Department of
Primary Industries and
Regional Development
GOVERNMENT OF
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Drought Priority Areas Map for Southwest Western Australia

Author

John Bruce[1], Li-Ann Koh[1], Kaylene Parker[2], Renee Manning[3] & Amanda Bourne[4]

[1]Department of Primary Industries and Regional Development
[2]Great Southern Development Commission
[3]Renee Manning
[4]Northern Agricultural Catchment Council

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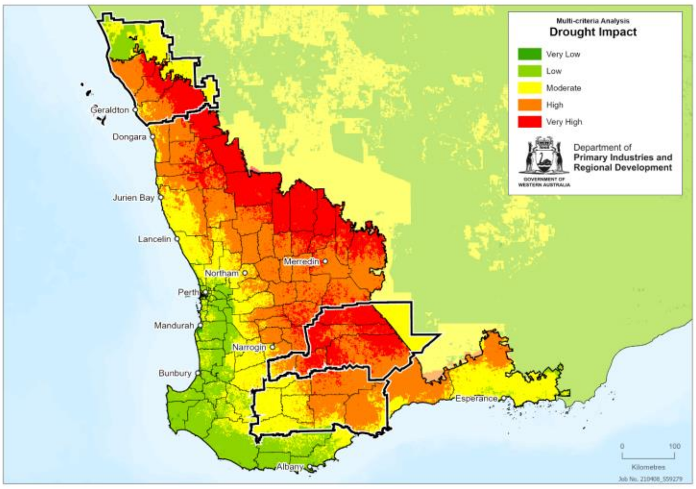
1. Summary

Using GIS-based multi-criteria analysis (MCA), 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). The team have produced a set of maps that identify 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 agreed RDRP conceptual framework, investigating aspects of exposure, sensitivity, impact and adaptive capacity.

The ways in which each of these components relate to and inform vulnerability and resilience to drought in the regions was informed by regional stakeholder engagement processes. The team has higher confidence in the data sets included in the exposure and sensitivity components (contributing to impact) than in the data sets included in the adaptive capacity component. We therefore recommend that the composite Drought Impact map be the primary tool used for local-level drought resilience planning. Areas at higher risk of drought include the northern and eastern Wheatbelt regions.



Summary drought impact map indicating drought priority areas in the northern and eastern Wheatbelt. Data include in the composite impact map include climate data (historical and projected), agricultural production data and information about water resources, on-farm practices and trends in regional communities. The impact map shown here should be the primary decision-support tool from this analysis.

2. Background

Many existing tools assume that climate change information is available in an accessible and understandable format and that decision makers are confident in interpreting such information to guide their decision-making at the local level. Tools focused on climate data alone are insufficient for supporting local level planning and implementation because they lack a comprehensive spatial planning component, are not packaged in a simple and understandable format and are limited in their integration of socio-economic and environmental factors along with the climatic aspects (Bourne et al., 2017; Jones et al., 2020; Pasquini & Cowling, 2015).

Context-specific information, at the scale of country driven administrative units, is needed to guide local level decision-making, planning and implementation (de Sherbinin, 2014). We argue that mainstreaming of drought resilience at the sub-national level is greatly enhanced by a taking a spatial and scenario-based planning approach at the scale of the known and familiar administrative boundary (Bourne et al., 2016; Cardoso da Silva et al., 2020; Kasecker et al., 2018). This is so even though social and ecological processes routinely transcend these boundaries (Egoh et al., 2008; Hamann et al., 2015). In Australia, these administrative units are Local Government Authority (Shire) boundaries.

Using a standard systematic planning approach based on spatial multi-criteria analysis (MCA, Ajibade et al., 2019; Chandio et al., 2013; Holness & Biggs, 2011; Joerin & Musy, 2000; Malczewski, 2006), we have generated maps that address climate change, the environment and local government priorities for infrastructure and community development. They systematically incorporate socio-economic priorities for local governments into spatial drought impact priority areas, providing a means of identifying locations for the implementation of drought resilience programs to maximum effect where resources are limited.

3. Method

3.1 Assessing vulnerability

We used the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report's definition of vulnerability (Field et al., 2014; Parry et al., 2007) as a function of exposure, sensitivity, and adaptive capacity. The most vulnerable areas are those where biophysical exposure (the nature and degree to which a system experiences drought) and sensitivity of regional communities (the degree to which human populations are affected by the impacts of drought) are highest; and where adaptive capacity (the ability of regional communities to adjust or accommodate drought behaviorally and/or technologically) is lowest (Jones et al., 2020). The drought vulnerability assessment was based on the Regional Drought Resilience Planning Program framework (Figure 1), drawing on past studies in Australia (Duxbury & Hodgson, 2014; Hughes et al., 2020; Rickards, 2013; Stenekes et al., 2012) and around the world (Bourne et al., 2016; Jones et al., 2020; Kasecker et al., 2018; Nelson et al., 2007) to ensure sufficient attention is paid to all important aspects of drought vulnerability and resilience in the affected regions. The inclusion of a consolidated Impact area combining exposure and sensitivity is peculiar to the approach taken by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, Hughes et al., 2020) and is utilised here for consistency across all components of a larger program being implemented by the Australian federal government.

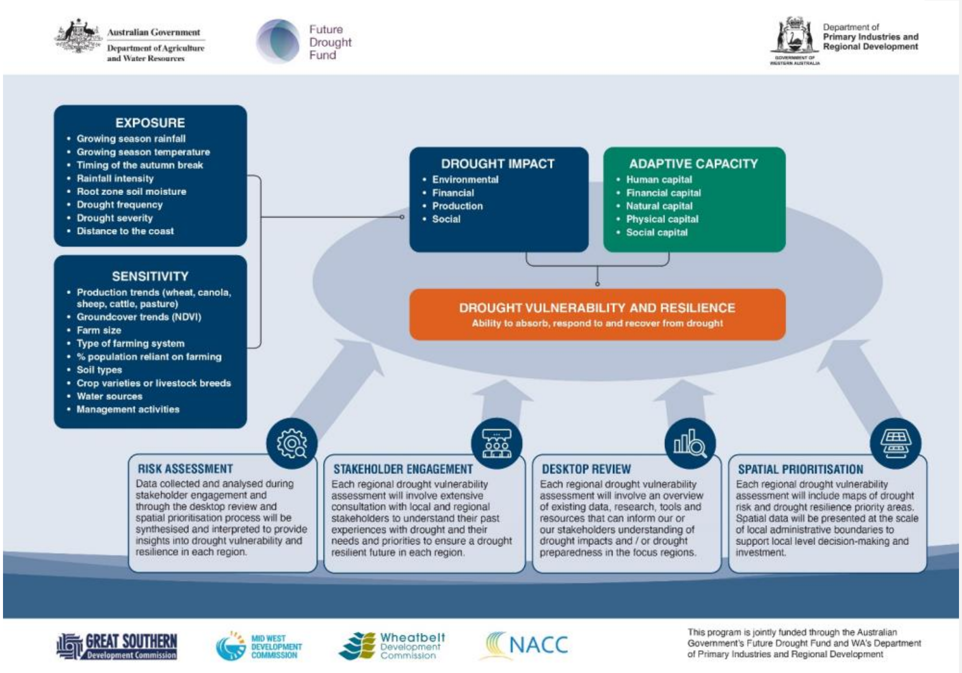


Figure 1: Overall conceptual framework for the DRDP drought vulnerability assessment. The spatial drought resilience priority areas analysis is one component of the vulnerability assessment, and follows the conceptual framework by collating contributing datasets into the exposure, sensitivity, impact and adaptive capacity categories.

3.2 Generating priority areas maps

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 summarised in Figure 1. The analysis was performed using the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) tool developed by ABARES (MCAS-S Development Partnership, 2018). 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.

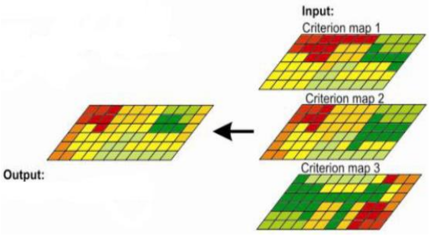


Figure 2: Multi-criterion GIS analysis works by standardising and overlaying spatial data to identify significant areas of overlap.

All spatial data were prepared for MCAS-S analysis using ArcGIS Pro 2.9.2 GIS software. Layers were classified to 5 classes showing roughly equal representation of the data within each dataset across the south west of WA. Lowest risk areas were allocated to Class 1 and highest risk areas were allocated to Class 5. Where relevant, variables were classed according to their presence or absence (e.g. whether or not a river or stream was present). Values were considered high when they contributed most to drought risk. Metadata and processing for each layer is described in Table 1.

Final input layers were exported to a standard .tiff raster format with a consistent scale (statewide 1km grid) and projection ready for analysis. The .tiff input layers were loaded into the MCAS-S software and combined to produce a series of composite maps. Standard colours were used throughout. Areas of low resilience (or high vulnerability) were consistently represented in the same colours, with red indicating highest risk from drought. The final composite drought vulnerability map incorporates 44 individual data sets and 10 composite maps.

The authors recognise that quite different variables have been combined, but argue that all are directly relevant for identifying priority areas for drought risk and the implementation of drought resilience programs. Care was taken to ensure that the data ranges and levels of priority that these ranges represent in the different summary layers were sufficiently similar to allow them to be sensibly combined, with each layer representing a consistent range from lowest priority through to highest priority for identifying drought risk.

The data layers included in the drought resilience priority areas map are described in Table 1. Variables and composite maps were weighted according to their likely

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-Info on scale and scoring used to standardise layers

influence on drought resilience, based on expert opinion and feedback from regional stakeholders (Table 2). Once composite maps for impact and adaptive capacity contributing to drought risk and resilience were produced, these were equally weighted and combined into a single composite map. Through this process, priority areas for the implementation of drought resilience programs emerge clearly. Priority areas for drought resilience lie in the overlap between impact and adaptive capacity. The large majority of the data used in the drought resilience priority areas analysis are publicly available at the national level in Australia or for South West WA and could be readily applied to all 113 LGAs within the WA southwest. For replication outside of South West WA, the four broad categories of information could be applied, but would have to be populated with nationally or locally available data, clipped to the relevant political or administrative boundary for local-level decision-making.

3.3 Ground-truthing the priority areas maps

We conducted participatory mapping exercises during three workshops with 77 people representing 52 business and organisations, including Aboriginal community groups, broadacre farmers and agribusiness. During the workshops, participants were asked to refer to large printed topographical maps of their area and identify the locations most vulnerable to drought based on their past experiences with drought in the region. The maps created by workshop participants were converted into a data layer on the same scale as all other included data layers and used to ground-truth the composite maps generated by MCA.

The conceptual framework was developed in consultation with an informal 22-member technical working group and three regional 5- to 15-member project advisory groups. Technical working group members represented expertise in the agricultural, climate, environmental and social sciences as well as in economics, mental health, disaster relief and rural leadership. Project advisory group members included local and state government, producer group, industry, university and natural resource management representatives. Draft drought priority areas maps were presented to the same group after local ground-truthing and their feedback incorporated into the final products presented here.

Table 1: detailed information about each layer of data included in the multi-criteria spatial analysis, including metadata description, data source and processing.

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Output Spatial Resolution	Processing Notes
Population >65 years	Population estimates by age and sex, by SA2, 2020	This product contains preliminary estimates of the resident population by age and sex as at 30 June 2020. Data are provided for Statistical Areas Level 2 (SA2s) and states and territories of Australia, according to the 2016 edition of the Australian Statistical Geography Standard (ASGS).	ABS Data Cube	Australian Bureau of Statistics (ABS)	Table	Open/Public	Component data (births, deaths and overseas and internal migration) are confidential and constrained to add to the relevant state component estimates by age and sex. The resultant estimated resident populations are subsequently constrained to state population estimates by age and sex. As a result of confidentiality and forced additivity, estimates of under three people should be regarded as synthetic and only exist to ensure additivity to higher levels. While output is presented by five-year age group, all calculations are made at single year of age level.	https://www.abs.gov.au/ methodologies/ regional-population-age-and-sex-methodology /2020	1km Grid	Table joined to SA2 polygons
Unemployment %	Census 2016, G43 Labour force status by age by sex (LGA)	Census 2016 Australia/State/GCCSA/SA4/SA3/SA2 based data for Total Labour force status *by* sex of parents by age of dependent children for families, for the 2016 Census of Population and Housing. Unit of measure: Count of all persons on Census night, based on place of usual residence. Excludes Overseas Visitors. Geographic coverage: LGA2016	ABS Data Explorer	ABS	Table	Open/Public		https://www.abs.gov.au/ methodologies/data-region-methodology /2015-20#data-download	1km Grid	Table joined to LGA polygons

Land capability for dryland cropping	Land Capability - Dryland Cropping (DPIRD-031)	Land capability for cropping in the south west of Western Australia based on analysis and interpretation of the best available soil-landscape mapping dataset (DPIRD-027). This assessment covers the production of rain-fed (non-irrigated) field crops under a cropping system that incorporates minimal tillage practices and stubble retention.	Data WA	DPIRD	Polygon	Open/Public	Capability ratings do not take into account factors such as the availability and quality of water supplies for irrigation or climatic risks such as frost or heat stress. Such factors need to be considered as a separate layer of information. Accuracy of attribution is variable depending upon scale of survey and the hierarchy level of the mapping.	https://catalogue.data.wa.gov.au/dataset/land-capability-dryland-cropping/resource/f392dd06-00c0-4ff4-8c06-71c2d198dbf0	1km Grid	N/A

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Plant available water capacity of the soil	Soil and Landscape Grid National Soil Attribute Maps - Available Water Capacity (3" resolution) - Release 1. Version v5.	This is Version 1 of the Australian Soil Available Water Capacity product of the Soil and Landscape Grid of Australia. The Soil and Landscape Grid of Australia has produced a range of digital soil attribute products. Each product contains six digital soil attribute maps, and their upper and lower confidence limits, representing the soil attribute at six depths: 0-5cm, 5-15cm, 15-30cm, 30-60cm, 60-100cm and 100-200cm.	TERN Data Discovery Portal	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Raster	Open/Public	National Soil Attribute Maps are generated by combining best available digital soil maps to calculate a variance weighted mean for each pixel. For this soil attribute the Australia-wide three-dimensional Digital Soil Property Maps are the only maps available. Thus the modelling for this soil attribute only used decision trees with piecewise linear models with kriging of residuals developed from soil site data across Australia.	https://portal.tern.org.au/soil-landscape-grid-release-1/23082	1km Grid	TERN soil water availability depth: 15-30cm
Native vegetation extent	Native Vegetation Extent (DPIRD-005)	A data set containing vegetation extent polygons from the mapping of remnant vegetation in Western Australia.	Data WA	DPIRD	Polygon	Open/Public	Vegetation type is not attributed to this dataset. Attribution is limited to information relating to the capture of the dataset, see Data Dictionary for a list of attributes.	https://catalogue.data.wa.gov.au/dataset/native-vegetation-extent/resource/a7a4b590-604c-4ebb-806a-0eb0451c1a27	1km Grid	Native vegetation percent calculated per 1km area of grid cell

NDVI trends, NDVI 20 year average, NDVI 20yr lowest 10%	MODIS Vegetation Index Products (NDVI and EVI)	MODIS vegetation indices, produced on 16-day intervals and at multiple spatial resolutions, provide consistent spatial and temporal comparisons of vegetation canopy greenness, a composite property of leaf area, chlorophyll and canopy structure.	https://www0.landgate.wa.gov.au/business-and-government/product-onsellers/value-added-resellers/property-products/ndvi-satellite-imagery	Landgate	Raster	Open/Public	The quality of the MOD13Q1/A1 product is assessed through the quality assessment (QA) metadata objects and per-pixel QA science data sets (SDS's). The QA metadata objects summarize tile-level (granule) quality with several single words and numeric numbers, and thus are useful during data searching/ordering and screening processes. The QA SDS's, on the other hand, document product quality on a pixel-by-pixel basis and thus are useful for data analyses, filtering, and application.	https://vip.arizona.edu/documents/MODIS/MODIS_VI_UsersGuide_June_2015_C6.pdf	1km Grid	NDVI trend (4yr ave 2002 to 2005 compared to 4yr ave 2018 to 2021) NDVI average 2002-2021 Lowest 10% 2002-2021

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Surface salinity	Soil landscape land quality - Surface Salinity (current) (DPIRD-039)	Soil surface salinity is a land quality which may impact upon a variety of agricultural land uses and is based on analysis and interpretation of the best available soil-landscape mapping dataset (DPIRD-027).	Data WA	DPIRD	Polygon	Open/ Public	Accuracy of attribution is variable depending upon scale of survey and the hierarchy level of the mapping.	https://catalogue.data.wa.gov.au/dataset/soil-landscape-surface-salinity-current/resource/5a424acc-0d79-4b19-8690-3772163ab9ae	1km Grid	N/A
Important water resources	DBCA - Legislated Lands and Waters (DBCA-011)	The DBCA Legislated Lands and Waters data set shows all lands and waters defined under acts which are applicable to DBCA.	Data WA	DBCA	Polygon	Open/ Public	N/A	https://catalogue.data.wa.gov.au/dataset/dbca-legislated-lands-and-waters	1km Grid	Definition Query: Reserve Name LIKE '%Wetlands%'
	South Coast Significant Wetlands (DBCA-018)	The former WRC SC region have developed a spreadsheet which aims to document the South Coast natural assets which come under the WRC jurisdiction.	Data WA	DBCA	Polygon	Open/ Public	N/A	https://catalogue.data.wa.gov.au/dataset/south-coast-significant-wetlands	1km Grid	N/A
	Directory of Important Wetlands in Australia - Western Australia (DBCA-045)	This is a polygon coverage representing the Western Australian wetlands cited in the "A Directory of Important Wetlands in Australia" Third Edition (EA, 2001), plus various additions for wetlands listed after 2001.	Data WA	DBCA	Polygon	Open/ Public	N/A	https://catalogue.data.wa.gov.au/dataset/directory-of-important-wetlands-in-western-australia	1km Grid	N/A

	Ramsar Sites (DBCA-010)	This data set describes the official boundaries of the nine wetland areas proposed in February 1990 by the Government of Western Australia for listing as Wetlands of International Importance under the Convention on Wetlands of Importance especially as Waterfowl Habitat, otherwise known as the Ramsar Convention.	Data WA	DBCA	Polygon	Open/ Public	N/A	https://catalogue.data.wa.gov.au/dataset/ramsar-sites	1km Grid	N/A

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Important water resources	Hydrography, Linear (Hierarchy) (DWER-031)	Major streamlines of WA, coded with a hierarchy and are named. The dataset includes many streams in addition to the detailed Hydrography in areas where its data is limited (eg. Eastern Wheatbelt and Western Plateau).	Data WA	DWER	Polyline	Open/ Public	The Hydrography, Linear (Hierarchy) dataset is used by DWER for broad scale streamline presentation. It also provides definition of streamlines in ancient drainage landscapes, when other datasets do not have linework.	https://catalogue.data.wa.gov.au/dataset/hydrography-linear-hierarchy/resource/9908c7d1-7160-4cfa-884d-c5f631185859	1km Grid	Definition Query: level_name IN ('Mainstream', 'Major River') To convert polyline dataset to polygon, a 20m buffer was applied.
	Medium Scale Topo Water (Polygon) (LGATE-016)	Water features that relate to the interior of the country. Multiple points that describe the feature's perimeter.	Data WA	Landgate	Polygon	Closed/ Restricted	Based on DEM data. The accuracy of the contours derived from the DEM will be influenced by a number of factors.	https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-water-polygon-lgate-016/resource/562b221a-ddb3-4e49-ae40-25a366f84a80	1km Grid	Only used features that intersected with buffered 20m Hydrography, Linear (Hierarchy) dataset to assist in the conversion of polyline to polygon.
Availability of groundwater resources	Bores	The current dataset is an extract of the National Groundwater Information System (NGIS), water levels, salinity measurements and hydro-chemistry data for a particular state, which has been processed for	Australian Groundwater Explorer	Bureau of Meteorology (BOM)	Point	Open/ Public	The Bureau of Meteorology maintains the NGIS data model that standardises and spatially enables the groundwater data. The Bureau then undertakes Quality Assurance/Quality Control (QA/QC) of the	http://www.bom.gov.au/water/groundwater/ngis/documentation.shtml	1km Grid	N/A

		download from the Australian Groundwater Explorer.					State/Territory geodatabases and integrates them into the national geodatabase.			
Quality of groundwater resources (salinity)	Groundwater Salinity State wide (DWER-026)	Interpretive and indicative Groundwater salinity mapping state wide.	Date WA	Department of Water and Environmental Regulation (DWER)	Polygon	Open/ Public	The dataset is highly interpretive, and only broadly indicative of the likely groundwater salinity, bearing in mind the generalisations needed at such a small scale.	https://catalogue.data.wa.gov.au/dataset/groundwater-salinity-statewide/resource/1882325f-f639-46fb-ba0a-d78889ac8b4b	1km Grid	N/A
Water protection area	Public Drinking Water Source Areas (DWER-033)	Public drinking water source areas (PDWSAs) are surface water catchments and groundwater areas that provide drinking water to cities, towns and communities throughout the state.	Data WA	DWER	Polygon	Open/ Public	Good but variable as the accuracy is based on different means, scales and methods of capture and definition. Where possible the original mapping and/or legal description was used for definition.	https://catalogue.data.wa.gov.au/dataset/public-drinking-water-source-areas/resource/33352803-7348-48d0-842f-de31b2f23c0c	1km Grid	N/A
Proximity to main road infrastructure	Medium Scale Topo General Transport (Line) (LGATE-117)	Topographic features whose primary characteristics are of a general transport nature.	Data WA	Landgate	Polyline	Closed/ Restricted	N/A	https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-general-transport-line-lgate-117	1km Grid	Created using multi ring buffers showing distance to Main roads : 0-10, 10-25, 25-50, 50-100, >100km

Proximity to strategic community water supplies	Strategic Community Water supplies	A network of strategic community water supplies has been developed across Western Australia's dryland agricultural areas to provide an important source of emergency stock water during dry seasons. These water supplies are for emergency use at times when low rainfall causes on-farm supplies to fail and forces farmers to travel outside their farm gate to collect water for livestock and other essential farming purposes. The Department of Water and Environmental Regulation keeps in regular contact with rural communities to monitor the condition of strategic community water supplies and identify and address any maintenance issues.	DWER Rural water ruralwater@dwer.wa.gov.au.	DWER	Point	Closed/ Restricted	N/A	https://www.water.wa.gov.au/planning-for-the-future/rural-water-support/management-of-strategic-community-water-supplies	1km Grid	Created using multi ring buffers showing distance to water supply points: 0-10,10-20,20-40, 40-70, >70km

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Proximity to scheme water coverage	Water pipe (WCORP-002)	This dataset contains Centrelines only for all the Trunk, Distribution & Reticulation Water Mains in all the locations where the Water Corporation is licensed to provide Potable Water. It does not include Bore mains, Wastewater Reuse or Saline Mains. Bunbury & Busselton are excluded as the Water Service is supplied by those particular Local Councils.	Data WA	Water Corporation	Polyline	Open/Public	N/A	https://catalogue.data.wa.gov.au/dataset/water-pipe-wcorp-002	1km Grid	Created using multi ring buffers showing distance to water pipe lines: 0-10,10-20,20-40, 40-70, >70km
Change in growing season rainfall (Apr – Oct) - Historical	Average rainfall (mm), April to October, 1961 to 1990; Average rainfall (mm), April to October, 1991 to 2020	Average rainfall (mm) interpolated from DPIRD's network of automatic weather stations and radars throughout the state.	Climate Services for Agriculture	Department of Agriculture, Water and Environment (DAWE)	Raster	Open/Public	N/A	https://climateservicesforag.indraweb.io/	1km Grid	Created by calculating the percentage difference of average rainfall (mm) between 1961 to 1990 and 1991 to 2020 during April to October.

Change in growing season rainfall (Apr – Oct) - Projected	Projected Average rainfall (mm), April to October, 2030; Average rainfall (mm), April to October, 2050	The Statistical Seasonal Forecast (SSF) system uses historical relationships between global sea surface temperature and sea level pressure with rainfall in south-west Australia to produce forecasts of rainfall for future months.	Climate Services for Agriculture	DAWE	Raster	Open/Public	Statistical forecasts are not for exact amounts. They take the form of probability distributions that may represent a shift from historical rainfall probabilities.	https://climateservicesforag.indraweb.io/	1km Grid	Created by calculating the percentage difference of projected average rainfall (mm) between 2030 and 2050 during April to October.
Rainfall intensity (number of rainfall events >10mm) - Historical	Average number of days per annum with rainfall greater than 10mm (1990-2020)	The days of rain map series shows the average number of days when rainfall exceeds the total specified annually. The Patched Point Dataset (PPD) combines observations and interpolations to provide daily data for a selected set of stations (locations).	Silo Patched Point Data	Queensland Department of Environment and Science	Point	Open/Public	The observational (station) data on which the analyses were based have an associated accuracy of the order of 0.01 degrees (approximately 1km) or better.	http://qldspatial.information.qld.gov.au/catalogueadmin/catalog/search/resource/details.page?uuid=%7B0D1DF4A9-1D43-45E1-AC31-5A03BD93A406%7D	1km Grid	Point data interpolated to 1km grid

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Rainfall intensity (number of rainfall events >25mm) - Historical	Average number of days annum with rainfall greater than 25mm (1990-2020)	The days of rain map series shows the average number of days when rainfall exceeds the total specified annually. The Patched Point Dataset (PPD) combines observations and interpolations to provide daily data for a selected set of stations (locations).	Silo Patched Point Data	QLD Dept of Environment and Science	point	Open/Public	The observational (station) data on which the analyses were based have an associated accuracy of the order of 0.01 degrees (approximately 1km) or better.	http://qldspatial.information.qld.gov.au/catalogueadmin/catalog/search/resource/details.page?uuid=%7B0D1DF4A9-1D43-45E1-AC31-5A03BD93A406%7D	1km Grid	Point data interpolated to 1km grid
Change in maturing season temperature (Aug to Nov) - Historical	Number of days above 34 degrees (Aug to Nov), 1961 to 1990; Number of days above 34 degrees (Aug to Nov) 1991 to 2020	Data shows number of days above 34 degrees, interpolated using DPIRD and BOM automatic weather stations.	Climate Services for Agriculture	DAWE	Raster	Open/Public	Data produced using patched point and DPIRD station data	https://climateservicesforag.indraweb.io/	1km Grid	Created by calculating the difference of the number of days above 34 degrees between 1961 to 1990 and 1991 to 2020 during August to November.
Change in maturing season temperature (Aug to Nov) - Projected	Future number of days above 34 degrees (Aug to Nov), 2030; Future number of days above 34 degrees (Aug to Nov) 2050	Data shows projected number of days above 34 degrees, interpolated using DPIRD and BOM automatic weather stations.	Climate Services for Agriculture	DAWE	Raster	Open/Public	N/A	https://climateservicesforag.indraweb.io/	1km Grid	Created by calculating the difference of the number of days above 34 degrees between 2030 and 2050 during August to November

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Change in root zone soil moisture (%), 2000 to 2021	Root zone soil moisture	Root Zone Soil Moisture is the sum of water in the Australian Water Resources Assessment Landscape model (AWRA-L) Upper and Lower soil layers and represents the percentage of available water content in the top 1 m of the soil profile. The maximum storage within the soil layer is calculated from the depth of the soil and the relative soil water storage capacity.	Australian Landscape Water Balance	BOM	Raster	Open/Public	Each of the models have differing strengths and weaknesses. Overall, given runoff/streamflow is the dominant hydrological variable used in surface water resource assessment, and that AWRA-L simultaneously performs well for root zone soil moisture (a key agricultural variable), AWRA-L is considered the most fit-for-purpose national hydrological model estimator for water resource and agricultural applications. Overall, the spatial plots and the time-series give confidence in the use of AWRA-L for water resources assessment; as they broadly follow the expected catchment responses and spatial and temporal trends expected across Australia.	http://www.bom.gov.au/water/landscape/assets/static/publications/AWRALv6_Model_Description_Report.pdf http://www.bom.gov.au/water/landscape/assets/static/publications/AWRALv6_Model_Evaluation_Report.pdf	1km Grid	Created by calculating the percentage difference between the actual values of the root zone soil moisture from 2000 and the actual values of the root zone soil moisture from 2020.
Change in autumn break (%), 1975-1999 to 2000-2020	Change in autumn break 1975 to 1999; Change in autumn break 2000 to 2020	Data shows median break of season for the period of 1975-1999 and 2000-2020, interpolated using DPIRD and BOM automatic weather stations.	DPIRD	DPIRD	Raster	Closed/ Restricted	N/A	N/A	1km Grid	Created by calculating the percentage difference of values in autumn break between 1975 to 1999 and 2000 to 2020.

Distance from the coast	Coastline	The line of contact between the ocean/sea and the land as best interpreted from ortho-imagery. This is a polygonised version of the Framework Line (LGATE-121) dataset more suited to mapping purposes.	Data WA	Land gate	Polyg on	Closed/ Restricted	N/A	https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-framework-polygon-coastline-lgate-120	1km Grid	Created using buffers of 20km increments.
Decline in average yield potential (1975-1999 to 2000-2020)	Average potential yield difference	Potential yield is the maximum yield possible given rainfall in the absence of any other constraints. Estimates of potential wheat yield are obtained using the French & Schultz potential yield model.	Meredith Guthrie	DPIR D	Raste r	Closed/ Restricted	The potential yield model assumes that crop emergence occurs in April or May, the timing of rainfall during the season does not negatively affect crop growth (there is no drying off), and there are no soil constraints that hinder root growth. For later sowing and emergence (for example in June) use evaporation rate of 90 instead of 110 mm. If any of these assumptions are not met, then potential yield could be considerably lower than shown in the maps.	https://www.agric.wa.gov.au/dry-seasons-and-drought/seasonal-climate-information	1km Grid	Created by calculating the percentage difference of average potential yield (t/ha) between 1975 to 1999 and 2000 to 2020.
Average yield potential (t/ha) (2000-2020)	Average potential yield	Potential yield is the maximum yield possible given rainfall in the absence of any other constraints. Estimates of potential wheat yield are obtained using the French & Schultz potential yield model.	Meredith Guthrie	DPR D	Raste r	Closed/ Restricted	The potential yield model assumes that crop emergence occurs in April or May, the timing of rainfall during the season does not negatively affect crop growth (there is no drying off), and there are no soil constraints that hinder root growth. For later sowing and emergence (for example in June) use	https://www.agric.wa.gov.au/dry-seasons-and-drought/seasonal-climate-information	1km Grid	N/A

							evaporation rate of 90 instead of 110 mm. If any of these assumptions are not met, then potential yield could be considerably lower than shown in the maps.			
Wheat yield (t/h)	Agricultural commodities, Australia and state/territory and LGA regions - 2015-16	This publication contains final estimates for data items collected in the 2015-16 Agricultural Census. Included are statistics on land use, crop and horticultural area and production, livestock numbers, farm management and demographic information.	Australian Bureau of Statistics	ABS	Table	Open/Public	The estimates in this publication are based on information obtained from agricultural businesses that responded to the 2015-16 Agricultural Census. However, since not all of the businesses that were selected provided data, the estimates are subject to sampling variability; that is, they may differ from the figures that would have been produced if information had been collected from all businesses.	https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/7121.0Explanatory%20Notes12015-16?OpenDocument	1km Grid	Clipped to Wheatbelt of WA (DPIRD-24) polygon. https://catalogue.data.wa.gov.au/dataset/wheatbelt-of-wa-dpird-028

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Canola yield (t/h)	Agricultural commodities, Australia and state/territory and LGA regions - 2015-16	This publication contains final estimates for data items collected in the 2015-16 Agricultural Census. Included are statistics on land use, crop and horticultural area and production, livestock numbers, farm management and demographic information.	ABS	ABS	Table	Open/Public	The estimates in this publication are based on information obtained from agricultural businesses that responded to the 2015-16 Agricultural Census. However, since not all of the businesses that were selected provided data, the estimates are subject to sampling variability; that is, they may differ from the figures that would have been produced if information had been collected from all businesses.	https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/7121.0Explanatory%20Notes12015-16?OpenDocument	1km Grid	Clipped to Wheatbelt of WA (DPIRD-24) polygon. https://catalogue.data.wa.gov.au/dataset/wheatbelt-of-wa-dpird-028
Sheep numbers per LGA	Agricultural commodities, Australia and state/territory and LGA regions - 2015-16	This publication contains final estimates for data items collected in the 2015-16 Agricultural Census. Included are statistics on land use, crop and horticultural area and production, livestock numbers, farm management and demographic information.	ABS	ABS	Table	Open/Public	The estimates in this publication are based on information obtained from agricultural businesses that responded to the 2015-16 Agricultural Census. However, since not all of the businesses that were selected provided data, the estimates are subject to sampling variability; that is, they may differ from the	https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/7121.0Explanatory%20Notes12015-16?OpenDocument	1km Grid	

							figures that would have been produced if information had been collected from all businesses.			
Cattle numbers per LGA	Agricultural commodities , Australia and state/territory and LGA regions - 2015-16	This publication contains final estimates for data items collected in the 2015-16 Agricultural Census. Included are statistics on land use, crop and horticultural area and production, livestock numbers, farm management and demographic information.	ABS	ABS	Table	Open/Public	The estimates in this publication are based on information obtained from agricultural businesses that responded to the 2015-16 Agricultural Census. However, since not all of the businesses that were selected provided data, the estimates are subject to sampling variability; that is, they may differ from the figures that would have been produced if information had been collected from all businesses.	https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/7121.0Explanatory%20Notes12015-16?OpenDocument	1km Grid	

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Barley yield (t/ha)	Agricultural commodities, Australia and state/territory and LGA regions - 2015-16	This publication contains final estimates for data items collected in the 2015-16 Agricultural Census. Included are statistics on land use, crop and horticultural area and production, livestock numbers, farm management and demographic information.	Australian Bureau of Statistics	ABS	Table	Open/ Public	The estimates in this publication are based on information obtained from agricultural businesses that responded to the 2015-16 Agricultural Census. However, since not all of the businesses that were selected provided data, the estimates are subject to sampling variability; that is, they may differ from the figures that would have been produced if information had been collected from all businesses.	https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/7121.0Explanatory%20Notes12015-16?OpenDocument	1km Grid	Clipped to Wheatbelt of WA (DPIRD-24) polygon. https://catalogue.data.wa.gov.au/dataset/wheatbelt-of-wa-dpird-028
High quality agriculture land (HQAL) wheat yield potential (t/ha)	**High quality agriculture land (HQAL) Stages 1-3**	The Department of Agriculture and Food, Western Australia, has worked closely with state and local planners and agricultural practitioners over the last four years to develop a new way to identify high quality agricultural land (HQAL). This methodology combines land capability for horticulture and dry land cropping and grazing with irrigation supplies, rainfall and yield information. It then ranks large tracts of "similar" land according to its versatility for a range of agricultural land uses.	DPIRD	DPIRD	Raster	Restricted	Batavia Coast and North Midlands Midwest planning regions. Central coast Wheatbelt planning region.	https://www.agric.wa.gov.au/sites/gateway/files/RMTR%20386%20HQAL%20Geraldton%202nd%20edition.pdf	1km Grid	Detailed Broadacre map unit wheat yield (t/ha)

Average household income ($/week)	Australian 2016 census of population and housing	This publication outlines the nature and content of Australia's next Census, to be held on Tuesday 9 August 2016.	ABS geopackage https://datapacks.censusdata.abs.gov.au/geopackages/	ABS	SA1 Polygon	Open/ Public	The estimates are based on a sample of possible observations and are subject to sampling variability. The estimates may therefore differ from the figures that would have been produced if information had been collected for all households. A measure of the sampling error for a given estimate is provided by the standard error, which may be expressed as a percentage of the estimate (relative standard error).	https://www.abs.gov.au/ausstats/abs@.nsf/mf/2008.0	1km Grid	Used table *Median_tot_hhd_inc_weekly*

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Average farm size (hectare)	Client Property Event System - Properties (DPIRD-018)	The Property boundaries dataset is a publically available subset of the information held in DPIRD's Client Property Event (CPE) database. CPE is a spatially linked database of agricultural and other properties in Western Australia.	Data WA	DPIRD	Polygon	Open/ Public	Properties consist of one or more contiguous cadastral parcels – aggregated on land management (this does not necessarily correspond with land management). The purpose of the database is to support the biosecurity and regulatory operations of DPIRD. Property information is collected through direct contact with landholders through mail-outs and attendance at field days. Properties may also contain information auto-generated from Landgate parcel data records. The underlying parcel data is updated twice a year using Cadastral boundaries supplied by Landgate. Property boundary and ownership information are updated	https://catalogue.data.wa.gov.au/dataset/client-property-event-system-properties/resource/e0ad6de0-b425-4103-ada7-12c1087f06c6	1km Grid	Average Agricultural property size (>2ha) by locality. Property type determined from CPE database attribution

							on a daily basis. Landgate parcel data records. Accuracy of information is variable depending upon the degree of contact with landholders.			
Count of water assets (bores and dams)	Water Bore (WCORP-073)	Water Corporation access point for subsurface water delivery	Data WA	Water Corporation	Point	Open/ Public	N/A	N/A	1km Grid	N/A
	Water Dam (WCORP-075)	Water Corporation water storage facility	Data WA	Water Corporation	Polygon	Open/ Public	N/A	N/A	1km Grid	N/A
	Farm dams of Western Australia (DPIRD-083)	Spatial boundaries of over 175,000 agricultural dams in Western Australia.	Data WA	DPIRD	Polygon	Open/ Public	It has been calculated that with the South West agricultural region of WA this product excludes about 24,000 farm dams and that 1,800 features labelled as farm dams are in fact not farm dams. This is a result of the automated capture method.	https://catalogue.data.wa.gov.au/dataset/farm-dams-of-the-south-west-agricultural-region-of-wa/resource/bfb59742-8d3e-4a5c-8721-c0de17b84a65	1km Grid	N/A

Diversity of farm activities	Multiple data sources - Client Property Event (CPE) System – Property Activity. Stock Brands and PIC register - stock numbers. Catchment Scale Landuse Mapping (ALUM V7)	Catchment scale Landuse - This vector dataset is a compilation of land use data for Western Australia, as at August 2018. It has been derived from various vector datasets with attribution relevant to land use in Western Australia. The date of mapping (2008 to 2018) and scale of mapping (1:5 000 to 1:250 000) vary, reflecting the source data, capture date and scale.	DPIRD	DPIRD	Polygon	Restricted		https://data.gov.au/dataset/ds-dga-d897e165-46a3-4f3b-a2f2-b348ac06ddfe/details https://www.agric.wa.gov.au/livestock-biosecurity/stock-brand-and-pic-register-search-guide https://catalogue.data.wa.gov.au/dataset/client-property-event-system-properties/resource/e0ad6de0-b425-4103-ada7-12c1087f06c6	1km Grid	Count of agricultural activity types per agricultural property. Activities included Sheep, Cattle, Pigs, Feedlot, Horticulture, Dairy, Plantations, Pivot Irrigation and Broadacre Cropping. Total count of Agricultural activities and properties with broadacre cropping only were used to create a composite product

Accessibility and remoteness index of Australia	Remoteness Area (RA) ASGS Ed 2016	The Australian Statistical Geography Standard (ASGS) defines Remoteness Areas into 5 classes of relative remoteness across Australia. These 5 classes of remoteness are: Major Cities of Australia, Inner Regional Australia, Outer Regional Australia, Remote Australia and Very Remote Australia	ABS Data Cube	ABS	Polygon	Open/ Public	The five classes of remoteness are determined using a process that provides a consistent definition across Australia and over time. This allows statistical data to be classified in a consistent way that allows users to analyse changes in data for different remoteness categories over time. Relative remoteness is measured in an objective way using the Accessibility and Remoteness Index of Australia (ARIA+), which is developed by the Hugo Centre for Migration and Population Research at the University of Adelaide.	https://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/1270.0.55.005Main%20Features1July%202016?opendocument&tabname=Summary&prodno=1270.0.55.005&issue=July%202016&num=&view=	1km Grid	N/A

Criteria Layer	Data Name	Description (Metadata Statement)	Source	Agency	Data Type	Restrictions	Accuracy/Intended Use	Metadata Link	Spatial Resolution	Processing Notes
Population % change from 2011 to 2020	Australian Population Grid 2011 and Australian Population Grid 2020	Estimated resident population (ERP) is the official estimate of the Australian population, which links people to a place of usual residence within Australia. Usual residence is the address at which a person considers themselves to currently live. ERP includes all people who usually live in Australia (regardless of nationality, citizenship or visa status), with the exception of people present for foreign military, consular or diplomatic reasons.	ABS population grids 2011: https://www.abs.gov.au/ausstats/abs@.nsf/mf/1270.0.55.007 2020: https://www.abs.gov.au/statistics/people/population/regional-population/2019-20#data-downloads-population-grid-files	ABS	Grid	Open/ Public	The sub-state estimates in this product are subject to some error. Some caution should be exercised when using the estimates, especially for areas with very small populations. An indication of the accuracy of ERP can be gauged by assessing the size and direction of intercensal differences.	https://www.abs.gov.au/methodologies/regional-population-methodology/2019-20	1km Grid	% change in grid population from 2011 to 2020

Count of LGAs declared water deficient	Water Deficiency Declarations DWER	A 'water deficiency declaration' is a government response to safeguard the commercial interests of farmers during very dry periods. A declaration occurs when a group of five or more farmers, within a 20-kilometre radius, require water from an off-farm source and have to travel greater than a 40-kilometre radius from their farm to get this. In extreme circumstances, water may be provided for individual famers.	DWER Rural water ruralwater@dwer.wa.gov.au.	DWER	Table	Restricted		https://www.water.wa.gov.au/planning-for-the-future/rural-water-support/emergency-farmland-water-response-planning-and-water-deficiency-arrangements	LGA and Locality – 1km Grid	Count of LGA or locality from1994-2021

Table 2: Organisation and weighting of each data layer.

Framework category	Sub-category	Data set	Weight
Exposure		Composite map	1.25[a]
	Not applicable	Change in growing season rainfall	1
	Not applicable	Projected future change in growing season rainfall	1
	Not applicable	Rainfall intensity events > 10mm	1
	Not applicable	Rainfall intensity events > 25mm	1
	Not applicable	Change in maturing season temperature	1
	Not applicable	Projected future change in maturing season temperature	1
	Not applicable	Seasonal root zone soil moisture	1
	Not applicable	Change in timing of the autumn break	1
	Not applicable	Distance from the coast	1
	Not applicable	Change in drought frequency	1
	Not applicable	Change in potential wheat yield	1
Sensitivity		Composite map	1
	Production	Composite map	1.25[b]
	Production	Average potential wheat yield	1.5[c]
	Production	Crop production (t/h; wheat, canola, barley)	1
	Production	Livestock production (numbers; sheep, cattle)	1
	Production	High quality agricultural land	1
	Production	NDVI at the end of the growing season (20yr average)	1.5[d]
	Other	Composite map	1
	Other	Trends in water quality	1
	Other	NDVI at the end of the growing season (lowest 10%)	1.5[e]
	Other	Average household income	1
	Other	Farm profit	1
	Other	Percentage employment in agriculture	1
	Other	Average farm size	1
	Other	Presence of bore and dams	1
	Other	Farm diversity	1

	Other	Accessibility and remoteness index	1
	Other	Population trends	1
	Other	Declared water deficient areas	1.25[f]
Impact		Composite map (Exposure + Sensitivity)	1
Adaptive Capacity		Composite map	1
	Human Capital	Composite map	1
	Human capital	Population > 65yrs	1
	Human capital	Percentage unemployment	1
	Natural Capital	Composite map (Other + Water)	1.5[g]
	Natural Capital (Other)	Composite map	1
	Natural capital	Soil capability	1.5[h]
	Natural capital	Plant available soil water capacity	1
	Natural capital	Native vegetation extent	1
	Natural capital	NDVI trend	1
	Natural capital	Surface Salinity	1
	Natural Capital (Water)	Composite map	1
	Natural capital	Important natural water resources	0.5[i]
	Natural capital	Groundwater availability	1
	Natural capital	Groundwater quality	1
	Natural capital	Proclaimed water protection areas	1
	Physical Capital	Composite map	1.5[j]
	Physical capital	Proximity to main roads	1
	Physical capital	Proximity to strategic community water supplies	1
	Physical capital	Proximity to scheme water	1

[a] Weighted higher because of the importance of climate factors in predicting the likelihood and severity of drought; [b] weighted higher because of the importance of agriculture for the economies of the focus regions and because the agriculture sector is likely to be hit hardest by drought; [c] weighted higher because of the importance of wheat production in the agriculture sector in the focus regions; [d,e] weighted higher because of the detectability of drought impacts in NDVI data and the importance of vegetation cover for mitigating impacts of drought such as soil erosion; [f] weighted higher because of the importance of water for mitigating impacts of drought on livestock and on farming communities; [g] weighted higher because of the higher relative importance and higher level of confidence in the natural capital data compared to the human capital data; [h] weighted higher because of the importance of soil capability for predicting agricultural production potential, an important part of resilience for agricultural communities; [i] weighted lower because the natural water resources in the focus regions are largely ephemeral, frequently saline and unlikely to contribute much to drought resilience as a result; [j] weighted higher because of the higher relative importance and higher level of confidence in the physical capital data compared to the human capital data.

4. Results

4.1 Exposure

The exposure map included datasets related to change in growing season rainfall (historical and projected), maturing season temperature (historical and projected), change in average potential wheat yield (historical), timing of the autumn break (historical) and drought frequency (historical) as well as records of rainfall intensity (number of rainfall events >10mm and >25mm), root zone soil moisture and distance from the coast. Areas most exposed to drought are the northern and eastern Wheatbelt (Figure 3).

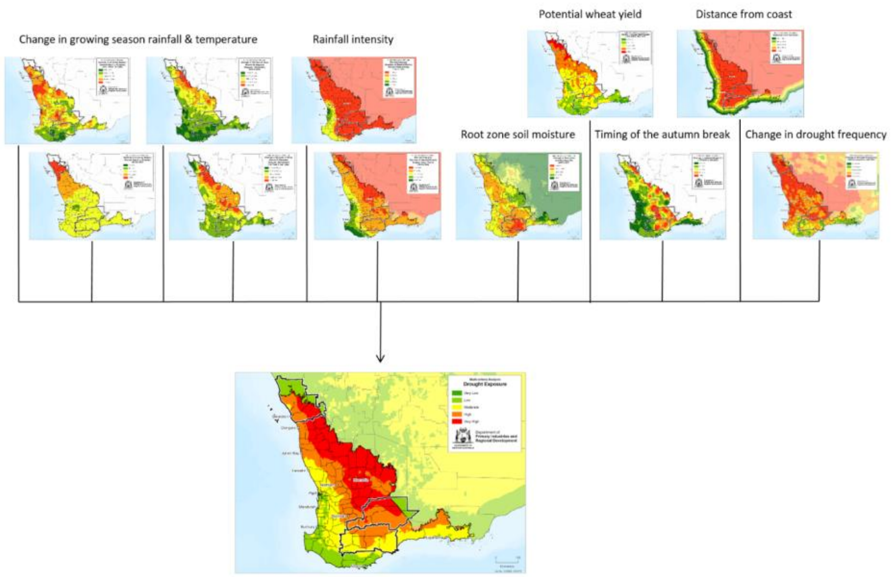

Figure 3: Drought exposure map showing all included data sets. All component data sets were equally weighted.

4.2 Sensitivity

The sensitivity map is made up of a composite map of production-related datasets and several other datasets related to factors likely to influence how sensitive an area will be to drought. The production map included datasets related to production of wheat, canola, barley, cattle and sheep (the five most common agricultural products in the region), high quality agricultural land (only available for the northern Wheatbelt), average potential wheat yield and 20-yr average NDVI. Areas most sensitive to drought are the northern and eastern Wheatbelt (Figure 4).

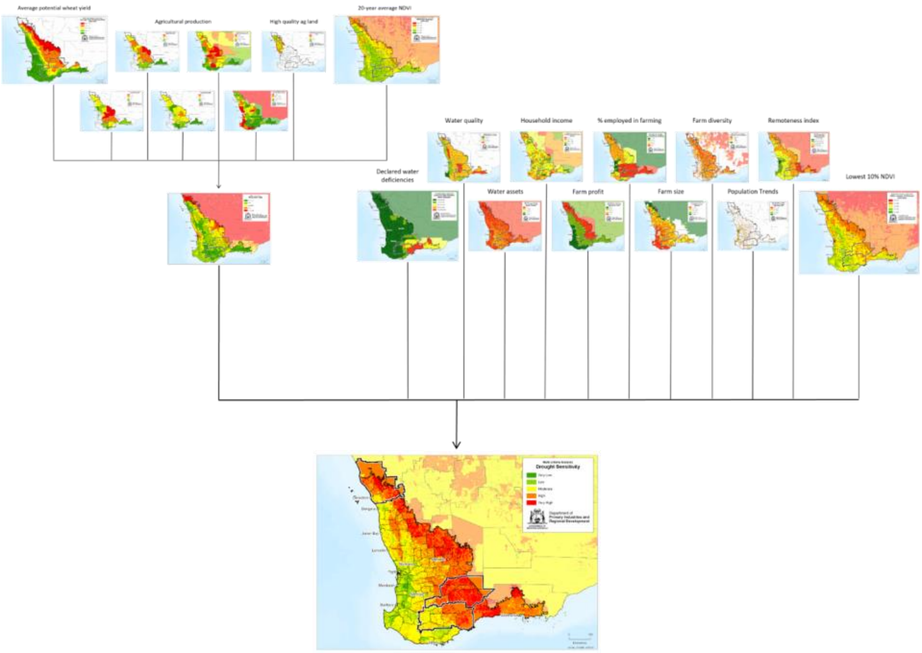

Figure 4: Drought sensitivity map showing all included data sets. Component data sets are sized according to their weighting.

4.3 Impact

The impact map is a composite of the exposure map and the sensitivity map (Figure 5). Areas most likely to experience high impacts of drought are the northern and eastern Wheatbelt (Figure 6).

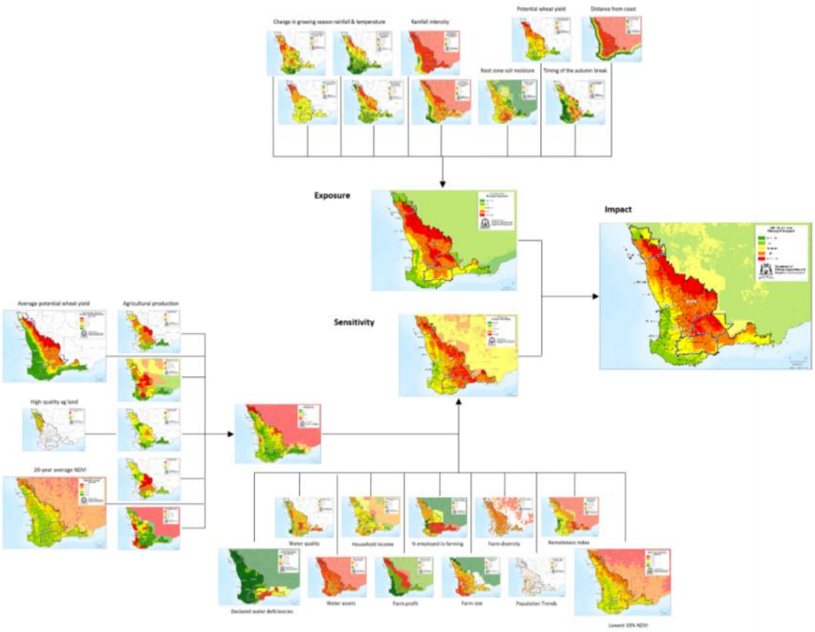

Figure 5: Drought impact map showing all included data sets. Component data sets are sized according to their weighting.

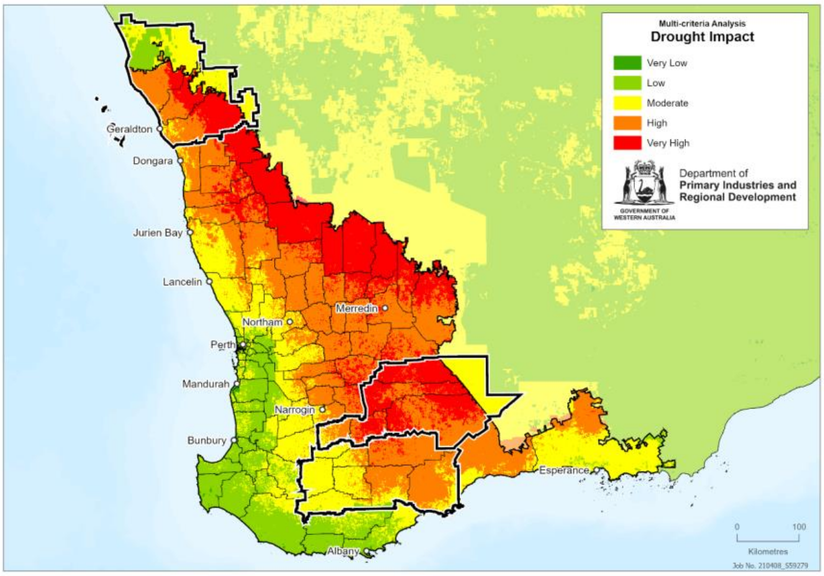

Figure 6: Final drought impact map highlighting that the areas most vulnerable to drought are the northern and eastern Wheatbelt.

4.4 Adaptive Capacity

The adaptive capacity map is made up of three composite maps for human capital, natural capital and physical capital. The human capital map includes data on population age and employment (Figure 7). This is the data layer we have the lowest confidence in, both in terms of the resolution of the data and relationships between the measured variable and resilience to drought. The natural capital map (Figure 8) is made up of two composite maps for water and other natural capital. The physical capital map includes data on proximity to road and water infrastructure (Figure 9). Areas with the lowest adaptive capacity to drought follow a less clear pattern and tend to be concentrated in the more populated areas along the coast. The Mid West region is likely to be more vulnerable to drought from the perspective of adaptive capacity than the Wheatbelt and Great Southern regions (Figure 10).

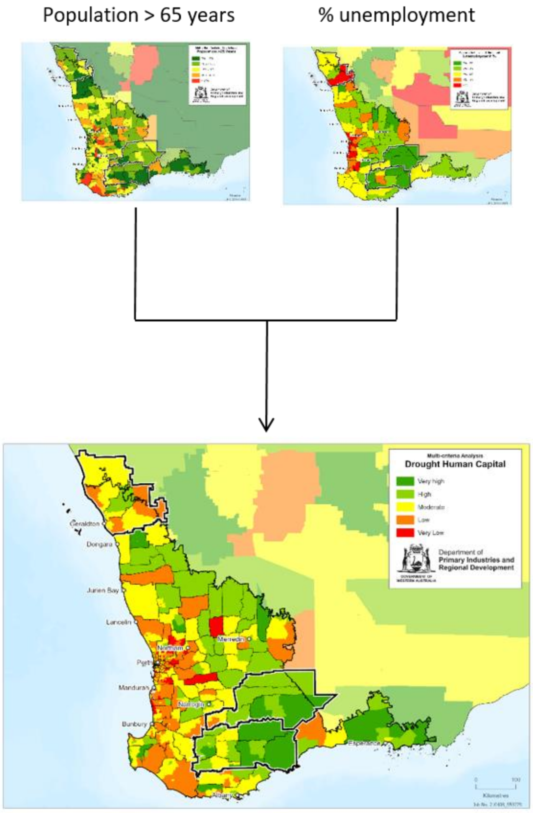

Figure 7: Human capital map showing all included data sets. All component data sets are equally weighted.

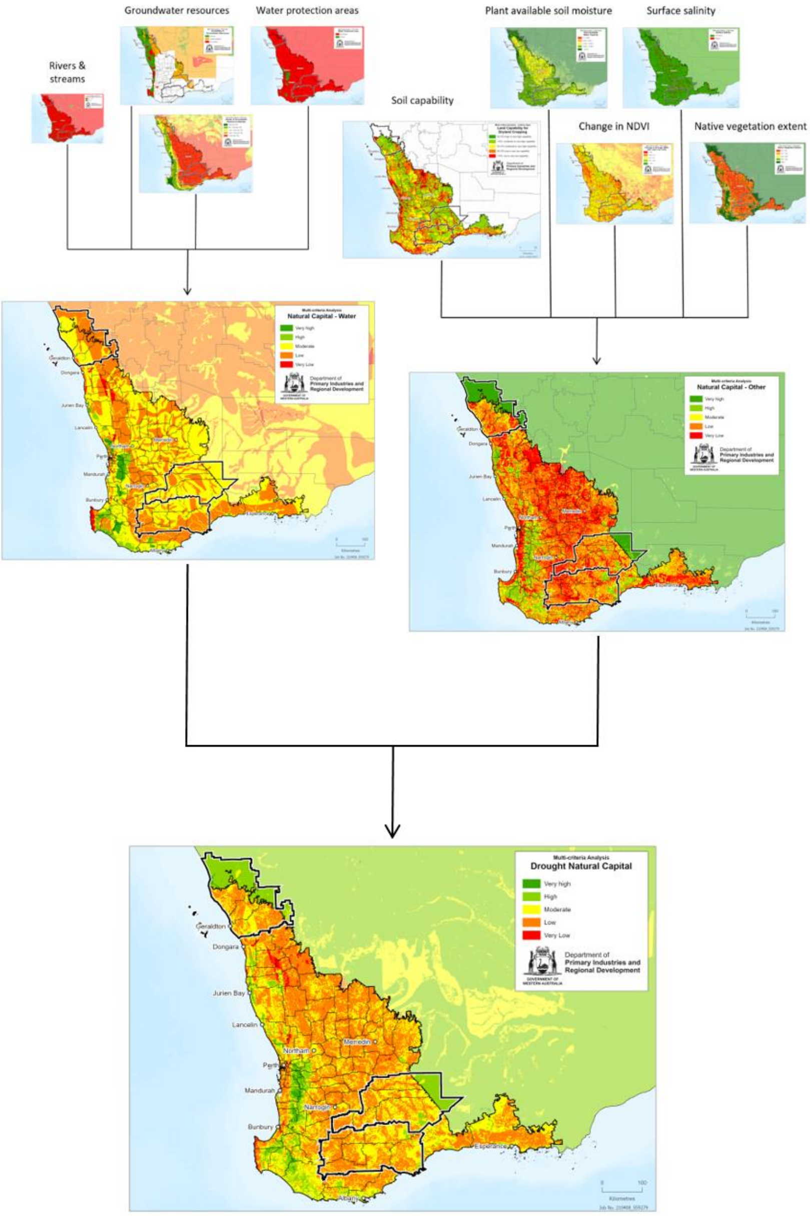

Figure 8: Natural capital map showing all included data sets. Component data sets are sized according to their weighting.

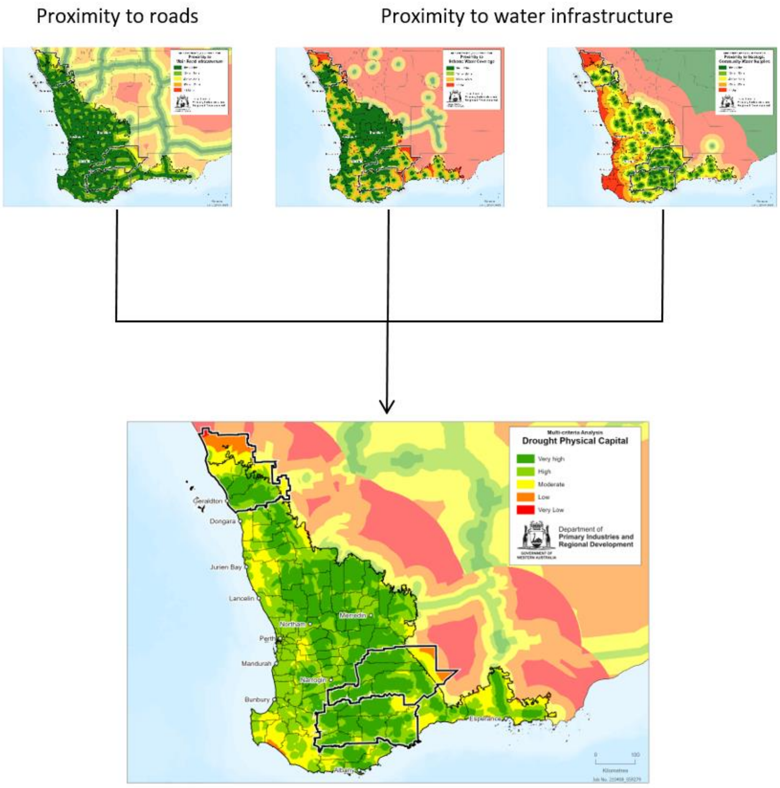

Figure 9: Physical capital map showing all included data sets. All component data sets are equally weighted.

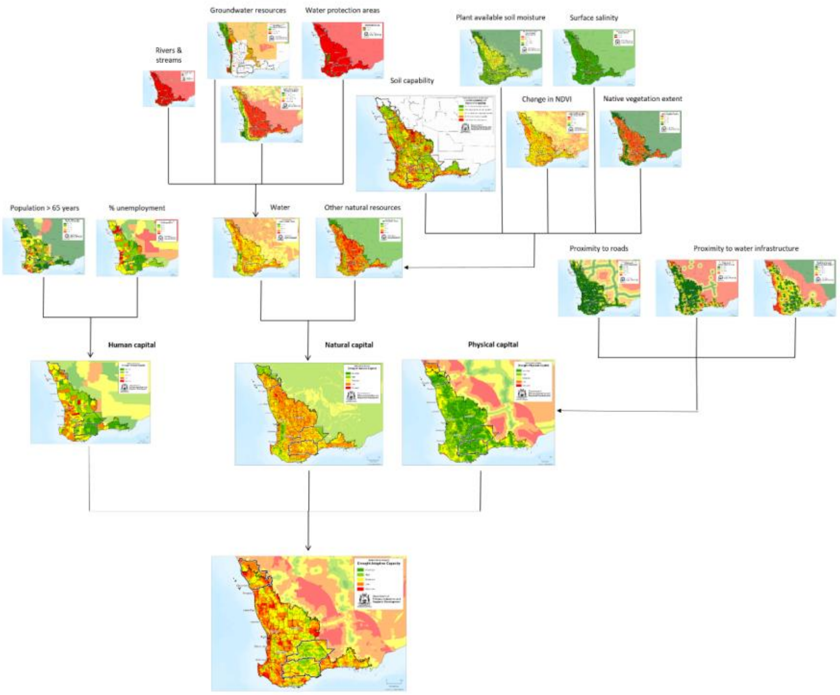

Figure 10: Adaptive capacity map showing all included data sets. Component data sets are sized according to their weighting.

4.4 Vulnerability

The final drought resilience priority areas map highlights the most vulnerable areas to drought and is made up of two composite maps for impact and adaptive capacity (Figure 11). Areas at highest risk from drought are the northern and eastern Wheatbelt (Figure 12-13). The drought vulnerability map highlights locations in the landscape that are more likely to be experience drought, are more sensitive to the impacts of drought and potentially have a lower ability to respond effectively during drought due to, for example, relatively poorer access to services and infrastructure, higher dependence on agriculture or relatively lower levels of income and employment.

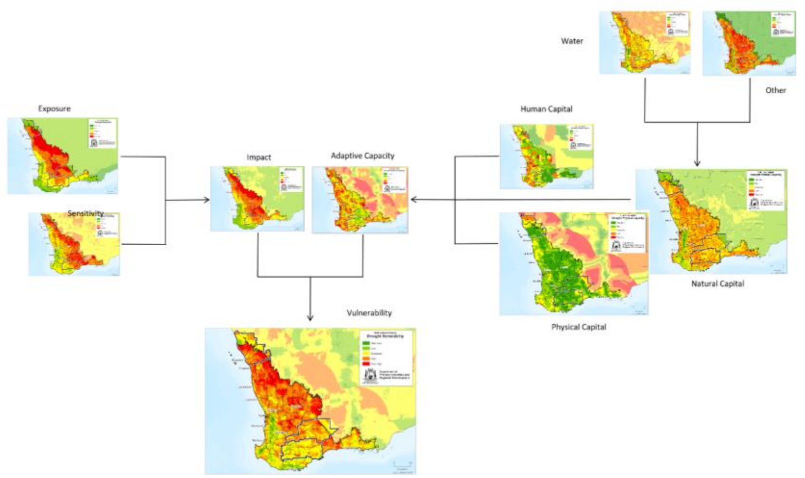

Figure 11: Drought vulnerability map showing all the composite maps that contribute to the final product. Component maps are sized according to their weighting.

Figure 12: Drought vulnerability map showing all the contributing datasets.. Component datasets are sized according to their weighting.

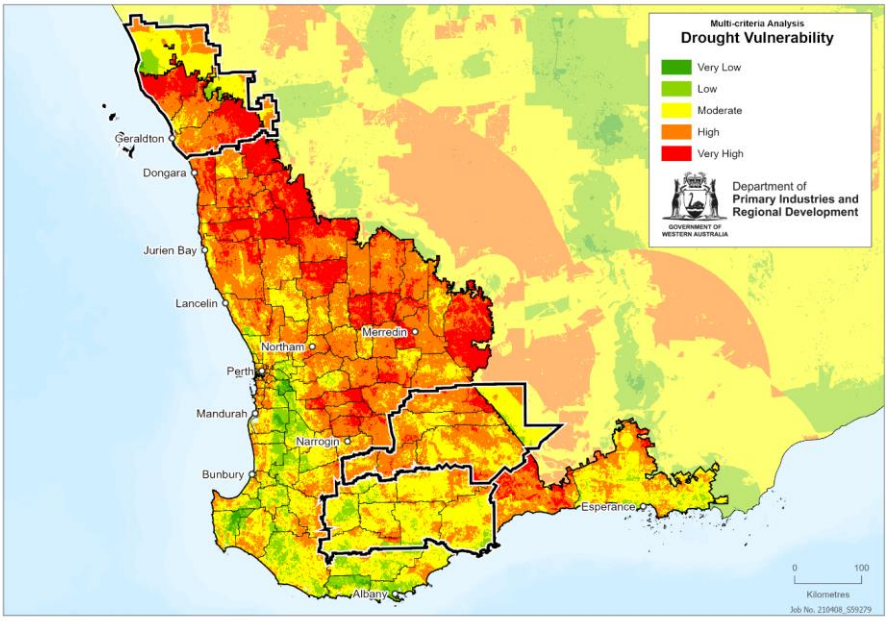

Figure 13: Final drought vulnerability map highlighting that the areas most vulnerable to drought are the northern and eastern Wheatbelt.

5. Ground-truthing

Workshop participants in the Mid West region identified drought vulnerable locations in the Southern Rangelands, the areas north of Ogilvie and east of Tenindewa and the areas on poor soils (Figure 14). Inland northern Wheatbelt towns of Binnu and Yuna were both mentioned specifically more than once. Participants also mentioned that the central and coastal grainbelt regions may be quite vulnerable to drought because they have not experienced it as often or as severely in the past and therefore might be less prepared. The area identified through participatory mapping (Figure 14) overlaps substantially with the area identified in the drought impact (Figure 6) and drought vulnerability (Figure 13) maps.

Southern Wheatbelt and Great Southern stakeholders identified the areas most vulnerable to drought as those with lower levels of access to reliable water supplies and water infrastructure, including strategic community water supplies, piped scheme water and on-farm water capture and storage. In the Southern Wheatbelt specific localities mentioned as more vulnerable than others due to the lack of reliable water supplies were (to be listed).

Figure 14: Results of participatory mapping in the Mid West planning area.

6. Conclusion

The MCA conducted here scientifically prioritises focus areas for the implementation of drought resilience programs, highlighting for decision-makers those places that will derive maximum benefit from investment. The composite drought impact map (Figure 6) has the potential to be a powerful decision support tool for regional southwest WA. We have a high level of confidence in the component datasets, which include climate data, agricultural production data and data relating to water quality and availability, levels of engagement in agriculture and economic and population trends in regional communities. These data are robust, regularly collected and available at high spatial and temporal resolution across southwest WA, including all three focus regions. The links between the component datasets and impacts of drought are clear and well understood. Low rainfall exacerbates drought risk, as does a shorter or warmer growing season; drought is associated with reduced production and farm income; and 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. There is a high level of agreement between the priority areas highlighted in the drought impact map and those identified through a participatory mapping process involving a large number of regional stakeholders, many of whom have experienced drought in the region previously.

Including data layers representing adaptive capacity is important, because we know that socio-economic, natural and physical characteristics of regions and regional communities contribute a huge amount to overall resilience (Carnie et al., 2011; Edwards et al., 2018; Munroe et al., 2012; Nelson et al., 2007). Important human capital components of adaptive capacity include the ability of individuals to access and use information to guide decision-making, make effective decisions under conditions of uncertainty, maintain employment, engage with experts and in education and training and adopt new approaches, tools and technologies. Important physical capital components of adaptive capacity include mobile and internet connectivity, capital expenditure and access to infrastructure and equipment. Important financial capital components of adaptive capacity include access to savings or credit, earnings before income and tax (EBIT), the number of agricultural business and the diversity of agricultural commodities. Important natural capital components of adaptive capacity include soil health and capability, vegetation cover and native vegetation extent. Important social capital components of adaptive capacity include membership of groups or clubs, levels of participation in community events, remoteness, population trends and social media activity. Where possible, these components have been included in the MCA, see Table 1. However, these components can be difficult to measure. Many are reported infrequently, if at all, and often only at small, local scales. They can be difficult to represent spatially, and therefore to include in MCA. Our inability to include a large number of the adaptive capacity components we identified as extremely important, due to limitations on data quality, resolution or availability, reduces our confidence in the adaptive capacity component of the MCA. It is likely to be incomplete.

Another feature of the data that reduces our confidence in the adaptive capacity component of the MCA is that the direction of effect of some components is unclear and our assumptions about the direction of effect may not hold for all included components in all regions or situations. For example, we have included the percentage of the population aged over 65yrs in the human capital component, assuming that communities with an aging population are more vulnerable. However, the experience that comes with age could be an advantage when preparing for and responding to drought. In addition, some of the included datasets are only available at the scale of the LGA bounday, for example percentage of the working age population that are employed, which reduces the extent to which such datasets can contribute to fine-scale, local level interpretation.

The way that the conceptual framework is structured gives a larger relative influence to the adaptive capacity component than the exposure and sensitivity components. This is because, for consistency with other Australian drought vulnerability assessment frameworks (Hughes et al., 2020), exposure and sensitivity are first combined into a single composite map for drought impact before the composite impact map is combined with adaptive capacity. Impact and adaptive capacity are then combined with equal weighting to generate the final drought vulnerability map. Including a comprehensive and well-designed adaptive capacity component in MCA can be extremely valuable for decision-making (Bourne et al., 2016; Cardoso da Silva et al., 2020; Jones et al., 2020; Kasecker et al., 2018). However, in this case, we have somewhat lower confidence in the adaptive capacity than the impact map and this means that we also have lower confidence in the overall vulnerability map than in the impact map.

Local authorities need information at the scale of the political and administrative units that they manage (Ahmadalipour & Moradkhani, 2018). There can be limited ability or willingness to take up information when it does not align well with the political unit (Bourne et al., 2017; Pasquini & Cowling, 2015). This includes where the available information does not cover the full area of responsibility and hence needs to be integrated with other data sources to provide a complete picture or where the information extends beyond their jurisdiction and where only a portion is relevant for the decision-maker (Baudoin & Ziervogel, 2016). 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 (Ayers et al., 2014; Bourne et al., 2016; Carrão et al., 2016; Reid, 2015). Local government authorities are the entities most directly responsible for local-level planning, management and implementation of drought resilience activities (Huq et al., 2007; Measham et al., 2011; Wamsler et al., 2014). We argue that spatial products such as these 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 image or series of images.

The products presented here provide that information at the practical scale of the familiar administrative boundaries within which local government officials operate and have a legal mandate. The products were developed together with local government representatives. The methodological approach for identifying priority areas involves overlaying environmental and demographic data using standard multivariate GIS analyses and many publically available national data sets. Using industry standard software, publically available data and straightforward methodological approaches allows for transparency, easy updating, revision, refinement and replication. The approach can be replicated widely, in Australia and elsewhere, with minor adjustments to account for location-specific variations in socio-ecological systems.

As a next step, spatially defined priority areas need to be linked explicitly with clear, site-specific implementation activities. Participatory and stakeholder engaged local work is needed to identify what drought resilience actions to implement, when these are the most appropriate actions and to what extent they can be effective given the actual or potential limits of regional natural and social systems in terms of the extent of drought they themselves can withstand. Given the limitations of the data included in the adaptive capacity component and related to conceptual framework applied, as discussed previously, it is our recommendation that the impact map be used as the primary decision-support tool from this particular MCA.

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