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Ecological Economics, 2020; 169:106564-1-106564-9

Final publication at: http://dx.doi.org/10.1016/j.ecolecon.2019.106564

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

FINAL ACCEPTED VERSION IN ECOLOGICAL ECONOMICS (2020), VOL. 169, 106564

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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.

Key words: *Millennium drought; farmer mental health; irrigation; HILDA.*

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. 2019; 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 Murray-Darling Basin (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[1] (Quiggin et al. 2010; Wheeler et al. 2015).

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

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 Figure One).

FIGURE ONE

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 and 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 has 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 in the MDB is considerably high (Wheeler et al. 2018; Daghagh Yazd et al. 2019). 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. 2019), 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 MDB water scarcity (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. This 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, and social variables on farmers' mental health.

2. Literature Review

2.1 Physical Health and Climate Variability

Human health is sensitive to ecological factors including seasonality, aridity and climate change (McMicheal 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).

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 amongst 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 amongst 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.

2.3 Farmer Mental Health, Wellbeing and Climate 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. (2019) 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).

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 is 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. Very few studies have sought to look at actual land induced environmental change (also known as natural capital of a farm) with mental health (Speldewinde et al. (2009) found an association between increased dryland salinity and mental health in Western Australia), albeit 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. (2019) 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 combining the aspects of irrigation water scarcity with climate variability. This illustrates 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 both 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 there has been little study to date that explores the interaction of financial with social and natural capital influences on mental health.

What we are most interested in is how the socio-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 all the impacts of water on farmer mental health. This research attempts to address this gap in the literature and provides insights to the various dimensions 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 of Australia 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) (particularly in times of drought) 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.

3. Methods

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% of the value of Australia's agricultural production, but the region is predicted to be extremely vulnerable to future climate change impacts. This will result in increasing temperature, evaporation, drought risk and more variable rainfall (CSIRO 2011; Zuo et al. 2015). The MDB has experienced considerable drought and extreme weather, as highlighted in Figure One. Figure Two illustrates the location of the MDB.

FIGURE TWO

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).

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 1 provides descriptive summary statistics).

TABLE ONE

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 a high response rate. Data was available for 2001/02-2014/15 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, who provided at least one interview in wave one, 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.

This study used 14 waves (2001/02-2014/15) 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 2006). 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 the modelling was 235 who answered all 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, farm rate of return, debt, farm type data 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.

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 and 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 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[2] 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 qualifications (year 11 or below), age, yearly gross wage and income, a negative life event experience in the past year,[3] gender and marital status. The selected demographic variables were based on previous literature findings and the availability of data in HILDA. In order to test our hypothesis two regarding the effect of income on mental health during drought, the yearly gross wage and income variable was interacted with the drought

[2]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.”

[3]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.

dummy variable to create two independent variables: income during drought years and income during non-drought years.

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 summer temperature and percentage of regional water allocations over a 14-year period. Statistical Local Area (SLA) location data and date of interview in any given wave was available from HILDA, hence climate data were geo-referenced across time and space. In order to measure climate variables in a consistent manner (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[4] variable for a particular area, a rainfall deficiency dataset from the BOM (Bureau of Meteorology) was applied. 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.

[4]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.

The percentage of water allocations over 14 years (2001-2014) was collected from *Water Audit Monitoring Reports* and the *Transition period water-take reports* (e.g. MDBA 2012). Dummy variables were generated to check if water allocation below a certain level was an influence on MDB farmer stress.[5] 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 Socio-economic Index for Areas (SEIFA), from the ABS population census, 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).

Descriptive statistics of climatic and socio-economic variables are reported in Table 1. To test our hypothesis two (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.

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 and Hansen 2007). The CRE approach proposes strategies for allowing unobserved heterogeneity to be correlated with observed covariates for unbalanced panel datasets (Wooldridge 2010). 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

[5]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.

estimators. However, estimation based on T→∞ may perform poorly in practice (Bester and Hansen 2007). The CRE model nests the conventional fixed effects specification by introducing additional parameter heterogeneity. The advantage of CRE is that it is 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 and 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 observable 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 and Schure 2013). However, it is more likely that α_i is correlated with independent variables 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 $\bar{X}_i$ 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, $\bar{X}_i$ is the average of covariates over time periods, and $\rho,\ \beta,\ \gamma$ are parameters or vectors of parameters to be estimated. To detect the presence of serious multicollinearity, the variance inflation factors (VIF) and correlations were checked, with no sign of serious multicollinearity (mean VIF=1.28).

4. Results

Although climate change has been a prominent topic of research for the past several decades, the impact of climate variability on farmers has only recently been investigated. Results in Table 2 indicate a combined impact of social, ecological and financial issues on MDB farmer mental health.

TABLE 2

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 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' risk of depression (McShane et al. 2016; Ellis and Albrecht 2017).

FIGURE 3

The findings also confirmed 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, it just missed statistical significance (i.e. p=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 studies as one of the largest stresses faced by farmers (Peel et al. 2015) and irrigators (Daghagh Yazd et al. 2019). Wheeler and 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 direct economic impact of water scarcity (e.g. reduction in yield of crops and farm productivity) and social impacts (e.g. migration, sense of loss and conflicts in society for water), combined with environmental impacts (aridity and drought), have been identified consistently in the literature as the 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 worse farmer mental health. This result is very common within the literature (e.g. Linn and Husaini 1987).

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. 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 is impossible to tell 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 the most important 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. 2019; Wheeler et al. 2019) by confirming that the combination of drought and financial crises and a healthy working environment considerably 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 multidisciplinary approaches are necessary to respond to climate change and water scarcity impacts, 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. (2019) 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. (2019) 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).

6. Conclusion

There is a growing literature seeking to understand the emotional and social effects of water scarcity on farmer mental health. The current study sought to more fully understand the socio-ecological economic influences on MDB farmer mental health. We used a unique longitudinal dataset of 14 waves from HILDA from 2001/02 to 2014/15 to investigate the link between water scarcity, farm finances and farmer mental health in the MDB. This time-period 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 to date has been described as the worst drought in recorded history for the entire MDB. Farmer survey data were combined with a variety of other locational and climate information databases and a correlated random effect regression methodology was used to model the impacts on farmer mental health. 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.

Acknowledgments

This work was supported by the Australian Research Council [FT140100773] and an Australian Postgraduate Award. The authors acknowledge helpful comments from reviewers and special issue editors that much improved this manuscript.

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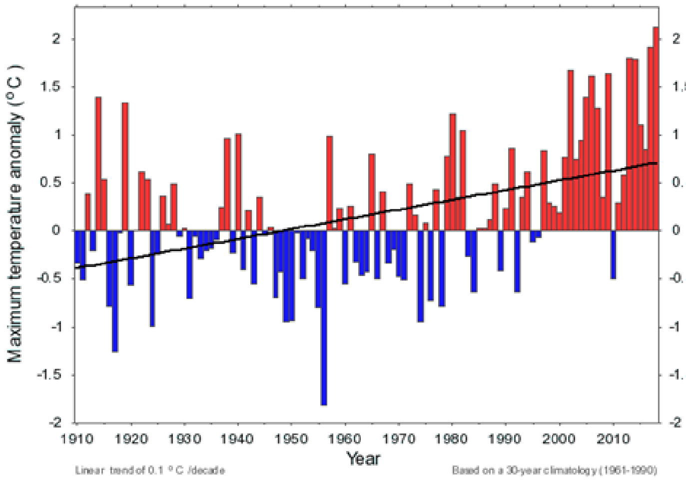
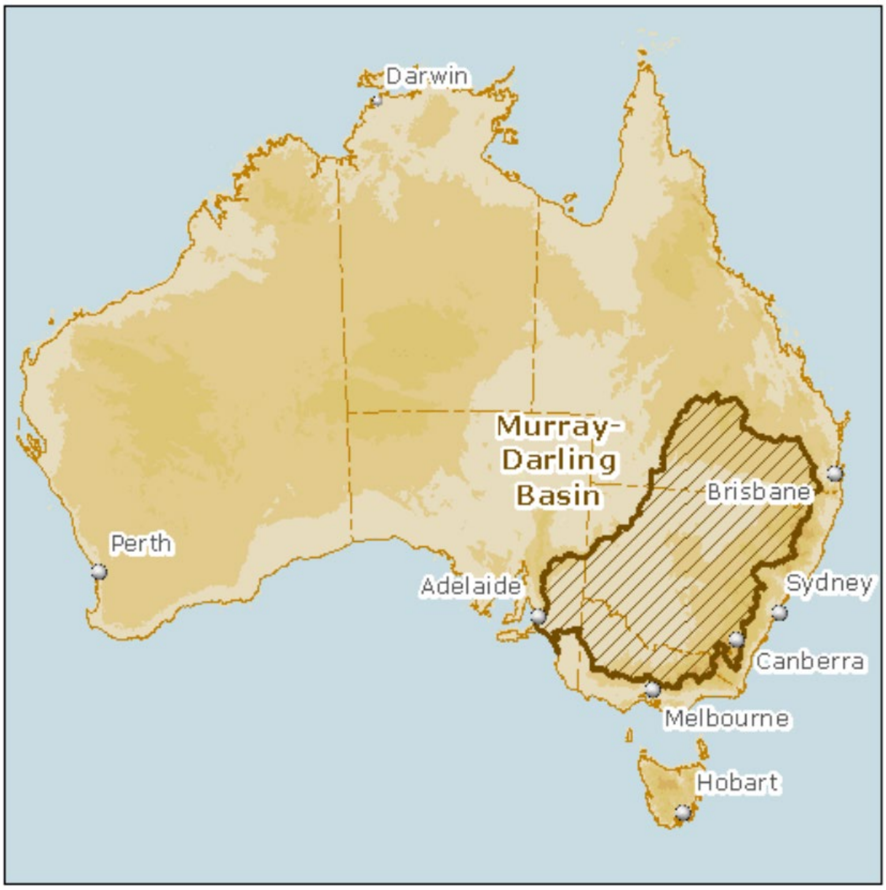
Figure 1. Annual maximum temperature in MDB (1910-2018)



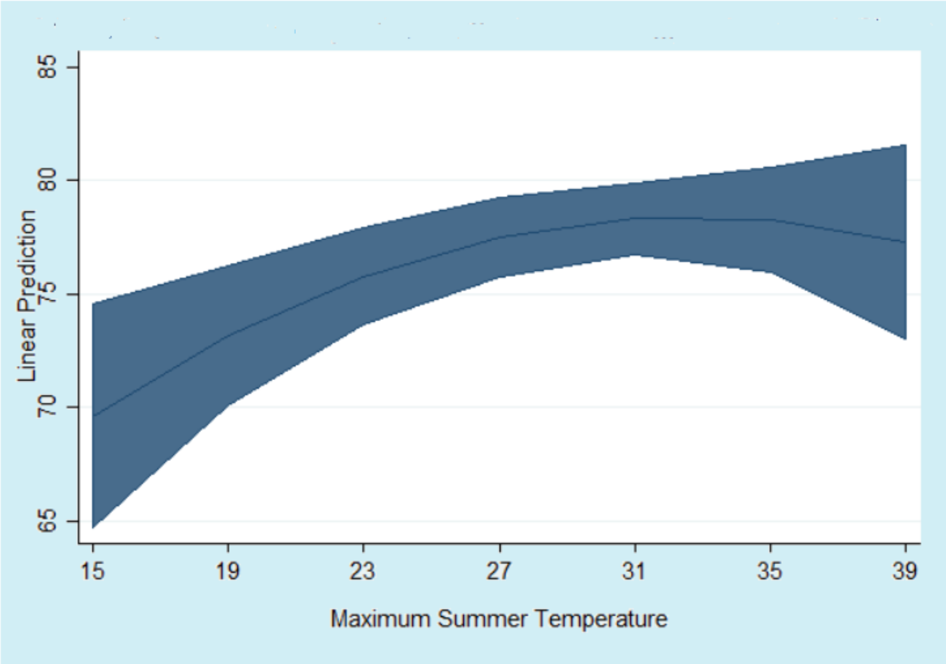
Source: BOM. Available at: http://www.bom.gov.au/climate/change/#tabs=Tracker&tracker=timeseries&tQ=graph%3Dtmax%26area%3Dmdb%26season%3D0112%26ave_yr%3DT

Figure 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].

Figure 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.

TABLES

Table 1: Descriptive Statistics

Variables	*Mean*	*Std. Dev.*	*Min*	*Max*
Mental health, MHI-5 subscale-MDB farmers[a]	77.99	14.62	4	100
Water/Climate Variables				
Rain-days[b]	105.06	29.96	32	196
Mean daily maximum summer temperature (C°)	29.21	3.32	14.37	38.50
End of season water allocation (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
Socio-demographic variables				
Negative life event (1=negative life event in 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
Economic Variable				
Income ($AUD yearly gross salary in 1,000)[g]	14.84	49.98	0	2000

[a]Only include farmers living in the MDB. Mental health uses MHI-5 subscale from the SF-36, available in HILDA, and higher scores indicate less distress.
[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 is a measure of the social and economic disadvantage of different geographical areas across Australia, with higher=less disadvantage.
[g]Note this is the individual salary attributed to the respondent in HILDA, hence does not represent total farm household income/revenue.

Table 2 CRE panel model on MDB farmers' mental health, 2001/02-2014/15

Independent Variables	Coefficient
Water/Climate Variables	
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)
Economic Variables	
Income (drought)	0.035**
	(0.030)
Income (non-drought)	0.004
	(0.118)
Socio-demographic variables	
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)
Wald chi2	98.52***
Observations	2,141
Farmer number	235
R-sq.(overall)	0.08

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