IMPACTS OF CLIMATIC VARIABILITY, WATER SCARCITY AND SOCIO-ECONOMIC DEMOGRAPHICS ON FARMERS' MENTAL HEALTH IN AUSTRALIA

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II. List of Abbreviations

AAS	Australian Academy of Science
ABARES	Australian Bureau of Agricultural Economics and Science
ABS	Australian Bureau of Statistics
AGBRS	Australian Government Bureau of Rural Science
AIHW	Australian Institute of Health and Welfare
BOM	Bureau of Meteorology
COAG	Council of Australian Governments
CRE	Correlated Random Effects
CRRMH	Centre for Rural and Remote Health
CSIRO	Commonwealth Scientific Research and Industrial Research Organisation
DOH	Department of Health
DAFF	Department of Agriculture and Food
DA	Department of Agriculture
EC	Exceptional Circumstances
EP	Exit Package
ENSO	El Niño–Southern Oscillation
FAO	Food and Agriculture Organisation
FMB	Farm Management Bond
GDA	Geocentric Datum of Australia
GDP	Gross Domestic Product
GIS	Geographic Information System
GL	Giglitre
GLS	Generalised Least Squares
GP	General Practitioner
HILDA	Household Income and Labour Dynamic in Australia
IED	Income Equalisation Deposits
IOD	Indian Ocean Dipole
IPCC	Inter-governmental Panel on Climate Change
K10	Kessler-10
LTAAY	Long Term Average Annual Yield Factor
MDBA	Murray-Darling Basin Authority

MDB	Murray-Darling Basin
MDBC	Murray-Darling Basin Commission
nMDB	Northern Murray-Darling Basin
MHI-5	Mental Health Inventory
NAP	National Action Plan
NDP	National Drought Policy
NDRA	Natural Disaster Relief Arrangements
NRAC	National Rural Advisory Council
NRHA	Natural Rural Health Alliance
NRM	Natural Resource Management
NSW	New South Wales
NWC	National Water Commission
NWI	National Water Initiative
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QLD	Queensland
RtB	Restoring the Balance
SA	South Australia
SAM	Southern Annular Mode
SDL	Sustainable Diversion Limits
SEIFA	Socioeconomic Index for Areas
SLA	Statistical Local Area
sMDB	Southern Murray-Darling Basin
TFP	Total Factor Productivity
UK	United Kingdom
USA	United States of America
UV	Ultraviolet
VIC	Victoria
VIF	Variance Inflation Factor
WA	Western Australia
WHO	World Health Organisation

III. Abstract

Climatic conditions in recent decades have been characterised with more frequent, long-term, and severely adverse events (e.g. drought) occurring in many countries. Many studies have found a link between various climatic evens and their negative impact on societies' health, wellbeing and work productivity. In particular, there has been an increasing focus in the literature on the link between mental health and climatic variability, especially for rural communities. This is especially so for farming communities in Australia's Murray-Darling Basin (MDB). MDB farmers have experienced significant increases in temperature and evaporation over the past three decades, and reductions in rainfall and runoff due to climate change.

The main question investigated in this thesis was to try to understand the key stress factors affecting farmers' mental health around the world, particularly focussing upon the consequences of climatic variability for farmers (both dryland and irrigators) in the MDB. To answer this question, a mixed-methods approach was employed involving: a) a systematic review of 167 articles on farmers' mental health, using a standardised electronic literature search strategy and PRISMA guidelines, to understand the potential key stressors affecting farmers' mental health around the world; b) Correlative Random Effects panel data regression analysis of MDB farmers' (2,141 observations), and all Australian farmers (5,426 observations) mental health using 14 waves (2001-02 to 2014-15) of the national longitudinal survey from the 'Household, Income and Labour Dynamics in Australia' and utilising spatial analysis from various climate, agricultural and water databases (e.g. rainfall, drought periods, soil moisture, maximum summer temperatures); and c) Ordered Probit regression modelling of the influences on irrigator mental health, using a 2015-16 survey sample of 1,000 irrigators in the southern MDB, merged with a variety of spatial data (e.g. drought, water allocation and temperature).

Key findings of this thesis show that water scarcity was associated with MDB farmers (both dryland and irrigators) worsening mental health. In particular, the most important proxies of water scarcity were found to be rainfall, low water allocations, and higher summer temperatures. Results also highlight the importance of financial capital in influencing southern MDB irrigators' psychological distress, with net farm income, debt, productivity changes, and land capital value being the most important influences, respectively. This thesis also provides some evidence that landholder governance and natural resource management (such as being a

certified organic irrigator) statistically positively influenced southern MDB irrigators' mental health, especially in the horticultural industry (where larger sample sizes were available).

These findings will become increasingly policy-relevant, given the increasing pressure placed on farming communities by the impacts of climate change, along with the fact that financial problems are increasing in drought-affected areas across Australia. Key recommendations of this thesis indicate the need for a strong focus on policy that is designed to build greater natural farming and financial capital on-farms, and encourage higher risk-management strategies to withstand a drier future in Australia. In summary, the focus must be to integrate: 1) drought/climate change policy; 2) mental health policy; 3) natural resource management/extension policy; and 4) rural economic and social development policy.

IV. Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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VI. Publications and presentations from this Thesis

Published Journal articles

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Daghagh Yazd, S., Wheeler, S.A., Zuo, A. (2020). Understanding the impacts of water scarcity and socio-economic farm demographics on farmer mental health in the Murray-Darling Basin, published in *Ecological Economics,* doi.org/10.1016/j.ecolecon.2019.106564

Daghagh Yazd, S., Wheeler, S.A., Zuo, A. (2019). Exploring the Drivers of Irrigator Mental Health in the Murray–Darling Basin, Australia, published in *Sustainability*, doi.org/10.3390/su11216097

Governmental Report

Wheeler, S. A., Zuo, A., Xu, Y., Grafton, Q., & Yazd, S. (2019). *Emergency Drought Relief Package — Health and Resilience Services: an Evidence Check*, Sax Institute. Available at: https://www.saxinstitute.org.au/wp-content/uploads/19.04.09_Evidence-Check_Emergency-Drought-Relief-Package-Health-and-Resilience-Services.pdf

Conference papers and seminars

Daghagh Yazd, S. (2016). 'Impacts of water scarcity on the Murray-Darling Basin farmers' mental health'. The University of Adelaide Centre of Global Food Studies Seminar Series, Adelaide, Australia.

Daghagh Yazd, S., Wheeler, S., Zuo, A. (2016). 'Exploring how climatic conditions may affect farmers' mental health in the Murray-Darling Basin', *XXIII annual conference of the Agri-food Research Network* (AFRN), Adelaide, 7-10 December

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Daghagh Yazd, S., Wheeler, S., Zuo, A. (2018). 'The influence of climate conditions and water scarcity on farmers' mental health in the Murray-Darling Basin', Selected Papers Program, *62nd Australasian Agriculture and Resource Economics Society*, Adelaide, 6-9 February

CHAPTER 1 Introduction

1.1 Introductory Background of Climate Change

Farmers' mental health is of global concern due to the recent increase in the frequency and severity of climate change related pressures (Berry et al., 2011). Damage to the local environment and economic losses are contributing to worsening mental health of farmers and residents in rural communities (Haines & Patz, 2004; Ellis et al., 2017). Climate change can be considered as any changes in climate over time; those changes can be a result of natural variability or be due to human activities (Change, 2007). Climate change is the greatest challenge of the 21st century and threatens all aspects of the society in which we live (IPCC, 2014). Increased water scarcity, soil erosion, vegetation loss, wildfire damage, coastal degradation and tropical crop yield decline are reported to be associated with the current levels of global climate change (IPCC, 2019). However, some areas will benefit from changing climate patterns such as some positive impacts on winter wheat yields as a result of warmer temperatures and increasing sunshine (Tian et al,. 2012).

Although there is still uncertainty about the exact level of change, it is clearly occurring and differing climatic patterns will increasingly be revealed in the future (Karl & Trenberth, 2003). Future climate model simulations warn of increasing changes in climatic patterns within a long-term shift (Crane et al., 2011). Most models predict that the Earth's average surface temperature will continue to rise (Dow et al., 2016), the ocean will continue to warm in tropical and subtropical regions (Roxy et al., 2016), while snow-cover on land will continue to decrease in many areas (Szczypta et al., 2015). The Intergovernmental Panel on Climate Change (IPCC) predicts that hotter summers and heat waves will occur with greater frequency and for longer duration, and infrequent winter extremes will be more severe (IPCC, 2018). Additionally, rainfall patterns are projected to vary widely between different regions. The increasing frequency of heavy rainstorms in some areas, as well as more extended drought periods in other areas, are other projected future consequences of a warming climate (Trenberth et al., 2003). Long drought periods continue to place stress on available water supply by lowering lake levels, contributing to falling groundwater supplies and by reducing soil moisture (Yusa et al., 2015). Another predicted effect of climate change is an immense soil and groundwater degradation process known as dryland salinity; it occurs when salts build up in the root zone, resulting in reduced agricultural productivity (John et al., 2005; Marchesini et al., 2017). Researchers expect an increase in salinization in arid and semi-arid regions (one of the most noticeable phenomena of water-quality degradation) as a result of climate change (Vengosh, 2003; Dasgupta et al., 2018). Saltwater intrusion is projected to worsen in low-lying coastal areas with significant changes in river salinity in coastal zones, resulting in greater scarcity of water for irrigation (Dasgupta et al., 2015).

Similar to the rest of the world, Australia faces significant climatic challenges, and climate change projections indicate that Australia is likely to become hotter and drier (Lucas et al., 2007) and it is confidently predicted that the time in drought will increase over southern Australia (CSIRO, 2018). Moreover, Australia's Murray-Darling Basin (MDB), which is known as the nation's 'food bowl', is highly vulnerable to climate change impacts; predicted to be increasing temperatures, greater evaporation and reduced rainfall (Pittock & Finlayson, 2011). Chapter Two provides considerable more detail on the impacts of climate change on Australian agriculture, and particular challenges that will be faced by the MDB.

1.2 Environmental and Health Impacts of Climate Change

Environmental changes can create significant environmental hazards, such as reduced water quality, wetland loss, environmental degradation, increased risk of wildfires, and, consequently, of health issues for humans (Trenberth et al., 2003; Nichols et al., 2009; Dasgupta et al., 2015). Environmental changes can affect human health directly or indirectly through a complex set of pathways (Mcmichael et al., 2006; Godsmark et al., 2018). Direct pathways are through extreme weather events such as: cyclones, storms and hurricanes (Costello et al., 2009; Gasparrini et al., 2017). While indirect pathways include water and food-borne disease, vector borne disease, and shortages of drinking water (Kinney, 2008; Dasgupta et al., 2015). A significant concern is that the effects of climate change may be more severe among the elderly, younger people undertaking heavy labour or those populations which experience socioeconomic disadvantage (Berry et al., 2010). It has been recognised that climate change and the altered frequency of associated extreme events, such as drought, have negative impacts on mental health (Berry et al., 2010), which may lead to post-traumatic stress disorder (Yusa et al., 2015), hopelessness and increased suicide (Berry et al., 2010; 2011a). Recently, mental health has been identified as a leading indicator for measuring the evolution of the human impacts of climate change (Berry et al., 2018).

1.2.1 Farmer Specific Health Impacts from Climate Change

Several studies have reported that climate change in Australia, especially prolonged drought, has increased the risk of mental health problems among people in rural communities and among farmers (Berry et al., 2008; Gunn et al., 2012; Bryant & Garnham, 2014; Alston et al., 2018, Wheeler et al., 2018). Damage to the local environment and economic losses are some of the reasons for increased psychiatric disorders, such as depression and anxiety, in residents of rural communities (Haines & Patz, 2004). Farmers have long faced significant challenges in maintaining health, and their circumstances have been shaped by emerging climatic changes over the past decade (Horton et al., 2010; Fennell et al., 2016). Changes in rainfall patterns, higher temperature and salinization can cause reduced agricultural production, crop loss, livestock death and reduced animal productivity (McMicheal et al., 2006; Kureshi et al., 2018; Greene, 2018), resulting in increased stress and anxiety about the future (Stehlik et al., 2000; Kunde et al., 2017; Alston et al., 2018; Greene, 2018). Australian irrigators have also been substantially impacted by climate change and long-lasting drought (Wheeler et al., 2018). Prolonged drought resulted in seasonal irrigation allocations declining to historic lows and affected crop production and the economic bases which irrigators depend on (Wheeler & Marning, 2019). Lower rainfall also indirectly impacted agricultural productivity through changes in the prevalence of pests and diseases and increased rates of soil degradation (Adams et al., 1999).

Managing changes in climate are an overwhelming task for : a) scientists, who need to understand and explain future changes; b) health professionals, who must recommend health based policies to address negative externalities of climate change, c) economists, who must recommend policies to balance risks and costs (Nordhaus, 1994).

1.3 Literature Review

1.3.1 Climate Variability and Human Physical Health

Human health is sensitive to shifts in weather patterns and climate variability (Woodward et al., 2014). Studies show that the impact of climate change on physical health is indeed real, with an increase in mortality rates due to both increases and decreases in temperature (McMichael & Wilkinson, 2008; Gasparrini et al., 2017).

1.3.1.1 *High Temperature Impact*

Extremely high temperatures are associated with fatalities (Kovats & Hajat, 2008) and the ability to perform complex tasks (Page et al., 2016). Green et al., (2010) identified that increases in temperature were positively associated with dehydration and acute renal failure. Wu et al., (2016) stated that increases in the earth's average temperature have a direct influence on the distribution of vector-borne diseases. Every year, more than one billion people are infected with vector-borne disease, resulting in a million deaths each year (Campbell-Lendrum et al., 2015). Warmer temperatures increase mosquito reproduction and biting activity; warmer temperatures also permit parasites to mature in time for mosquitos to transfer infections (Epstein, 2001; Reinhold et al., 2018). With warmer temperatures, more people are harmed by growth in the number and species of biting flies and insects, many of which had never been seen before (Furgal & Seguin, 2006). Ebi et al., (2016) argue that the incidence of dengue has increased 30-fold over the past 50 years, as a result of a warmer climate, with more than 390 million infections in 2010. However, Nichols et al., (2009) argue that several environmental factors, such as temperature, humidity, levels of precipitation, soil moisture and sea level rise can all have an impact on the transmission of vector-borne disease; determining how these factors may affect the incidence of disease is not straightforward. Moreover, rising temperatures will lead to an increase in human ultraviolet (UV) exposure, as individuals spend more time in the sun, resulting in an increase in incidence of skin cancer and cataracts (Nichols et al., 2009).

1.3.1.2 *Heat Waves*

Human life has limited capacity to adapt to rapid or extreme climatic variability, such as heat waves. It has been shown that the adaptive capacity of individuals to respond to the impact of heat waves depends on several factors such as knowledge and awareness of heat waves (Das, 2011). Heat waves result in heat stress for the body, and, over consecutive hot days, individuals around the globe may suffer from thermoregulatory failure, increasing the risk of illnesses (Bouchama & Knochel, 2002; Ward et al., 2016). A summer heat wave in Europe in 2003 killed thousands of people (Epstein, 2005) and a 1995 heat wave in Chicago increased hospitalizations for heat stroke, heat exhaustion and degenerative diseases, such as Parkinson[1]

[1] Parkinson's is a progressive nervous system disorder and some of the symptoms are tremor, slowed movement, rigid muscles, and mpaired posture (WHO, 2006).

and Alzheimer (Semenza et al., 1999). The very severe summer heatwave in Russia during 2010 resulted in more than 11,000 additional deaths compared to the summer of 2009 (Watts et al., 2015). Studies have revealed that people with a history of diabetes (Semenza et al., 1999), pre-existing cardiovascular disease (McMichael & Hales, 2006), older people (Hajat et al., 2014), school-aged children (Green et al., 2010), urban populations (McMichael et al., 2008) and homeless people (Epstein, 2005) are at greater risk of heat wave related deaths. A time-series analysis on climate change effects on human health in the UK indicates increases in the risk of heat-related mortality by 66% in the 2020s 257% in the 2050s and 535% in the 2080s (Hajat et al., 2014).

1.3.1.3 *Food Insecurity*

Global climate change is seriously challenging marginal agricultural ecosystems, which may lead to food insecurity, with risks for nutrition and health (Yusa et al., 2015; Cheeseman et al., 2016). Also, it can negatively impact the quality of drinking water, resulting in water-related disease (Levy et al., 2016). A global cross-sectional study of children under five years of age showed that each 10mm decrease in precipitation per month is associated with a 4% increase in the incidence of all types of diarrhoea (Lloyd et al., 2007). El-Fadel et al., (2012) found that in Beirut there is also a strong association between changes in temperature and food and water borne illnesses among children. Chou et al., (2010) identified a higher morbidity rate, because of food and water borne disease in Taiwan, during a hot summer. Burr et al., (1978) reported that higher temperatures and drought negatively impacted the quality of drinking water in many areas of England and Wales, causing an increase in the incidence of diarrhoea and vomiting.

1.3.1.4 *Changes in Percipitation*

In addition, climate change will be associated with changes in precipitation and decrease in wind speed and boundary layer height, resulting in significant implications for air pollution levels. The high levels of air pollution increase the respiratory disease, and is an important risks to human health (Watts et al., 2015). On the other hand Hong et al., (2019) reported that increases in heavy precipitation events result in a 6% reduction of the climate-driven air pollution-related mortality rate in China. Further, researchers have shown that decreasing air pollution may avoid more than two million deaths per year (McMichael et al., 2014). The association between PM10 (solid or liquid airborne particles with a diameter of 10 micrometers or less), and respiratory mortality in four big Chinese cities indicates that a 10 μg/m3 increase in PM10 is significantly associated with a 0.13 percent increase in respiratory mortality (Zhang et al., 2008). Further, statistics show an increase in the prevalence of asthma because of climate-related pollution in the United States (Epstein, 2005). Based on the 2018 WHO report, if current emissions continue, ground-level ozone events are projected to increase, especially in densely populated areas, leading to more respiratory illness. Climate change leads to dust storms and can increase airborne allergens and dust concentrations in the air (Gamble et al., 2012). Airborne allergens are small airborne materials, such as pollen, resulting in allergic reactions (Yusa et al., 2015). The most commonly-reported allergic conditions in response to all aeroallergens are allergic rhinitis, bronchial asthma, skin problems and oral allergy syndrome (Gilles et al., 2018).

1.3.2 Climate Variability and Human Mental Health

Climate variability is responsible for mental health problems as well. For example, it has been shown that one-unit increase in temperature is significantly associated with a 0.1% increase in mental distress in a sample of the NSW population (Ding et al., 2016). Similarly, Xu et al., (2018) found that an increase in the annual average daily maximum temperature is associated with higher mental health problems amongst Australian children. Obradovich et al., (2018) found that increases in monthly temperatures to >30 °C increases the probability of mental health problems by 0.5% points. Coelho et al., (2004) reveals that people living in a drought-prone area in Brazil had higher levels of anxiety and distress compared to a non-drought affected area in the same region. Dryland salinity has also been associated with an increased risk of hospitalization for depression in Australia (Speldewinde et al., 2009). Assessment of stressors among individuals after flood found that flooding had positive effects on anxiety, depressive and physical symptoms (Verger et al., 2003). In-depth interviews conducted with Canadian community members reported that changes in weather, snow and ice stability, attributed to climate change, negatively impacted their mental health due to disruption in land-based activities and a loss of place-based solace and cultural identity (Willox et al., 2013). Exposure to Hurricane Katrina among US residents was associated with a 4% increase in the probability of mental health issues (Obradovich et al., 2018). There is some evidence that climatic variability, especially drought, will increase the risk of stress experienced by farmers, resulting in poorer mental health and, possibly, impacting on suicide rates (Berry et al., 2010;

2011a; Sherval & Askew, 2012; Kolstrup et al., 2013). Potential health and safety hazards associated with farming will be discussed more in the next section.

1.3.3 Farmers' and Rural Communities' Mental Health

Research to date has found that participants in farming face a range of environmental and financial difficulties, and other uncertainties, related to farming, which may lead to mental health disorders (Berry et al., 2010). A range of work-related stresses resulted in various symptoms among farmers (Walker & Walker, 1987). Work-related stress is defined as a conflict where the demands of work are high, and the worker cannot manage, control, or cope with that stress associated with these demands (Kolstrup et al., 2013). The majority of farmers think that their job is becoming even more stressful because of the impacts of climate change (Kearney et al., 2014). Gray & Dunn's (1993) qualitative research describes how farmers report a range of emotions after stressful events; most notably, farmers clearly identified depression, worry and anxiety. Most farmers mentioned that their family relations worsened, with some discussing suicidal ideation after difficult events. Also, it has been argued that farmers are more likely to drink alcohol at short-term high risk levels than the general Australian population (Brumby et al., 2013).

1.3.3.1 *Financial Challenges*

Many studies have reported financial challenges as a main source of stress negatively impacting on farmers' mental health, particularly where farming is the primary income source (Sartore et al., 2008; Edwards et al., 2009; Bryant & Garnham, 2014; Wheeler et al., 2018). Farmers reported various types of financial stress, including market prices for crops and livestock, irregular/insufficient cash flow, increased input costs, taxes, health care costs and high debt levels (Kearney et al., 2014).

1.3.3.2 *Pesticide Exposures/Government Requirements/ Isolation*

In addition, high enough exposure to pesticides has also been suggested as a cause of higher levels of depressive symptoms among farm residents (Harrison et al., 2016). Some pesticides, such as organophosphates are neurotoxic; they can enter an individual's body through the skin, or through inhalation, and directly affect neural systems, which is known to cause mental illness (Malekirad et al., 2013). Investigation among farming communities has revealed that farm residents self-reporting physical illness tend to have higher levels of self-reported psychiatric impairment. For example, depressive symptoms had a significant association with neck, shoulder and back pain amongst farmers (Beseler, 2005). Meeting government requirements is another stressor affecting farmers. This can include additional paperwork, such as the Business Activity Statements, or meeting the training requirements for Occupational Health and Safety and training for pesticide application (Fragar et al., 2008). It is frequently stated that isolation, loneliness and lack of social relationships among people living in rural communities are detrimental to an individual's mental health (Rohde et al., 2014). On the other hand, individuals who feel more connected to their local community are less likely to have psychological distress (e.g., Stain et al., 2008; 2011; Austin et al., 2018).

1.3.3.3 *Climate Variability*

Because future weather conditions are uncertain, farmers around the world must deal with risk daily. Although farmers have long experience in dealing with climatic variability and uncertainty, especially in countries that experience great water scarcity, increases in the variety of climate variability and uncertainty pose substantial challenges for farmers in the future (Crane et al., 2011). Adverse mental health impacts associated with climatic variability, especially drought, have been reported in several studies (Sartore et al., 2007; Edwards et al., 2009; Stain et al., 2011). Drought is one of the main sources of stress for farmers and directly impacts their employment and economic success via effects on agricultural production and animal productivity (McMicheal et al., 2006; Greene, 2018). Drought can also cause increased costs, such as feed costs, costs of water purchase, and reductions in net farm household income (Sartore et al., 2008; Peel et al., 2015; Edwards et al., 2019; Wheeler et al., 2018). Decreased agricultural production and increased costs result in high levels of stress and anxiety about the future (Alston et al., 2018; Greene, 2018). For example, North American farmers reported unfavourable climate conditions and the unpredictability of the weather as their primary stress factor (Walker & Walker, 1988). Bad weather is also reported as "very stressful" by farmers in Eastern North Carolina (Kearney et al., 2014). Besides, farmers stated that the observed patterns of climate change have worsened their worries about the future climate and contributed to chronic mental distress (Ellis & Albrecht, 2017). Brew et al., (2016) found farmers reported higher drought-related stress than other rural workers, and Edwards et al., (2015) also found more significant mental health distress for farmers and farm workers who were experiencing drought compared to others in rural communities. Peel et al., (2015) identified the length of drought period as another mental health risk factor. Reduced employment is another consequence of climate change, strongly related to drought in rural areas, resulting in mental disorders (Sherval & Askew, 2012). A rural community with a stronger dependence on farm production will suffer more because of reduced employment during droughts (Padhy et al., 2015; Birhanu et al., 2017). Drought has been common and widespread in Australia, with the Millennium Drought in the 2000s perhaps the most notable occurrence (the worst ever recorded drought since European settlement). Because of the Millennium Drought, the River Murray experienced very low flows and irrigators faced significant stress in dealing with reductions in water allocations, higher temperatures and lower rainfall (Bryant & Garnham, 2013), resulting in an expansion of their traditional agricultural causes for worry (King et al., 2009, Edwards et al., 2009).

Researchers stress the urgent need to understand more about the consequences of extreme weather after reviewing the mental health impacts of climate change in rural and remote Australia (Berry et al., 2010). Also, Berry et al., (2018) argue that the mental health effects of climate change have received little attention in research and policy and needs systems-based analysis.

1.3.4 The Gap

As mentioned, climate variability can affect crop yields and, possibly, force agricultural communities to develop successful strategies to address the impacts on their mental health. Therefore, to ensure the health and welfare of farmers and the residents of rural communities, it is essential to shape effective policies that prevent adverse health outcomes. Also, other successful strategies to support the mental health and well-being of agricultural communities could be based on coordinated efforts across Commonwealth, state and local delivery of health services. Although the impact of climate variability on farmers' mental health has been well studied in Australia, not many of the publicly expressed views have been supported by quantitative evidence (most of the studies in this field are discussion based or review studies). Also, most of the quantitative studies linking climate change–related disasters to mental disorders among farmers have used cross-sectional designs. Cross-sectional designs prevent researchers from making strong inferences about causality and the directionality of the effects reported in the studies because the data observe the study population at only one point in time.

Longitudinal research might overcome these limitations, by illustrating, over the longer term, how mental distress is connected with climate change. There is also very little focus on many economic or financial drivers of mental distress in farmers, nor is there much focus on any natural capital influence. This research therefore aims to provide a fuller and more comprehensive understanding of the mental-health and emotional consequences of climate change (drought, lower rainfall levels, higher temperatures, lower levels of water allocation, financial factors, natural capital and farm practices) for farmers in the MDB, using a variety of databases. For example, it uses: a) national longitudinal survey database across fourteen waves (2001-02 to 2014-15) of 2,141 observations of farmers in the MDB and 5,426 observations of farmers in Australia; and b) a large-scale profile (n=1000) of irrigators (a subset of Australian farmers in the Murray-Darling Basin) to explore the influences on farmer stress in Australia.

1.4 Mental Disorders

Mental disorders are normally defined by some combination of abnormal thoughts, emotion, behaviour and relationship with others (WHO, 2017). Mental health disorders can include depression, anxiety, stress, schizophrenia, bipolar disorder and emotional/psychological distress. As reported by the Department of Health, the most common mental disorders are anxiety and depressive disorders, which are a reaction to the stresses of life (DOH, 2013). A person with an anxiety disorder feels distressed a lot of the time, for no apparent reason, and a person with a depressive disorder can experience a long-term depressed mood or feeling of sadness, and loss of interest in activities that used to be enjoyable (DOH, 2013; DSM-5, 2013). According to the Australian Institute of Health and Welfare, mental disorders are the third most common disease after cancer and cardiovascular disease, and 45% of Australians aged 16–85 will experience a mental illness in their lifetime (AIHW, 2018). Mental health problems can affect people's lives in different ways. Twenty-seven percent of Australian people with mental disorders reported they had a severe problem with their domestic responsibilities, work, study, close relationships and their social life. In a group of people with psychotic disorders, 32% reported a significant disability in caring for themselves and 22% reported feeling socially isolated and lonely. Forty-nine percent of people who live with a psychotic illness reported that they had attempted suicide during their lifetime (AIHW, 2014). In terms of the cost of mental health problems in Australia, Lee et al., (2017) estimated that they were the third biggest disease burden, with a total cost of at least AUD$12.7 billion in 2007. It has become a generally accepted that mental illness is related to excessive stress, which affect individuals' mental capacity and fear of future relapse is often immense for those people (Bertelsen et al., 2008; Jaco, 2017).

Furthermore, it has been shown that major difficulties arise because many of the stresses are not paid sufficient attention, since mental health professionals are relatively rare in rural areas and some barriers stop health help-seeking for mental health problems (Staniford et al., 2009). The WHO Mental Health Atlas (2017) reveals that although some countries have made progress in mental health policy-making, there is still an overall shortage of mental health professionals and a lack of investment in community-based mental health facilities. Each year, one in five Australians are affected by mental health disorders. However, it is suggested that only 38% of them receive help from a mental health professional (Fragar et al., 2008).

There are several assessments of mental health status. For example, the SF-36 which is known to be an indicator of overall health status, is one of the world's standard health outcome measures (Jenkinson et al., 1997). The Kessler-10 (K10) 10-item questionnaire, which is a measure of distress based on questions about anxiety and depressive symptoms experienced in the most recent four-week period, is another widely used assessment of mental health disorders. Several measures have also been constructed to measure agriculture-related stress among farmers: specifically, the Farm/Ranch Stress Scale (Walker et al., 1987), the Edinburgh Farming Stress Inventory (Deary et al., 1997), Welke's Farm Ranch Stress Inventory (Kearney et al., 2014) and the Migrant Farmworker Stress Inventory (Tribble et al., 2016).

1.4.1 Suicide in Australia

Suicide is defined as an act of deliberately ending one's own life. If this self-initiated act does not result in death, it is referred to as a "suicide attempt" or "suicidal behaviour" (Gvion & Apter, 2012). Suicide is a significant cause of mortality, accounting for nearly 1 million deaths per year around the world (Sinyor et al., 2017). It has been revealed that suicide rates increased between 1999 and 2014 for both males and females, and for all ages (Curtin et al., 2016). Hopelessness has been shown to be an important psychological concept for understanding suicide. It is measured by the Hopelessness Scale and is the variable linking depression and suicidal behaviour (Kovacs & Garrison, 1985). Suicide is reported as one of the major health problems in Australia. Each year, 2500 deaths are registered as suicides in Australia (Judd et al., 2006); and this rate, particularly among young males, has increased during the past three decades (Beautrais, 2000). People who feel hopeless can view suicide as a way out of a painful situation, especially when they believe there is no solution to their severe life problems (Kovacs & Garrison, 1985). Some studies show that there is a higher rate of suicide in rural communities than in urban areas (Fraser et al., 2005; Judd et al., 2006; Arnautovska et al., 2014). However, some studies find no significant differences in mental health status between farmers, metropolitan dwellers and other rural residents (e.g., Fragar et al., 2010; Brew et al., 2016). Also, Fraser et al., (2002) argue that the death rate from suicide for men in capital cities is 33% lower than in rural and remote areas. The higher suicide rates in rural areas may imply the role of socio-demographic and service-related factors in suicide rates (Caldwell et al., 2004a).

Several other risk factors said to influence suicide attempts are: the global financial crisis; natural disasters; social disadvantage; exposure to stressful life events; and cultural and contextual factors (Beautrais, 2000; Sinyor et al., 2017). Besides, higher suicide rates appear in areas where people have lower income, lower levels of education, and lower levels of employment (Cantor et al., 1995). In Australia, people who die by suicide were significantly more likely to have an alcohol-use disorder, recent serious arguments with spouse/partner, be a victim of crime, and were less likely to be from a non-English speaking background (Kõlves et al., 2017). In a study by Hovey & King (1997), migrant farmers with previous suicidal ideation, reported lower self-esteem, greater family dysfunction, greater hopelessness, and more depression compared with migrant farmer with no suicidal ideations. A study in New South Wales demonstrated that the combination of isolation and low socioeconomic status heightened risks of suicide (Burnley, 1995). Chapter 3 provides considerable more details on farmers' suicide risk factors worldwide and in Australia.

1.5 Objectives and Research Questions

It has been indicated that there is a need for large-scale, multi-disciplinary projects and co-generation of knowledge to understand the links between climatic variability and mental health, particularly for some of the world's most vulnerable groups (Berry et al., 2018). Therefore, the aim of this research is the identification of the key influences on farmers' mental health. In the case of MDB farming communities, future climate change, along with periods of extensive drought, is likely to create additional pressure for farmers, further exacerbating the potential for stressors linked to farming lifestyles to culminate in mental disorders, and even suicide.

To meet the outlined objectives, the following research questions will be investigated:

[1] What are the potential key risk factors affecting farmers' mental health, and how does this differ around the world?

[2] How is Australian farmers' mental health influenced by extreme (and changing) climatic conditions (e.g. drought, low rainfall, high temperature), holding as many other influences constant as possible?

[3] How do contextual variables (such as socioeconomic status, education level and area) affect Australian farmers' mental health?

[4] Do extreme climatic conditions (especially drought) interact with contextual variables (e.g., low socioeconomic status) to impact on psychological outcomes among Australian farmers?

[5] Do irrigators (a subset of Australian farmers in the Murray-Darling Basin) who are certified organic agricultural growers experience lower levels of psychological distress than conventional irrigators?

[6] How does access to the five capitals (physical, social, human, natural and financial) affect Australian irrigators' mental health?

1.6 Research Design/Methodology

This research relies primarily on quantitative methods to investigate the issues that affect Australian farmers' mental health. Econometric regression modellings were employed to explore questions about mental health status, using a variety of independent variables that influence mental health. Datasets from multiple sources were collected and used to satisfy the requirements of this research. Chapter 4 addresses research question 1, using a systematic review of 167 articles on farmers' mental health, and PRISMA[2] guidelines. Chapter 5 addresses research questions 2, 3, and 4, and does so by merging the national longitudinal survey from the 'Household, Income and Labour Dynamics in Australia' (HILDA)[3] study with

[2] The PRISMA Statement involves a 27 item checklist, intending to help authors to improve the reporting of systematic reviews and meta-analysis (Moher et al., 2009). (PDF template of the checklist is available at: http://prisma-statement.org/PRISMAStatement/Checklist.aspx).

[3] The HILDA survey is managed by the Melbourne Institute of Applied Economic and Social Research at the University of Melbourne, and is an Australian Government funded survey conducted through the Department of Social Services (DSS) since 2001.

various climate, agricultural and water databases. A number of climate data and proxies for water scarcity— such as rainy-days, drought periods, soil moisture, maximum summer temperatures and regional water allocation levels over 14 years—were collected and were geocoded[4] across time and space using a Geographic Information System (GIS)[5]. The research questions were answered using correlative random effects panel data regression. The impact of a changing climate and water scarcity on farmers' mental health was examined both in the MDB and separately in several Australian states. Chapter 6 combines some collected climate data (drought, water allocation and temperature) with a recent irrigator survey from 2015-16 to address research questions 5 and 6. An Ordered Probit regression model was utilised to understand the drivers of psychological distress among irrigators.

1.7 Thesis Structure

This thesis is organised into seven chapters. Following this introductory chapter, chapter 2 introduces the study area (the MDB) and provides an overview of climate variability and water scarcity in the MDB and Australia-wide, as well as outlining the consequence of changes in climate on Australian agriculture. Chapter 3 provides background on farmers' and rural communities' mental health, drawing on a comprehensive literature review on the influences on Australian farmers' mental health and suicide.

Chapter 4 presents the published journal article:

Daghagh Yazd, S., Wheeler, S.A., Zuo, A. (2019). Key Risk Factors Affecting Farmers' Mental Health: A Systematic Review, published in the *International Journal of Environmental Research and Public Health.* doi.org/10.3390/ijerph16234849.

This chapter provides a systematic review of 167 studies on farmers' mental health to identify gaps in the literature and possible avenues for advancement of knowledge. One hundred and sixty seven articles on farmers' mental health were included in a final systematic review, using a standardised electronic literature search strategy and PRISMA guidelines. It specifically highlights the most cited influences on farmers' mental health in the literature and clearly

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[4] Geocoding is the process of conveying an XY coordinate pair to the description of a place by linking the descriptive location specific elements to those in the reference data (Zandbergen, 2008, p.125)

[5] GIS is a system that provides answers to queries of a geographical nature by using a spatial database (Cowen, 1988). The most crucial ability of the GIS system is a combination of valuable information and location characteristics, which can provide a new dataset through manipulating and converting spatial data with the help of different analysis tools (Anselin, 1992).

identifies that climate variability has adverse impacts on farmers' mental health and is the fastest growing risk factor focussed upon in the literature.

Chapter 5 presents the published journal article:

Daghagh Yazd, S., Wheeler, S.A., Zuo, A. (2020). Understanding the impacts of water scarcity and socio-economic farm demographics on farmer mental health in the Murray-Darling Basin, published in *Ecological Economics*. doi.org/10.1016/j.ecolecon.2019.106564.

This study examined whether climatic conditions and water scarcity were associated with worsening farmer (dryland and irrigators) mental health in the MDB. The sample consisted of 2,141 observations (for 235 farmers) from a national longitudinal survey database across fourteen waves (2001-02 to 2014-15) and was modelled using correlative random effects panel data regression. This chapter also extended the econometric model and tested the impact of water scarcity on farmers in different states New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA), and Western Australia (WA). The sample consisted of 5,801 observations (for 571 farmers).

Chapter 6 also presents the published journal article:

Daghagh Yazd, S., Wheeler, S.A., Zuo, A. (2019). Exploring the drivers of Irrigator Mental Health in the Murray-Darling Basin, Australia, published in *Sustainability*. doi.org/10.3390/su11216097.

This chapter aims to provide a comprehensive understanding of the influence of the five capitals on irrigators' mental health in the southern MDB and to answer the question: do organic irrigators have lower psychological distress than conventional irrigators? This study used a telephone survey conducted with irrigators in October-November 2015 (n=1,000).

Chapter 7 summarises the findings of the thesis, discusses its policy implications and limitations, and provides recommendations for future research.

CHAPTER 2 Climate Variability and Change in Australia

This chapter introduces climatic variability in Australia and describes how the climate has changed in the past 100 years, according to scientific literature. Also, this chapter introduces the study area (MDB) which is the area of primary agricultural significance in Australia, as well as explaining how climate change affects the MDB's climate. There is a global concern that climate change may contribute to widespread crop failure, livestock losses, debt, and damage to property, resulting in uncertainty about the future and expanding farmers' agricultural worries (Alston, 2007; Kureshi et al., 2018). This chapter provides some evidence on the effect of climate change on agricultural production in Australia. Because extreme climatic conditions, especially drought, are expected to become more frequent in Australia, there has been an increased interest in the sustainable management of the MDB's water resources. The final part of this chapter briefly describes water markets in the MDB and introduces the major water policy reforms that have shaped them.

2.1 Introduction

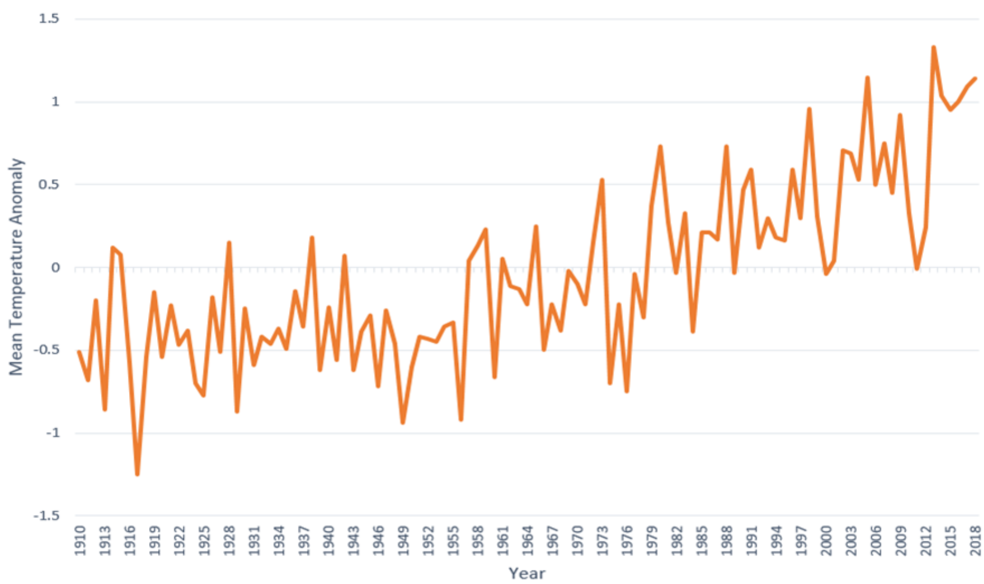
Australia is a vast continent, which is affected by a wide range of weather systems. Tropical systems affect the north and, toward the south, the influence of the tropical systems diminishes while the temperature difference between winter and summer increases (CSIRO, 2015). One reason for the climate variability in Australia is the impact of large-scale ocean– environment event. These include the following: the El Niño–Southern Oscillation (ENSO) system; the Indian Ocean Dipole (IOD) system; the Southern Annular Mode (SAM) system; and atmospheric characteristics such as the strength and location of the subtropical ridge (STR) and the presence of atmospheric blocking (BLK) (BOM, 2012). It is generally understood that the ENSO and IOD phenomena result in extreme weather conditions around the largest part of Australia. The IOD phenomenon is defined by the difference in sea surface temperature between two areas (a western pole in the Arabian Sea and an eastern pole in the eastern Indian Ocean) and significantly influences the rainfall pattern in this region. El Niño events bring lower than average winter-spring rainfall over eastern and northern Australia result in drought, while La Niño conditions result in above average rainfall mainly inland eastern and northern regions, and sometimes causing floods (BOM, 2012). Fenby & Gergis (2013) have identified 27 drought years in south-eastern Australia between 1788 and 1860, and 14 years of high rainfall in NSW between 1788 and 1840, using a range of secondary historical sources. Future climate modelling shows ongoing, long-term climate changes interacting with underlying natural variability (CSIRO, 2018). The following introduces a summary of long-term Australian climatic trends and the factors that influence them.

2.1.1 Climate Change in Australia

In recent decades, like the rest of the world, Australia faces climatic challenges due to global warming. A total of 92 El Niño and 82 La Niño events were reconstructed since A.D. 1525 (Gergis et al., 2010). However, since 1990, El Niño events have increased and La Niña events have decreased and global warming is an explanation for this trend (Hughes, 2003). Australia has been getting warmer and the annual mean temperature has increased across Australia since the 1910s.

Figure 2.1 shows Australia’s annual mean temperature anomaly (the difference from an average temperature) from 1910 to 2018. Warming has occurred in all seasons and all States (BOM, 2014) and night-time temperatures have increased more than daytime temperatures (Hughes, 2003). Since 2001, the number of daytime extremely high temperature records in Australia has exceeded extreme cool temperature records by almost 3 to 1 (Trewin & Vermont, 2010; Trewin & Smalley, 2013) resulting in raises in the length, and power of heatwaves in many parts of the nation (Perkins et al., 2013, 2017).

Figure 2.1: Australia's Annual Mean Temperature Anomaly (1910-2018)



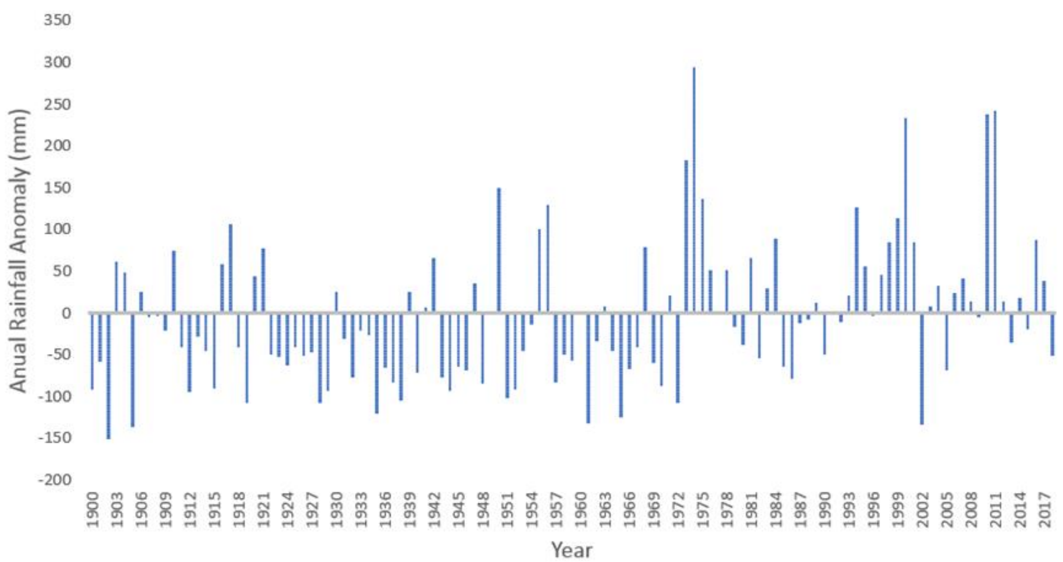
Source: Created from data in BOM (2018). Available at: http://www.bom.gov.au/climate/change/index.shtml#tabs=Datasets&tracker=timeseries&tQ=graph%3Dtmean%26area%3Daus%26season%3D0112%26ave_yr%3DT [Accessed June 7, 2019].

Examining the shift in the distribution of monthly temperatures demonstrates that very high monthly maximum temperatures that happened around 2% of the time in the 1951–1980 period, occurred around 12% of the time between 2003 and 2017 (CSIRO, 2018). It has been projected that by 2030 Australia's annual average temperatures will increase by between 0.4 and 2.0 C° over the 1990 level. Such a rise in temperatures will warm Australia's land and likely lead to more severe heat waves (Preston & Jones, 2006).

Heat waves, which are often characterised by consecutive days above a threshold maximum temperature (Cowan et al., 2014), hit southern Australia in 2009 with unprecedented intensity, duration and maximum temperatures which were 12–15°C above normal (Horton et al., 2010). In southern Australia, such events can be up to 15C° warmer than the climatological maximum because the southern latitudes experience a high occurrence of synoptic prefrontal weather systems (Cowan et al., 2014), causing more severe heat waves to develop due to the great variability of summer temperatures (Nairn & Fawcett, 2013). As Cowan et al., (2014) stated, between 1950-and 2005, central and southeastern Australia experienced more than 2.5 heat wave days per summer, equivalent to almost 1 event per season. Pezza et al., (2012) projected that the frequency, duration, and intensity of heat wave events will increase in many regions of Australia. Similarly, Cowan et al., (2014) projected that Australia will experience an increase in the frequency and duration of summer heat wave events in the future, and the heat waves will be significantly hotter than in the past.

Among various hydro-climatic variables (rainfall, evaporation, temperature), rainfall is arguably the most important because of its significance for sustainable water, and agricultural and ecological management (Loch et al., 2013). Australian precipitation patterns are more variable than could be expected for similar climates elsewhere in the world (Nicholls et al., 2017). As stated in CSIRO (2018), the precipitation pattern has declined in every part of the continent since 1960, with a shift towards drier conditions across Australia (Figure 2.2). A significant decrease in winter rainfall in the vast majority of Australia affected the availability of freshwater and, subsequently, agricultural production (Loch et al., 2013). It has been reported that the drying across south-eastern Australia is the most sustained large-scale change in rainfall since national records began in 1900 (BOM, 2009). Projections from the CSIRO and BOM (2015) report slight future change in precipitation levels in northern Australia, but southern areas are projected to encounter reduced precipitation of up to 40% in winter and spring by 2070.

Figure 2.2: Australia's Annual Rainfall Anomaly (1900-2018)



Source: Created from data in BOM (2018), http://www.bom.gov.au/climate/change/index.shtml#tabs=Datasets&tracker=timeseries&tQ=graph%3Dtmean%26area%3Daus%26season%3D0112%26ave_yr%3DT [Accessed June 7, 2019].

On the other hand, an increase in the extent of overwhelming and heavy precipitation has been recognized throughout Australia. Evidence from observed weather stations records that a higher proportion of total annual rainfall in recent decades has come from heavy rain days (CSIRO, 2018). The portion of Australia receiving a high proportion of yearly precipitation from extreme rain days (greater than the 90th percentile for 24-hour precipitation) has been increasing since the 1970s (Courageous et al., 2013). Also, the mean and the variability of Queensland summer rainfall increased significantly in the second half of the twentieth century (Nicholls et al., 2017). As climate change projections show, the combination of increases in heavy rainfall and rising sea levels may create an increase in flood risk from multiple causes (CSIRO, 2018).

Over the last 50 years, sea surface salinity around Australia has also changed, ending up being progressively saline in southern and south-eastern Australia and less saline in northern Australia (Ridgway, 2007; Durack & Wijffels, 2010). Changes in surface salinity may affect ocean circulation and precipitation patterns. In some southern regions, models demonstrate an increase in ocean surface temperature and surface salinity, especially under higher carbon emissions.

Local warming and drier conditions have expanded the length and intensity of the fire seasons in Australia (CSIRO, 2018). The Fire Danger Index (FFDI), which is determined from daily temperatures, wind speeds, humidity and the drought factor across Australia, demonstrates an increase in the length of fire season in Australia from 1973 to 2010, especially in the south-eastern part of the nation (Clarke et al., 2013). The number of dangerous bushfire weather days with a FFDI greater than 25 (very high fire danger) during spring in Victoria is increasing (CSIRO, 2018). The Black Saturday (2009) bushfires attacked Victoria and caused the highest death toll of any bushfire in Australia's written history; 173 individuals died, and more than 2000 homes were destroyed (Horton et al., 2010). There is also the possibility of an increasing number of high fire danger days combined with conditions that allow bushfires to generate thunderstorms, as well as causing additional fires from lightning strikes, as observed in Canberra in 2003 (CSIRO, 2018).

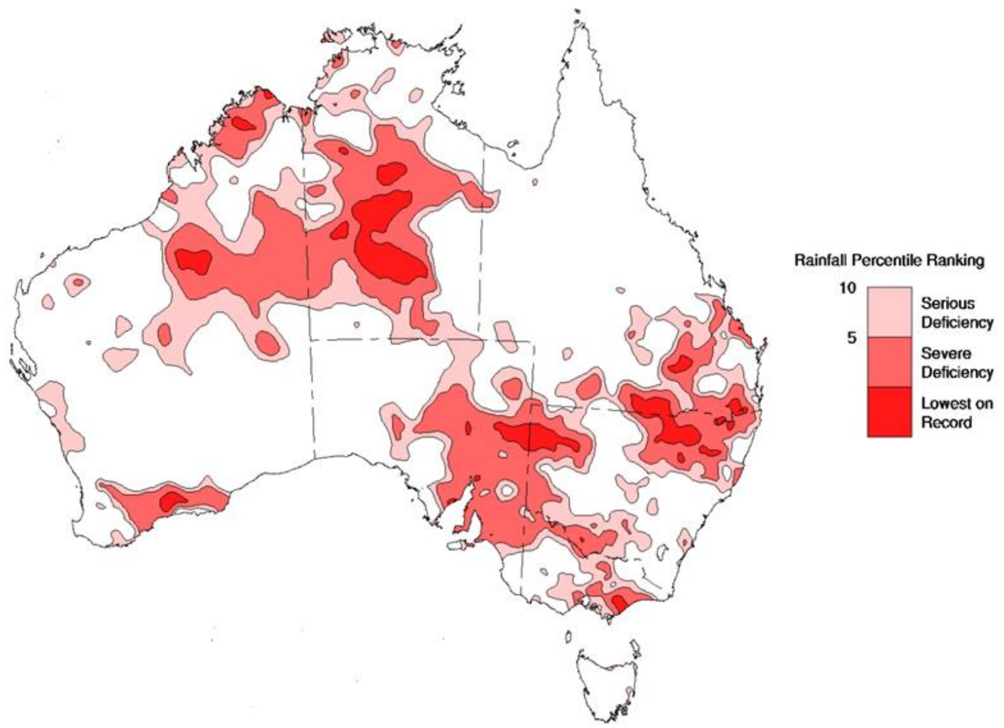
A standout amongst the most commonly repeated descriptions of the Australian environment in this context is that Australia is the driest occupied continent on earth. There have been many serious droughts in Australia in the last 200 years, including the “Federation Drought’ (1895-

1903)[6], the “World War II Drought” (1939-1945), and the “Millennium Drought” (1997-2010). The “Federation Drought’ lasted eight years and caused the death of half of Australia's sheep and forty percent of its cattle. The World War II Drought shocked regional agriculture and the broader economy (Freund et al., 2017). The Millennium Drought, which was the most widespread drought in Australia, worsened through mostly dry years in 2001 and 2002. April to December 2002 was recorded as one of the most severe droughts on record, with rainfall below the 10th percentile for nine months (Horridge et al., 2005) and this contributed to widespread crop failures, livestock losses, dust storms, and bushfires (Heberger, 2012). Many rivers experienced record low flows over this period, in some cases almost 40% below past records (MDBC, 2007). The Millennium Drought, experienced most severely in south-eastern Australia, caused income losses of up to 20% in some areas, reduced GDP by 1.6% in 2002-2003, and contributed to a worsening balance of trade (Horridge et al., 2005). It also added to the enforcement of water restrictions in most urban areas and increased electricity prices (Dijk et al., 2013).

Both anecdotal observations and empirical data clearly indicate that the drought had severe impacts on Australia. However, there is no agreed definition of drought and researchers emphasize different dimensions, such as: meteorological (problematic weather patterns); hydrological (lack of rain); agricultural (insufficient soil moisture); and socioeconomic (low incomes and social consequences) (Alston & Kent, 2004). Some studies of Australia’s recent climate define drought patterns in Australia by rainfall below the 5th percentile at the 12-month timescale and rainfall below the 10th percentile over rolling 3-month periods (Gallant et al., 2014). Others (e.g. Stain et al., 2011; Hanigan et al., 2012) measure drought by assessing six monthly gridded rainfall data to calculate a Hutchinson Drought Index, which counts consecutive months of lower-than-median rainfall based on percentiles of rainfall records at each location. Over 100 drought indexes are available, with no consensus on what is the best measure (Austin et al., 2018). As an example of this, Figure 2.3 shows recent 13 month rainfall deficiencies across Australia from April 2018 to April 2019.

[6] Published drought assessments used various criteria to determine the start and end of the drought and accordingly found different periods.

Figure 2.3: Rainfall Deficiencies across Australia from April 2018 to April 2019



Source: BOM (2019); available at: http://www.bom.gov.au/climate/drought/ [Accessed June 7, 2019].

It is projected that, there will be up to 20% more drought months, as measured by the standardized Precipitation Index, over most of Australia by 2030. The frequency of drought will increase by up to 40% in eastern Australia by 2070. The nature of drought is also projected to change, with a greater frequency of extreme drought, and less frequent moderate- to-severe drought for all regions (CSIRO & BOM, 2015).

2.2 The Murray-Darling Basin

The MDB covers 14% of Australia's land area and spans southern Queensland, New South Wales, Victoria and the south-eastern part of South Australia, including 77,000 kilometres of rivers, many of which are connected (Quiggin et al., 2010). The region is named a Basin because all of the streams, creeks and rivers run to a common point. There are 22 major catchments (or sub-Basins) within the MDB (MDBA, 2015). The Basin is a landscape that is over 60 million years old. While its shape, for the most part, has remained unchanged during this time, earthquakes, volcanic activity and the coming and going of ice ages have shaped the

Basin to house 23 major rivers, over 30,000 wetlands and expansive riverine plains. Almost 4 million people rely on the Basin's rivers and their catchments for the survival of their families. Animals and plants have grown and adapted to the seasonal patterns of water flow from the Basin's rivers (MDBA, 2009). Figure 2.4 shows the MDB's location in the southeast of Australia.

Figure 2.4: Location Map of the MDB within Australia

<u>Source</u>: MDBA(2016); available at: https://www.mdba.gov.au/publications/products/murray%E2%80%93darling-basin-boundary-map, [Accessed November 18, 2019].

The MDB is the most important agricultural production region in Australia and is often called the 'food bowl' of Australia. About one third of the population's food supply and overseas exports originate from the MDB (MDBA, 2009). The MDB is home to more than 2.6 million

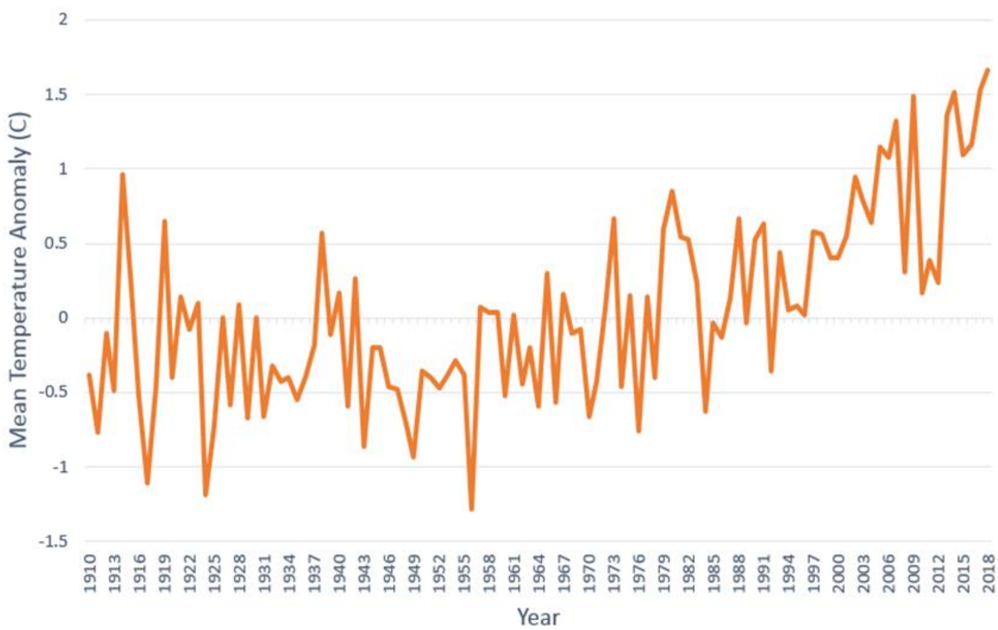
Australians and farming runs through all its regions. Although irrigated agriculture occupies a relatively small portion of the MDB, more than half of all irrigated agriculture takes place in this region. (ABS, 2008). Irrigated agriculture is a significant economic contributor to the Basin, valued at approximately $7 billion per year (MDBA, 2017). In 2014-15 the MDB produced 100% of Australia's rice; 96% of Australia's cotton; 74% of Australia's grapes; 46% of Australia's fruits; and 30% of Australia's dairy. Pasture, mainly for livestock production (dryland sheep and cattle production), accounted for almost 76% of the MDB land (MDBA, 2014).

2.2.1 Climate Variability and Change in the MDB

As a result of climate change, Australia’s MDB has experienced increases in temperature and evaporation, and reductions in rainfall and runoff to rivers and wetlands, especially in the southern MDB (MDBA, 2011). It is stated that the rainfall anomaly recorded during 1998–2008 in sought-eastern Australia is the worst record since the first European settlement of Australia and unusual in the context of the past two centuries (Gergis et al., 2012). Not surprisingly, low rainfall levels during the droughts before 1945 and after 2000, caused a reduction in river flows in the MDB. However, compared to the droughts prior to 1945, flows were reduced more severely during the Millennium Drought and runoff in the southern MDB was far below the long-term mean rainfall during the recent drought (Loch et al., 2013). This might be because of: (1) the greater proportional reduction in autumn and winter rainfall in the recent drought, because most runoff occurs in the winter months; (2) the observed increase in annually averaged daily mean and maximum temperatures; (3) a lack of high rainfall years; and (4) changes in the daily distribution of rainfall amounts and rainfall sequencing (Potter et al., 2010). Also, although the 2007–08 La Niña events were relatively weak, the events brought some heavy rainfall to the most of northern Australia and the eastern tropics, but the southern half of the MDB did not receive enough rainfall typical of past La Niña events (BOM, 2012). Long-term, low level rainfall across the MDB caused loss of large quantities of water from the MDB’s surface and soils (Leblanc et al., 2009), as well as environmental degradation of its numerous floodplains and wetlands (CSIRO, 2008). Also, reduction in annual MDB rainfall of about 2% in the north and about 5% in the south has been projected by 2030, resulting in less water available for irrigation (e.g., median stream flow is projected to decline by 10% to 25% in some catchments) (CSIRO, 2011).

The increase in maximum temperatures in south-eastern Australia has been found to be greater than the increase in minimum temperatures; mean annual daily maximum temperature has increased by 0.9°C since 1990 in the MDB (Timbal et al., 2010). The Millennium Drought across the MDB was the worst drought in the instrumental record (Timbal & Fawcett, 2013). At the time of the Millennium Drought, the mean daily maximum temperature in the MDB was 0.7^0C warmer than the previous record, and more than 1^0C warmer than the two earlier droughts in this area, resulting in reduced soil moisture and irrigation efficiency (Nicolls, 2004). On an annual basis, a rise of 1°C leads to about 9% decrease in sub-surface soil moisture in the southern MDB. Also, it is reported that during the Millennium Drought the sensitivity of soil moisture to rainfall decline was 80% higher than during the World War II Drought (Cai et al., 2009). Figure 2.5 shows the annual mean temperature anomaly (the difference from an average temperature) across the MDB (1910-2018).

Figure 2.5: The Annual Mean Temperature Anomaly across the MDB (1910-2018)



Source: Created from data in BOM (2018). Available at: http://www.bom.gov.au/climate/change/index.shtml#tabs=Datasets&tracker=timeseries&tQ=graph%3Dtmean%26area%3Daus%26season%3D0112%26ave_yr%3DT [Accessed June 9, 2019].

It has been argued that a 1C° rise in average temperature is associated with a 15% reduction in inflows in the MDB. So, with a projected 2C° increase in temperature by 2060, there could be a 30% reduction in inflows from reduced precipitation and increased evapotranspiration (Cai & Cowan, 2008). There is an argument that the southern MDB will, on average, be drier in the future compared to the northern MDB. For example Whetton (2017) argued that in the northern Basin median rainfall is projected to reduce by about 6% and median annual runoff is projected to reduce by approximately 20%. For the southern Basin median rainfall is projected to reduce by approximately 8% while median annual runoff is projected to reduce by approximately 24% in the south-west (CSIRO, 2011). Also, examination indicates that climate change impacts weather systems differently in the northern Basin, compared to the southern Basin. A small increase in total annual rainfall in the northern Basin is projected to happen in the medium to long-term, while decreasing winter and spring rainfall is predicted to consistently occur in the southern Basin (MDBA, 2019). During the Millennium Drought, between 2001 and 2005, the River Murray received only 40% of its long-term mean inflows (MDBC, 2006). A long dry spell such as this caused much lower average water allocations for irrigation and placed wetlands under serious threat (Murphy et al., 2008). Also, the condition of the Coorong and Lakes Alexandrina and Albert, at the lower end of the River Murray, deteriorated significantly, with: low water levels; acidification, increasing salinity and ecological changes (Phillips & Muller, 2006). Reduced surface inflows strikingly increased salinity in the lower reaches of the River Murray and future climate change is expected to exacerbate its salinity (Nielsen & Brock, 2009).

The MDB water balance is provided by the net difference between rainfall and evapotranspiration. The majority of the MDB water balance is negative, which means evapotranspiration exceeds rainfall (CSIRO, 2008a). Evapotranspiration is naturally high in floodplain wetlands and is also high in irrigated areas. Related work by CSIRO and the BOM indicates that the recent Millennium Drought caused severe reductions in water runoff in the southern MDB, and the future mean annual runoff in the MDB is estimated to be lower by 5% to 10% in 2030 relative to 1990 in the north-east and southern half, and by about 15% in the southernmost parts (CSIRO, 2008b). Similar conditions are likely to occur in the future, with surface water availability. For example, it has been projected that by 2030 total MDB surface water availability will decline by 11%, with surface water use falling by 4%, and flows at the Murray Mouth falling by 24% (CSIRO, 2008c).

Loch et al., (2013) summarised the scientific evidence for water outlook in the MDB and suggested that climate change will put water security at risk; the frequency of drought will increase in the southern and south-eastern regions of the MDB; heavy rainfall and tropical cyclone events will increase in the north-eastern regions of the MDB; the impacts of drought in the southern areas will be exacerbated by decreasing rainfall and increasing temperatures; supply reliability will suffer, with the security of general water entitlements in NSW and low security water entitlements in Victoria being particularly affected; and there will be an increase in extensive and prolonged flooding, causing infrastructure damage and productive/environmental losses. Supplementary figures are shown in Appendix A.

Climate change has influenced more than just the quantity of water in the MDB. Various aspects of water quality such as: water temperature; dissolved oxygen levels; and concentrations of salt and pollutants are susceptible to various climate change drivers (Whitworth et al., 2012), which may result in significant negative effects for the environment and for consumptive use (Neave et al., 2015), as well as for irrigated and dryland agriculture. The other reported effect is toxicity in the lakes at the end of the Murray River due to low river inflows and large-scale floodplain forest mortality throughout the basin (Dijk et al., 2013). In 1991, a toxic cyanobacterial bloom that extended for 1000 km along the Darling River was the clearest pointer that the health of the river system was approaching disaster levels (Bowling & Baker, 1996). Moreover, sudden weather events or changes in flows mix the warmer surface water and colder deep water resulting in mixing the warmer oxygenated surface water with colder and low oxygen deep water, this dissolves oxygen levels and can become critical and leading cause of fish kills. Thousands of dead fish were recorded along the Darling River on 15 December 2018. A second, larger fish kill event was reported on 6 January 2019. A third event happened on 28 January, killing millions of fish. The beginnings of a fourth event was seen on 4 February 2019 (AAS, 2019).

2.3 Agricultural Climate Change Impacts Worldwide and in Australia

By 2080, climate change is projected to decrease global agricultural production by approximately 16% due to changes in water availability, water quality and temperature rises (Cline, 2007). The higher temperatures will lead to stress on agricultural reproduction, increase the cost of production, and increase food insecurity (IPCC, 2014). Agricultural development in Australia started with the arrival of the first European settlers in 1788 (Henzell, 2007). However, the productivity of Australian lands, like many other arid countries, is limited because of severe droughts and water scarcity (Judd, 2005). The Millennium Drought in

Australia reduced dryland farming production and the volume of water allocated to irrigate agriculture, resulting in reduced total agricultural production and exports (Qureshi et al., 2013).

Water quality issues, such as salinity and the level of nitrogen, have also significantly impacted irrigated agriculture in Australia. Salinity is one of the factors which may pose an additional challenge to irrigated land and consequently to irrigated agriculture (Schwabe et al., 2006) and affect agricultural production by lowering crop yields (Letey & Dinar, 1986). The traditional reaction to the threat of salinity-induced crop yield decreases is to apply water in excess of plant necessity to filter the salt out of the root zone. This approach turns out to be problematic in the case of climate change and for Australia's drought prone areas (Connor et al., 2012).

Furthermore, as previously mentioned, climate change has reduced seasonal rainfall patterns in Australia (Chiew et al., 2009). Rainfall is the most important climatic parameter influencing agriculture. Both the amount of rainfall and its variability is vital for agricultural production because around 98% of the MDB surface land area is dedicated to rain-fed agriculture (Grafton et al., 2014). Insufficient rainfall will directly affect crop production and agriculture in the MDB by decreasing the flow of surface water, which mainly services irrigation (Quiggin et al., 2010). Madadgar et al., (2017) argue that rainfall and soil moisture shortage in dry growing seasons decreases the average annual yield of the five main crops in Australia (wheat, broad beans, canola, lupine, and barley) by 25–45% compared to the wet growing seasons. Hochman et al., (2017) showed that reductions in rainfall and rising temperatures have reduced potential wheat yield in Australia by around 27% since 1990; however, elevated CO_2 concentrations due to climate change prevented a further 4% loss.

Figure 2.6 estimate climate-adjusted total factor productivity (TFP) under representative dry and wet conditions. The orange line shows TFP from 1997-98 to 2012-13. The red line shows what TFP would look like if all farms in all years experienced 1 in 20-year drought conditions, while the light blue line shows productivity assuming 1 in 20-year normal wet conditions.

Figure 2.6: Total Factor Productivity under Dry and Wet Conditions, 1977–78 to 2014–15

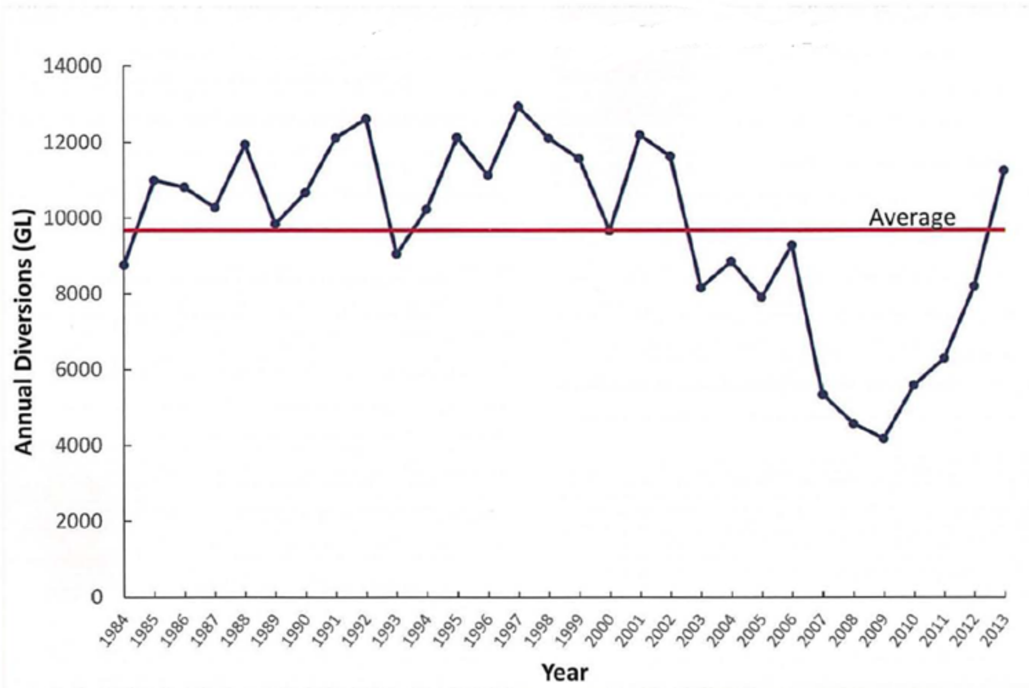
Source: ABARES (2017a; p.25)

2.4 Agricultural Climate Change Impacts in the MDB

The MDB's major agricultural commodity activities are horticulture (e.g. fruit trees or wine grapes), rice and other annual crops (e.g. cereal, pasture and vegetables), dairy cattle, using purchased or self-grown feed, and mixed farming operations where irrigated and dry-land production is combined (Grafton & Jiang, 2011). The southeast of the Basin contains irrigated pastures for dairy, beef, and sheep. Crops are rain feed for much of the year. About 550–750 mm of water is diverted per crop in the east, where the rainfall varies from 700 mm per year, to less than 400 mm per year in the west (Grafton et al., 2014). Water diversions average more than 1000 mm per crop and happen in highly variable rainfall environments of between 200 and 400 mm per year. In the southern MDB, with water mostly applied by a sprinkler or by microsystems, grapes and citrus are grown, and perennial horticulture dominates. Cotton is grown in the northern Basin where water use is around 700–800 mm per year; this takes place in rainfall locations of about 400–550 mm per year. During the Millennium Drought, average annual net inflows in the Murray River were the lowest ever recorded for a 5-year period, resulted in greatly reduced water diversions to irrigated farmers of between 30% and 50% (Grafton et al., 2014).

Water use on irrigated farms in the MDB is highly variable from year to year, depending on changes in seasonal conditions, water availability, the mix and type of irrigated enterprises and trade in seasonal water allocations and permanent water entitlements (Wheeler et al., 2018). Declining total irrigation surface-water diversions as a result of climate change, drought and water policy to return consumptive entitlements to environmental use in the MDB can be seen in Figure 2.7 and Table 2.1. Diversions significantly dropped below average during severe droughts, though the Figure 8 indicates some increase in the diversions after the Millennium Drought. However, it did not achieve the peak diversion levels of the 1990s. Further, as noted in Table 2.1, the number of agricultural businesses and agricultural irrigating farms in the MDB has been steadily declining, particularly in the southern MDB (there is an exception for 2010-11 and 2011-12 in the northern region).

Figure 2.7: The MDB Diversions 1984-2013



Source: Neave et al. (2015: p.105)

Table 2.1: Water Use on MDB Farms 2005-06 to 2017-18

Year	*Agricultural businesses (no.)*	*Agricultural businesses irrigating (no.)*	*Area irrigated (ha)*	*Volume applied (GL)*	*Application rate (ML/ha)*
2005-2006	61,504	18,674	1,664,000	7,398	4.45
2006-2007	59,864	17,063	1,101,000	4,458	4.05
2007-2008	56,585	15,479	957,753	3,142	3.28
2008-2009	54,096	15,077	929,074	3,492	3.76
2009-2010	53,681	15,121	975,660	3,564	3.65
2010-2011	54,023	15,406	1,194,253	4,518	3.78
2011-2012	53,946	14,358	1,411,612	5,875	4.16
2012-2013	51,203	13,023	1,597,454	8,283	5.19
2013-2014	50,929	14,496	1,559,565	7,736	4.96
2014-2015	49,096	14,588	1,366,738	5,869	4.29
2015-2016	35,465	9,217	1,238,106	4,938	3.99
2016-2017	36,083	9,197	1,347,592	6,355	4.72
2017-2018	35,203	9,496	1,460,054	6,798	4.66

Source: ABS (from 2007-8 to 2017-18) water use surveys

During the Millennium Drought, some forms of irrigated production declined in the MDB, especially rice production, which fell from 1643 kilo-tonnes in 2000–2001 to 1003 kilo-tonnes in 2005–2006 and 18 kilo-tonnes in 2007–2008. Empirical analysis shows that in the southern MDB, in dry conditions (using 2005–2006 as the base year for production), wheat production fell by 25%, and, for the same area, rice production fell by approximately 70% in dry conditions (Qureshi et al., 2013). Climate change projections show that a decline in effective[7] rainfall and water allocations for irrigation reduces production of major Australian agricultural commodities, including wheat, beef, dairy and sugar production by 9–10% by 2030 and 13–19% by 2050 (Gunasekera et al., 2007). The effect of changes in climate on agricultural productivity vary across Australia. It has been projected that by 2050 agricultural productivity in the south-eastern, the south-western, and the northern parts of Australia will change by -7%, -9% and -27%, respectively (Cline, 2007). However, Kirby et al., (2014; Table 1; p.157) identified that the decrease in economic returns to irrigation is less than the reduction in water available for irrigation. They compared actual farming outcomes in the MDB from 2000-01 to 2007-08 and found that the real adjusted gross value of irrigated production dropped by 10%, despite a 70% reduction in irrigated surface-water use. Connor et al., (2014) identified that hotter and drier climate conditions in a time of drought effected crops differently: some crop revenues suffered, while higher evapotranspiration and yield potential appeared to support higher revenue outcomes for other crops.

Further, a warmer climate is found to negatively impact wine grape quality in Australia. It has been argued that in a warming scenario, the season is shorter, and harvest is earlier, which can negatively impact grape quality (Webb et al., 2007). Webb et al., (2008) determined the wine grape quality for different premium wine grape varieties separately and identified that, without adaptation, quality might be reduced nationally by 39% by 2030.

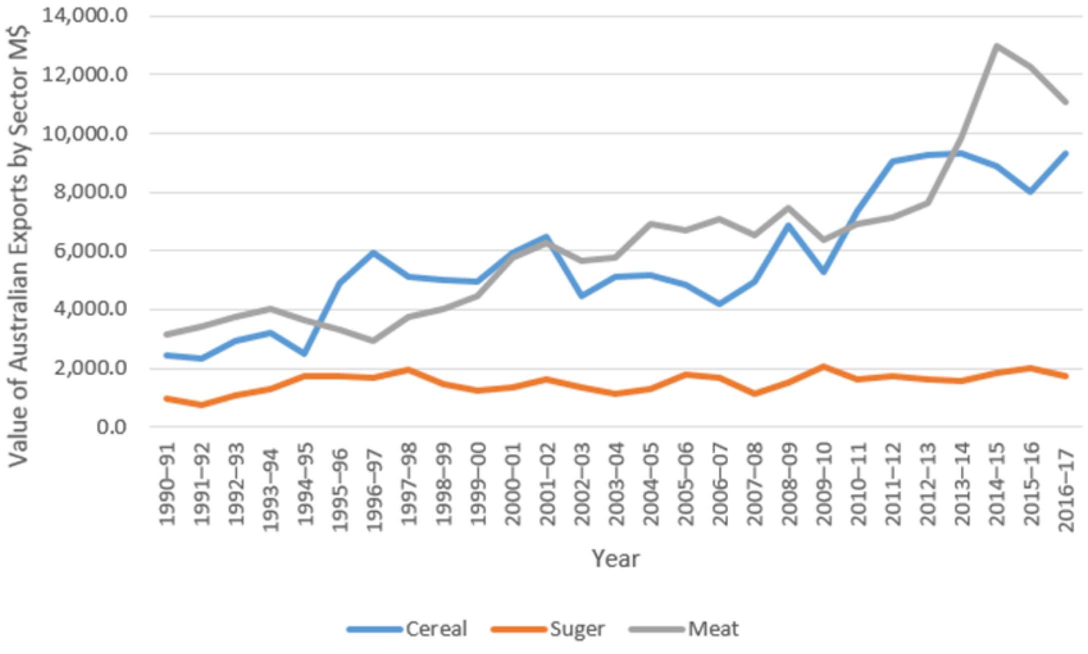
2.5 Australian Agriculture Exports

Agriculture is a vital part of Australia's economy, with the total gross value of crops totalling AUD$29.3 billion in 2017-18 and adding 2.7% to GDP in 2016–17 (ABS, 2019). Australia contributes significantly to world food supply and is a substantial exporter of agricultural products, such as meat, rice, and dairy products. Based on ABARES (2018a), there has been

[7] Effective rainfall is the amount of rainfall that stored in the soil. During drier periods less than 5mm of daily rainfall would not be considered as effective, because this amount of water would likely evaporate from the surface before soaking into the ground.

an increase in the value of agriculture, and forestry exports over the recent years with the highest value increase occurring in meat and live animals export (Figure 2.8).

Figure 2.8: Value of Australian Exports by Sector 1990-2017



Source: Created from data in (ABARES 2018; reference year 2015-16)

An increase in the demand for Australian agriculture and food production is expected because of the world's population increase, as well as increased calorie intake in China and India, and rising demand for fresh food, meat and live animal exports from Middle Eastern countries (ABARE, 2012). Thus, a reduction in the volume of production due to climate change and water scarcity will have implications for food security, both nationally and in export destinations (Qureshi et al., 2013).

As previously mentioned, water is a valuable commodity within agriculture, which accounts for around three quarters of Australia's total water use. In 2017-18, more than two thirds (70%) of all Australian agricultural water use was within the MDB region (ABS, 2017a). As Table 2.1 illustrates, the number of agricultural business and agricultural businesses irrigating in the MDB have a decreasing trend over the time. However, the amount of irrigated area and the water application rate (volume applied (ML)/area irrigated (ha)), shows both increasing and decreasing movements over the time-period. Overall, there is not much change in the irrigated area and water application rates.

Because extreme climatic conditions, especially drought, are expected to become more frequent in Australia (CSIRO, 2018), there has been an increased interest in the sustainable management of water resources in the MDB to help farmers approach water scarcity-management and sustainability. Although climate change will worsen hydrological impacts on river systems, currently high levels of water extractions continue the major contributor to reduced system flows. They suggest that changes in governance, including sharing the variability between the environment and consumers, are urgently required to maintain the health of these rivers (Grafton et al., 2013). Thus, in recent decades, many governments around the world have developed national conservation strategies to address “ecologically sustainable development”, which is related to water management, rural land management, agricultural land use protection and watershed management (Hannam, 1999). Banerjee et al., (2013) analysed economic estimation of hydrological ecosystem service losses because of the Millennium Drought in the MDB and found that nearly $810 million was spent during the drought to mitigate losses, replace ecosystem services and adapt to new ecosystem equilibria. Finally, many management institutions are now adapting new frameworks, such as ecosystem-based management, and theoretical tools such as coupled social-ecological systems (Gray, 2010). Australia has developed a number of water markets for managing water use, where water rights are freely traded between end users, which are discussed in the following section.

2.6 Water Markets for Managing Water Use in the MDB

Given growing water scarcity and increasing water demand world-wide, there has been an increased focus on demand-based management solutions (FAO, 2012). Although climate change will worsen hydrological impacts on river systems, currently high levels of water extractions continue to be the major contributor to reduced system flows. Thus, changes in governance, including sharing the variability between the environment and consumers, are required urgently to maintain the health of the river systems (Grafton et al., 2013). Water managers and policy makers in Australia have led the world in introducing demand-management strategies for water scarcity. For the history of water reform policy in Australia, please see Wheeler (2014) and Grafton & Wheeler (2018).

In the past thirty years, the most major water reforms in Australia were driven by the Council of Australian Governments (COAG). After a series of environmental disasters in the MDB, and growing water scarcity, in 1994, the COAG agreed to a series of water reforms. One such reform was to ensure that water resources are put to their most beneficial use through tradable water entitlements (Bjornlund & McKay, 1998). With the introduction of the National Water Initiative (NWI) in 2004 (i.e. Australia's blueprint for water reform), water markets converted to an essential tool for water management and reallocation in the MDB (Bjornlund, 2006; COAG, 2004). This reform initiated the formal shift to a market-based approach to water resource management (Lee & Ancev, 2009). Water markets allow Australia's scarce water resources to be efficiently allocated between competing users in response to fluctuations in supply and demand (ABARES, 2017b). This reform also emphasised the requirement for catchment management which include the devolution of existing water authorities and the reorganisation of responsibilities as well as shift of operational function to local irrigation bodies (Bjornlund, 2006).

Two different water markets exist in Australia: 1) the entitlements (permanent) market; and 2) the allocations (temporary) market. They are defined in COAG's (2004, P.30) *National Water Initiative* as:

Water entitlement: *a perpetual or ongoing right to exclusive access to a share of water from a specified consumptive pool as defined in the relevant water plan.*

Water allocation: *the specific volume of water allocated to the water entitlement in a given season, defined according to rules established in the relevant water plan.*

The trade in both entitlements and allocations within the MDB represents about 80% of all such trade in Australia (Grafton & Horne, 2014). Over the years, irrigators in the MDB have been adapting to fluctuating seasonal water allocation during droughts and to various changes in their operating environment, as the government introduced additional policies to alleviate the pressure on environmental, economic, and societal systems (Wheeler et al., 2014). Water markets help irrigators to manage water scarcity risks and demand requirements, also governments will be benefited from water markets due to having additional amounts of water resources to provide or maintain planned environmental outcomes (Wheeler & Cheesman 2013). Water trading is now widely used as a risk-management strategy (e.g., Zuo et al., 2014; Nauges et al., 2016). Also, some economic studies (e.g., Jiang & Grafton, 2012) have highlighted the financial benefit of having water markets in place. Water markets and water resources management allocate water to its peak value user by forming a price signal for the value of that water. Thus, the ideal water allocation method requires the assessment of the value of water for its various uses (Grafton & Wheeler, 2018).

In response to the prolonged Millennium Drought, the Australian government promulgated the *Water Act* in 2007 that involved substantial legislative, regulatory, and stakeholder water reform. The *Water Act* formed new administrative procedures and water market organisations, such as the Murray-Darling Basin Authority (MDBA, 2012) to replace the Murray-Darling Basin Commission (MDBC). The MDBA is responsible for sustainable water management in the MDB. The *Water Act 2007* was renamed the Water for the Future (WFF) in 2008 (Connell & Grafton, 2008).

Moreover, Australia currently offers a leading example of a government buying back water for the environment (Wheeler et al., 2013). The water buyback program was developed to produce environmental benefits in deteriorated sites across the MDB in the government's primary market-based instrument. The water buyback program aims to reallocate water, which previously allocated for consumptive uses, back to the environment (Grafton & Wheeler, 2018). In response to the environmental harm caused by the over allocation of water entitlements, in 2007–2008 the Australian Government committed about AUD$3 billion to buy back existing permanent water entitlements from willing sellers over ten years in the MDB, with the program known as *Restoring the Balance* (RtB) (Wheeler et al., 2013).

Australia has also used considerable other nonmarket approaches to respond to water scarcity. For example, the Australian government has spent approximately AUD$4 billion on infrastructure subsidies to increase irrigation efficiency and to increase stream flows in the MDB. The objective of such infrastructure subsidies was to deliver returns for the environment and also to allocate some grants for on- and off-farm irrigation water-use efficiency to secure a long-term future for irrigation communities (Grafton & Wheeler, 2018). However, the program has been highly criticised by economists, who argue that return flows are not accounted for, it incentivises permanent plantings and increased irrigated area, and it is not cost-effective. A comparison between buy-backs of water entitlements from willing sellers and subsidies program, shows that subsidies are at least three times more expensive than buy-back programs (Grafton & Wheeler, 2018). So, although nonmarket approaches are preferred by many irrigators (Loch at al., 2014), it is not cost-effective, and may not meet long term sustainability aims of being able to flexibil respond to an uncertain future climate (Adamson & Loch, 2014).

Water allocation differs across the MDB and there are differences between the States, river valleys and regions, depending upon the reliability of supply (MDBA, 2015). Allocation announcement processes provide water access entitlement holders with a volumetric amount that can be used or traded in each water year. Table 2.2 provides a historical overview of the end of season allocations in the southern MDB (sMDB), from 1998 to 2019. It highlights the water shortage that irrigators experienced during the recent drought, especially from 2006–07 to 2009-10, and more recently in 2018-19.

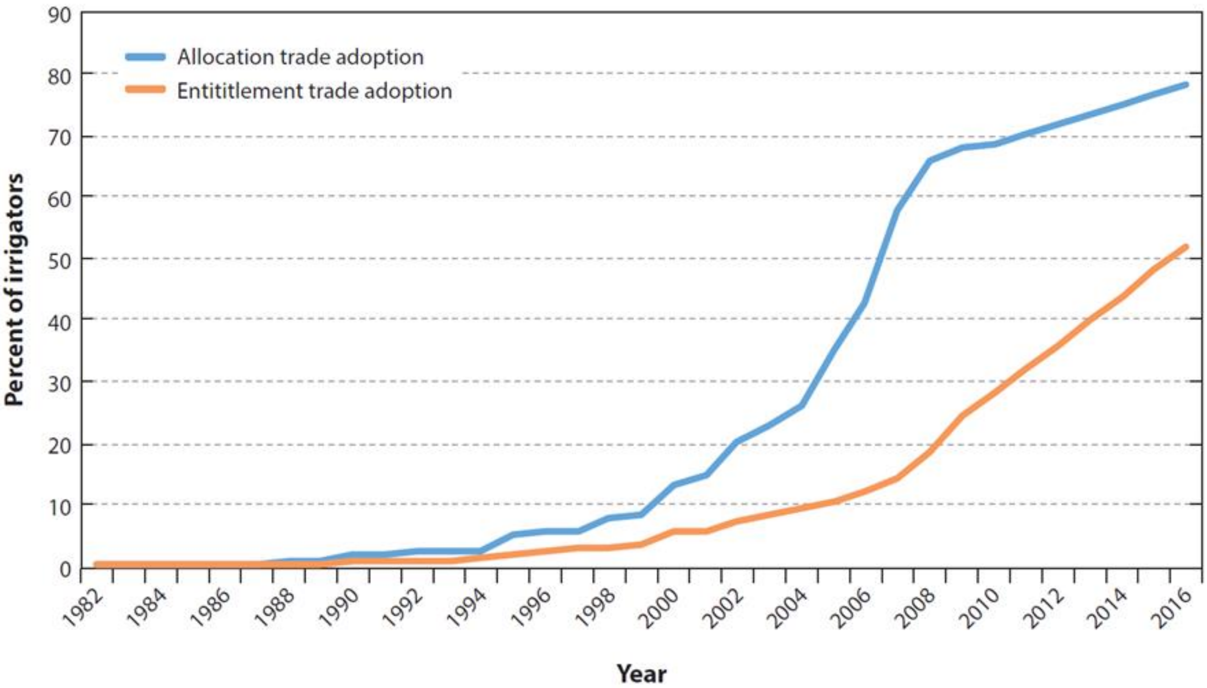
Table 2.2: End of Season Water Allocations in the sMDB

	High reliability rights					***Lower reliability rights***			
Year	***VIC Goul-burn***	***VIC Murr-ay***	***NSW Murr-ay***	***NSW Murrumb-idgee***	***SA Murr-ay***	***VIC Goulb-urn (low)***	***VIC Murr-ay (low)***	***NSW Murra-y (general)***	***NSW Murrum-bidgee (general)***
1998-99	100	100	100	100	100	0	100	93	85
1999-00	100	100	100	100	100	0	90	35	78
2000-01	100	100	100	100	100	0	100	95	90
2001-02	100	100	100	100	100	0	100	105	72
2002-03	57	100	100	100	100	0	29	10	38
2003-04	100	100	100	95	95	0	0	55	41
2004-05	100	100	97	95	95	0	0	49	40
2005-06	100	100	97	95	100	0	0	63	54
2006-07	29	95	69	90	60	0	0	0	10
2007-08	57	43	50	90	32	0	0	0	13
2008-09	33	35	95	95	18	0	0	9	21
2009-10	71	100	97	95	62	0	0	27	27
2010-11	100	100	100	100	67	0	0	100	105
2011-12	100	100	100	100	100	0	0	100	105
2012-13	100	100	100	100	100	0	0	100	105
2013-14	100	100	100	100	100	0	0	100	63
2014-15	100	100	97	95	100	0	0	61	53
2015-16	90	100	97	95	100	0	0	23	37
2016-17	100	100	100	100	100	0	5	100	100
2017-18	100	100	100	95	100	0	0	51	45
2018-19	100	100	97	95	100	0	0	0	7
LTAAY	0.95	0.95	0.95	0.95	0.9	0.35	0.24	0.81	0.64

Source: various state water registers.

Water markets have been part of the water policy landscape in Australia and were first introduced in Australia in the 1980s (Loch et al., 2013). However, water trade was not very common until further reform at the beginning of the 1990s, with the introduction of a cap on water consumption in 1995 (Wheeler et al., 2017). Water markets currently function predominately in the MDB of Australia, and more particularly, in the sMDB. For example, in 2015-16, 89% of surface water allocation trading and 42% of entitlement trading occurred in the sMDB (ABARES, 2017). Water allocation trading is less complex and is often used by Australian irrigators to manage their water use by purchasing water when it is most needed (Zuo et al., 2014; Wheeler et al., 2014). The water market has become gradually more active during recent years, and this progress is expected to continue (NWC, 2011). Figure 2.9 shows how water market trade has increased over time in the sMDB, and represents the cumulative adoption of allocation and entitlement trade by irrigators. Water entitlement trade increased substantially after the Millennium Drought, while water allocation trade was adopted a lot earlier (Grafton & Wheeler, 2018).

Figure 2.9: Water Market Trade Cumulative Participation Adoption in the sMDB, 1982-2016



Source: Grafton & Wheeler (2018; p.496)

Water markets in the MDB have been shown to have a number of positive impacts such as: environmental benefits; enabling irrigators to adapt to climate change; increasing the gross value added to farming activities; and achieving some social goals (Wheeler et al., 2014). For example, during the Millennium Drought in the MDB, water markets have re-allocated some water away from low value agricultural activities — such as cereals, rice and other broadacre staple crops — to high value perennial horticultural activities (such as grapevines, citrus and almonds (Qureshi et al., 2013). However, there are many perceptions regarding the impacts of water markets. Some of these perceptions include the reduction in local spending, employment, and public services because of a decline in the water diverted in rural areas. These issues are said to be the most relevant for water entitlement trade (Bjornlund et al., 2011); however, the economic literature has not found evidence to date to support such claims (Grafton & Wheeler, 2018).

2.7 Murray-Darling Basin Plan

After the *Water Act 2007*, the MDBA was formed from the MDBC and was charged with delivering a Basin plan, with a guide released in 2010 (Grafton & Wheeler, 2018). The Basin Plan is aimed to provide a catchment-wide framework for sustainable management (Connell & Grafton, 2011). Also, it is aimed to ensure the return to environmentally sustainable levels of extraction for water resources that are over allocated or overused; and to protect and provide for the ecological values and ecosystem services of the MDB (Wheeler, 2014; Bark et al., 2016). So, the Plan included a series of actions, and milestones until 2024 to reduce surface-water diversions in the MDB, through the implementation of sustainable diversion limits (SDLs). The Plan would reduce overall diversions by irrigators, on an average annual basis, by 2,750 GL based on a long-term average annual yield (LTAAY) (Grafton & Wheeler, 2018).

The MDB Plan has been a significant step in Australian water reform, which balances environmental, social, and economic considerations by setting water use to an environmentally sustainable level and can help water security (Connell & Grafton, 2008). However, Connell & Grafton (2011) reported several major challenges in the success of the Basin plan (e.g., human resource constraints, legislative tensions within the Australian federal system, difficulties in coordinating the network of water-related agencies in the six jurisdictions with responsibilities in the MDB, and some social, economic, and environmental limitations that limit policy implementation). It has been reported that although it is difficult to quantify the long-term social, economic and environmental benefits of the Basin plan, but the benefits are more significant than the long-term costs (Wheeler, 2014).

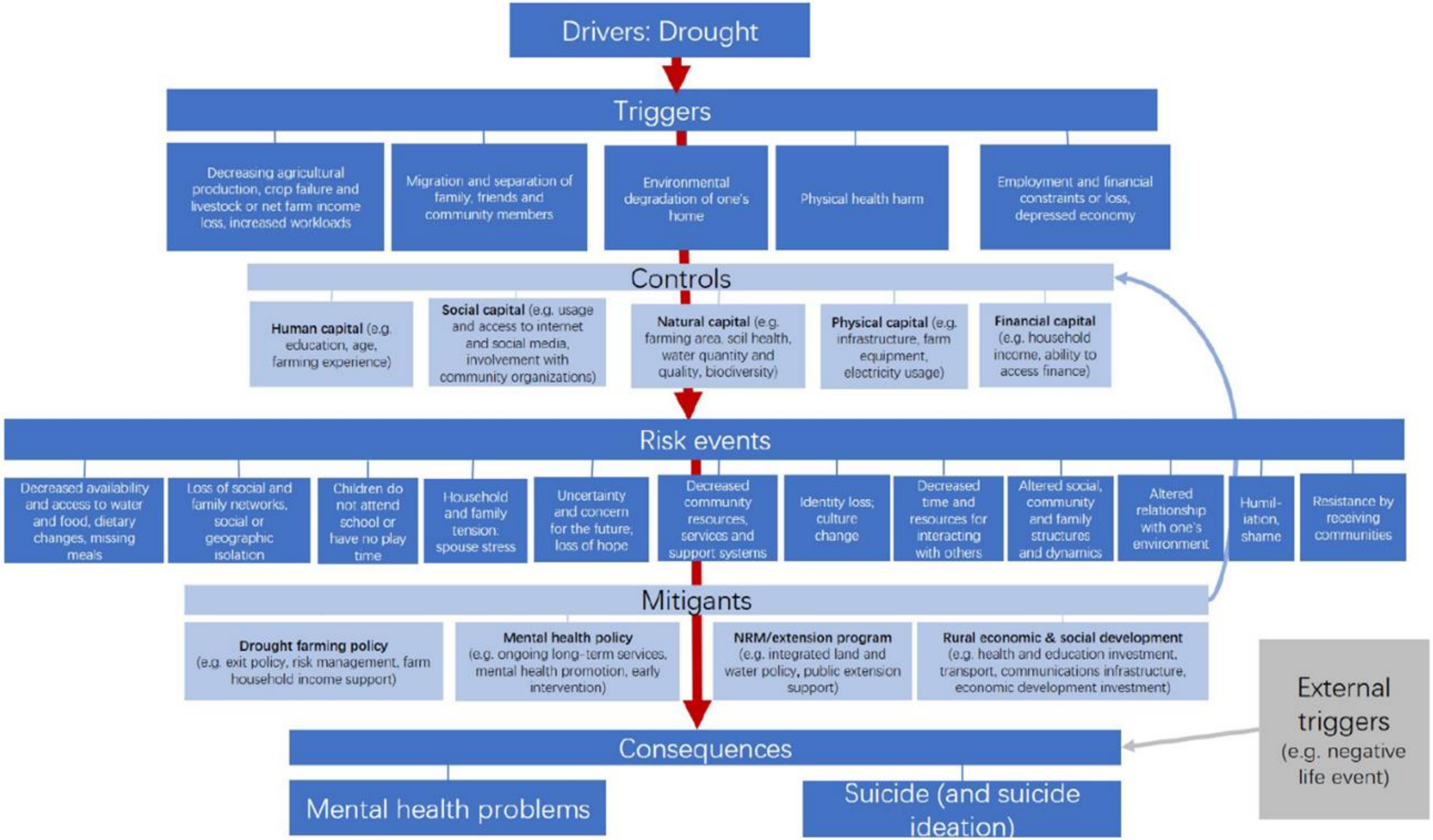
Pittock et al., (2015) stated that climate change is a serious risk to the expected outcomes of the Basin Plan. Similarly Kirby et al., (2014b) estimated that water reallocation will result in improved environmental water availability only under no-climate change or wet climate change projection. Examining water recovery and the information available on environment, Grafton & Wheeler (2018) stated that the current Basin Plan was failing on many environmental outcomes, let alone cost-effectiveness of water recovery. Thus, some scientists have argued that there is a need to rebuild and adjust the Basin Plan as despite a huge expenditure on the Basin Plan, in terms of environmental benefits, there is a lack of progress to date (Williams, 2017). Grafton et al., (2014) also argue that better water planning can increase the overall benefits of consumptive and non-consumptive water use, can improve riparian environments under climatic variability, and can have small effects on the profits and gross value of food production. Supplementary figures are shown in Appendix A.

2.8 The Mental Health Outcomes of Drought

Drought is described as a slow-moving disaster with significant health effects, often mediated through complex environmental, economic and social pathways (Vins et al., 2015). It has been identified that a wide range of populations may be at mental health risks as a result of drought including children, elderly people, the socially and economically disadvantaged, women, people who spend time outdoors and those with chronic diseases and compromised immune systems (Yusa et al., 2015).

Australian farmers often face hardship due to periods of less frequent rain events or above-normal evaporation from dry soils, water scarcity and a constantly growing demand for water (Berry et al., 2011a). Drought and water scarcity have been regular events in Australia but predicting future weather condition is uncertain and farmers must deal with risk on a daily basis (Berry et al., 2008; O’Brien et al., 2014). Figure 2.10 summarises the risk systems casual pathways between drought and mental health.

Figure 2.10: Risk Systems Casual Pathways between Drought and Mental Health



Source: Wheeler et al. (2019; p. 21)

The figure 2.10 shows five components: a) identifying the driver (e.g., drought); b) identifying the triggers (e.g., the events that are the immediate cause of drought); c) assessing causal risks; d) identifying and analysing controls and mitigants; and e) identifying risk events which in turn contribute to consequences (e.g., psychological distress and suicide in drought-affected rural and remote communities). The impact of drought and reducing water supply on farmers' mental health in Australia, will be discussed in detail in the next chapter.

2.9 Summary

This chapter provided a comprehensive introduction to climatic variability over of several decades in Australia. This chapter specifically introduced the study area (the MDB), which is Australia's most important agricultural region, along with the environmental issues affecting the MDB, including drought, salinity, and change to water quality and quantity. Also, it provided an overview on how climate change affects Australian agriculture in multiple ways. Furthermore, this chapter briefly summarised the recent history of water reform in the Basin, and in particular, water market reforms in Australia.

CHAPTER 3 Farm-Related Concerns and Farmer Mental Health

Globally, farming has been identified as one of the most stressful jobs. Working in agriculture exposes farmers to some of the highest rates of stress-related illnesses, including cardio-vascular disease, hypertension and psychological disorders (Demos et al., 2013). This chapter discusses the causes of farmers' stress and explains the key influences on their mental health, particularly in Australia. Moreover, there is some evidence that people who live and work on farms have higher rates of suicide. In the face of this, this chapter also summarises evidence to explore perceived causes of suicides among farmers. Finally, to identify farmer-specific factors that make mental health help seeking difficult, this chapter highlights some important help-seeking barriers within farming communities.

3.1 Farming and Mental Health

Agriculture is one of the biggest economic sectors in many countries and, worldwide, approximately 70% of the working population is employed in agriculture (Fuchs et al., 2007). Despite the common belief that farming is a peaceful and healthy occupation with lower morbidity and mortality rates, farmers experience some of the highest rates of stress-related illnesses (Fraser et al., 2005; Price et al., 2009; Demos et al., 2013; Daghagh Yazd et al., 2019a). Long working hours create physical burdens while stress factors, such as uncertainty about future conditions, contribute to mental health issues (Kearney et al., 2014). High levels of stress may have long-term effects on mental health and may influence the ability to make decisions, to solve problems, as well as to stay mentally healthy (Cary & Weston, 1978). The physiological outcomes of stress are also linked with an increase in alcohol consumption, increase in smoking, sleep disruption, impaired mood, and inability to relax (Walker & Walker, 1987; Olowogbon et al., 2019). Farmers also report less satisfaction with their sense of security for their future and with their spirituality (Berry et al., 2011a). Torske et al., (2016) examined the association between occupation at baseline and symptoms of mental distress 11 years later, and identified that farmers were more likely to have high depression level compared to other occupational groups. Cottini & Lucifora, (2013) estimated the potential endogeneity of working conditions, and their results for a number of stylized workers based on a selected personal characteristics and job attributes, showed a significant risk of mental distress associated with adverse working conditions, especially for male workers, who have high job responsibility.

One of the most common concerns raised is that farmers have more significant mental health issues than the general population. For example, Demos et al., (2013) compared certain clinical and neurobehavioral health outcomes between farmers and non-farmers living in the same rural area in Greece and revealed that farmers have significantly more physical and mental health issues. Torske et al., (2015) compared farmers with workers in other occupational groups and found that both male and female farmers have higher levels of depression symptoms than the general working population in Norway. Arcury et al., (2018) compared employed farmworkers', employed non-farmworkers' and unemployed non-farmworkers' mental health among Latinos, and concluded that farmworkers have higher average stress and anxiety scores than do employed and unemployed non-farmworkers. Face-to-face interviews with 784 attendees from farming and non-farming populations revealed that mental disorders for farmers were significantly higher than those for the non-farming community, indicating higher psychological morbidity among UK farmers (Hounsome et al., 2012). Comparing stresses among farmworker and non-farmworker participants in three agricultural periods (pre-thinning season, the thinning season, and the non-spray season), Ulrich et al., (2018) showed that stress is significantly higher in farmworkers compared with non-farm workers in the non-spray farming season among Latinos. Thelin et al., (1998), with respect to worry about the future, reveal that Swedish farmers reported a significantly higher index than all other occupational groups.

A large-scale survey of 8,000 individuals in Australia during the Millennium Drought, showed that the mental health of farmers and farm workers is most impacted by drought compared with the mental health of those employed outside agriculture (Edwards et al., 2015). Also, MDB irrigators, in some key irrigation industries, reported higher levels of psychological distress than dryland farmers or the general Australian population (Wheeler et al., 2018).

On the other hand, some studies find no significant differences in mental health status between farmers and other rural or metropolitan residents. Judd et al., (2006), in their quantitative study, found no support for the proposition that farmers experience higher rates of mental health problems than do non-farmer in rural areas. Otsuka & Kato (2000) compared occupational groups in traditional societies (e.g., farmers and skilled manual workers) with occupational groups in industrialised societies (e.g., managers and technicians), and found that occupational groups in industrialised societies had higher levels of depression in Japan. Similarly, in a study by Thomas et al., (2003), British farmers reported a lower prevalence of mental illness than the general population but they were more likely to report thinking that life was not worth living. Feng et al., (2015) stated that, overall, farmers of rural China did not report a significantly higher prevalence of mental distress than non-farmers; however, farmers aged 51–70 years reported significantly higher mental distress than the non-farmer participants.

3.1.1 Health Risk Factors Affecting Farmer Mental Health

Many studies have identified several factors affecting farmers' mental health, such as pesticide exposure, financial difficulties, an unpredictable climate, past injuries, heavy workloads, role conflict, and isolation.

Farmers, by the nature of their work, are exposed to several types of pesticides, which may cause chronic adverse health effects including the possibility of neuropsychological effects (Povey et al., 2014; Malekirad et al., 2013). Body weakness, excessive perspiration, headaches, poor appetite, chronic bronchitis and productive coughs, eczema, and depression are the most frequently reported symptom by farmers who use pesticides (Beshwari et al., 1999; Mwabulambo et al., 2018). Also, some argue that agricultural workers with organophosphorus exposure have major depression, alongside suicidal ideation, anxiety and combined depression–anxiety (Serrano-Medina et al., 2019). Pesticide poisoning may have occurred during most agricultural activities such as spraying, mixing, loading, and field re-entry, resulting in being easily fatigued and having mental issues (Lu, 2017). A recent study by Mwabulambo et al., (2018) stated that ninety-five percent of males who were employed in spraying pesticides on farms in Tanzania, have reported some health issues due to handling organophosphate pesticides. Koh et al., (2017) revealed that the association with depression was stronger amongst farmers with past pesticide poisoning episodes than amongst those with no such reported experience. Also, a positive correlation between drinking alcohol, the number of years of farming, and the yearly frequency of pesticide spraying among farmers has been reported (Hong et al., 2009).

Globally, the important factor closely associated with mental health issues among adults or children is low income (Santiago et al., 2013). Income allows people to buy good food and adequate housing, to have access to a range of health care options, to live in safe neighbourhoods, and to have the chance to be better educated (NRHA, 2011). Financial challenges are also an important negative influence on farmers' mental health. For example, Logstein (2016) identified that farm income is strongly associated with farmers' mental health, especially when farming constitutes a major part of total household income. Pulgar et al., (2016) argue that economic hardship is the factor most associated with depressive symptoms among farmers, and is even more significant than general farm work-related stress. Kearney et al., (2014) reported various types of financial stress affecting farmers' mental health, including market prices for crops and livestock, irregular/insufficient cash flow, increased input costs, taxes, health care costs and high debt. In a study by Rosenblatt & Killer (1983), farm families which reported economic losses in the past year, reported greater financial distress and worries. Some farmers commented that pressure from banks is an additional source of stress (Simkin et al., 1998). Taxes related to dairy production, irregular and uncertain income, fluctuating markets, and financial debt have been reported as significant stress factors among dairy farmers (Kolstrup et al., 2013). However, beginning farmers (less than ten years farming experience), are more likely to experience financial stress (Katchova & Dinterman, 2018).

As discussed in the second chapter, the agricultural sector is one of the hardest hit by climate change, especially drought[8], with farmers experiencing decreased production, crop failures, and livestock losses (Heberger, 2012). Vulnerable people, like farmers, are more likely to be affected by various aspects of climate change through direct and indirect pathways (Kureshi et al., 2018; Keshavrz et al., 2013). Bad weather, or "acts of God", has been reported as stressors over which farmers have little control (Alpass et al., 2004). Drought can affect rural communities' mental health in five direct ways: 1) decline in agricultural production and livelihoods; 2) changed environmental conditions; 3) reduced employment and depressed rural communities; 4) migration and family separation; and 5) harm to physical health (Vins et al., 2015; Yusa et al., 2015; Wheeler et al., 2019). Researchers also illuminate the cumulative and compounding manner in which changes in climatic conditions are affecting farmers' place-related mental health and wellbeing (e.g., Ellis, 2017).

Moreover, farming is recognised as one of the highest risk groups for occupational injuries (Voaklander et al., 2009). There is no mandatory retirement age for farmers, and many farmers continue to perform tasks beyond their ability, which is a potential risk factor for injury (Hernandez, 2001). Studies show that common occupational injuries among farmers and

[8] Drought can be defined in four different ways: meteorological drought (a period of time with less rainfall); agricultural drought (dryness of surface soil layers); hydrological drought (prolonged moisture deficits); and socioeconomic drought (the effect of elements of the droughts on supply and demand of economic goods) (Hennessey et al., 2008).

farmworkers are musculoskeletal injuries, skin diseases, hearing loss, and eye injuries (May et al., 2009). Also, road vehicle accidents, asthma and cardiovascular disease are reported to be higher among farmers (Brumby et al., 2012; Tribble et al., 2016). Injury at a workplace may impact a farmer's wellbeing and life satisfaction (Dixon & Welch, 2000). Moreover, self-employment is a risk factor that makes farmers and agricultural workers different from all other occupations in the pattern of occupational injuries (Zwerling et al., 1995). The use of 'any' medications, especially sleep medications, are significant risk factors for injury among farmers (Voaklander et al., 2009). The overall result of the 31 studies and meta-analysis by Jadhav et al., (2015) showed that farmers with mental distress or depression had 1.86 times higher probability of injury than farmers who did not experience depression or distress.

Farmers' levels of stress may be compounded by other issues such as long working hours, heavy workloads and conflict between farm and home roles (McShane et al., 2016). Agricultural workers mostly live and work in the same area and their jobs are characterised by a high degree of self-employment and long hours. Statistics show that 56% of Australian farmers work 49 hours or more a week, compared with 30% of self-employed people in other occupations (ABS, 2012). Agricultural work and family are tied, which often leads to work-family conflicts, negatively influencing farmers' mental health (Arcury et al., 2018). McShane et al., (2016) developed a Farming Family Stressor scale, which found that the overlap between work and family environments is a dominant source of stress for farmers and their families. Similarly, work overload and role conflict were found to be key stress-factors among farm women (Walker & Walker, 1988). Farmers who suffered from role conflict experienced lower job satisfaction, higher job-related tension, and lower self-confidence (Cooper et al., 1976). Also, farming families need to cope with generational differences and teamwork, which is a stress factor for younger generations, resulting in higher levels of vulnerability and risk (Weigel & Weigel, 1987).

Government policies and regulations of rural industries are an additional strain for farmers (Hossain et al., 2008). Kallioniemi et al., (2016) argue that the most common stressors among farmers are external: the amount of paperwork; changes in agriculture policy; or new legislation, which may lead to a situation in which farmers feel nervous or anxious. For migrant farmworkers, issues surrounding documentation, such as being worried about not having a permit to work in the country, can affect their mental health (Hiott et al., 2008; Grzywacz et al., 2010). The EU's agricultural policy has been reported as one of the most common stressors among 265 Finnish dairy farmers farmers (Kallioniemi et al., 2016).

Isolation, low levels of social activity, and the absence of adequate social support are also significant causes of farmers' mental disorders (Austin, 2018; Truchot & Andela, 2018). Social isolation was the second most important stress factors contributing to depression among Latino migrant farmworkers (Ramos et al., 2015). Similarly, Hossain et al., (2008), by utilising interactive focus groups among farmers, identified that increasing isolation in its varying forms is one of the contributions to decline in farmers' mental health. Moreover, the danger of burnout and exhaustion is possible to increase with loneliness among agricultural workers (Kallioniemi et al., 2016). On the other hand, a high number of close friends is identified as decreasing the levels of mental health issues among farmers (Logstein, 2016).

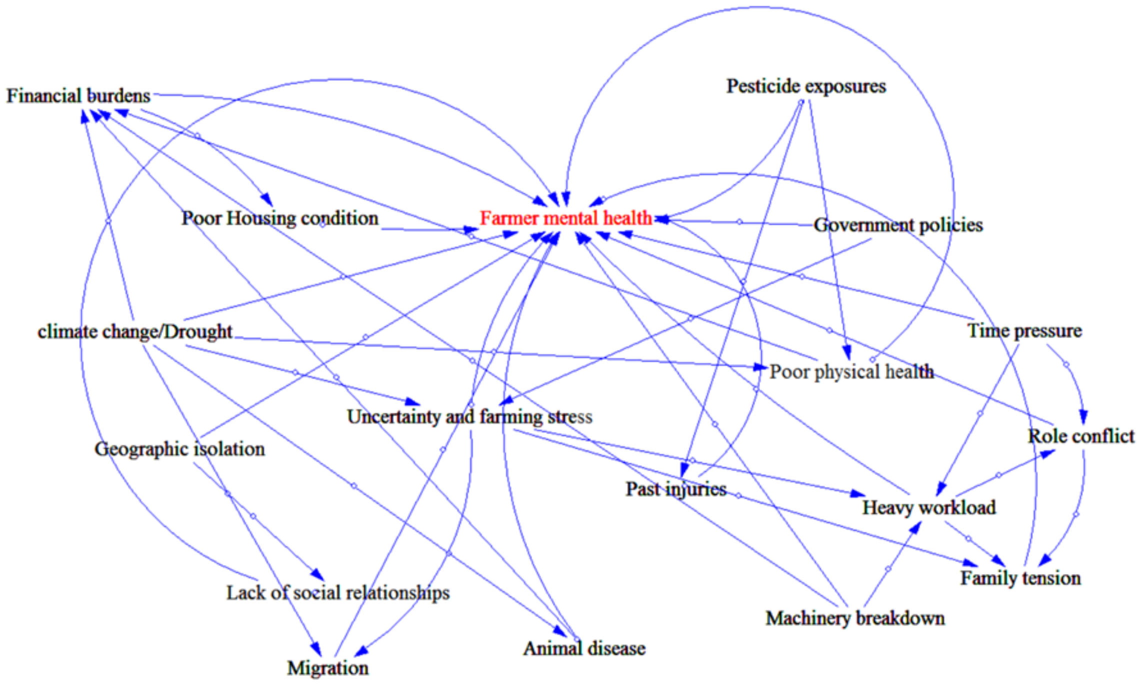
Housing security and depression are also linked for farmers and farmworkers (Mora et al., 2016). Poor housing security provides insufficient protection from the external environment, from noise and from external scrutiny, which can be a source of suffering, resulting in anxiety, insomnia, and paranoid feelings among immigrant farmworkers (O'Connor et al., 2015). Also, poor quality, overcrowded, and substandard houses have been reported to be associated with elevated depressive and anxiety symptoms amongst farmers (Grzywacz et al., 2010).

The majority of animal farmers were affected by stress, depression, and worries during the 2001 foot-and-mouth disease epidemic in the United Kingdom, which resulted in 600,000 animals being culled on 451 farms (Hannay & Jones, 2002). A positive relationship has been reported between psychological distress and self-blame among farmers who fell victim to the foot-and-mouth crisis in 2001 (Garnefski et al., 2005). Even years after, almost half of the farmers whose livestock were culled had symptoms of post-traumatic stress. Even in areas with severe restrictions, but no culling, many farmers had symptoms at levels requiring professional help (Olff et al., 2005).

The following casual loop diagram summarises the identified mental health risk factors affecting farmers' mental health, using a Vensim[9] software.

[9] Vensim is a simulation software for improving the performance of real systems.

Figure 3.1: Farmers' Mental Health Risk Factors



Source: Created from results reported in the literature search

3.2 The Main Stress Factors Affecting Australian Farmers' Mental Health

Farming has been a major part of the Australian economy since the earliest days of European settlement (Henzell, 2007). As reported by the NFF (2017), Australia's main agriculture exports commodities in 2015-16 were 29% meat, 24% grains and oilseeds, and 7% dairy products, also, based on the ABARES (2018b), as of 2016, 28,372 people were employed in the Australian agricultural sector. Research has found that Australian farm participants, like other farmers around the world, face a range of difficulties and uncertainties related to farming, which may lead to physical and mental health problems. The following sections detail the main risk factors that influence Australian farmers' mental health, as reported in the literature, beginning with the most cited.

3.2.1 Climate Variability and Financial Factors

Australia is indeed a sunburnt country and the situation will probably become worse due to climate change (Edwards et al., 2009). Australian researchers have undertaken a large amount of research on climatic and weather stresses for farmers as climatic variability, and especially drought, has been frequent and widespread around Australia (please see Chapter 4 for more details). Drought is a long-term natural disaster and its effect on health can be chronic (Sartore et al., 2007). It can change environmental conditions including: native tree damage, destroying the natural capital of a farm, decimating topsoils, green space and wildlife, which can affect the mental health advantages that are derived from environmental benefits (Albrecht et al., 2007; Greene et al., 2018). Drought can also lead to increased farmers' workloads; for example, increasing hand feeding and stock checking, and incurring greater distances travelled (Alston, 2006).

Drought-affected farm families in Australia face significant health and welfare stresses (Alston, 2007). Edwards et al., (2019) argue that mental health problems are higher among farmers who reported that their productivity had been reduced to its lowest point ever because of drought, compared to farmers whose productivity was only substantially reduced by drought. Stain et al., (2011) found a relationship between prolonged drought exposure, high levels of drought-related worry, and significant levels of psychological distress among Australian farmers. A qualitative case study in the Western Australian wheat-belt by Ellis & Albrecht (2017), revealed that recently observed patterns of climate change have worsened farmers' worries about the future climate, and contributed to cumulative and chronic forms of place-based distress. Australian citrus growers also reported uncontrollable, adverse weather effects as their main source of stress (Staniford et al., 2009). Farmers have strong emotional connections to their farmland; this sense of connection may accentuate the adverse psychological impact of environmental change and their level of distress (Ellis & Albrecht, 2017; Dean & Stain, 2010; Stain et al., 2008). Sometimes it is impossible to farm due to drought, thus reduced employment during droughts is another strong climate-related stressor on Australian farmers (Stehlik et al., 2000; Sherval & Askew, 2012).

Drought and climate related disasters may erode the economic bases on which farming communities depend (Berry et al., 2011a). Climate change may increase costs, through increased feed costs and increased water purchase costs, resulting in reduced net farm household income (Sartore et al., 2008; Edwards et al., 2018; Wheeler et al., 2018). Farmers outside drought-affected areas are more likely to have above average on-farm income compared to farmers in drought-affected areas. For example as reported by Edwards et al. (2008) a higher percentage of farmers in drought-affected areas are experiencing financial hardship than those in areas of above-average rainfall. In 2006-07, severe drought across southern and central Australia reduced farm incomes to their lowest level from the previous thirty years (King et al., 2009). Moreover, because of the high cost of production (e.g., feed and water prices), 75% of Australian dairy farmers, and 50% of broadacre farmers stated that they expected to receive a lower income in 2018–19 compared to the previous year (ABARES, 2019). So, drought and climate change may increase farmers' on- and off-farm labour in an attempt to overcome financial burdens, resulting in over-work and distress (Alston et al., 2018).

McShane et al., (2016) recruited farmers from across Australia to gain insight into the key stressors for Australian farming families and found that financial concerns and family factors are the primary stressors for Australian farming communities. More specifically, during times of drought, uncertainty about the future and financial pressure are major stress factors for South Australian farmers (Fennell et al., 2016). During prolonged drought, almost half of Australia's farmers experienced at least one form of severe financial hardship, such as the inability to pay household bills, going without meals, or having to seek help from a welfare agency (Edwards et al., 2009). An increase in financial pressures as a result of environmental degradation, lack of resources and financial difficulties have been reported amongst Australian farmers, leading to depression and mental health issues (Speldewinde et al., 2009; Sartore at al., 2008). Similarly, economic conditions, globalisation, the ability of farmers to continue to work on the farm, and feelings of economic hopelessness are reported as the dominant stress-related discourse of Australian farmers (Wallis et al., 2008; Bryant & Garnham, 2013). Australian irrigators in the southern MDB have reported financial burdens, commodity prices, electricity costs in irrigation, labour costs, and pressure from banks as some of their most important stress factors (Wheeler et al., 2018). Among South Australian farmers, financial hardship, work pressures, and greater worry about finances put considerable pressure on their mental health and wellbeing (Staniford et al., 2009; King et al., 2009).

Austin et al., (2018) considered three primary stress measures: personal drought-related stress, community drought-related stress, and general psychological distress, and concluded that NSW farmers experienced significant drought related stress on all three measures - particularly those who are younger, live and work on a farm, and who have financial burdens are at particular risk of drought-related stress. In-depth interviews among Australian grape growers showed their concern about the social and economic effects of drought and their problematic situation in the micro politics of the corporate wine industry (Bryant & Garnham, 2013). On the other hand, Peel et al., (2015) found a significant relationship between higher profitability, greater well-being and less distress among Australian farmers.

3.2.2 Socio-Demographic and Other Stress Factors

A few Australian researchers provide an insight into the association between farmers' level of psychological distress and socio demographic factors such as age, education, and gender. Overall, younger Australian farmers experienced higher levels of stress-related symptoms. For example, Gunn et al., (2012) found that younger Australian farmers, aged between 25-54 years, were experiencing significantly higher levels of distress. Stain et al., (2011) found that higher drought-related stress was associated with younger farmers (<35 years). Similarly, Wheeler et al., (2018) highlighted that younger Australian irrigators in the MDB experience higher psychological distress than older ones. Hanigan et al., (2018), argued that drought-exposed younger rural women (aged 40–54) reported higher distress than older rural women or men. Austin et al., (2018) measured personal drought-related stress, community drought-related stress, and general psychological distress and stated that Australian farmers who are younger (18-34 year olds) are at particular risk of personal drought-related stress and community drought-related stress compared with older ones. On the other hand, some researchers reported some negative impacts on older farmers during Australia's worst climatic conditions, such as declining physical ability, decreased confidence in their decision-making, challenges faced leaving the farm, and managing succession, which can affect their wellbeing and increase their risk of mental health problems (Fraser et al., 2005; Kennedy et al., 2014; Sartore et al., 2008).

Based on the ABS (2017b), in general, Australian females are more likely to experience mental or behavioural problems than males (22% compared with 18%). There is some evidence that female Australian farmers are at greater risk of psychological distress than Australian male farmers (King et al., 2009; Wheeler et al., 2018). However, although Austin et al., (2018) did not identify sex differences in drought-related stress, Australian male farmers in their study reported that they experienced significantly greater psychological distress.

Some evidence suggests that Australian farmers who have never married were experiencing less personal drought-related stress than others (Austin et al., 2018). Similarly, those who were married reported higher levels of worry during the drought (Stain et al., 2011). Living in remote areas, government legislation, coal seam gas development, and physical health are other identified stress factors affecting Australian farmers. For example, Brew et al., (2016) found farmers had worse mental health than non-farmers in remote communities, and they also argue that remoteness is a more significant factor in influencing the mental health and wellbeing of Australian farmers than financial stress. Similarly, Austin et al., (2018) found that, compared with inner regional areas, participants in outer regional areas, remote areas, and very remote areas have greater drought related stress. Fragar et al., (2008) reported that, meeting government requirements and paperwork; Business Activity Statements, training requirements for Occupational Health and Safety and pesticide application are significant stress factors affecting Australian farmers. Huth et al., (2018) conducted three workshops with farmers from the Surat Basin in southern Queensland, where the Coal Seam Gas (CSG) extraction industry is developing rapidly. Their findings show that CSG development was the cause of much frustration and farmers' mental health issues. Brumby et al., (2011) revealed that there is a significant association between psychological distress, obesity, abdominal adiposity, and percentage of body fat in the Australian farming population.

3.3 Wellbeing of Farmers and Rural Communities

Wellbeing is the consequence of many different effects which interact with each other in complex and dynamic ways and is sometimes used interchangeably with related concepts such as 'quality of life,' 'life satisfaction,' 'wellness,' 'health' and 'mental health' (Schirmer, 2015).

It has been reported that there is a significant relationship between higher profitability, greater wellbeing, and less distress among farmers (Peel et al., 2015). Examining the links between social capital and health and wellbeing in rural China, showed that cognitive, social capital (i.e., trust) is positively associated with psychological health and subjective wellbeing in rural communities (Yip et al., 2007). Kelly et al., (2010) identified a significant relationship between wellbeing and exposure to rural adversity (e.g., greater drought-related worry, lower perceived service and support availability, a greater number of years living in the current district). Pailler & Tsaneva (2018) examined the effects of climatic variability on psychological well-being. They identified that hot weather in the previous year worsens psychological well-being among rural Indian adults. The investigation of the effects of environmental risk perception on the evaluation of socioeconomic development and subjective well-being in China, showed that environmental risk perception has a direct negative effect on perceived socioeconomic development and on subjective wellbeing (Xu et al., 2017). Brew et al., (2016) stated that remoteness is a significant factor in the mental health and wellbeing of farmers in rural NSW.

Feddersen et al., (2016) studied the effect of short-term weather and long-term climate on self-reported life satisfaction and showed that day-to-day weather variation impacts self-reported life satisfaction. Maddison & Rehdanz (2011) analysed the impact of climate on average life satisfaction in 79 countries and showed that countries with climates characterised by a large number of degree per months (larger than 18.3°C) experienced significantly lower levels of life satisfaction. Kjellstrom (2016) argued that the increasing need for rest at higher heat exposures will decrease worker productivity and wellbeing and results lower income and exhaustion. Carroll et al., (2009) found that a drought in spring has a damaging effect on life satisfaction equal to an annual reduction in income of AUD$18,000 for individuals living in Australia's rural areas. Peel et al., (2016) investigated the relationship between farm exit intention and farmer wellbeing through a quantitative analysis of 674 Australian farmers. They identified that farmers with poorer wellbeing are more likely to leave farming. Toxic cotton farms in India impact farmers' wellbeing through multiple, complex cultural, psychological, and economic vectors. However, such processes cannot be simply understood as a linear cause and effect outcomes (Kannuri & Jadhav, 2018). On the other hand, there has been reported a consistent and significant relationship between higher profitability, greater well-being, and less psychological distress among farmers (Peel et al., 2015).

3.4 Suicide among Farmers

Suicidal behaviour is defined as an act by which a person seeks to take his/her own life (Padurariu et al., 2016). Suicide is a serious public health issue, resulting in 800,000 deaths every year worldwide (WHO, 2017). Hopelessness, substance use disorders, mood disorders, and anxiety disorders have been shown to be the most important drivers of suicidal behaviour (Bhise et al., 2016; Wang et al., 2018; Liu et al., 2018). People who feel hopeless can view suicide as a way out of a painful situation, especially when they believe there is no solution to severe life problems (Kovacs & Garrison, 1985). Suicide is one of the most serious health concerns in rural areas, with higher suicide rates than in urban areas (Hirsch, 2006). Overall, suicide rates seem to be higher among older people (Hamermesh & Soss, 1974; Segal et al., 2004) and higher in the middle class as well as among the most disadvantaged.

Also, there seem to be a relationship between the risk of suicide and specific occupations. Suicide risks in occupations may be related to high occupational stress, access to lethal means, lowest skilled occupations, client-dependent occupations, and occupations with high workloads (Stack, 2001; Milner et al., 2013). Farming is one of the occupations with higher rates of suicide compared with other industries (Staples et al., 2012; Milner et al., 2013; Wang et al., 2018). Farmers' suicides are said to be caused by the complex interplay of social, political, environmental and chemical constraints (Dongre & Deshmukh, 2012). Socioeconomic disadvantage and economic factors have been associated with increased risk of suicide among farmers (Knipe et al., 2017; Thomas & Tavernier, 2017). Similarly, debt levels, financial loss and continual financial uncertainty have been identified as the leading causes of suicide among farmers (Sturgeon et al., 2010; Bhise et al., 2016).

In a recent case-control study, farmers with longer time exposure to organophosphates, reported more suicide attempts than controls and scored higher on violence-related scales (Lyu et al., 2018). Also, farmers who used organophosphate reported significantly higher suicidal ideation (Wesseling et al., 2010) and suicide mortality (Freire et al., 2013). Kim et al., (2014) found that hospitalization due to pesticide poisoning is a significant risk factor for suicidal ideation among male farmers. With considering other compounds of pesticides, Lee et al., (2007) showed that lifetime use of Chlorpyrifos was related to increased suicide mortality among agricultural workers. It is reported that middle aged (35–64 years) and younger aged men (15–34 years) who had reported cases of pesticide poisonings have higher levels of suicide rates compared with older farmers (Faria et al., 2014). There is surprisingly little research on possible associations between organic farming and suicide rates. Vijayakumar & Satheesh-Babu (2009) showed that restriction of pesticide availability and accessibility by non-pesticide management program has significantly reduced pesticide suicides in four villages in India. Similarly, improvement in organic farming reported as one of the possible solutions to prevent farmers' suicides in the future (Rao, 2004; Shiva & Jalees, 2005).

Deshpande (2002) reported a lack of support for farmers on new technology, loss of crops due to poor quality of inputs and their non-availability on time, and market failures are risk factors for farmers' suicide. Zhang et al., (2004) reported poor physical health, and family disputes as potential farmers' suicide risks. Bossard et al., (2016) considered different types of farming and found that the suicide rate was higher among some specific types of farming activity, notably dairy and beef cattle farming.

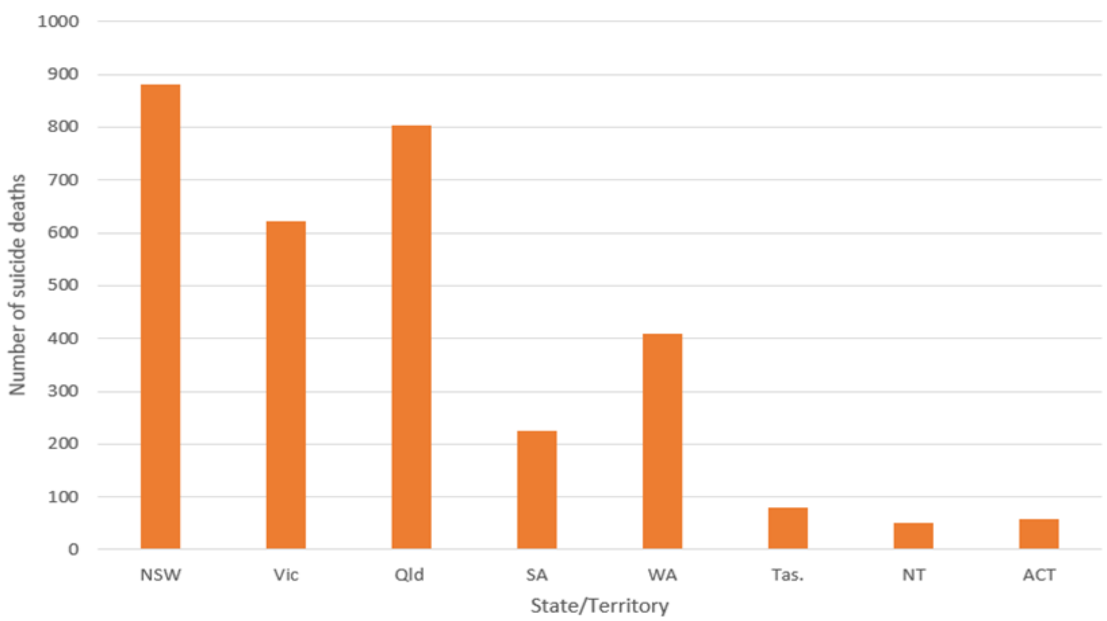
Further, climatic variables, specifically high temperatures, have been reported as key suicide risk factors among farmers (Fountoulakis et al., 2016). Increasing ambient temperatures is likely to raise rates of violent suicides[10], while prolonged droughts are more likely to increase the number of farmer suicides (Padhy et al., 2015). Climatic variability and drought have an indirect causal effect on farmers' suicide rates due to reducing crop yields and increasing debt (Carleton, 2017; Plewis, 2018).

Researchers have identified that Australia's rural populations and farmers face an increasing burden of death due to suicide (Kõlves et al., 2012). The following section highlights the contextual influences on suicide among Australian farmers.

3.4.1 Suicide Deaths in Australia

Suicide is a noticeable public health concern in Australia. Primary data shows that, on average, 8.57 suicides happen daily in Australia (ABS, 2018). The highest number of suicides occurred in NSW, followed by QLD and VIC (Figure 3.2).

Figure 3.2: Number of Suicide Deaths by State/Territory in 2017

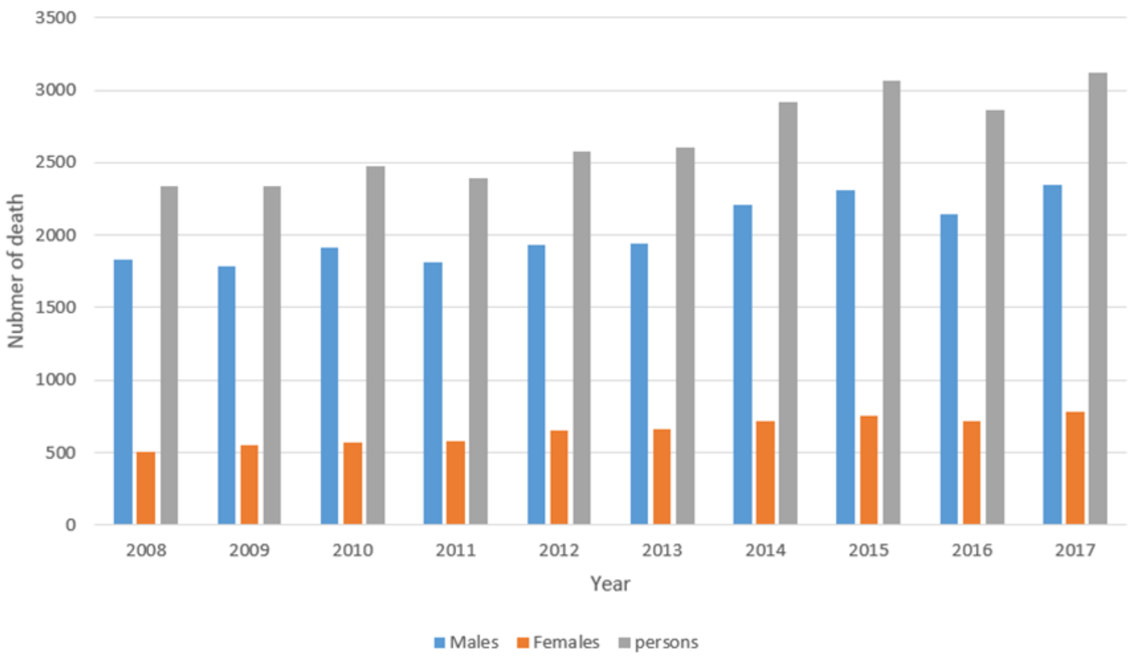


Source: Created from data in ABS (2018). Available at: https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3303.02017?OpenDocument [Accessed June 15, 2019].

[10] Usually, suicide is defined by the method (e.g., firearm suicide and hanging are named as violent while poisoning or drowning are non-violent) (Ludwig & Dwivedi, 2018).

The data indicate that, over a decade, men's suicide is three times higher than women's suicide (Figure 3.3). Suicide is ranked in the top 10 causes of death for Australian males, while it does not appear in the top 20 leading causes of death for Australian females (ABS, 2017c).

Figure 3.3: Number of Suicides by Sex, Australia 2008-2017

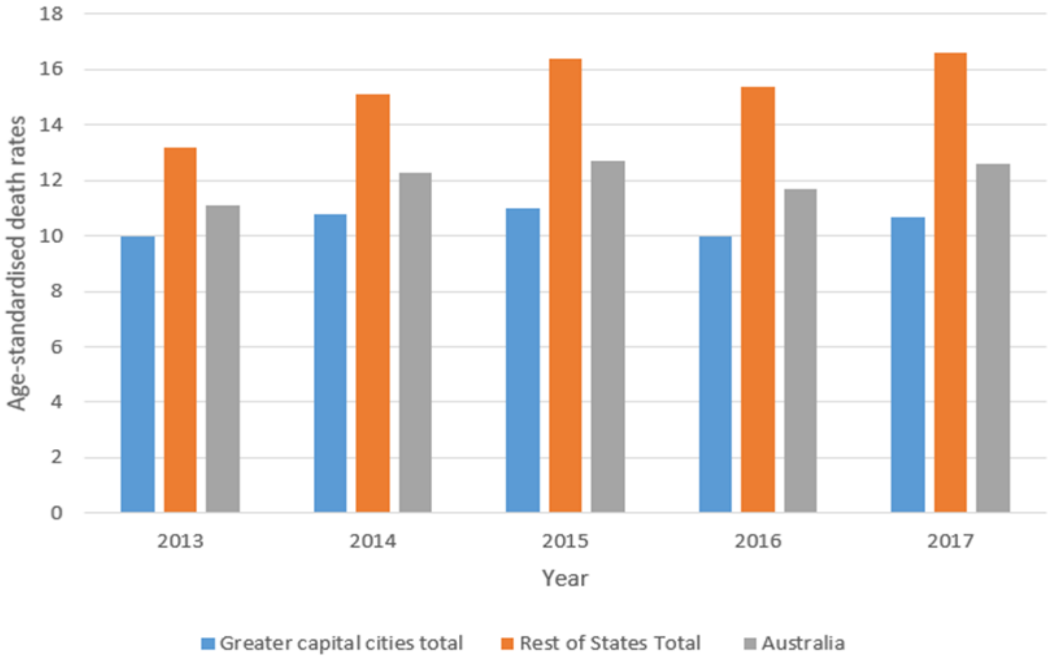


Source: Created from data in ABS (2018). Available at: https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3303.02017?OpenDocument, [Accessed June 15, 2019].

Also, a study on suicide rates by geographic area for males (all ages) shows significantly higher rates in rural areas compared to urban ones (Taylor et al., 2005). Statistical data from the ABS on the age-standardised[11] death rates from suicide, show similar results for rural (mainly rest of the state) and urban Australia (namely greater capital city) (Figure 3.4).

[11] Age-standardised death rates enable the comparison of death rates over time and between populations of different age-structures (ABS 2017).

Figure 3.4: Region of Usual Residence, Age-Standardised Suicide Death Rates, 2013-2017



Source: Created from data in ABS (2018)

Almost one-third of Australians live in areas outside major cities, with 2.3% of the population living in remote or very remote areas (Kennedy et al., 2014). The Centre for Rural and Remote Mental Health (CRRMH, 2017) defines regional, rural, and remote areas as:

- Regional areas: the areas that have a various population, a diversified economic and social base, which provides education, health and other professional services to an isolated geographic area and also includes rural industries, such as agriculture or mining.
- Rural areas: places of varying size that mainly offer services that support local industries, such as mining, agriculture, recreation, and tourism.
- Remote areas: places that often exist along minor highways or at crossroads, with an only small range of services for the needs of travellers and those in the transport industry.

Rural and remote Australia is identified as having low population numbers and density; areas of socioeconomic disadvantage; geographic isolation; a limited division of labour; a reluctance to acknowledge problems and conservative attitudes (Kennedy et al., 2014). Rural people in general have poorer health (e.g., higher blood pressure, diabetes, and obesity), higher risk factors for poor health (e.g., smoking and excessive drinking), poorer housing, and greater exposure to inherently dangerous occupations (NRHA, 2016). All these factors play a role in mental health problems and, in extreme cases, suicide (Judd et al., 2006; Taylor et al., 2005).

There are some other structural factors influencing suicide in regional, rural, and remote Australia, including unemployment, greater availability of lethal means, barriers to accessing mental health care services. However, personal vulnerability is also a significant factor, which may be heightened by factors such as: loneliness; previous significant losses; unrecognised depression; having little privacy; having 'nothing to do'; pessimism about future prospects; and excessive alcohol and other drug use. Burns (2008) identified that the rate of farm suicide is significantly higher than the rate of rural suicide, and the overall rate of suicide in South Australia in 2001. As discussed, many stress factors are affecting Australian farmers' mental health and wellbeing; many of them, especially external ones, are very difficult to control (Staniford et al., 2009). Long-term mental health problems and psychiatric disorder are said to be linked to Australian farmers' suicide (Kunde et al., 2017). Some Australian literature identifies three broad categories of suicide risk factors for farmers: environment and society; community and relationships; and individual factors (e.g., Perceval et al., 2017). Among the 'society' category subthemes community attitudes, stigma, and relationship issues; are regarded as important risks for suicide among Australian farmers (Perceval et al., 2018). Lower socioeconomic status in rural areas has been reported as another key factor explaining higher suicide rates among male farmers (Cantor et al., 1995; Miller et al., 2008). Burnley (1995) demonstrated that the combination of low socioeconomic factors and isolation heightened male suicide rates in rural NSW.

Given the well-documented hardship many farmers experienced during the prolonged drought in Australia, there is surprisingly little research on possible associations between drought and Australian farmers' suicide rates. Exposure to drought is reported as one of the suicide risk factors for Australian farmers who had lived and died in Queensland (Kunde et al., 2017). Hanigan et al., (2012) found an increased risk of suicide associated with drought in Australian rural males aged 30–49 (they assume that this subgroup contained a high proportion of farmers). They found a smaller association during unusually warm months at any time of year, but some increased risk of suicide in spring and early summer. On the other hand, one study provided no evidence of a pattern of increasing farming suicides during the Victorian drought between 2001 and 2007 (Guiney, 2012). They argued that the elevated risk of suicide among farmers is related to multiple psychological, social, economic and environmental factors.

Also, the role of easy access to firearms in rural communities has been reported as a reason for a higher rate of farmer suicide. It has been argued that the lack of legislative restrictions on access to firearms, with a greater household prevalence of such weapons and different cultural attitudes, is linked to higher suicide rates in Queensland (Cantor & Lewin, 1990). Based on Page & Fragar (2002) study of 921 farmer's suicides in the period 1988 to 1997, firearms accounted for 51% of male farm manager and farmworkers' suicides, in comparison to 23% for the broader Australian male population. Some Australian researchers considered the link between national firearms agreement, which placed strong access restrictions on firearms and suicide. De Leo et al., (2003), argue that after the restrictions to weapon purchases in 1996, the firearm suicide rate dropped more rapidly in Queensland urban areas compared to rural areas. However, Klieve et al., (2009) argued that the restriction is not responsible for the observed reductions in firearms suicide. They suggest that a change in social and cultural attitudes contributed to the shift in method preference.

Australian researchers also offer some other different arguments about the causes of farmers' suicide. For example, Kunde et al., (2017) investigated the pathways to suicide among 18 Australian male farmers and found relationship problems, pending retirement, long working hours, physical illnesses, and alcohol abuse as common suicidal factors. Kunde et al., (2018) conducted semi-structured interviews with 12 relatives of male farmers who had died by suicide in Australia and identified that masculinity (discussed in the next section more), uncertainty and lack of control in farming, feelings of failure, interpersonal conflicts, and access to means, were the reasons for their suicide.

There is also some occupational differentiation and geographic variation among Australian farmers. Page & Fragar (2002) reported that most suicides were among farm managers compared to farm labourers. Arnautovska et al., (2016) reported a twice greater prevalence of suicide among QLD farmers compared with those in New South Wales. They also noted that across Australia, QLD reported the highest increase in suicide deaths (804 number of deaths in 2017 compared with 674 deaths in 2016).

Although there are some arguments that suicide is closely linked to mental illnesses, especially depression; higher rates of suicide in farming communities may not merely be due to mental health problems, but also relate to stigma about expressing such problems and seeking help for them (Judd et al., 2006).

3.5 Help-Seeking Behaviour among Farmers

Rural men have higher rates of suicide but are less likely to seek help for mental illness or other signs of emotional stress (Fuller et al., 2000; Alston & Kent, 2004). Multiple factors have been identified which may negatively impact rural communities and farmers' help-seeking behaviour. Staniford et al., (2009) listed five broad themes of barriers preventing help-seeking among Australian drought-stricken citrus growers. They noted self-reliance (e.g., problems are my responsibility); social image (e.g., men do not ask for help); lack of knowledge (e.g., difficulty recognizing problems); negative perceptions of health professionals' efficacy (e.g., they do not understand mental issues); restrictive lifestyle (e.g., be in a geographically isolated area). Moreover, other identified factors are lack of early diagnosis, stigma, reluctance to acknowledge mental health issues, greater isolation due to a growing distance between farms, increased competition and less cooperation among farmers (Fuller et al., 2000; Brumby et al., 2011). Roy et al., (2014) found pride and lack of knowledge about services among male farmers the main barriers to help-seeking. Wrigley et al., (2005) argue that causal attributions and stigma, rather than participants' levels of symptomatology and incapacity, affects help seeking in rural communities if mental health problems occur. Murray et al., (2008) argue that greater levels of stoicism (e.g., not displaying feelings about complaints of pain or hardship – also known as 'bush identity') are associated with less positive attitudes to seeking professional help. Non-help seeking behaviour among rural men is congruent with a particular definition of masculinity among rural men (Alston & Kent, 2004). While the hegemony of traditional masculinity among male farmers can benefit them during good times, in times of heightened stress (such as drought), it can lead them to fail to address their mental health needs (Alston et al., 2008). There are other arguments that rural people often tend to rely on their family and friends for support rather than seeking help from health services, thinking it is their responsibility to find ways to cope with their mental health problems (Lynne-Wilson et al., 2012). Also, using other forms of services for mental health support, such as friends, families, and co-workers, is less stigmatised and is more acceptable and appropriate for many farmers (Fragar, 2005; Fuller et al., 2000). Further, rural people are more likely to persist with mental health problems while they are still able to work and remain productive and delay help-seeking until symptoms become disabling (Judd et al., 2006; Rawolle et al., 2016). To assess the differences between farming and non-farming populations in barriers to mental health help-seeking in rural Australia, Hull et al., (2017), identified that stoicism and self-reliance are a stronger barrier for help-seeking among farmers than non-farmers.

Finally, there is an argument that the impact of mental health issues for those living in rural areas is greater because of the differences in access to treatment and services. For example, in major cities, there are 668 GPs per 1000 people, and in rural and remote areas there are 241 GPs per 1000 people (CRRMH, 2017). Some studies report that the higher rate of mental issues and suicide in rural communities is because of lack of health care access or avoiding seeking health care (e.g., Caldwell et al., 2004b; Brumby et al., 2011; Spleen et al., 2014). However, Booth et al., (2000) did not support the hypothesis that farmers are less likely to seek help from mental health services. They argue that it is possible that farmers, by having easy access to guns, increase their risk of carrying out and dying from an impulsive suicidal act. Similarly, Kavalidou et al., (2015) studied levels of contact with health care providers in the three months before suicide by farming men in rural QLD. They found that the levels of suicidal farmers' contact with a GP were not significantly different from other rural men in the area.

3.6 Importance of Mental Health Care

Access to mental health care is an important predictor of suicide risk and reducing the death rate from suicide (Hawton, 1998). The majority of individuals who attempt suicide have had prior mental health issues (Simon-Davies, 2011). Self-reported data from the ABS has specified mental health problems as chronic diseases. Chronic diseases are the leading cause of ill health, disability and, death, and are generally characterised by their long-lasting and persistent effects. Many chronic diseases, such as mental health issues, are manageable with changes in behaviour, identify the potential barriers, and, timely and effective medical treatments (Ibrahim et al., 2017). The most prevalent chronic diseases related to suicide are depressive disorders and substance use disorders (Henriksson et al., 1993). However, anxiety, personality, eating related disorders, are also important (Bachmann, 2018).

A telephone survey among a community-dwelling sample of rural and remote Australians revealed a significant relationship between depression and suicidal behaviour (Handley et al., 2018). So, suicides rates can, at least partially, be reduced by training primary care physicians to identify people at risk, as well as by providing proper follow-up care (Bachmann, 2018).

3.6.1 Attitudes towards Formal Help-Seeking

Almost 70% of people around the world with mental illness receive no treatment from professionals (Henderson et al., 2013). Formal help-seeking for mental health problems requires that individuals first be able to recognise that a mental health problem exists, and secondly to believe that seeking some help may be beneficial for solving their problem (Henderson et al., 2013). Self-recognition is influenced by health beliefs, attitudes, values and the knowledge that people have about health and health services (Judd et al., 2006). Positive attitudes toward help-seeking are correlated with higher education levels, above-average incomes, and stable personal relationships (Labra et al., 2019). Females are reported to have more positive attitudes toward help-seeking from professionals and were more willing to identify their personal need compared to males (Ang et al., 2004). Also, there is some evidence that young people who had positive experiences with professionals in the past, and who have social support are more willing to engage in a help-seeking process (Gulliver et al., 2010).

3.7 Intervention Programs to Improve Mental Health Outcomes in Rural Communities

Farmers in distress need varied help, including financial advice, social support, job counselling, and emotional therapy. Researchers suggest a variety of potential solutions to help farmers in crisis. For example, Williams (1996) argued that one of the most helpful things is a network between agencies in the community to identify farmers' needs and to be able to refer farm families to appropriate assistance. He argued that there are several barriers to overcome for agencies willing to establish farm families' support groups: 1) farm families have become more and more isolated; 2) families lack the time and energy to become involved; and 3) the pride of farm families makes it difficult for them to share their concerns. He suggested some basic principles to overcome these barriers: 1) go where the energy is; 2) include time for socialising; 3) share responsibility for the group; 4) emphasise nurturing and acceptance; 5) make sure people have a chance to talk; 6) encourage contact between sessions; and 7) emphasise the importance of confidentiality.

Moreover, Funk & Minoletti (2005) outlined some helpful mental health interventions for drought-affected rural communities including: establishing informal healthcare and counselling services; providing accommodation support; improving primary services for mental health (GPs, nurses, and first-aid providers courses); and providing specialist healthcare services (psychiatric services in hospitals, long-stay facilities, and special suicide prevention services).

Some other interventions to reduce suicide have been reported by Ridani et al., (2016) such as: improving mental care services for people post suicide attempts; providing accessible mental health care through problem-solving therapy; providing training at schools to increase help-seeking skills and to reduce stigma; using media guidelines to encourage reporting suicide accurately; and restricting access to means of suicide, such as firearms.

Dunbar et al., (2007) stated that lack of access to GPs and mental health specialist services in rural and remote Australia are important factors and suggested a focus on how to develop rural training programs to encourage professionals to stay in rural and remote regions. Hossain et al., (2010) developed Mental Health First Aid training in response to the increasing levels of stress and mental health issues in Australian rural areas. They argue that the training improved the participants' confidence levels, helped them to improve their knowledge of mental health issues, and improved their understanding of mental health problems. Hunt et al., (2011) introduce the SheepConnect-Tasmania program to help the development of psycho-social support services for rural communities. They argue that almost all SheepConnect group members involved in the program gained benefits in the area of networking, group support and learning as well as helping them maintain morale. This also contributed to maintaining cohesiveness in the face of drought. In focus group discussion of the effect of drought on Australian farming communities, participants pointed to some solutions to deal with the drought: talking about worries with a knowledgeable listener; access to specialist mental health counsellors or more time to talk with GPs about mental health issues; small group meetings to encourage people to talk about their concerns; and financial planning advice (Sartore et al., 2008). Hart et al., (2011) described how the Rural Adversity Mental Health Program (mental health first aid, community mental health and drought information forums, booklets for rural health and agricultural service), increased awareness of drought-related mental health needs in rural and remote NSW. They argue that the program was effective in helping communities build capacity and resilience in the face of prolonged drought.

Francis et al., (2014) introduce a nurse practitioner program which offers nurses who work in rural and remote settings an opportunity to advance their careers. They argue that the program will improve rural populations' access to healthcare and has the potential to improve health outcomes through increasing the number of rural nurses. A study by Iancu et al., (2015), which systematically reviewed the evidence on the effectiveness of farm-based interventions, revealed that social and occupational components of interventions were beneficial for farming communities. Blackburn et al., (2009) outlined a Sustainable Farm Families project to influence Australian farmers' behaviour with respect to family health and well-being. Secondary prevention of suicide is also recommended for those who are at higher risk of becoming suicidal. For example, individuals with risky drinking patterns, previous self-harm, or experience with painful illness, can be provided with the support they need to address their psychological vulnerability, which would increase their resilience and lower their suicide risk (CRRMH, 2017).

3.8 Summary

This chapter has concentrated on reviewing the evidence on risk factors affecting farmers' mental health in rural Australia and worldwide. It was shown that around the world agriculture ranks as one of the most hazardous and stressful jobs.

Several studies suggested pesticide exposures, climatic stress, financial difficulties, isolation, and government policies are key stress factors for farmers, which may result in adverse mental health outcomes, and, in extreme cases, suicide. Australian literature is dominated by introducing the idea that climate change is one of the key stressors for Australian farmers. Studies show that climatic variability can cause distress among Australian farmers through direct and indirect pathways. Studies have demonstrated that environmental stressors have adverse effects on the economic, social and cultural lives of rural communities, resulting in rural mental health issues.

Moreover, this chapter summarised some evidence that farming is an occupation with a higher risk of suicide than other occupations. In comparison with urban communities, rural and remote communities suffer higher suicide rates. Going further, researchers have found that farmers are at elevated risk of suicide compared with the general working population. The evidence outlined in this chapter suggests that rates of farmer suicide are not occurring from one organic process, such as mental health problems, but are also occurring due to other circumstances, such as workplace access to firearms, socioeconomic disadvantage and isolation. Higher farmer suicide rates also can be explained by the stressful work environment, and barriers to accessing mental health care services.

In addition, this chapter highlighted the importance of mental health care for rural and remote communities and identified some help seeking barriers among farmers. This chapter underscored the importance of establishing training programs, and connecting farmers to health professionals.

The next chapter provides a systematic review of the 167 relevant studies on farmers' mental health around the world to identify gaps in the literature and possible avenues for the development of knowledge.

CHAPTER 4 Key Risk Factors Affecting Farmers’ Mental Health: A Systematic Review

To better examine the concepts presented in Chapter 3, this chapter presents a published systematic review paper of current studies on farmers’ mental health. One hundred sixty-seven articles on farmer mental health are included in a final systematic review using a standardized electronic literature search strategy and PRISMA guidelines. This chapter reviews comparative studies on the mental health of farmers and other occupational workers. Also, details of study design, methods, location, and assessment tools used to examine mental disorder prevalence rates among farmers are summarised. The result section in this chapter highlights the most reported risk factors affecting farmers’ mental health.

Statement of Authorship

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Principal Author

Name of Principal Author (Candidate)	Sahar Daghagh Yazd		
Contribution to the Paper	Identified the relevant studies, undertook the literature review, and wrote the manuscript.		
Overall percentage (%)	80%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	7/12/2019

Co-Author Contributions

Name of Co-Author	Professor Sarah Wheeler		
Contribution to the Paper	Discussed the research questions, supervised constantly, and edited the manuscript.		
Signature		Date	7/12/19

Name of Co-Author	Associate Professor Alec Zuo		
Contribution to the Paper	Participated in supervision and editing.		
Signature		Date	7/12/19

Key Risk Factors Affecting Farmers' Mental Health: A Systematic Review

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Abstract

Recently, concern has increased globally over farmers' mental health issues. We present a systematic review of the outcomes, locations, study designs, and methods of current studies on farmers' mental health. In particular, this review aims to fill an important gap in understanding of the potential key risk factors affecting farmers' mental health around the world. 167 articles on farmer mental health were included in a final systematic review using a standardized electronic literature search strategy and PRISMA guidelines. The four most-cited influences on farmers' mental health in the reviewed literature respectively were pesticide exposure, financial difficulties, climate variabilities/drought, and poor physical health/past injuries. The majority of studies were from developed countries, most specifically from the United States, Australia, and the United Kingdom. Comparative studies on the mental health of farmers and other occupational workers showed mixed results, with a larger portion identifying that psychological health disturbances were more common in farmers and farm-workers. Knowledge of farmer psychological disorder risk factors and its impacts are essential for reducing the burden of mental illness. Further research will be required on climate change impacts, developing country farmers' mental health, and information on how to reduce help-seeking barriers amongst farmers.

Keywords: farmers' mental health; farming stress; mental disorder; systematic review

4.1 Introduction

Researchers have identified a number of occupational health risks through studies of farming communities, and some have specified farming as an especially stressful occupation (Fraser et al., 2005; Gregoire, 2002; Price & Evans, 2009; Roy et al., 2013). Farming is associated with a range of physical and mental health risks because of the hard work under challenging conditions (Fraser et al., 2005). Studies on mental health in farming communities have identified several common risk factors, namely: commodity prices, debt, climate change, drought, overwork, government regulations, isolation, role conflict, time pressure and poor housing (Bin & Tipples, 2008; Carvajal et al., 2014; Deary & McGregor, 1997; Firth et al., 2007; Grzywacz et al., 2010; Hanklang et al., 2016; Hedlund & Berkowitz, 1979; Hiott et al., 2008; Hossain et al., 2008; Hovey & Magaña, 2002a, 2002b; Logstein, 2016a; McShane et al., 2016; Mora et al., 2016; Raine 1999; Ramos et al., 2015; Simkin et al., 1998; Warheit & Palacio, 1985; Williams, 1996).

It has been shown that chronic stressors have a major influence on well-being and health. Particularly, stress is associated with an increased prevalence of mental disorders, such as depression and anxiety (Deary & McGregor, 1997). Stress has dominated the literature as one of the most broadly researched psychosocial constructs, mainly in the work-related stress area. Work-related stress is defined as a conflict when the demands of work are high, and the worker cannot manage, control, or cope with that stress (Lunner Kolstrup et al., 2013). The majority of farmers think that their job is becoming even more stressful because of the impacts of climate change (Kearney et al., 2014). Williams (2001) reported that chronic stress among farming communities might lead to physical problems (e.g., headaches, sleep problems), mental health problems (e.g., anxiety, anger, depression), and cognitive issues (e.g., memory loss, inability to make decisions). Farmers are also more likely to report that life was not worth living than non-farmers (Fraser et al., 2005). Mental health problems among farmers can affect their lives in different ways, and the impact of stress factors varies amongst them. These include less interest in pleasure, less concentration, loss of appetite, weight change, tiredness, irritability, problems sleeping, fatigue, loss of control and anxiety (Kearney et al., 2014; Liu et al., 2018; O’Connor et al., 2015; Simsek et al., 2015; Terrazas & McCormick, 2018; Walker & Walker, 1987). Also, loss of self-esteem, withdrawal from social activity, relationship breakdown, forgetfulness, loss of temper, relaxation problem, feeling blue and substance abuse have been reported (Glasscock et al., 2006; Logstein 2016a; Olowogbon et al., 2019; Staniford et al., 2009). A danger of burnout and exhaustion is possible with all these symptoms. Burnout is a gradually developing disorder that may consist of physical and mental exhaustion, a cynical attitude towards work and a reduction in self-esteem (Kallioniemi et al., 2016). Most importantly, mental disorders have been identified as one of the key risk factors for suicide attempts among farmers (Liu et al., 2018). High suicide rates among farmers, farm manager and agricultural labourer have been reported in several studies (Das, 2011; Kunde et al., 2017; Page & Fragar, 2002; Perceval et al., 2017), which is one of the most serious concerns affecting farming communities. As the issue of farmers' mental health raises many concerns, we conducted a search of the literature to answer the following main research questions: what are the potential key stress factors affecting farmers' mental health and how does this differ around the world?

To explore the research question, this paper systematically reviews published studies on farmers' mental health , the prevalence of this stress, the risk factors that have been considered and farmer mental health has been measured. What is clear is that, interpretations of mental health outcomes vary across identified studies, and most of the times outcomes are not clearly defined. We distinguish between mental health and mental disorder here. According to the (WHO 2007; p.1) , mental health is: "a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community". Mental disorders are normally defined by some combination of abnormal thoughts, emotion, behaviour and relationship with others (WHO, 2017). Mental disorders include depression, anxiety, stress, schizophrenia, bipolar disorder and emotional/psychological distress (WHO, 2004). As reported by the Department of Health, The most common mental disorders are said to be anxiety and depressive disorders, which are a reaction to the stresses of life. A person with an anxiety disorder feels distressed a lot of the time, for no apparent reason, and a person with a depressive disorder can experience a long-term depressed mood and loss of interest in activities that used to be enjoyable (DOH, 2013). The burden of mental disorders continues to grow with substantial impacts on health and major social, human rights and economic consequences around the world (WHO, 2004).

Given the growing farming pressures in many countries (e.g. declining productivity, declining terms of trade, worsening weather impacts, and deteriorating soil and water quality), evidence-based understanding of risk factors on farmer mental health will become increasingly more essential important to improve the efficiency of prevention efforts. Hence, we sought to understand what the potential key risks affecting farmers' mental health are, as well as if these risks vary across space and time.

4.2 Materials and Methods

This systematic review followed the standard Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009), namely: 1) identification of literature; 2) screening questions; 3) eligibility using inclusion criteria ; and 4) assessment of the quality of the studies and detection of any possible bias.,which are discussed in the following sections.

(1) Identification

To identify relevant literature, we searched the literature published until April 2019 in electronic databases PsycINFO, PubMed, Scopus and Google Scholar using the following keywords: "Mental health" OR "mental disorder" OR "depression" OR "distress" OR "anxiety" OR "stressors" in the combination of "farmer" "farmworker" "agricultural worker". Note: suicide and suicide ideation was not included in this review.

(2) Screening questions:

The electronic database search generated 1,224 English language articles (excluding duplicates), and after screening the title and abstract, 436 studies were included in the review. Then the body of these selected articles were screened with the following questions:

1. Are farmers included as a general study population? (y/n)
2. Are any kind of "mental disorders" part of the study? (y/n)

Based on the results of the screening questions, 329 studies were included in the review. Studies were excluded because of limited relevance to farmers' mental health issues (e.g. those focused on rural communities as a whole or those related to farmer/rural suicidal behaviours only).

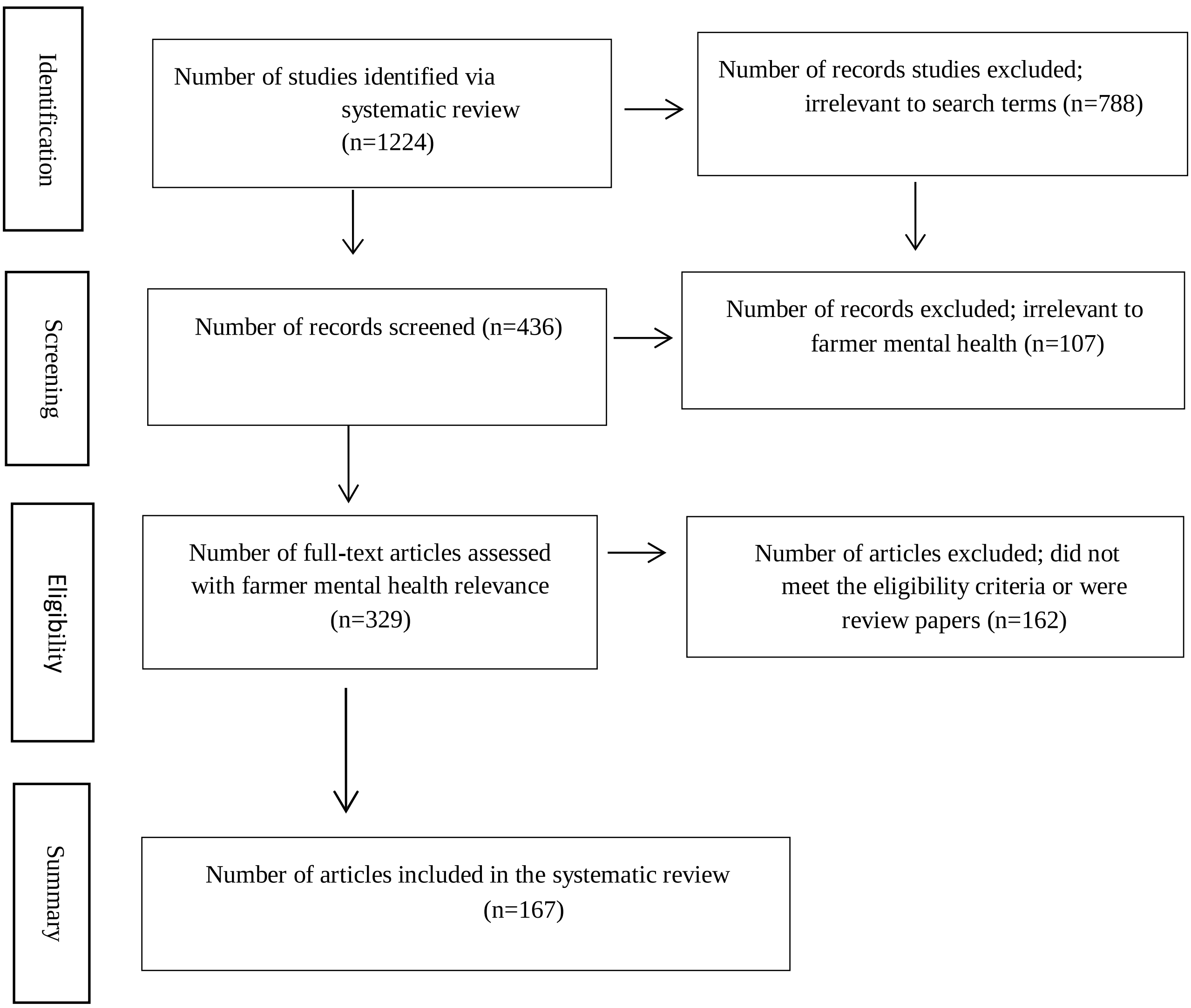
(3) Eligibility assessment

The following inclusion criteria were then applied:

1. Does the study clearly mention which risk factors/stressors affect farmers' mental health (y/n)?
2. Does the study detail the direction on farmers' mental health (+/-/0)?

Among the identified articles, 162 articles failed to meet the eligibility criteria, hence 167 articles were included in the review. Figure 4.1 provides the roadmap followed for the studies selection.

Figure 4.1: Schematic for Identifying Studies



(4) Assessment of the Quality of the Studies and Detection of Possible Bias

Each study that used quantitative methods was rated using the OHAT risk of bias rating tool (Handbook of OHAT). The OHAT risk of bias tool consists of a set of questions to address the main bias domains. Each question within the tool receives one of four assessment levels (definitely low risk of bias, probably low risk of bias, probably high risk of bias, and definitely high risk of bias). Based on the answers to the assessment questions, each study was classified into one of the three tiers proposed by the OHAT to synthesise risk of bias evaluations across studies.

NVivo, a qualitative data analysis software, was used to classify the total 167 selected studies on farmer mental health. We provide an overview of the findings of this review for: i) study (geographical focus, ii) mental health scales or measures, iii) mental health of farmers versus non-farmers, iv) key farm stressors, v) socio-demographic characteristics of farmers with poorer mental health, locations and vi) farmer help seeking behaviour).

4.3 Systematic Review Results

4.3.1 Geographic focus

Research into farmer mental health has been conducted in several countries, but mostly in developed countries. As Figure 4.2 and Table 4.1 show, the United States, Australia and the United Kingdom have conducted the greatest amount of research (27%, 17% and 7% respectively). Of the papers that focused on farmers' mental health, the majority used quantitative methods (146 studies) versus qualitative methods (18), versus a combination of both qualitative and quantitative (3).

Figure 4.3 shows an increasing focus on farmer mental health research over the past couple of decades, with an increase from the mid-2000s onwards. This increase was driven by a surge in research by researchers on Australian farmers' mental health 2005 onwards (with was near the middle of the Millennium Drought in Australia). The highest number of publications was in 2018.

Table 4.1: Geographical Locations of the Selected Studies

Geographical location	***Number of studies***	***% of Total***
US	45	27%
Australia	29	17%
UK	13	8%
Mexico	10	6%
China	5	3%
South Korea	6	3%
Norway	5	3%
Iran	6	3%
India	5	3%
France	4	2%
Brazil	5	2%
Canada	3	2%
New Zealand	3	2%
Chile	2	1%
Sweden	2	1%
Turkey	2	1%
Finland	2	1%
Netherlands	2	1%
Tanzania	2	1%
Philippines	2	1%
Other countries (e.g. Iceland, Nepal, Egypt, Pakistan, United Arab Emirates, Costa Rica, Greece, Japan, Malaysia, Thailand, Bolivia, Ghana, Nigeria, Europe countries)	14	Less than 1% each

Note: Percent totals may not exactly sum to 100% due to rounding.

Figure 4.2: Number of Farmers' Mental Health Studies Published by Country

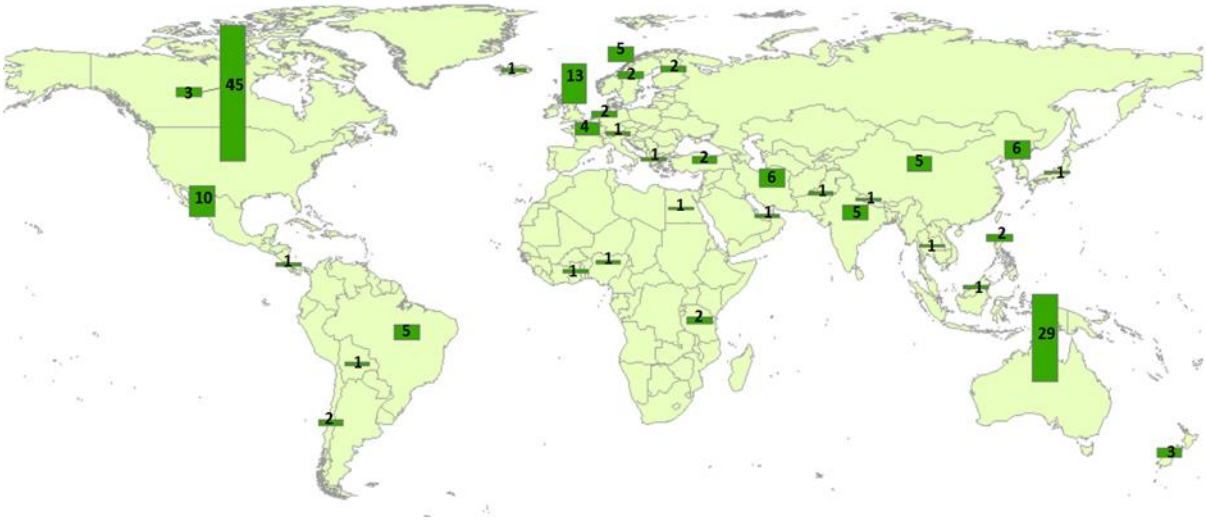
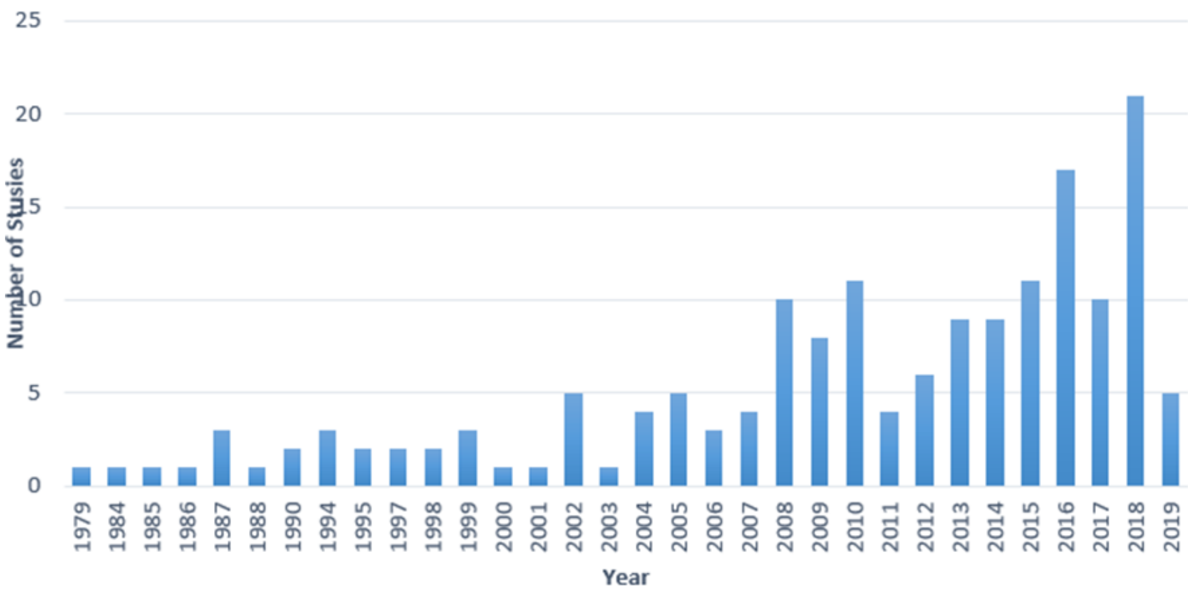


Figure 4.3: Number of Farmers' Mental Health Studies from 1979-2019



4.3.2 Measures and Methods of Farmer Mental Health and Assessment of Quality

Method and measurement assessment of farmer mental illness has varied greatly (see Table 4.2). Our systematic review indicates that literature used a variety of methods and scales for measuring farmer mental health. The most common method for measuring mental health was the Centre for Epidemiologic Studies-Depression Scale. However, other reasonably common methods such as Kessler 10, Hospital Anxiety and Depression, Clinical Tests, Mini-Mental State Examination, and SF- 36.

Several measures have also been constructed to measure agricultural-related stress, including the Farm/Ranch Stress Scale, the Edinburgh Farming Stress Inventory, Welke's Farm Ranch Stress Inventory and Migrant Farmworker Stress Inventory (e.g., Walker & Walker, 1987).

Table 4.2: Details of the Measures Used in the Selected Studies

Scale	*Count*	*%*
Centre for Epidemiologic Studies-Depression (CES-D) (Terrazas et al., 2018)	29	18%
Questionnaires based on the Midtown Manhattan study (Berkowitz & Wesley,1984)/ the Warheit study (Ortega et al., 1994)/ the Raitasalo study (Kallioniemi et al., 2009)/ the Karasek and Theorells study/ asked questions such as: “has a DOCTOR ever told you that you had been diagnosed with depression requiring medication?”(Beseler et al., 2005)/ “how would you rate your level of depression in the last quarter?” (Onwuameze et al., 2013)/ “the most stressful situation you had experienced in the past month” (Fennell et al., 2016)/ “have you had any injuries at work that required medical attention or treatment?: (Zwerling et al., 1995)/”had any treatments or hospitalization for depression?” (Otsuka & Kato 2000)/ “do you currently feel the defined type of stress?” (Kallioniemi et al., 2016)/ “have you had previous hospitalization for depression, by exposure to different pesticides?” (Weisskopf et al., 2013)/ Cognitive Emotion Regulation Questionnaire (Garnefski & Kraaij, 2005) /Copenhagen Psychosocial Questionnaire (Garnefski & Kraaij, 2005)/ Patient Health Questionnaire (PHQ-9) (Brew et al., 2016)	28	17%
In depth interviews (Staniford et al., 2009), Focus groups (Hossain et al., 2008)*	18	11%
Brief Symptom Inventory Scale (Wesseling et al., 2010)/ 15-item impact of Event Scale (Olff et al., 2005)/ 19 item Inventory Scale (Walker & Walker, 1988)/48 item Stress Scale (Simsek et al., 2015)/ Depression-Anxiety-Stress Scale (McShane et al., 2009)/ Geriatric Depression Screening Scale (Kim et al., 2013)/ Wechsler Adult Intelligence Scale (Hong et al., 2008)/ Farming Family Stressor scale (McShane et al., 2016)/ Beck Depression Scale (BDS) (Çakmur 2014)/ 12-item Stress Scale (Alpass et al., 2004)/ Border Community and Immigration Stress Scale (Carvajal et al., 2014)/ Environmental Distress Scale (EDS) (Albrecht et al., 2007)	16	9%
(Kessler 10) K10 (Peel et al., 2015)	12	7%
Clinical Test (Atreya et al., 2012)/ Medical Symptom Validity Test (Mackenzie Ross et al., 2010)/ Mini International Neuropsychiatric Interview Diagnostic Test (MINI)	12	7%
Farm Stressor Inventory (Walker & Walker, 1987)/ Personality Assessment Inventory (PAI) (Hovey & Magaña, 2002b)/ Edinburgh Farming Stress Inventory (EFSI)(Deary et al., 1997)/ Beck Depression Inventory (BDI) (Hong et al., 2009)/ Welke’s Farm Ranch Stress Inventory (Kearney et al. 2014)/ Migrant Farmworker Stress Inventory (Tribble et al., 2016)	11	6%
Mini-Mental State Examination (MMSE) (Bayrami et al., 2012)	9	5%
Hospital Anxiety and Depression (HAD) (Guillien et al., 2018)	8	4%
General Health Questionnaire-12 (King et al., 2009)/ General Health Questionnaire-28 (Booth & Lloyd 2000)	7	4%
SF-36 (Rostamabadi et al., 2014)	4	2%
Health Option Survey (HOS) (Vega et al., 1985)/ Farm Stress Survey (FSS) (Eberhardt & Pooyan, 1990)	2	1%
Other methods (COOP/ WONCA charts) (Hannay & Jones, 2002)/ short-form Geriatric Depression (Koh et al., 2017)/ psychological domain score of WHOQOLBREF(Saxena et al., 2013)/(EQ-5D-3L) (Liu et al., 2017)/ (SCL-25)(Logstein, 2016a)/ (SCL-90) (Wang, 2005)/ Well-being Index (WHO-5)	11	6%

Note: Percent totals may not exactly sum to 100% due to rounding.

*: These studies often used self-reporting methods to allow participants to tell their stories, and discuss their issues. The reults of the discussions were defined as revealing farmers’ mental health issues.

The assessment of bias by using the tiering approach across the studies showed that, out of the 146 quantitative studies, 99 (68%) of studies were categorised in “Tier1” or “plausible bias unlikely to seriously alter the results”;, 37 (25%) of studies were categorised in “Tier2” or “plausible bias that raises some doubt about the results”;, and only 10 studies (7%) of studies were categorised in “Tier3” or “plausible bias that seriously weakens confidence in the results.”

4.3.3 Mental Disorders among Farmers versus non-Farmers

The systematic review found that 28 articles (17% of the total) compared farmers’ mental health with other occupational groups. Out of those articles, 20 studies (71%) suggested farmers have worse mental health issues than the general population (Stallones & Beseler, 2004; Syson-Nibbs et al., 2006). Also, the National Institute for Occupational Safety and Health, examined 130 different occupations and found farm workers and farm owners had the highest rate of deaths due to stress-related conditions and mental disorders. Higher mental disorder levels and poorer vitality have been reported for animal (Kolstrup et al., 2008; Sanne et al., 2004) and dairy farmers (Kolstrup et al., 2008; Wallis & Dollard, 2008) compared to non-farmers. Others also find a higher prevalence of mental disorders in farm workers as compared to employed non-farmworkers and other occupations such as teaching, office work and building construction (Arcury et al., 2018; Cohidon et al., 2010; Hounsome et al., 2012; Kolstrup et al., 2008; Konstantinos et al., 2013; Rayens & Reed, 2014; Stallones & Beseler, 2004; Thelin 1998; Torske et al., 2015; Walker & Walker, 1988; Wang et al., 2017; Yin et al., 2018). Jessie et al. (2018) found farmers, self-employed and own account workers have worse mental health compared to medium-to-large employers and liberal professions. Ulrich et al. (2018) identified that stress was significantly higher in farmworkers compared with non-farmworkers only in one farming period (the non-spray period) out of three within one farming season.

However, not all studies confirm that farmers have worse mental health than the general population (Judd et al., 2006). Our review showed that 18% of the studies found farmers have a lower prevalence of mental illness then non-farmers, and 11% reported that there was no difference. For example, Otsuka & Kato (2000) compared traditional society occupation group (e.g., farmers and skilled manual workers) with industry occupation group (e.g., managers and technicians) and revealed that industrialised society occupation group had higher levels of depression. Similarly, Liu et al., (2017) found that general workers suffer from higher levels of mental stress and worse physical health compared with farmers. Thomas et al., (2003) and Feng & Xu (2015) reported farmers have a lower prevalence of mental illness than the general population, although were more likely to report thinking that life was not worth living. Tomasson & Gudmundsson (2009) stated that farmers were less likely to consume alcohol and that farmers' mental health problems were 5% lower than non-farmers. Brew et al., (2016) and Stain et al., (2008) argued that there is no difference between mental health outcomes and wellbeing of farmers compare to non-farm workers in general, although Brew et al., (2016) added that those farmers who lived more remotely had poorer mental health than non-farm workers living remotely.

4.3.4 Farm Risk Factors

Our systematic review identified several types of farmers' risk factors.Table 4.3 depicts the main cited key risk factors of farmers that have been cited in the literature, namely: pesticide exposure, financial problems, and climate variability/drought, physical health, isolation, role conflict and time pressure respectively. We discuss each in more detail below.

Table 4.3: Key Farmer Mental Health Risk Factors

Key Risk Factors	*Number (and %) of times studies naming this stress*	*Developed countries (no. and %)*	*Developing countries (no. and %)*	*USA (no. and %)*	*Australia (no. and %)*
Pesticide exposure	43 (19%)	25 (15%)	18 (34%)	11 (16%)	1 (2%)
Finances in general (input prices/income/profit/market condition)	39 (18%)	31 (18%)	8 (18%)	14 (21%)	6 (15%)
Weather uncertainty (incl. drought and climate change)	25 (11%)	22 (13%)	3 (5%)	5 (7%)	16 (40%)
Poor physical health/past injury	23 (10%)	18 (10%)	5 (7%)	9 (13%)	1 (2%)
Farming in general/heavy workload/stress/hazards in farming	17 (8%)	12 (7%)	5 (11%)	7 (10%)	2 (5%)
Government policies and regulations/paper-work	14 (6%)	13 (8%)	1 (2%)	5 (7%)	2 (5%)
Isolation/loneliness/lack of social relationships	14 (6%)	11 (7%)	3 (7%)	4 (6%)	2 (5%)
Concern about the future of the farm/animal disease/machinery breakdown	12 (5%)	12 (7%)	0 (0%)	3 (4%)	2 (5%)
Working with family (role conflict)	12 (5%)	11 (7%)	1 (2%)	5 (7%)	2 (5%)
Time pressure	9 (4%)	7 (4%)	2 (5%)	2 (3%)	2 (5%)
Other issues (e.g. paddy glut/firearm exposure/media criticism/coal seam gas/electricity irrigation costs development/leaving family for work/community characteristics/Work Ability/ lack of skilled labour/ living condition/poor housing)/ poor access to market information/ levels of mindfulness	14 (6%)	10 (5%)	5 (9%)	4 (6%)	5 (12%)

Note: Percent totals may not exactly sum to 100% due to rounding.

4.3.4.1 *Pesticide Exposure*

An association between pesticide exposure and farmer mental disorders has been reported in 43 reviewed studies in both developed and developing countries. As Table 4.3 illustrates, pesticide exposure is more issues in developing country literature, for example Brazil, India, Nepal, Philippines, Iran, Tanzania, China, Egypt, Pakistan, and Costa Rica have focused on pesticide exposures and farmer mental distress. Among developed country literature, United States studies have also studied links between pesticide exposure and farmer mental health. Some pesticides are neurotoxic, which are said to directly affect neural systems known to cause mental illness (Aiwerasia et al., 2001; Corral et al., 2017; Jamal et al., 2002; Malekirad et al., 2013; Muñoz-Quezada et al., 2017; Steenland et al., 1994) and depression (Atreya et al., 2012; Bayrami et al., 2012; Beseler, 2005; Conti et al., 2018; Silva et al., 2016; Fariba et al., 2016;

Harrison & Mackenzie Ross, 2016; Hong et al., 2009; Hong et al., 2008; Kim et al., 2013; Povey et al., 2014; Quandt et al., 2010; Siegel et al., 2017; Suten Geofrey et al., 2018; Weisskopf et al., 2013; Wesseling et al., 2010; Zhang et al., 2016). Some studies have examined pesticide exposure in general, while others considered specific compounds such as organophosphates. Organophosphates can enter an individual's body by the skin or through inhalation, (Mearns et al., 1994) and there is considerable evidence of this is associated with a range of physical symptoms (e.g dementia, Parkinson, phobia, diarrhoea, vomiting, dizziness, chest-pain, memory loss, concentration difficulties, body weakness, irritation etc.) (Beshwari et al., 1999; Mearns et al.,1994; Povey et al., 2014; Suten et al., 2018; Wesseling et al., 2010). Wesseling et al., (2010) found a relationship between acute occupational poisoning with organophosphates and psychological distress. Koh et al., (2017) revealed that the association with depression was stronger amongst farmers with past pesticide poisoning episodes than amongst those with no such reported experiences. A recent study by Serrano-Medina et al., (2019) on 140 agricultural workers with Organophosphorus pesticide exposure in Mexico showed that 25% of them had major depression with suicidal attitudes, 23.9% had anxiety, 23.5% had combined depression–anxiety, and 22% of them had major depression and no psychiatric diagnosis disorder. Focus group discussions with cotton-growing farmers in India showed that during hot summer and windy seasons, some farmers reported serious health problems such as cancer, mental illness and diabetes (Kannuri & Jadhav, 2018).

4.3.4.2 *Financial Pressures*

Financial challenges were reported in 39 articles of reviewed studies to negatively impact farmers' mental health, particularly where farming was the primary income source (e.g., Bryant & Garnham 2014; Eberhardt & Pooyan, 1990; Feng et al., 2015; Hovey & Magaña, 2002b; Kallioniemi et al., 2016; Kureshi & Somsundaram, 2018; Pulgar et al., 2016; Ramos et al., 2015; Simsek et al., 2015; Truchot & Andela, 2018; Vega et al., 1985; Williams, 1996). Various types of financial stress were reported by farmers in both developed and developing countries, including market prices for crops and livestock, irregular/insufficient cash flow, increased input costs, taxes, health care costs and high debt (Kearney et al., 2014). A few studies have examined the links between the 1980s farm financial crisis and mental health among U.S. farmers. During the crisis farmers were faced with decreasing world demand, higher input high costs, and low commodity prices (Belyea & Lobao, 1990; Bultena et al., 1986; Ortega et al., 1994; Williams, 1996). Bultena et al., (1986) found this decline caused farmer psychological distress, depression, lower life satisfaction, alcoholism and even suicide. Farmers experiencing significant financial losses usually seek to make significant farm changes (e.g., through reducing the number of paid farm employees, working longer hours), diversify/change production or decide to exit (Bryant & Garnham, 2013).

Given that many other family members are impacted by farm financial problems, this has been found positively associated with farmers' family unit stress perceptions (Welke, 2004). Other mental health associations with financial stress include children numbers, broadacre production and rental land (Belyea & Lobao, 1990). Lawrence et al., (2018) indicated that farmers are more successful in finding some alternative agronomic options for adapting to drought, but adapting to financial burdens is more difficult. Inversely, there has been found a positive and consistent relationship between higher farm profit, greater well-being and less distress amongst farmers and farm-workers (Peel et al., 2015).

4.3.4.3 *Climate Variability*

Climate variability was revealed as another large risk factor for farmers (25 articles of included studies focused on that, mostly in developed countries). It is predicted that severe and widespread droughts will increase in the future (Dai, 2013). Droughts have been categorized as slow-moving disasters which can have significant health effects, usually mediated through environmental, economic, and social pathways [King et al., 2009; Vins et al., 2015). For example, 75% of farmers in a study by Walker et al., (1986) reported unfavourable climate conditions and the unpredictability of the weather as their key stress in North America. Kearney et al., (2014) found 60% of farmers who worked more than 40 hours per week identified bad weather as "very stressful" in Eastern North Carolina. In-depth interviews with 16 citrus growers in Australia, revealed that 11 of them cited drought and insufficient water allocations as potential stressors (Staniford et al., 2009). The uncertainty of weather was also reported by 70% of farmers in New York State (Hedlund & Berkowitz, 1979). The observed patterns of climate change have worsened farmers' worries about the future climate and contributed to their chronic forms of mental distress (Ellis & Albrecht, 2017).

Droughts have been categorized as slow-moving disasters which can have significant health effects, usually mediated through environmental, economic and social pathways (King et al., 2009; Vins et al., 2015). The agricultural sector is hit the hardest by drought, with farmers experiencing declined production, crop loss, and livestock failure (Berry et al., 2008). Farmers reported a strong association between prolonged drought and stress, and higher levels of psychological morbidity (Acharibasam & Anuga, 2018; Edwards et al., 2009; Kureshi & Somsundaram, 2018; Sartore et al., 2007; Stain et al., 2011). Some studies reported that the major stress in a time of drought is financial hardship. For example, Edwards et al., (2009) identified that drought has significant negative economic impacts, especially for farmers who reported that the drought had reduced their output substantially. Table 4.3 indicates that Australia stands out in terms of the pressure of climate variability on farmer mental health in our review. Climate stressors were mentioned in 40% of Australian studies, the highest risk factor out of all possible factors. For example, Edwards et al., (2015) found that the more severe the drought, the higher the adverse effects on farmer mental health. With the ongoing threat of water scarcity, falling water allocations, water reform and drought in Australia, Wheeler et al., (2018) found that some irrigators in particular industries have higher mental health problems than dryland farmers. Austin et al. (2018) found that higher drought-related stress was associated with young farmers (<35 years) who live and work on a farm, and having greater financial hardship. A study by Hanigan et al., (2018) showed significant associations between distress and drought duration in young rural women regardless of whether they were in farming occupations or not. They reported that the level of drought-related distress did not differ between farmers and non-farmers in their sample.

In addition, summer heat waves are likely to have immediate effects on the prevalence and severity of farmers' mental health. Farmers and farm workers often have no choice but to keep working even in extreme hot weather (Singh et al., 2013). There are also the emotional effects of changes to the landscape and loss of garden (and 'greenness') have been reported as a source of real distress by farming families (Albrecht et al., 2007).

Despite several studies found climate variability or drought as risk factors on farmers, studies with the focus on the climate variability and farmer mental health outcomes are relatively thin. Our review found that only a small amount of research (much of it from Australia (40%)) have focused on the effects of climate change/drought. We could find only three studies in a non-developed countries (India, Ghana and Iran) concentrating on the mental health effect of climate on farmers. Similar to our finding a recent study by Berry et al., (2018) argue that mental health effects of climate change, has received little attention in research and policy and needs systems thinking.

4.3.4.4 *Poor Physical Health/ Past Injury*

Greater mental illness amongst farmers who have poor physical health, past injury or work disability has also been found (Çakmur, 2014; Kallioniemi et al., 2009; Linn & Husaini 1987; Onwuameze et al., 2013). Farming is one of the highest risk groups for occupational injury and illness (Dixon & Welch, 2000). Often agricultural workers live at their worksite, so, it is not surprising that an injury at work can impact their life satisfaction (Zwerling et al., 1995). Distress related to increased injury and physical illness on spouses and children, is particularly felt by farm women (Carruth & Logan, 2002). It has been found that farm residents with self-reported physical illness (e.g. neck, shoulder and back pain (Tribble et al., 2016)) obesity, metabolic syndrome, abdominal adiposity and cardiovascular disease (Brumby et al., 2012; Schulz et al., 2018)) tend to have higher self-reported psychiatric impairment. Hawes et al., (2019) found that higher body mass index (BMI) and poor sleep quality also were associated with higher depression scores. Carvalho et al., (2018) found an association between work end time on the relationship between sleep onset time and farmer psychological well-being. Mazzoni et al., (2007) and Stieglitz et al., (2015) found that those farmers who diagnosed with depression had a significantly higher total disability score. DeArmond et al., (2006) found high levels of somatic symptom disorder (SSD) among farmers. SSD occurs when a person feels extreme anxiety about physical symptoms such as pain or fatigue and is significantly related to depression. Physical toxicity by agro-chemicals and damage to farmer health have also been found (Kannuri & Jadhav, 2018). Crandall et al., (1997) argued that mental illness and the side effect of its medication can cause cognitive changes, which can put farmers at more risk of injury. Rostamabadi et al., (2019) reported that musculoskeletal disorders, cuts, and fractures accounted for the most frequent injuries amongst farmers, affecting their mental health. Other researchers discussed that depression and dissatisfaction with life were more strongly associated with agricultural worker injury than among other workers, and that farmers may work longer with physical health problems before receiving a disability pension than other occupations (Scarth et al., 1997; Torske et al., 2015; Zwerling et al., 1995). Also, as previously reported, increased symptoms of depression and suicidal thoughts, were found for farm workers with a previous organophosphate poisoning (Wesseling et al., 2010).

4.3.4.5 *Other Risk Factors*

Several other risk factors and symptoms predictive of psychological distress in farmers have been identified by researchers, such as government policies (Alpass et al., 2004; Booth & Lloyd 2000; Grzywacz et al., 2010; Hiott et al., 2008; Hossain et al., 2008; Walker et al., 1986); isolation (Hiott et al., 2008; Hossain et al., 2008; Kallioniemi et al., 2016; Logstein 2016b; Staniford et al., 2009); heavy workload (Kallioniemi et al., 2016; McShane et al., 2016); role conflict (Hedlund & Berkowitz, 1979; McShane et al., 2016); time pressure (Alpass et al., 2004; Eberhardt & Pooyan, 1990; McShane et al., 2016); poor housing conditions (Çakmur 2014; Grzywacz et al., 2010; Mora et al., 2016; O'Connor et al., 2015); foot and mouth disease among livestock (Garnefski et al., 2005; Hannay & Jones 2002; Olff et al., 2005; Peck et al., 2002); coal and gas development (Huth et al., 2018; Morgan et al., 2016), beef crisis (Eddy et al., 2019; Eisner et al., 1999); lower levels of mindfulness and farmers' work ability (Rostamabadi et al., 2014). Overall these risk factors were stated in almost 42% of the identified studies as psychological risk factors affecting farmers' mental health. Other agricultural stressors which have been identified to be common in developing countries due to their developmental status such as, poor agricultural extension services/contact, poor road infrastructure, unfavourable market prices, poor access to market information and poor access to credit facilities (Olowogbon et al., 2019).

4.3.5 Socio-demographic and Farm Characteristic Associated with Mental Health

We concentrate here on three of the most identified socio-demograhic and farm characteristics cited in our systematic review that have been investigated with farmer mental health, namely: gender issues (particularly for female farmers), age and farming system type.

The literature has mainly focussed on male farmers' mental health, even though farm women usually engage in several farm roles, which include farm labour/management, household duties and childcare (Mulder et al., 2000). Overall, our review suggested that female farmers experience more psychological distress than male farmers (Booth & Lloyd, 2000; Deary, Willock & McGregor, 1997; Hanklang et al., 2016; Hannay & Jones, 2002; Hedlund & Berkowitz, 1979; Kallioniemi et al., 2009; Lee et al., 2019; Poletto & Gontijo, 2012; Walker & Walker, 1988; Walker & Walker, 1987; Weigel & Weigel, 1987). However, a few studies found otherwise (Gunn 2008; Logstein et al., 2016). Role conflict between farm and home roles, and the absence of husband support are all potential risk factors (Berkowitz et al., 1984).

Berkowitz and Perkins (Berkowitz & Perkins, 1985) found that farm women who are in conflict with their husbands about farm roles, or are unhappy with their marriages, are more likely to report stress related health symptoms. Female farmers whose husbands worked more hours on the farm reported higher depressive symptoms (Rayens & Reed, 2014). Farm women's depressive symptoms have also been found positively associated with perceived racial or ethnic discrimination and family conflict (Zapata et al., 2015). Alston et al., (2018) found a significant increase in women's work hours that reflect their emotional distress; also they add that farm women are more likely to talk about their men's health and ignore their own. Pattnaik et al., (2018) also describe the feminization of agriculture as the feminization of agrarian distress.

Similar to male farmers, pesticide exposure, economic hardship and worrying about finances has often been identified as significant risk factors for female farmers' mental health (Alpass et al., 2004; Hanklang et al., 2016; Hedlund & Berkowitz 1979; Lu 2017; Pulgar et al., 2016; Walker & Walker, 1987; Zapata et al., 2015). This may be a result of women undertaking additional on-farm work because of a reduction in farm paid labour (Fraser et al., 2005). Carruth & Logan (2002) found that women were more likely to report depressive symptoms if they reported driving a tractor, using pesticides, and if they had a recent farm-related injury. Beseler et al., (2006) found an increase in the risk of depression among women with a history of pesticide poisoning, Lu (2017) examined pesticide exposure based on the duration of pesticide use amongst Philippines farmers, and reported the mean duration of pesticide exposure of 14.23 years for males and 15.4 years for females, resulting in mental and physical abnormalities in 5.4% of males and 13.3% of females. In addition, a lack of family support and listening to loud machines were also predictors of poor female mental health (Hanklang et al., 2016). Alpass et al., (2004) found that farm women experience higher levels of stress in trying to understand new farming technologies.

Age of farmers and the association with mental health issues has been discussed in-depth in the literature. Overall, younger farmers experienced higher levels of stress-related symptoms (Elliott et al., 1995; Walker & Walker, 1988; Wang et al., 2017; Wang 2005). This is most likely associated with higher debt levels of younger farmers. However, Çakmur (2014) found that the frequency of depressive symptoms were higher among farmers who were 35 years or older. It has also been found that there are more mental impairments observed with aging farmers (Konstantinos et al., 2013; McClure et al., 2015; Pulgar et al., 2016; Rayens & Reed, 2014; Torske, Hilt et al., 2015). Polain et al., (2011) found that older farmers felt an irresistible sense of loss during prolonged drought compared with younger farmers. Scarth et al., (1997) found a farmer's depressive symptoms were not significantly related to their age. In addition, lower education levels (Çakmur 2014; Logstein 2016; Rostamabadi et al., 2019; Saxena et al., 2013; Wang et al., 2017), being married and having marital stress (Hedlund & Berkowitz, 1979; Saxena et al., 2013; Stain et al., 2011), and not living in a joint family (Saxena et al., 2013) were found associated with poorer farmer mental health.

The association with farm type (system used – such as organic farming and industry type) was also a considerable focus in the literature (Daghagh Yazd et al., 2019b). A study on comparing the self-reported psychological health of workers on organic and conventional horticultural farms by Cross et al., (2008) showed no significant difference between farmworkers psychological health on organic and conventional farms. However, using scores from the Short Depression Happiness Scale, organic farmers were significantly happier than conventional farmers. Similar self-reported questionnaire survey by Khan et al., (2018) on 200 conventional and 157 organic farmers living in Indiana, USA, found conventional farmers demonstrated a significantly higher frequency of neurological symptoms and depression problems. Similar results were found in Australian irrigation (Daghagh Yazd et al., 2019b) . However, Brigance et al., (2018) indicated that some of the risk factors that affect the mental health of organic farmers, e.g., economic insecurity, long hours of work, social isolation and unpredictable weather conditions, are the same as the mental risk factors for the conventional farmer. A recent qualitative study by Soto Mas et al., (2018) on health issues in organic farming argue that although exposure to hazardous pesticides is lower amongst organic farmers, organic farming mostly relies on a few people performing a lot of tasks for cultivation, harvesting, and distribution. This issue can put severe psychological and physical risk factors on organic farmers.

4.3.6 Barriers to Help-Seeking Behaviour

The final area that our systematic review covered was identifying barriers to farmers' helpseeking behaviour. Not many of the identified studies (only 9 studies, 5% of total) reported help seeking barriers among farmers. Farmer stress and exhaustion of an individual farmer is often hidden, which may delay help-seeking behaviour (Kallioniemi et al., 2016). Help-seeking is an active search for a relief or cure to fulfil a need and is a complex decision-making process especially for persons suffering from mental disorders (Cornally & McCarthy, 2011). Usually lack of knowledge or the belief that a person should deal with his or her mental health problems alone were common reasons that decrease the possibility of individuals' help-seeking (Zartaloudi & Madianos, 2010). Lack of access to mental health services in rural areas is another major burden to the delivery of appropriate mental health services (Matsea et al., 2018). Polain et al. (2011) found that usually, older farmers try to access mental health support, but, practical and cultural barriers often prevented them from succeeding. Singh et al. (2013) identified that existing policies were impractical and conflicts between various policies and other safety programmes were common barriers to implementation. Other barriers include farmer self-reliance, social image/stigma, and negative perceptions of health professionals' efficacy and lack of knowledge (Staniford et al., 2009). Brew et al., (2016) and Staniford et al., (2009) found that farmers were half as likely to visit general practitioners or mental health professionals in the last 12 months as compared to non-farmers. Farmers felt that it is better to manage themselves rather than access help for physical or mental health needs. Also, it has been argued that while the traditional masculine hegemony of male farmers can be a benefit to them during good times, in times of heightened stress (like drought) it can lead them to fail to address their mental health needs (Alston & Kent, 2008).

4.4 Discussion

This chapter systematically reviewed relevant research (n=167) in order to identify the key risk factors on farming communities around the world and summarize the state of knowledge about farmer mental health. Studies reviewed were undertaken in 34 different countries, using several different assessment tools. Of the identified papers, the majority used quantitative approaches and most of them were undertaken within the past 10 years, showing increasing interest in farmers' mental health issues, both in developed and developing countries.

Elevated levels of mental disorder within farming populations were identified by many studies (Carruth & Logan, 2002; Kureshi & Somsundaram, 2018; Raine 1999; Terrazas & McCormick, 2018; Truchot & Andela, 2018). However, it is also important to note that there is mixed evidence regarding the prevalence of whether mental health was worse in farmers as compared to non-farmers, but a larger portion of studies identified that psychological health disturbances were more common in farmers and farm-workers.

The most reported risk factors for farmers respectively were daily pesticides exposure (Aiwerasia et al., 2001; Beseler & Stallones, 2006; Fariba et al., 2016; Jamal et al., 2002), financial problems (Hovey & Magaña, 2002b; Kallioniemi et al., 2016; Pulgar et al., 2016; Ramos et al., 2015; Simsek etal., 2015), unpredictable climate (Edwards et al., 2009, 2015; Ellis & Albrecht, 2017; Stain et al., 2011), and past injuries (Çakmur 2014; Dixon & Welch, 2000; Linn & Husaini, 1987; Onwuameze et al., 2013; Thu et al., 1997). Further, machinery breakdown (Alpass et al., 2004); hearing loud machines (Hanklang et al., 2016); time pressure (Alpass et al., 2004; Eberhardt & Pooyan, 1990); and governmental regulations (Raine 1999; Walker et al., 1986) are other identified risk factors. These conditions potentially make farmers more vulnerable to mental health problems. Outcomes include loss of self-esteem, withdrawal from social/community activity, relationship breakdown, hopelessness, nervousness, inability to function in occupational roles, feelings of suffocation, fatigue, insomnia, loss of control violence and substance abuse.

The US represents the country with the highest number of farmer mental health studies, followed by Australia. American researchers were mostly focused on the associations between financial problems and farmer mental health, which has been driven by the fact that the US experienced several agricultural crisis in the past few decades. Australian researchers were also concerned with financial influences on farmer mental health (Daghagh Yazd et al., 2019b), however Australian studies undertook the largest amount of research on climate and weather stresses for farmers due to the Millennium Drought conditions in Australia in the 2000s which triggered much mental health research (Wheeler et al., 2019; Daghagh Yazd et al., 2020).

Most of the studies included in the systematic review used cross-sectional design (92%). The cross-sectional design prevented researchers from making strong inferences about causality and the directionality of effects reported in the studies, as the data observe the study population at only one point in time. Although several key risk factors assessed in the selected studies were significantly associated with farmer mental health status, it is unclear whether farmer stress dimensions are the primary drivers of psychological illness outcomes or not. Longitudinal research might overcome these limitations, by illustrating over the longer time, how mental distress, depression, and anxiety are connected with environmental, social and economic pressures. Also, there is a need to study the association between natural capital factors (e.g. type of farming – regenerative, organic, impact of the environment) and mental distress over the long-term.

Similarly, greater consistency in assessment tools used to examine mental disorder prevalence rates among farmers may be beneficial for future research. The assessment tools used in the reviewed studies varied widely. While each of these tools may be reliable and valid indicators of clinically relevant mental disorders, they may not be directly comparable. As shown in this systematic review, farm environments are hazardous to farmer health both mentally and physically. One area that will need further research is the link between climate variability, rainfall deficiency and severe drought across the world. There is a clear need for more longitudinal research and detailed research in this space, which this thesis seeks to address somewhat.

While there is extensive evidence that farming is a complex and demanding occupation with various risk factors, we suggest that access to primary care and specialist ongoing services for rural and remote communities needs greater priority. There is an argument that the impact of mental health issues for those living in rural areas is greater because many of the stresses are not paid sufficient attention, since mental health professionals are not as common in rural areas and because considerable barriers stop farmers help-seeking for mental health problems (Staniford et al., 2009). Formal help-seeking for mental health problems requires that individuals first be able to recognise that a mental health problem exists, and secondly to believe that seeking some help may be beneficial for solving their problem (Henderson et al., 2013). Limited studies to date have investigated help-seeking behaviour among farmers. Future research needs to investigate how to break down the help-seeking barriers amongst farming communities to decrease the risk of their mental disorders, as well as understanding how different types of policies can influence farmer mental health.

While this study has provided useful information to understand the issues surrounding farmer mental health, it is not without limitations. Although using systematic review principles can help researchers improve the extent of literature reviews, there might be literature inadvertently missed, particularly the grey literature. The issue of identifying causality of risk factors with mental health also needs careful consideration. In addition, there are somemany other unexamined factors which may affect farmers' mental health but they are broader in concept and not just related to farmers. One plausible example could be solar radiation exposure for all outdoor workers, resulting in several severe adverse health effects with possible psychological consequences but also a supposed beneficial effect on some psychiatric disorders, such as depression (Modenese et al., 2018). Indeed, there might be some therapeutic potential of outdoor activities or being more outdoor vs indoor, which might be encouraged to improve individual's (not specifically farmers) mental health and vitamin D status (Roberts et al., 2018;

Rafie et al., 2018), but these aspects were not the specific focus of this study and they are left for future research.

4.5 Conclusion

The findings of this systematic review support the view that farmers' mental health issues are a result of a complex interplay between social, environmental, and economic factors. The four most cited influences on farmers' mental health included pesticide exposure, financial difficulties, climate variabilities/drought and poor physical health/past injuries. Studies in developed countries dominated the literature, with comparative studies suggesting that farmers generally experienced worse psychological health disturbances. Thus, future social, environmental, financial, and health policy needs to consider how best to address various stress issues in the most effective way, as well as understanding how future adverse impacts from climate change can be addressed. Knowledge of risk factors affecting farmers' mental issues is essential for reducing the burden of mental illness, hence this research is an important step in synthesising some of these important factors and outlining possible suggestions for prevention, as well as areas for future research.

Author Contributions: All authors discussed the research questions. S.D.Y. searched and screened the literature (under S.A.W. and A.Z.'s supervision) and conducted the literature review, assessment of the quality of the studies, and preliminary analysis. S.D.Y. and S.A.W. drafted the paper, and S.A.W., S.D.Y., and A.Z. participated in revisions.

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CHAPTER 5 Understanding the Impacts of Water Scarcity and Socio-economic Farm Demographics on Farmer Mental Health in the Murray-Darling Basin

This chapter presents a paper published in *Ecological Economics* (2020) and examines whether climatic conditions and water scarcity is associated with worsening farmer mental health in the MDB. The time period is 2001-2014, which included the Millennium Drought, to allow natural experiment test of the impact of water scarcity on farmer mental health. The sample consisted of 2,141 observations (for 235 farmers) from a national longitudinal survey database across fourteen waves in the MDB. The model using in this chapter is Correlative Random Effects panel data regression. Furthermore, the analysis in this chapter extends the modelling framework to all Australian farmers in five different states. The sample consisted of 5,801 observations (for 571 farmers). The result section in this chapter tests the social-ecological aspect of water scarcity on farmer mental health, as well as the combined socio-ecological economic aspect of water scarcity on farmers' mental health.

Statement of Authorship

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Name of Principal Author (Candidate)	Sahar Daghagh Yazd		
Contribution to the Paper	Undertook the literature review, prepared the spatial data, applied econometric analysis, and wrote the manuscript.		
Overall percentage (%)	80%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	7/12/19

Co-Author Contributions

Name of Co-Author	Professor Sarah Wheeler		
Contribution to the Paper	Discussed the research questions, advised to choose the variables, supervised constantly and helped in interpreting the results.		
Signature		Date	7/12/19

Name of Co-Author	Associate Professor Alec Zuo		
Contribution to the Paper	Helped with the spatial data analysis and econometric analysis.		
Signature		Date	7/12/19

Understanding the impacts of water scarcity and socio-economic demographics on farmer mental health in the Murray-Darling Basin

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Abstract

Changes in climate pose a significant threat to human health, which is not only expected to influence physical health, but also affect mental health. For farming communities that are dependent on ecological and environmental resources for their living, climate variability may significantly influence future farm viability. This study examined whether climatic conditions and water scarcity were associated with worsening farmer (dryland and irrigators) mental health in the Murray-Darling Basin (MDB), Australia. The sample consisted of 2,141 observations (for 235 farmers) from a national longitudinal survey across fourteen waves (2001-02 to 2014-15) and was modelled using Correlative Random Effects panel data regression. This time-period included the Millennium Drought, allowing a natural experiment test of the impact of water scarcity on farmer mental health. Key findings were that farmers located in areas that had experienced reduced rainfall, water allocations less than 30% and mean daily summer temperature over 32°C had significantly worse mental health than farmers in other areas. In addition, farmers who had lower income during drought were much more likely to have worse mental health than in non-drought times.

Keywords: Millennium drought; farmer mental health; irrigation; HILDA.

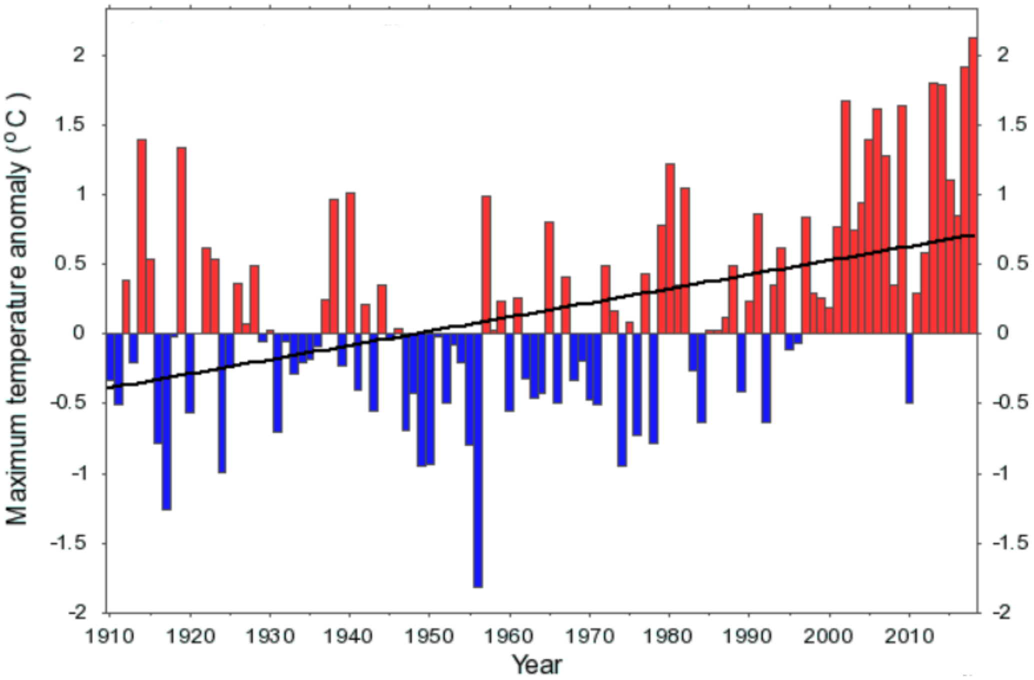
5.1 Introduction

Social and ecological impacts of climate change, such as distress caused by negative changes in the home landscape and feelings of loss and hopelessness, can be damaging to health in many ways, including physical health and work productivity (Zander et al. 2015). The social effects of climate change and natural hazards on peoples' quality of life and wellbeing is a global concern (Berry et al. 2010; 2011). There is also an increasingly recognised link between mental health and climate (Qi et al. 2015); and particularly between climate variability and rural populations' mental health (Stain et al. 2011; Edwards et al. 2015; Pailler and Tsaneva 2018). Increasing weather uncertainty and climate change are set to exacerbate the stress experienced by rural populations, hence worsening mental health and suicide rates (Berry et al. 2010; 2011). The resilience of individuals to these impacts is influenced by their access to a range of capitals and their capacity to adapt and change (Daghagh Yazd et al., 2019b; Wheeler et al. 2019).

Australia in particular faces a considerably varied climate and ecosystems, and Australian farmers have long faced significant economic, environmental and social challenges (Sartore et al. 2008; Fennell et al. 2016). The MDB, which is also known as Australia's 'food bowl', is highly vulnerable to environmental and social impacts of climate change and drought (CSIRO, 2011). The MDB is an area of great environmental, social, indigenous, economic and tourism importance (Bark et al. 2015). Environmental impacts of climate change, such as increasing temperature, evaporation and reduced rainfall, directly affect crop production and agriculture by decreasing the flow of surface-water, and hence impact on irrigation activities and water allocations[12] (Quiggin et al., 2010; Wheeler et al., 2014). This is in the context of a long-term trend in the MDB of maximum temperature anomalies increasing in size and frequency over the last 100 years (see Fig. 5.1).

[12]Water allocations represent the amount of water allocated to water rights in a season.

Figure 5.1: Annual maximum temperature in MDB (1910-–2018)



Source: BOM. Available at: http://www.bom.gov.au/climate/change/#tabs=Tracker&tracker=timeseries&tQ=graph%3Dtmax%26area%3Dmdb%26season%3D0112%26ave_yr%3DT[accessed 9/10/2019].

Rainfall also shows great volatility but does not seem to reflect a decline in absolute volumes over time (CSIRO, 2012). Indeed, during the Millennium Drought (which varied from area to area, but was generally considered to cover the period 2001-02 to 2009-10 in the MDB), the River Murray experienced the lowest flows on record. Farmers faced significant stress dealing with low allocations of irrigation water, higher temperatures and lower rainfall (Wheeler & Zuo, 2017). Predictions for average river flows in the MDB suggest reductions of 10% to 25% in some regions of southern part of Australia by 2030 (CSIRO, 2011). Since mid 2017, the state of New South Wales and parts of Queensland haves been in the grip of another major drought in the MDB. On top of these ecological and natural capital influences, Australian farmers are among the least subsidised in developed countries (OECD, 2017) and consequently are often more impacted by world commodity and input price shocks than farmers in other countries.

Given this background, previous research has illustrated that farmer mental health issues in the MDB is considerably high (Wheeler et al. 2018; Daghagh Yazd et al., 2019b). One reason why mental health issues are of great concern in rural Australia is because farmer suicide rates are up to two times higher than the general population (Fraser et al. 2005; Arnautovska et al. 2014), a statistic that has large social and economic costs. Farmers are affected by various aspects of climate change through direct (e.g. changes to crop/livestock productivity, farm costs and revenue) and indirect pathways (e.g. health impacts, increased stress from ecological degradation) (Berry et al. 2010; Keshavrz et al. 2013).

To date, much of the research in this space has been a cross-sectional snapshot (e.g. Edwards et al. 2015; Daghagh Yazd et al., 2019b), and often does not consider longitudinal analysis over time, taking into consideration the variability of socio-ecological water scarcity factors and their influence on both a) farm economics and b) farmer mental health. The purpose of this study was to examine some of the social and ecological dimensions of water scarcity in the MDB (using five measures of water scarcity) on farmer mental health, using a unique longitudinal dataset from 2001/02 to 2014/15. We sought to examine whether water scarcity increased psychological distress for MDB farmers; and whether water scarcity and financial difficulties together worsened psychological distress. The study time-period spans 14 years, and includes the Millennium Drought, so provides a natural experiment to investigate the combined effect of water-related environmental, ecological, economic and social variables on farmers'' mental health.

5.2 Literature Review

5.2.1 Physical Health and Climate Variability

Human health is sensitive to ecological factors including seasonality, aridity and climate change (McMichael et al., 2008). Direct health harm may result from heat waves, floods, droughts and fires. Indirectly, health may be damaged by crop failures, changes in nutrition or finances (Woodward et al., 2014). There is increasing research on the link between health and climate around the world. For example, higher temperature has been found to impact negatively on living and working in Australia (Hanna et al., 2011) and in low and middle-income countries (Kjellstrom 2009). Prolonged high temperature pose a risk to outdoor workers (Singh et al., 2013), and increases hospital admissions for heat exhaustion, stroke, dementia and kidney disease (McMichael et al., 2008; Gasparrini et al., 2017).

5.2.2 Mental Health, Wellbeing and Climate Variability

Researchers have identified a direct link between heat waves, droughts and high temperatures with mental disorders and wellbeing (Hansen et al. 2008; Ding et al. 2016; Coelho et al. 2017, Pailler and Tsaneva 2018). Wellbeing is the consequence of many different interactions and the term is sometimes used interchangeably with related concepts such as 'quality of life', 'life satisfaction', 'wellness', 'health' and 'mental health' (Schirmer et al., 2015).

Brereton et al. (2008) signalled the importance of climate in adults'' subjective wellbeing. Recently, attention paid to psychological and emotional well-being of people living and working in rural communities has increased largely due to widespread drought and higher rural suicide rates, particularly among rural males in Australia (Fraser et al., 2005). Stain et al. (2011) documented strong association between drought worry, risk of job loss and psychological distress among drought affected Australian rural communities. Sartore et al. (2008) stated that chronic stress and uncertainty about future prospects in times of drought, along with isolation, increased the risk of depression and anxiety for NSW rural communities. It has been found that isolation, loneliness and lack of social relationships among Australian people living in rural communities is detrimental to mental health (Rohde et al., 2014; Austin et al., 2018).

The wellbeing literature also finds a significant relationship between wellbeing and exposure to climate variability (Kelly et al., 2010; Maddison and Rehdanz, 2011; Pailler and Tsaneva, 2018). Carroll et al. (2009) found that a drought in spring negatively affected life satisfaction in rural communities. The following sections focuses in particular on farmers'' mental health and wellbeing.

5.2.3 Farmer Mental Health,Wellbeing and Climatic Variability

Farming has been identified as a highly stressful occupation (Berry et al., 2011). Predictors of stress in farming often include financial difficulties (Staniford et al., 2009); social isolation (Alston, 2012); pesticide exposure; lack of health services (Staniford et al., 2009); and socioeconomic disadvantage (Page et al., 2006; Berry et al., 2011).

Climate change, decreased water inflows and intense competition for water supply occur on top of other key farming stresses and are expected to exacerbate the stresses inherit in farming and impact wellbeing and mental health (Wheeler et al., 2018). Several studies on farmers and rural communities in Australia confirm that prolonged drought can lead to distress, mental disorders and suicide (e.g. Fennell et al., 2012, 2016; Edwards et al., 2009, 2015; Stain et al., 2011; O'Brien et al., 2014; Friel et al., 2014). Edwards et al. (2009) found that during the Millennium Drought almost half of Australian farmers reported distress because of financial burden, their inability to pay bills or mortgage or going without meals. Although increased financial difficulties is strongly associated with increased farmer stress (e.g. Peel et al., 2015; Wheeler et al., 2018), it has not often been a focus of many mental health studies to date. Daghagh Yazd et al. (2019b) found that the main drivers of MDB irrigator psychological distress in 2015/16 (not a significant drought year) were worsening financial capital (namely lower farmland value, higher farm debt, lower percentage of off-farm income, lower productivity change over the past five years and lower net farm income).

5.2.4 Socio-ecological Influences on Farmer Mental Health

As discussed in the social ecological economics of water literature, there are also serious ecological consequences of water scarcity that have correspondingly an impact on economic and social outcomes (Buchs et al., 2018). Water is more than just a mere commodity or economic good, as highlighted above, it has multi-layered impacts on economics, society and environment, which in turn, influence each other (Wheeler et al., 2019). Water is part of a farm''s natural capital, where the sustainable livelihood framework distinguishes five different types of capitals that influence wellbeing in general (namely: physical, social, financial, human, and natural). These capitals influence the capacity to help people survive shocks and stresses, and the quality of their lives (Ellis, 2000).

These multi-layered impacts occur through higher temperatures (and hence increased evaporation); reduced rainfall, reduced water allocations for irrigators; prolonged drought conditions and reduced land productivity (through reduced soil moisture). All these water impacts have varying impacts that can directly lead to worsening farmer mental health: 1) declined agricultural production and livelihoods: 2) changed environmental conditions: 3) reduced employment and depressed rural community: 4) migration and separation of family: and 5) physical health harm. Research has found that the more individuals had a 'sense of place' (e.g. connection to one's home or surrounding land and the positioning of one''s identity as a symbolic extension of self and environment), the higher their psychological distress or worry in times of drought (Stain et al., 2011; Austin et al., 2018). Sense of place is linked to sostalgia - which is the distress felt in response to environmental change (Ellis and Albrecht, 2017). Distress is also related to the concept of “ecological distribution conflicts” (Martinez-Alier, 1995) where water scarcity is felt differently across individuals, time and space. A few studies have sought to look at actual land induced environmental change (also known as natural capital of a farm) with mental health. For example, Speldewinde et al. (2009) found an association between increased dryland salinity and mental health in Western Australia. Wheeler et al. (2015) found some influence of natural capital (namely being a certified organic grower) on reducing water use volumes, and Daghagh Yazd et al. (2019b) found that being a certified organic irrigator was also weakly significantly associated with lower psychological distress. However, to date there has been a lack of study on the multi-dimensional links of water scarcity on farmer mental health around Australia, and especially in trying to understand the aspects of irrigation water scarcity with climate variability. This is important given the great diversity of values attached to water which is a central fundamental tenant of the social ecological economics of water (Buchs et al., 2018).

The combination of socio-economic and ecological challenges make individuals more vulnerable to climate variability (Gasper at al., 2011). Social capital, which describes how people improve and utilise their connections within communities, has increased to prominence recently, and social and community ties play an important role in determining the mental health of individuals beyond genetics (Boyd and Parr, 2008). People who are socially isolated tend to have more diet disorders, may heavily smoke or have high rates of alcohol consumption (Yang et al., 2011). For rural communities, social capital is a key asset where the feeling of emotional connections to the community play an important role in improvement of mental health (Boyd et al., 2008). Financial capital is also a key asset influencing mental health issues (Wheeler et al., 2018), yet as already mentioned there has been little study that explores the interaction of financial with social and natural capital influences on mental health.

What we are most interested in is how the sociol-ecological economic impacts of water scarcity influence farmer mental health. Given that water scarcity is multi-dimensional, and can have multiple level impacts on different scales (e.g., higher temperature versus reduced water allocations), to date there has not been a comprehensive study of the all the impacts of water on farmer mental health. This research attempts to address this gap in the literature and provides insights to the social-ecological economic dimension of water scarcity (using five measures of water scarcity). A longitudinal panel dataset of observations from 2001/02 to 2014/15 for farmers in the MDB was used. In particular, the following hypotheses were tested:

Hypothesis One: Water scarcity (measured through decreased rainy days; drought period; increased summer temperatures; reduced water allocations; lower soil moisture) increases psychological distress for farmers in the MDB;

Hypothesis Two: Farmers experiencing financial difficulties (measured through respondent annual income) are more likely to experience psychological distress;

Hypothesis One tests the direct impact of water scarcity on farmer mental health, while Hypothesis Two examines the combined socio-ecological economic aspect of water scarcity on mental health.

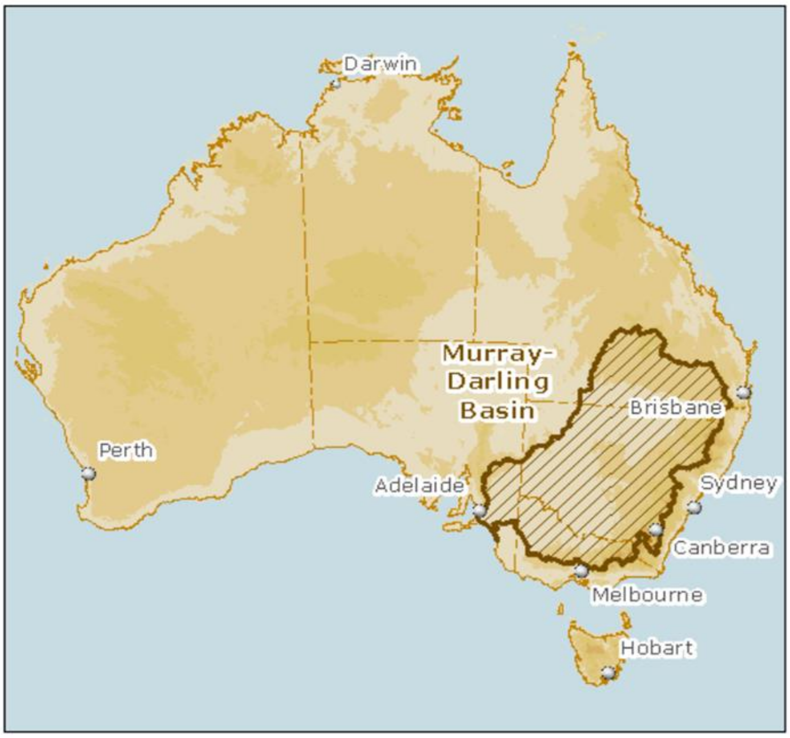
5.3 Methods

5.3.1 Study location

The MDB covers 14% of Australia's land area and spans from southern Queensland, NSW and Victoria to the southeast part of South Australia (Quiggin et al., 2010). It traditionally produces about 40%, by value, of Australia's agricultural production, but the region is predicted to be extremely vulnerable to future climate change impacts, which are predicted to result in increasing temperature, evaporation and reduced rainfall (Pittock & Finlayson, 2011; Zuo et al., 2015). The MDB has experienced considerable drought and extreme weather, as highlighted in Figure5.1. Figure 5.2 illustrates the location of the MDB.

The MDB has Australia's largest share of irrigated production, where irrigators hold differing security of water entitlements that have a variable water allocation assigned annually. Water allocation differs across the MDB and there are differences between states, valleys and regions depending upon reliability of supply. Allocation announcement processes provide water access entitlement holders with a volumetric amount of water that can be used or traded each year. Within the MDB, dryland farmers make up the majority of farmers, with about 20% of farmers irrigators (Wheeler et al., 2014).

Figure 5.2: Location Map of the MDB within Australia



Source: National water account (NWA) (2011); available at: http://www.bom.gov.au/water/nwa/2011/[Accessed June 7, 2019].

5.3.2 Data

A number of databases were merged to investigate the research questions of this study, including the national longitudinal survey from the 'Household, Income and Labour Dynamics in Australia' (HILDA) and various climate and water databases (Table 5.1 provides description and summary statistics).

5.3.2.1 *HILDA Survey*

The HILDA survey is conducted annually and asks a wide range of questions regarding financial and emotional well-being, health-related quality of life and social connectedness (Wooden et al., 2002). Interviews take place annually with interviewer briefing occurring at the end of July to mid-August. The vast majority of data is collected in face-to-face interviews, while telephone interviews and assisted interviews are conducted to ensure high response rate. At the time of this study data was available for 2001/02-2014/5 and each year is known as a 'wave'.

In each wave, adult members aged 15-years and above in each household are interviewed. In wave 1 (year 2001), 13,969 people were randomly interviewed across Australia, including rural and urban communities (known as the main sample). As the survey is a longitudinal design, all members of households, which provided at least one interview in wave 1 formed the basis of the panel to be pursued in each subsequent wave. However, within each survey wave some additional questions are asked that are not repeated every year (Summerfield et al., 2016).

This study used 14 waves (2001-02 to 2014-15) from HILDA, and isolated farmers (and farm workers) occupation data from the dataset. Occupation variables were coded and reported in HILDA based on the 4-digit Australian and New Zealand Standard Classification of Occupations (ABS, 2009). In total, HILDA had information on 571 farmers and farm workers (5,801 observations for 14 waves) around Australia, of which 245 (2,483 observations) lived in the MDB. However, the final number of farmers used in modelling was 235 who answered the mental health questions (2,141 observations over time).

Our measure of farmers is a broad occupation definition and includes dryland and irrigated farmers, so we cannot distinguish whether farmers in our sample are dryland versus irrigated or dairy versus viticulture. Types of farming can be important for investigating individual impacts of water scarcity; for example, percentage of water allocations received is likely to be more important for irrigator mental health than dryland farmer mental health (Wheeler et al., 2018). In addition, as the HILDA survey was designed predominantly as a household survey, not a farmer survey, there is very limited information on farm characteristics (e.g. farm production, rate of return, debt, industry is not available). However, as a broad measure the HILDA dataset and farmer occupation variable provide an interesting snapshot of the influences of drought and water availability on MDB farmer mental health, especially as it provides a natural experiment of changes experienced over the Millennium Drought time-period.

5.3.2.2 *Dependent Variable – Mental Health*

Mental disorders are normally defined by some combination of abnormal thoughts, emotions, behaviours and relationship with others. The most common mental disorders are anxiety and depressive disorders, which are a reaction to the stresses of life. A person with an anxiety disorder feels distressed a lot of the time for no apparent reason and a person with a depressive disorder can have a long-term depressed mood and loss of interest in activities that used to be enjoyable (Paykel & Priest 1992). The HILDA dataset provided an estimate of the transformed mental health inventory (MHI-5), a sub-scale of the SF-36, which is available in all waves of the HILDA dataset. The SF-36 is an indicator of overall health status which is widely used and modified as a standard health outcome measure (Jenkinson et al., 1997). Eight aspects of health status were examined by 36 questions in the SF-36 from 40 concepts available in the Medical Outcomes Study (Ware, 2000). The MHI-5 sub-scale of the SF-36 is a self-reported instrument which is a composite index from the five mental health questions[13] that best predicted the summary score for the 38-item Mental Health Inventory. Six response categories were given to each question: All of the time; Most of the time; A good bit of the time; A little of the time; and none of the time. Scores are normalised ranging from 0-100, with a higher score indicating better mental health.

Mental health studies have demonstrated that the MHI-5 is an effective screening tool for high-prevalence mental disorders in general communities. The MHI-5 data from HILDA have been used a number of times in investigating mental health (e.g. Berry and Welsh, 2010; Kiely et al., 2015).

We also used the following other independent characteristics from the survey: educational qualification (year 11 or below), age, yearly gross wage and income, whether the respondent had a negative life event in the past year,[14] gender and marital status. The selected demographic variables were based on previous literature and availability of data in HILDA.

5.3.2.3 *Data Sources of Other Independent Variables*

Given the multi-dimensional impacts of water scarcity, we considered a number of proxies, such as rainy-days, drought period, soil moisture, maximum daily summer temperature and percentage of regional water allocations over the 14-year period. Statistical Local Area (SLA) location data and date of interview in any given wave were available from HILDA, hence climate data were geo-referenced across time and space (preparation of the climate data is discussed further in Appendix B). In order to measure climate variables in a consistent manner

[13]The five questions include "How much of the time during the past 4 weeks have you: 1) been a nervous person; 2) felt so down in the dumps nothing could cheer you up; 3) felt calm and peaceful; 4) felt down; and 5) been a happy person."

[14] Separated from spouse, serious personal injury/illness, injury/illness to family members, death of spouse/child/close relative/family member/close friend, victim of physical violence, jail, close family in jail, and major worsening in finances in the past year were considered as a negative life event in the past year.

(i.e. same seasons for all respondents) and to avoid using future conditions to explain current mental health status, climate variables for the whole year prior to the year when the interview was undertaken (lagged) were used. For farmers, previous year climatic conditions would have an impact on previous year yield and therefore previous year farming income, which in turn may be a financial source of psychological distress given that current year farming income was not yet realised.

To create the drought[15] variable for a particular area, a rainfall deficiency dataset from the BOM was used. Our measure of drought involved identifying the fifth percentile (or within the lowest 5% of rainfall records) rainfall deficiency relative to the long-term average for the specific area. In other words, the monthly gridded rainfall deficiency recorded as being at or below the fifth percentile for 12-month rolling grids, from Jan 2000 to Dec 2014, was used to define whether an area of the MDB was classified as in drought. Weather and climate data were then matched to date and location of respondents.

The percentage of water allocations over 14 years (2001-2014) was collected from the MDBA's *Water Audit Monitoring Reports* and the *Transition period water-take reports* (e.g. MDBA, 2012). The reports provide information on base valley water entitlements, water availability through allocations and water trading for each year in different water systems. Dummy variables were generated to check if water allocation below a certain level was a factor in MDB farmer stress.[16] In order to take into account the amount of water present in soil (soil moisture), we used the *Australian Water Availability Project* soil moisture data (e.g., Raupach et al., 2009).

The Socioeconomic Index for Areas (SEIFA), from the ABS population census, was available in HILDA and was used to examine socio-economic status of location in this study. The SEIFA is a measure of the social and economic disadvantage of different geographical areas in Australia. An increase in the index indicates less disadvantage (economically and socially).

[15]It is common to define drought by a deficiency of frequent rain events over an extended time-period. In part how drought is defined depends on the purpose for which the concept is going to be used. Hennessey et al. (2008) defined drought in four different ways: meteorological drought (a period of time with less rainfall), agricultural drought (dryness of surface soil-layers), hydrological drought (prolonged moisture deficits), and socio-economic drought (the effect on supply and demand of economic goods). Given the focus of this research on climatic conditions the most appropriate conceptual definition was meteorological drought.

[16]We created five dummies, if water allocation was equal to or smaller than 20/25/30/35/40%, respectively, and tested each separately. Only the water allocation below 30% was significant. All other dummies were insignificant, although all with negative coefficients as expected.

Descriptive statistics of climatic and socioeconomic variables are reported in Table 5.1. To test Hypothesis Tow (impacts of water scarcity and financial impacts on distress in times of drought), we created two interaction terms of drought and annual income so that two separate effects of income on farmer mental health could be estimated: drought vs non-drought.

Table 5.1: Descriptive Statistics for MDB Farmers

Dependent Variable	***Mean***	***Std. Dev.***	***Min***	***Max***
Mental health, MHI-5 subscale-MDB farmers[a]	77.99	14.62	4	100
Independent Variables				
Rain days[b] (days with rain)	105.06	29.96	32	196
Mean daily maximum summer temperature (C°)	29.21	3.32	14.37	38.50
Water allocation (%), (end of season 1=,0.30; 0=otherwise)[c]	0.51	0.50	0	1
Soil moisture index[d]	0.27	0.09	0.07	0.74
Drought condition[e] (1=drought; 0=otherwise)	0.24	0.43	0	1
Negative life event (1=negative life event in the last year; 0=otherwise)	0.34	0.47	0	1
Age (years)	49.72	16.19	15	89
Marital status (1=married; 0=otherwise)	0.66	0.47	0	1
Male (1=male; 0=female)	0.65	0.48	0	1
Low education (1=year 11 or below; 0=otherwise)	0.48	0.50	0	1
SEIFA[f]	965.73	62.48	622.93	1221.01
Income ($AUD yearly gross salary in 1,000)	14.84	49.98	0	2000

[a]Only includes farmers living in the MDB. Mental health uses MHI-5 subscale from the SF-36, available in HILDA.
[b]All climate variables from 2000/01-2014/15 were collected from BOM, and lagged by one year.
[c.]For example, see MDBA (2012).
[d.]Raupach et al. (2009).
[e.]Drought is defined as the fifth percentile rainfall deficiency relative to the long-term average for the specific SLA.
[f.]The Socioeconomic Index for Areas (SEIFA) is a measure of the social and economic disadvantage of different geographical areas across Australia, with higher indicating better advantage.

5.3.3 Regression Methodology

The Correlated Random Effects (CRE) panel data model from Mundlak (1978) was used to model farmer mental health in the MDB. In panel data settings, individual specific effects are unobservable parameters that may be correlated with observed explanatory variables (Bester & Hansen, 2007). The CRE approach proposes strategies for allowing unobserved heterogeneity to be correlated with observed covariates for unbalanced panel datasets (Wooldridge, 2010) by projecting unobserved heterogeneity onto the average of explanatory variables (Elzinga & Gasperini, 2015).

Usually researchers assume that N (cross-sectional units) and T (time-periods) go to infinity where estimation schemes are broadly referred to as fixed effects estimators. However, estimation based on $T \rightarrow \infty$ may perform poorly in practice (Bester & Hansen 2007). The CRE model nests the conventional fixed effects specification by introducing additional parameter heterogeneity (Elzinga & Gasperini, 2015). The advantage of CRE is that this a flexible extension to random effect models which allows us to include both within and between variations in the model (Schunck, 2013). This approach increases model flexibility and solves the correlation between covariates and residual problem (Bell & Jones, 2015). A linear panel-data model with additive heterogeneity is given by:

$$Y_{it} = X_{it}\beta + \alpha_i + u_{it} \tag{1}$$

i = cross-sectional unit, i = 1…N

t = time-period, t = 1…T

where X_{it} is a vector of time varying observed independent variables, α_i is an unobserved individual specific effect of the ith farmer that cannot be explained by X_{it}, and u_{it} is the classical error term. When α_i is not correlated with explanatory variables (random effect) or with initial mental health status, equation (1) could be estimated by generalised least squares (GLS) approach (Roy & Schure 2013). However, it is more likely that α_i is correlated with independent variables (X_{it}) of the model, which will result in biased coefficient estimates (Wooldridge, 2005). By applying the CRE model, heterogeneity is correlated with covariates of the model:

$$\alpha_i = \bar{X}_i\rho + Z_i\gamma + \nu_i \tag{2}$$

where $\bar{X}$ is the average of covariates over time periods and, ν_i is a true random effect, so we can rewrite equation (1) as (3), which generates unbiased estimates asymptotically equivalent to fixed effect estimation:

$$Y_{it} = X_{it}\beta + \bar{X}_i\rho + Z_i\gamma + \nu_i + u_{it} \tag{3}$$

where Z_i is a vector of time-constant variables, X_{it} is a vector of time varying observable independent variables, $\bar{X}$ is the average of covariates over time periods, and $\rho,\ \beta,\ \gamma$ are parameters or vectors of parameters to be estimated. In addition, the variance inflation factors (VIF) and correlations were checked, with no sign of serious multicollinearity (mean VIF=1.20 and the strongest correlation coefficient= 1.66). Please see Appendix C for more detail.

5.4 Results

Although climate change has been a prominent topic of research for the past several decades, the impact of climate variability on farmers' mental health has only recently been investigated. Results in Table 5.2 indicate a combined impact of social, ecological and financial issues on MDB farmers' mental health.

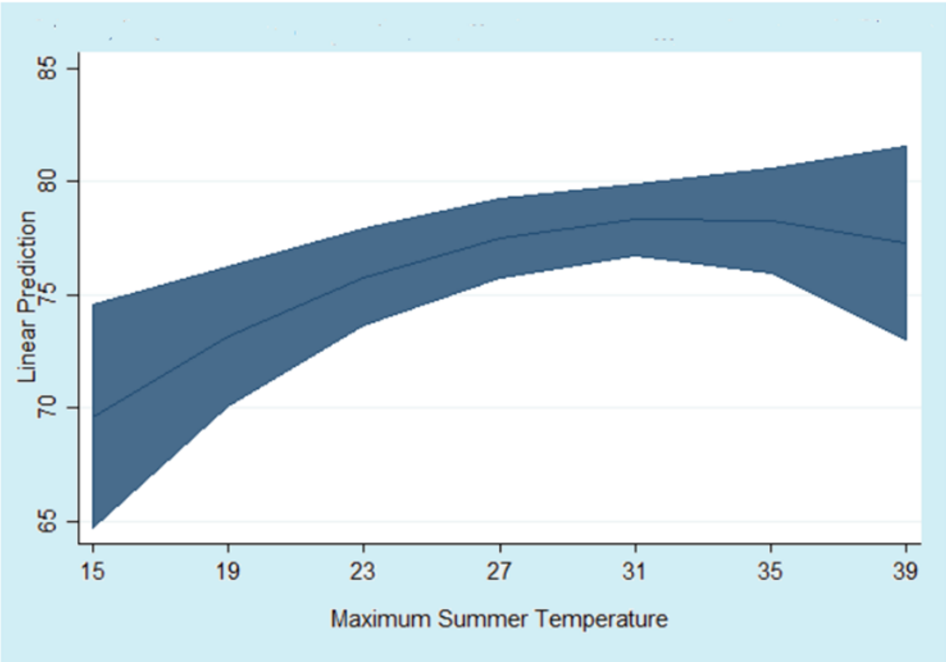
Table 5.2: CRE panel model on MDB farmers' mental health, 2001-02 to 2014-15

Variables	***Coefficient***
Rain days	0.038**
	(0.011)
Maximum daily summer temperature	1.890**
	(0.014)
Squared daily maximum summer temperature	-0.030**
	(0.036)
Water allocation <30%	-1.322*
	(0.077)
Soil moisture	-6.190
	(0.241)
Drought	-0.386
	(0.589)
Income (drought)	0.035**
	(0.030)
Income (non-drought)	0.004
	(0.118)
Negative life event	-1.989***
	(0.001)
Age (years)	0.027
	(0.764)
Married	-0.294
	(0.617)
Male	0.146
	(0.937)
Low education	2.164
	(0.519)
SEIFA	0.003
	(0.684)
Constant	24.289
	(0.535)
Observations	2,141
Number of farmers	235
Wald chi2	98.52***
R-squared (overall)	0.075

Notes: An increase in the index indicates better mental health.
Robust p-values in parentheses ***p<0.01, **p<0.05, *p<0.1
Std. Err. adjusted for 235 number of farmers

There was reasonable evidence found to support our Hypothesis One: that some forms of water scarcity increased MDB farmers' psychological distress. However, not all water scarcity variables were found to be significant. More specifically, we found that the following water characteristics had a positive statistically significant impact on farmer mental health: i) higher rain days in the past year; and ii) water allocation percentages above a seasonal end-allocation of 30%. Temperature impacts were interesting: an increase in maximum daily summer temperature in general is associated with an improvement in farmer mental health, but only up to a certain threshold, beyond which mental health significantly worsens. Farmer mental health peaks at about 32°C and worsens as maximum summer temperature further increases (illustrated further in Figure 5.3 with a 95% confidence interval). Our finding in this regards is consistent with previous research on the link between climate variability and bad weather in heightening farmers' perceived risk of depression (McShane et al., 2016; Ellis & Albrecht, 2017). It also confirms findings of the impact of hotter temperatures worsening children's mental health in Australia (Xu et al., 2018).

Figure 5.3: Predictions of Farmer Mental Health at Different Levels of Summer Temperature



Note: Mental health peaks at about 32°C and gets worse when maximum summer temperature further increases. The shaded area is the 95% confidence interval of mental health score prediction.

The findings also confirmed the second part of our Hypothesis Two: that common economic stress factors, like lower farmer household income, are most associated with worse mental health during a drought period. Although, income was a positive influence on farmer mental health during a non-drought period, but just missed statistical significance (i.e. p-value =0 .12). Water scarcity often leads to worsening farm finances and an associated increase in stress effects and potential psychological problems. Financial issues have been identified in past literature as one of the largest stresses faced by farmers (Peel et al., 2015) and irrigators (Daghagh Yazd et al., 2019b). Wheeler & Zuo (2017) showed that financial farm variables such as rate of return, farm net income and severe debt were drivers of farm exit intentions in periods of drought, but not in periods of non-drought. The obvious economic impact of water scarcity (e.g. reduce in yield of crops and farm productivity) and social impacts (e.g. migration, sense of loss and conflicts in society for water) along with environmental impacts (aridity and drought) have been identified consistently in the literature as main sources of stresses faced by farmers (McShane et al., 2016; Wheeler et al., 2019). These findings are in agreement with the present study which reports a significant positive association between water scarcity, climate variability and psychological distress for MDB farmers.

Finally, farmers who experienced a negative life event in the past year had strongly significant worse mental health. . This result is common within the literature (e.g. Linn & Husaini 1987).

5.5 Discussion

Although farmers have experience dealing with climate variability and uncertainty, especially in countries that experience water scarcity, increasing climate unpredictability poses future substantial challenges for farmers. Water is an ecological asset in the MDB (and elsewhere) and projections of future climate show that water scarcity will continue to be a major issue (CSIRO, 2011).

Results of this study confirm that water scarcity can make traditional farm stresses much worse. Although it was impossible to tell exactly if our respondents were irrigators or dryland farmers, one can surmise that rainfall would probably be of the most upmost importance for dryland farmers and water allocations would be of the most upmost importance for irrigators (Wheeler et al., 2018). Further research, with more detailed information on the type and industry of farmers, would need to confirm this. The relatively small sample size used in this study (albeit our longitudinal database covered a time-period of over fourteen years), also suggests that further work with larger sample sizes should be conducted once additional data is available. Indeed, further economic or social work needs to be conducted on what is the actual cost and impact of this mental health impairment of farmers.

Farmer mental illness is a result of complex interplay between ecological, social, locational and economic factors. This study added to the existing body of literature (e.g. Peel et al., 2015;

Daghagh Yazd et al., 2019b; Wheeler et al., 2019) by confirming that the combination of drought and financial crises affect farmer mental health. It seems that an increase in salary/farm income is a larger and more significant positive impact on farmer mental health in periods of drought than non-drought. We recommend that to respond to climate change impacts, multidisciplinary approaches are necessary and it is time to combine environmental/ecological and social/financial theories and apply them to real-world data to advance work in farming health policy. Policy must be focussed on long-term, preventative approaches, as opposed to the current short-term, reactive and potentially harmful policies currently being implemented by the Australian Government to address the crisis of the latest drought. As argued by Wheeler and Marning (2019), there is a need to focus much more on agro-ecological and soil/water management methods in the MDB which have historically been ignored by government policy. For adaptation and for adaptive capacity in general, the findings in Wheeler and Marning (2019) and Daghagh Yazd et al. (2019b) may provide some evidence that a focus on farm-level (internal) methods of water security may reduce farmers' vulnerability to water security shocks. We must work to develop policies that consider how, even in the middle of a drought (and especially within the middle of a drought), farmers can earn a livelihood. Policies that help create markets and conditions where farmers are rewarded for public good activities (e.g. protecting (and creating) environmental/ecosystem services, increasing soil carbon for carbon sequestration purposes) may play a very important role: both in creating more resilient farms to withstand drought effects, but also in providing income when traditional farm production is not possible. Other policies that seek to improve farmers'' risk management behaviour like insurance and farm management deposits also need encouraging, while policy that does not encourage adaptive capacity to change to a hotter and drier future needs reform. For example, Wheeler et al. (2018) recommends that subsidies for on-farm irrigation infrastructure in the MDB must be removed as they provide perverse farm incentives to convert to more permanent cropping and increase water use, increasing the likelihood of these irrigators experiencing severe water scarcity in the next drought and losing years of investment. The increased use of exit packages is also something that needs to be considered (Zuo et al., 2015).

At the macro-level, effective climate change and drought policy action is needed. Daghagh Yazd et al. (2019b) and Wheeler et al. (2019) recommends greater investment in preventative measures, such as greater mental health (and health in general) expenditure in rural regions. There is a need to understand what preventative health policies, government support or farming policies have the most beneficial impact on farmer mental health. To date many solutions and adapting strategies are reactive and, therefore, only treat the symptoms and impacts of drought and water scarcity rather than the underlying causes (Wheeler et al., 2019).

5.6 Conclusion

There is a growing literature seeking to understand the emotional and social effects of water scarcity on farmer mental health. This chapter sought to more fully understand the ecological, environmental and economic issues that impact on farmer mental health in the MDB, the most important food producing area in Australia. This study used a unique longitudinal dataset of 14 waves from HILDA from 2001-02 to 2014-15 to investigate a series of hypotheses about the link between water scarcity, farm finances and farmer mental health. Our sample included both dryland farmers and irrigators in the MDB. The time-period studied provided a natural experiment test of the link between water scarcity and MDB farmer mental health, as it covered the Millennium Drought period in Australia, which is often described as the worst drought in recorded history for the MDB. Farmer survey data were combined with a variety of other locational and climate information databases and a Correlated Random Effect regression methodology was applied.

Results found that increasing water scarcity was negatively significantly associated with MDB farmer mental health. In particular, the most important proxies of water scarcity were found to be rainfall, low water allocations and higher summer temperatures (above 32 °C). As also hypothesised, better finances (measured through farmer annual salary) were positively linked to farmer mental health, and income was most important in drought times, rather than non-drought. With the increasing pressure placed on farming communities by the impacts of climate change, future rural economic, ecological and health policy needs to consider how best to address these issues in the most effective and efficient way. In particular, focus must be given towards long-term, preventative policies (at both the micro and macro-levels) that help farmers adapt to a hotter and drier future.

Declaration of competing interest

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5.7 Extended Correlated Random Effects (CRE) panel data model for farmers in five Australian States

We extended the CRE model to answer the question of how is Australian farmers' mental health influenced by extreme (and changing) climatic conditions. Similarly, to test the impacts of water scarcity and financial impacts on distress in times of drought, we created two interaction terms of drought and annual income to be able to test two separate effects of income on farmer mental health: drought vs non-drought. Table 5.3 demonstrates the descriptive statistics of climatic and socioeconomic variables for farmers in five Australian States.

Table 5.3: Descriptive Statistics for farmers in five Australian States (NSW, VIC, QLD, SA, WA)

Dependent Variable	***Mean***	***Std. Dev.***	***Min***	***Max***
Mental health, MHI-5 subscale Australian farmers[a]	77.29	16.19	16	100
Independent Variables				
Rain days[b] (days with rain)	117.13	35.56	26.5	189
Mean daily maximum summer temperature (C°)	28.08	3.71	17.36	38.96
Soil moisture index[c]	0.311	0.12	0.51	0.92
Drought condition (1=drought; 0=otherwise)[d]	0.24	0.42	0	1
Negative life event (1=negative life event in the last year; 0=otherwise)	0.32	0.46	0	1
Age (years)	50.74	16.10	15	91
Marital status (1=married; 0=otherwise)	0.65	0.47	0	1
Male (1=male; 0=female)	0.66	0.47	0	1
Low education (1=year 11 or below; 0=otherwise)	0.46	0.49	0	1
SEIFA[e]	981.80	60.45	809.86	1201
Income ($AUD yearly gross salary in 1,000)	19.42	28.31	0	328.63

[a.] Only include farmers. Mental health uses MHI-5 subscale from the SF-36, available in HILDA.
[b.] All climate variables from 2000/01-2014/15 were collected from BOM, and lagged by one year.
[c.] Raupach et al. (2009).
[d.] Drought is defined as the fifth percentile rainfall deficiency relative to the long-term average for the specific SLA.
[e.] The Socioeconomic Index for Areas (SEIFA) is a measure of the social and economic disadvantage of different geographical areas across Australia, with higher being better advantage.

Table 5.4 illustrates the extended CRE panel model. As reported, Farmer survey data were combined with a variety of other locational and climate information.

Table 5.4: CRE panel model on farmers' mental health in different Australian states, 2001-02 to 2014-15

Variables	***NSW***	***VIC***	***QLD***	***SA***	***WA***
Rain days	0.03*	0.11*	0.02	0.06***	-0.01
	(0.10)	(0.08)	(0.26)	(0.01)	(0.53)
Squared rain days squared		-0.00*			
		(0.07)			
Maximum daily summer temperature	0.07	1.99*	0.11	9.15**	
	(0.68)	(0.06)	(0.72)	(0.02)	
Squared daily maximum summer temperature		-0.04*		-0.17**	
		(0.07)		(0.02)	
Soil moisture		0.49		-12.58	
		(0.91)		(0.27)	
Drought	-0.37	0.36	-1.99*	0.28	0.38
	(0.65)	(0.60)	(0.06)	(0.84)	(0.64)
Income-drought	0.03	-0.01	0.07**	0.02	-0.01
	(0.11)	(0.75)	(0.01)	(0.59)	(0.76)
Income-non-drought	-0.01	-0.00	0.00*	0.01	-0.00
	(0.66)	(0.69)	(0.06)	(0.74)	(0.83)
Age	-0.06	0.26***	-0.02	0.12	0.01
	(0.59)	(0.00)	(0.86)	(0.45)	(0.94)
Negative-life-event	-1.88***	-1.92***	-0.57	-2.77***	-1.08*
	(0.00)	(0.00)	(0.45)	(0.00)	(0.08)
Low Education	2.59	3.57	-4.38	3.97	1.23
	(0.38)	(0.35)	(0.32)	(0.16)	(0.71)
Married	-0.28	-0.20	-1.01	0.88	-0.26
	(0.70)	(0.76)	(0.25)	(0.39)	(0.75)
Male	2.63	-1.06	1.40	1.37	1.34
	(0.30)	(0.55)	(0.74)	(0.69)	(0.64)
SEIFA	0.01	-0.00	0.00	0.00	-0.00
	(0.05)	(0.82)	(0.61)	(0.75)	(0.34)
Constant	61.35*	93.19*	17.55	-14.09	108.92***
	(0.06)	(0.09)	(0.71)	(0.95)	(0.00)
Observations	1,369	1,709	738	784	826
Number of farmers	146	172	79	78	87
Wald chi2	84.04	73.49	36.96	54.66	70.63
R-squared (overall)	0.097	0.094	0.126	0.080	0.228

An increase in the index indicates better mental health. p-values in parentheses ***p<0.01, **p<0.05, *p<0.1

Results in Table 5.4 confirm that climate variability can make traditional farm stresses much worse. The results indicate a combined impact of social, ecological and financial issues on farmers' mental health in Australian states.

As Table 5.4 illustrates, there is a significant quadratic relationship between the previous year's summer temperatures and farmers' mental health in VIC and SA. Also, more rainy days in the past year had a positive and significant impact on farmers' mental health in NSW, VIC, and SA. Moreover, it was found that lower levels of income significantly affected QLD farmers' mental health. Experiencing a negative life event had a significant impact on farmers' mental health in NSW, VIC, SA and WA states.

Similarly, these results support the need for financial, risk-management and business management principles as a primary method to help drought-affected farmers. Further, in the face of increasing drought conditions in Australia, policies on farmers' decisions to adopt adaptation measures in times of drought is warranted.

CHAPTER 6 Exploring the Drivers of Irrigator Mental Health in the MDB

This chapter presents a paper published in *Sustainability* (2019). Maintaining the physical and mental health of farmers is important for not only their own personal wellbeing but also for society. The previous chapter studied the influences of farmer mental health in the MDB, however it was impossible to distinguish between dryland and irrigated farmers. This issue is important as it has been suggested that irrigator mental health is worse than dryland farmer mental health in the Basin (Wheeler et al. 2018). This chapter therefore seeks to examine the issue of irrigator mental health in more detail. In particular, it seeks to distinguish the particular roles of natural and financial capital in irrigator mental health, across differing industries. In doing so, this chapter uses a 2015-16 survey sample of 1,000 irrigators (both conventional and certified organic practitioners) from the sMDB, to model the drivers of irrigators' psychological distress. This chapter also tests the association between certified organic farming and less mental distress for irrigators in the sMDB.

Statement of Authorship

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Name of Principal Author	Sahar Daghagh Yazd		
Contribution to the Paper	Undertook the literature review, prepared the historical spatial data, applied econometric analysis, and wrote the manuscript.		
Overall percentage (%)	70%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	7/12/19

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

Name of Co-Author	Professor Sarah Wheeler		
Contribution to the Paper	Provided the dataset and research question, advised on econometrics, supervised constantly, and edited the manuscript.		
Signature		Date	7/12/19

Name of Co-Author	Associate Professor Alec Zuo		
Contribution to the Paper	Helped in providing the spatial dataset and supervised the econometric analysis.		
Signature		Date	7/12/19

Exploring the Drivers of Irrigator Mental Health in the Murray–Darling Basin, Australia

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Abstract

There has been little work conducted on how landholders' farm management approaches and financial capital (specifically (i) farm method such as organic farming and (ii) financial profitability) may impact mental health. In particular, there is emerging evidence that an increase in natural farm capital and environmental conditions may improve farmers' wellbeing. We used a 2015–2016 survey, which randomly sampled 1000 irrigators from the southern Murray–Darling Basin, to model the drivers of irrigators' psychological distress. Results highlight that worsening financial capital (namely, lower farmland value, higher farm debt, lower percentage of off-farm income, lower productivity change over the past five years, and lower net farm income) was the most statistically significant factor associated with increased irrigator distress. In addition, there was some evidence that being a certified organic irrigator was also associated with lower psychological distress; however, it was only weakly significant in our overall model, with the most significance within the horticultural industry model. Contrary to expectations, drought and water scarcity were not the main drivers of psychological distress in the time-period studied, with their influence seemingly through reducing financial capital as a whole.

Keywords: Murray–Darling Basin; irrigator; certified organic agriculture; wellbeing; psychological distress

6.1 Introduction

Studies have identified several occupational stressors that are unique to farming communities and that are potentially harmful to mental and wellbeing (Bhise & Behere, 2016; Dongre & Deshmukh, 2012; Fraser et al., 2005; Khan et al., 2018; Welke, 2004). In Australia, prolonged drought in rural and remote regions is considered as one of the key factors influencing psychological distress and poor wellbeing (Gunn et al., 2012). Water scarcity has been particularly relevant for irrigators in the Murray-Darling Basin (MDB) in Australia who have experienced the Millennium Drought (the worst ever recorded drought since European settlement – with the commonly-assessed time-frame of 2002-2010) and ongoing low rainfall and low water allocations over the past decade (Wheeler et al., 2018). The Millennium Drought caused severe rainfall deficiency in stream flows and contributed to widespread crop failures, livestock losses, dust storms and bushfires (Heberger, 2012). As a result, uncertainty about the future expanded irrigators' traditional agricultural sources of worry (Alston & Kent, 2004; Edwards et al., 2009; King et al., 2009). Other issues associated with drought include declining and unpredictable soil moisture, and reduced water allocations, causing increased stress for permanent crop growers (Lawrence et al., 2018; Wheeler et al., 2018). In addition, changes in commodity prices and, arguably, unequitable processor contracts, have increasingly negatively impacted irrigators (e.g. dairy farmers and grape growers especially) in the MDB (Bryant & Garnham, 2013).

Farmers' mental health is an important factor contributing to their overall wellbeing (Schirmer et al., 2015). The sustainable livelihood framework distinguishes five different types of capitals that influence wellbeing (namely: physical, social, financial, human, and natural). These capitals influence the capacity to help people survive shocks and stresses, as well as the quality of their lives (Ellis, 1999, 2000; Thennakoon, 2004; Zhang et al., 2018). Although there has been considerable research on the links between human, social and physical capital assets and farmer mental health (e.g. King et al., 2009), there is emerging literature on the importance of natural capital in influencing mental health. Natural capital refers to both the natural land assets (and farm management practises) of the farm, and to the natural resources of a region such as climate, rainfall, water quality, air quality, and the health of vegetation (Schirmer et al., 2013; Wheeler & Marning, 2019). Schirmer et al., (2013) identified natural resource management practices and the physical environment of the agricultural landscape as influences on farmers' wellbeing.

This paper seeks to test the link between natural, physical, social, financial, and human capital and irrigators' mental health. It uses certified organic farm management practise as a proxy of natural capital and controls for a wide variety of other farm and farmer variables to provide a comprehensive understanding of the drivers of 1000 irrigators' mental health in the southern MDB in 2015–2016.

6.2 Literature Review

6.2.1 Overall Influences on Farmer Mental Health

Farming is associated with a range of physical and mental health risks because of the hard work under challenging conditions (Fraser et al., 2005). A range of occupational stresses result in various symptoms for farmers, such as physical problems (e.g., headaches, sleep problems, weight change), mental health problems (e.g., anxiety, anger, depression), and cognitive issues (e.g., memory loss, inability to make decisions) (Walker & Walker, 1987; Williams, 2001; Kearney et al., 2014; Simsek et al., 2015). Some studies have identified greater mental health issues and less life satisfaction amongst farmers than non-farmers (Stallones & Beseler, 2004; Sanne et al., 2004; Syson-Nibbs et al., 2006; Berry et al., 2011a). The literature suggests that farmers' stress is attributable to pesticide exposure, financial difficulties, climate variability, injuries, regulations, uncertainty about the future, role conflict between work and home roles and heavy workloads (Sartore et al., 2008; Berry et al., 2011a; Brumby et al., 2011; Kearney et al., 2014). Most importantly, mental disorders have been recognised as one of the key risk factors for suicide and suicidal ideation in farmers (Page et al., 2002; Berry et al., 2011).

A person's resilience is one reason explaining why some people do not suffer significant distress in the face of stress (Brown & Schirmer, 2018). Stain et al. (2011) argue that greater levels of personal resilience, personal hope and optimism help people deal with, and recover from, difficult times such as drought. Also, many have studied various coping techniques for farmers that may increase their resilience and, therefore, decrease their probability of mental health issues in difficult times. For example Gunn et al., (2012) identified the coping strategies used in the Australian farming population in a time of drought. The most commonly employed farming coping strategies were planning, acceptance, and active coping, whereas the least used were alcohol/drug use, denial, behavioural disengagement, and religion. Winkelman et al., (2013) examined behaviours to cope with stress amongst Latino farmworkers and showed that higher wages, sleep, and family support helped. In addition, Zarafshani et al., (2007) evaluated differences in drought perceptions and coping strategies among Iranian farmers and showed that farmers in drought-stricken areas used more emotion-focused coping strategies such as acceptance and praying.

Resilience relies on a variety of capitals: a) social capital; b) human, financial and physical capital; c) natural capital (landholders' management approaches); and d) governance (Lockwood et al., 2015). It also relies on using natural resource management techniques (Brown & Schirmer, 2018) which result in less significant distress during environmental changes. It is argued that having greater access to five capitals and having higher resilience, allows farmers to better cope with adverse events such as drought and climate variability (King et al., 2009).

Berry et al., (2011a) argue that the major stress in a time of drought is socio-economic hardship, which is known to have a significant influence on farmers' wellbeing. Farmers can be more successful in finding some alternative agronomic options for adapting to drought than in adapting to financial burden. In general, there has been a lack of research on the role that financial conditions play in driving mental health, even though there have been a wealth of studies that have looked at the drivers of farmers' stresses. Specific drivers of farm's financial status, such as off-farm income, farmland value, farm debt, and net farm income are rarely studied (see Wheeler et al., (2019) for further discussion), and only very broad consideration of finances and economic burdens have been considered (Austin et al., 2018). Our study fills this gap by incorporating a wide range of measures of financial capital to understand what the key drivers of psychological distress are for southern MDB irrigators.

Natural farm capital (e.g., locational and 'place' factors, such as natural resource bases, including land, water, air, minerals, soils, fossil fuels, and landscapes) and farmers' landholder practises can influence farmers' wellbeing (Albrecht et al., 2007; Speldwinde et al., 2009; Berry et al., 2011b) . Emerging literature is considering the relationship between farmers who undertake certain activities (e.g., natural resource management techniques) and their overall mental health and wellbeing (Brown & Schirmer, 2018). One proxy for natural capital and management of land is certified organic or alternative management (discussed later), as it has been consistently shown these practices have greater environmental benefits on and off farms (Knapp & Van der Heijden, 2018). There is an increasingly recognised link between farmers' mental health, climate variability, and events such as droughts (Gunn et al., 2012; Ellis & Albrecht, 2017). However, as Stain et al., (2011) point out, the existence of drought itself is not necessarily associated with high drought-related worry. The definition of drought, and its many different connotations, is discussed later.

Irrigators in particular face additional pressures in times of drought through falling seasonal water allocations. For example, South Australian irrigators, who commonly received 90% of the water from their high-security water entitlements, received only 32% in 2007–2008, and, in 2008–2009, only received 18% (Wheeler & Marning, 2019). As at 2019, many general security irrigators in NSW have been on 0% allocation for the past couple of years. Partly as a result of water variability, Wheeler et al., (2018) suggested that MDB irrigators in 2015–2016 recorded higher levels of psychological distress than other dryland farmers, or the general Australian population. They also found that irrigators' psychological distress varied by industry and location, with the highest levels of distress amongst horticulturists, followed by broadacre, dairy, and livestock producers.

6.2.2 Potential Influence of Organic Farming on Mental Health

One of the most researched aspects of farming and mental health is the link between the use of neurotoxic pesticides and neural systems (not used in certified organic farming) known to cause mental illness and depression (Harrison & Mackenzie, 2016). Khan et al. (2018) found that organic farmers have a significantly lower frequency of neurological symptoms and depression. Others have found that organic farmers are happier and have higher levels of life satisfaction (Cross et al., 2008; Mzoughi, 2014). However, the increased labour demands of organic agriculture, and the need to negotiate price premiums and markets, can cause additional stress (Wheeler & Crisp, 2011). There is also an argument that organic farmers' social-ecological systems approach to managing their farm (and also the greater environmental benefits derived from organic farming (Knapp & Vander, 2018)) increases farmer wellbeing (Ikred, 1993). Schirmer and Brown (2019) discuss the importance of defining farmer participation in alternative agricultural systems, on the basis of measuring their implementation of social-ecological systems-based farming principles. Their evidence shows that farmers practising alternative practices had significantly higher subjective wellbeing compared to those who only self-labelled as using alternative practices.

Australia leads the world in the amount of land devoted to certified organic agriculture (albeit it has a much lower percentage share of organic agriculture compared to other countries) (Wheeler, 2011). Especially in areas such as horticulture, growers are increasingly converting to certified organic agriculture, and name water security, finance, and environmental issues as their main motivations for conversion (Wheeler & Marning, 2019). Some other potential benefits and costs of organic agriculture include reduced input costs, poverty reduction, and improved soil conditions (Qiao, 2016; Altenbuchner et al., 2018); higher income (especially in dry years) [38,39]; and more diversified production and resilience (Ogilvy et al., 2018; Mcrae et al., 2007). In South Australia, it has been found that organic and biodynamic grape growers perceive less vulnerability to reduced water and greater resilience to water stress due to their higher soil water retention and carbon matter in soils (Wheeler & Marning, 2019). Given that Brown & Schirmer (2018) also found that farmers who undertake natural resource management techniques have improved overall mental health and wellbeing, in this current study, we seek to explore the following question: do certified organic southern MDB irrigators experience lower levels of psychological distress than conventional irrigators, holding all other factors constant? We also seek to explore how access to the five capitals (physical, social, human, natural, and financial) affects Australian irrigators' mental health?

6.3 Methods

6.3.1 Location

The location of this study is the southern MDB in Australia, which is one of Australia's most productive agricultural regions, producing more than one-third of the nation's food. The southern MDB spans New South Wales (where mostly annual cotton and rice crops are grown); to Victoria (mostly dairy and livestock); and the south-eastern part of South Australia (citrus, wine grapes, fruits, and nuts) (Wheeler et al., 2018).

6.3.2 Data

After gaining ethics approval, a telephone survey was conducted in October–November 2015 (n=1,000), with irrigators, not dryland farmers, in the southern MDB. Participants were randomly sampled, with a final response rate of 51% (or 73% including those who agreed to be surveyed but were not rung back because the sample size was achieved). The telephone survey collected information from 957 (95.7%) conventional and 43 (4.3%) certified organic irrigators living in the southern MDB. The largest number of organic irrigators was in the horticultural industry (8.3%). Overall, in our sample, certified organic irrigators, compared with conventional irrigators, were significantly younger (p-value=0.09), had lower debt (p-value=0.03), lower off-farm income (p-value=0.09), and higher farm productivity change over the past five years (p-value 0.00).

Wheeler et al., (2018) compared southern MDB irrigators stress to dryland farmers' stress, identifying stress across irrigation industries and factors broadly associated with high levels of psychological distress in the irrigator population. They found 58.5% of the irrigator population in the southern MDB had low distress (K10 scores of 10-15, explained in section 3.3.1); 24.1% medium distress (16-21); 12.1% high distress (22-29); and 5.3% very high distress (30+). This study expands on the simple methodology used in Wheeler et al., (2018) by using more sophisticated regression methods to explore the influences on irrigators' stress, as well as exploring in detail the question about the role that farm management practice, location and natural capital play. Statistical analysis was performed by STATA SE Version 16.

6.3.3 Regression Methodology

A variety of methods were tested, with an Ordered Probit model chosen as the most appropriate method to examine influences on irrigators' distress levels given the nature of our dependent variable Y^* (low—coded as 1 below; moderate—coded as 2; high—coded as 3; and very high distress levels—coded as 4):

$$Y^* = x\beta + \varepsilon$$

$$Y = 1 \; if{-\infty} \leq Y^* < \mu 1$$

$$Y = 2 \; if \; \mu 1 \leq Y^* < \mu 2$$

$$Y = 3 \; if \; \mu 2 \leq Y^* < \mu 3$$

$$Y = 4 \; if \; \mu 3 <= Y^* < +\infty;$$

where X_i is the vector of independent variables, β, $\mu 1$, $\mu 2$ and $\mu 3$ are unknown parameters to be estimated by the maximum likelihood method using the log-likelihood function , and ε is the error term, which is assumed to be normally distributed with zero mean (see Greene 2008; 831-835).

6.3.3.1 *Dependent Variable – Mental health*

Our indicator of the mental health and wellbeing of the irrigator population is provided by the Kessler Psychological Distress Scale (K10). Past research has found the K10 a valid and accurate screening and assessment tool for mental disorders (Spies et al., 2009). A 10-item self-report questionnaire was included in the survey, assessing the frequency of psychological distress over the past four weeks, with higher scores denoting greater psychological distress. Respondents indicated how frequently they felt distressed on a 5-point response format from one (none of the time) to five (all of the time) (Kessler et al., 2003). Although K10 scores are a continuous variable from 10-50, researchers usually group K10 into categories. For the purposes of this study, we used the Health and Wellbeing Survey (2000) and the National Health Survey (2001) cut-off scores: low (10–15); moderate (16–21); high (22–29); and very high (30–50) distress.

6.3.3.2 *Independent variables*

Our regression methodology utilises the five capitals as independent variables to model irrigators' psychological distress. Financial capital factors include: the percentage of off-farm income; net farm income in 2014/15; farm debt in 2014/15; farm productivity and farmland value in 2014/15 were included to estimate mental health from 2015-16. Note that earlier year financial capital values were used to avoid endogeneity issues with irrigators' mental health. Human capital variables included education (low educational qualifications; year 10 or below), age, marital status, gender and number of children, whereas social capital variables included whether the irrigator is a member of a social group and has a successor in place (expecting a family member to take over the farm). Physical capital factors included the irrigated area in 2014-15; the farm's long-term average annual yield (LTAAY)[17] of all water entitlements; and whether their farm's productivity has changed in the last five years. For natural capital factors, we included locational and place measures of drought, net evaporation, mean historical temperature, water allocations and being a certified organic grower.

Although a large number of studies highlight the significance and importance of drought on farmers' and rural communities members' mental health (Sartore et al., 2007; Gunn et al., 2012; Udmale et al., 2014; Vins et al., 2015), there is no agreed definition of drought, various definitions include: meteorological (problematic weather patterns); hydrological (lack of rain); agricultural (low commodity production); or socioeconomic (low incomes and related social consequences). In the Australian literature, it is common to define drought by a deficiency of

[17]The LTAAY is the estimated long-term average annual yield that accrues to a given water entitlement over a given time-period of 100 years

rainfall over an extended period (e.g. Stain et al., 2011; Hanigan et al., 2012; OBrien et al., 2014; Friel et al., 2014). Given the finding that an extended length of drought period seems to be most associated with mental health stress (e.g. O'Brien et al., 2014), we used a figure of 12 months of rainfall deficiency to signify drought, and used a 12 month rolling rainfall deficiency grid from November 2014 to October 2015 from the Australian Bureau of Meteorology (BOM).The rolling ASCII (American Standard Code for Information Interchange) format gridded data was converted to the raster format to create a projection in ArcMap, based on the Australian national grid. The measure of drought involved spatial analyses of the data in the ArcMap and creating a dummy variable based on the identifying the tenth percentile (or within the lowest 10% of rainfall records) rainfall deficiency for each specific area based on the statistical local area (SLA). Drought data were then matched to the location of respondents based on their available postcode.

Detailed evaporation and maximum temperature data were also collected from the BOM. Climate data were geo-referenced to spatial levels based on the SLA and then were linked to irrigators' postcodes. The definition of the full list of variables, and their summary statistics, are provided in Table 6.1.

Table 6.1: Descriptive Statistics for sMDB Irrigators

Dependent Variable	***Mean***	***Std.Dev.***	***Min***	***Max***
K10: (1=low, 2=moderate, 3=high and 4=very high)	1.64	.88	1	4
Independent Variables				
Gender (Male)	.86	.34	0	1
Age (Years)	58.66	11.41	24	90
Low education (1=higher education level is year 10 or below; 0=otherwise)	.16	.37	0	1
Marital status (1=married; 0=otherwise)	.87	.33	0	1
Number of children	2.78	1.38	0	10
Succession (1=expecting a family member to take over the farm; 0=otherwise)	.39	.48	0	1
Social group (1= being part of any social group; 0=otherwise)	.57	.49	0	1
Farm generations (number of generations)	3.10	1.42	1	14
Irrigated area 2014/15 (hectares)	242.95	523.09	0	8000
Certified organic (1=certified organic grower; 0=otherwise)	.04	.20	0	1
Productivity change (Likert scale of farm productivity change in the last 5 years:1=strongly decreasing; 5=strongly increasing)	3.22	1.21	1	5
Off-farm income (% of irrigators' total household income from off-farm work)	24.79	31.11	0	100
Net farm income 2014-15 ($1,000 AUD yearly net income)	85.36	84.53	0	250
Farm debt 2014-15 (AUD$1,000)	419.07	482.35	0	1250
Farmland value 2014/15 (AUD$1,000)	1385.16	1010.10	125	3000
Drought condition[a] (1=drought condition; 0=otherwise)	.24	.43	0	1
Mean annual historical temperature (C°)[b]	23.33	.92	20.07	25.24
Net annual evaporation[b] (evaporation minus rainfall)	1581.55	296.17	812.81	2438
Average final water allocation[c] factor in last year	.77	.32	0	1
LTAAY of all water entitlements (GL)	634.47	1405.94	0	30995

[a.]Drought is defined as the tenth percentile rainfall deficiency for the specific SLA area, based on 12 month rolling rainfall deficiency grids, from Nov 2014 to Oct 2015.
[b.]Rainfall, evaporation, and temperature data over a 30 year period (1986-2015) were collected from the BOM.
[c.]Water allocations is the seasonal amount of water received by owned water entitlements based on security and location.

6.4 Results

Table 6.2 provides the regression results on the psychological distress levels for all southern MDB irrigators, and by industry in 2015-16.

Table 6.2: Ordered Probit Regression Results on Drivers of Irrigator Psychological Distress (K10) in the sMDB

Variables	*All Irrigators*	*Horticultural*	*Broadacre*	*Dairy/livestock*
Male	-0.25** (0.03)	-0.63** (0.01)	-0.04 (0.88)	-0.19 (0.23)
Age	-0.01***(0.002)	-0.005 (0.50)	-0.02**(0.01)	-0.01**(0.05)
Education<Year 10	0.13 (0.25)	0.32 (0.15)	0.07 (0.73)	0.09 (0.59)
Marital status	-0.10 (0.42)	0.18 (0.47)	-0.40 (0.10)	-0.16 (0.39)
Number of children	0.03 (0.37)	-0.03 (0.55)	0.07 (0.22)	0.06 (0.17)
Succession	-0.08 (0.33)	0.13 (0.41)	-0.22 (0.18)	-0.12 (0.35)
Social group	-0.06 (0.40)	0.05 (0.70)	-0.24 (0.14)	-0.08 (0.53)
Farm generations	-0.007 (0.79)	0.05 (0.32)	0.005 (0.91)	-0.07 (0.11)
Irrigated area	-0.000 (0.12)	-0.000 (0.92)	-0.000 (0.11)	0.000 (0.58)
Certified organic	-0.34*(0.08)	-0.57*(0.05)	-0.11(0.80)	0.09 (0.76)
Productivity change	-0.12***(0.00)	-0.10 (0.13)	-0.19***(0.004)	-0.17***(0.006)
Off-farm income (%)	-0.003*(0.06)	-0.002 (0.39)	0.001 (0.75)	-0.006***(0.003)
Net farm income in 2014/15	-0.001**(0.02)	-0.001 (0.24)	-0.001 (0.30)	-0.001 (0.34)
Farm debt for 2014/15	0.000***(0.000)	0.0004 (0.14)	-0.0001 (0.84)	0.001***(0.000)
Farmland value in 2014/15	-0.0002***(0.004)	-0.0001 (0.45)	-0.0001 (0.42)	-0.0002***(0.007)
Drought condition	0.008 (0.94)	-0.58 (0.13)	0.16 (0.48)	0.06 (0.69)
Mean annual temperature	0.02 (0.66)	-0.009 (0.93)	0.15 (0.29)	0.11 (0.22)
Net annual evaporation	0.0001 (0.74)	0.0001 (0.72)	-0.0004 (0.37)	0.0002 (0.38)
Average allocation	-0.07 (0.58)	-0.19 (0.39)	0.27 (0.32)	-0.12 (0.60)
LTAAY of all entitlements	0.0001 (0.23)	-0.0001 (0.19)	0.0001***(0.00)	-0.0002 (0.12)
Horticulture	0.02 (0.86)			
Broadacre	0.09 (0.35)			
Constant cut1	-0.81 (0.56)	-1.10 (0.67)	1.06 (0.74)	1.13 (0.61)
Constant cut2	-0.05 (0.96)	-0.50 (0.84)	1.82 (0.57)	2.10 (0.35)
Constant cut3	0.64 (0.64)	0.10 (0.96)	2.74 (0.40)	2.84 (0.21)
Observations	910	281	253	376
McKelvey & Zavoina R^2	0.11	0.15	0.23	0.20
Pseudo R^2	0.04	0.05	0.08	0.08
% correctly predicted	0.58	0.60	0.58	0.61

Note: Robust p-value in parentheses *** p<0.01, ** p<0.05, * p<0.1

The models were estimated with robust standard errors. Checks on correlation analysis and variance inflation factor (VIF) showed that serious multicollinearity was not present (mean VIF=1.50 and strongest correlation coefficient = 2.48) (please see Appendix D for more detail). In ordered probit models, the McKelvey & Zavoina's R^2 is the closest measurement to R^2 in OLS models (Veall & Zimmermann, 1996), which ranges from 0.11-0.20. In addition, the percentage of correct prediction ranges from 0.58-0.61.

Similar results were obtained from the reduced form of the Ordered Probit models, which are summarised in Table 6.3.

Table 6.3: Reduced Form Ordered Probit Regression Model of Irrigator Psychological Distress (K10) in the sMDB

Variables	***All Irrigators***	***Horticultural***	***Broadcare***	***Dairy/Livestock***
Male	-0.25**(0.03)	-0.73***(0.002)		
Age	-0.01***(0.002)		-0.01**(0.01)	-0.01**(0.04)
Productivity change	-0.13***(0.0001)		-0.20***(0.002)	-0.17***(0.003)
Off-farm income (%)	-0.002*(0.06)			-0.005**(0.01)
Net farm income in 2014/15	-0.001**(0.01)		-0.002**(0.03)	
Farmland value in 2014/15	-0.000***(0.001)			-0.000***(0.000)
Farm debt in 2014/15	0.000***(0.001)			0.001***(0.000)
Certified organic	-0.34*(0.08)	-0.69**(0.01)		
Irrigated area			-0.000*(0.05)	
LTAAY of all entitlements			0.000***(0.006)	
Social group			-0.26*(0.096)	
Constant cut1	-1.38***(0.000)	-0.46**(0.03)	-1.77***(0.000)	-1.32***(0.002)
Constant cut2	-0.63**(0.01)	0.10 (0.63)	-1.03**(0.02)	-0.37 (0.38)
Constant cut3	0.06 (0.81)	0.69***(0.003)	-0.15 (0.73)	0.34 (0.42)
Observations	910	281	253	376
McKelvey & Zavoina	0.10	0.07	0.18	0.15
% correctly predicted	0.58	0.59	0.57	0.60

Note: Robust p-value in parentheses *** p<0.01, ** p<0.05, * p<0.1

6.4.1 Natural Capital

After controlling for a variety of influences on irrigator mental health, results suggest that certified organic southern MDB irrigators are slightly more likely to experience lower levels of psychological distress than conventional irrigators ($p < 0.08$). Specifically, the results indicate that certified organic irrigators are 4% less likely to be in the high level of psychological distress band and 2% less likely to be in the very high level of psychological distress stratum. In the horticultural industry only regression, these probabilities increase to 7% (high) and 5% (very high), and were significant at the $p < 0.05$ level. Marginal effects are calculated for each level of the dependent variables and are reported in Appendix D. This supports Khan et al., (2018), who demonstrated a significantly lower frequency of depression problems among organic farmers compared to conventional farmers. The small sample sizes of certified organic irrigators in broadacre and livestock/dairy meant that no robust results were obtained.

On the other hand, perhaps somewhat surprisingly, we found no significance for the impact of locational natural capital (drought, mean historical temperature, net-evaporation, and last year's average allocation factor) on irrigators' psychological distress. However, it is worth noting that only 24% of our sample were classified as in drought conditions using our definition. Drought started to increase in severity from 2016–2017, especially for New SouthWales. Similarly, Stain et al., (2011) reported that existence of drought was not necessarily the main driver of psychological distress for rural and remote Australian communities. Hanigan et al. (2018) also found a more complex story associated with drought, where drought duration was associated with higher distress in younger rural women but not older rural women or men. The relationship between drought and financial capital is explored in more detail in the next section.

6.4.2 Financial Capital

Compared to the natural capital results, there is strong evidence suggesting an association between financial capital and irrigators' level of psychological distress. As Table 6.2 (all irrigation industry results) illustrates, financial capital variables are the ones most associated with irrigators' mental distress. Irrigators with a lower percentage of off-farm income; lower farmland value; higher farm debt; lower farm productivity and lower net farm income were significantly more likely to experience higher distress. Specifically, the results indicate that an increase in net farm income by AUD$100,000 decreases the likelihood of being in the high level of psychological distress category by 2 percentage points and the very high level of psychological distress band by 1 percentage point . Also, an increase in farm debt of AUD$1000,000, increases the likelihood of being in the high level of psychological distress stratum by 5 percentage points and the very high level of distress category by 3 percentage points . Our result is consistent with other studies which found financial problems as the most common issue associated with farming stress (Jenkins et al., 2008; Staniford et al., 2009; Fraser et al., 2005; Fennell et al., 2016; Wheeler et al., 2018).

Considering different industries, the impact of lower off-farm income, lower farmland values, and higher farm debt were more likely to worsen mental health issues for dairy and livestock irrigators, while lower net farm income was identified as one of the key financial worries for broadacre irrigators.

6.4.3 Other socio-demographic influences

Other significant influences on southern MDB irrigators' psychological distress are being female and younger. Our results indicated that male irrigators were 3% less likely to be in the high level of psychological distress category and 2% less likely to be in the very high level of psychological distress stratum. This does not differ substantially from the existing literature which suggests females report more psychological distress than men in surveys (e.g. Walker & Walker, 1988), though male farmers have higher suicide rates. Male farmers embody a particular form of masculinity which make it difficult for them to seek help (or reveal distress, including in surveys), and thus this can increase their suicide risk (Alston & Kent, 2008). Much of the literature has found that younger farmers experience higher levels of stress-related symptoms (Walker & Walker, 1988; Elliott et al., 1995; Wang, 2005), which is probably because they are more likely to have higher debt levels.

6.5 Discussion

The results of the modelling in this paper suggest that drought and water scarcity are not necessarily the main drivers of irrigators' psychological distress, or at least, they were not in 2015–16. Resilience, defined as the ability to successfully adapt to adversity and to capitalise on opportunities and to maintain family livelihood, is one reason why some farmers do not suffer significant distress, whereas others do (Brown & Schirmer 2018). The capacity of farm families to maintain a source of livelihood is also important. Resilience, and adaptive capacity to change, are often described as relying on the five capitals: a) social (e.g. how interconnected someone is within society); b) human (e.g. age, education); c) financial (e.g. farm profitability; farm debt); d) physical capital (e.g. farm size, water entitlements, and regional factors); and e) natural capital (e.g. location and farm environmental factors). Our results highlight that, in particular, financial capital plays a very important role as an alleviator of psychological distress, and that farm management practice (natural capital) may also be very important. Correspondingly, it is not the actual industry or drought situation that drives mental distress, but the different capitals held by irrigators.

Despite the large body of research and literature that exists on farmer mental health, there has been little comparison between psychological levels of organic and conventional irrigators. The results in this paper suggest that certified organic farmers experience less mental distress. Our result adds to the other literature emerging on the link between natural capital and farm management practices, on the one hand, with farmer wellbeing on the other(e.g. Brown & Schirmer, 2018; Oglivy et al., 2019). It is important to note that our research was limited by its small sample of alternative growers (with the exception of the horticultural industry), but the results do suggest the need for increased research in this area with a bigger sample size, plus the need to follow and track irrigator mental health over time, such as looking at how farmer mental health changes as they convert to organic farming (e.g., namely the need to create a cross-sectional panel longitudinal dataset over time). Other limitations with our current methodology include the fact that in an ordered probit model it is difficult to set the ranking if the distribution is biased. Usually, K10 has more 10–15 points compared to 30–50 points.

Wheeler et al., (2019) suggests that in order to reduce the psychological distress of Australian farmers, there needs to be a combination of four main policy mitigates: 1) drought policy for farms (e.g. farm household assistance; farm management deposit schemes; insurance; better decision-making; exit packages; and reducing subsidies for inputs and outputs); 2) mental health policy (e.g. health promotion; early intervention); 3) natural resource management/extension policy (e.g. climate change policy; land and water policy; soil carbon markets; land clearing regulations; public extension support); and 4) rural economic and social development policy (e.g. basic health and education services; communications and transport infrastructure; tourism policy).

Building up the five areas of capital through the above policy mitigants will help move rural policy from a 'crisis response' approach towards a preventive approach. Numerous commentators have suggested that current Australian assistance programs may not be equitable. For example, Botterill et al., (2017) argue that current attitudes to drought assistance do not provide adequate protection to farmers from insolvency risks, and suggest other insurance schemes such as revenue contingent loans. O'Connor, (2013) also recommended crop insurance to allow farmers to become more resilient to extreme weather conditions. From a water and environmental management perspective, as argued by Wheeler and Marning, (2019), policy-makers should encourage the adoption of more agro-ecological methods which have often historically been ignored. Given the findings of the importance of financial capital on mental distress, further consideration must be given to how farmers can have a livelihood and receive money, even in the middle of a drought. Most farmers do not want handouts, however, there is a need for society to create markets and conditions where farmers are rewarded for undertaking activities that society values (e.g., protecting (and creating) environmental services, increasing soil carbon for sequestration purposes). For water policy in particular, Wheeler et al. (2018) recommended the buy-back of water entitlements, the use of exit packages, and the need to eliminate on-farm irrigation infrastructure subsidies. They argue that the flexible nature of the water buy-back policy allows for compensated farm exit, and the ability to spend the proceeds on the farm or in whatever way is seen fit (e.g., decreasing debt that is not possible through irrigation infrastructure subsidies). Helping farmers leave in a dignified manner (which includes exit packages) is preferable to many other worst case scenarios. The other issue is that subsidising infrastructure decreases capital costs and increases incentives to convert to more permanent cropping, increasing the probability of these irrigators' experiencing severe water scarcity in the next drought and losing years of investment.

6.6 Conclusion

Maintaining the physical and mental health of farmers is important for not only for their own personal wellbeing but also for society. our results indicate that financial capital seems to play the most significant role in influencing southern MDB irrigators' psychological distress, with net farm income, debt, productivity changes and land capital value being the most important influences, respectively. This research also provides some evidence that landholder governance and natural resource management (such as being a certified organic irrigator) statistically positively influences irrigators' mental health, especially in the horticultural industry (where larger sample sizes were available). Being female and younger were the other significant factors associated with higher levels of distress, while, perhaps surprisingly, no significant relationship was found between drought status, water allocations, weather patterns and psychological distress in our study year of 2015–2016. On the one hand, this reinforces findings from other literature that it is not drought that directly causes psychological distress, it happens indirectly through reduced yields, increased costs and debt, along with reduced farm returns overall. Our results suggest that those farmers who have strong financial and natural capital, adequate productivity and good land management are far better able to deal with, and are more resilient to, weather uncertainty. This paper has argued that to better build natural farming and financial capital and encourage greater risk-management strategies to withstand a hotter and drier future in Australia, the focus must be to integrate: 1) drought/climate change policy; 2) mental health policy; 3) natural resource management/extension policy; and 4) rural economic and social development policy.

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CHAPTER 7 Overview and Policy Implications

This chapter provides a summary of this thesis, including its findings and policy implications, its strengths and limitations. A series of policy suggestions for reducing the consequences of future distress, and mental health issues, among farmers are commented upon. Lastly, future research needs are highlighted.

7.1 Key Findings of the Thesis

As has been previously indicated in the literature, there is a need for large-scale, multi-disciplinary projects and co-generation of knowledge to understand the links between climatic variability and mental health, particularly for some of the most vulnerable groups (Berry et al., 2018). Thus, the aim of this thesis was the identification of the key influences on farmers' mental health. Specifically, this thesis has investigated the emotional consequences of climatic variability for both dryland and irrigation farmers in the MDB and the five different Australian states, using a variety of databases. This thesis covers a significant gap in the vast body of literature regarding climatic variability effects on farmers' mental health. The key findings of this thesis show that water scarcity is associated with worsening mental health, among dryland farmers and irrigators in the MDB. The results also highlight the importance of financial capital in influencing southern MDB irrigators' psychological distress. This thesis also provides some evidence that landholder governance and natural resource management (such as being a certified organic irrigator) is statistically positively associated with southern MDB irrigators' mental health.

Following the introduction in Chapter 1, Chapter 2 provided a detailed description of the MDB, which is Australia's most important agricultural region. An overview of climatic variability in Australia and the MDB described how the climate has changed in the past 100 years and, looking to the future, showed that experts project higher temperatures, lower levels of rainfall and, for some regions, more frequent periods of drought. It has been shown that climate change and the Millennium Drought affected the MDB's agricultural sector and contributed to farmers' agricultural worries. Furthermore, this chapter briefly summarised the recent history of water reform in the Basin, which shows the complexity of the water environment that irrigators' operate within.

Chapter 3 provided a detailed exploration of how working in agriculture exposes farmers to some of the highest rates of stress-related illnesses. It was shown that farming is one of the most stressful jobs and exposes farmers to mental health issues (e.g., depression, anxiety, schizophrenia, and eating disorders) and, in extreme cases, suicide. This chapter also highlighted some help-seeking barriers among farmers. It also pointed to the importance of mental health care for people in rural and remote communities, and the need to connect farmers to health professionals, as well as underscoring the importance of establishing training programs for health professionals.

To better examine the concepts presented in Chapter 3, Chapter 4 provided a published systematic review of relevant national and international studies on farmers' mental health. The findings showed that the most frequently reported stressors for farmers respectively were: pesticide exposure, financial problems, an unpredictable climate, and past injuries. In addition, it identified that Australian studies undertook the largest amount of research on climate and weather stresses for farmers, due to the experience of the Millennium Drought. Weather uncertainty (including drought and climate change) followed by financial problems were the most cited stress factors for Australian farmers. This chapter concluded that knowledge of risk factors for farmers' psychological disorders, and their impacts, is essential for reducing the burden of mental illness. Further, the chapter found there is a lack of long-term, quantitative studies linking climate related disasters to mental health disorders among Australian farmers. There was also a lack of attention on the financial drivers of farmers' psychological distress, as well as a lack of studies on specific groups of farmers, such as irrigators (which is highly relevant for the MDB in Australia).

In an attempt to address these identified gaps, Chapter 5 employed quantitative methods based on a unique longitudinal dataset from HILDA (14 years from 2001-02 to 2014-15), to investigate a series of hypotheses about the link between climatic variability, water scarcity, and MDB farmers' mental health (2,141 observations). The study is published and the results showed that increasing water scarcity was negatively associated with farmers' mental health in the MDB. In particular, the most important proxies of water scarcity were found to be rainfall, percentage of water allocations received and the period of drought. More specifically, a reduced number of days with rain, water allocations <30% and temperatures >32°C worsened farmers' mental health. Also, better finances (measured through farmers' annual salary) were found to be linked positively to farmers' mental health. The results showed farmers with lower incomes during drought had significantly worse mental health. However, it was found that all these influences were of greatest importance in times of drought, rather than non-drought, indicating how a variety of influences can be synergistic. Moreover, this chapter extended the analysis to five Australian states and concluded that there is a significant quadratic relationship between the previous year's summer temperatures and farmers' mental health in VIC and SA. Also, more rainy days in the past year had a positive and significant impact on farmers' mental health in NSW, VIC, and SA. Moreover, it was found that lower levels of income significantly affected QLD farmers' mental health. Also, experiencing negative life event had a significant impact on farmers' mental health in NSW, VIC, SA and WA states.

Chapter 6 continued the analysis of identifying the drivers of Australian farmers' mental health, by looking at a specific cohort of farmers: irrigators in the MDB. This published article studied how landholders' farm practices, and financial profitability impact MDB irrigators' mental health. Survey data from 1,000 irrigators in the southern MDB was used to model the drivers of psychological distress. The results showed financial capital factors (net farm income, debt, productivity changes, and land capital values) were the most statistically significant factors associated with farmers' distress. This chapter also provided some evidence that landholder governance and natural resource management (such as being a certified organic irrigator) was statistically positively associated with southern MDB irrigators' mental health, especially in the horticultural industry (where larger sample sizes were available).

Table 7.1 below highlights the key findings of the thesis and provides an overview of the significant relationships identified between climatic variability and farmers' mental health.

Table 7.1: Summary of Key Thesis Findings

Chapter	***Findings***	***Method***
Two	Australia' s climate has changed in the past 100 years and these changes have contributed to widespread crop failure, livestock losses, debt, and damage to property, resulting in greater agricultural worries for farmers.	Literature review
Two	Water managers and policy-makers in Australia have led the world in introducing demand-management strategies for water scarcity. Part of this change in management has meant increasing water scarcity has been placed back on irrigators to manage over time.	Literature review
Three	Agricultural ranks as one of the most stressful jobs around the world, resulting in farmers' mental distress and, in extreme cases, suicide. Rural men have higher rates of suicide but are less likely to seek help for mental illness, because of some help seeking barriers for farmers and other people in rural areas.	Literature review
Four	Worldwide, farming is associated with a range of mental health risks among farmers. However, there is mixed evidence regarding whether mental health issues are more prevalent among farmers than non-farmers. Weather uncertainty /drought followed by financial problems were the most cited stress factors for Australian farmers.	Systematic Literature review
Five	Climate variability is negatively associated with Australian farmers' mental health in the MDB. More specifically, reduced rainfall, water allocations <30% and temperatures >32°C worsened farmer mental health.	Correlated Random Effect modelling
Five	More rainy days in the past year have a positive and significant impact on farmers' mental health in NSW, VIC, and SA. Also, lower income, is found to negatively affect QLD farmers' mental health. Moreover, experiencing negative life event had a significant impact on farmers' mental health in NSW, VIC, SA and WA states.	Correlated Random Effect modelling
Six	Financial capital factors are the most significant factors associated with MDB irrigators' level of distress.	Ordered Probit modelling
Six	Being a certified organic irrigator is statistically associated with better mental health for southern MDB irrigators, especially in the horticultural industry.	Ordered Probit modelling

7.2 The Important Features of this Thesis

Three stages are featured in this thesis. The first is the comprehensive systematic review of 167 relevant studies, spanning 40 years, which show the main risk factors for psychological disorder among male and female farmers worldwide. The second is use of a variety of databases: such as the HILDA longitudinal survey database across 14 waves (2001-02 to 2014-

15) (2,141 observations of farmers in the MDB and 5,426 observations of farmers in Australia); and other climate databases; while the third uses a large-scale telephone survey (n=1000) of Australian irrigators.

HILDA is a broad social and economic longitudinal survey and collects information about financial and personal well-being, labour market dynamics, and family life. The HILDA survey tracks the same people over time, so it can make observations of seasonal climatic conditions' influence on mental health more accurately than cross-sectional studies. Another feature of this thesis is the use of the Geographic Information System (GIS) (ArcMap 10.2) to geo-code the climate data (drought, temperature, rainfall, and water allocation) to specific locations. All climate and weather information data per SLA (Statistical Local Area), or postcode, were estimated based on the National Grids (GDA 1994 Geoscience Australian Lambert) and then were matched with each farmer's geographic area. Preparation of the climate data is discussed further in Appendix B.

7.3 Policy Implications

The predicted future increase in climatic variability and/or drought highlights the need for effective policy development to help farmers to cope with drought's impacts. Policy programs have been reported as one of the main mechanisms that must be considered to support people's mental health in a changing climate (Hayes et al., 2018). Wheeler et al., (2019) report that there are four main possible policy mitigants for reducing the consequences of distress among farmers during drought: 1) Drought/climate change farming policy; 2) Mental health policy; 3) NRM/extension policy; and 4) Rural economic and social development policy. The following sections provide an overview of these four main policies mitigants for reducing psychological distress, and its consequences, among Australian farmers during climatic variability/drought.

7.3.1 Drought/Climate Change Farming Policy

In Australia, the establishment of drought policy, which has been developed by successive governments, has a long history (Aslin & Russell, 2008). From 1971 to 1989, drought was treated as a natural disaster with the access to welfare support payments for affected families (Botterill & Chapman, 2002). So, drought-affected farm businesses could apply for assistance under the Natural Disaster Relief Arrangements (NDRA) (Aslin & Russell, 2008). A 1989 review determined that the previous drought policy was poorly targeted, and drought was therefore excluded from the NDRA. This exclusion led to a National Drought Policy (NDP) being announced in 1992. The NDP was based on principles of self-reliance and risk management and it determined that drought would be viewed as a business risk, rather than a natural disaster, reflecting neo-liberal economic policy approach (Botterill, 2003; Alston & Kent 2004). Also, in 1992, the Income Equalisation Deposits (IED) scheme and the Farm Management Bond (FMB) scheme were introduced. These schemes were income smoothing schemes, and farmers were encouraged to use these programs to manage their drought risk (Botterill, 2003). These schemes also allowed farmers to deposit pre-tax income for use in later years and provided mechanisms to encourage farmers to increase their self-reliance through improved risk management (Botterill, 2005).

Although self-reliance was a key term in the NDP's objectives, the NDP also recognised that there are severe events that are not manageable for many farmers. So, if the weather conditions are sufficiently intense the affected areas can be declared as experiencing Exceptional Circumstances (EC) (White & Karssies, 1999). Thus, the Rural Adjustment Scheme was proposed to support the NDP in two ways: a) assisting farmers in improving their management skills for dealing with "normal" drought; and b) providing extra assistance in the event of an EC (Botterill, 2005). To be classified as an EC event, the event must be rare (not have happened more than once, on average, every 20 to 25 years) and cover events outside the range of "normal" (Aslin & Russell, 2008). However, the EC requirements were not limited to drought events; they were planned to support farmers faced with any type of exceptional events that were beyond the capacity of good management (Botterill, 2010).

Another major policy announcement relating to rural Australia was the Farm Household Support Scheme, developed by the Commonwealth government. This scheme was proposed to encourage those farmers who seemed to be without a long-term sustainable future in farming to leave the industry (Botterill, 2003). This scheme linked the established drought relief payments with the 'Exceptional Circumstances Exit Package' (Botterill, 2005). With this package, farmers could receive some financial compensation for selling their farms and some support in adapting to a new business or employment (Stehlik 2009). This package consists of an Exit Grant, which offered a taxable payment, an Advice and Retraining Grant, and a Relocation Grant (DAFF, 2014). An earlier version of the Exit Package was the MDB Small

Block Irrigators Exit Grant Package, which implemented by the national government until early 2010 (Zuo et al., 2015).

In 2011, after the Millennium Drought, primary industries ministers agreed to a new framework to support farmers and their families without the need for EC declarations. The important part of the new package was removing the national EC Interest Rate Subsidy, because it was determined that the interest rate subsidy neither helped the farming community to prepare for drought, nor improved risk management (Ludwig, 2012). However, by 2013, drought had returned to large areas of eastern Australia, so, there were once again calls for financial support, including calls for interest rate subsidies. Thus, in February 2014, another new drought assistance package, with subsidised loans, was announced to support farm businesses, farm families, and rural communities facing hardship (Peterson, 2016). The latest drought policy package in 2019 revealed an additional Farm Household Support supplement, which is available for farmers in need in two instalments. The Government has simplified the support process and made it easier to succeed by increasing the net asset threshold cap from $2.6 million to $5 million (DAFF, 2019).

7.3.1.1 *Benefits and Weaknesses of the Drought Policy*

Botterill et al., (2017) argue that current attitudes to drought assistance are not reasonable and do not provide adequate protection to farmers from insolvency risks. They suggest that the government can minimise taxpayer subsidies while at the same time delivering insurance for farmers against default (Revenue Contingent Loan). Also, the attitudes of individual farmers in relation to risk has not changed, and there is no single drought strategy that addresses the needs of all agricultural sectors at the industry level. Thus, farmers decide on their own drought strategies according to their expectations and financial position (Watson, 2019). Further, several farmers in a study by Alston (2007), noted that the EC process was too complicated, cumbersome, and slow and that there was no guarantee that those farmers in poverty would receive some assistance. As a result, farming families caught in a cycle of poverty, were seeking off-farm work in order to maintain some cash flow. This often made them ineligible for welfare support even if the area was finally declared to be in EC. Moreover, while Australia accepts gender mainstreaming, the consequences of drought policy for women have not been addressed through any formal mechanisms, and the social construction of women as less important in agriculture continues (Alston, 2006). Moreover, there are some arguments that the drought policy settings are expensive. Botterill (2005) stated that in October 2003, the Commonwealth Minister announced that spending on the 2001-03 drought amounted to more than AUD$1 billion. She also argued that spending of this extent increases questions of the fairness of the distribution of funds to farmers relative to other groups in the community.

On the other hand, Botterill (2010) identified that the government is supporting a risk management approach to drought by providing a tax-related savings mechanism to encourage farmers to build financial reserves—the Farm Management Deposit scheme. The scheme, has been shown to be an effective mechanism for farmers to accumulate financial reserves during high revenue years for use during downturns. She argues that this mechanism attracts favourable tax treatment, which decreases the farmers' tax burden and encourages savings in high-income years, thus providing financial reserves for future downturns. Chapman et al., (2004) stated that an income related loan is another potential improvement in delivery of drought relief to farmers. The recovery of funds from farmers once their economic position improves, can reduce the cost of drought relief to taxpayers and can make support available to more farmers. They noted that compared with the existing interest rate subsidies, an income related loan offers some advantages as it is more equitable, effective and efficient means for delivering drought relief to farm business. McColl et al., (1997) stated that providing grants or loans to obtain farm management skills is effective in raising productivity. Also, providing regional support and investment programs sometimes offer as an alternative approach to directly assist producers by minimising third party effects, stimulating regional economic activity and creating employment opportunities (McColl & Young, 2005).

From an economics perspective, assessment of drought policy should be consider whether there is a clear market failure justifying intervention and whether specific intervention strategies result in overall net gains to the community through improvements to efficiency in resource allocation and/or to welfare improvements (O'Meagher, 2005). Kokic et al., (2007) argue that the bio-economic modelling system (e.g., adjust an econometric model of farm incomes to agro-ecological models to forecast crop and pasture growth for the coming season), will close the policy-relevance gap between climatic science and decision making, and can be used to enhance the value of climate science to Australian drought policy.

7.3.2 Mental Health Policy

In 2000, The *National Action Plan for Promotion, Prevention and Early Intervention for Mental Health* was formulated. The Plan outlines strategies that help improve mental health at the individual, family, community and societal levels (Fragar et al., 2008b). However, the development of the farmers' mental health program was not introduced directly within the 2000 Action Plan framework (Fragar et al., 2008b). In July 2006, The Council of Australian Governments (COAG) had agreed to a National Action Plan on Mental Health, providing an opportunity to support people in managing their mental illness appropriately. The COAG had decided to establish new arrangements for the Commonwealth and States and Territories to work together to effectively implement commitments. For example, the Action Plan included specific policy directions to improve its ability to meet patient's needs in rural and regional areas and for Aboriginal and Torres Strait Islander people (COAG, 2006). Further, the Australian Centre for Agricultural Health and Safety introduced a Blueprint in 2006 by the NSW Farmers Association, along with 18 other organisations. Fragar et al., (2008b; p.174) noted that the "*Blueprint provided a useful means for all agencies to recognise key issues that are open to preventive action, and for identifying the complexity and interrelationship between risk and preventive factors".* They also noted that the Blueprint provided the means to define the key roles that each agency participating in the Network could play in improving the mental health and well-being of the farming population. Hart et al., (2011) added that the Blueprint marked the need for a program to link farming communities to more effective local responses to meeting mental health needs. Further, in 2007, in response to a major drought in NSW, the NSW Government funded the Drought Mental Health Assistance Package (DMHAP). The program was designed to improve mental health promotion, and early intervention and also to help build individual, service provider, and community capacity to cope with drought (Tonna et al., 2009).

With the focus on improving rural communities' mental care, some other short-term interventions to reduce mental issues in rural areas have been reported. For example, the Access to Allied Psychological Services component of the Better Outcomes in Mental Health Care program was introduced in July 2001 to provide better outcomes for individuals with common mental health disorders. The services offer short-term psychological interventions: referral pathways for GPs; non-pharmacological methods for the management of common mental disorders; and help to bolster a team approach to the management of mental disorders (DOH, 2001). It has been shown that the project have the potential to improve access to mental health care in rural areas (Morley et al., 2007). In 2005, The Rural Mental Health Support line (24-hour support service), was established for some of the immediate mental health needs of farming families and other residents of rural communities in times of drought. However, the number of calls did not have a significant linear relationship with the percentage of the state declared in drought (Crockett et al., 2009), implying that other important factors besides drought contribute to mental health problems in rural Australia.

It is well accepted that an adequate mental health policy is necessary to reduce the potentially negative impacts of drought in rural areas and among farmers, but there has not been an integrative framework to guide research or policy-making (Berry et al., 2008). Allan (2010) argues that a better understanding of the causes of mental health and well-being in rural and remote areas is very important to develop a policy and to make all the necessary changes to existing mental health policies. Wheeler et al., (2019) reviewed all current research and showed that there are very few studies that provide information on mental health policy programs in drought-affected communities, while there is very little specific consideration on farming communities. Recent studies have not focused much attention on the willingness of community members to seek help; cultural and attitudinal change; improved mental health wellbeing; and decreases in suicide or self-harm (Wheeler et al., 2019). Alston (2007) argued that the distribution of services in rural areas is not uniform and there are critical gaps in service delivery. She pointed out that it is difficult for rural communities to know where to turn for help.

In an international review of mental health promotion effectiveness, Jané-Llopis and Barry (2005; p. 53) outlined recommendations to consider when designing a mental health promotion program. Their recommendations are as follows:

1. Development and implementation of mental health promotion programs based on the principals of efficacy and process that is empowering, collaborative, participatory and that includes partnerships with key stakeholders
2. Clarify key goals and objectives of the action plan and its programs and specify the key resources required for effective implementation, including training and support mechanisms
3. Take into account all key factors that will enhance intervention efficiency when designing a mental health promotion strategy; for example, undertake a needs assessment of the population, and an analysis of the determinants of mental health

4. Support capacity building and training in mental health promotion for effective action across a range of settings
5. Develop and sustain a system of monitoring and evaluation of process, impact and outcome evaluations of mental health indicators
6. Build on existing health promotion programs and integrate a mental health promotion component already being implemented such as health promoting school, home based educational interventions, health promotion in the workplace and in the community
7. In the adoption and adaptation of a given programme or strategy across diverse cultural and economic settings (e.g., low income countries), consider their feasibility, efficacy and sustainability in settings with low levels of infrastructure.

On the other hand, some short-term rural mental health assistance packages have been reported as being beneficial. For example, the Drought Mental Health Assistance Package has effectively targeted mental distress that may arise directly from the impact of drought (Tonna et al., 2009). Further, Mental Health First Aid training, in response to the increasing levels of mental health issues arising from the prolonged drought, helped participants from rural areas to increase their confidence, and improved their understanding of mental health problems (Hossain et al., 2010). Similarly, the Tasmanian SheepConnect program, to help the development of psycho-social support services for drought-affected rural communities, was helpful in maintain morale (Hunt et al., 2011). Wheeler et al., (2019) reviewed all current research and showed that the common thread in much of the literature was the need for prevention rather than mitigation. They suggested ways to achieve this through: a) longer-term strategies; b) ongoing rural mental health care; c) continuity of service funding with less reliance on crisis-driven responses; and d) improved community capacity building.

7.3.3 Natural Resource Management

The term Natural Resource Management (NRM), refers to policies and programs provided by government or non-governmental organisations and has been a guiding framework for environmental management in Australia for several years (Browne & Bishop, 2011). The Australian government has developed a range of programs for sustainable agriculture and to protect Australia’s natural resources (e.g., the National Landcare Program and those funded under the Natural Heritage Trust) (Nelson, 2004). Cockfield & Botterill (2013; p.136) outlined the history of government NRM programs with the following stages: the Natural Heritage Trust

(1997–2008); the National Action Plan on Water Quality and Salinity (NAP) (2001–08); the National Water Initiative (NWI) (from 2004); the Water Act 2007, which led to the MDB Plan (please see Chapter 2 for an overview of the development of the MDB Plan).

Initially, publicly funded NRM programs began with a focus on threats (e.g., pest plants and animals, and soil erosion) to the productive capacity of agriculture and developed strategies to manage those threats. The New South Wales Soil Conservation Service was the earliest, with the introduction of the Soil Conservation Act 1938, while the Victorian Soil Conservation Act of 1940 authorised forming the Soil Conservation Board in that state (Curtis & Lefroy, 2010). Then, in 1996, there was a significant shift in policy orientation towards building on the Landcare model (Dovers, 2013). This approach highlights the need for public investment in those parts of the landscape with high value, rather than protecting large areas against broad-scale threats (Dovers, 2013). Later, a condition-based approach to NRM was proposed based on the best of the threat-based and asset-based approaches. The new plan aims to investigate in the social, economic, human, and cultural capital required to support lasting change (Curtis & Lefroy, 2010).

The social framework of NRM is considered a significant contributing factor influencing the success or failure of landscape improvement programs (Green & Dzidic, 2014). The NRM helps farmers address environmental degradation through some programs —e.g., revegetating the land, protecting streams, or altering their farm management practices (Schirmer et al., 2013). Some argue that NRM activities help landholders/farmers increase their resilience in facing the effects of drought through increasing groundcover, increasing water use efficiency, reducing the loss of pasture during dry times, and increasing planning for risks associated with drought (Brown & Schirmer, 2018). Although NRM is not concerned with human health, studies reveal that farmers are often sensitive to changes on their land and to their relationship with it (Berry et al., 2011b). Schirmer et al., (2013) argued that NRM practices and improving the physical environment of the agricultural landscape are practices that may influence farmers' wellbeing. King et al., (2009) argue that the resources and strategies utilised by farmers to build resilience, and therefore mental health and wellbeing, are determined by family, government, economy and society. Thus, to provide adequate support to farmers, policy advisers who plan, and implement Australian and state government programs, need to understand and influence farmer's adoption and adaptation of improved natural resource management practices (Nelson, 2004). It has been argued that current policies are not efficient enough in the sense that they pay farmers for the adoption of alternative practices rather than per unit of environmental benefit provided by the practices, and therefore do not account for the spatial variability in costs and benefits related to the adoption of developed management practices (Antlea & McCarl 2002). Wheeler & Marning (2019) argue that policy-makers need to focus more on adaptation rather than adoption natural resource management (e.g. water management policy). In particular, greater attention needs to fully understand the benefits from improved soil management from a range of agricultural practices, and help develop soil carbon markets for farmers to capture those benefits. They also noted that learning about agro-ecological practices is best coming from other farmers; hence it requires a new focus on the role of social and human capital in relation to natural resource management adaptation.

Carbon markets offer opportunities for NRM agencies and landowners to generate profits through mitigation and sequestration activities and can be a useful activity to help reduce greenhouse gas emissions, restore landscapes, and to achieve NRM objectives (Reeson, 2009). Marland et al., (2001) discuss success in sequestration of carbon in agricultural soils depend on the incentive structure developed and the way in which carbon sequestration is integrated into the total fabric of agricultural policy.

7.3.4 Rural Economic and Social Development Policy

Severe droughts are not only environmentally devastating but can also be an economic disaster in regions (Ding et al., 2011). Low farm incomes have been a focus of farm policies in Australia for many years, with policy aimed at reducing poverty and stabilising farm income levels (Kenny et al., 2008). Given farm poverty in Australia in the 1930s and 1940s, the focus on farm incomes turned to encouraging effective production at prices that are fair to the consumer and offer an adequate return to the producer (Botterill, 2007). The first major government involvement in the area of farm finance was the Loan (Farmers' Debt Adjustment) scheme, which started in 1935 and continued until 1971. The scheme was followed by a series of Rural Reconstruction and Rural Adjustment Schemes, which were a contradictory mix of industry policy measures and farm welfare support (Botterill, 2016). Since 1971, some other wide-ranging rural adjustment schemes, with a range of purposes from debt assistance to encouraging exits from agricultural industries, have operated (Cockfield & Botterill 2006). However, before 1972, levels of support and the nature of the policies differed between industries; for example, while some industries, such as dairy, were highly assisted, others received nearly no support for many years (Lloyd, 1982).

The Australian Government released the Agricultural Competitiveness White Paper (White Paper) in July 2015. The White Paper aims to be a clear strategy to improve the affordability and profitability of the agricultural sector, improving its contribution to trade and economic growth, and building its productive capacity through innovation (DA, 2017). It also includes money for Farm Business Concessional Loans, to break down technical barriers, manage pests and weeds in drought-affected areas, increasing the Farm Management Deposits (FMD), and increasing Farm Household Allowance case management for farmers (DA, 2017). The White Paper argues that the ability of farmers to secure investment is an essential aspect of farming. Thus, the shift towards private investment in farming, and the governments' role as an enabler of this shift, is described as a strategy to manage the ongoing financial sustainability of Australian farmers (O'Keeffe, 2017). However, the business models identified in the White Paper scheme limit farmers' level of control over decision making about their farms. This might lead to farmers' dependence on private capital. Thus, there are some arguments that the Australian Government has not considered how the White Paper might change land-use decisions, and the environmental, social, and economic consequences of these decisions (O'Keeffe, 2017).

There is some suggestion for the development of policies that lead to real change. For example, Wittwer & Dixon (2013) argue that voluntary and fully compensated buybacks are much cheaper than infrastructure upgrades as a means of obtaining a target volume of environmental water, even during drought. Thus, there should be some funds reserved for infrastructure upgrades redirected towards services such as health, education, and aged care in Basin communities.

The social impacts of prolonged drought in rural areas have been significant, resulting in poorer health and educational standards, lack of services and infrastructure, loss of employment opportunities and increasing social isolation (Alston, 2002). In areas affected by environmental crises, the concept of social vulnerability has arisen to describe the capacity of people to cope with the impacts of environmental changes. Social vulnerability outlines degrees of poverty and inequality to explain and describe variable adaptation amongst those experiencing natural disasters (Alston, 2017).

With the impacts of globalisation on rural economies and the rising costs of services, many rural areas are struggling to retain essential human services, such as education and health (Halsey, 2009). There is little research directly examining the social impact of drought on education and training in Australian rural areas (Aslin & Russell, 2008). Alston & Kent (2009) argue that as a result of social exclusion, rural and remote young people's access to education and employment is restricted. Also, there is some evidence that increased workloads and increased debt among farming families lead to an increase in working hours, which has affected young people's schooling (Aslin & Russell, 2008). Wallace & Boylan (2007) stated that there are unfair strategies affecting education in Australian rural areas and that policies often reflect a city-based view of rural areas. Guenther et al., (2015) argue that how students get to school and home again plays a vital role in influencing whether children in rural and remote areas can access education. Halsey (2011) stated that transporting students to bigger, better equipped, and well-staffed schools, based on the policy of consolidation adopted by the South Australian Education Department, helped in the development of area schools. This consolidation was worthwhile because the cost of providing transport was less than the cost of staffing and maintaining small one-teacher rural schools.

Further, there is some evidence that staffing of rural, remote, and isolated schools has been a significant issue of concern in Australian education. Teachers have faced some professional challenges such as isolation, teaching outside their expertise, and teaching multi-age classes; along with some personal challenges, such as social isolation, fitting in with their new community, and a lack of privacy (Downes & Roberts, 2018). Studies highlight that rural schools: have higher teacher turnover rates; teachers who feel personally, socially, and professionally isolated; and fewer services and facilities (Wallace & Boylan, 2007; Lyons, 2009). Rural education has been a challenging and problematic policy area for Australian governments (Halsey, 2009). Downes & Roberts (2018) argue that there has been a better focus on preparing teachers for rural settings, rather than with providing motivations to encourage teachers to adopt a rural position. In contrast to concerns about the staffing in rural and remote schools in Australia, McConaghy (2006) suggests that there is a need to consider teacher transience in new ways; for example, there is a need to focus on the question of how we can get teachers to stay in rural areas within the broader social and political contexts. Lock et al., (2012) argue that financial benefits, and improved housing are other ways to attract teachers to rural areas. Halsey (2009) argue that pre-service teachers need to have access to the improved social capital to allow them to be an effective educator, and community member in a rural setting. Social capital can be defined as networks and associated values, participation in voluntary organisations, informal networks, and levels of trust, reciprocity, and belonging (King et al., 2009).

According to Alston (2007), there are no drought-specific social support services in some areas and the distribution of services has not been uniform, with some areas losing services altogether and others having multiple service providers. Moreover, human services in rural areas are mostly overloaded and not adequately resourced, and delivery of human services in times of crisis is not straightforward. So, it is necessary for policy-makers to continue to promote policies that support the farming communities more broadly.

7.4 Future Policy Improvements

The findings of this thesis support the view that farmers' mental illness is a result of a interplay between social, environmental, and economic factors. Thus, future social, environmental, financial, and health policy needs to consider how best to address these issues in the most effective way to limit the adverse impacts of climate change and to improve farmers' mental health. Policy reviews have shown that some of the current assistance programs are not equitable and do not adequately protect farmers from the risk of insolvency. O'Keeffe (2017) stated that, in recent decades, Australian agricultural policy has shifted from protecting farmers towards protecting markets, which re-imagines governments' role in agriculture. Cockfield & Botterill (2013) argue that instead of an underlying movement across time, policy attention has shifted according to political, climatological, and market conditions. They noted that current rural policies could not be explained as a case of punctuated equilibrium, rather the increasing power of the Commonwealth, an increasing focus on the international economy, and few direct payment obligations to farmers may have enabled the change. Ross & Dovers (2008) argue that leadership capacity, the long period of embedding of policy integration, and implementation capacity, are the most noticeable barriers to, and gaps in, environmental policy. Thus: better leadership, cultural change and capacity building; embedding sustainability in structures and processes; development of long-term evidence-based approaches; strengthening decentralised implementation arrangements; and evaluation of policy integration initiatives are factors deserving further research and policy attention. O'Connor (2013) recommend a form of crop insurance to allow farmers to use their farm management skills to become more resilient to extreme weather conditions. She argues that crop insurance program reduces the risk of crop loss by offering technically sound management practices, which both reduce the risk of loss in the near-term, as well as building soil health and increasing productive capacity in the long-term. Head (2008) suggested that there are three broad types of knowledge (political knowledge, researched-based knowledge, and practical implementation knowledge) that are essential to the design, implementation, and evaluation of policies and programs. Warner et al., (2009) argued that traditional insurance schemes for risk reduction investment requires differentiation in premium levels; that is, charging premiums that reflect the true level of risk (and hence, offering appropriate discounts for risk reduction). The National Flood Insurance Program (NFIP), a publicly-funded insurance programme in the United States which has replaced the private market is an example of this. Another example is the insurance pilot packages loans and insurance for smallholder farmers in Malawi, which enabled them to buy affordable index-based drought insurance. Linnerooth-Bayer & Mechler, (2008) argue that insurance and other risk financing strategies are efforts to recover from negative income shocks through risk pooling and transfer. Borensztein, Cavallo, & Jeanne, (2017) estimated the welfare gains that a small open economy can derive from insuring against natural disasters. They found that the countries' most vulnerable to these risks would find it optimal to use insurance. From a water management perspective, as argued by Wheeler & Marning (2019), policy-makers should encourage the adoption of more agro-ecological methods which have often historically been ignored. They noted that a successful adaptation policy will need farmers to adequately study both internal and external factors for future adaptation and for adaptive capacity in general (e.g., an exclusive water security orientation towards external factors may increase farmers' vulnerability to shocks happening). Wheeler et al., (2018) recommend that future water policy must focus on encouraging farmer adaptation by supporting the buy-back of water entitlements and eliminating on-farm irrigation infrastructure subsidies. They argue that the flexible nature of the water buy-back policy allows for compensated farm exit, and the ability to spend the proceeds on the farm or in whatever way is seen fit (e.g. decreasing debt which is not likely through irrigation infrastructure subsidies). The other issue is that the infrastructure subsidisation policy drops capital costs and rises incentives to convert to more permanent cropping, resulting in increases the likelihood of these irrigators' experiencing severe water scarcity in the next drought and losing years of investment (Adamson et al., 2017). Hatton MacDonald et al., (2014) investigated the accessibility and usefulness of the Ecosystem Services (ES) framework to policy analysts and examined how an ES assessment of the benefits of restoring water to the MDB has been used by government agencies in policy and planning. They identified that the ES assessment raised awareness and this may lead to broader usage of the information and framework in the implementation phase of MDB water reform. Brown et al., (2015) reported financial capital with low profitability and high land costs as farmers' major constraint to climate change adaptation. They suggest high education and intellectual ability, involvement in active industry and farmer groups, current favourable climate and good access to markets are the factors enabling adaptation.

One of the major criticisms of the previous Australian government drought policy is the availability of the developed commercial agricultural risk-management options (Laurie et al., 2019). It has been argued that Australian agricultural risk management systems are less developed than other countries and Australian farm businesses use a range of different strategies to manage risk in a highly volatile operating environment with little to no government support (NRAC, 2012). A more comprehensive range of risk-management opportunities as one of the outcomes of the 2013 Intergovernmental Agreement was expected. However, the revised National Drought Agreement (COAG, 2018) signed between the Federal, state and territory governments seems materially similar to the 2013 agreement (Laurie et al., 2019).

7.5 Policy Recommendations

Current policies need to be carefully reassessed, with greater emphasis given to building the resilience and the adaptive capacity of rural and farming communities. Based on the results discussed within this thesis, a series of policy recommendations have been developed. The first recommendation is derived from Chapter 5 which showed that the climatic variables and water scarcity were negatively associated with farmers' mental health in the MDB. This issue warrants further action and assistance concerning climate-related mental health issues for farmers in rural areas. It is suggested that there is a significant need for greater health spending in rural areas. Further, it is essential that policy-makers develop responses that address the economic, social, environmental, and political dimensions of Australian farming communities' well-being. Developing Mental Health First Aid training in order to help farmers to improve their knowledge of mental health issues, and improve their understanding of mental health problems, as suggested by Hossain et al., (2010), could be beneficial (see Chapter 3 for more discussion of intervention programs to improve mental health outcomes in rural communities). Moreover, some policies to concentrate on strategies to mitigate future climate change and global warming are warranted, especially as this will be critically linked to the future effective development of drought farm risk-management strategies such as soil carbon markets. In the face of climate change, policy-makers must avoid poorly designed strategies that increase producers' reliance on risky inputs. In addition, further attention must be given to a) reconfiguring irrigation landscapes and b) facilitating exit and increased risk management issues (such as greater insurance schemes) (Botterill et al., 2017; Wheeler et al., 2018).

Laurie et al., (2019) suggested ways to help build risk resilience across agricultural subsectors and into supply chains including: a) industry bodies and advocacy groups have a responsibility to monitor new and developing institutional risks as they are a multi-faceted and significant threat to many agricultural sectors; b) government and industry should cooperate on a steady education approach to increase the sector's level of financial literacy and awareness of types of risk and offer information and resources to improve diverse methods; c) behavioural economics filters (e.g., perceptions of cost related to risk appetite) should be applied in the development of risk managements products such as insurance and derivatives to advance uptake; d) weather derivative products competing in the agricultural insurance market place should be licensed in the same manner as other insurance products; e) government and official statistics agencies (e.g., ABS, ABARES) should collaborate with industry to support and assist the supply of appropriate industry data to make risk information more readily accessible; f) continued investment in R,D&E to develop new technologies (such as more drought tolerant fodder species and grain types) and better weather and climate forecasting should be considered a necessary part of the Government's investment in risk mitigation.

The results from Chapters 5 and 6 also demonstrate that farm income was of key importance in times of drought, rather than during non-drought periods, and that financial factors were the major reason for farmer stress. This leads to the recommendation of the need for financial, risk-management and business management principles as a primary method to help drought-affected farmers. Further, in the face of increasing drought conditions in Australia, policies on farmers' decisions to adopt adaptation measures in times of drought is warranted. Further, as discussed, climate change and natural disasters pose a severe challenge to the sustainable livelihoods framework (Zhao et al., 2019). New policies such as disaster emergency relief package and budget allocations, need to apply towards helping the most vulnerable groups, including farmers, to achieve sustainable livelihoods.

Chapter 6's finding that being a certified organic irrigator was statistically positively associated with better mental health for southern MDB irrigators also suggests a need for improved policy programs to support greater natural resource management practices. Wheeler (2011; p.906) suggested ways to achieve this through: a) creating clearer property rights; b) having better information provision through research and extension; and c) formulating market based instruments for environmental services. Wheeler & Marning (2019) also suggested more focus on agro-ecological methods and sustainable solution to water saving through the enhancement of soil water retention. Also, there is an obvious next step to help farmers who have difficulties. Greater communication may be the key. Questions to seek answers to include: do they need financial help, access to mental health services, any specific education sessions, or is it something else?

7.6 Summary of Policy Implications

It is more likely that farmers will accept the economic, social, or physical risks of changing their farming practice if they feel they have support (Sobels et al., 2001). Cockfield & Botterill (2006) argue that there is minimal direct impact from government policies on overall adjustment in rural industries. In other words, rural adjustment schemes are rather unbalanced, compared to other sectors which accept significant modification with little adjustment funding. Moreover, the irregular nature of human services in rural and remote areas and the structuring of drought-support services, in terms of financial and business management principles, show that policy formulation and service coordination have been less prominent than they could have been (Alston 2007). Thus, what is necessary is a robust focus on policy that acknowledges the difficult circumstances of rural and remote people and their families, and builds opportunities, rather than barriers, to their participation (Alston & Kent, 2009). There is still uncertainty about the effectiveness of proposed policies in Australia. Sysak & Beilin (2017) state that whether the drought policy will be an effective way to manage drought in Australia is yet to be seen. In Australia, past policy has been targeted to cope with risk (through government disaster relief programs) rather than mitigating or transferring risk, although this policy has changed significantly recently. If this change of policy is to be successful, then a range of ways addressing multiple risks for multiple stakeholders needs to be available (Laurie et al., 2019), and nowhere is this more true than the irrigation sector.

7.7 Limitations and Future Work

While this thesis has provided new and useful information about farmers' mental health, it is not without limitations. This section highlights the challenges faced, how they were dealt with, and the possible effect on the results. Limitations included potential missing information in the systematic review, drought definitions and data and modelling limitations.

The systematic review of 167 relevant studies in Chapter 4 was undertaken to understand the issues surrounding farmer mental stress. It is well accepted that, although using systematic review principles can help researchers improve the extent of literature reviews, there might be literature inadvertently missed, particularly the grey literature. In addition, our focus was primarily on farmer distress, and not necessarily farmer well-being (which is a broader topic). Additional insights may be gained from broadening the scope in the future.

A mentioned in Chapter 5, measure of 'farmers' in the HILDA dataset is a broad occupational definition and hence includes both dryland and irrigated farmers, so it was not possible to distinguish between types of farmers; dryland or irrigated farmers; or dairy farmers versus viticultural farmers. These differences can be important for investigating the individual impacts of water scarcity. For example, the percentage of water allocations received is most likely to have greater importance for irrigators' mental health than for dryland farmers' mental health. In addition, as the HILDA survey is designed mainly as a household survey, not a farmer survey, there was only limited information available on farm characteristics (e.g., farm rate of return, debt, and farm type). Also, the sample size of farmers in the survey was not very big (n=235 in the MDB and n=562 in Australia), however, given the longitudinal nature of the dataset, over 2,000 observations were available in the MDB alone. Further iterations of the HILDA survey, especially over the current drought, may offer more insights and a larger sample size.

Merging climate and water allocation data based on SLA/postcode with the HILDA dataset might not be adequate because SLA/postcode areas are not typical units at which climate or water data are provided. Climate data usually report with the station names and numbers with a specific locality, and water-related information is usually reported at the larger river valley level. Thus, SLA/postcode areas needed to be geo-referenced to the closest area of the station numbers or river valley.

As mentioned in Chapter 6, research data from the irrigators' survey was limited by its small sample of organic growers (except for the horticultural industry). The results may suffer due to the smaller sample size. There is also need for future research to track mental health of organic farmers converting over time from conventional to transition to fully organic. This will provide more evidence on the causality impact of organic practise on farmer mental health.

Another possible research limitation of this thesis relates to the definition of drought. The definition of drought is itself complex. Although it is common to define drought by a deficiency of frequent rain events over an extended time, factors apart from rainfall deficiencies are often used in a drought declaration. Hence, the BOM does not declare drought, though they provide information on areas considered to be suffering from a serious or severe rainfall deficiency (lowest 10% and 5% of records). Therefore, the difficulty of defining drought is reflected in any assessment of its consequences. Among the many available drought indices, there is no agreement on the best measure (Zargar et al., 2011). Given the focus of this thesis on climatic conditions, it considered meteorological drought. However, it may also be just as relevant to consider the impact of other types of drought (hydrological, agricultural, and socioeconomic) on drought-related stress among farmers.

Several avenues for future work have been identified in this thesis. First, from the systematic review research, it has been shown that most studies on farmers' mental health were from developed countries, most specifically from the United States, Australia, and the United Kingdom. Thus, further research will be required on climate change impacts on farmers' mental health in developing countries, as well as information on how to reduce help-seeking barriers amongst farmers. It is important to investigate how to break down the help-seeking barriers amongst farming communities to decrease the risk of their mental disorders, as well as understanding how different types of policies can influence farmers' mental health issues. Also, it is identified that compared to the research on male farmer's mental health; limited research is available on female farmers' mental health. Considering that female farmers experience more psychological distress than male farmers (Walker & Walker, 1987; Hanklang et al., 2016), future research may need to work more specifically on female farmers' mental health. Additionally, as mentioned in Chapter 3, given the well-documented hardship many farmers experienced during the prolonged drought in Australia, there is surprisingly little research on possible associations between drought and Australian farmers' suicide rates. It has been revealed that the impact of each suicide extends beyond the tragic loss of an individual life, affects the victim's family, friends, and members of their community (Leo & Sveticic, 2007). So, there is a clear need for future studies on the effects of climate on farmers' suicide rates and suicide prevention among them should be the focus of sustained action and policy. Further, a time-series analysis of suicide rates/attempts of farmers across time and space needs more research.

This thesis found a lack of information on the outcome of policies (e.g., before and after policy implementation). As shown, there has been considerable money, time, and effort invested in various drought, mental health, social, and financial policies. However, there has not been adequate evaluation of their effectiveness. Also, very little research on the link between climate change and policy development for women has been reported. Women have increased their efforts in the wake of climate and policy changes and their efforts go mostly ignored beyond the farm gate (Alston et al., 2018). Thus, a greater understanding of how policy implications reduce the consequences of distress among female farmers during drought is required.

Other areas where there are clear gaps in the farm health literature include the Indigenous farming population and children living on farms. Given the argument that during a drought, children are at particular risk, with impacts on their schooling, emotional wellbeing, and suicide rates (Dean, 2007), this area warrants further examination. Also, while at all levels of Indigenous people are more disadvantaged (Alston & Kent, 2009), this research reveals that there is a clear need for policy focused on improving Indigenous farming communities' mental health.

Moreover, as mentioned before in this thesis, the panel data analysis was only possible for the household survey. Therefore, a suitable farm level longitudinal survey would be beneficial to further improve the understanding of factors potentially affecting Australian farmers' mental health.

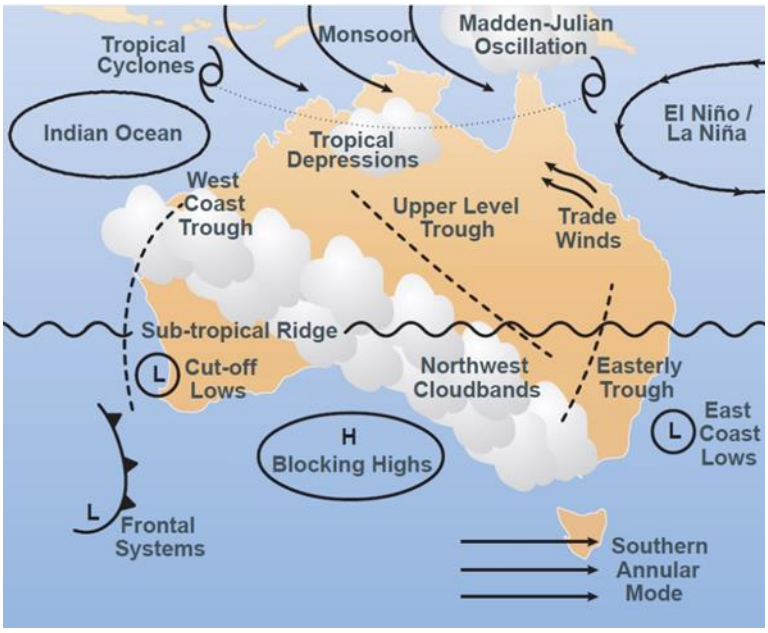
Also, further research is warranted to better understand the results of the association between Australian certified organic farming, and other natural resource management techniques, and reduced mental distress. Given Khan's et al., (2018) results on 200 conventional and 157 organic farmers living in the USA, which demonstrated a significantly higher frequency of depression among conventional farmers, also, considering Brown et al., (2018) results on Australian farmers, which showed those practicing regenerative farming have better wellbeing when compared with other farmers of similar farm type, age, and gender, future research further exploring Australian organic farmers' mental health would be beneficial. The dataset used was limited by its small sample of alternative growers and as well as selection into alternative growers not being explicitly accounted for, so additional research in this area, with bigger sample sizes, could provide a complete picture of the causal relationship between organic farming and farmers' mental health.

Despite some limitations, this thesis has explored the key influences on farmers' (both dryland and irrigation) mental health and covered a significant gap in the vast body of literature regarding climatic variability effects on farmers' mental health. The result suggests that water scarcity is associated with worsening mental health, especially among farmers in the MDB.

The results also highlight the importance of financial capital in influencing southern MDB irrigators' psychological distress. This thesis also provides some evidence that landholder governance and natural resource management (such as being a certified organic irrigator) is statistically positively associated with southern MDB irrigators' mental health. Overall, the findings of this thesis will become increasingly policy-relevant, given the increasing pressure placed on farming communities by the impacts of climate change, along with the fact that financial problems are increasing in drought-affected areas across Australia.

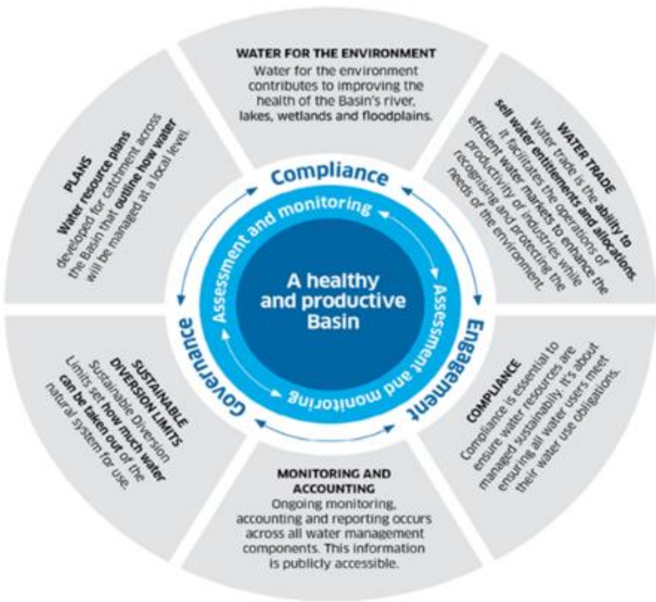
Appendix A : Supplementary Figures and Tables for Chapters 2 & 3

Figure A.1: Large-scale Features that affect the Climate of South-eastern Australia



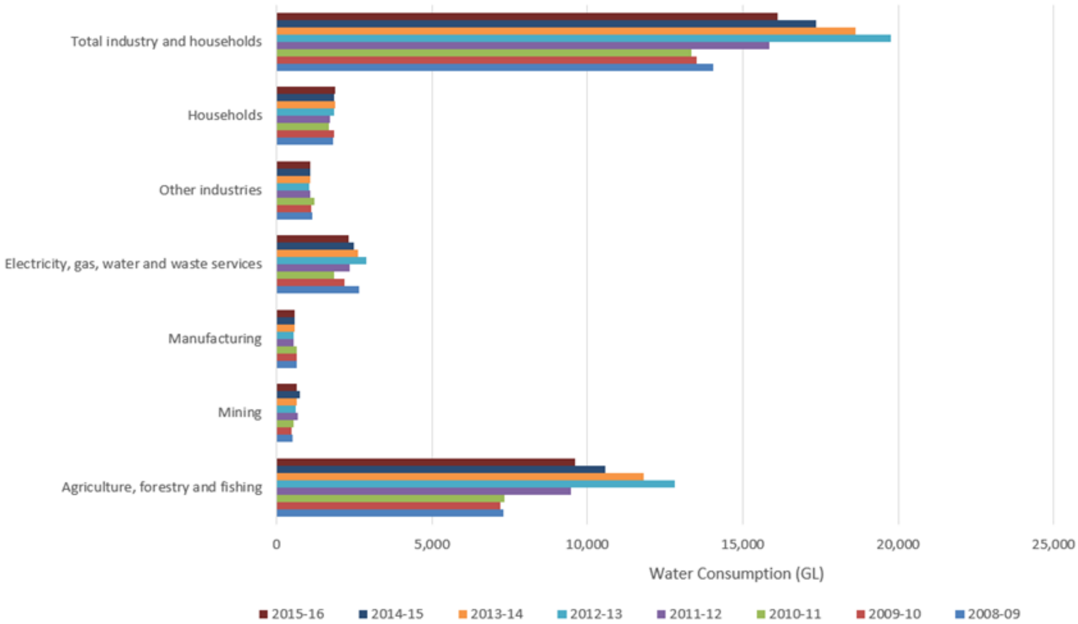
Source: CSIRO (2010; p.8)

Figure A.2: Main Elements of the Basin Plan



Source: MDBA (2019; p.12)

Figure A.3: Water Consumption, by Industry and Households (GL), 2008-09 to 2015-16



<u>Source:</u> Created from data in ABS (2018)

Table A.1: Literature Findings on Drivers Associated with Mental Health, Depression and Anxiety

Age	Mental health disorders is higher among older age group (Das et al. 2007; Baladón et al. 2015; Li, Wu & Tsang 2017; Rovner et al. 1986). Increasing age is associated with less likelihood of having any mental disorder (Trollor et al. 2007; Araújo Patrício et al. 2016).	Immigration	Immigration is a great stressor for people resulting in mental health problems (Ahmad et al., 2005).
Sex	Female and widowed are at more risk of mental health problem (Das et al. 2007). Women experienced higher rates of affective disorders and anxiety disorder compared with men (Trollor et al. 2007; Seeman 1997). High school girls tended to have higher mental health disorders than boys high school students (Coles et al. 2016).	Retirement Age of Men	Retirees especially men who had retired at a younger age before 55, and between 55 and 59 had consistently higher rates of mental health problem compare to their working peers who had retired at age 60 or older (Gill et al., 2006).
Social Isolation	Feeling of isolation significantly affect mental health and the effects are greater for women, older people and individuals with more education (Rohde et al., 2015).	Unemployment Rate	Higher unemployment rate is significantly associated with suicide in most of the Australian capital city (Qi et al., 2015).
Employment Status	Mental health score declined for women and persons in higher professional skill levels in relation to longer working hours compare with men and persons in lower professional skills (Milner et al., 2015).	Housing Affordability	Unaffordable hosing experience for private renters shows significant decline in mental health. Unaffordable hosing experience for home purchasers shows no changes in mental health (Bentley et al., 2015).
Social Support	There is a strong association between social support and mental health (Milner et al., 2016).	Missing Meals	Those people who missed their meal or consumed below average levels of core food, reported higher mental health disorders than those not missing meals (Friel et al., 2014).
Disability	The risk of mental health disorder for disabled men is more than 70% under high hardship conditions. These findings are not the case for women with disabilities (Honey et al., 2011). Cognitively impaired patients reported higher rate of mental disorder (Friedman et al., 2005).	Exposure to Violence	People who experience war and violence are highly at risk of having mental health disorders. The rate of mental disorders between refugees can be varied between 2% and 80% (Lindert et al., 2008).

Table A.1: Continued

Socioeconomic Variables	Mental health disorders are higher among the most disadvantaged groups of people (Araya et al., 2003). Lower level of education, poor housing conditions and a recent income decrease, increase the prevalence of mental health disorders (Araya et al., 2003). Educational achievement, employment opportunities including self-employment have significant positive effects on community mental health (Goetz et al., 2015).	Working Hours	People who work between 49-59h per week or more than 60h, had consistently higher rates of mental health problem compare with those working standard full time hours 35-40 h per week (Milner et al., 2015). Patients working rotating shifts and irregularly changing hours showed more problems related to their psychological performance. Patients working on temporary employment contracts reported significantly more problems with their psychological perform (Martens et al., 1999). Shift works and long working hours indicate adverse effect on mental health (Harrington, 2001). There is inconsistent results in the association between working hours and mental health disorders (Spector et al., 2004; Fujino et al. 2006).
Education	The lower educational level is associated with a greater level of mental disorders (Friedman et al., 2005; Lund et al. 2010).	Parental Divorced	The adults with the experience of their parents divorced report 26.5% greater frequency of mental health problems than others (Mirowsky, 2013).
Single Mothers	Australian single mothers (including those separated, divorced, widowed or never legally married), have greatest level of mental health disorders compared with parented mothers. Also, they are more likely to receive low levels of social support and experience greater financial hardship rather than parented mothers (Crosier et al., 2007). Separated/divorced mothers compared to married mothers are more likely to have an anxious-misery disorder or depression. However, from the viewpoint of mental health never-married mothers are similar to married mothers (Afifi et al., 2006). Single mothers who have at least one child between 2-6 years old living with them, have at least mild depression (Peden et al., 2004). Single mothers' rates of major depression is more than double compared to married mothers. Also, single mothers with lower education levels, are less likely to perceive social support, have less contact with their friends and more recent life events compared to married mothers (Cairney et al., 2003).	Financial Hardship	People, who have reported that they have financial hardship, had greater risk of mental health problem (Kiely et al., 2015). Between two components of financial hardship (deprivation and income poverty), responders who have reported deprivation had a greater risk of future mental health than people with only income poverty (Kiely et al., 2015). People who have reported themselves as welfare recipients were significantly more likely to experience mental health disorders than others. Among all welfare receiver, those receiving disability and sickness payments presented very high rate of mental disability (Butterworth et al.,2004). The association between mental health and poverty is stronger than general health in high-income countries such as the UK and South Korea (Lund et al., 2011).

Table A.1: continued

Weather	Drought have negative mental health impact. Who are most impacted are farmers (Edwards et al., 2015). Rural adolescents didn't report higher emotional distress than adolescents of similar age and gender in the Australian community. The study repeated three years later to the same sample after ongoing drought. This time adolescents reported considerably higher distress than those in the previous study in the same region (Dean & Stain, 2010). Long lasting period of drought is associated with emotional distress for rural but not for urban residents (O'Brien et al., 2014). There is a linear correlation between temperature and men and women suicide attempts rate. However the suicide attempt rate related to temperature is more significant for men than women (Fountoulakis et al., 2016). Among different patterns of drought exposure, rural people who experienced "constant and long dry" were more likely to consume their core meal below the average due to cost than those experiencing "very dry drought" or "long period of dry" (Friel et al., 2014).	Economic Insecurity	Financial displeasure, fear of being unable to meet standard household costs in the future and failure to produce emergency funds, due to job insecurity associated with mental health disorders (Rohde et al., 2016). Economic crisis may increase suicide rate and alcohol-related disorders in affected countries. Families, especially poor families, have no choice rather than reduce or even cut their health and education budgets after economic crises, which may worsen their children's mental health as well (Wahlbeck & McDaid, 2012). Exposure to economic uncertainty, financial dissatisfaction and feeling of job insecurity has small but constantly damaging mental health effect (Rohde et al., 2016). Job insecurity is positively linked to mental health outcomes. Young unemployed people are at higher risk of mental health disorders compared with older unemployed people (Adam & Flatau, 2006). Financial displeasure, lack of access to emergency funds or decrease in incomes, present greater emotional problems (Rohde et al., 2014).

Appendix B Preparing the Climate and Weather Data

B.1 Preparing Daily/Monthly Rainfall and Evaporation Data

Firstly, 14 years of the weather data (rain days, monthly rain, and evaporation) were collected from the BOM. The data format has changed from text file format to STATA format with the purpose of generating a raw STATA file of climate data. Then Australia's weather station names and numbers with a specific locality from the BOM were imported to the ArcGIS with the intention of generating a shapefile (a shapefile is an Esri vector data storage format for storing the location). Yearly (from 2000-01 to 2014-15) evaporation, monthly rainfall and daily rainfall data were joined with the shapefile station numbers, the attribute table was checked and the missing data were identified. Next, Statistical location Area (SLA) data which is available at the ABS in the Esri shapefile format were imported to the ArcGIS. Finally, the weather data which have been already jointed with the weather station numbers with a specific locality, were joined with the SLA shapefile based on spatial location (the missing data were merged with the nearest available SLA). The purpose was specifying the exact geographical area of climate data.

B.2 Preparing Water Allocation and Soil Moisture Data

Firstly, 14 years of the water allocation data were collected from the "Water Audit Monitoring Report", after importing the surface-water SDL (Sustainable Diversion Limit) resource units, which is available in the Esri shapefile to the ArcGIS, yearly (from 2000-01 to 2014-15) water allocation information were joined with the SDL shapefile. Then, the SLA data in the Esri shapefile format were imported to the ArcGIS, and the water allocation data which have been already jointed with the SDL shapefile with a specific locality, were joined based on the spatial locations with the SLA shapefile. The purpose was specifying the exact geographical area of weather data.

Also, historical series of soil moisture data from 2000-01 to 2014-15 were collected from the CSIRO in ESRI binary grid format, for specifying the exact geographical location of each soil moisture data, all data were projected based on Australian national grid for fourteen years. Then the attribute table was checked and the missing data were identified to be merged with the nearest available SLA. Finally, projected data were merged with the SLA shape file map and were exported as a text file.

B.3 Preparing Temperature Data

Firstly, 14 years of the monthly temperature data were collected from the BOM. The data format has changed from text file format to STATA format to generate a raw STATA file of the monthly temperature data. It was decided to have more detailed temperature data with the purpose of getting more accurate results. So the maximum summer temperature, minimum summer temperature, maximum winter temperature, minimum winter temperature, maximum annual temperature, and minimum annual temperature for each year were calculated. Then, Australia's temperature station names and numbers with a specific locality from the BOM were imported to the ArcGIS to generate a shape-file. Yearly (from 2000-01 to 2014-15) all mentioned temperature data was joined with the shape-file station numbers, to identify the exact geographical area of the temperature data. The temperature data which has already been jointed with the weather station numbers with a specific locality, were joined based on spatial location with the SLA shape-file. Next, the attribute table was checked, the missing pieces of data were identified, and were merged with the nearest available SLA.

Also, 14 years of the daily temperature data were collected from the BOM. As mental health questions in the HILDA survey ask about responder's feeling in the past four weeks, the temperature related to the 28 days before the interview date was considered. Then, the process of daily temperature data continued as the monthly temperature data in the ArcGIS (explained above), until all of the observations become ready to be merged with the SLA shape-file. Next, there was a need to change the format of the interview date in the HILDA dataset via STATA code to be the same as the BOM daily temperature dataset date (e.g., 1/6/2011 instead of 1/June/2011). Finally, the completed monthly and daily temperature dataset were merged with the panel HILDA dataset via STATA code.

B.4 Preparing Drought Data

Rolling rainfall deficiency dataset from 2000-01 to 2014-15 were collected from the BOM to create the drought variable for a particular area, measure of drought is based on both the 5th percentile and 10th percentile rainfall deficiency. The collected data were in an ASCII gridded file format and there was a need to convert them to the RASTER format to create a projection in ArcMap based on the Australian National Grid.

The 12 month rolling rainfall deficiency were used to calculate the drought based on interview date available in the HILDA dataset as bellow:

Rain-percentile-200009-200108-grid→for interview in Aug 2001

Rain-percentile-200010-200109-grid→for interview in Sep 2001

Rain-percentile-200011-200110-grid→for interview in Oct 2001

Rain-percentile-200012-200111-grid→for interview in Nov 2001

Rain-percentile-200101-200112-grid→for interview in Dec 2001

Rain-percentile-200102-200201-grid→for interview in Jan 2002

Rain-percentile-200109-200208-grid→for interview in Aug 2002

Rain-percentile-200110-200209-grid→for interview in Sep 2002

Rain-percentile-200111-200210-grid→for interview in Oct 2002

Rain-percentile-200112-200211-grid→for interview in Nov 2002

Rain-percentile-200201-200212-grid→for interview in Dec 2002

Rain-percentile-200202-200301-grid→for interview in Jan 2003

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Rain-percentile-201309-201408-grid→ for interview in Aug 2014

Rain-percentile-201310-201409-grid→ for interview in Sep 2014

Rain-percentile-201311-201410-grid→ for interview in Oct 2014

Rain-percentile-201312-201411-grid→ for interview in Nov 2014

Rain-percentile-201401-201412-grid→ for interview in Dec 2014

Rain-percentile-201402-201501-grid→ for interview in Jan 2015.

A binary raster dataset was created in the ArcMap, which shows drought and non-drought area for each SLA (<=5 severe drought, <=10 serious drought). Unfortunately, the matching results for some of the SLA didn't calculate in the zonal output as their size was too small. So the centroid value point of each messing SLA calculated separately and the exact raster value for each point considered separately. Then the output of the zonal and value to point tools were combined, the data exported as a text file, and STATA do file were used to combine the output of the zonal and value point.

B.5 Preparing the HILDA Dataset

300 variables from HILDA dataset, which have been related to this research were kept. The MDB postcodes were merged with the kept variables to provide access to the survey participants, who are living in the MDB. Then, household, enumerated and responding person files from different HILDA files were matched during the 14 waves, and a code was written in the STATA do file, to generate long format balanced panel data of the HILDA survey for 14 years. The SLA data in the HILDA dataset were based on 2001 census and in the climate dataset were based on 2006 census. In order to be able to merge the HILDA dataset with the climate dataset, SLA based on 2001 census data in the HILDA dataset were changed via STATA code to SLA based on 2006 census. Then, the dataset were cleaned and missing variables were filled via STATA code. There was a need to create some dummy variables, so a STATA code was written to create dummy variables out of continuous variables. Finally, all lagged-climate variables (daily rainfall, monthly rainfall, maximum temperature, minimum temperature, soil moisture, evaporations, water allocation levels, and drought) were calculated via STATA and merged with the HILDA dataset based on Postcode or SLA.

Figure B.1: Example for Preparing Climate Data in the ArcMap

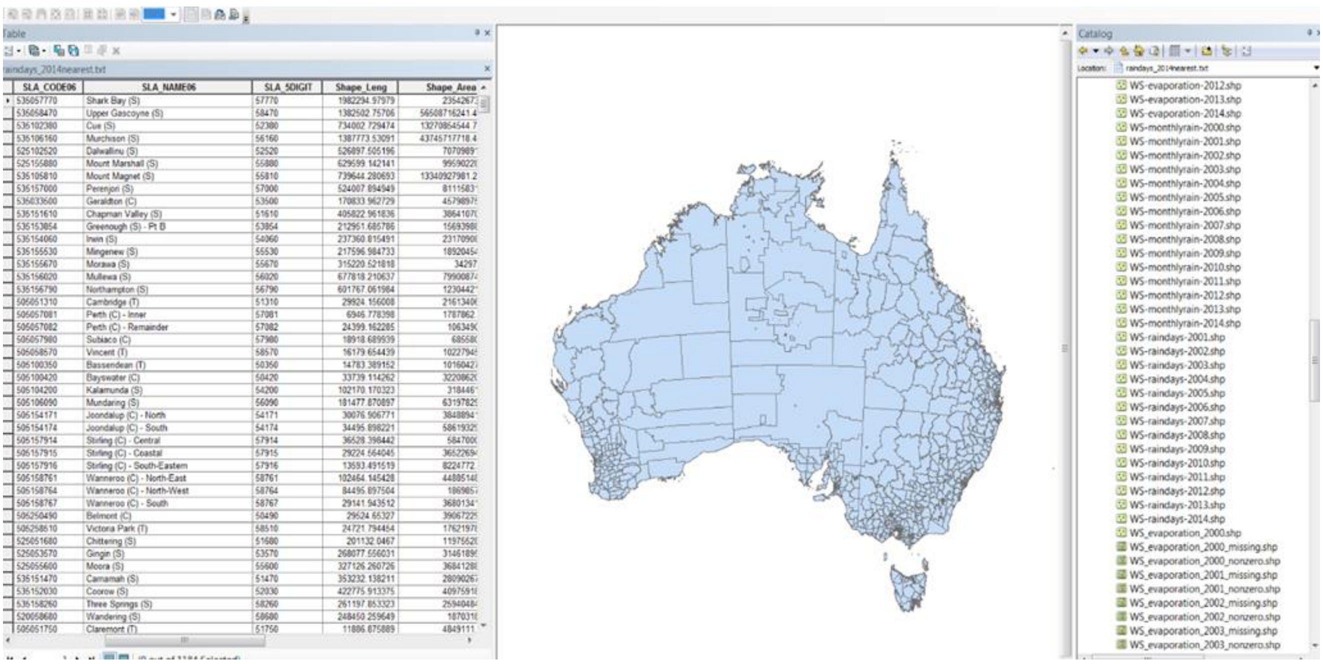
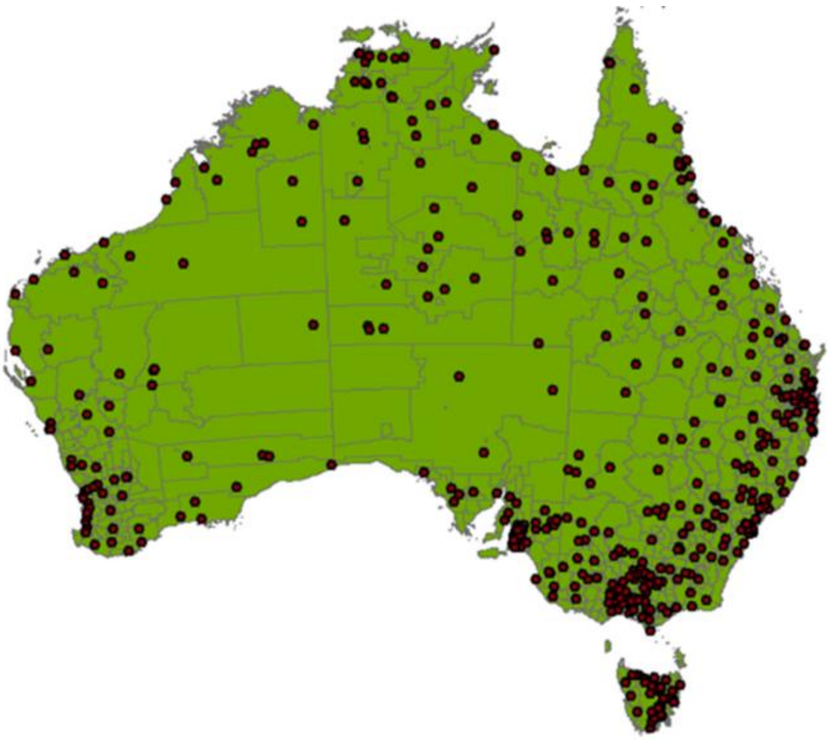


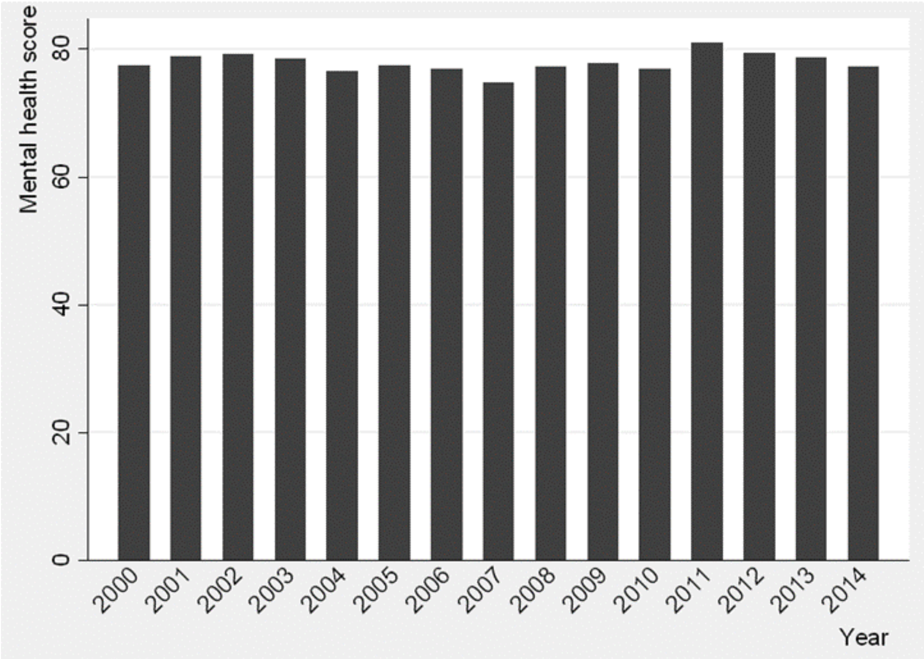
Figure B.2: The weather data were referenced to real locations based on Postcodes and SLA, using the GIS software.



Source: Created from weather data provided by BOM in a specialised data request

Appendix C Supplementary Tables and Figures for Chapter 5

Figure C.1: Difference in the Average Mental Health Score of MDB Farmers across Fourteen Years



Note: The Millennium Drought in the 2000s reached the worst conditions in 2006, 2007, 2008 and 2009. A two-sample t-test for the mean mental health score suggests that in the MDB, farmers' mental health was significantly (p-value=0.02) worse during these four years (mean=76.7) than during the rest of the period (mean=78.4).

Table C.1: Collinearity Diagnostics for CRE Model (MDB farmer model) in Chapter 5

Variables	***VIF***
Rain days	1.66
Maximum daily summer temperature	1.51
Drought	1.27
Income (drought)	1.25
Age	1.16
Water allocation	1.14
Marital status	1.12
SEIFA	1.12
Education	1.11
Male	1.09
Negative life event	1.08
Income (non-drought)	1.03
Mean VIF	1.20

Table C.2: Correlation Results for CRE Model (MDB farmer model) in Chapter 5

	MHI-5	*Rain day*	*Max summer temp.*	*Water allocation*	*Age*	*Negative life event*	*Drought*	*Low education*	*Marital status*	*Income (drought)*	*Income (non-drought)*	*SEIFA*	*Male*
MHI-5	1.000												
Rain days	0.052	1.000											
Max summer temperature	0.004	-0.548	1.000										
Water allocation	-0.053	-0.269	0.121	1.000									
Age	0.033	0.018	-0.142	0.141	1.000								
Negative life event	-0.112	0.006	-0.109	0.062	0.100	1.000							
Drought condition	-0.015	-0.134	0.077	-0.025	-0.015	0.085	1.000						
Low education	-0.091	-0.078	0.027	0.057	0.235	-0.016	0.047	1.000					
Marital status	-0.004	0.043	-0.077	0.158	0.156	0.201	-0.058	-0.088	1.000				
Income(drought)	0.060	-0.072	0.053	-0.001	-0.112	0.040	0.420	-0.028	-0.054	1.000			
Income (non-drought)	0.038	0.015	-0.015	0.010	-0.044	-0.026	-0.133	-0.046	0.001	-0.056	1.000		
SEIFA	0.064	0.262	-0.057	-0.103	0.044	-0.010	-0.062	-0.090	0.082	-0.013	0.008	1.000	
Male	-0.053	0.050	-0.077	0.001	0.004	0.115	-0.003	-0.115	0.089	-0.061	-0.081	0.097	1.000

Table C.3: Collinearity Diagnostics for CRE Model (farmers in five states), NSW

Variables	***VIF***
Soil moisture	2.64
Rain days	2.36
Maximum daily summer temperature	1.69
Drought	1.29
Age	1.28
Income (drought)	1.24
Income (non-drought)	1.23
Negative life event	1.12
Married	1.12
SEIFA	1.11
Male	1.10
Low education	1.07
Mean VIF	1.41

Table C.4: Collinearity Diagnostics for CRE Model (farmers in five states), VIC

Variables	***VIF***
Soil moisture	1.73
Maximum daily summer temperature	1.58
Rain days	1.33
Age	1.24
Drought	1.23
Income (drought)	1.19
Low education	1.18
Income (non-drought)	1.15
SEIFA	1.10
Negative life event	1.06
Married	1.06
Male	1.04
Mean VIF	1.23

Table C.5: Collinearity Diagnostics for CRE Model (farmers in five states), QLD

Variables	***VIF***
Rain days	2.77
Soil moisture	2.75
Income (drought)	1.50
Drought	1.47
Age	1.25
SEIFA	1.20
Low education	1.18
Maximum daily summer temperature	1.11
Married	1.10
Male	1.08
Negative life event	1.04
Income (non-drought)	1.02
Mean VIF	1.43

Table C.6: Collinearity Diagnostics for CRE Model (farmers in five states), SA

Variables	***VIF***
Rain days	1.97
Soil moisture	1.62
Drought	1.45
Income (drought)	1.41
Maximum daily summer temperature	1.40
Age	1.36
Low education	1.29
Male	1.26
Married	1.22
SEIFA	1.15
Income (non-drought)	1.14
Negative life event	1.08
Mean VIF	1.34

Table C.7: **Collinearity Diagnostics for CRE Model (farmers in five states), WA**

Variables	VIF
Rain days	5.59
Maximum daily summer temperature	3.04
Soil moisture	2.76
Drought	1.51
Income (drought)	1.40
Age	1.38
Low education	1.25
SEIFA	1.21
Income (non-drought)	1.19
Married	1.17
Negative life event	1.08
Male	1.07
Mean VIF	1.89

Table C.8: CRE Panel Model on MDB Farmers’ Mental Health (male and female), 2001/02-2014/15

Variables	*Female-MDB*	*Male-MDB*
Rain days	0.047	0.032*
	(0.103)	(0.070)
Maximum daily summer temperature	2.996**	1.202
	(0.014)	(0.190)
Squared daily maximum summer temperature	-0.050**	-0.018
	(0.033)	(0.298)
Water allocation below 30%	-2.267	-0.860
	(0.149)	(0.312)
Soil moisture	-11.934	-2.611
	(0.162)	(0.691)
Age	0.133	-0.027
	(0.413)	(0.799)
Negative life event	-1.975***	-2.036***
	(0.007)	(0.001)
Drought	0.075	-0.553
	(0.958)	(0.499)
Low education Level	3.059	1.603
	(0.599)	(0.676)
Married	-0.776	-0.057
	(0.527)	(0.932)
Income(drought)	0.021	0.040**
	(0.583)	(0.037)
Income(non-drought)	0.021	0.004
	(0.500)	(0.104)
SEIFA	-0.006	-0.002
	(0.701)	(0.810)
Constant	-45.094	37.371
	(0.452)	(0.455)
Observations	746	1,395
Number of farmers	71	164

Note: Robust p-value in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix D Supplementary Tables and Figures for Chapter 6

Table D.1: **Collinearity Diagnostics for Ordered Probit Model in Chapter 6**

Variables	***VIF***
Mean annual temperature	2.48
Farmland value	2.36
Horticulture	2.27
Irrigated area	2.22
LTAAY of all entitlements	2.00
Farm debt for 2014-15	1.82
Net annual evaporation	1.64
Net farm income in 2014-15	1.50
Drought condition	1.47
Broadacre	1.44
Age	1.31
Succession	1.23
Average allocation	1.19
Number of children	1.18
Off farm income	1.15
Productivity change	1.13
Education	1.13
Marital status	1.13
Farm generations	1.13
Social group	1.10
Certified organic	1.06
Male	1.05
Mean VIF	1.50

Table D.2: Correlation Results for Ordered Probit Model in Chapter 6

	K10	*Male*	*Age*	*Education*	*Married*	*Children*	*Succession*	*Social group*	*Farm generation*	*Irrigated area*	*Certified organic*	*Productivity change*	*Off farm income*	*Net farm income*
K10	1													
Male	-0.096	1												
Age	-0.095	0.066	1											
Education level	0.042	0.066	0.280	1										
Marital status	-0.034	0.071	-0.050	0.015	1									
Number of children	-0.004	-0.041	0.186	0.045	0.257	1								
Succession	-0.065	-0.012	0.067	0.041	0.058	0.200	1							
Social group	-0.076	-0.049	0.052	-0.105	-0.004	0.065	0.121	1						
Farm generation	-0.028	0.020	-0.059	-0.002	0.013	-0.025	0.130	0.125	1					
Irrigated area	-0.041	0.053	-0.075	-0.053	0.030	0.043	0.130	0.093	0.092	1				
Certified organic	-0.059	-0.055	-0.089	-0.018	-0.004	-0.011	-0.026	-0.025	-0.045	-0.050	1			
Productivity change	-0.147	0.005	0.086	-0.123	0.061	0.062	0.116	0.119	0.027	0.008	0.134	1		
Off farm income	-0.020	0.025	-0.131	0.032	0.062	-0.029	-0.168	-0.041	-0.126	-0.145	-0.063	-0.123	1	
Net farm income	-0.124	0.053	-0.305	-0.085	0.101	0.038	0.217	0.132	0.090	0.344	-0.010	0.187	-0.219	1

Table D.2: Continued

	K10	*Male*	*Age*	*Education*	*Married*	*Children*	*Succession*	*Social group*	*Farm generation*	*Irrig. area*	*Cert. organic*	*Productivity change*	*Off farm income*	*Net farm income*
Debt	0.053	-0.015	-0.191	-0.072	0.106	0.052	0.236	0.101	0.141	0.340	-0.075	0.130	-0.253	0.350
Farmland value	-0.093	0.025	0.007	-0.087	0.059	0.051	0.318	0.181	0.238	0.412	-0.072	0.136	-0.267	0.524
Drought condition	-0.048	0.001	0.007	0.054	0.018	0.005	-0.083	-0.002	-0.013	-0.074	0.019	0.032	-0.016	0.024
Maximum Temperature	0.064	-0.010	0.001	0.007	0.011	-0.024	-0.011	-0.081	-0.147	0.026	0.054	-0.016	0.043	-0.083
Annual evaporation	0.057	0.020	0.004	0.035	0.008	0.007	-0.017	-0.113	-0.135	-0.072	0.051	-0.012	0.053	-0.117
Water allocation	-0.032	0.088	-0.001	0.007	0.054	-0.019	-0.074	-0.020	-0.031	-0.128	0.041	0.091	0.015	-0.078
LTAAY	-0.011	0.044	-0.018	-0.031	0.028	0.040	0.113	0.026	0.035	0.691	-0.051	0.003	-0.112	0.300
Horticulture	0.041	0.033	0.002	-0.012	0.035	-0.050	-0.142	-0.110	-0.241	-0.246	0.134	0.080	0.105	-0.178
Broadcare	0.011	0.023	-0.039	-0.016	-0.011	0.063	0.154	0.107	0.111	0.312	-0.080	-0.051	-0.065	0.189
Dairy Livestock	-0.049	-0.052	0.034	0.026	-0.022	-0.010	-0.007	0.006	0.125	-0.053	-0.052	-0.028	-0.039	-0.005

Table D.2: Continued

	Debt	*Land value*	*drought*	*temperature*	*Evaporation*	*Allocation*	*LTAAY*	*Horticulture*	*Broadcare*	*Live stock*
Debt	1									
Land value	0.616	1								
Drought condition	0.001	-0.007	1							
Maximum temperature	-0.082	-0.191	-0.5200	1						
Annual evaporation	-0.074	-0.171	-0.2408	0.5770	1					
Water allocation	-0.082	-0.145	0.2051	-0.1393	-0.0864	1				
LTAAY	0.231	0.333	-0.0791	0.0902	-0.0085	-0.0876	1			
Horticulture	-0.165	0.333	-0.1949	0.5995	0.4763	0.1653	-0.1571	1		
Broadcare	0.152	0.229	-0.1104	0.0052	-0.0394	-0.2427	0.2404	-0.4148	1	
Dairy/Livestock	0.0163	0.103	0.2833	-0.5109	-0.4110	0.0657	-0.0713	-0.5609	-0.5207	1

Table D.3: Ordered Probit Marginal Effects, Low Level Psychological Distress

Variables	***All Irrigators (dy/dx)***	***Hort. (dy/dx)***	***Broadacre (dy/dx)***	***Dairy/ livestock (dy/dx)***
Male	0.10**	0.24***	0.01	0.07
Age	0.004***	0.001	0.007**	0.004**
Education<year 10	-0.05	-0.12	-0.03	-0.03
Marital status	0.03	-0.06	0.16	0.06
Number of children	-0.01	0.01	-0.03	-0.02
Succession	0.03	-0.05	0.08	0.05
Social group	0.02	-0.02	0.09	0.03
Farm generations	0.002	-0.01	-0.002	0.02
Irrigated area	0.00007	0.00003	0.0001	-0.00006
Certified organic	0.12*	0.20**	0.04	-0.03
Productivity change	0.05***	0.03	0.07***	0.06***
Off-farm income (%)	0.0009*	0.0007	-0.0004	0.002***
Net farm income	0.0005**	0.0005	0.0004	0.0003
Farm debt	-0.0001***	-0.0001	0.00001	-0.0002***
Farmland value	0.00006***	0.00004	0.00003	0.00009***
Drought	-0.003	0.20*	-0.06	-0.02
Mean annual temperature	-0.01	0.003	-0.06	-0.04
Net annual evaporation	-0.00002	-0.00003	0.0001	-0.00009
Average allocation	0.03	0.07	-0.10	0.04
LTAAY of all entitlements	-0.00002	0.00005	-0.0003***	0.00007
Horticultural	-0.008			
Broadcare	-0.03			
Observations	910	281	253	376

Table D.4: Ordered Probit Marginal Effects, Moderate Level Psychological Distress

Variables	***All Irrigators (dy/dx)***	***Hort. (dy/dx)***	***Broadacre (dy/dx)***	***Dairy/ livestock (dy/dx)***
Male	-0.03**	-0.04***	-0.005	-0.03
Age	-0.001***	-0.0005	-0.002**	-0.002*
Education<year 10	0.01	0.02*	0.01	0.01
Marital status	-0.01	0.02	-0.04**	-0.03
Number of children	0.004	-0.004	0.01	0.01
Succession	-0.01	0.01	-0.03	-0.02
Social group	-0.009	0.006	-0.03	-0.01
Farm generations	-0.001	0.005	0.0007	-0.01
Irrigated area	-0.00002	-0.00001	-0.00003	0.00003
Certified organic	-0.05	-0.07*	-0.01	0.01
Productivity change	-0.01***	-0.01	-0.02**	-0.03**
Off-farm income (%)	-0.0003*	-0.0002	0.0001	-0.001***
Net farm income	-0.0001**	-0.0001	-0.0001	-0.0001
Farm debt	0.00005***	0.00004	-0.00005	0.0001***
Farmland value	-2.42e-05***	-1.22e-05	-1.23e-05	-5.01e-05***
Drought	0.001	-0.07	0.02	0.01
Mean annual temperature	0.003	-0.0009	0.02	0.02
Net annual evaporation	0.000006	0.00001	-0.00004	0.00004
Average allocation	-0.01	-0.02	0.03	-0.02
LTAAY of all entitlements	7.59e-06	-1.61e-05	1.24e-05**	-3.81e-05
Horticultural	0.003			
Broadcare	0.01			
Observations	910	281	253	376

Table D.5: Ordered Probit Marginal Effects, High Level Psychological Distress

Variables	*All Irrigators (dy/dx)*	*Hort. (dy/dx)*	*Broadacre (dy/dx)*	*Dairy/livestock (dy/dx)*
Male	-0.03**	-0.08***	-0.007	-0.02
Age	-0.001***	-0.0007	-0.003**	-0.001*
Education<Year 10	0.02	0.04	0.01	0.01
Marital status	-0.01	0.02	-0.07	-0.02
Number of children	0.004	-0.005	0.01	0.008
Succession	-0.01	0.01	-0.04	-0.01
Social group	-0.01	0.007	-0.04	-0.01
Farm generations	-0.001	0.006	0.0009	-0.009
Irrigated area	-0.00002	-0.00001	-0.00004	0.00002
Certified organic	-0.04*	-0.07**	-0.01	0.01
Productivity change	-0.01***	-0.01	-0.03***	-0.02***
Off-farm income (%)	-0.0003*	-0.0002	0.0001	-0.0008***
Net farm income	-0.0002**	-0.0002	-0.0002	-0.0001
Farm debt	0.00005***	0.00005	-0.00007	0.0001***
Farmland value	-0.00002***	-0.00001	-0.00001	-0.00003**
Drought	0.001	-0.07	0.02	0.008
Mean temperature	0.003	-0.001	0.02	0.01
Net evaporation	7.99e-06	1.33e-05	-5.61e-05	3.28e-05
Average allocation	-0.01	-0.02	0.05	-0.01
LTAAY of all entitlements	7.99e-06	-2.06e-05	1.58e-05***	-2.54e-05
Horticultural	0.003			
Broadacre	0.01			
Observations	910	281	253	376

Table D.6: Ordered Probit Marginal Effects, Very High Level Psychological Distress

Variables	***All Irrigators (dy/dx)***	***Hort. (dy/dx)***	***Broadacre (dy/dx)***	***Dairy/livestock (dy/dx)***
Male	-0.02*	-0.12*	-0.002	-0.01
Age	-0.001***	-0.0006	-0.001**	-0.0007*
Education<Year 10	0.01	0.05	0.005	0.006
Marital status	-0.01	0.02	-0.03	-0.01
Number of children	0.002	-0.005	0.005	0.004
Succession	-0.008	0.01	-0.01	-0.007
Social group	-0.006	0.007	-0.01	-0.004
Farm generations	-0.0007	0.006	0.0003	-0.004
Irrigated area	-1.88e-05	-1.34e-05	-1.77e-05	9.53e-06
Certified organic	-0.02**	-0.05***	-0.006	0.005
Productivity change	-0.01***	-0.01	-0.01**	-0.01**
Off-farm income (%)	-0.0002*	-0.0002	6.92e-05	-0.0003**
Net farm income	-0.0001**	-0.0001	-8.18e-05	-5.20e-05
Farm debt	0.00003***	0.00005	-0.00002	0.00004***
Farmland value	-0.00001***	-0.00001	-0.00005	-0.00001**
Drought	0.0007	-0.05**	0.01	0.003
Mean temperature	0.002	-0.001	0.01	0.006
Net evaporation	5.17e-06	1.29e-05	-2.10e-05	1.48e-05
Average allocation	-0.007	-0.02	0.01	-0.007
LTAAY of all entitlements	5.17e-06	-1.99e-05	5.90e-06**	-1.15e-05
Horticultural	0.002			
Broadacre	0.009			
Observations	910	281	253	376

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