wheatbelt South region (WDC unpublished) identified opportunities to increase diversification of the economy and build economic and community resilience are occurring through:

- Investment into value adding of agricultural produce;
- businesses pivoting to service both the mining and agriculture sectors; and
- the growth of the population services sector across the region.

There is also opportunity to capture opportunities that decarbonisation of the economy present, with growing interest and investment in renewable energy and biofuels projects, and large scale carbon farming plantings.

The Wheatbelt South Sub-Regional Economic Strategy 2014 provides an overall strategy for the region's economic development, informing sub-regional and regional land use and strategic planning activities. It identifies the Wheatbelt South as being a diverse economic region with potential growth opportunities in Agriculture, Livestock and Supply Chains, Health and Education, Lifestyle Amenity and Retirement, and Tourism. [63]

In its report Entrepreneurial Innovation in the Wheatbelt (2016), Regional Development Australia Wheatbelt (RDAW) explores the barriers preventing innovation and entrepreneurial growth in the Wheatbelt. The report identifies innovation and entrepreneurialism as key community strengths in the Wheatbelt (with Narrogin and Wandering categorised in the second tier of innovation), this report identifies eastern and southern areas of the Wheatbelt are disadvantaged from an innovation perspective. [64]

RDAW identified the following barriers to businesses achieving entrepreneurial innovation in the Wheatbelt [65] :

- High cost, poor quality and lack of accessibility of internet and mobile;
- High costs of business development including connection power and water supplies;
- Lack of access to funding to support entrepreneurial innovation in the region;
- Lack of training and education for starting a business or about innovation; and
- Lack of skilled labour supplies.

According to Regional Development Australia Wheatbelt's Innovation Report (2016) [66], a restructuring of the agricultural industry, either through consolidation of family farms into larger holdings, or purchase of large scale holdings by corporate interests seeking economies of scale, has contributed to a drop in populations in small agriculturally

dependent communities across the Wheatbelt. The pull of educational employment opportunities beyond rural towns has also contributed to this decline [67].

Wheatbelt Natural Resource Management (WNRM) is an active community-based organisation that aims to 'lead positive change in natural resource management through the creation of respectful partnerships, innovation and community action'.

WNRM's three-year plan for 2021-2024 outlines its priorities (relevant to this report) as soil acidity issues, prevention of further salinity, and land use planning support. Objectives of this plan include:

- Improving the condition of agricultural land;
- Exploring solutions through research and innovation;
- Building resilience to a changing climate;
- Promoting responsible land management across all sectors, and;
- Diversifying income streams. [68]

WNRM's 2020/21 Annual Report identified a key aim to increasing perennial vegetation cover across the Wheatbelt and optimising the Mixed Farming Fodder Systems Project, and the Living Lakes Project that intends to improve water holding capacity and water quality of lake systems across the region. [69]

- WNRM's Sustainable Industries program is focused on:
- Improving soil health;
- Maximising ground cover; and
- Increasing adoption of methods for building soil carbon and improving the biological function of soil [70]

Wheatbelt NRM is a member of the CRC for High Performance Soils and, every two years, it holds a Talkin' Soil Health conference - the largest of its kind in WA. WRNM's Regional Agriculture Landcare Facilitator (RALF) offers access to government services such as grants, information on areas of interest, information on changes in government policy affecting the agriculture industry, information on the latest ideas, trends and practices to improve productivity and sustainability. [71]

3.1.4 Local

Recurring themes emerging from each of the LGA Strategic Community plans (outlined in detail in the Socio-Economic Analysis in Chapter 3) include economic and community sustainability, quality long term water supply, water security, and water holding infrastructure and harvesting.

Anecdotal evidence suggests that farm numbers and on-farm based populations are declining, but regional 'town' populations are not - a gap that warrants further investigation. In terms of farm numbers, South Wheatbelt has experienced a near three-fold decline, falling from 13,106 in 1970 to 4,941 in 2013. [72]

Whilst the number of businesses in most areas has stayed the same or declined over the past five years, this overall decline is small (-2.9%), suggesting a high level of resilience amongst the community despite tough economic and environmental conditions. [73]

Historically, improvement of agricultural efficiencies, including adoption new farming systems has been the dominant strategy in this region for mitigating climate and economic risks.[74] Improvement of water supplies have been explored through programs such as the Rural Towns-Liquid Assets Program in the early 2000s. This program was focused on addressing townsite salinity and researched desalination technology. In 2022, the DPIRD and Grower Group Alliance led WaterSmart Farms initiative is revisiting desalination and on farm water supply improvements opportunities in this region. The Department of Water and Environmental Regulation's Community Water Supply Partnership Program continues to fund non-potable water supply improvements in partnership with local governments across the region.

The Western Australian Local Government Association's Regional Climate Alliance Program is an initiative under the State Government's WA Climate Policy, and is focused on actions on climate change, energy and sustainability through regional partnerships.

4. Climate Data

4.1 Defining Drought

Definitions of drought are restricted to the Western Australian South-West Land Division as rainfall patterns and requirements for the WA rangelands and tropical north are markedly different from those of the focus regions for the RDRP Program.

The term 'drought' refers to a prolonged, abnormally dry period when the amount of available water is insufficient to meet our normal use [75, 76, 77]. It is not simply about low rainfall but refers to how conditions in a given season or year compare to normal conditions [78]. Meteorological definitions focus on rainfall deficiencies, or shortages, compared to average rainfall over a preceding period.

In Western Australia to date, rainfall deficiencies have been determined by comparing annual rainfall over a given year or two with the average annual rainfall [79]. Given the importance of growing season rainfall in April to October for wheat production in the region, we proposed meteorological definitions of drought focused on total rainfall in the April to October wheat growing season:

- **Drought Year**: Total rainfall (mm) during the April to October growing season is in decile 1 (the lowest 10%).
- **Severe Drought**: Total rainfall (mm) during the April to October growing season is in decile 1 for two or more consecutive years.
- **Hot Drought:** Total rainfall (mm) during the April to October growing season is in decile 1 AND daily maximum air temperatures during the August to November maturing season are in decile 9 (the hottest 10%).

Declining rainfall in the grainbelt has resulted in a westward shift in rainfall zones by up to 100 kilometres in some areas [80].

According to the above definitions, drought years occurred in the Southern Wheatbelt in 1980, 2000, 2002, 2006, 2010, 2012, 2015, 2020, with no incidence of severe drought (*Figure 16*). Hot years occurred in 2019 (*Figure 17*), with no hot drought experienced in the region.

Meteorological definitions of drought are useful because they are readily quantifiable and lend themselves well to analyses of historical climate trends and future climate projections. As drought is also defined in terms of its impact on primary production, surface and groundwater levels and regional communities[21, 81, 82, 83], an expanded definition of drought was used for overall communications and analyses in the drought resilience plans:

"The term drought refers to a prolonged period of abnormally dry conditions that impact negatively on water availability and agricultural production in a region and, consequently, impacts negatively on the economy and environment of the region and the health and well-being of its residents."

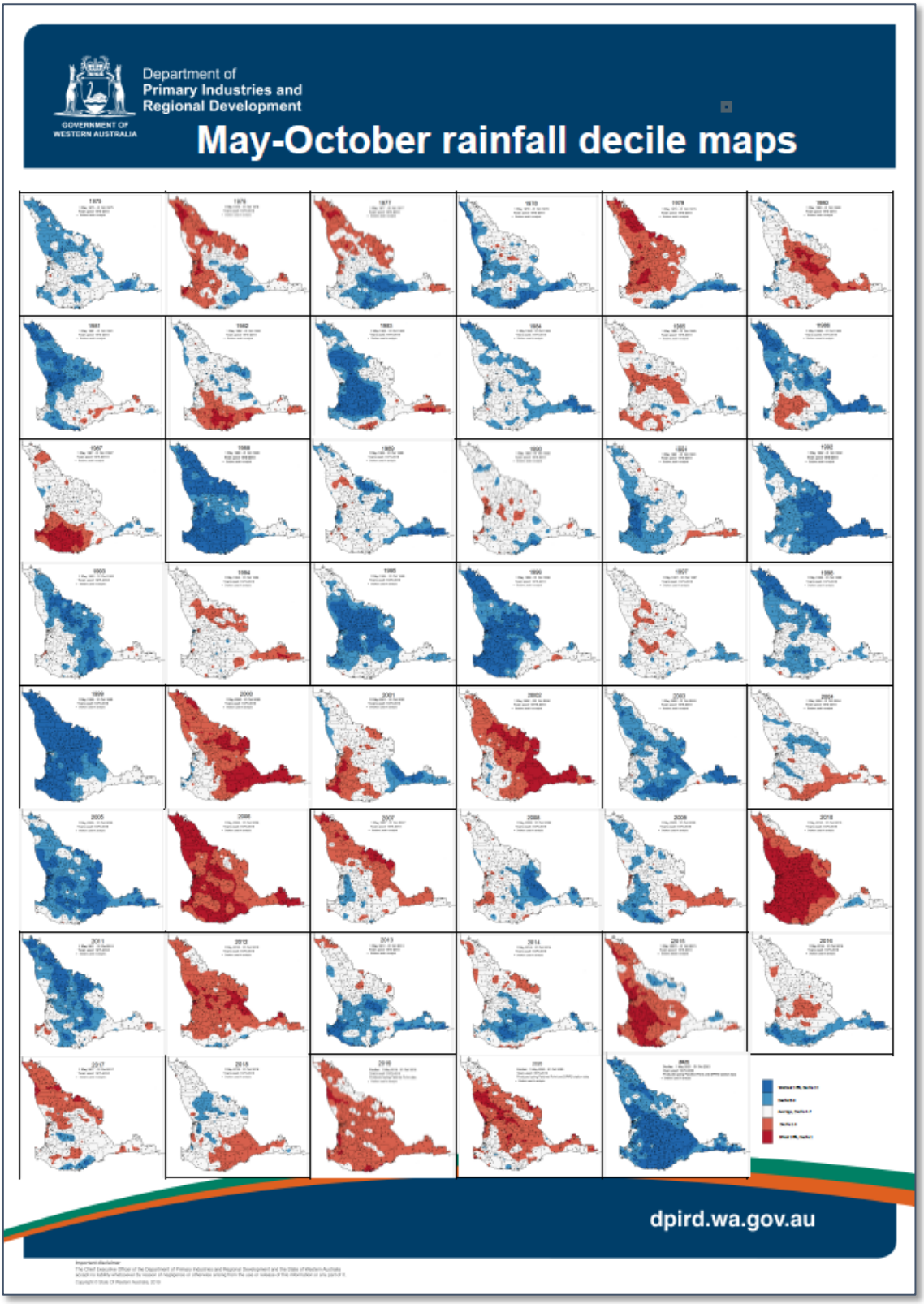

Figure 16: Maps showing rainfall deciles for the May to October wheat growing season each year, with the period 1975-2018 used to calculate average growing season rainfall.

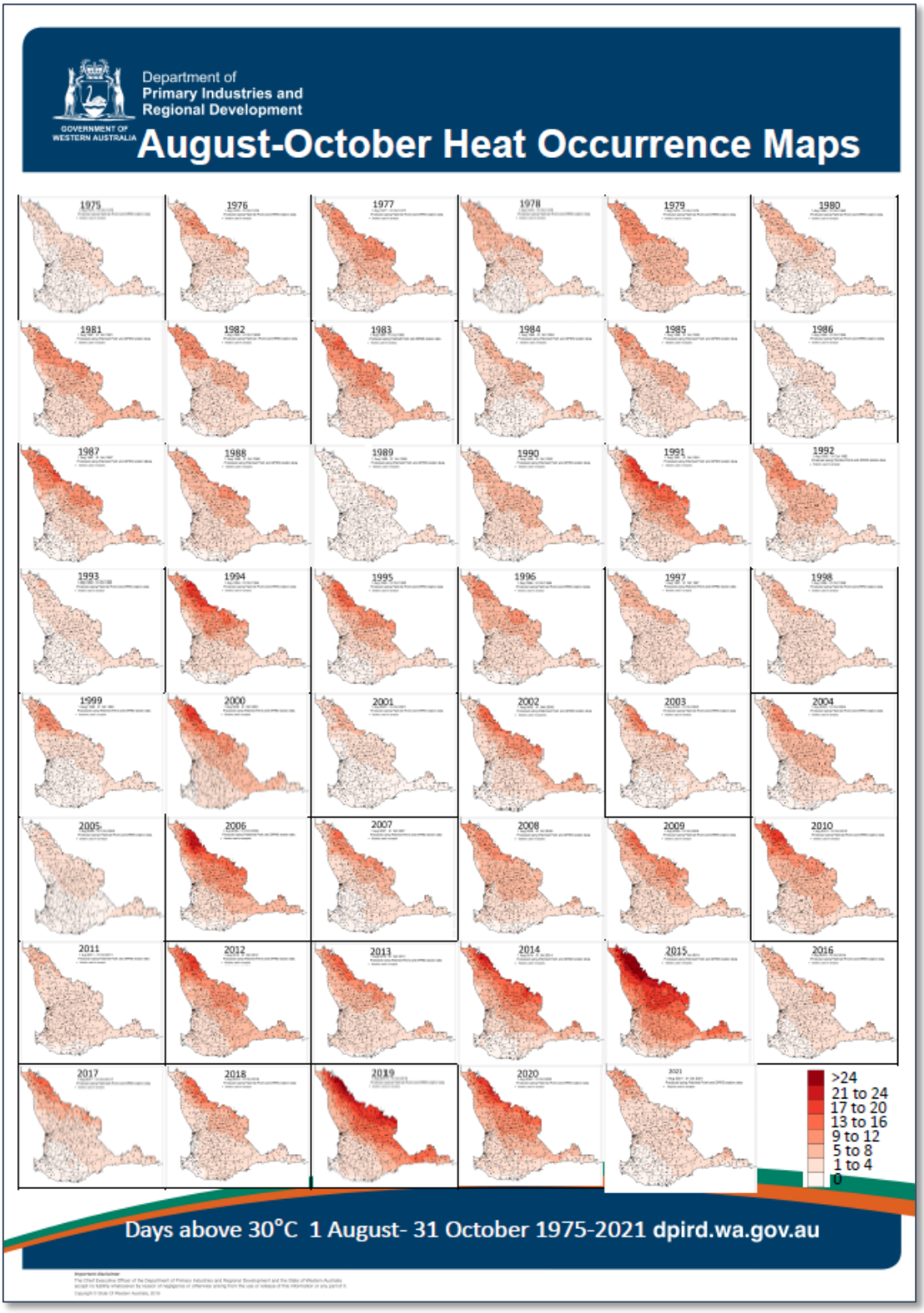

Figure 17: Maps showing the number days above 30°C in August and October, when wheat crops are maturing. The >24 category is equivalent with decile 9.

4.2 Redefining drought for WA

The way that drought is defined has implications for drought policy and, therefore, important consequences for Australian farmers [84]. The need for a regionally-appropriate definition of drought was raised several times during stakeholder consultation for this project.

Curtin University's Centre for Crop and Disease Management was commissioned to compare different definitions of meteorological drought, based on seasonal vs annual rainfall percentiles, and identify which approach to defining drought is most appropriate for the wheat-producing areas of south-west WA. While other methods such as remote sensing are gaining popularity for monitoring drought [85], rainfall percentiles are widely used in Australia [86, 87] and have been adopted by the Australian Bureau of Meteorology, as well as state and federal government agencies, to inform decision-making around drought support programs[75]. Meteorological definitions of drought based on rainfall percentiles were therefore considered suitable for the analyses presented here.

Consultation with farmers and agribusiness indicated that growing season rainfall was most important for their regions, and that most farm businesses are set up to withstand only a single dry season. It was noted that two or more consecutive dry seasons can have severe consequences for their lives and livelihoods, with hot droughts identified an emerging threat with potentially serious consequences [88, 89]. This feedback was incorporated into the drought definitions that were tested (Table 4).

Table 3: Drought definitions tested

	DEFINITION	SOURCE
Annual Drought	Total rainfall (mm) for the calendar year is in decile 1 (lowest 10%).	Based on Australian Bureau of Meteorology rainfall deficiencies. This is how drought is typically defined in Australia and Western Australia now.
Severe Annual Drought	Total rainfall (mm) for the year is in decile 1 (lowest 10%) for two or more consecutive years.	Based on discussions with farmers and agribusiness in the regions, two or more consecutive droughts are considered severe.
Seasonal Drought	Total rainfall (mm) during the April to October growing season is in decile 1 (lowest 10%).	Based on discussions with a 22-member expert Technical Working Group and all regional project advisory groups, growing season rainfall was considered more relevant than annual rainfall.
Severe Seasonal Drought	Total rainfall (mm) during the April to October growing season is in decile 1 (lowest 10%) for two or more consecutive years.	Based on discussions with farmers and agribusiness in the regions, two or more consecutive droughts are considered severe.
Hot Drought	Total rainfall (mm) during the April to October growing season is in decile 1 (lowest 10%) and temperatures (°C) during the August to November maturing season are in decile 9 (highest 10%).	Based on recent studies in the global literature and research that the project team have been involved in, high maturing season temperatures were considered a potentially concerning compounding risk in combination with drought.

Climate data for the analyses were extracted from the Queensland government's SILO Long paddock database [90, 91] for the period 1980 to 2020. This timeframe was selected because Western Australia has experienced a significantly drying climate over the last four decades [92, 93, 94, 95] and calculations of deciles would therefore have been skewed were earlier data included. For each year, climate data are compared against deciles calculated for the full 40-year dataset. For example, if recorded rainfall at a given location for a given year falls below the 1st decile (lowest 10%) as calculated over the 40 included years, that location will be classified as 'in drought' for that year. The frequency of drought events was calculated for 2000-2020 based on percentiles from 1980 to 2020 and for 1980-1999 based on percentiles from 1960 to 1999. Maps and figures to visualise the analyses were created in R version 4.0.4 [96].

Comparing annual drought with seasonal drought shows that a seasonal definition of drought, based on growing season rainfall, may be more suited for the Southern Wheatbelt region than a definition of drought based on annual rainfall (Figure 18). This

is due to the dominance of grain production across the region and reliance on rainfall during the April to October months. In this region, it is acknowledged that rainfall over the summer months is vital in contributing to water supplies for livestock.

Since 2000, droughts have increased in frequency across parts of the region (Figure 19). No hot droughts were recorded in the South West of Western Australia until 2006, but since then pockets of hot drought have been recorded in several years, sometimes over large areas (Figure 20).

This work shows clear and significant differences in the frequency, extent and pattern of drought depending on which definition of drought is applied. While there can be good agreement between definitions (see 2007), it is more common that larger areas would have been recognised as in drought had the seasonal drought definition been applied rather than the annual drought definition (see 2006, 2017). This is because summer rainfall totals, which do not contribute to the bulk of agricultural production in the region, are included in definitions of drought based on annual rainfall and can obscure the fact that growing season was low.

A definition of drought based on rainfall during the growing season is preferred over definitions based on annual rainfall for the Southern Wheatbelt region. A seasonal definition will better represent agricultural drought in the region, where dryland cropping in autumn and winter is the primary land use. More closely representing agricultural drought is important because agriculture makes a significant contribution to the regional economy [97].

The analysis highlights a potentially concerning trend, with the composite hazard of hot drought beginning to occur in recent years. Combined high temperatures and low rainfall can be devastating for the environment and societies[82,83] and are likely to occur more frequently and over larger areas in future given global climate trends [98]. Appropriate steps must be taken to anticipate and mitigate the potentially devastating effects of hot droughts.

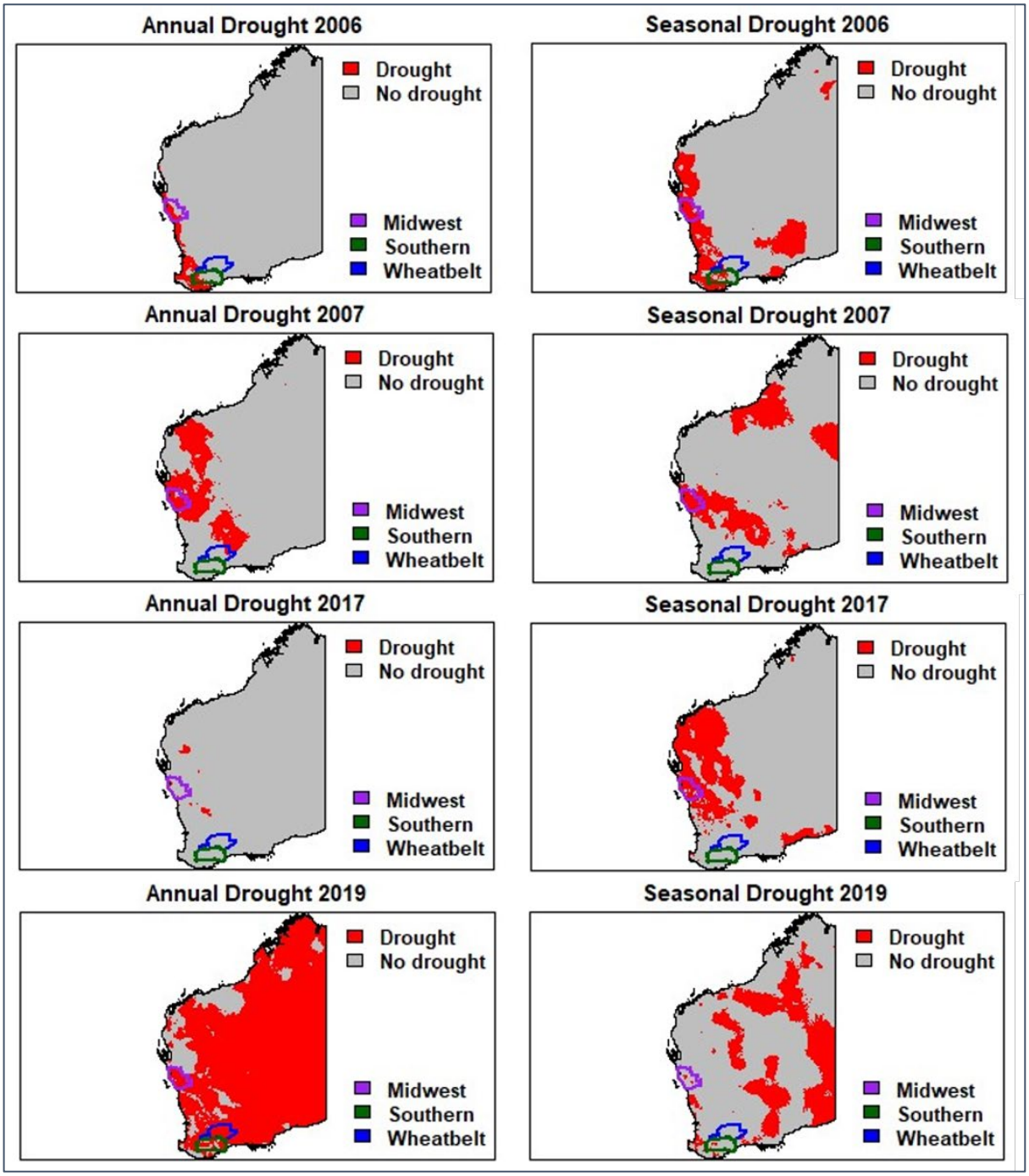

Figure 18: Comparison of the spatial extent of drought when using a definition of drought based on total annual rainfall (Annual Drought, maps on the left) and a definition of drought based on growing season rainfall (Seasonal Drought, maps on the right)

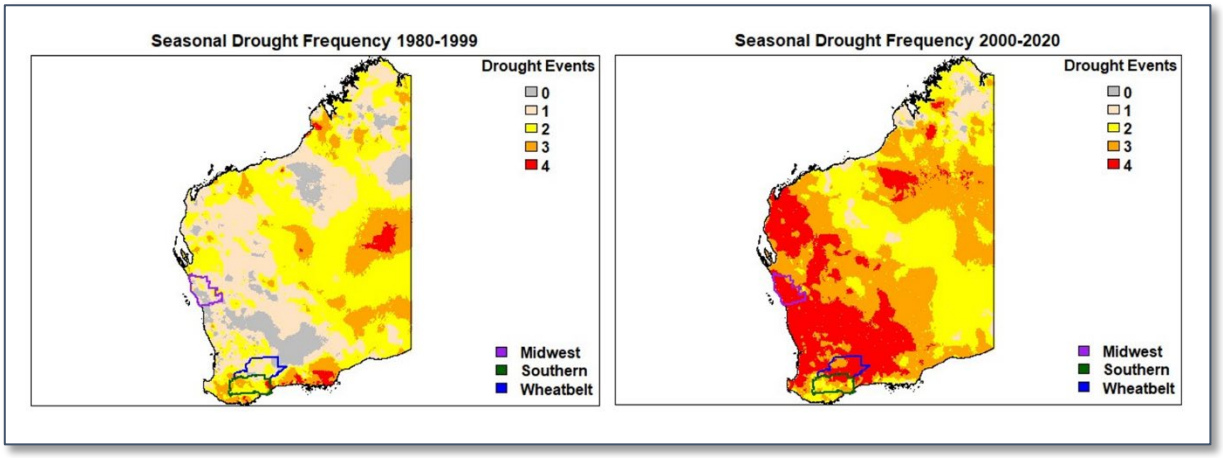

Figure 19: The frequency of seasonal drought for the period between 1980 and 1999 (left) and between 2000-and 2020 (right) for WA.

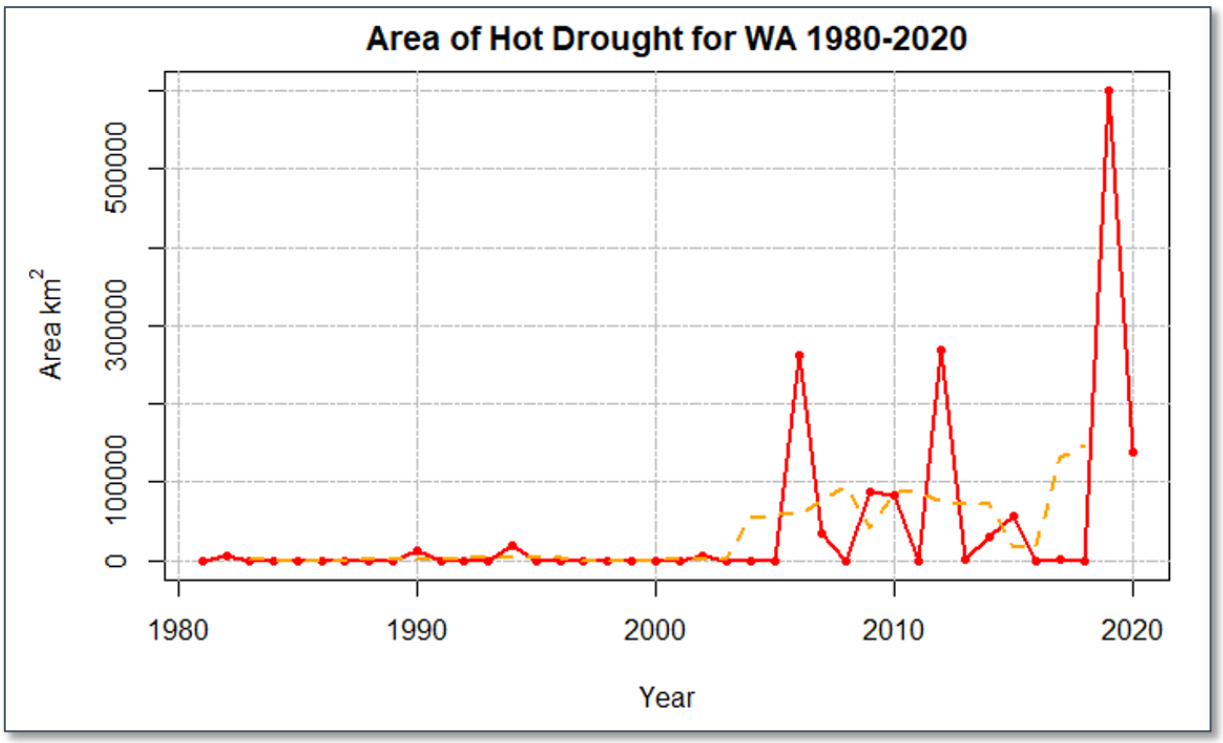

Figure 20: Area (km²) of hot drought across Western Australia for the study period (solid red line), including a five-year running average (dashed orange line).

A copy of the *Defining Drought for Western Australia* report is available on request. See Section 10.

4.3 Historical Drought

The Southern Wheatbelt region has a Mediterranean climate, with warm dry summers and cool wet winters. Mean monthly maximum temperatures in Wagin are ~31°C in summer (January) and ~15°C in winter (July) in Wagin. Further inland Kondinin experiences mean monthly maximum temperatures of ~34°C in summer (January) and ~17°C in winter (July)[99]. Hot days are increasing.

Annual rainfalls in the region range from 400mm in Wagin on the western edge of the region, with 350mm in Dumbleyung, and 330mm in Kondinin, Kulin and Lake Grace.

Hyden and Newdegate, on the eastern edge of the region, have average rainfalls of 350mm and 370mm, respectively. Rainfall has decreased in the autumn months and increased in spring, with winter rainfall generally reliable and summer rainfall less so [100].

This rainfall supports broadacre agriculture (livestock and cropping) across the region. Winter rainfall is generally reliable, with ~40 mm difference from one year to the next. The autumn break (defined as at least 25 mm of rainfall over three days, prior to the commencement of sowing) can occur anywhere between mid-May to mid-June. In some cases, there is no break in eastern areas of the region [101].

In Australia, average temperatures have increased by 1.4°C since 1910 leading to an increase in the frequency and severity of extreme heat events and heat waves [102]. In recent years, the average number of hot days (daily maximum air temperature > 34°C) during the wheat maturing season per year has increased by almost 25%[21] (*Figure 21*). The years 2015 and 2019 were the hottest on record[22].

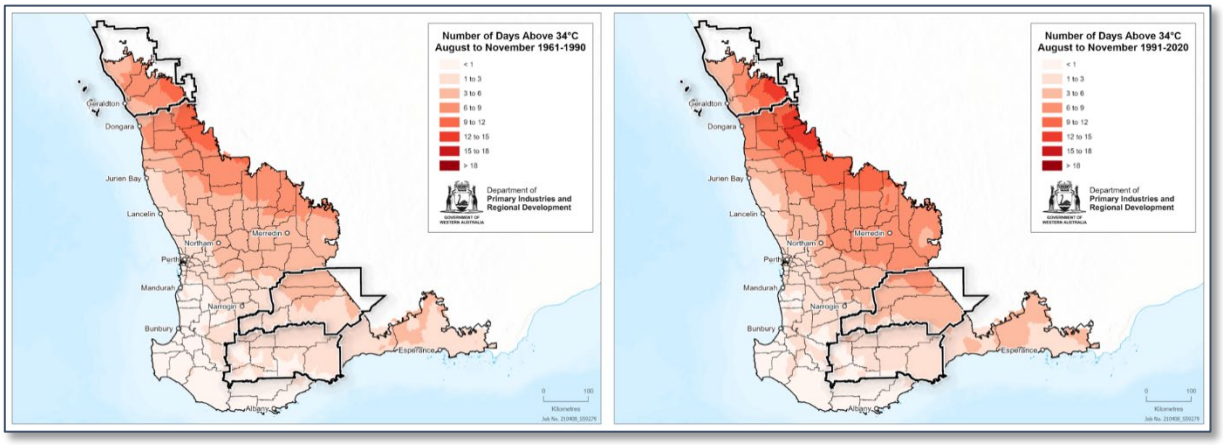

Figure 21: Maps showing the number of hot days during the wheat maturing season from August to November for the period 1961-1990 (left) compared with the period 1991-2020 (right).

There has been a prolonged period of extensive drying in the region since the 1970s [103] (*Figure 22*). In the last 30 years, autumn and early winter rainfall has decreased by around 20% and average annual rainfall has decreased by 8% when compared to the previous 30 years. Dry years (lowest 30% within the range of natural variability) have occurred 12 times and wet years (highest 30%) four times, compared to nine dry years and eight wet years during the previous 30-year period. Winter rainfall over the period 2000 to 2020 is the lowest on record[23].

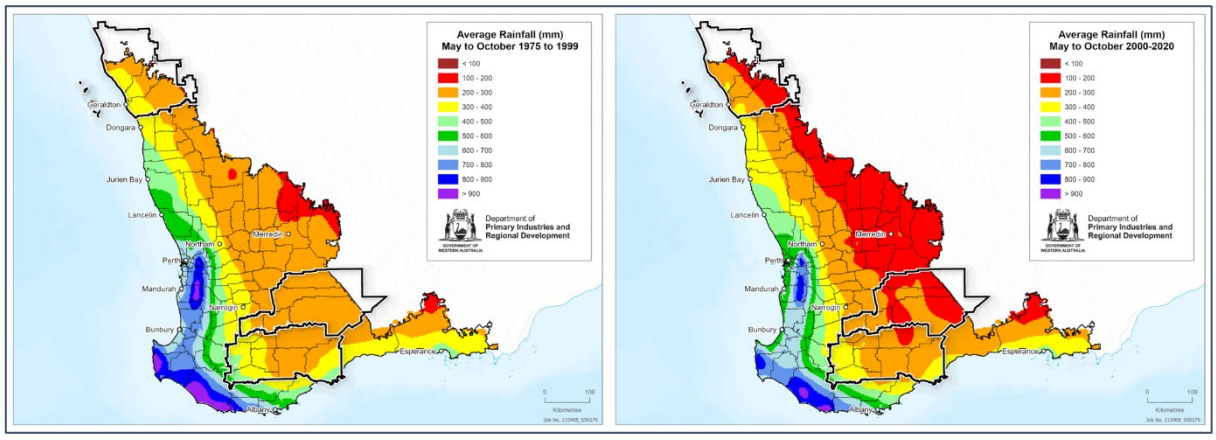

Figure 22: Maps showing average rainfall during the wheat growing season from May to October for the period 1975-1999 (left) compared with the period 2000-2020 (right).

Across the entire region, the autumn break now occurs up to 3 weeks later than it did in the previous 30-year period (*Figure 23*).

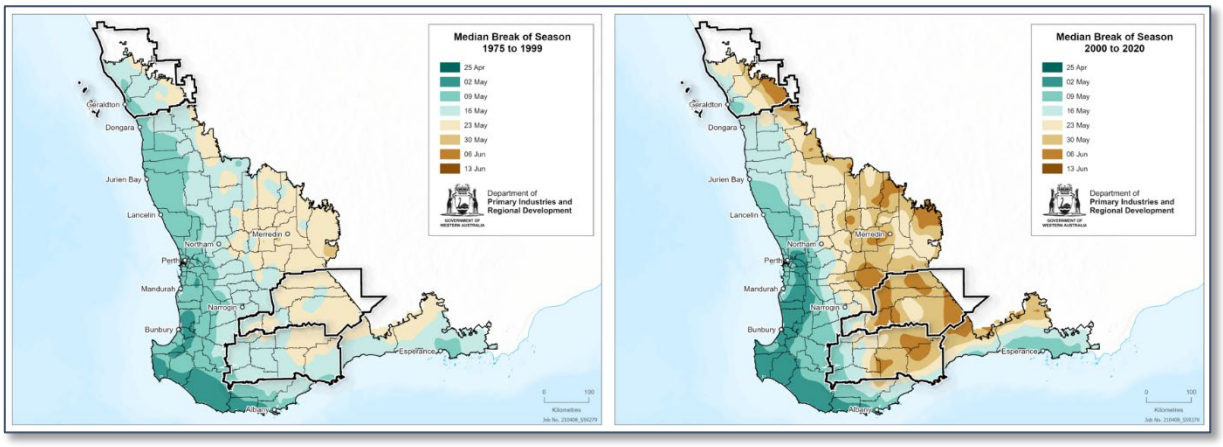

Figure 23: Maps showing the timing of the autumn break when at least 25 mm of rainfall occurs over three days prior to commencement of sowing for the period 1975-1999 (left) compared with the period 2000-2020 (right).

4.4 Future Drought

By 2030, annual average temperatures across all emissions scenarios are expected to increase by a further 0.5 to 1.2°C above the 1986-2005 climate [104, 105]. Towards the end of the century (2090), temperatures are projected to be 2.6 to 4.2°C warmer than they are now on average under a high emissions scenario, and 1.1 to 2.1°C warmer under intermediate emissions scenarios. Accordingly, the number of hot days (daily maximum air temperature > 34°C) during the wheat maturing season is expected to continue to increase (*Figure 24*).

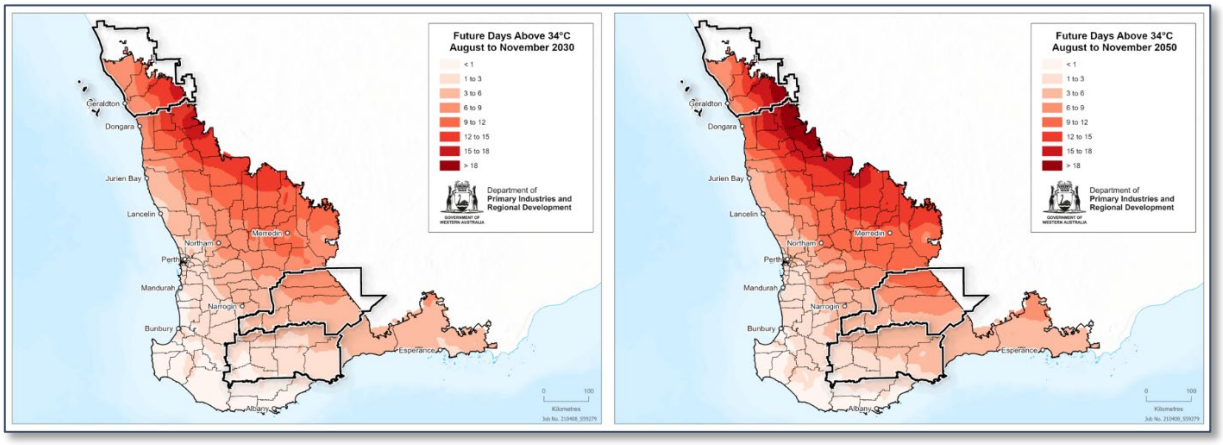

Figure 24: Maps showing the projected number of hot days during the wheat maturing season from August to November by 2030 (left) and by 2050 (right).

Winter and spring (growing season) rainfall is very likely to continue to decrease across the region in future as climate change progresses (*Figure 25*). The time spent in meteorological drought, where conditions are significantly drier than the average over the preceding 30 years, will increase over the course of the century and across the region.

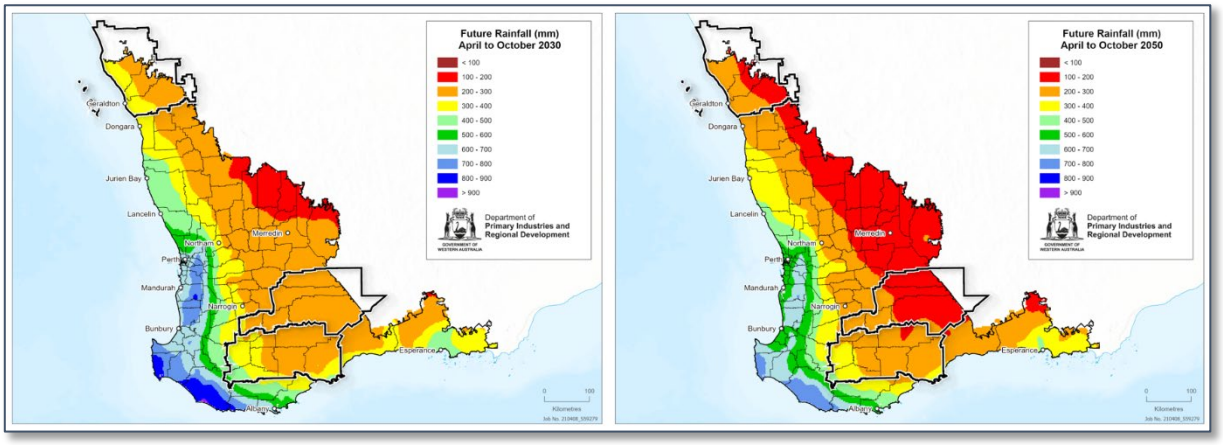

Figure 25: Maps showing the projected rainfall during the wheat growing season from April to October by 2030 (left) and by 2050 (right).

4.5 Impacts of Drought

Crop and livestock farms in the region will be adversely affected by climate change [106, 107]. Climate change will give rise to an increased number of adverse seasonal conditions and result in poorer production and reduced profitability over time. Projected increases in extreme events such as droughts and floods could also trigger increases in insect outbreaks and weed prevalence as the climate becomes more inhospitable for native vegetation and the competitive advantage of weeds increases.

Broadacre crop and pasture production may also decline in drier, warmer northern and eastern areas. Average potential yield (t/ha) has declined across the Southern Wheatbelt region because of declining temperature and increased evapotranspiration (*Figure 26*). The amount of water available for industry and community purposes will be affected by reduced surface water flows into farm dams and community waters supplies [108].

Livestock welfare risks may increase if higher temperatures reduce the availability of feed and increase heat stress prevalence. Higher temperatures can also affect livestock productivity by reducing reproductive rates, growth rates and milk production[29].

While water erosion and salinisation may reduce due to declining rainfall, wind erosion may increase in regions as declining rainfall limits groundcover.

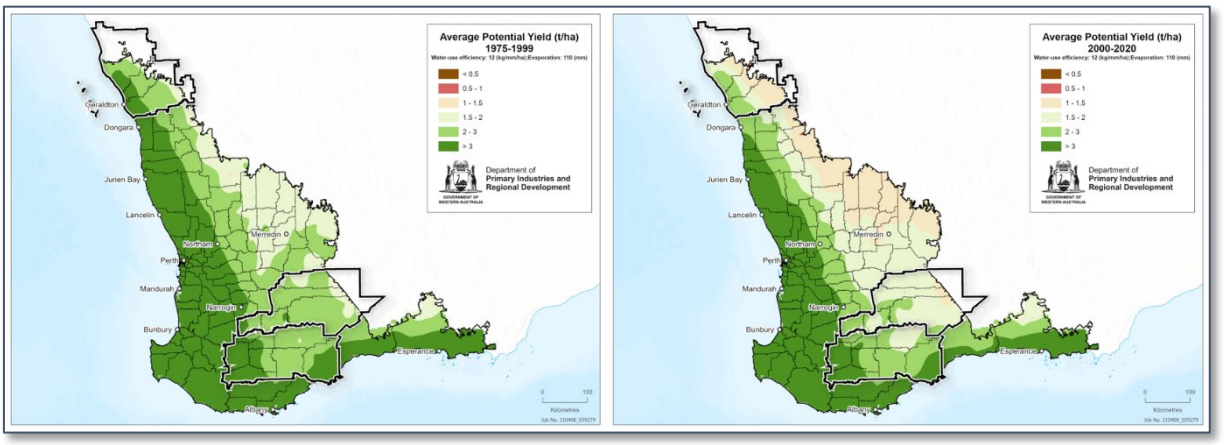

Figure 26: Maps showing average potential wheat yield in tonnes per hectare for the period 1975-1999 (left) compared with the period 2000-2020 (right).

5. Drought Impacts

The below is a summary of drought impact across the region. More detailed analysis is provided in Sections

5.1 Economic Impacts of Drought

The economic impacts of drought extend beyond the farm gate, due to the inter-relatedness of farming businesses, agricultural supply chain businesses and support services, non-agricultural businesses in agriculturally dependent communities.

See Section 2.1.2 for an overview of the Southern Wheatbelt economy.

5.1.1 Review of Economic Impacts of Drought

The dominance of agriculture and exposure of agriculture to drought, could mean that droughts impact negatively on the economic and social well-being of these communities. Due to the seriousness of economic impacts of drought, the project team commissioned LA One Economics & Consulting Pty Ltd to conduct a review the available literature.

Agriculture is a key driver of the economy in the region, and as drought has a direct biophysical impact on production of crops and livestock, due to reduced available water and higher temperatures, it has a collective adverse impact on the total economic output of the region attributed to agriculture. As the Southern Wheatbelt has a collective value of $466 million, this impact could be significant.

Southern Wheatbelt stakeholders report experiencing financial stress because of failed production during drought. Farming families sell or euthanise livestock, liquidate assets or increase their debt to survive. It should be noted some farmers do benefit from drought, through increases in farm size and becoming more crop dominant, increasing their wealth over time [109].

Unexpectedly, farm business with higher incomes are generally considered less vulnerable to drought. Anderton [110] suggests that turnover of more than $600,000 is required to be viable, with $1 million turnover preferred to support a family. In this region, the majority of agricultural businesses turnover less than $2m per year, indicating a potentially higher level of resilience.

Stakeholders noted that the lessons learnt over time from dealing with dry seasons, adoption of new practice and improved business management, including use of farm management deposits, have mitigated impacts for some, smoothing weather influenced income variability. Non-farming families experience reduced throughout of business, reduced employment opportunities, inability to retain staff and reduced cash flows.

Small and Medium Enterprises (SMEs) considered most vulnerable to drought are those with short term planning and narrow focus; less skills in management; fewer resources; limited market share and a conservative approach to risk management. Those with direct links to rainfall, such as those servicing the agricultural industry are particularly exposed.

5.1.2 Impact on the agriculture sector

The most obvious economic impact of drought is on the volume of agricultural production, particularly crops. Crop production typically falls sharply during a drought.

Figure 27 illustrates how WA wheat production fluctuates between years 2002 to 2021, showing significant impacts on production in the dry years of 2002, 2006, 2010 and 2019.

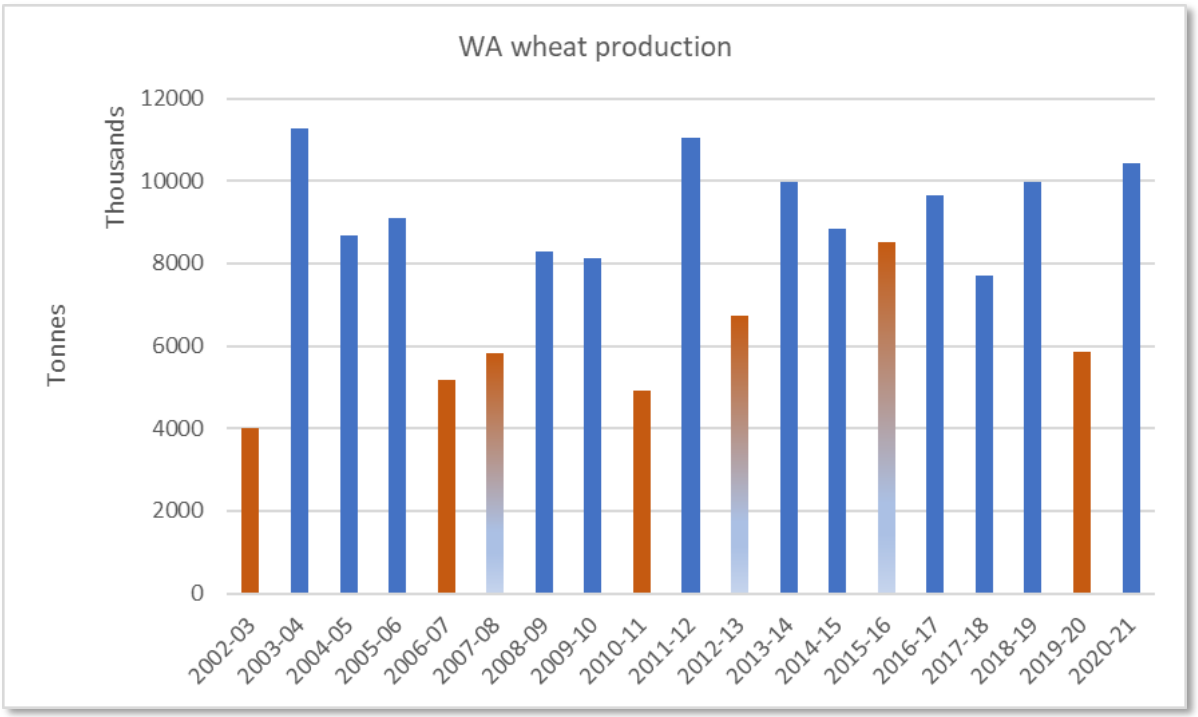

Figure 27 WA Wheat Production 2002-2021

The impact of drought on livestock products (meat and wool) is a little more complicated. Once drought conditions have become sufficiently established, livestock producers will seek to reduce their herds or flocks, resulting in a temporary increase in the recorded volume of meat production. When the drought breaks, recorded meat production typically falls as graziers focus on rebuilding their herds[111]. In 2019-2020, 1.36 million sheep were transported to Eastern Australia to support flock rebuilding and to meet market demands.

Meat processors experience tight margins during dry periods, with smaller processors struggling to remain open. Hermann[112] sums up the processing game as a “cents and pennies game” with throughput the key economic driver. Economies of scale are vital for efficiency so the variability in seasonal supply of lamb for small processors with intermitent supply creates difficulties, especially maintaining or accessing a workforce. Most processors in WA have a winter break, when supply is low for maintenance shut down.

WA is reliant on three main processors, Fletcher’s at Narrikup, Western Australian Meat Marketing Co-Operative (WAMMCO) in Katanning and V & V Walsh in Bunbury. If any one of these processors were to close the reduction in buyers competing in the marketplace will create a downward pressure on prices. WA saleyard prices lag Eastern State saleyard prices due less competition between buyers, with the difference as high as 200 cents per kg at times. During these periods trade flows from WA to South Australia increase, usually when the price gap is more than 50 cents per kg or greater, and when the price difference is greater than the cost of freight[112].

If the processing sector in WA were to contract, farm gate sheep enterprise profitability will be negatively impacted, potentially decreasing sheep numbers further creating pressure on processors. Droughts are intermittent and most processors have the

flexibility to manage the decrease in supply. Processors implement strategies to manage short-term shortages of supply including winter shutdowns, reducing number of shifts in a week and improving technology to reduce labour shortages. They can also increase operations rapidly subject to labour availability.

The impacts of drought are often highly farm specific [113]. Financial ramifications can change year to year, with impacts varying from business to business [114]. Identifying the real impact of drought conditions can be difficult using aggregated data, which masks the volatility of individual farm incomes. Nonetheless, long term studies have shown that most farm businesses are wealthier, despite the incidence of drought.

Compromised production has large effects on household income, which can lead to long-term financial hardship, deterioration in household financial positions and knock-on effects on employment in regional areas [115, 116]. When farm operating surplus is impacted by drought, farm businesses are challenged to meet all financial commitments, using equity, increasing debt or seeking off-farm income to meet shortfalls. This can deplete farm capital, impacting on business growth.

While there is an overall increasing trend in operating surplus for agricultural businesses in WA, low operating surpluses are evident during drought years, with surpluses tending to drop below $50 per hectare in low rainfall areas (*Figure 28*). Changes in climate over the period 2000 to 2019 (relative to the period 1950 to 1999) have had a negative effect on the profitability of broadacre farms Australia-wide, reducing farm profits by 22% [117].

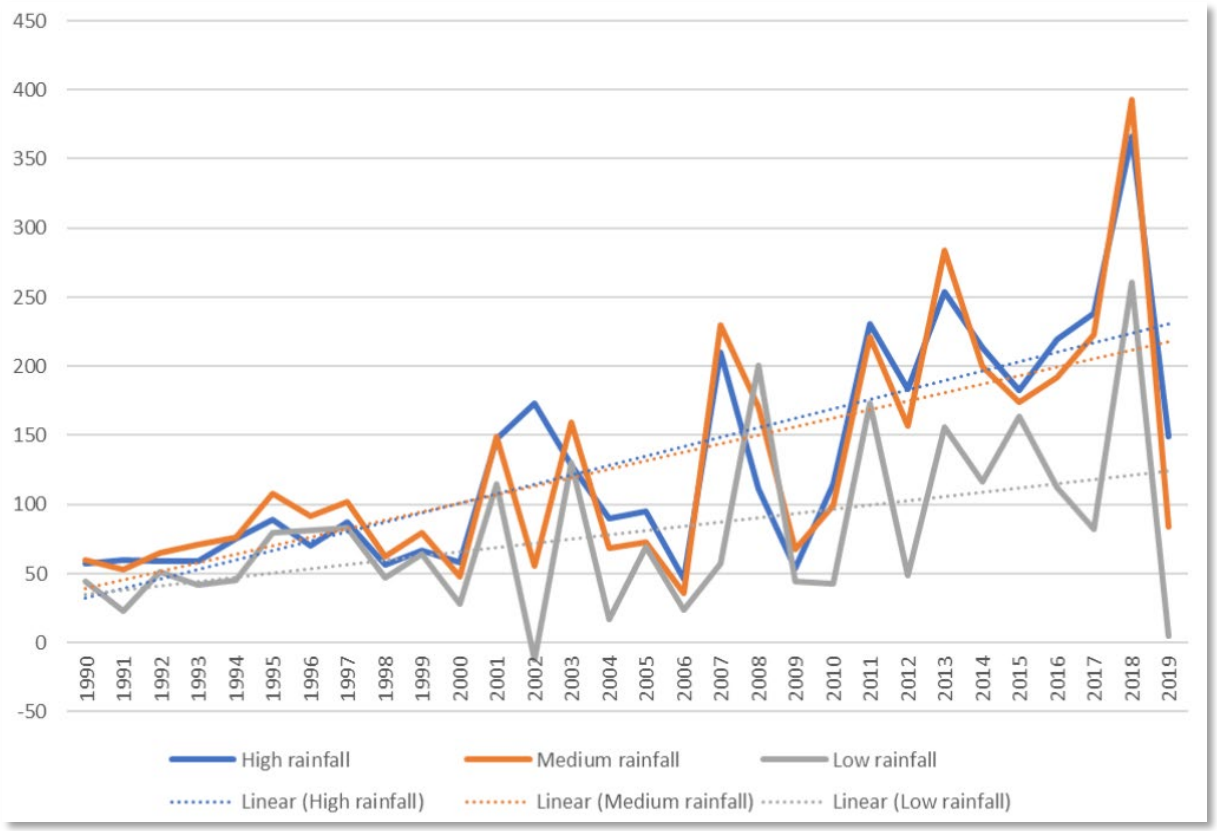

Figure 28: Trends in operating surplus ($ per ha) for WA farms between 1990 and 2019.

Despite experiencing highly variable seasonal conditions, including dry seasons and droughts and reduced government investment in research, development and extension

over the last 20 years[118, 119, 120], Australian farmers have maintained profitability. Adoption and implementation of farming systems technology, new varieties and increasing sophistication in business and financial management, has increased efficiencies, productivity and profitability. The agriculture sector is well-adapted to highly variable conditions, with WA a world leader in dryland grain production area. Returns are being achieved from seasons that would have been loss-makers a decade ago. Australian farmers are managing inputs and costs more effectively than ever before and achieve returns on both good and marginal land.

The drive for continued efficiencies to maintain and enhance profitability will remain. A dependence on export markets, climate change trends, rising rural debt and the increasing costs of doing business[121] increases the vulnerability of the agriculture sector to the economic impacts of future drought, particularly if droughts span consecutive years.

To support the resilience of the agriculture sector to drought and the impacts of climate change, the following are required:

- Planning of and investment in quality, reliable enabling infrastructure such as power, water, telecommunications and transport infrastructure
- Farming systems innovations to improve soil health and manage non-wetting soils
- Integration of precision agriculture and labour saving technologies
- Research and development of drought and frost-tolerant crop varieties, resilient pastures and livestock breeds
- Access to quality expertise and advise, including rural financial counsellors during drought
- Flexible financial mechanisms to aid drought preparedness and in-drought assistance, including farm household income support, Farm Management Deposit Schemes and low-interest loans
- Use of data and automation to enhance on farm and regional capacity to forecast and manage seasonal variability and longer term climatic impacts

Resilient farming systems enable adaptation to changing conditions and deal with high levels of uncertainty. Decision-making under conditions of uncertainty is a skill that farmers will increasingly need as climate change progresses[122]. Arguably, some on farm decisions have moved beyond human capacity and using technology to provide the intellectual power required to optimise decisions is inevitable[123, 124]. Automated, data-based decision-tools need to be user friendly, relevant and credible. Early detection, monitoring and dissemination of information to farming communities about the potential of drought conditions will allow for timely decisions. Using the right measures to understand drought in a timely manner will assist with the management of farm businesses and assist policy decisions. With early information, appropriate services can be provided and accessed by rural and regional communities experiencing drought.

A more detailed analysis of the economic impact of drought is available on request. See Section 10.

5.1.3 Farm business drought viability

Drought events are frequently associated with financial shocks for farming businesses[125, 126]. Regional stakeholders identified financial stress due to failed crops, lost inputs and the high costs of maintaining livestock through a drought, as one of the

main impacts of drought. Financial stress is recognised as a key impact of drought identified in consultation.

Planning for and alleviating financial stress during drought included improving business planning, and making use of financial mechanisms, including renegotiation of debt and accessing farm management deposits.

The experience of the 2006 and 2007 droughts in the Midwest region places this region in a unique position to analyse the characteristics of farm businesses that have managed to recover from drought, and where they are now from a financial perspective. Farm business consultants Planfarm Pty Ltd were commissioned to analyse the ability of current farming businesses in the City of Greater Geraldton and the Shires of Chapman Valley and Northampton to withstand the shock of drought from a financial perspective. The impact of the 2006 and 2007 drought was widespread. Though since then, due to mostly favourable conditions, good profits and escalating land values, business equity has risen significantly in recent years and 2018 and 2021 were particularly profitable.

The analysis identified that the financial impact of the poor season in 2019 was more severe than the combined effect of the 2006 and 2007 consecutive drought years. Equity dropped 10% in 2019 versus only 8% in 2006/07. While there was more rain in 2019, its distribution was poor, and crops did not finish well. Whilst yields were below average, spending was not, and many took a financial hit. All businesses within the cohort in 2019 are still trading today, suggesting that they will be capable of withstanding drought years in the future.

Suffering consecutive droughts may present a different proposition. The trading losses and subsequent drop in available cash, if it re-occurred in consecutive years, would lead to increased borrowing to finance operations in the following year and likely dent land values. Costs of producing a crop are much higher now than in previous years and this presents a significant risk. Planfarm concluded that most farming businesses in the cohort are moderately to strongly resilient and have recently demonstrated this resilience by surviving a poor season in 2019.

In the Midwest, generational businesses with accrued wealth tended to demonstrate a consistent ability to generate profit and reinvest profits into the business via, for example, soil amelioration or land acquisition. These businesses are large scale, in terms of both gross income and effective hectares, and have a low representation of livestock as part of the business (only 1 in 6 have any livestock at all). These are the most robust businesses, most capable over surviving consecutive droughts.

Given recent increases in the costs of operating, the risks of a poor season are greater today than in the past. Leaning on equity to finance trading losses is an important part of effectively managing this risk and well-capitalised businesses with a good profit and reinvestment histories are more likely to survive.

Planfarm Benchmarks reporting identified that businesses in lower rainfall regions continue to outperform those in higher rainfall regions over the long term, driven by the impact of land prices on the size of a business's capital base. Though it is noted that those businesses in medium and high rainfall regions have experienced stronger annual land value growth in recent years and are less exposed to the volatility in low rainfall regions [127]. Kingwell and Payne [128] note that higher rainfall areas may benefit from climate change through creating more favourable conditions for grain crowing.

The Planfarm viability analysis undertaken in the Midwest region is available on request. See Section 10.

5.1.4 Impact on non-farming businesses

Small and medium sized enterprises (SMEs) are considered critically important in the local communities, especially in regional areas and their viability is considered a prerequisite to the future vitality of regional areas. Despite this, little is known about the impact of drought on the operation and viability of SMEs.

A Queensland study identified businesses experience cash flow problems, increased prices, reduction in staffing, costs, stock and spending. These issues were compounded through lack of entrepreneurial and managerial skills, declining populations, skills shortages, business discontinuance, lack of infrastructure and lack of access to government assistance or incentives. SMEs considered most vulnerable to drought are those with short term planning and narrow focus; less skills in management; fewer resources; limited market share and a conservative approach to risk management. Those with direct links to rainfall, such as those servicing the agricultural industry are particularly exposed.

This study found that SMEs able to access diverse income streams reduced the financial impact of drought, including government, non-agricultural industries and tourism markets [129].

During times of drought, assistance is often targeted to farming businesses. The WA Drought Pilot focused on building farmer business skills and have resulted in increased farm business drought resilience [130]. The extension of financial counselling to rurally based businesses not tied to agriculture is a step forward in recognising the need to support SMEs in regional WA [131].

The Wheatbelt Development Commission and Wheatbelt Local governments understand the importance of SMEs to the economy, with economic diversification a key strategic goal. A range of initiatives and policy settings are required to enable business development, and include industrial and residential land activation, business development incentives and planning that supports economic development.

In the Wheatbelt, regional business networks are active in supporting SMEs through tailored programs, professional development and networking events. Many Wheatbelt based SMEs are active in building their resilience to shocks, with the recent pandemic seeing businesses pivot to service both mining and agriculture, as well as markets beyond their immediate geographical area. The WDC are commissioning and in-depth study to understand the impact of SMEs to the Wheatbelt economy. This study will support ongoing investigation into the role of SMEs in building drought resilience.

5.1.5 Economic diversification opportunities

In the Southern Wheatbelt region, there are opportunities for economic diversification into the population and mining and agricultural service sector, niche value adding agribusinesses, meat processing and renewable energy sector[30]. There is opportunity to develop a framework for business incubation using existing infrastructure such as the Community Resource Centre network.

The Curtin Bankwest Economic Centre[31] identifies diversification strongly linked to the agriculture and mining sectors, manufacturing and tourism industries as key opportunities. Alcoholic beverage manufacturing has potential to value add commodities and tourism. Meat processing and food product manufacturing are

identified as opportunities. Access to high quality and reliable water supply is vital to establishment of these industries. Three Farmers based in Wagin have pursued diversification opportunities, accessing government support to expand their broadacre cropping enterprise to develop a wheat free oat product.

There is opportunity to capitalise on the shift of professionals to the regions observed in recent years. This requires investment into high quality internet services, population services and amenity to attract and retain "knowledge economy" participants.

5.2 Environmental Impacts of Drought

Landscapes do not function solely to produce saleable commodities, they are also environments providing a range of ecosystem goods and services, including biodiversity and public amenity [132]. Regional communities are dependent on natural resources, including land, water and vegetation, for their livelihoods. Ecosystems provide important services to agricultural production, for example through soil structure and fertility, nutrient cycling, soil retention, crop pollination, food sources, water provision and purification [133, 134, 135]. Environmental impacts can be widespread and long-lasting, contributing to land degradation processes, and are among the most noticeable effects of drought. During the consultation process, Southern Wheatbelt stakeholders stated that drought negatively affected soil health, water resources (natural and scheme) and biodiversity.

The project team commissioned LA. One Economics & Consulting Pty Ltd to conduct a review the available literature of the impact of drought on the environment.

The conversion of land to agriculture has contributed to the global loss and degradation of habitat and biodiversity, directly impacting on plant and animal populations and altering ecological and hydrologic processes. In addition to habitat loss, farming practices such as tillage, burning, livestock grazing, and nutrient and chemical usage can have significant negative impacts on biodiversity, soil, water and air quality. Is widely recognised that agriculture has contributed substantially to a drying climate and therefore increased risk of drought [136].

5.2.1 Impact on natural resources

Droughts exacerbate impacts on already fragile environments. In the context of broader degradation, drought conditions can have a significant impact on natural resources, including irreversible damage to water quality, soil and vegetation, leading in turn to dust storms and a loss of topsoil, soil nutrients, organic matter and soil carbon [137].

Annual environmental condition scores [138, 139] for the Southern Wheatbelt shows the impact of drought on the environment. Scores report on inundation, streamflow, vegetation growth, leaf area, ground cover (exposed soil), tree cover, and number of hot days experienced. Environmental scores were lowest in 2002, 2010, 2019 and 2020, reflecting poor seasons (*Figure 30*). Effects of drought on the environment persist and are detectable in environmental condition scores in following years.

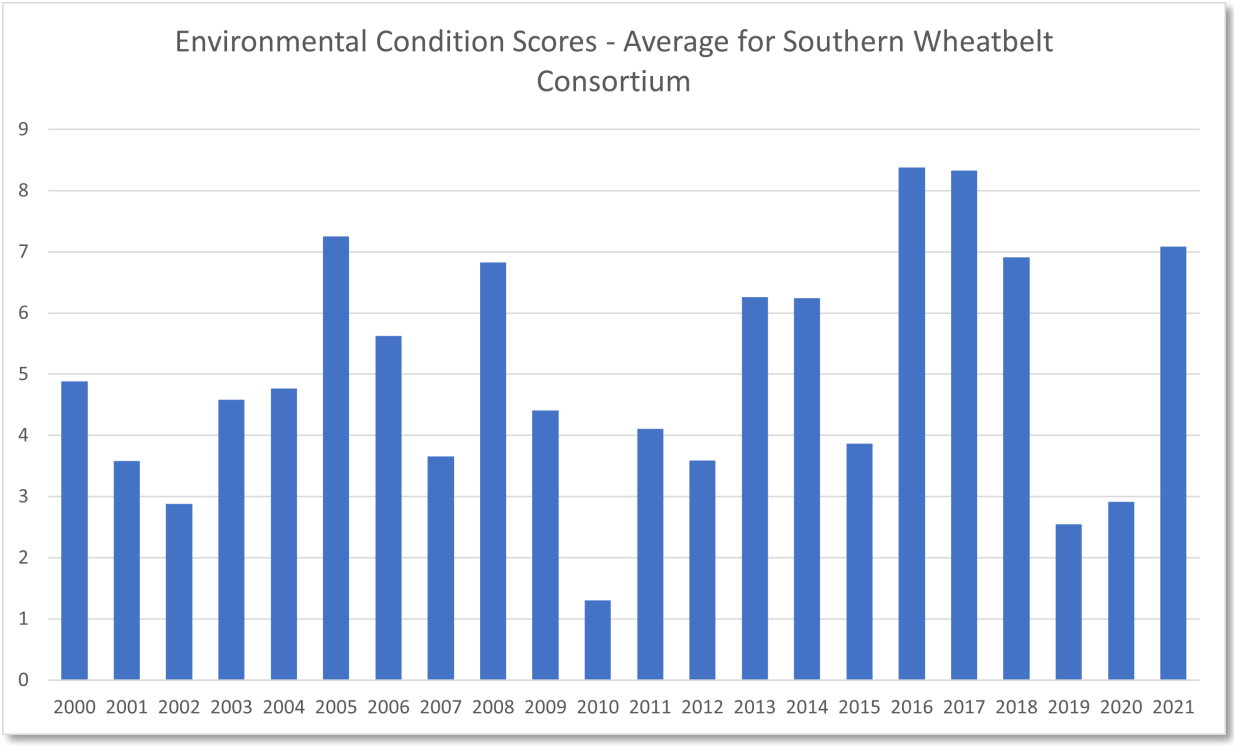

Figure 29: Annual environmental condition scores averaged across the Southern Wheatbelt Shires

Exposed soil (soil protection), leaf area and plant growth are widely used indicators that demonstrate the impacts of drought on the environment (*Figure 31*). Cultivated lands experience the largest drought impacts have high sensitivity to drought compared to natural biomes [140].

Natural environments in more arid settings tended to have higher sensitivity to drought while shrublands show the greatest resilience. That said, drought-induced vegetation declines have been reported across Australia [141, 142, 143, 144]. Declines in vegetation productivity and increases in plant mortality during drought have the potential to trigger abrupt and irreversible changes in ecosystem structure and function, with profound implications for biodiversity, ecosystem services, and carbon storage [145, 146, 147, 148].

The potential future environmental impacts of drought are soil degradation, increasing risk of fire, damage from feral animals and weeds and ongoing biodiversity loss. Soils are non-renewable resources that are critically vulnerable to loss and degradation, particularly during drought. Reduced rainfall and higher temperatures dry out the soil, creating cracks that reduce the moisture and volume of the soil, affect the activity of soil microbes, reduce soil particle cohesion, change soil texture, decrease soil water holding capacity and limit plant growth. Erosion is one of the greatest risks to soil health during drought, as it strips away the fertile top layers of soil and organic matter. Erosion affects agricultural production and water quality.

Healthy ecosystems build resilience to drought, and nature-based solutions can offer cost-effective protections while delivering co-benefits such as carbon capture and storage and improved food and water security. Sustainable natural resource management, including of soil, water and biodiversity, must be prioritised in the plan for building resilience to drought in the Southern Wheatbelt.

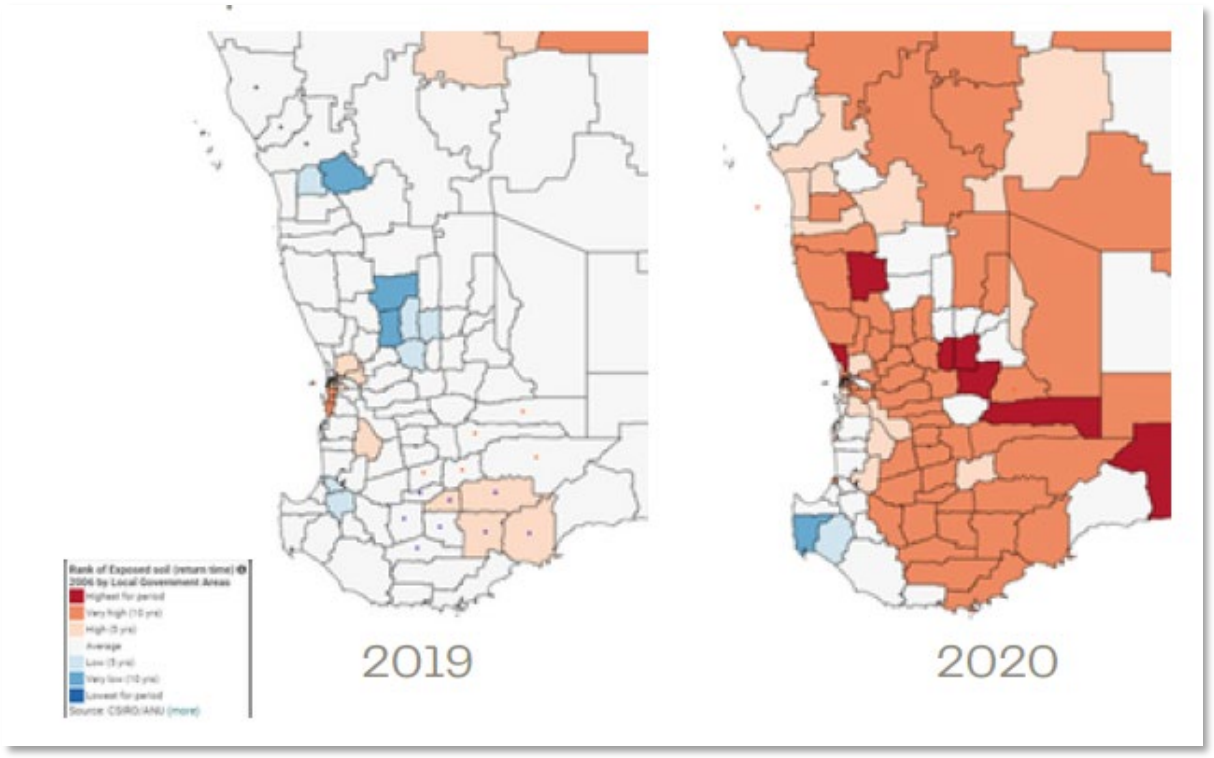

Figure 30: Environmental condition scores for exposed soil showing the impact of the 2019 drought on ground cover in 2020.

The declining vegetation condition and reduced water flows impacts on the use and amenity of public reserves. The study region includes several public reserves with significant granite exposures, often adjacent to lake systems or dams that collect water captured from constructed catchments and significant Aboriginal heritage sites. A good growing season coincides with good wildflower season, attracting visitors during the spring months. Sites across the region include Katter Kich/Wave Rock (site of the Wave Rock weekender), Jilakin Lake and Rock (site of the Kulin Bush Races), Dumbleyung Lake (largest body of inland water in WA). These reserves are key tourism infrastructure in the region, supporting tourism business development, including Aboriginal tourism. Declining condition and amenity of these reserves due to drought impacts detracts visitors.

Community consultation indicate a desire to improve the condition of these important environmental, tourism and culturally significant sites through conservation and wetland and vegetation condition monitoring.

5.2.2 Drought events and increased fire risk

The Mediterranean-type climate in the southwest of WA is characterised by conditions that are conducive to ignition and spread over a 4–8-month period[149]. There are various weather factors that influence the fire environment including coastal sea-breezes, strong easterly winds, abrupt wind changes, and regular lightning storms during the dry months. The traditional fire season has been prolonged, sometimes by several months because of the sustained decrease in rainfall during the past three decades.

The timing, intensity, and frequency of drought events have divergent impacts on fuel flammability and fire behaviour[150]. Droughts after a wet spring can result in an abundance of rapidly drying fuels in bushland and forest understories, but prolonged

droughts can limit fire occurrence due to a reduced availability of fuels from a lack of rainfall stimulating vegetation growth.

Fire has devastating effects on the environment. Fires that tear through forests and bushland can cause serious loss of vegetation and biodiversity, as plants are burnt off, and animals are killed both from the fire, and from the loss of their home and food source following.[151] Farmland is scorched, destroying pastures crops, and infrastructure, and killing livestock.

It is important to note that bushfires can play an important role in Australia's environmental ecology[152]. Fire can trigger natural processes like stimulating seed germination and can benefit biodiversity. By clearing out thick undergrowth germination and regrowth of native vegetation is encouraged, while freeing them from competition with weeds, and eliminating diseases and damaging insects. Recurrent fires however potentially threaten regeneration by killing seedlings and impoverishing the seed bank, therefore reducing forest postfire recovery ability[153].

A report on the environmental impact of drought can be provided upon request. See Section 10.

5.3 Social Impacts of Drought

During the consultation process, Southern Wheatbelt stakeholders stated that drought negatively affects mental health, led to business closures, causing people to move away from the region, reducing population sizes and access to skills and services. Drought strained community services and support networks. Stakeholders highlighted the need for stronger support to community groups and networks during drought.

5.3.1 A model for understanding individual and community resilience

Given the importance of social impacts of drought to regional stakeholders, the University of Western Australia's Centre for Social Impact was commissioned to conduct a review of the evidence around the social impacts of drought, factors which may mitigate those impacts, and what can make communities more resilient and/or more vulnerable to drought. Drought is a meteorological phenomenon that is recognised as a natural disaster when it results in severe socio-economic impacts for affected communities. The focus of this section is on the social impacts that low rainfall can have on individuals, households and communities.

The immediate and medium-term, direct and indirect social impacts of drought are diverse, related to employment, education, migration, family relationships, mistrust of government, uncertainty over the future and over community resources and support systems (*Figure 30*)[154]. All these factors have the potential to impact on physical, mental, social and emotional health directly or indirectly and wellbeing[155, 156, 157, 158, 159, 160, 161, 162, 163].

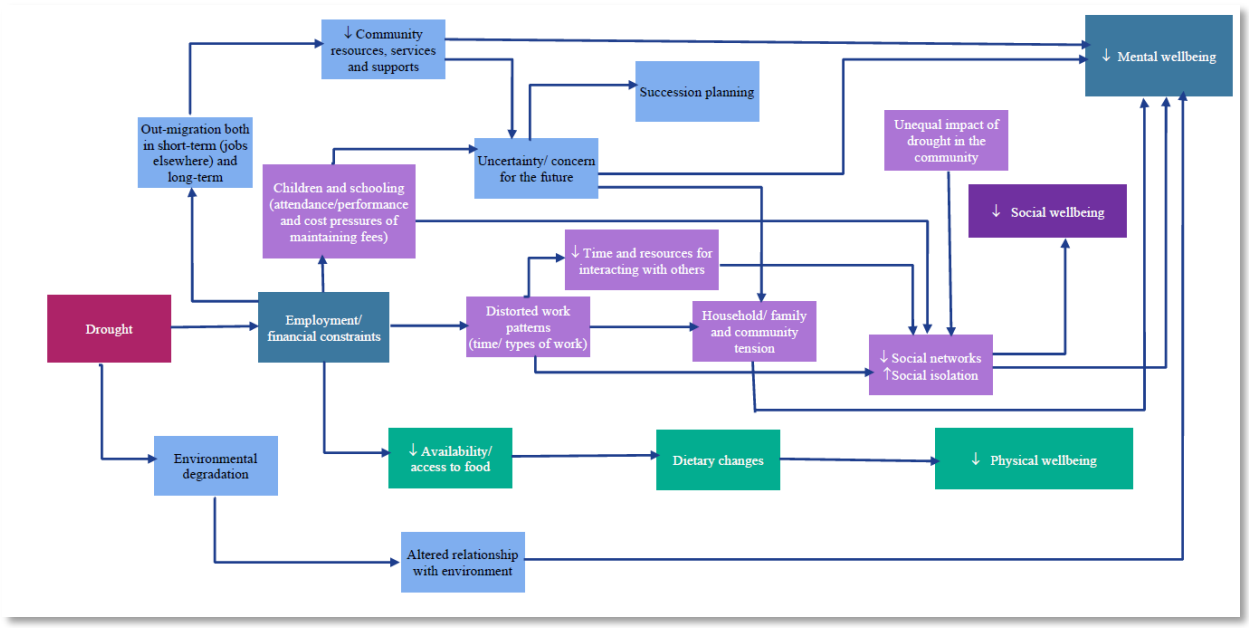

Figure 31: Graphical representation of the relationships between direct and indirect impacts of drought-related economic (income, employment) and environmental (degradation) processes on social outcomes such as altered relationships with the environment, family, government and community; out-migration; health and wellbeing; uncertainty over the future; and the availability and functionality of community resources, services and support systems.

The primary driver of social impacts of drought is the effect that drought has on financial security [164]. Economic factors include direct effects on income and employment [165, 166, 167] as well as indirect effects of hardship, stress [168], accumulating debt [169], lost productivity, declining populations, disruption of social connections, loss of services, missed schooling [170,], depletion of resources and trauma associated with witnessing damage to livestock, crops, soil and native vegetation [171].

Building resilience to the impacts of drought involves acting at both the individual and community level. Individual resilience refers to the capacity to recover quickly from difficulties and negative experiences such as trauma, tragedy, threats, or significant sources of stress [172, 173]. Resilience is impacted by personal (e.g. gender, attitude, perspective), community (e.g. social and community support, service access) and business (e.g. role diversification, succession planning) factors (*Figure 31*) [174, 175].

Community resilience refers to the ability of a community to undertake collective action to deal with adversity [176, 177, 178, 179, 180, 181, 182]. It can be described through a set of adaptive capacities, including economic development, social capital, community competence, information and communication (*Figure 32*) [183]. There is a need for the whole community to be supported during drought, with many non-farming people and businesses also impacted by the loss of income and regional outmigration associated with drought [184].

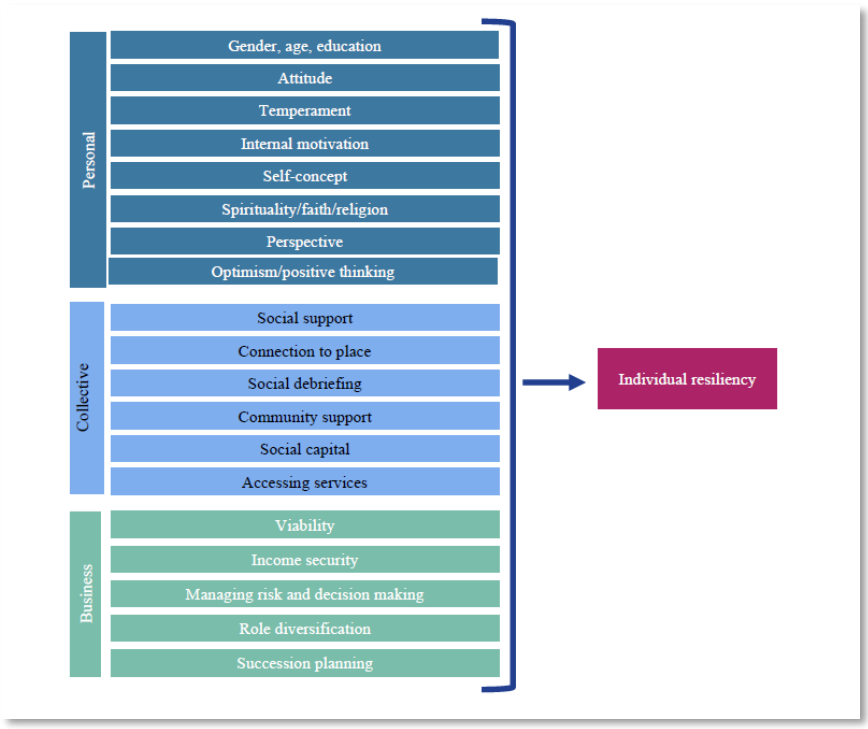

Figure 32: Factors impacting on individual resilience in the face of adversity.

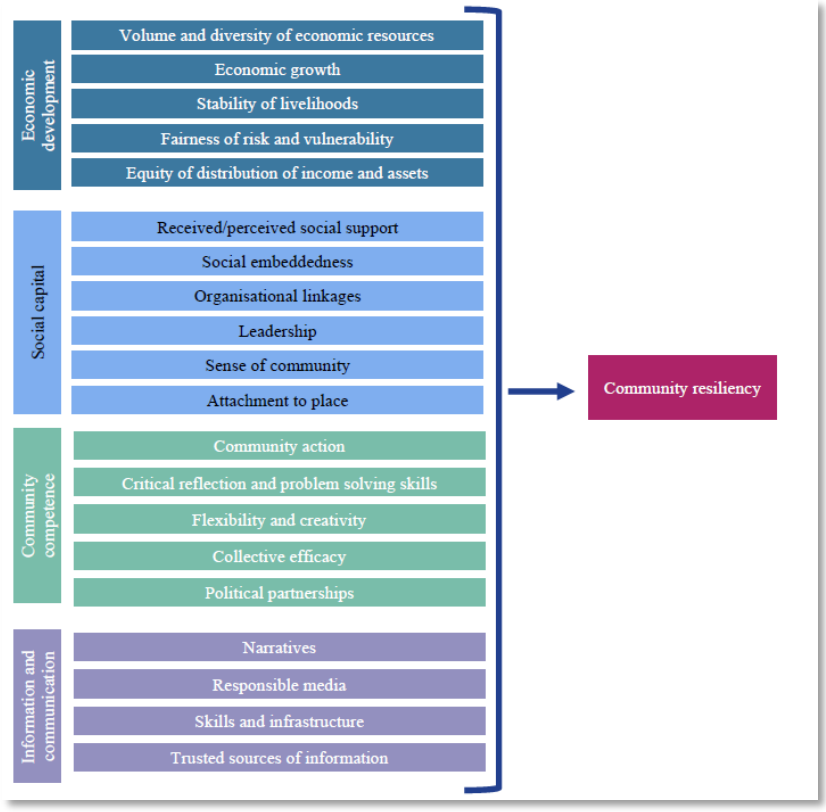

Figure 33: The adaptive capacities that make up community resilience.

5.3.2 Southern Wheatbelt social capital

In the Southern Wheatbelt region, community events and projects support ongoing connection and opportunities to volunteer during periods of drought. There is significant existing social capital in the region, with large events in the Southern Wheatbelt include the Wagin Woolarama, Newdegate Machinery Field Days, the Kulin Bush Races, the Wave Rock Weekender. These events attract thousands of people for short periods of time, and have positive economic and social impacts, with pre and post event activities contributing to social capital building.

While communities came together to support each other, the burden of organising events and coordinating groups often falls to the same people, who are also struggling to get their businesses through drought. It was recognised that the lack of local capacity to stage and event manage events to meet regulatory requirements meant large events may be more difficult to offer in the future in regional areas. This is inside and outside of drought situations. The financial and emotional stress of drought may result in a decline in the frequency of local events and gatherings.

Community focused projects and participation in sport or recreational pursuits provided much needed relief during dry periods. Stakeholders value maintenance of green spaces – both at the community and individual level – in supporting sporting participation and sense of escape in a droughted landscape.

Aboriginal people have strong interactions and connections with natural resources and landscapes in the region. Traditional owners in the Wheatbelt region identify the decline in conditions of vegetation and waterways across the region as emotionally damaging. Active efforts to rehabilitate and regenerate landscapes are restoring connection to land, while supporting the economic participation of Aboriginal people through business opportunities including seed collection and seedling raising and revegetation efforts. The demand for seedlings for carbon offset plantings are providing a driver for this activity in the region [185].

The UWA team used the resilience literature [186, 187, 188, 189, 190, 191] to develop a transition roadmap for building resilience to the social impacts of drought. The roadmap includes four stages: infrastructure; governance; population retention; and social capital.

Stage 1 Infrastructure: development of quality water, road and support services infrastructure forms the essential basis for building resilience in drought-exposed communities [192].

Stage 2 Good governance: establishes drought risk reduction and preparedness measures through drought planning, secure and continuous government funding for drought resilience and the ongoing involvement of community leaders and local government in the dissemination of relevant information.

Stage 3 Population retention: in rural and regional areas experiencing drought is achieved through financial support, employment opportunities and stimulus packages.

Stage 4 Social capital: is built by supporting community social networks and social cohesion [193, 194]. Both social and task-focused community groups positively impact community well-being. Social cohesion can be encouraged by developing and implementing programs that strengthen intercultural initiatives, celebrate diversity and address social justice and equity issues.

Recommendations for building social resilience to drought, based on the literature to date, include:

- Ensuring communities have sufficient water, energy, transport and support services infrastructure to support the needs of the whole community, including local health [195, 196, 197] and financial services;
- Ensuring good governance, including the development of drought plans and strategies, water management planning and investment in disaster management, risk reduction and preparedness;
- Ensuring population retention in rural and regional areas through government financial support during drought, providing income security to both farming and non-farming populations, decreasing out-migration and helping to retain employment within rural communities;
- Increasing local support service networks, including access to rural financial counsellors, education and health care services, recreational facilities and work opportunities;
- Strengthening community social networks and social capital and supporting community events;
- Ensuring early recognition of and effective response to poor mental health, including employment of drought support workers, programs to support youth and the elderly, after-hours access, home visits and telephone / online services for counselling and advice [198, 199] ; and
- Mapping government funding for drought resilience against outcomes frameworks which are in line with resilience and vulnerability frameworks.

A detailed report on the social impacts of drought can be provided on request. See Section 10.

5.4 Impact of Drought on Aboriginal communities

Aboriginal Australians are likely to be disproportionately affected by drought based on pre-existing health and social disadvantage [200]. Adaptive capacity and resilience to drought may be impacted by inadequate infrastructure and health services, and by social disadvantage [201]. The health status of Aboriginal Australians is lower than that of the general Australian population. Specifically, Aboriginal Australians are more likely to have a disability or a chronic disease and have a significantly lower life expectancy than non-Aboriginal Australians [202, 203]. Remote and very remote communities are particularly vulnerable.

In these communities, Aboriginal Australians' health status is even poorer, and this increases vulnerability to drought. Partnerships with Aboriginal Corporations and Organisations and related health services are critical to addressing the needs of Aboriginal people, particularly youth and the elderly [204]. Mental health services need to focus on social connectedness and a wider range of support services are required, at a younger age, for Aboriginal compared to non-Aboriginal people.

Extreme weather events such as drought can impact on physical and social wellbeing, trigger feelings of loss and trauma during and immediately after the events, exacerbate existing stress and mental health issues, impact on livelihoods, affect financial security and cause significant uncertainty and concern for the future[107]. Prolonged drought impacts on rural and regional employment opportunities and degrades the environment.

This can affect Aboriginal peoples' ability to carry out cultural roles that support cultural identity. Barriers to Caring for Country impact on mental, emotional and physical wellbeing in Aboriginal communities[205, 206]. During prolonged drought, Aboriginal Australians can experience solastalgia, a feeling of psychological desolation caused by the recognition that one's home is under physical threat and eroding one's sense of belonging[207, 208]. The loss of identity associated with the inability to carry out cultural roles is highly correlated with increased rates of substance use and dependency, violence and suicide[103,106, 209, 210].

During stakeholder consultation, we consulted with 17 Nyoongar people representing 14 businesses and organisations in the Wheatbelt region. The consultation process included in-person interviews, meetings and workshops.

A series of videos were produced with Noongar Elders and business people from across the region. Elders reflected on the degradation of significant water pools due to the drying climate, and the inability to recreate, gather food, share stories and connect with community on country. Comments were made about the drying climate driving people indoors, further exacerbating the sense of solastalgia and the challenges in passing down knowledge to the next generations.

5.4.1 Integration of traditional knowledge

Traditional ecological knowledge (TEK) can offer effective solutions for land management and adaptation strategies. Operationalising TEK can provide opportunities for local empowerment and employment that can, in turn, address health and wellbeing, cultural and social needs[211].

Nyoongar people highly value *kallip* – the amassing and preservation of knowledge about people, their environment and its systems. There is a desire to share this knowledge with government and industry, though there is a lack of a suitable framework to do so in agricultural regions.

Developing and sharing Noongar "science" to support the improved condition and potential restoration of significant gathering places such as the water pools, was an expressed desire of Nyoongar Elders. Ballardong Noongar Elder Aunty Faye Collard explains how climate change has impacted on Noongar people in the region.

Barriers to participation and integration of Noongar cultural land management to support drought resilience include:

- Lack of appropriate access to country; limited Noongar owned country
- Inappropriate Noongar engagement, being considered an afterthought or add on, not genuine in its intent; including lack of appropriate compensation when mobs are engaged
- Lack of respect, awareness or value of Noongar knowledge and cultural heritage, including incorrect use of cultural protocols
- Misalignment of government boundaries with Noongar Boodjar and Noongar clan groups
- Funded projects that do not weight Noongar led initiatives adequately, limiting collaboration; and projects that require Noongar engagement, but do not consider the costs of this, with an expectation this is done voluntarily

- Noongar people feel over consulted and underrepresented in strategies and projects

5.4.2 Aboriginal Economic Development opportunities

There are opportunities for Aboriginal businesses to participate and benefit from initiatives to support drought resilience. The Noongar Boodja Ranger program has a strong presence in the Wheatbelt region, and is growing its operations, capturing opportunities that decarbonising the economy are presenting. This includes collection and nursery raising of native seedlings for carbon and biodiversity plantings. The expansion of the Noongar Boodja Ranger program across the Wheatbelt may assist in diversifying employment opportunities for Aboriginal people. The Noongar Boodja Rangers explain the importance of the program and the impact of drought on the Ballardong Noongar people and how they are building resilience of the landscape across the Wheatbelt region.

Noongar Land Enterprise Group (NLE) is a grower group, Noongar owned and operated, active in its pursuit of a range of business ventures including beef, honey, sheep, sandalwood, cultural tourism, bush foods and youth training programs[212]. Looking after country, cultural connectivity and rejuvenation are core elements of the management of NLE land assets in the Wheatbelt region. NLE are well placed to tap into opportunities to build drought resilience across the landscape, while achieving economic and cultural outcomes. NLE are small compared to other farming enterprises and diverse, with objectives to drive genuine change for Aboriginal people.

Three case studies were showcased by NLE as part of their research for this project. The case studies demonstrate how degraded *boodjar* (land) can be regenerated through traditional land management knowledge and practices, while still generating a profit.

Climate and drought resilience initiatives would be important to include as part of the economic framework being developed to sit alongside the Indigenous Land Use Agreements that form part of the Southwest Settlement.

5.4.3 A way forward?

NLE propose the need for a Framework for Action to facilitate genuine coordinated engagement of Noongar people in initiatives across the regions. They recommend the framework should be Noongar led and that this approach would improve coordination of consultation efforts across agencies – often working in isolation, though consulting with the same people and organisations.

It is proposed this approach would facilitate and indicate a commitment from government and industry to genuinely incorporate Noongar knowledge and practices.

It would encourage cross agency collaboration and alignment to regional and organisational priorities; focus on healthy country and work from a strength based approach; encourage Noongar participation in the restoration economy; allow for community engagement and collaboration on industry priorities, markets and outputs.

The Djarlma Plan developed for the WA forestry industry is referenced as a model to work towards[213].

Detailed reports on the impact of drought on Aboriginal people and communities are available on request. See Section 10.

5.5 Impact of Drought on Water Supply

Water is an underpinning resource supporting economic, social and environmental functions across WA, with agriculture accounting for three quarters of total water use in WA. In the Southern Wheatbelt, agriculture is rain-fed, though demand for water is changing. There is a growing need for clean good quality water for spraying crops, as cropping programs grow.

Despite having relatively good access to piped water from the scheme, and proximity to community water supplies, water deficiencies are still being experienced. The cost to cart water to impacted locations was estimated to cost the State government $11 million from 2010 to June 2020 [214].

Low storage levels in local town dams seen water carted to top up town supplies in recent years. Water was carted to Dumbleyung and Lake Grace in 2020 [215].

Southern Wheatbelt stakeholders stated that having confidence in water supplies to get through dry seasons or periods of drought (2 or more decile 1 rainfall years) is the number one priority to build drought resilience. The lack of adequate on farm water supplies was cited as a key issue to be addressed to support farm business production into the future. Reliable, cost effective and accessible water supplies – both potable and non-potable sources, are believed to support improved drought resilience in agriculture and allied industries in the region.

Improvements to water infrastructure were among the most mentioned responses to help manage past dry seasons at both the farm and community level. Installation of more reliable and appropriate water capture, treatment and storage options, generally incentivised through government rebate schemes, were considered pivotal.

5.5.1 Key water issues for the Southern Wheatbelt region

A review of issues across the region undertaken by identifying the following impacts to water supplies during periods of drought. These key issues include:

- Local government authorities generally lack knowledge of current and future supply and demand needs
- Lack of coordination at the regional level to support planning for water into the future
- Use of potable water supplies where non-potable water supplies would be more appropriate
- Inability to maintain green spaces in town, including town ovals, limiting use of recreational facilities to support social connection
- Stand pipes being used for “non-emergency” purposes – e.g. spray water as opposed to emergency supply for livestock
- Relationships with DWER’s Rural Water Planning branch are very good
- A need to build relationships with Water Corporation to ensure understanding of local and regional needs
- Lack of coordinated, regional scale water supply planning – approach is often ad hoc or reactive

The following were noted as key to improving planning and implementation of non-potable water projects to support drought resilience:

- Updating of key regional and State strategies relating to provision of water to the region
- Coordination across agencies is required, particularly in ensuring joined up approaches to planning, implementation, finalising licences and leases for use of Crown land
- Creating a forum to share issues across the region
- Improve knowledge on current water supply and demand, and future needs
- Investigate streamlining clearing legislation on roaded catchments to enable quicker restoration of their function
- Implementing a rebate scheme for water storage and water supply improvement on farms and in towns
- Share responsibility of water resources with traditional owners, considering heritage values
- Include objectives for drought resilience in local government Community Strategic Plans
- Demonstration sites for water efficiency and water harvesting and storage innovation

A detailed summary of water issues across the Southern Wheatbelt is available on request. See Section 10.

5.5.2 System vulnerability

The water system of the Wheatbelt draws from a range of potable and non-potable water sources including:

- Potable Water Corporation managed piped scheme water (desalinated seawater, Darling range reservoirs and groundwater from aquifers on the Swan Coastal Plain) from the Goldfields Agricultural Water Supply Scheme (GAWSS) and Great Southern Towns Water Supply Scheme (GSTWSS)
- Non-potable localised farm water supplies – surface and groundwater derived
- Non-potable community supplies – surface water derived – rock catchments – mixed management, Water Corporation, DWER, Local government
- Non-potable residential and commercial building rainwater harvesting
- Localised use of small scale desalination (trials at community scale to be implemented in 2022)
- Water Corporation managed waste water re-use from waste water treatment plants (in some communities)
- Allocated groundwater - limited to the central coast region of the Wheatbelt

A study of the changing vulnerability of water systems in the Wheatbelt[216] identified that climate, heat and growth of population and industry impact supply capacities and demand levels on the system.

Those without access to piped scheme water, or located further from piped scheme water, mean increased vulnerability as they are subject to highly variable inter-annual and intra-annual variation in rainfall. Those experiencing higher temperatures are also considered more vulnerable. Lake Grace is located at the end of the scheme and is vulnerable to draw down effects across the system.

The factors that influence ability to supply current and historic demands have had the greatest influence on system vulnerability in eastern parts of the Wheatbelt most vulnerable to decreasing water availability (*Figure 33*)[216]. This includes Shires in the study region.

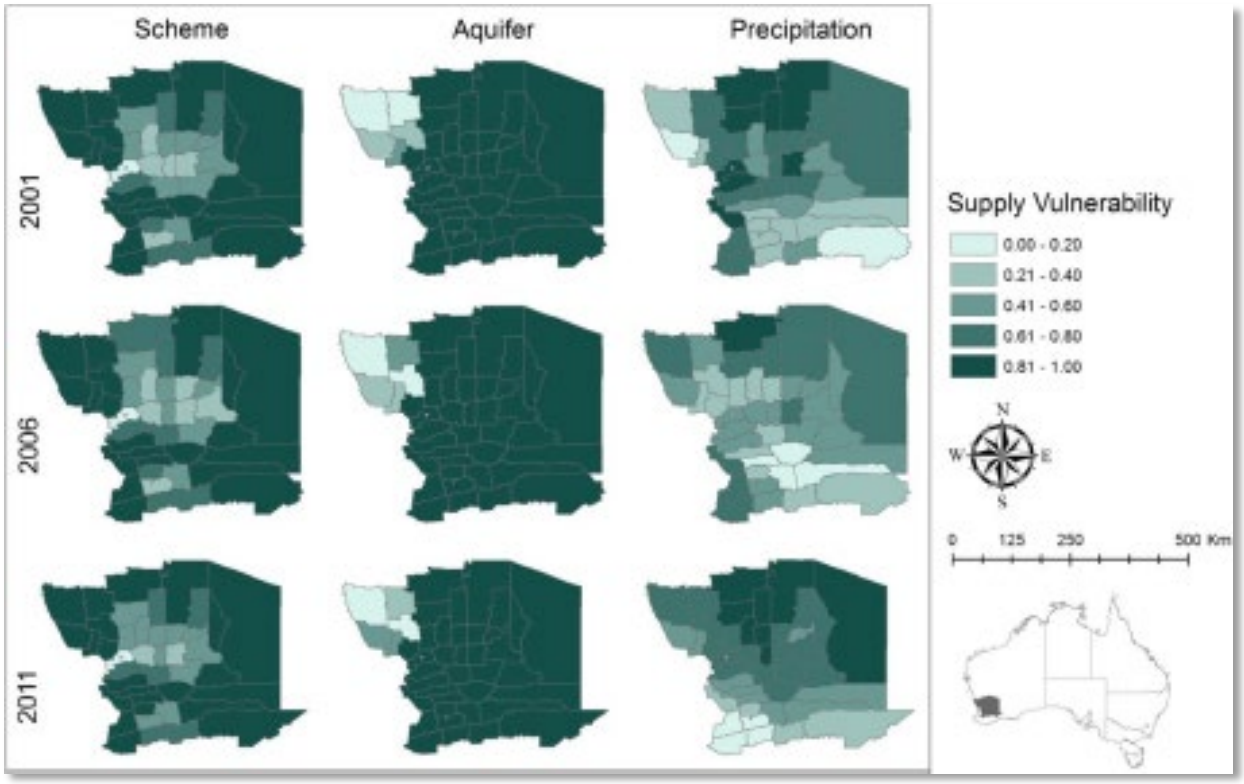

Figure 34 Supply vulnerability, note the high vulnerability of scheme water supplies in eastern parts of the Wheatbelt[215]

5.5.3 Water Planning and program and policy response

Unlike the Mid West and Great Southern, the Wheatbelt region does not have whole of region water supply strategy. Local government level strategies exist that cover emergency rural water supplies and ground and surface water management in towns, completed under programs such as the Rural Towns-Liquid Assets program[217] [218] [219]. DWER Emergency Rural Water Plans are currently under review for all the study region local governments.

See *Table 5* for a list of relevant water management plans across the sub-region.

Table 4 Relevant water plans for the Shires in the Study region

Shire	Document	Comments
Kulin	Emergency Farmwater Response Plan for Shire of Kulin	DWER and Shire updating Ref: https://www.water.wa.gov.au/__data/assets/pdf_file/0016/1618/82299.pdf
Lake Grace	Water Management Plan for the Shire of Lake Grace, 2006	Comprehensive plan to address water and salinity issues in Lake Grace, including urban water balance for town (scheme water, wastewater outflow, modelled stormwater runoff), options for water management options/projects – requires update Ref: https://researchlibrary.agric.wa.gov.au/cgi/viewcontent.

		cgi?article=1332&context=rmtr
Lake Grace	Lake Grace Emergency Farmland Water Response Plan, 2009	DWER and Shire updating Ref: https://www.water.wa.gov.au/__data/assets/pdf_file/0017/2933/89579.pdf
Kondinin	Shire of Kondinin Emergency Farmland Water Response plan, 2006	DWER Shire and updating https://www.water.wa.gov.au/__data/assets/pdf_file/0011/1721/82298.pdf
Dumbleyung	Groundwater study of the Dumbleyung Townsite, 2001	Groundwater investigation of Dumbleyung townsite Ref: https://researchlibrary.agric.wa.gov.au/rmtr/195/
Dumbleyung	Strategic Water Assessment – Dumbleyung Townsite, Stormwater Reuse and Water Balance Analysis, 2015	GHD undertook modelling work and recommendations for stormwater reuse extension Report held by Shire of Dumbleyung

Despite a declining or stagnant population growth, the Wheatbelt region's gross regional product is growing as the agricultural and mining sector grows, and small and medium enterprises establish to service those underpinning sectors.

The high costs of maintaining the piped water scheme and reducing populations in eastern parts of the region may limit future government investment in this critical infrastructure. Water planning assumptions based on population growth may lead to perverse outcomes for regional economic and ultimately, drought resilience in the Wheatbelt.

Interventions to address localised and acute water needs are delivered through the Water Corporation and DWER. Recent examples include recent Water Corporation upgrades to water supplies to the Shire of Kondinin to connect a new tank and pumping station the GSTWSS and installation of buffer tanks in Lake Grace to support stand pipe functioning. DWER are very active in supporting upgrades to on farm and community water supplies under State and Federal government programs, including the National Water Grid and Farm Water Rebates scheme and Community Water Supply program. Oversubscription to these programs indicates the strong demand and desire to proactively improve water supplies.

A range of actors are responsible for planning and managing water supplies in Western Australia, including DWER, Water Corporation and Local government. Improved coordination and transparency; and application of a regional lens would be welcome by all Shires in the study region.

A reimagination of State led programs such as the Rural Towns-Liquid Assets program may provide an opportunity to address holistic total water management planning considerate of climate change, growing industry demand and advances in water systems technology. An updated supply and demand analysis will be complete for the study region in 2022 and aims to quantify supply and demand and future scenarios under business as usual, RCP 4.5 and 8.5 climate predictions. Gaps in supply will be identified to support investment planning.

The Southern Wheatbelt DVA will be updated to reflect the findings of this analysis.

6. Drought Risk Priority Areas

6.1 Drought Resilience Priority Areas Maps

Using GIS-based multi-criteria analysis (MCA) [220, 221, 222, 223, 224], DPIRD's Geographical Information System (GIS) team have spatially integrated relevant economic, environmental and social data at a scale appropriate to inform local level political, administrative and operational decision-making (LGA boundaries).

A set of maps were produced identifying high priority drought risk areas, taking into consideration farm water supply, agricultural production, soil health and erosion potential along with a range of socio-economic and landscape features that contribute to drought resilience or exacerbate drought risk in the region. These features include water-related ecological infrastructure, high value agricultural land and areas of higher socio-economic vulnerability.

The approach consolidates complex information into user-friendly spatial products designed to enable fine-scale, local-level decision making on drought resilience. The maps will be included in the Regional Drought Resilience Planning Program (RDRP) Drought Vulnerability Assessments, forming part of the evidence base for regional Drought Resilience Plans.

Inputs into the MCA follow the RDRP conceptual framework, investigating aspects of exposure, sensitivity, impact and adaptive capacity. Our understanding of the ways in which each of these components relate to and inform vulnerability and resilience to drought in the regions was guided by a comprehensive regional stakeholder engagement process.

Drought resilience priority areas maps are made up of a set of composite maps for i) exposure, ii) sensitivity, iii) impact (combining exposure and sensitivity and iv) adaptive capacity. The integration method is shown in Figure 34 and Figure 35. Individual data layers included in the drought resilience priority areas map are described in Table 6 and Table 7. Forty-four variables and 10 composite maps were weighted according to their likely influence on drought resilience, based on literature review, expert opinion and feedback from regional stakeholders, and combined to create the final drought priority map.

The analysis was performed using the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) tool developed by ABARES [225]. Drought resilience priority areas lie at the intersection of all categories, where exposure, sensitivity and adaptive capacity overlap. The overlapping areas highlight where droughts are likely to occur most frequently and have the largest impact on water resources and agricultural production. They also identify locations where regional communities may be more vulnerable to the impacts of drought due to socio-economic factors including relative remoteness, access to infrastructure and income.

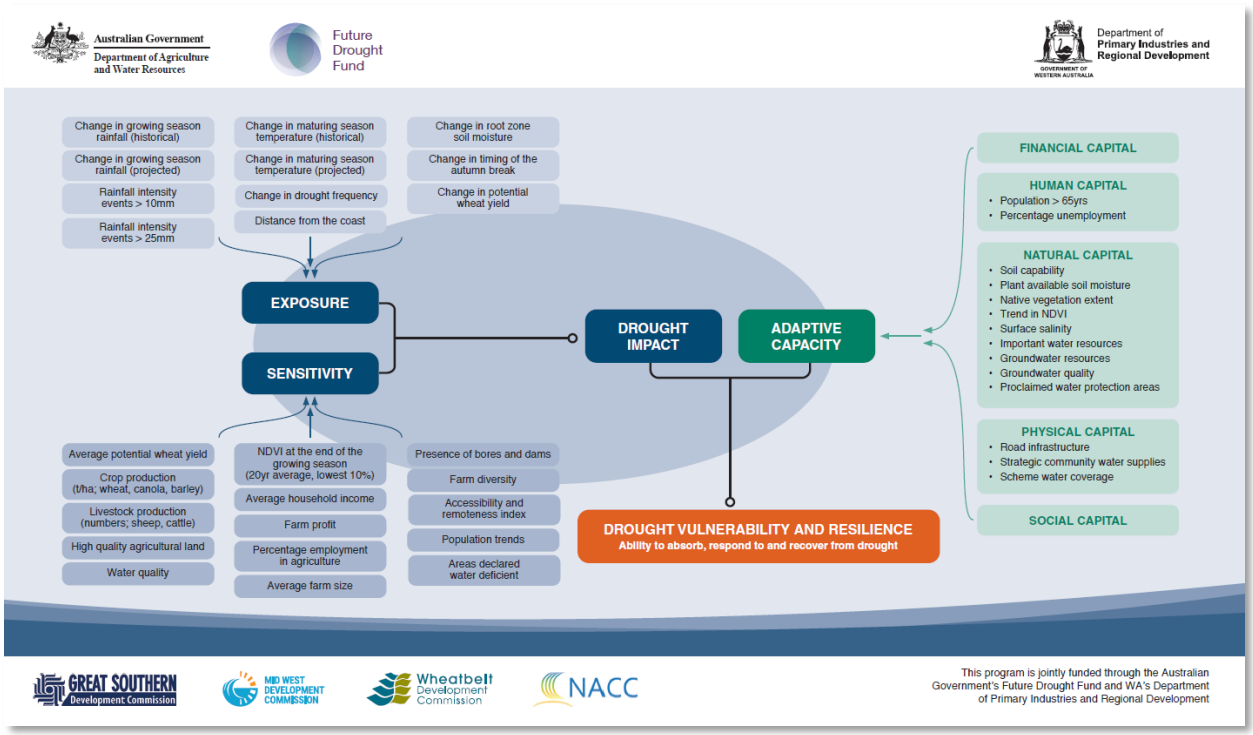

Figure 35: Data sets included in the analysis, showing how each data set fits within the over-arching program conceptual framework.

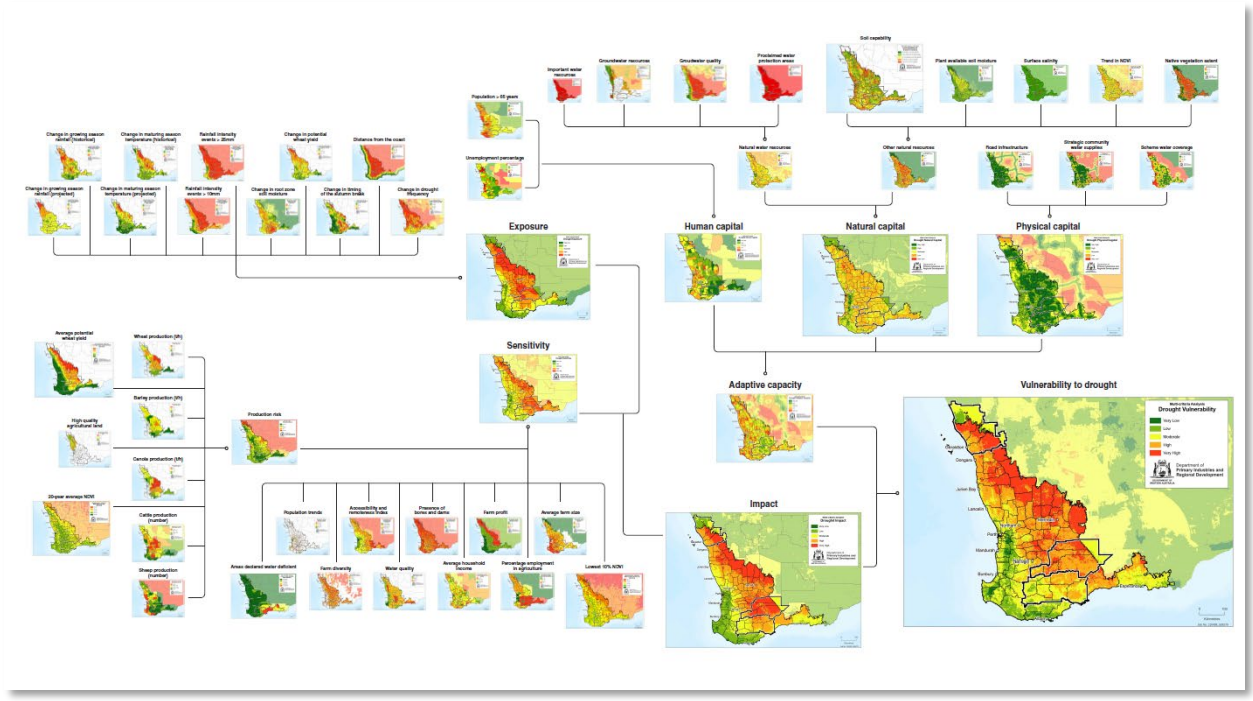

Figure 36: Drought vulnerability map for southwest Western Australia, showing all the contributing datasets and the steps followed for combining individual datasets into a series of composite maps. The size of each map reflects is level of analysis (size class) and weighting (size relative to other maps in the same size class).

Table 5: Data sets contributing to the Exposure component, including all data sources. Weights provided describe the relative weighting applied to the data set during analysis and are relative to the other datasets within the same tier. Tier describes the level of analysis; primary = all individual component datasets and first-level composite maps, secondary = second-level composite maps made up of primary datasets and first-level composite maps, tertiary = composite maps made up of second-level composite maps, final = the final analysis drought vulnerability priority areas map made up of the tertiary maps.

COMPONENT	CATEGORY	DATA SET	SOURCE	WEIGHT	TIER
Vulnerability		Composite map – combines Impact and Adaptive Capacity	Impact & Adaptive Capacity maps	N/A	Final
Impact		Composite map – combines Exposure and Sensitivity	Exposure & Sensitivity maps	2	Tertiary
Exposure		Composite map – combines all data within the Exposure component	Various	1.25	Secondary
	N/A	Change in growing season rainfall (historical, projected)	Department of Agriculture, Water and Environment (DAWE) – Climate Services for Agriculture	1	Primary
	N/A	Change in maturing season temperature (historical, projected)	DAWE – Climate Services for Agriculture	1	Primary
	N/A	Rainfall intensity (events > 10mm, events > 25mm)	Queensland Department of Environment & Science – SILO Patch Point data[b]	1	Primary
	N/A	Change in root zone soil moisture	Bureau of Meteorology (BOM) – Australian Landscape Water Balance	1	Primary
	N/A	Change in timing of the autumn break	Department of Primary Industries and Regional Development (DPIRD)	1	Primary
	N/A	Change in drought frequency	Curtin University using Queensland Government SILO Longpaddock data[d]	1	Primary
	N/A	Change in potential wheat yield	DPIRD[e]	1	Primary
	N/A	Distance from the coast	DataWA – Landgate[f]	1	Primary

[a] https://climateservicesforag.indraweb.io/; [b] http://qldspatial.information.qld.gov.au/catalogueadmin/catalog/search/resource/details.page?uuid=%7B0D1DF4A9-1D43-45E1-AC31-5A03BD93A406%7D; [c] http://www.bom.gov.au/water/landscape/assets/static/publications/AWRALv6_Model_Description_Report.pdf; [d] https://www.longpaddock.qld.gov.au/silo/; [e] https://www.agric.wa.gov.au/dry-seasons-and-drought/seasonal-climate-information; [f] https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-framework-polygon-coastline-lgate-120

Table 6: Data sets contributing to the Sensitivity component, including all data sources. Weights provided describe the relative weighting applied to the data set during analysis and are relative to the other datasets within the same tier. Tier describes the level of analysis; primary = all individual component datasets and first-level composite maps, secondary = second-level composite maps made up of primary datasets and first-level composite maps, tertiary = composite maps made up of second-level composite maps, final = the final analysis drought vulnerability priority areas map made up of the tertiary maps.

COMPONENT	CATEGORY	DATA SET	SOURCE	WEIGHT	TIER
Vulnerability		Composite map – combines Impact and Adaptive Capacity	Impact & Adaptive Capacity maps	N/A	Final
Impact		Composite map – combines Exposure and Sensitivity	Exposure & Sensitivity maps	2	Tertiary
Sensitivity		Composite map – combines Production Risk with all other primary data within the Sensitivity component	Various	1	Secondary
Production Risk		Composite map – combines all data within the Production category	Various	1.25	Primary
	Production	Average potential wheat yield	DPIRD [a]	1.5	Primary
	Production	Crop production (t/ha; wheat, canola, barley)	Australian Bureau of Statistics (ABS) – Agricultural Commodities[b]	1	Primary
	Production	Livestock production (numbers; sheep, cattle)	ABS – Agricultural Commodities[b]	1	Primary
	Production	High quality agricultural land	DPIRD[c]	1	Primary
	Production	NDVI at the end of the growing season (20yr average)	Landgate – MODIS Vegetation Index Products (NDVI & EVI)[d]	1.5	Primary
	Other	Water quality	DPIRD[e]	1	Primary
	Other	NDVI at the end of the growing season (lowest 10%)	DPIRD[e]	1.5	Primary
	Other	Average household income	ABS[f]	1	Primary
	Other	Farm profit	Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)[g]	1	Primary

[a] https://www.agric.wa.gov.au/dry-seasons-and-drought/seasonal-climate-information; [b] https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/7121.0Explanatory%20Notes12015-16?OpenDocument; [c] https://www.agric.wa.gov.au/sites/gateway/files/RMTR%20386%20HQAL%20Geraldton%202nd%20edition.pdf; [d] https://vip.arizona.edu/documents/MODIS/MODIS_VI_UsersGuide_June_2015_C6.pdf; [e] https://www.agric.wa.gov.au/resource-assessment/interactive-groundwater-and-salinity-map-south-west-agricultural-region; [f] https://www.abs.gov.au/ausstats/abs@.nsf/mf/2008.0; [g] https://data.gov.au/data/dataset/abares-drought-risk-by-farm-profit; [h] https://datapacks.censusdata.abs.gov.au/datapacks/; [i] https://catalogue.data.wa.gov.au/dataset/client-property-event-system-properties/resource/e0ad6de0-b425-4103-ada7-12c1087f06c6

Table 8: Data sets contributing to the Exposure component, including all data sources. Weights provided describe the relative weighting applied to the data set during analysis and are relative to the other datasets within the same tier. Tier describes the level of analysis; primary = all individual component datasets and first-level composite maps, secondary = second-level composite maps made up of primary datasets and first-level composite maps, tertiary = composite maps made up of second-level composite maps, final = the final analysis drought vulnerability priority areas map made up of the tertiary maps.

COMPONENT	CATEGORY	DATA SET	SOURCE	WEIGHT	TIER
Vulnerability		Composite map – combines Impact and Adaptive Capacity	Impact & Adaptive Capacity maps	N/A	Final
Adaptive Capacity		Composite map – combines Human, Natural and Physical Capital	Human, Natural & Physical Capital maps	1	Tertiary
Human Capital		Composite map – combines all data within the Human Capital component	Various	1	Secondary
	N/A	Population > 65yrs	ABS Population Estimates[a]	1	Primary
	N/A	Percentage unemployment	ABS Census 2016[b]	1	Primary
Natural Capital		Composite map – combines Natural Capital – Water and Natural Capital - Other	Natural Capital – Water & Natural Capital Other maps	1.5	Secondary
Natural Capital - Water		Composite map - combines all data within the Water category	Various	1	Primary
	Water	Important water resources	Department of Biodiversity, Conservation and Attractions[c,d,e,f] DWER[g]; Data WA - Landgate[h]	0.5	Primary
	Water	Groundwater resources	BOM – Australian Groundwater Explorer[i]	1	Primary
	Water	Groundwater quality	DWER (DWER-026: State-wide Groundwater Salinity[j]	1	Primary
	Water	Proclaimed water protection areas	DWER (DWER-033: Public Drinking Water Source Areas)[k]	1	Primary
Natural Capital - Other		Composite map - combines all data within the Other category	Various	1	Primary
	Other	Soil capability	DPIRD (DPIRD-031: Land Capability – Dryland Cropping[l]	1.5	Primary
	Other	Plant available soil moisture	Commonwealth Scientific and Industrial Research Organisation (CSIRO) TERN data delivery portal – Soil and Landscape Grid[m]	1	Primary
	Other	Native vegetation extent	DPIRD (DPIRD-005: Native Vegetation Extent[n]	1	Primary
	Other	Trend in NDVI	Landgate – MODIS Vegetation Index Products (NDVI & EVI)[o]	1	Primary
	Other	Surface salinity	DPIRD (DPIRD-039: Soil Landscape Land Quality)[p]	1	Primary
Physical Capital		Composite map – combines all data within the Physical Capital component	Various	1.5	Secondary
	N/A	Road infrastructure	Data WA – Landgate: General Transport[q]	1	Primary
	N/A	Strategic community water supplies	DWER – Strategic Community Water Supplies[r]	1	Primary
	N/A	Scheme water coverage	Water Corporation (WCORP-002: Water Pipes)[s]	1	Primary

[a] https://www.abs.gov.au/statistics/people/population/regional-population-age-and-sex/latest-release; [b] https://www.abs.gov.au/methodologies/data-region-methodology/2015-20#data-download; [c] https://catalogue.data.wa.gov.au/dataset/dbca-legislated-lands-and-waters; [d] https://catalogue.data.wa.gov.au/dataset/south-coast-significant-wetlands; [e] https://catalogue.data.wa.gov.au/dataset/directory-of-important-wetlands-in-western-australia; [f] https://catalogue.data.wa.gov.au/dataset/ramsar-sites; [g] https://catalogue.data.wa.gov.au/dataset/hydrography-linear-hierarchy/resource/9908c7d1-7160-4cfa-884d-c5f631185859; [h] https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-water-polygon-lgate-016/resource/562b221a-ddb3-4e49-ae40-25a366f84a80; [i] http://www.bom.gov.au/water/groundwater/ngis/documentation.shtml; [j] https://catalogue.data.wa.gov.au/dataset/groundwater-salinity-statewide/resource/1882325f-f639-46fb-ba0a-d78889ac8b4b; [k] https://catalogue.data.wa.gov.au/dataset/public-drinking-water-source-areas/resource/33352803-7348-48d0-842f-de31b2f23c0c; [l] https://catalogue.data.wa.gov.au/dataset/land-capability-dryland-cropping/resource/f392dd06-00c0-4ff4-8c06-71c2d198dbf0; [m] https://portal.tern.org.au/soil-landscape-grid-release-1/23082; [m] https://catalogue.data.wa.gov.au/dataset/native-vegetation-extent/resource/a7a4b590-604c-4ebb-806a-0eb0451c1a27; [o] https://vip.arizona.edu/documents/MODIS/MODIS_VI_UsersGuide_June_2015_C6.pdf; [p] https://catalogue.data.wa.gov.au/dataset/soil-landscape-surface-salinity-current/resource/5a424acc-0d79-4b19-8690-3772163ab9ae; [q] https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-general-transport-line-lgate-117; [r] https://www.water.wa.gov.au/planning-for-the-future/rural-water-support/management-of-strategic-community-water-supplies

The maps were ground-truthed using participatory mapping exercises with the project advisory group, community and the technical working group and their feedback was incorporated into the final products.

The composite drought priority areas map (Figure 36 and Figure 37) has the potential to be a powerful decision-support tool for the South West of WA. There is a high level of confidence in the analysis as many of the included datasets are robust, regularly collected and available at high spatial and temporal resolution across southwest WA, including the participating Shires in the Southern Wheatbelt.

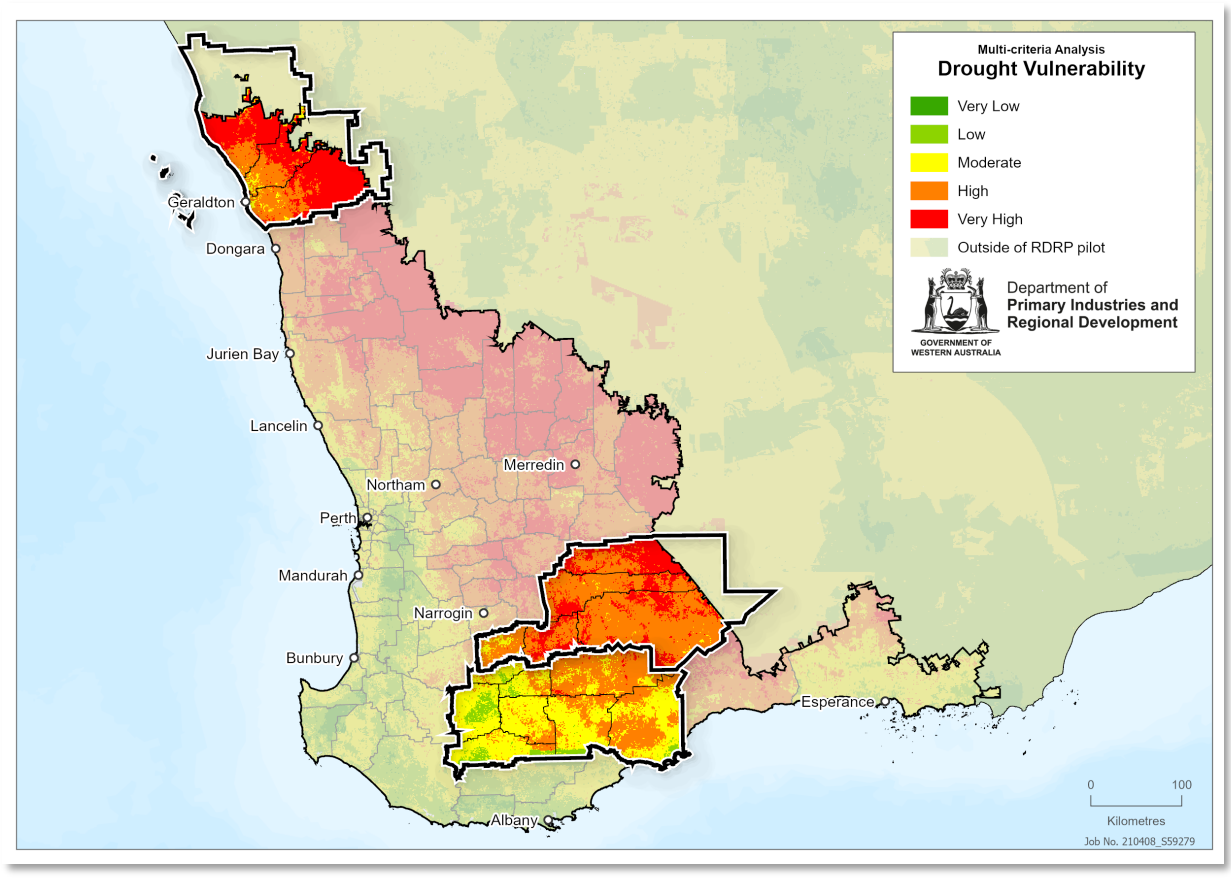

Figure 37: Final drought vulnerability map showing that the areas in Western Australia most vulnerable to drought are in the north and east of the region.

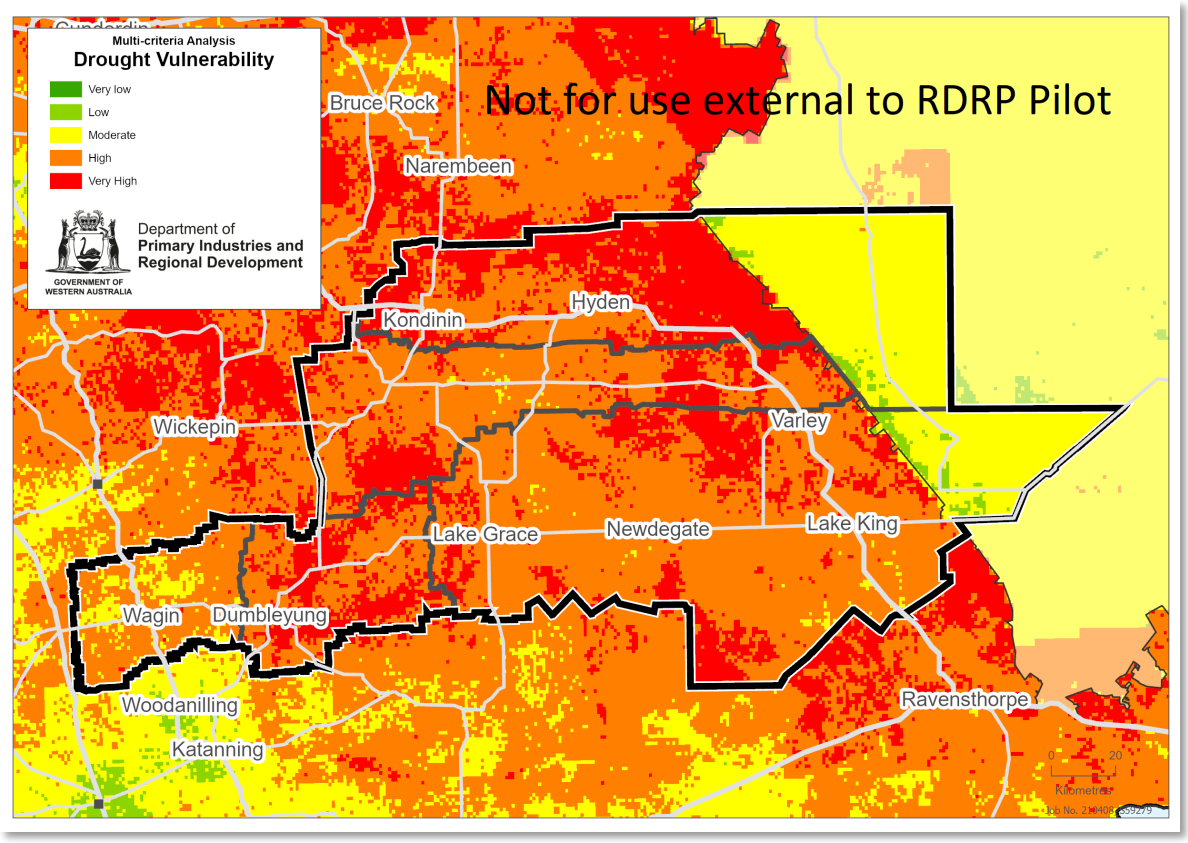

Figure 38: Final drought vulnerability map zoomed in to the Southern Wheatbelt region showing high to very high vulnerability across the region, with Kondinin more vulnerable than Wagin.

The links between the component datasets and impacts of drought well understood, for example low rainfall exacerbates drought risk, as does a shorter or warmer growing season; drought is associated with reduced production and farm income; problems with water quality or infrastructure can leave regional communities more vulnerable to the effects of drought.

The included datasets align well with regional communities' perceptions of how they are affected by drought, specifically low rainfall, high temperatures, compromised agricultural production, financial stress and shrinking regional communities. Those datasets in which we have lower confidence, either in terms of data quality and resolution or the link between the indicator and impacts of drought, are accounted for through the weighting structure applied throughout the analysis. There is a high level of agreement between the priority areas highlighted in the final map and those identified through participatory mapping with regional stakeholders.

Presenting information at the scale of the sub-national administrative unit enables direct embedding of the priority areas identified into wider government and institutional processes [226]. Spatial products such as the drought risk and resilience priority areas maps can provide significant support to decision-makers by collating complex climate, ecological, and socio-economic information into a single powerful image. These maps, developed together with regional stakeholders, are widely replicable.

As a next step, spatially defined priority areas need to be linked explicitly with clear, site-specific implementation activities, through participatory and stakeholder-engaged engaged planning and implementation.

A reporting detailing the analysis conducted by the DPIRD Climate Science and GIS team, additional workflow diagrams and additional regional maps for each component is available on request. See Section 10.

6.2 The Southern Wheatbelt maps

6.2.1 Drought Exposure map

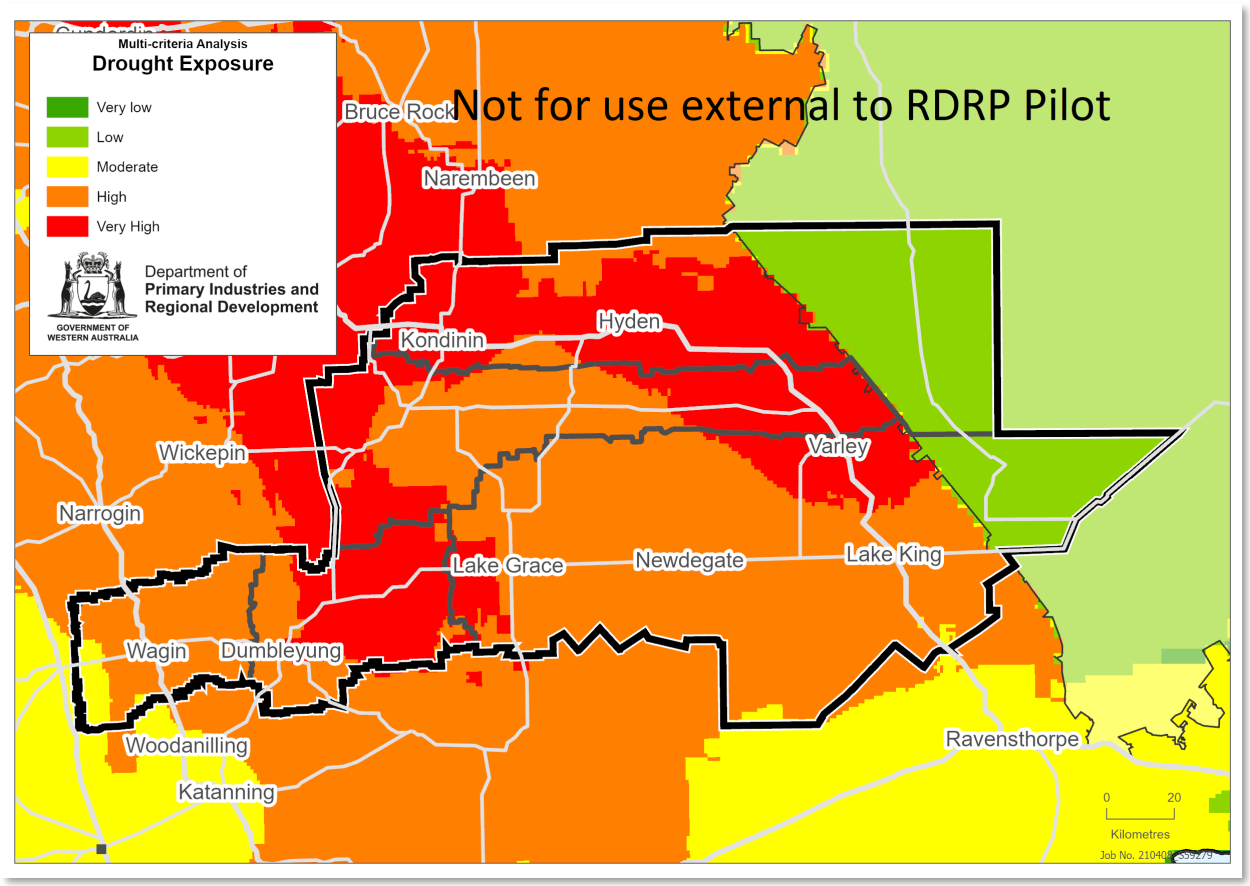

Figure 39: Southern Wheatbelt Drought Exposure Map

In the Southern Wheatbelt, exposure to drought ranges from moderate in the far west of the region (Wagin) to high (parts of Dumbleyung, Kondinin, Kulin and Lake Grace) and very high in Dumbleyung and the eastern edge of Kulin, Lake Grace and across the majority of Kondinin.

This result was influenced by the low incidence of rainfall events over 10mm and 25mm, the percentage change in the autumn break from 1975-1999 to 2000-2020, and decline in average yield potential from 1975-1999 to 2000-2020, number of hot days and decline in growing season rainfall.

6.2.2 Drought Sensitivity map

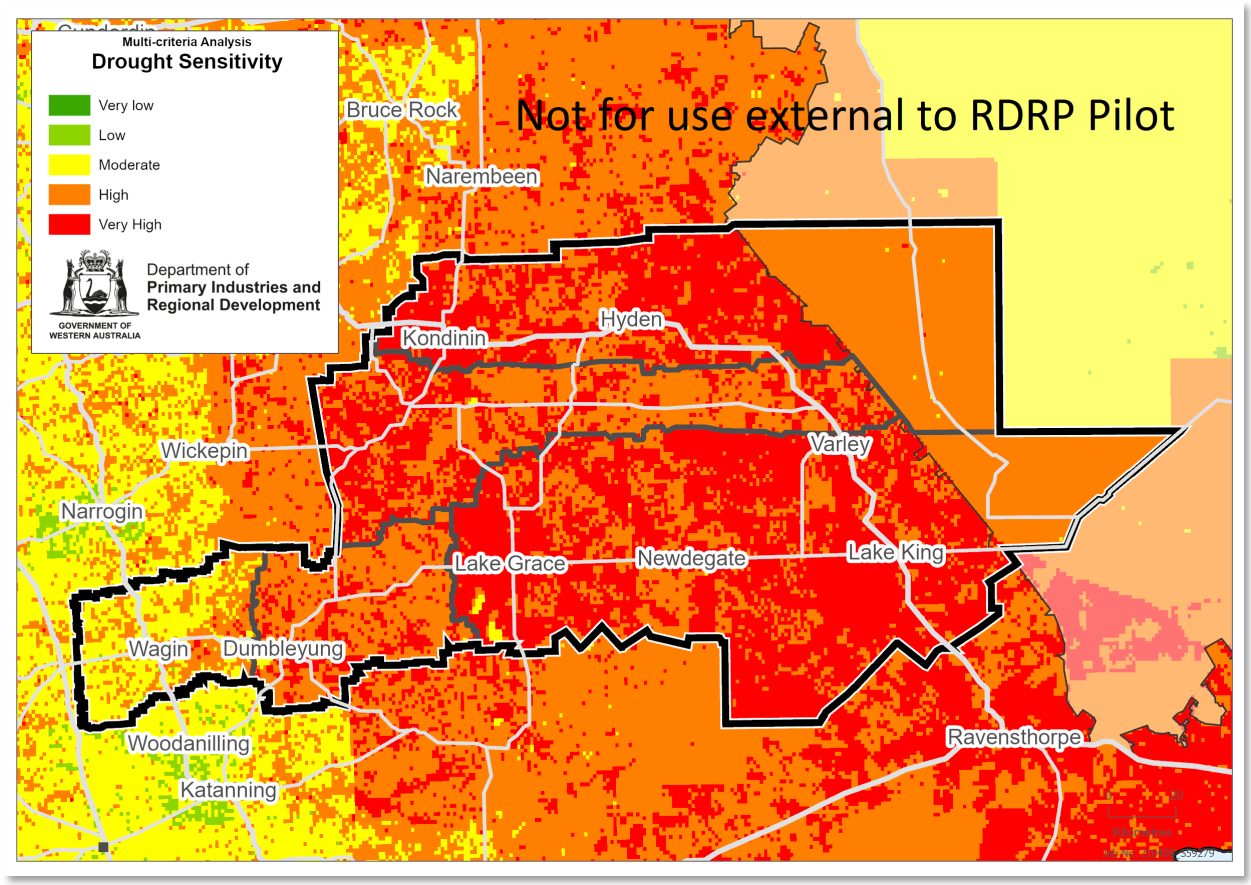

Figure 40: Southern Wheatbelt Drought Sensitivity map

The sensitivity to drought was determined using datasets related to production and economic and physical infrastructure.

In the Southern Wheatbelt, sensitivity to drought ranges from moderate-high in the far west of the region (Wagin) consistently high-very high across remaining parts of the region. Lake Grace and Kondinin have a higher proportion of very high sensitivity compared to other Shires.

Investigation of the datasets identify accessibility and remoteness, percentage of Drought Risk by farm profit, higher numbers of livestock in some Shires (Kondinin, Lake Grace), count of declared water deficiencies by Shire and low counts of water assets (bores and dams), and the high percentage of workers reliant on agriculture, may have contributed to the result.

6.2.3 Drought Impact map

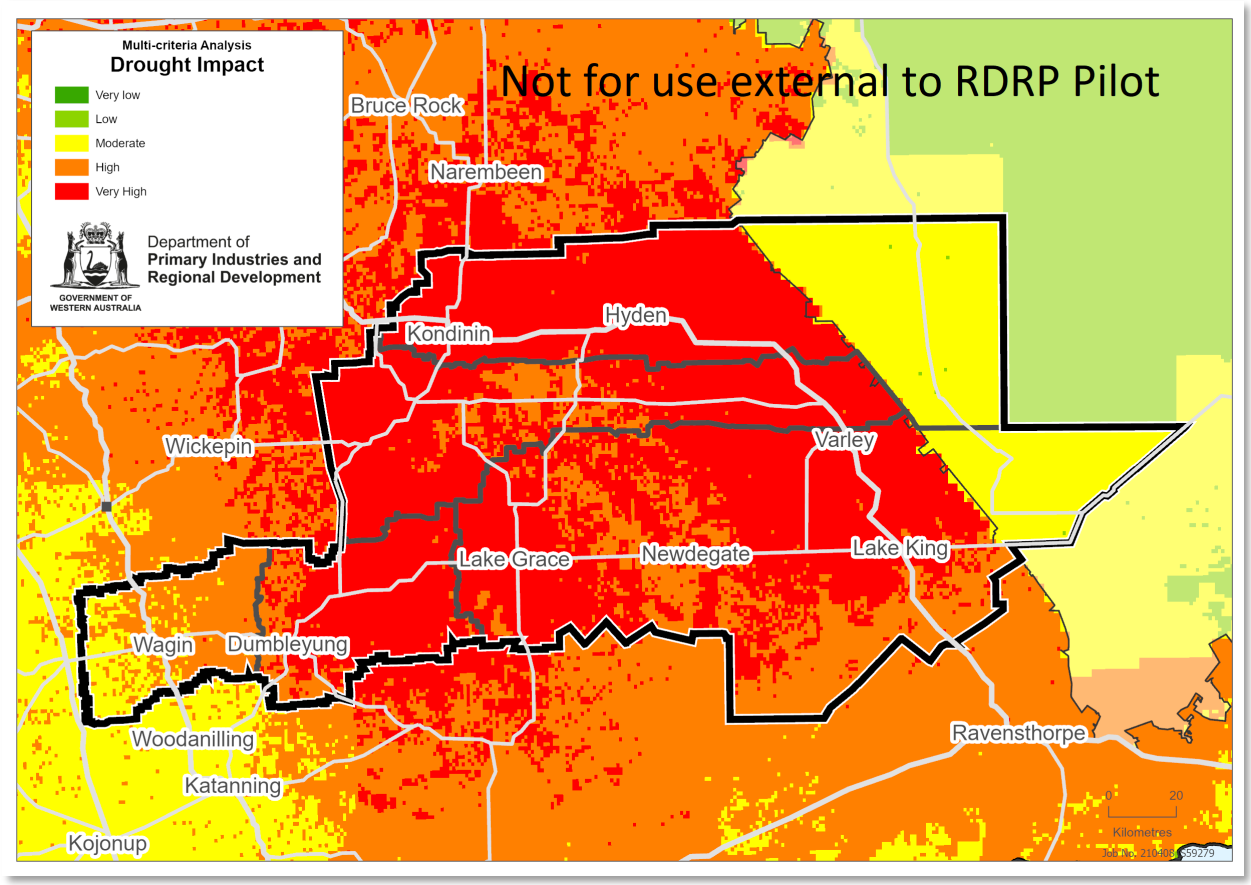

Figure 41: Southern Wheatbelt Drought Sensitivity map

The drought impact map is a composite of the Drought Exposure and Drought Sensitivity maps.

Apart from western Wagin, the entire Southern Wheatbelt RDRP study region has high and very high likelihood of being impacted adversely by drought.

Areas of most concern are the Shire of Kondinin, western and eastern Kulin, most of Dumbleyung, west and north east Lake Grace.

Actions that are targeted at improving the reliable harvesting and storage of water, support drought resilient farming systems, and diversification of economic activity across the region will support the ability of the region to lessen adverse impacts of drought.

6.2.4 Drought Adaptive Capacity Map

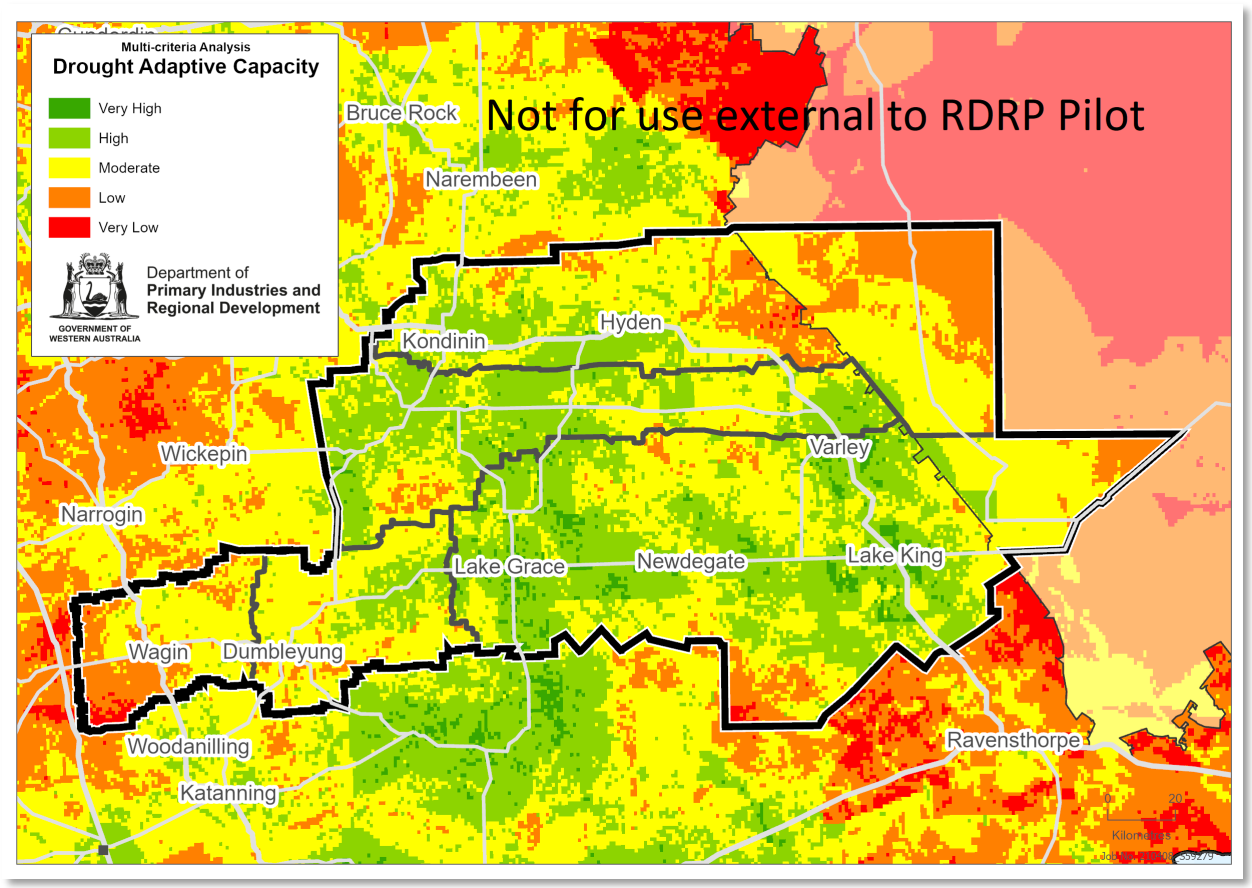

Figure 42: Southern Wheatbelt Drought Adaptive capacity map

The adaptive capacity map is made up of three composite maps for human capital, natural capital and physical capital.

This map is based primarily on the natural and physical capital of the region and limited in its depiction of human and social capital. Though through community consultation, and the outcomes of the social impact study, a strong link was identified between natural and physical capital and economic prosperity, which impacts on individual wellbeing and ultimately social and community resilience.

In the Southern Wheatbelt, the lower levels of adaptive capacity map are linked to the aging population (south west Wagin, east Kondinin), is less reliable from a human capital perspective, given lack of reliable and tracked human and social capital related datasets – for example, accurate information on presence and activity levels of community groups.

The very low unemployment rate across the region relates to better adaptive capacity, though this does not reflect the issues with attracting labour due to lack of housing options for workers. More exploration is needed of these factors to ascertain true adaptive capacity to drought.

6.2.5 Drought Vulnerability map

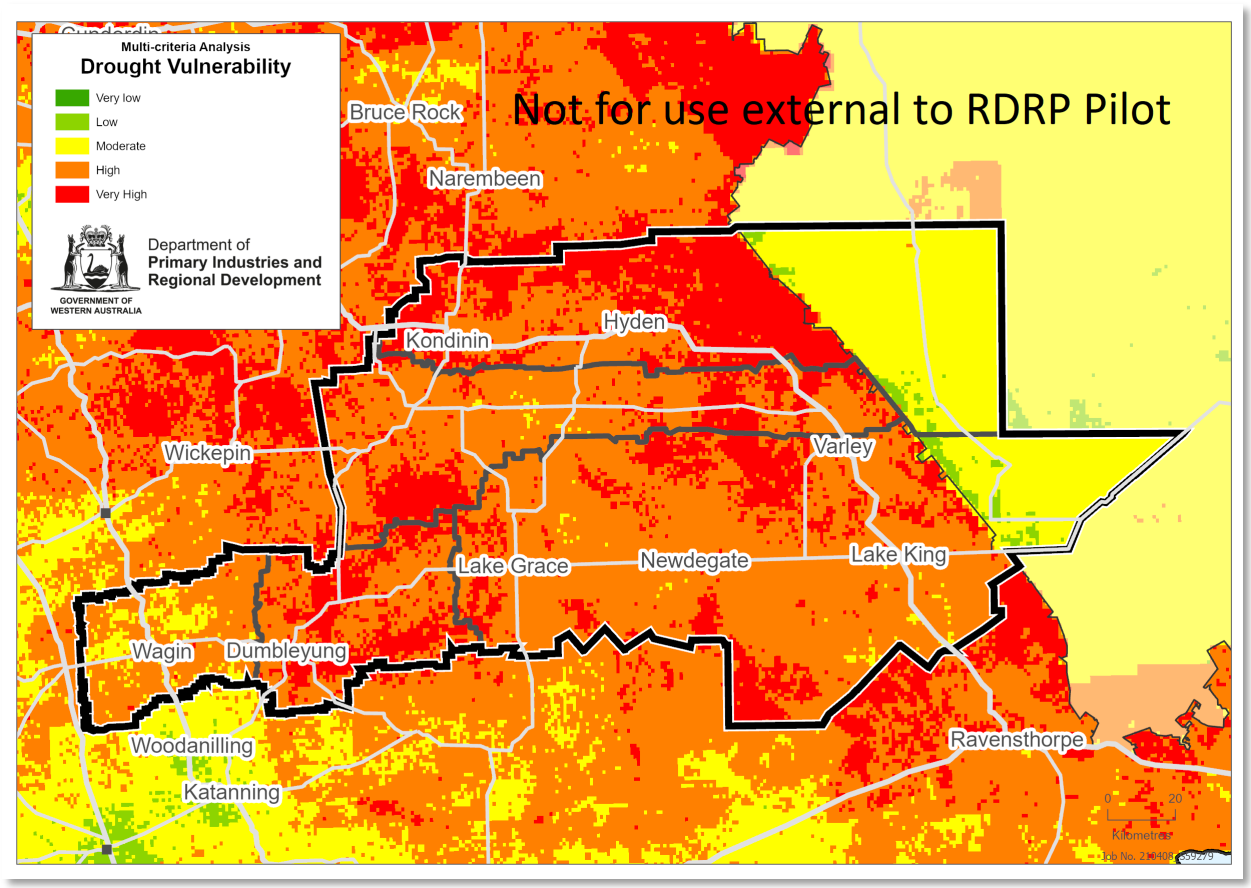

Figure 43: Southern Wheatbelt Drought Vulnerability map

The drought vulnerability map is a composite map of Adaptive Capacity and Drought Impact. There is variability in drought vulnerability across the Southern Wheatbelt.

Further assessment of the region's drought vulnerability is provided in Section 8.

A copy of the MCAS methodology and results can be provided on request. See Section 10.

7. Drought Vulnerability Assessment

The reports presented in this section summarise several different possible approaches to assessing drought vulnerability focusing primarily on measurable biophysical and economic indicators (Indicators of Drought) or primarily on socio-economic factors (Measuring Drought Resilience, Assessing Vulnerability to Drought). These contributions were considered and incorporated into the overarching conceptual framework for the vulnerability assessment.

Further work is needed to consolidate the different approaches and agree on a final vulnerability assessment framework for regional drought resilience planning in Western Australia. While the current drought vulnerability assessment for the Southern Wheatbelt is best represented by the regional drought priority areas maps in Section 6 of this report, the spatial analysis is limited in its ability to include social and economic data. These limitations are addressed in the approaches either tested or outlined below.

A final framework, which could be used for future years of the project, will be informed by the approaches outlined below and the lessons learned during the development and implementation of the draft framework during the foundational year 2021-22.

7.1 Indicators of Drought

Understanding the social and economic impacts of drought is critical for informing policies and initiatives to adequately prepare regions for drought and support them during and post drought. Drought indicators are generally described using observable changes in rainfall, temperature, soil moisture and other factors, though it was not clearly understood if these parameters can used to reliably predict social and economic impacts.

The project team commissioned CSIRO to conduct an analysis of social, economic and environmental data recently compiled by the Nous Group [227] to test whether social and economic impacts of drought (indicators) can be predicted from more readily measurable environmental and economic variables. Recently, machine learning models have been used successfully in predicting remote-sensed drought indices around the world, including the southern United States [228], Iran [229], Ethiopia [230] and the UK [231]. Noting this, the team used two machine learning methods, random forests [232] and regression trees [233], to model three social and five economic indicators (Table 8) as a function of environmental and economic variables (Table 9) for the broadacre cropping regions of southwest WA (*Figure 43*).

Table 7: The social and economic indicators used in the analysis conducted by CSIRO, along with the associated code used to refer to the indicator in the figures below, frequency at which data were collected and years for which data are available.

TYPE	INDICATOR	CODE	FREQUENCY	YEARS
Social[a]	Mental health-related presentations to emergency departments per 10,000 population	mh_ed	Annual	2015–2019
Social[a]	Episodes of residential mental health-related care per 10,000 population	mh_res	Annual	2013–2019
Social[a]	Mental health-related community contacts per 10,000 population	mh_comm	Annual	2014–2018
Economic[b]	Number of debtors in the past quarter per 100,000 population	debtors_q_pp	Quarterly	2007–2019
Economic[c]	Farm-based profit percentile rank score	farmprof_y	Annual	2000–2019
Economic[d]	Internet Vacancies Index, all occupations	ivi_tot	Monthly	2010–2020
Economic[e]	Social Security payments per person	ss_payments_pp	Quarterly	2015–2019
Economic[f]	Unemployment rate	unemployment	Quarterly	2010–2020

[a] Australian Institute of Health and Welfare [234], [b] Australian Financial Security Authority [235], [c] Australian Bureau of Agricultural and Resource Economics and Sciences [236], [d,f] Labour Market Information Portal [237, 238], [e] Australian Department of Social Services [239].

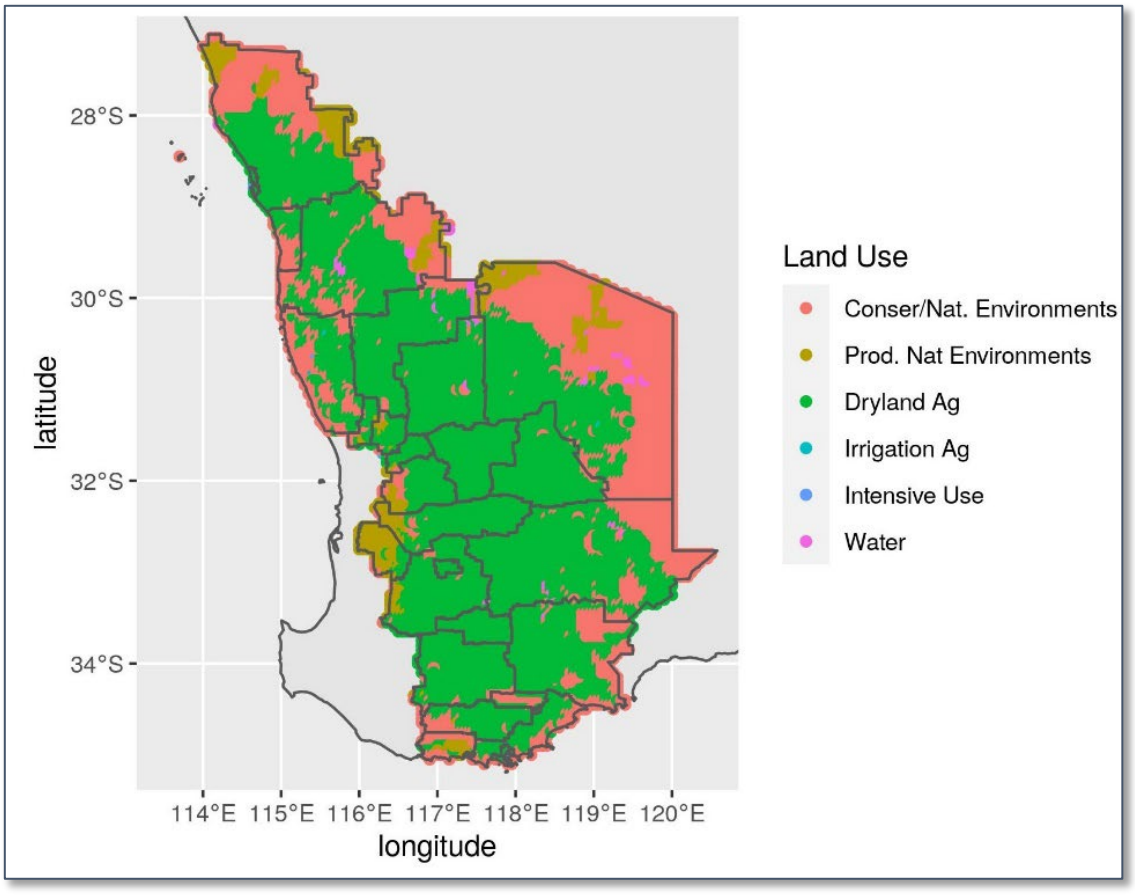

Figure 44: The area covered in the analysis conducted by CSIRO, also showing primary land use across this area; includes RDRP focus regions in WA. Boundaries shown are the included Statistical Area Level 2 (SA2) regions noting that the land connecting the three regions is of similar land use.

Table 8: The environmental and economic variables included in the analysis as predictors, along with the associated code used to refer to the predictor in the figures below, frequency at which data were collected and years for which data are available.

TYPE	INDICATOR	CODE	FREQUENCY	YEARS
Environmental[a]	Daily average rainfall in past 12 months	rain_y	Monthly	2000-2020
Environmental[b]	Mean maximum temperature over last 12 months	temp_max_y	Monthly	2000-2020
Environmental[c]	Average Forest Fire Danger Index over past 12 months	ffdi_y	Monthly	2000-2020
Environmental[d]	Root zone soil moisture for the past 12 months as an absolute value	soil_y_abs	Monthly	2000-2020
Terrestrial[e]	Growth in proportion of land that is vegetated as a percentile in overall distribution of growth over the years	veg_cov_ygp	Monthly	2002-2020
Terrestrial[f]	Relative proportion of land that is vegetated in past 12 months as a percentile in overall distribution of years	veg_cov_yp	Monthly	2001-2020
Terrestrial[g]	Monthly snapshot of proportion of land that is bare soil	bare_soil_m	Monthly	2001-2020
Economic[h]	Hours of agricultural-related employment (including downstream manufacturing) as a proportion of all employment	ag_related_empl_prop	Quarterly	2001-2020
Economic[i]	Index of Relative Socio-Economic Disadvantage	seifa	Every 4 years	2001-2016
Economic[j]	Economic Diversity Index (Hachman index based on employment by industry division)	edi	Assumed constant	2016

[a,b,c,d] Australian Government Bureau of Meteorology [240, 241, 242, 243], [e,f,g] National Computational Infrastructure Australia [244], [h,i] Australian Bureau of Statistics [245, 246], [j] Nous Group [247]

Temperature, rainfall and Forest Fire Danger Index were related to social and economic indicators and the predictive models fit well, returning sensible predictions for known relationships (e.g. between rainfall, vegetation cover and farm profits [248]). The team detected a clear signal relating environmental predictors (rainfall, temperature, vegetation cover, soil moisture etc.) coupled with temporally stable economic predictors (proportion employed in agriculture, EDI, SEIFA Index) to social and economic indicators. The relationships were, however, highly non-linear and difficult to interpret, with often contradictory results where one pathway to negative impacts may be drought related but others were clearly not. For example, regression trees for social indicators related to mental health included some branches with expected relationships if drought conditions were related to mental health impacts, but also many branches that were not related to drought conditions. This inconclusive result highlights that there are many factors influencing mental health in addition to drought.

The relationships were, however, highly non-linear and difficult to interpret, with often contradictory results where one pathway to negative impacts may be drought related but others were clearly not (Figure 45, Figure 46, Figure 47). For example, regression trees for social indicators related to mental health included some branches with expected relationships if drought conditions were related to mental health impacts, but also many branches that were not related to drought conditions.

This inconclusive result highlights that there are many factors influencing mental health in addition to drought.

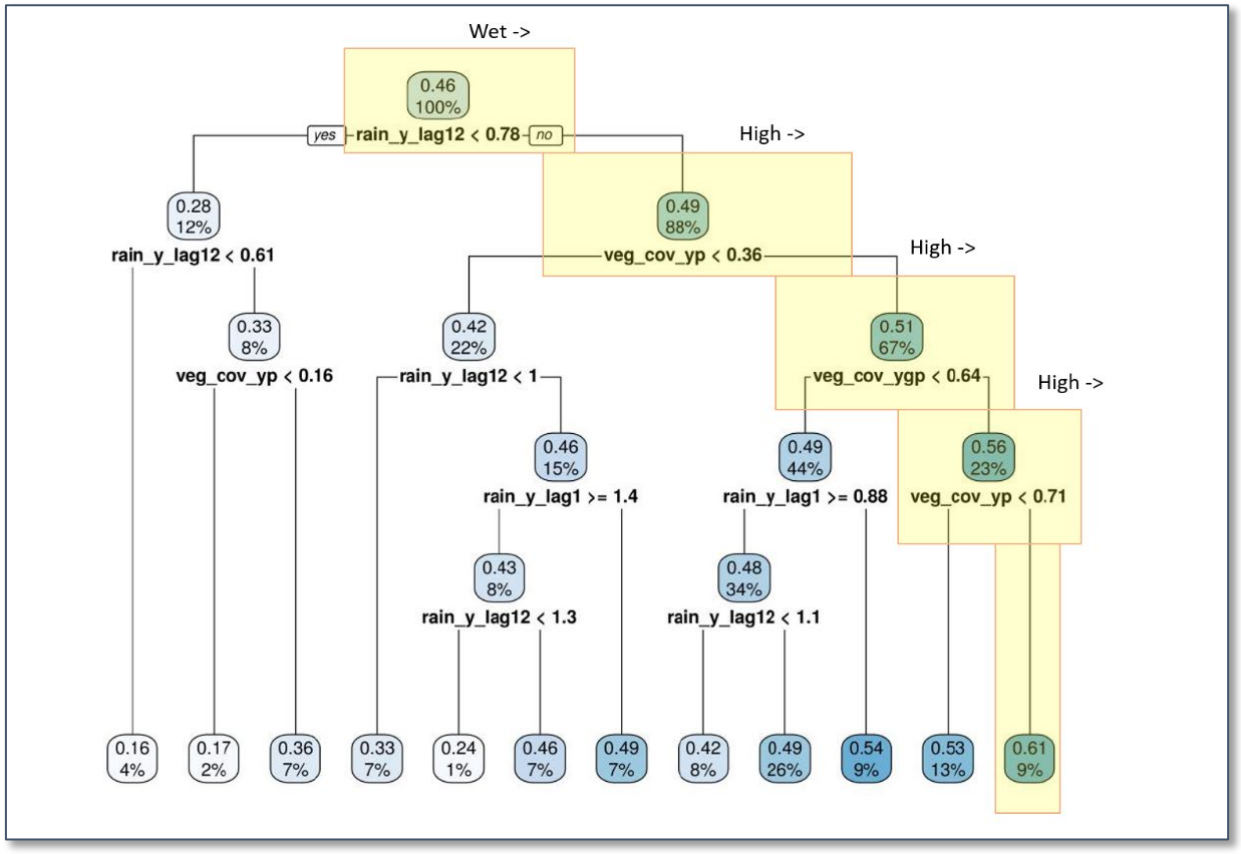

Figure 45: Regression tree estimating farm profit percentile rank score. White values indicate smaller values while blue values are higher. Left at each node indicates the stated condition has been met while right indicates not met. The number in each node represents the predicted value while the percentage represents the percentage of observations in the node. Yellow boxes show the predicted pathway to the node with the highest estimated value.

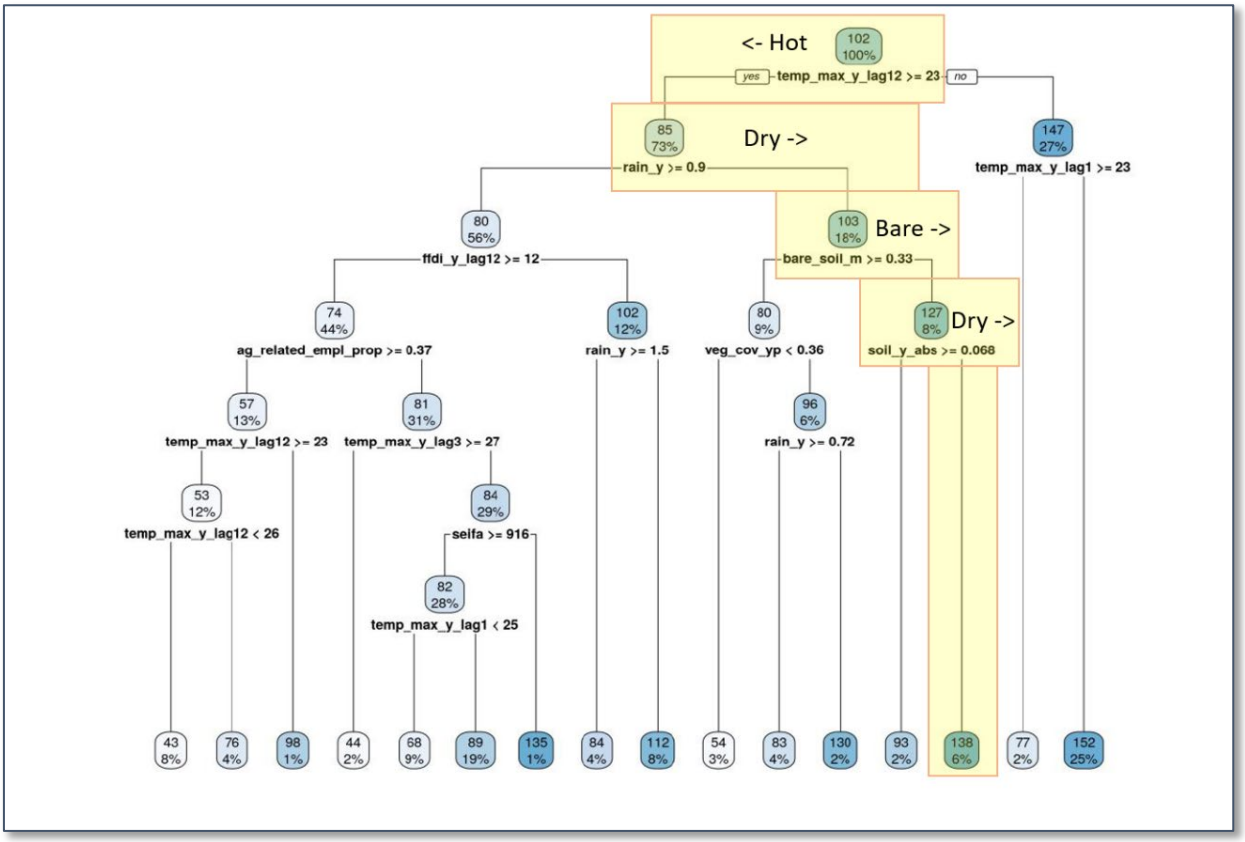

Figure 46: Regression tree estimating mental health related presentations to the emergency department per 10,000 population. White values indicate smaller values while blue values are higher. Left at each node indicates the stated condition has been met while right indicates not met. The number in each node represents predicted value while the percentage represents the percentage of observations in the node. Yellow boxes show the predicted pathway to the node with the second highest estimated value, an example of a pathway consistent with drought conditions as a driver. The highest number of mental health presentations to the emergency department (far right terminal node) occurred during lower temperatures, a result inconsistent with drought as a driver.

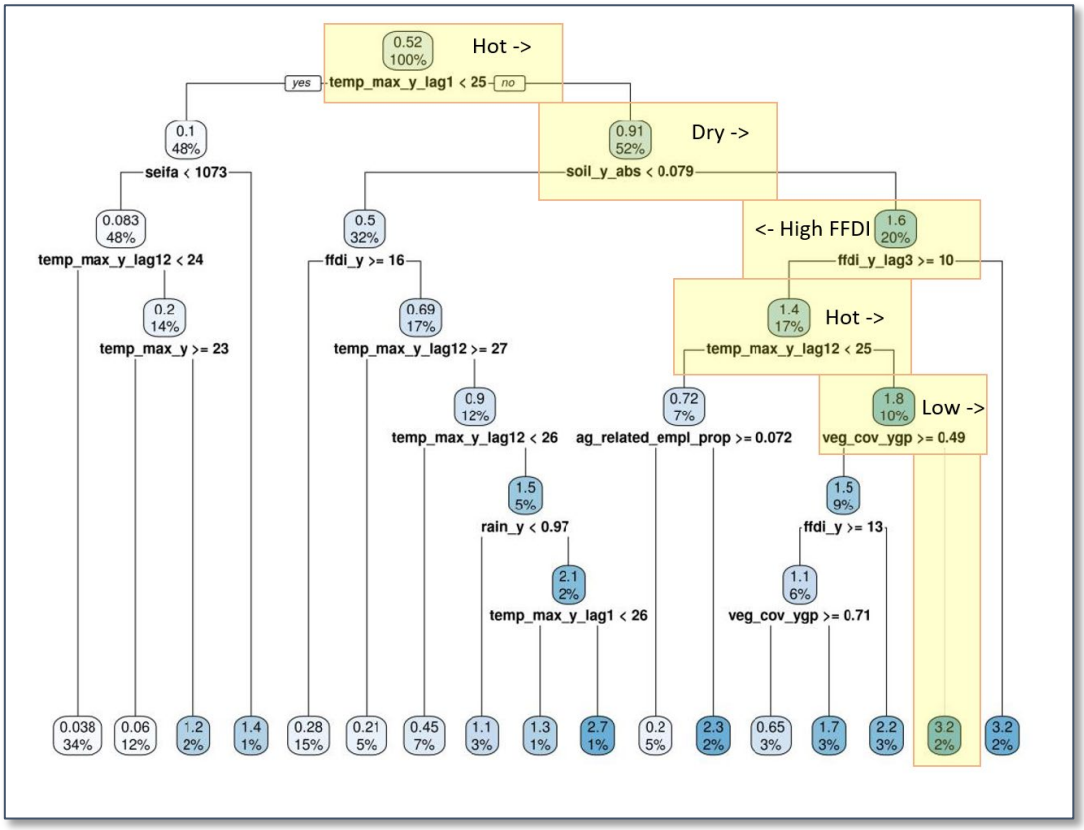

Figure 47: Regression tree estimating episodes of residential mental health related care per 10,000 population. White values indicate smaller values while blue values are higher. Left at each node indicates the stated condition has been met while right indicates not met. The number in each node represents predicted value while the percentage represents the percentage of observations in the node. Yellow boxes show the predicted pathway to the node with the equal highest estimated value, an example of a pathway consistent with drought conditions as a driver. The highest number of episodes of residential mental health related care (far right terminal node) occurred during warm temperatures but relatively high soil moisture and low FFDI, a result inconsistent with drought as a driver.

It is difficult for this analysis to definitively attribute driving conditions of drought (such as low rainfall, high temperature and low soil moisture) to social and economic impacts becoming more severe. While this work did determine a strong predictive model using the selected variables, the non-linear nature and complexity made it difficult to effectively attribute the relationship to drought. Several of the predictive pathways were not consistent with drought as the main driver of the measured social and economic impacts.

Further work is required to unpack the described relationships and further understand the links between social and economic impacts and environmental and economic predictors in the context of drought. This may include the application of a working definition of drought, or better-defined environmental predictors such as relative temperature and rainfall changes that account for spatial variation over the broadacre cropping regions of southwest WA. Initial exploration accounting for geographical influences has shown promise.

A copy of the full CSIRO Drought Indicators report is available on request. See Section 10.

7.2 Measuring Drought Resilience

Drought resilience can be difficult to measure. It is, however, important to attempt measurement to assist regional communities with assessing and prioritising their needs and goals, establish baselines for monitoring progress and recognising success and to raise awareness of the costs and benefits of resilience building activities [249].

As resilience can rarely be measured directly, assessment is commonly made via indices (containing indicators which represent a selected characteristic of resilience), scorecards (an evaluation of performance or progress toward a goal) and tools (models, frameworks or toolkits developed to measure resilience), all of which rely on a suite of proxy variables to represent likely resilience [250]. Currently, resilience is typically measured based on characteristics of a community as it now exists, not as the potential for transformations that will / could happen within and to that community after a crisis such as drought. This makes it challenging to measure transformational capabilities using indices.

A list of existing community disaster resilience assessment measures in use around the world is displayed in Table 10. Common elements in measures for assessing community resilience include attributes and assets (economic, social, environmental, infrastructure) and capacities (social capital, community functions, connectivity, planning, governance).

Assessing resilience consists of measuring a core set of attributes and assets, capacities and proxy measures including:

- economic capacities or indicators such as education, education equality, annual income, wealth of retirees, household income;
- social capacities or indicators such as the number of civic organisations and registered non-profit organisations, health access, faith-based networks;
- Community capacities and indicators such as physical assets, infrastructure and community services;
- environmental indicators such as impervious surfaces that prevent or hinder absorption of water into the soil; and
- institutional or governance indicators such as plans, support programs, insurance policies.

Table 9: Existing disaster resilience assessment measures used in the United States[195]

Measure	Type
Communities Advancing Resilience Toolkit [251]	Tool
Conjoint Community Resiliency Assessment Measure (CCRAM) [252]	Tool
Coastal Resilience Index [253]	Scorecard
Community Based Resilience Analysis [254]	Tool
Community Resilience System [255]	Tool
Community Resilience Index [256]	Index
Food and Agriculture Organisation Livelihoods [257]	Index
Oxfam Great Britain [258]	Index
Population and Demographics, Environmental/Ecosystem, Organized Governmental Services, Physical Infrastructure, Lifestyle and Community Competence, Economic Development, and Social-Cultural Capital (PEOPLES) [259]	Tool
Rockefeller 100 Resilient Cities [260]	Tool
Rural Resilience Index [261]	Index
San Francisco Bay Area Planning and Urban Research Association [262]	Scorecard

An inclusive and adaptive social-focused drought resilience framework could consist of five sub-dimensions of social resilience: social structure, social capital, social mechanisms, social equity and social belief [263]. Such a framework includes a set of 16 characteristics and 46 corresponding indicators for measuring social resilience (*Figure 47*) based on the most used and important resilience characteristics in the global literature. This framework can be adapted to any geographical area, hazard or community context and many of the indicators are available in the public domain. Where possible, local indicators will also need to be sourced and matched to each dimension. During the foundation year, UWA developed a draft framework based on the available literature and did not have time to apply it to the regions.

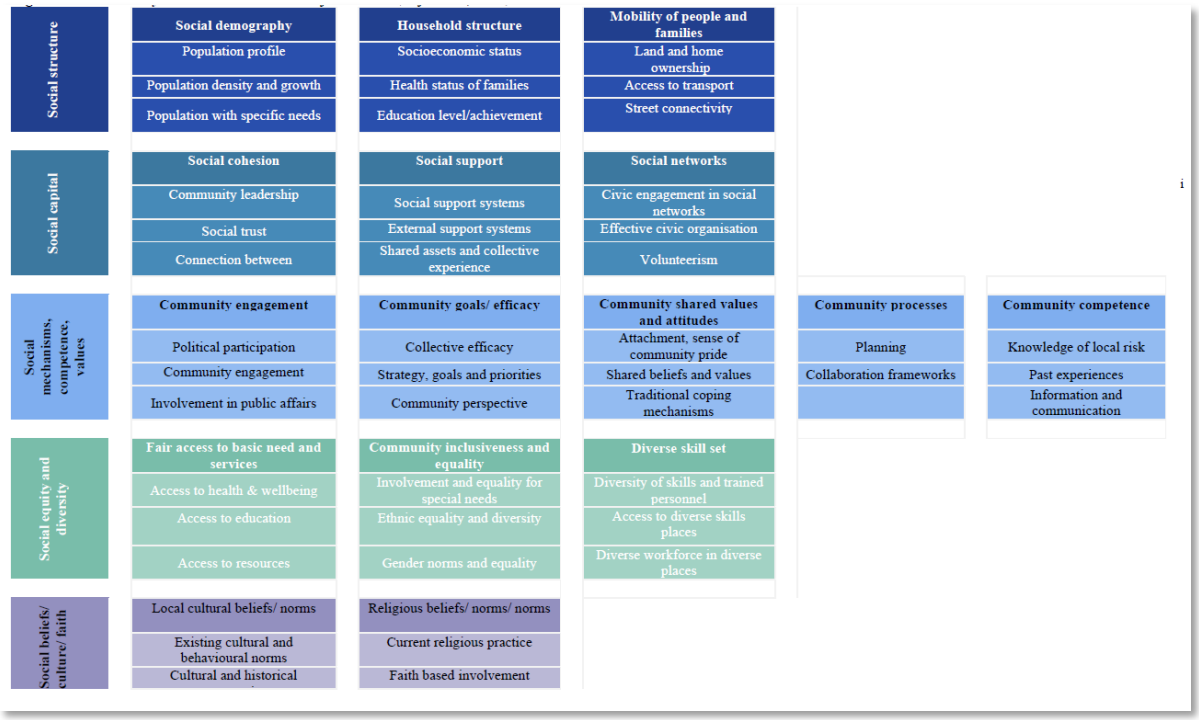

Figure 48: Framework for measuring community resilience.

The full report from the UWA Centre for Social Impact is available on request. See Section 10.

7.3 Assessing Vulnerability to Drought

Drought vulnerability is the degree of susceptibility within society to, and the capacity to cope with, the adverse impacts of drought[264]. It is a function of three major drivers: exposure to drought, the sensitivity of the community to the impacts of drought and the capacity of the community to adapt to drought (see Introduction to this report).

Vulnerability assessments aim to identify vulnerable places and populations and determine ways to make the affected place or population more resilient. This is achieved through identifying underlying causes of risk such as inadequate infrastructure, management or technology, or economic, environmental and social factors. A review of the literature shows that social, economic, physical, crime and conflict, governance, environment and farming practice risk factors are among the important metrics to include in a vulnerability assessment[211, 265, 266, 267].

The framework in *Figure 48* suggests the dimensions, factors and possible indicators that could be included when measuring drought vulnerability. Many of the listed indicators are available as publicly held datasets.

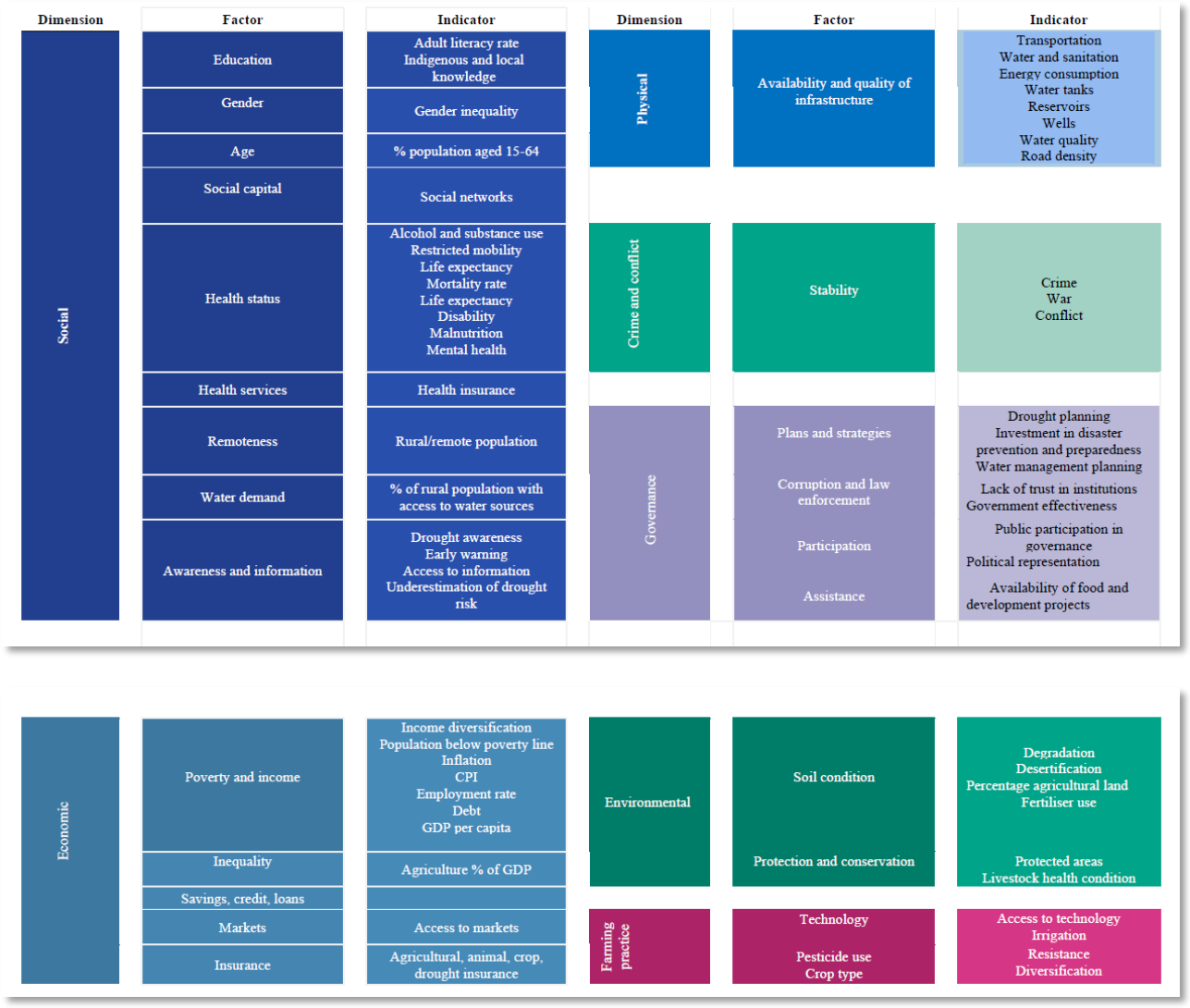

Figure 49: Suggested framework for a risk assessment component of drought vulnerability assessment.

Crisis management is the basis of much drought response activity the world over. Studies have shown, however, that effective drought management strategies are based on proactive risk assessment and risk management[213]. Drought risk management involves risk reduction (prevention, mitigation, preparation), disaster management (alert, response) and recovery and adaptation (rehabilitation)[268].

Prevention involves the ongoing involvement of the community and local government in the dissemination of information, promotion of water conservation and sustainable water practices, monitoring of health in vulnerable groups and capacity building of local health services.

Mitigation involves working with local stakeholders in the local community to identify, measure and reduce risk and vulnerability in the community, promoting participation in public policy programs for water resource infrastructure and participating in efforts to address drought impacts.

Preparation involves assessing response capacity, identifying local resources, establishing partnerships for action, participating in vulnerability and risk assessments, establishing an action plan, and working with community leaders and local government to inform and create awareness within the community.

Alert involves the active identification of vulnerable groups and the issue of timely and clear warnings to affected groups and communities.

Response involves identifying the direct and indirect impacts of drought and the providing an integrated, thorough and timely response.

Rehabilitation involves the evaluation of community vulnerabilities, risks, impacts and resilience to develop interventions. A coordinated and supportive government response is needed to empower the community, improve adaptive capacity and enhance community resilience in the long term.

A list of drought risk reduction and adaptation strategies is included in *Figure 49*, based on a review of more than 40 studies[221]. These strategies include structural (engineering-based or technical) solutions and non-structural solutions at the individual, government and ecosystem level.

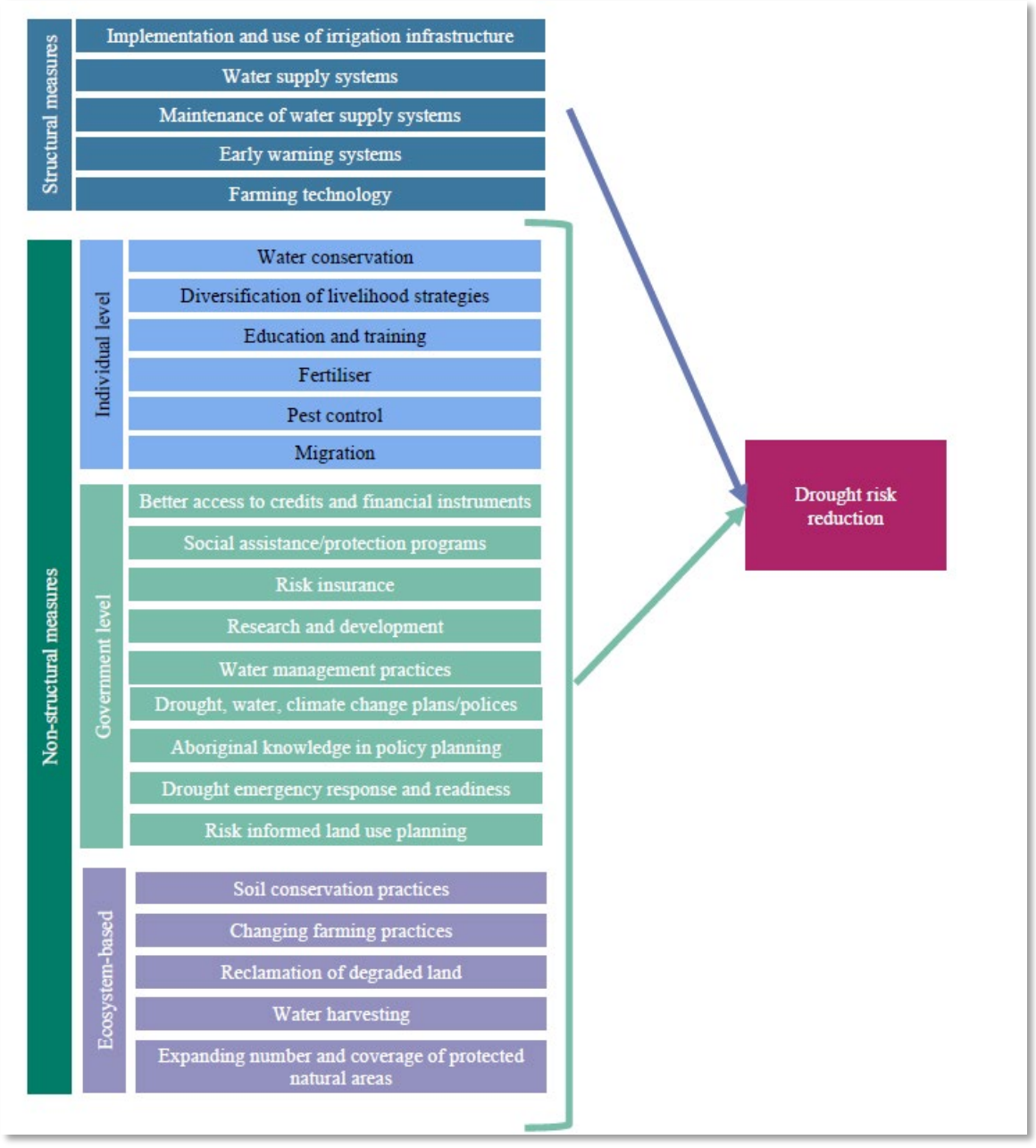

Figure 50: drought risk reduction and adaptation options based on literature review.

8. A Vulnerability Index for the Southern Wheatbelt

This chapter presents a Vulnerability Index for the Southern Wheatbelt region, which aims to assist local decision makers and managers in the rapid evaluation of drought risk in the region. The index designed to track change over time for the study, although it could be adapted for any region across WA and is primarily based on the regional and national datasets used throughout this report. The index could be a repeatable exercise providing a snapshot of vulnerability to drought, tracked over time.

The analysis utilizes the overarching DVA conceptual framework (*Figure 4*), understanding overall vulnerability as the outcome of interacting exposure, sensitivity and adaptive capacity parameters. We have used several indicators within each category to serve as proxies for **exposure**, **sensitivity** and **adaptive capacity** (Table 11).

Each sub-indicator was scored using a 1-5 sliding scale where 1 represents the most desirable condition (low vulnerability) and 5 represents the least desirable state (high vulnerability) in terms of drought risk. The data used for determining scores for each indicator were drawn from the same (largely) publicly available datasets used to create the drought risk priority areas map in Section 6 of this report. Scores represent the average for the region as a whole.

Table 10: List of the indicators used as proxies for exposure, sensitivity and adaptive capacity to calculate an index of vulnerability for the Southern Wheatbelt region.

Component	Data Set	Score
Exposure	Projected change in growing season rainfall and maturing season temperature	2
	Change in timing of the autumn break to date	4
	Change in drought frequency to date	4.5
Sensitivity	Production risk (crop and livestock combined)	2.5
	Trend in NDVI (lowest 10%)	3.5
	Percentage employment in agriculture	5
Adaptive capacity	Percentage unemployment	2
	Access to infrastructure	1.5
	Soil capability	3
	Ground water	5
	Average score	**3.3**

8.1.1 Exposure

Indicator 1 - Projected change in temperature and rainfall

Temperature change is the change in number of days above 34ºC August to November by 2050 based on data from Climate Services for Agriculture.

Rainfall change is the percentage change in rainfall April to October by 2050 based on data from Climate Services for Agriculture.

Sliding scale 1-5

- 1 No increase in number of hot days, no change or an increase in rainfall
- 2 Moderate increase in number of hot days (<2.5), moderate decrease in rainfall (<15%)

- 3 High increase in number of hot days (<2.5 more hot days), moderate decrease in rainfall (<15%)
- 4 Moderate increase in number of hot days (<2.5), large decrease in rainfall (≥15%)
- 5 High increase in number of hot days (≥2.5 more hot days), large decrease in rainfall (≥15%)

Given that Australia is a water stressed country overall, significant projected reductions in annual average rainfall will have stronger negative consequences than projected increases, which we take to represent opportunities.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 2 for drought risk in terms of projected temperature and rainfall change, showing moderate increases in temperature and moderate drying.

Description: Growing season rainfall is projected to decline by 10-15% across the entire region by 2050. The number of hots days during the maturing season is not expected to increase significantly across southern parts of the sub-region, increases of up to 2.5 days are expected in Kondinin and parts of Kulin (Figure 50: Maps showing (a) projected change in the number of hot days during the wheat maturing season by 2050 and (b) projected change in growing season rainfall shown as percentage change by 2050.).

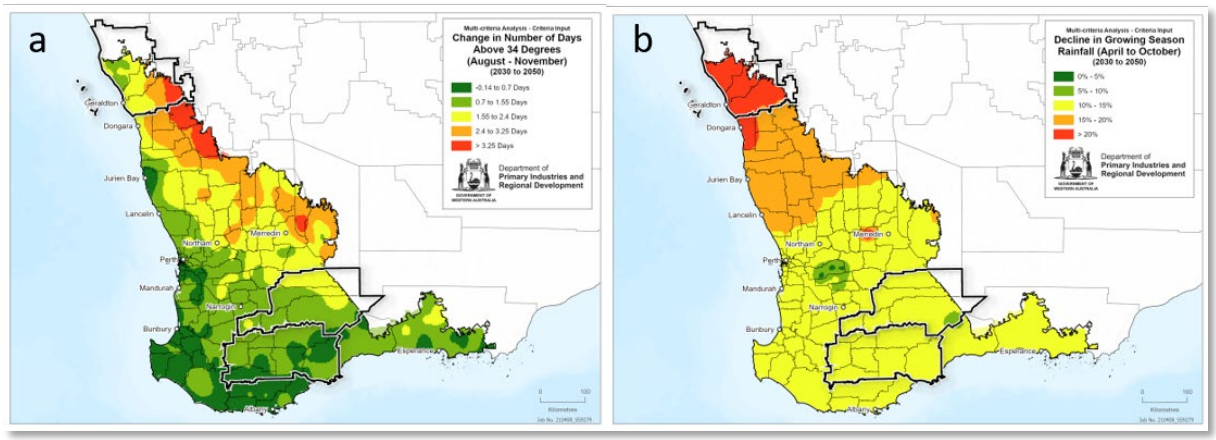

Figure 51: Maps showing (a) projected change in the number of hot days during the wheat maturing season by 2050 and (b) projected change in growing season rainfall shown as percentage change by 2050.

Indicator 2 - Change in timing of the autumn break

The data show the percentage difference between the median break of season for the period of 1975-1999 and 2000-2020, interpolated using DPIRD and BOM automatic weather stations. Autumn break is defined as at least 25 mm of rainfall over three consecutive days prior to the commencement of sowing.

Sliding scale 1-5

- 1 Percentage decrease in timing of the autumn break – break occurs earlier
- 2 Autumn break occurs later (0-2%)
- 3 Autumn break occurs later (3-5%)
- 4 Autumn break occurs later (6-8%)

- 5 Autumn break occurs later (≥9%)

Given that temperatures in region are too high to support wheat production in the late spring and summer months, a later autumn break shortens the available growing season.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 4 for drought risk in terms of change in timing of the autumn break experienced to date.

Description: Change in timing of the autumn break is variable in the Southern Wheatbelt, though has tended towards a later break of between 3 and 6% to some areas more than 9% (Figure 51).

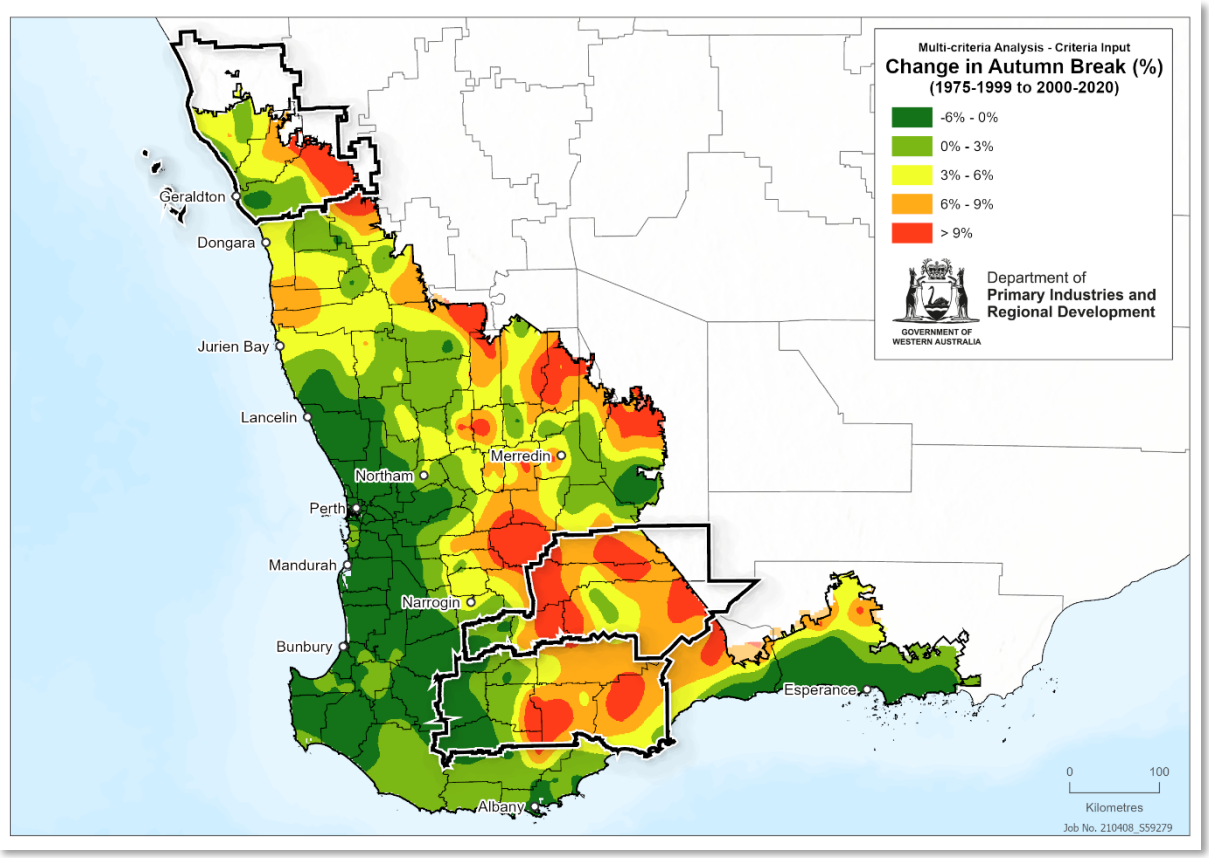

Figure 52: Change in timing of the autumn break.

Indicator 3 - Change in drought frequency

The data show different in the number of droughts that occurred during 1980-1999 compared to 2000-2020 (see Section 2). Drought is defined as rainfall during the growing season in the 10th percentile. It is calculated for each year against the average rainfall over the preceding 40 years.

Sliding scale 1-5

- 1 Three or four fewer droughts
- 2 One or two fewer drought
- 3 Equal number of droughts

- 4 One or two more droughts
- 5 Three or four more droughts

An increasing number of droughts is undesirable because droughts are associated with failed crop and livestock production.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 4.5 for drought risk in terms of increasing drought frequency.

Description: Half the Southern Wheatbelt region has experienced 1 or 2 more droughts in the last 20 years, and half 3 or more compared to the preceding 20 years (*Figure 52*).

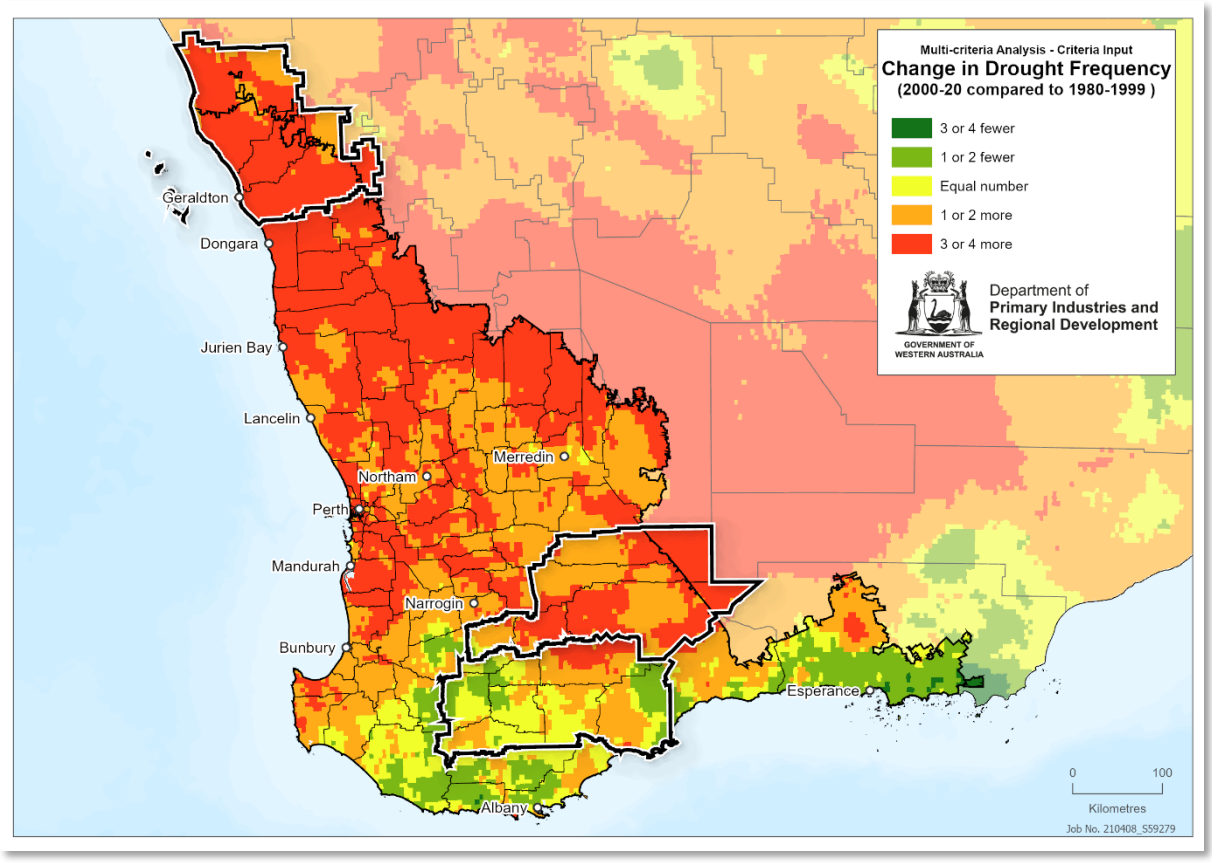

Figure 53: Change in drought frequency.

8.1.2 Sensitivity

Indicator 1 - Production risk

The assessment of production risk incorporates measures of average production in the region for wheat, barley, canola, sheep and cattle, high quality agricultural land, wheat yield potential and 20-yr average NDVI (see Section 4).

Sliding scale 1-5

- 1 Very low risk – good production, good soils and high average NDVI
- 2 Low risk
- 3 Moderate risk

- 4 High risk
- 5 Very high risk – marginal production, poor soils and low average NDVI

This indicator operates on the assumption that higher levels of production and ground cover are desirable and promote resilience.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 2.5 for drought risk in terms of production risk.

Description: While there are some more marginal areas in terms of average production, soil quality and/or average NDVI in the eastern parts of the region, the majority of the region is classified as having low to moderate production risk (Figure 53).

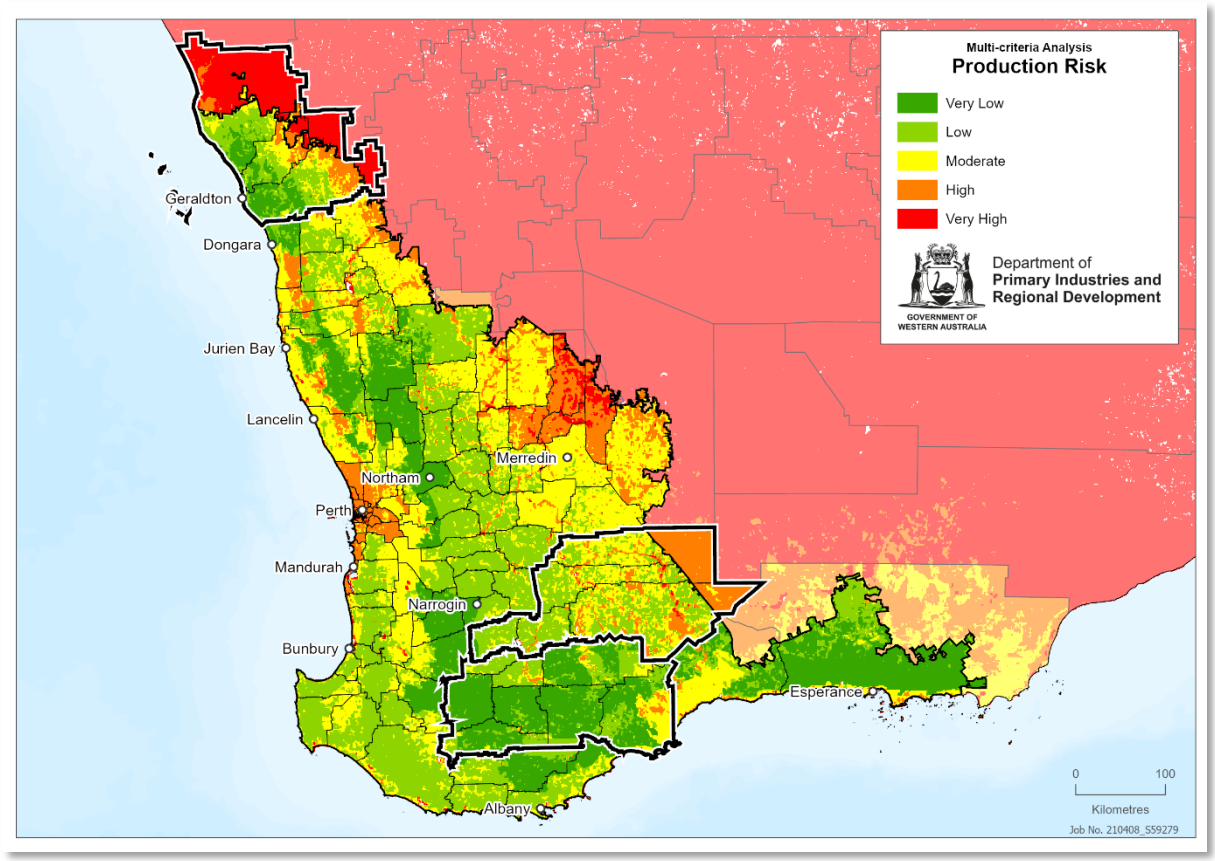

Figure 54: Production risk.

Indicator 2 (trend in NDVI – lowest 10%)

The data show values for the lowest 10% of MODIS vegetation indices (NDVI) between 2002 and 2021. MODIS indices are produced on 16-day intervals and at multiple spatial resolutions and provide spatial and temporal comparisons of vegetation canopy greenness, a composite property of leaf area, chlorophyll and canopy structure.

Sliding scale 1-5

- 1 NDVI 181-200
- 2 NDVI 161-180
- 3 NDVI 141-160

- 4 NDVI 121-140
- 5 NDVI 100-120

Low NDVI values indicate low levels of ground cover. Given that ground cover reduces the risk of soil erosion and improves soil health, low NDVI values are undesirable and likely to increase risk.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 3.5 for drought risk in terms of the lowest 10% of NDVI values recorded between 2002 and 2021.

Description: NDVI values across most of the region are in the 141-160 range, with a more area in the east in the 121-140 range (*Figure 54*), and tending towards the 161-180 range in Wagin.

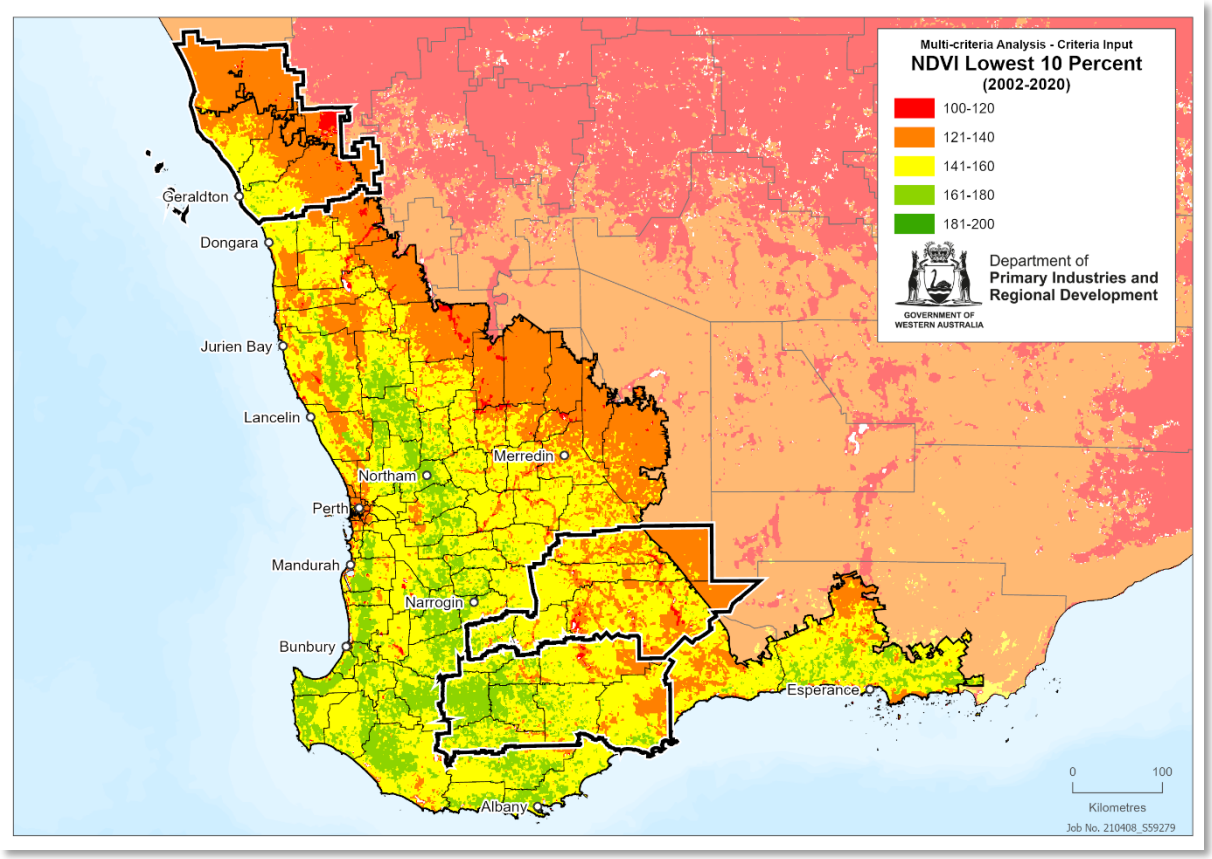

Figure 55: NDVI lowest 10%.

Indicator 3 - Percentage employment in agriculture

The data show the percentage of people who are employed in farming and allied industries according to the Australian Census 2016 records of characteristics of employed persons.

Sliding scale 1-5

- 1 Very few people employed in agriculture (<10%)
- 2 Few people employed in agriculture (10-20%)
- 3 Some people employed in agriculture (20-30%)

- 4 Many people employed in agriculture (30-40%)
- 5 Very many people employed in agriculture (>40%)

Livelihoods that depend directly on dryland agriculture are at higher risk of negative impacts from drought.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 5 for drought risk in terms of the percentage of the population that is employed in agriculture.

Description: More than 40% of the population are employed in agriculture across the whole region (*Figure 55*), meaning potentially high exposure to the impacts of drought.

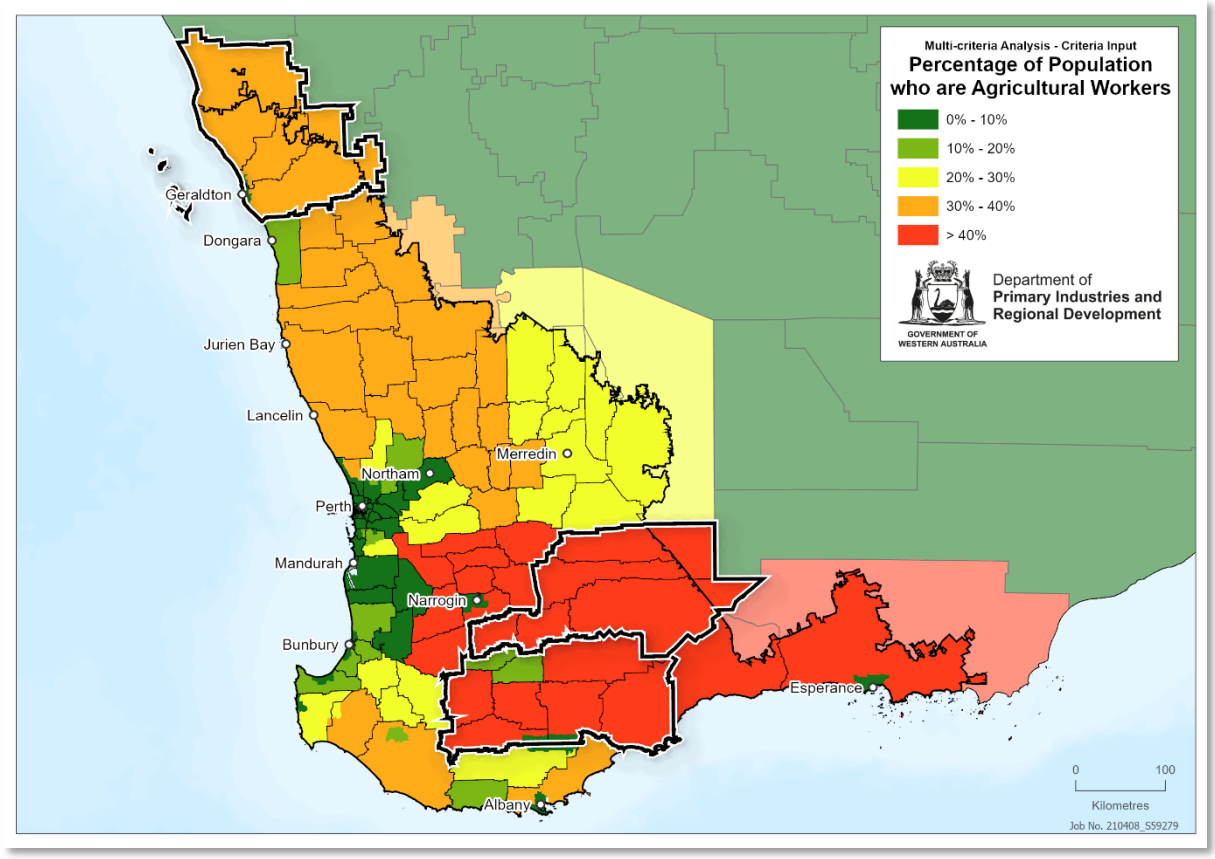

Figure 56: Percentage of the population employed in agriculture.

8.1.3 Adaptive Capacity

Indicator 1 - Percentage unemployment

The data show the percentage of people who are unemployed according to the Australian Census 2016 records of total labour force status.

Sliding scale 1-5

- 1 Very low unemployment (0-2%)
- 2 Low unemployment (2-3%)
- 3 Moderate unemployment (3-4%)
- 4 High unemployment (4-5%)

- 5 Very high unemployment (>5%)

Unemployment is an indicator for financial stress and dependency. Existing unemployment can increase the risk of adverse impacts from drought; economic consequences will exacerbate pre-existing social or economic disadvantage.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 2 for drought risk in terms of levels of existing unemployment in the region.

Description: Levels of unemployment are very low across eastern areas, with Dumbleyung and Wagin having slightly higher unemployment. Low unemployment across the region is also indicative of the difficulty in attracting people to the region due to competitive labour markets and low housing availability. This can impede on population and economic growth, impacting on drought resilience (Figure 49).

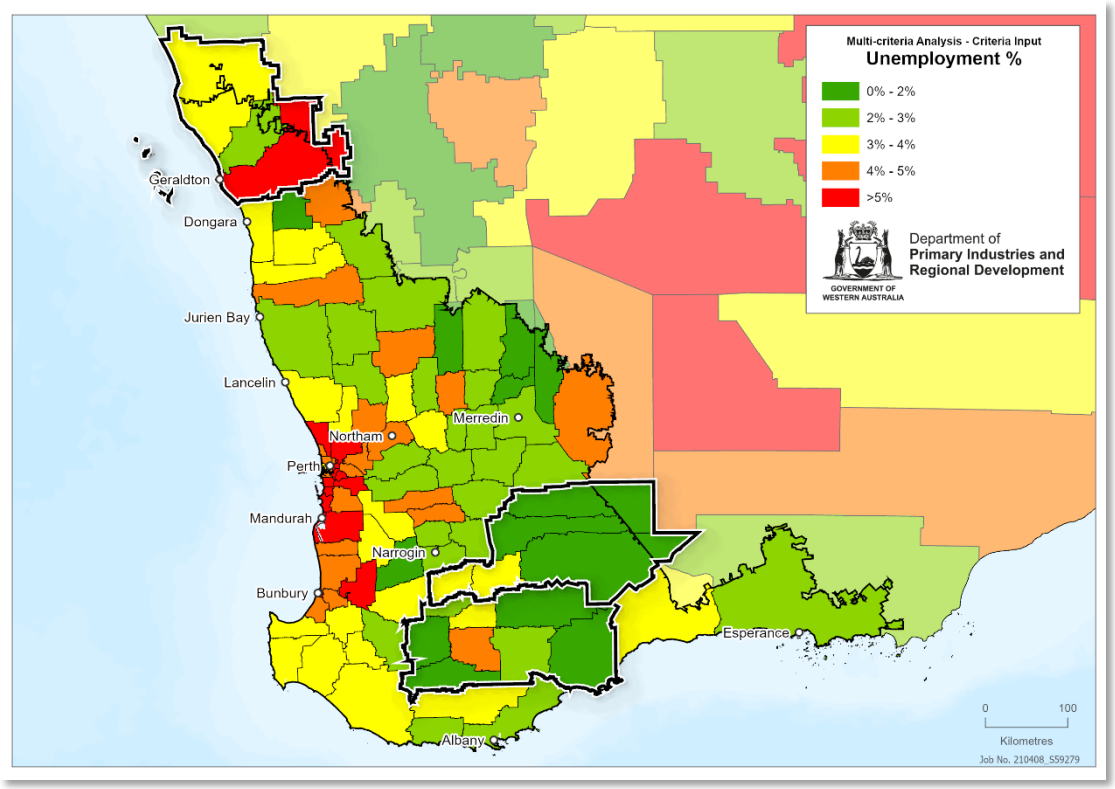

Figure 57: Unemployment as a percentage of the total working age population.

Indicator 2 - Access to infrastructure

The data show scheme water coverage and proximity to main road infrastructure and strategic community water supplies (see Section 4).

Sliding scale 1-5

- 1 Critical road and/or water infrastructure within 10km (very high)
- 2 Critical road and/or water infrastructure 10-25km away
- 3 Critical road and water infrastructure 25-50km away
- 4 Critical road and water infrastructure 50-100km away
- 5 Critical road and water infrastructure more than 100km away (very low)

Relative remoteness can affect drought resilience as people located further from infrastructure and services may find it more difficult to access emergency water supplies or transport services when needed during drought.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 1.5 for drought risk in terms of access to water services and transport infrastructure.

Description: Critical water services and road infrastructure are accessible across the Southern Wheatbelt region, with less accessibility noted in parts of Lake Grace. Note this map does not consider the limitations and constraints of the water system under drought conditions and periods of high water demand. Despite this high accessibility, parts of the region have experienced water deficiencies and restrictions applied to piped water infrastructure (*Figure 57*).

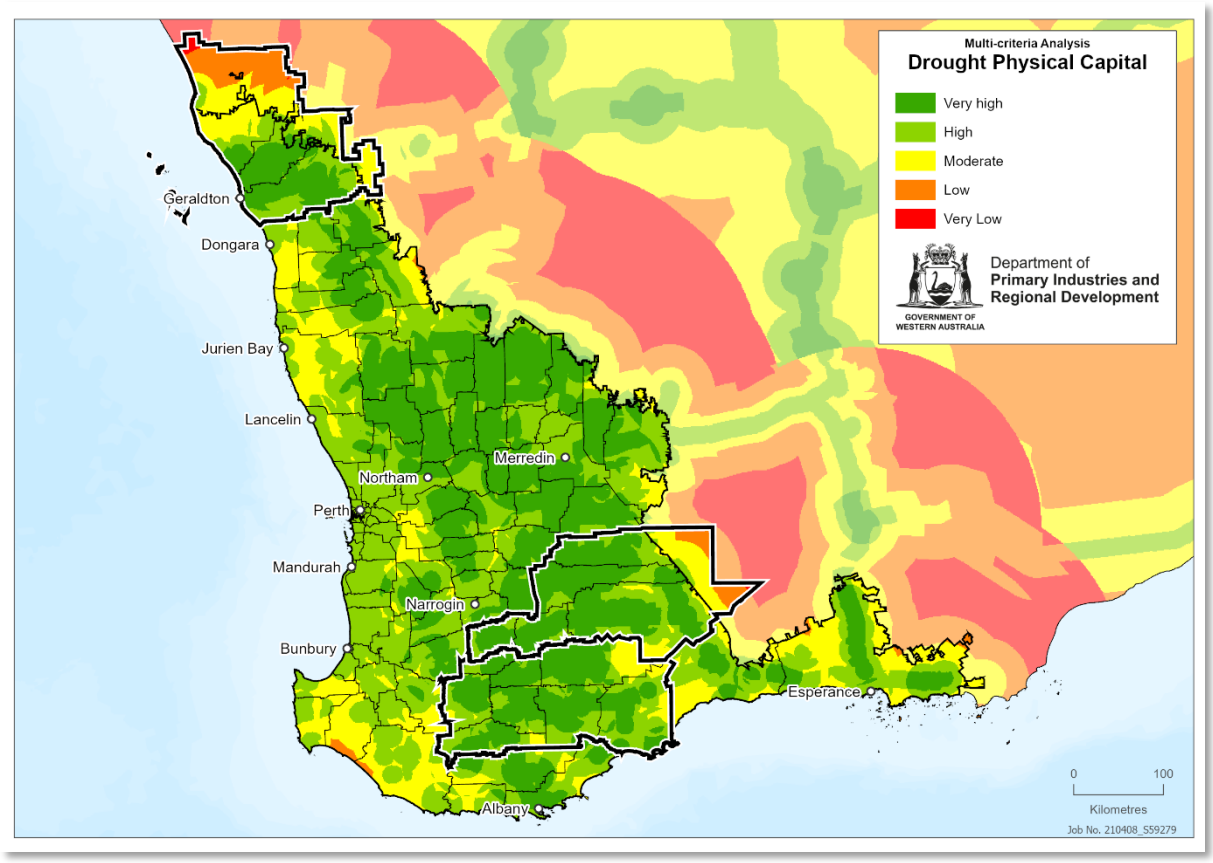

Figure 58: Proximity to water and road infrastructure.

Indicator 3 - Groundwater quality

The data show groundwater salinity.

Sliding scale 1-5

- 1 ≤500mg/L Total Dissolved Solids
- 2 500-999mg/L Total Dissolved Solids
- 3 1000-2999mg/L Total Dissolved Solids
- 4 3000-6999mg/L Total Dissolved Solids
- 5 ≥7000mg/L Total Dissolved Solids

Access to groundwater to augment water supplies may assist in building drought resilience, though in the Southern Wheatbelt, the sourcing of quality groundwater is challenging.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 5 for drought risk in terms of groundwater quality.

Description: Groundwater quality is highly saline across the region. Desalination is an opportunity, and would address the impacts of rising saline water tables on infrastructure and production, as well as providing an alternative water resource. More research will ascertain best fit technologies for extremely saline water environments (*Figure 58*).

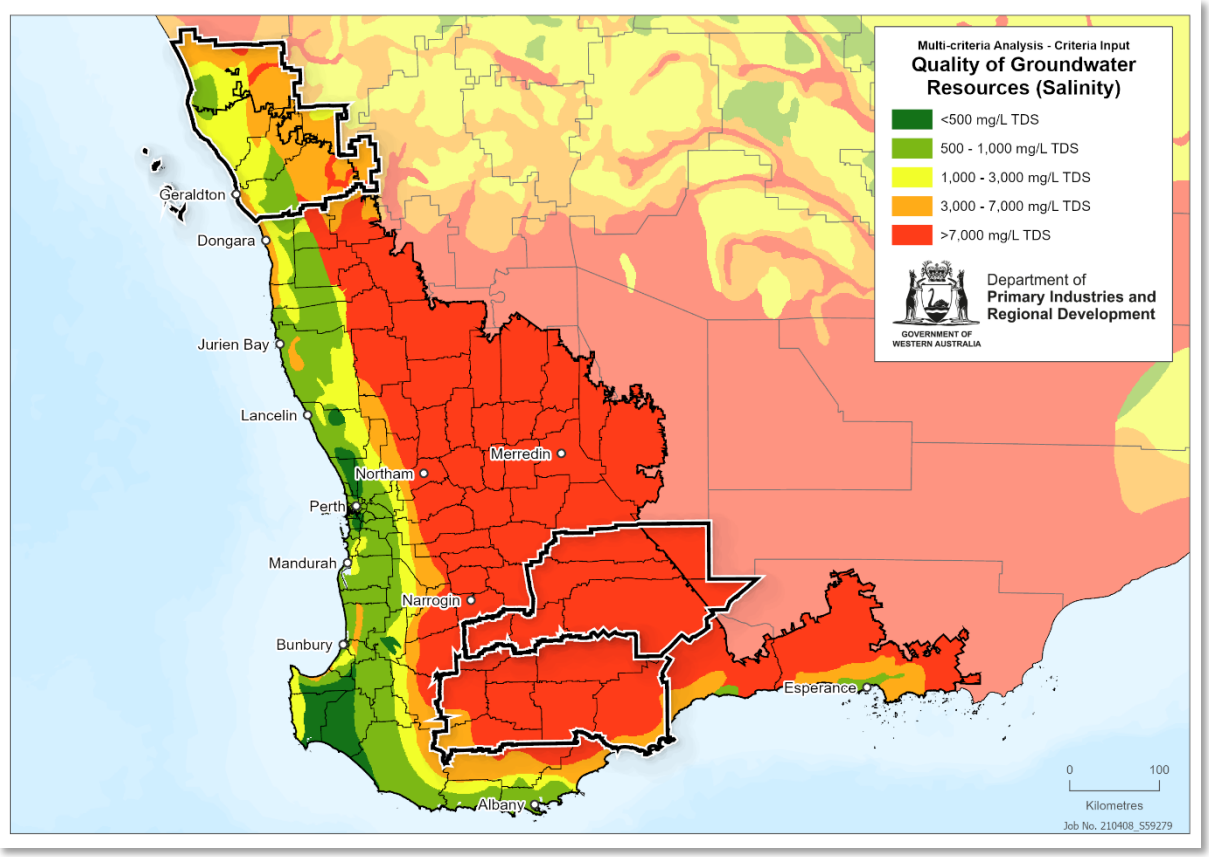

Figure 59: Groundwater quality

Indicator 4 - Soil capability

The data show land capability for cropping in the south west of Western Australia based on analysis and interpretation of the best available soil-landscape mapping dataset provided by DPIRD. The assessment covers dryland production of field crops under a cropping system that incorporates minimal tillage practices and stubble retention.

Sliding scale 1-5

- 1 High to very high capability 50-70%
- 2 Moderate to very high capability >70%
- 3 Moderate to very high capability 50-70%
- 4 Low to very low capability 50-70%

- 5 Low to very low capability >70%

Good soil capability contributes to drought resilience by ensuring reliable crop production in subsequent years, under better conditions, to make up for losses incurred due to failed production during drought.

Southern Wheatbelt Score: The Southern Wheatbelt region scores a 3 for drought risk in terms of soil capability.

Description: Soil capability for dryland cropping is variable across the region, with patches of very low to low soil capability in western areas, with high soil capability in eastern and northern areas of the region (Figure 59).

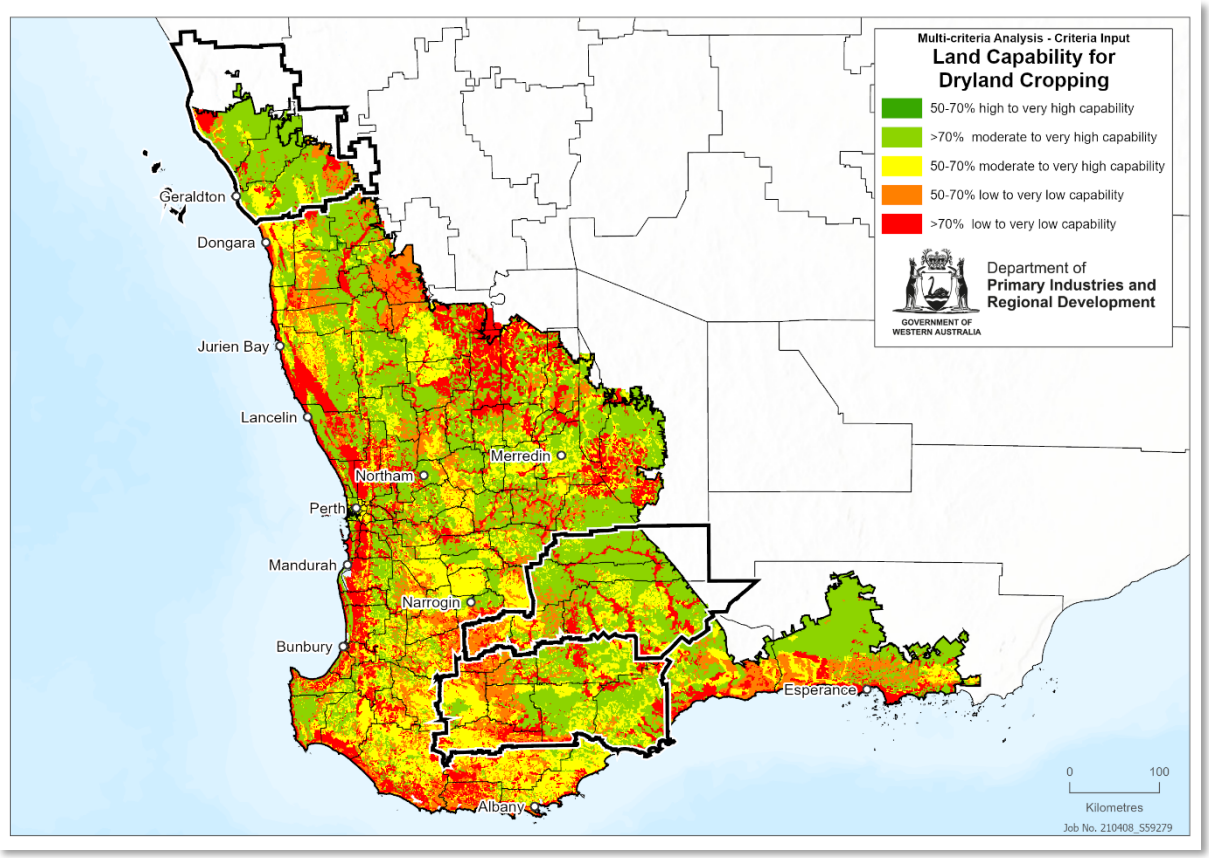

Figure 60: Land capability for dryland cropping.

8.1.4 Summary of Drought Vulnerability

Averaging the scores from each individual indicator returns an overall vulnerability index of 3.3, indicating moderate vulnerability to drought (see *Table 11*). A radar chart is useful for seeing which components of vulnerability need to be addressed most urgently as risk is not evenly spread across the selected indicators and therefore poorly represented by the average score. Given that each indicator has been scored on a 1-5 sliding scale where 1 represents the most desirable state and 5 the least desirable, it is most desirable for the indicators to cluster towards the centre of the radar chart. As can be seen in Figure 60, vulnerability to drought is unevenly spread throughout the indicators.

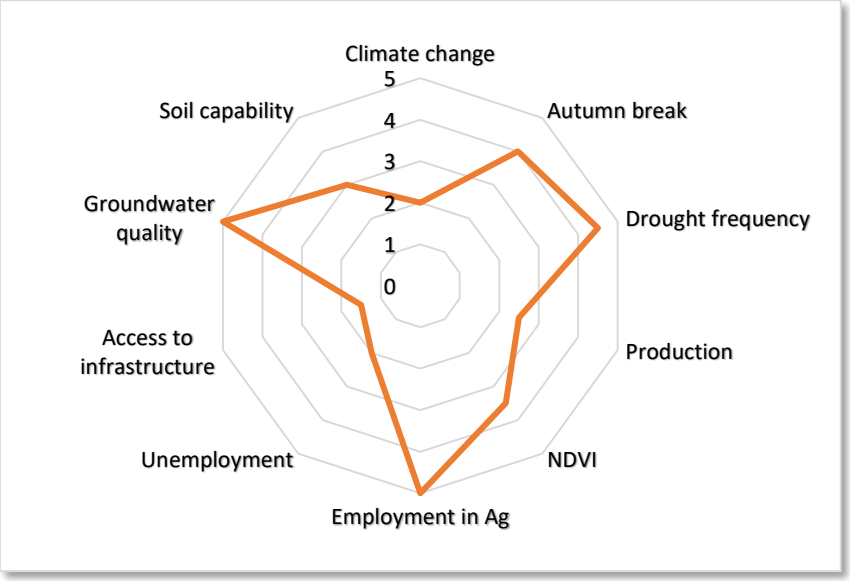

Figure 61: Radar chart of vulnerability index scores.

Areas of strength in terms of drought resilience in the Southern Wheatbelt region lie in soil and production capability, access to critical infrastructure and limited exposure to production risk. These are areas to maintain and build on for a successful response to future drought in the region. These are shown on the radar chart as points closer to the centre of the chart.

Weaker areas in terms of drought resilience are shown on the radar chart as those points further from the centre of the chart. These are the expected impacts of climate change on temperature and rainfall patterns, increasing drought frequency, NDVI trends and the level of direct dependence of local economies and livelihoods on agriculture. These are the aspects of vulnerability to drought in the region that need to be prioritised to improve resilience. If these can be improved, or better understood, planned for and dealt with, the region will be in a better position to respond effectively to drought. Improving levels of economic diversity are a desired outcome for the region to build drought resilience.

Improving understanding of the impact of changing weather patterns on agricultural production is required. Measures to improve access to water and road infrastructure, as well as other services, increase and diversify employment opportunities and adapt agricultural practices in the region to accommodate shorter or later growing seasons will improve resilience to drought. Current climate projections suggest that the situation is likely to worsen over time and steps should be taken now to ensure proactive adaptation to expected impacts.

9. Summary, actionable results and way forward

9.1 Summary

The goal of a drought vulnerability assessment is to identify key areas of vulnerability to inform priorities and actions to reduce susceptibility to the impacts of drought. The Southern Wheatbelt region, defined in this study as the Shires of Dumbleyung, Wagin, Lake Grace, Kulin and Kondinin, is a region at high risk of the impacts of drought, particularly those Shires on the eastern edge.

This vulnerability assessment provides localised analysis, guidance and recommendations to local decision makers and managers in the region regarding the possible impacts of drought and priority areas in which resilience-building efforts should be concentrated.

The impacts of drought are cross-cutting and require a joined-up approach to ensure regional communities can adapt to future drought. The patterns of climate change to date, high levels of direct dependency on agriculture and a demonstrated ability for the agricultural industry, regional businesses and communities to adapt to changing conditions make the region an excellent candidate for drought resilience action.

Efforts should be made to reduce socio-economic vulnerabilities and increase institutional capacities. This is important as enhanced capacities will result in an improvement in people's wellbeing, as well as an improved understanding of the importance of ecosystem services and natural resources for the region.

Although the current assessment represents a major step forward in our understanding of the drought-related vulnerabilities in the region, and our ability to represent these spatially, several datasets, particularly the human capital data require further refinement. As climate science advances and new economic, social and environmental data comes online, it may be necessary to update this analysis.

9.2 Actionable results

The actionable results of this report are as follows:

From Section 3 - Demographics and institutional arrangements

- Economic dependence on agriculture in the region is very high, with broadacre cropping the primary land use in eastern areas, with livestock production prevalent in western areas. Resilience building activities should focus on strengthening the ability of the agriculture sector and allied industries to prepare for and respond effectively to drought.
- Drought response planning around the world is moving from reactive crisis management to proactive risk management. Measures that promote self-reliance and preparedness are generally preferred by farmers, industry and government agencies alike. This includes appropriate use of financial instruments, business planning and access to professional advice to manage in intra and inter-season variability.
- Australia has a very comprehensive program to build resilience in regional areas in place under the Future Drought Fund. The Western Australian government is shifting its focus to climate resilience, with agencies such as DPIRD and DWER,

and government trading enterprises Western Power and Water Corporation addressing climate adaptation in their strategy and operations. There is opportunity to better connect links across international, national and local agencies involved in drought research, preparedness, response and recovery and in delivering drought resilience programs. Improved communication around the support available to regional communities, and how to access that support, is required.

From Section 4 - Climate data

- Meteorological definitions of drought need to focus on growing season rainfall. Defining drought based on annual rainfall totals can be misleading for regions that do receive some summer rainfall but rely fundamentally on autumn and winter rainfall to produce a crop.
- An expanded definition of drought is also useful because drought is defined in terms of its impact on primary production, surface and groundwater levels and regional communities. Drought could be defined as a prolonged period of abnormally dry conditions that impacts negatively on water availability and agricultural production in a region and, consequently, impacts negatively on the economy and environment of the region and the health and well-being of its residents.
- Average temperatures have increased by 1.4°C since 1910 leading to an increase in the frequency and severity of extreme heat events and heat waves in the region. There has been a prolonged period of extensive drying in the region since the 1970s, and the autumn break now occurs up to a month later than it used to.
- Droughts have increased in frequency and, alarmingly, hot droughts, which can be devastating for the environment. Appropriate steps must be taken to anticipate and mitigate the potentially devastating effects of hot droughts.
- Temperatures will continue to increase as climate change progresses and growing season rainfall will likely continue to decrease across the region. The time spent in meteorological drought, where conditions are significantly drier than the average over the preceding 30 years, will increase over the course of the century and across the region.
- Drought is expected to impact adversely on crop and livestock production in the region, as well as on the amount of water available other agricultural activities via impacts on surface water flows and aquifer recharge.

From Section 5 - Drought impacts

- **Economic:** Agriculture is the primary land use in the region and Southern Wheatbelt stakeholders report experiencing financial stress because of failed production during drought. Farming families sell or euthanise livestock, liquidate assets or increase their debt to survive, and non-farming families in regional areas suffer from reduced employment opportunities and cash flows.
- **Environmental:** Drought can have serious, long-term consequences for soil health, vegetation cover and biodiversity. Reduced vegetation cover and drier soils increases the risk of erosion and invasion by weeds, pests and diseases. This also impacts on the functioning of the landscape for economic and social purposes.

- **Impact on Aboriginal communities:** Aboriginal communities are likely to be disproportionately affected by drought based on pre-existing health and social disadvantage. Aboriginal community members expressed concern about the impact of drought on vegetation, water and fire regimes in the region, as well as the impact of land transformation and climate change on the region's vulnerability to drought.
- **Social:** The uncertainty and financial stress associated with drought negatively affects mental health in regional areas. Drought contributes to failed businesses, causing people to move away and, in turn, reducing population sizes, access to skills and services and the availability of community services and support networks in the region.
- **Water:** The Southern Wheatbelt is dependent on piped potable scheme water located in distant geographical areas, and a mix of locally sourced supplies for non-potable use. Groundwater is limited due to geology and requires desalination for productive use. To reduce reliance on scheme supplies, and enhance ability to cope with consecutive dry seasons, continued farm water supply improvement, and local and regional scale water supply planning and investment is required to address supply constraints and future demand under climate change scenarios.

From Section 6 - Drought risk priority areas

- High priority areas for drought resilience action occur at the intersection of high exposure to drought, high sensitivity to drought and low adaptive capacity. In the Southern Wheatbelt, areas most at risk from drought are in the northern and eastern Wheatbelt.
- Exposed areas are characterised by long-term increases in temperature and decreases in rainfall, measurable increases in drought frequency and measurable declines in potential wheat yield and root zone soil moisture.
- Sensitive areas are characterised by marginal crop and livestock production, low vegetation cover, high levels of economic dependence on agriculture and demographic factors such as relative remoteness, population size and economic diversity.
- Areas with low adaptive capacity are characterised by relatively poor access to infrastructure and resources, high unemployment and reliance on degraded and/or poor-quality natural resources, including water and soils.

From Section 7 - Assessing vulnerability to drought

- There are many good quality, publicly available data sets in Australia that can be used to assess vulnerability to drought and could serve as indicators to predict the impacts of drought.
- Several approaches are presented using publicly available data to assess vulnerability, these approaches all need further refinement and testing before they can be more generally applied in other regions.

- The region displays moderate vulnerability to drought with an overall index score of 3.3 out of 5. Areas of strength and resilience, which should be maintained and built upon, lie in the region's soil and production capability.
- The index highlights several areas of high vulnerability to drought, namely projected increases in temperature and decreases in rainfall, changes in the timing of rainfall and increases in the frequency of drought, trends in groundcover during dry years, unemployment, access to infrastructure and services and the level of direct dependence of local economies and livelihoods on agriculture. These are the aspects of vulnerability to drought in the region that need to be prioritised to improve resilience. If these can be improved, or better understood, planned for and dealt with, the region will be in a better position to respond effectively to drought.

9.3 Way forward

The Southern Wheatbelt Drought Vulnerability Assessment is intended to provide the evidence base for the Southern Wheatbelt Regional Drought Resilience Plan and investment into drought resilience actions.

There are limitations to some of the datasets used in the assessment process, due to the granularity, frequency of data capture and scale of the data. This relates especially to human capital components, often reported infrequently at small scales, with the difficulty in understanding the component's direction of effect on drought vulnerability.

It is recommended that the DVA is reviewed on a regular basis to integrate updated or new datasets of relevance. This would not only inform future planning and investment but enable longitudinal monitoring of drought resilience.

The agricultural regions of South West Western Australia are a success story in terms of climate adaptation to date. While regions like the Southern Wheatbelt are exposed to the impacts of climate change, and have demonstrated good capacity to adapt to date, there is a continual need to adapt, innovate and potentially transform to enable this success to be maintained or built upon. The region is also well placed to capitalise on opportunities to support the decarbonisation of the economy, further supporting drought resilience.

Future applications of the Vulnerability Assessment methodology should consider resilience to the broader impacts of climate change, not just drought impact, and the vulnerability and adaptive capacity of the broader regional economy; not just the agricultural and allied sectors. The rationale for this is in part because drought cannot be considered in isolation of climate change, and regional communities, while at the surface are dependent on agriculture, are made up of a complex mix of businesses and services, some highly dependent on agriculture, though many increasingly diversifying their service base. These businesses and services are likely to be the drivers of population and economic growth, building community, and playing an important role in supporting the retention of people, the region's most important resource.

The Southern Wheatbelt Drought Resilience Plan synthesises this work and articulates the key themes and high level interventions that may support drought resilience into the future. Implementation of the Plan including more detailed project concept development will be supported by the findings of transformative options research completed for this program (Appendix 2).

10. Supporting Reports

Please contact info@wheatbelt.wa.gov.au to request a copy.

AgDots 2022. *Transformative Options to build Drought resilience.* Report prepared for DPIRD's Regional Drought Resilience Planning Program

Anna Dixon Consulting 2022. *Regional Drought Vulnerability Assessment: Background Research and Analysis.* Report prepared for DPIRD's Regional Drought Resilience Planning Program

Bruce, J., Bourne, A., Guthrie, M., Veljanoski, I. Koh, L. and Parker, K. 2022. *Drought Priority Areas Map for Southwest Western Australia.* DPIRD

Clifton, P. and Price, M. 2022. *Water Issues and Policy Analysis for the Regional Drought Resilience Planning Program.* Report prepared for DPIRD's Regional Drought Resilience Planning Program. Aroura Consulting

Flatau, P. and Lester, L., Kyron, M. 2022. *Understanding the Social Impact of Drought.* Report prepared for DPIRD's Regional Drought Resilience Planning Program. Centre for Social Impact, University of Western Australia

Gladish, D.W. and Hochman, Zvi 2022. *Investigating the Application of Drought Indices to Western Australia*. Report prepared for DPIRD's Regional Drought Resilience Planning Program. CSIRO

Grima, R. 2022. *Drought Viability Report*. Planfarm

Mastrantonis, S 2022. *Defining Drought in Western Australia*. Report prepared for DPIRD's Regional Drought Resilience Planning Program. Centre or Crop and Disease Management, Curtin University

Noongar Land Enterprise Group 2022. *Valuing Noongar People and Practices in Drought Resilience*. Report prepared for DPIRD's Regional Drought Resilience Planning Program

Wheatbelt NRM 2022. *WA Regional Drought Resilience Planning, Grass Roots Community Consultation, Southern Wheatbelt Pilot Area.* Report prepared for DPIRD's Regional Drought Resilience Planning Program

Wheatbelt NRM 2022. WA Regional Drought Resilience Planning. *WA Regional Drought Resilience Planning, Targeted consultation with Aboriginal Communities on drought in the Lower Wheatbelt, Southern Wheatbelt Pilot Area.* Report prepared for DPIRD's Regional Drought Resilience Planning Program

Appendix 1 – Southern Wheatbelt Stakeholder Engagement Record

Wheatbelt Record of Drought Resilience Plan Stakeholder Engagement Record

A total of 323 people across 150 organisations were engaged during the RDRP Pilot process. This included local government, community and grower groups, regional businesses and technical experts and traditional owners. People participated in a range of opportunities, from surveys, one on one interviews, facilitated workshops and technical, steering or advisory meetings. The below table is the timeline record of engagements. Consultation reports are available on request. See Section 10.

Date	Location	Engagement type	Organisation
Sep-2021	Wagin	Inception meeting	Shire of Wagin Executive
Sep-2021	Kondinin	Inception meeting	Shire of Kondinin Executive
Sep-2021	Kulin	Inception meeting	Shire of Kulin Executive
Sep-2021	Grace	Inception meeting	Shire of Lake Grace Executive
Sep-2021	Dumbleyung	Inception meeting	Shire of Dumbleyung Executive
Sep-2021	Dumbleyung	Consultation	Dumbleyung LCDC
September 2021 to August 2022	Online/face to face	Steering Committee meetings	LGA Reps x 3, DPIRD, WDC, GSDC, MWDC, Drought Hub, NACC
Nov 21, Apr 2022	Online/face to face	Technical working group meeting	DPIRD (Policy, GIS, Farming Systems, Climate, Water Science), WDC, GSDC, MWDC, Drought Hub, NACC, DWER, Murdoch, UWA, Curtin, CSIRO, Water Corporation, Mental Health Commission, Regional Men's Health, Ruralwest, WALGA, GGA, Wheatbelt NRM, SCNRM, RRR Network, AgDots, LGA Reps
December 2021 to June 2022	Online	Southern Wheatbelt Project Advisory Group meeting	Shires of Dumbleyung, Wagin, Lake Grace, Kondinin, Kulin, WDC
Feb-2022	Kondinin	Consultation	Shire of Kondinin Council
Feb-2022	Kulin	Consultation	Shire of Kulin Council
Feb-2022	Dumbleyung	Consultation	Shire of Dumbleyung Council
Mar-2022	Wagin	Consultation	Shire of Wagin Council
Mar-2022	Grace	Consultation	Shire of Lake Grace Council
Mar-2022	Newdegate	Consultation	Newdegate CRC
Mar-2022	Merredin	Consultation	Ballardong ILUA
March-May 2022	Online/face to face	Interviews	Rural businesses x 15
May-June 2022	Various	Consultation/contracted	NLE
April-June 2022	Northam	Consultation/contracted	Wheatbelt NRM
Apr-2022	Online	Consultation	GGA
Apr-2022	Merredin	Consultation	Drought Hub

April-June 2022	Online	Consultation	Survey
Apr-2022	Wagin	Consultation	WIFE Wagin
Apr-2022	Lake Grace	Consultation	WIFE Lake Grace
Apr-2022	Wagin	Consultation	East Wagin Top Crop Group
Apr-2022	Wagin	Consultation	Wagin-Woodanilling Landcare Zone
Apr-2022	Online	Community meeting	Various - including Wheatbelt Business Network, RDA Wheatbelt, LGAs, WDC, Wheatbelt NRM, GGA, DWER, DPIRD
May-June 2022	Various in region	Interviews	Traditional Owners
April-June 2022	Various in region and online	Interviews	Agriculture and NRM champions
Various	Perth, Online	Consultation	DWER
Various	Online	Consultation	Water Corporation
Apr-2022	Merredin	Update	WDC Board
Apr-2022	Online	Update	Rural Water Council
May-2022	Merredin	Update	Great Eastern Country Zone Meeting
May-2022	Darkan	Update	Central Country Zone Meeting

Number of organisations and individuals, and nature of engagement during the Southern Wheatbelt RDRP Pilot

Below is the record of the unique organisations engaged and the method of engagement over the RDRP Pilot.

Organisation	Organisations represented	Number of people engaged	How involved				
			Stakeholder Meetings	One on one consultation or interview	Community Workshop	Video interview	Contracted to undertake work
Shire of Wagin	1	2	x	x	x		
Shire of Kondinin	1	2	x	x	x		
Shire of Kulin	1	2	x	x	x		
Shire of Lake Grace	1	2	x	x	x		
Shire of Dumbleyung	1	2	x	x	x		
Shire of Wagin Councillors x 9	9	11	x		x		
Shire of Kondinin Council x 9	9	11	x		x		
Shire of Kulin Council x 9	9	11	x		x		
Shire of Lake Grace Council x 9	9	11	x		x		

Shire of Dumbleyung Council x 7	7	9	x		x		
Dumbleyung LCDC	1	4		x			
Newdegate CRC	1	2		x			
Ballardong Indigenous Land Use Agreement	1	1		x			
Noongar Land Enterprise Group	1	6				x	x
Wheatbelt Natural Resource Management Inc	1	2	x		x	x	x
Grower Group Alliance	1	1	x		x		
South West WA Drought Innovation and Adoption Hub	1	2	x		x		
Wheatbelt NRM Survey participants x 34	34	34		x			
Women in Farm Enterprises Wagin	1	5		x			
Women in Farm Enterprises Lake Grace	1	5		x			
East Wagin Top Crop Group	1	5		x			
Wagin-Woodanilling Landcare Zone	1	5		x			
Department of Water and Environmental Regulation	1	2	x		x		
RDA Wheatbelt	1	2			x		
Wheatbelt Development Commission	1	6	x		x		
Noongar traditional Owners x 11	11	11		x		x	
Wheatbelt NRM interviews	10	10		x			
Water Corporation	1	2	x				
Great Eastern Country WALGA Zone	1	40	x				
Central Country WALGA Zone	1	40	x				
Rural Water Council	1	20	x				
Regionally based businesses x 15	15	20		x			
DPIRD (GIS, Farming Systems, Climate, Water Science, Soils)	1	10	x		x		x

Centre for Crop Disease Management - Curtin	1	1	x		x		x
Harry Butler Institute - Murdoch	1	3	x				x
CSIRO	1	3	x				
UWA (Centre for Social Impact, Agriculture, Economics)	1	6	x				x
Mental Health Commission	1	1	x				
RuralWest	1	2	x	x			
Western Australia Local Government Association	1	1	x	x			
Rural, Remote and Regional Women's Network	1	1	x				
AgDots	1	1	x				x
South Coast NRM	1	1	x	x			x
Northern Agricultural Catchments Council	1	2	x				x
Mid West Development Commission	1	2	x				
Regional Mens Health	1	1	x				
Total	**150**	**323**					

Appendix 2 – Summary of Transformative Drought Solutions

An examination of mega-trends, drivers, impacts, drivers and potential transformative ideas was completed by AgDots as part of the Regional Drought Resilience Planning Program in WA. This work informs the DVA and the consideration of interventions and proposed actions in the Regional Drought Resilience Plans. The table below summarises the mega trends as they relate to the regions in the RDRP.

MEGA TREND	RELEVANCE/ IMPACT	DRIVER	TRANSFORMATIVE IDEAS
Supply + Demand shocks	High input costs – substitution inputs, tight supply commodities, confidence ag industry, land value increases	Supply chain disruptions	• Low input cropping • Agtech • Localisation Supply chain eg fert
Food trends	Vegie oil + plant protein demand, aquaculture product demand, onshoring meat production	Demand vegie oil, plant protein + seafood	• Bio-oil demand • Aquculture industry supply chain development • Onshoring Meat value adding
Climate Crisis	Need for adaptive responses, ecosystem services, natural capital market, carbon market opports	Net zero transition/ decarbonising economy	• Farming systems options to build resilience, carbon farming, ecosystem service markets
Resource scarcity	Oil, gas, water, labour underpinning inputs for regions economy	Water, energy, labour key drivers	• Water source, efficiencies (treatment, capture, reuse), Storage/distribution, new technology
Digital transformation	Connectivity is the new highway, and data is currency	Connectivity and digitalisation of industries + commununities	• Better use of data to drive decision making, fit for purpose connectivity options, automation and EV's in ag, Agtech, Foodtech
Neo -ecology	Sustainability becoming major economic driver	Sustainability credentials for trade and markets	• Opportunities sustainability credentialling, sustainable use resource opportunities
Globalisation + pandemics	Less safe world which is very connected, ongoing impact from major events + tensions	Biosecurity	• What are strategic levers in biosecurity that could be applied at a regional scale that would help drought vulnerability or build adaptive responses
Well being	Well being of communities impacted by drought	Building community cohesion	• Social capital and capacity as a buffering factor in building resilience

Further investigation was undertaken to explore interventions under the seven themes that emerged during the research. The tables below summarise those interventions by themes. Comprehensive research was completed for priority interventions identifying each option in terms of feasibility, type, scale, dependencies, and linkages. This information will be used to support the development of the implementation plan.

Water Resilience	Digital Resilience	Farm Business Resilience	Farming Systems Resilience
• Water Supply and Risk Assessments (Regional Water Security and Investment Plans) • Conduct water source investigations for all new water sources • Support and expand desalination pilots in communities and on-farm • Support development of on farm planning tools to accelerate water resource planning at local scale (eg. Farm Cat project acceleration) • Incentivise on farm water infrastructure investment	• Improve connectivity through co-investment in digital infrastructure (includes backhaul + wireless networks to farms) • Build tech skill and support in ag (connectivity literacy, data management capability, farm tech capability of industry) • Regional tech support built withing regions (CRC flying squads) and develop long term plan to build tech capacity in regions	• Build capability for useage of on-farm data for insurance index products • Support grower education and training for risk management tools to support financial risk management • Advocate FMD maximum cap to be relative to the size of the business • Evaluate impact of drought support programs on farm businesses to inform future strategies	• Support R&D and industry development for alternative drought tolerant crops (legume, GM + long coleoptile wheat, alternative oil seed crop, bushfoods + cultivate endemic species) • Support R&D and industry development for livestock feeding options (carbon positive feed supply eg asparagopis) • Support R&D and adoption in low input cropping options (VRT, alternative fuels, electric vehicles, regen farming) • Support R&D and industry development for building soil health (greater depth soil amelioration, hostile soil management, biochar) • Support R&D and catchment management initiatives and build soil and water systems health (eg landscape ecology and rehydration)
Presented as an overarching framework to suggest no hierarchy in research options, and the areas of transformation are linked and impact each other			

Natural Capital Resilience	Community Resilience	Regional Economy Resilience
• Support national natural capital framework development in WA Ag to enable natural capital on balance sheets • Evaluate and expand biodiversity stewardship program and trials in WA • Pilot participation in national biodiversity trading platform • Improve carbon and climate literacy and understanding of the carbon market • Support projects to test market to develop smaller more integrated projects (pollination, soil conditions, biodiversity) + create a model to provide co-benefits and support local communities and businesses	• Build workforce capability through workforce planning, digital activation, recruit and train young people for high demand industries, active employer engagement + provide childcare • Build housing supply through innovation – encourage start up activity, support communities to build housing companies NFP's, provide incentives for building or renovating in rural communities (loans, grants or services), and create a seasonal accommodation matching platform • Support well being measures that build resilience including network strengthening activities and programs that increase physical well being and support positive health outcomes	• Support Tourism planning processes (destination management plans) and invest in regional and local tourism projects • Support higher level of integration and planning for major mining resource projects and develop community structures to capture benefit from investment • Develop more intensive farming opportunities eg. horticulture through water security assessments and identification of land/water/workforce/infrastructure packages for investors • Create a revolving loan fund to encourage regional entrepreneurship and innovation and support innovation/resilience training for regional businesses eg. WBN program for regional resilience
Presented as an overarching framework to suggest no hierarchy in research options, and the areas of transformation are linked and impact each other		

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