Health & Place 15 (2009) 880–887

Contents lists available at ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

A relationship between environmental degradation and mental health in rural Western Australia

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ARTICLE INFO

Article history:
Received 17 October 2008
Received in revised form
21 January 2009
Accepted 22 February 2009

Keywords:
Salinity
Depression
Ecosystem health
Environmental degradation
Bayesian statistics

ABSTRACT

Australia is currently experiencing a process of escalating ecosystem degradation. This landscape degradation is associated with many outcomes that may directly or indirectly impact on human health. This study used a Bayesian spatial method to examine the effects of environmental degradation (measured as dryland salinity) on the mental health of the resident rural population. An association was detected between dryland salinity and depression, indicating that environmental processes may be driving the degree of psychological ill-health in these populations.

Introduction

There have been very few studies examining the psychological effects of environmental degradation. The limited research has consistently found a positive correlation between environmental degradation and psychological distress (Sartore et al., 2008; Van Haaften and Van de Vijver, 1996a, b, 1999, 2003; Van Haaften et al., 2004). Furthermore, there is a strong association between many forms of psychological distress and the onset of depressive illness (Wheatley, 1994). Mental health problems associated with environmental degradation are not without precedent. Studies in Africa, Karakalpakstan and China found that such environmental processes were associated with higher levels of psychological distress (Crighton et al., 2003; Van Haaften and Van de Vijver, 1996a, b, 1999, 2003; Van Haaften et al., 2004).

Health effects of environmental change have been conceptualized along a continuum from sudden, immediate, traumatic physical and emotional impacts (such as the 2004 Indonesian earthquake and subsequent tsunami) to less acute processes (such as drought), which may be associated with gradual physical and psychological exhaustion (Cook et al., 2008; Were, 1989). Van Haaften and Van de Vijver (1999) noted that the rate of degradation was an important determinant of psychological distress.

This study examines the psychological impacts of dryland salinity in agricultural landscapes by using depression as an indicator of mental health. Dryland salinity is a slow form of degradation (depending on the soil type and level of the water table) and the manifestation of the degradation can vary from small changes in the pasture species, through to bare salt scalds (Beresford et al., 2001; Tille et al., 2001). Approximately 1 million hectares (5.5%) of the south-west agricultural zone of Western Australia is already affected by dryland salinity and this is predicted to rise to 5.4 million hectares by 2050 (NLWRA, 2001). Salinity typically leads to the loss of productive land area and subsequently agricultural production. Dryland salinity has two forms: *primary* and *secondary*. Primary salinity is the result of soils that are inherently saline as the result of a natural (non-anthropogenic) process. Secondary salinity is caused by agricultural activity, where the native vegetation is cleared and replaced with shallow-rooted crops and pastures. This shallow-rooted vegetation uses less groundwater, causing the water table to rise, bringing dissolved salts to the surface to contaminate land and surface water. Salinity often manifests itself as a visible salt scald, but may also be indicated by dead or dying trees, water-logging or the growth of more salt-tolerant species. Degradation in an affected ecosystem usually manifests as decreased biodiversity, reduced primary production and lowered resilience (Rapport, 1999). Jardine et al. (2007) suggested that there were three broad categories of human health, which could

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1353-8292/$ - see front matter © 2009 Published by Elsevier Ltd.
doi:10.1016/j.healthplace.2009.02.011

be affected by dryland salinity: dust-related illness, mosquito borne virus and mental health. Jardine et al. (2008) found that the vector for one mosquito borne virus (*Aedes camptorhynchus*) increased with the presence of dryland salinity, but that there was no corresponding increase in the relative risk of this infectious disease in the human population living in saline-affected areas.

Psychological quality of life has been linked to peoples sense of place (Ogunseitan, 2005) and environmental degradation influences this relationship (Rogan et al., 2005). This is captured in what Santiago-Rivera (2000) terms 'ecopsychology'—the relationship between humans and their environment. Albrecht (2005, 2006) and Albrecht et al. (2007) raises the concept of 'solastalgia', the pain or sadness caused by the loss or lack of solace and sense of isolation due to the present state of one's home and territory. Those who experience solastalgia can experience general distress which can escalate to serious health problems, such as depression and suicide (Albrecht, 2005; Higginbotham et al., 2006). Rogan et al. (2005) found that environmental degradation influenced the way people structured their relationship with their surroundings. Given the changes in residents surroundings due to dryland salinity, in some cases these changes can be quite rapid, there is potential for residents to experience psychological distress through such mechanisms.

Given the possible inter-related pathways that could initiate psychological distress—financial pressures due to reduced profitability, decline of social networks and solastalgia—we considered that there is potential for adverse mental health outcomes related to the environmental degradation of dryland salinity. The specific aim of this study was to determine if there were associations between areas with dryland salinity (and associated land degradation) and depression rates in the agricultural lands of south-Western Australia.

Methods

Study area

The study area was the largely rural south-western corner of Western Australia. This area was chosen for three main reasons: (1) it is the major agricultural zone in Western Australia and has an increasing incidence of dryland salinity, (2) it has extensive environmental data available through the Western Australian Department of Agriculture's soil and landscape mapping database, and (3) the population is encompassed by Western Australia's Data Linkage Unit (DLU) public health database.

The study area incorporated most of the dryland agriculture areas in Western Australia (Fig. 1). Dryland agriculture includes farms, which produce crops (such as canola, wheat, barley) and/or run livestock (mostly sheep, but some cattle). Rangeland grazing areas were not included because the farming systems are significantly different, the areas where rangeland grazing occurs are sparely populated and the geocoding of health data in these areas is relatively poor.

The City of Perth (Western Australia's capital city) is located approximately in the centre of the study area on the west coast. This major population centre was excluded from the analysis as the urban area was not relevant to the environmental data analysed. The study area (with the Perth metropolitan area omitted) had a population ranging between approximately 4,00,200 in 1996 (Australian Bureau of Statistics National census for 1996) to 4,90,500 in 2001 (Australian Bureau of Statistics National census for 2001).

Health data

The relevant morbidity and mortality data were collected from the extensive linked health outcome databases which form the Western Australian (WA) Record Linkage Project (for details see Holman et al. (1999)). This facility is operated by the Data Linkage Unit attached the WA Department of Health. The DLU manages, maintains and enhances the WA Data Linkage System of linkages across the state's health datasets, which include the Hospital Morbidity Data System, mortality records, Mental Health Information System, the Cancer Registry and the Midwives Notification System. The dataset used unique alpha-numeric identifiers, which allowed the linking of an individual's health records.

Calculation of the number of expected cases was made by indirect age adjustment (Gordis, 2004) with 5 year age groups for depression using ABS census data. Rather than use every admission in the calculations, only the first admission of an individual was used. This eliminated multiple counting of admissions for the same patient e.g. if a patient was admitted for depression more than once in the study period, only the first admission was counted as a depression "case".

Population data

Population estimates were derived from the Australian Bureau of Statistics (ABS) national census for 1996 and 2001 for each census collection district. The period 1996–2001 was used to provide a large number of cases for remote areas while minimising any temporal effects. For the estimation of the population of census collection districts during intercensual years, the following method was applied. For each district, the sum of the 2001 census and 1996 census was averaged and then multiplied by six (i.e. the number of years) to obtain the total number of person–years by region. This method of calculating the population was used, rather than using just one census, to incorporate any changes in population that may have occurred over the study period.

The populations within a census collection district across the study area varied considerably, ranging from less than 100 people up to 1760 people. The population density was highest along the west coast, whereas the majority of the agricultural region was relatively sparsely populated with less than 0.01 persons/ha (although regional towns were higher).

The boundaries for a number census collection districts changed between 1996 and 2001. This change was due either the creation of a new district, the removal of a district, the merging or splitting of a district or simply a shifting of the boundaries of districts. To allow for this change in boundaries artificial districts were created to cover those census collection districts which changed between censuses (Speldewinde, 2007).

The data extracted from the Data Linkage Unit database was geocoded at the census collection district. The records were geocoded using addresses to incorporate spatial data into the dataset by the Data Linkage Unit. Addresses which were 'care of' addresses, post office boxes or lot numbers were not geocoded in the dataset (Anon., 2002). In Western Australia, 85% of morbidity data and 80% of mortality data has been geocoded to census collection district (Anon., 2002). For the study area, 70–80% of records, which had a postcode had a census collection district recorded.

Socio-economic factors can affect human health (Carstairs, 2001; Murray et al., 2004; Wilkinson et al., 2001), the ABS has indexes to measure these variables, the Socio Economic Index For Areas (SEIFA). The SEIFA measures attributes of the population of an area such as education, income, employment and occupation. To provide broader classifications of the SEIFA code for analysis

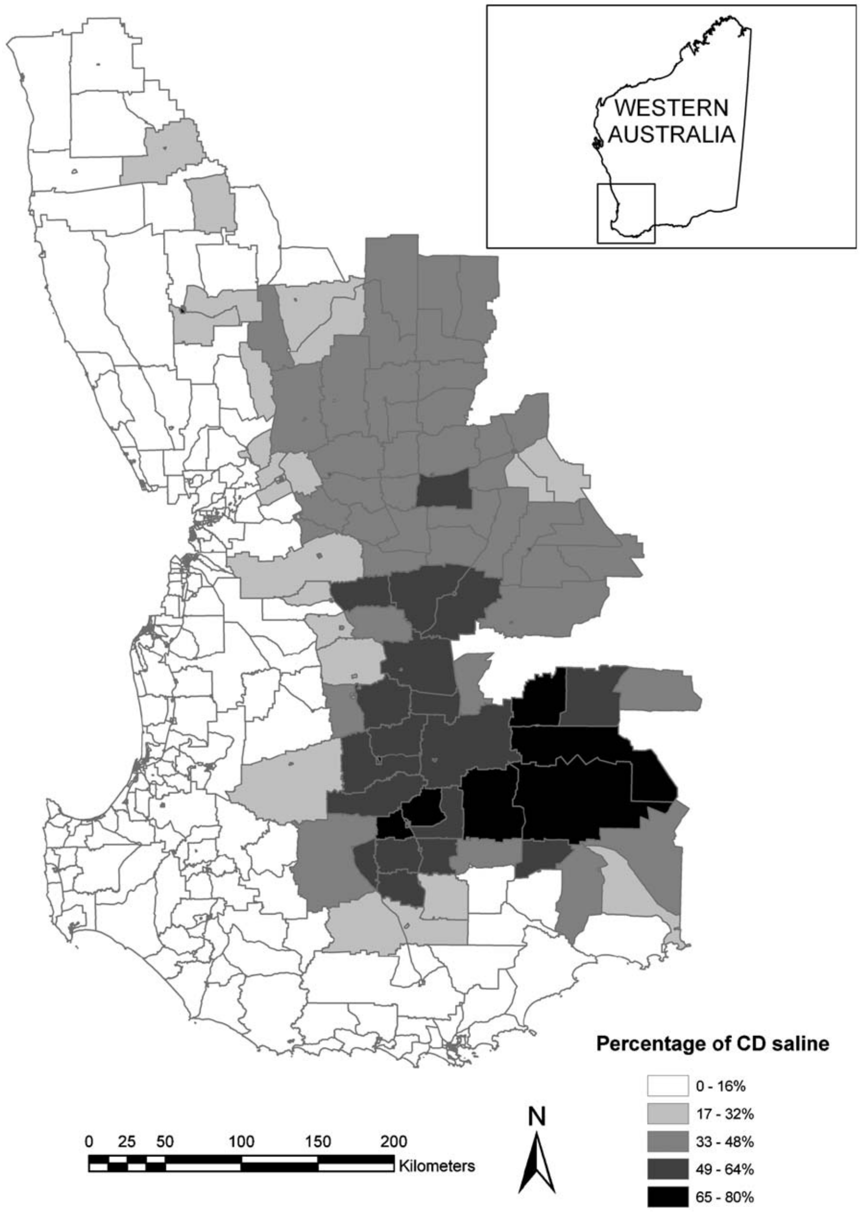

Fig. 1. Map of soil units within the study area showing the percentage of soil unit presently saline or at high risk of salinisation. Note that the Perth metropolitan area is not included in study area.

the census collection districts in the study area were divided into five equal quantiles (1048.56 and higher, 1048.55–1012.32, 1048.54–975.2, 975.19–926.64, and less than 926.64). The SEIFA, while the best available population level data for socio-economic disadvantage, uses commonality between a range of variables to determine socio-economic disadvantage and therefore does not capture every aspect of disadvantage (Pink, 2008). It should also be noted that as the SEIFA is an index constructed using a number of resources it is possible for two areas to have the same disadvantage score for differing reasons (Pink, 2008).

The proportion of the population who were Indigenous was calculated using the 1996 and 2001 census at census collection district level.

Environmental data

The Western Australian Department of Agriculture's soil and landscape mapping database was used to determine the proportion of each CD affected by a number of the environmental variables, which can be associated with dryland salinity. The database maps soil types and defines a number of soil characteristics such as salinity, soil pH, subsoil compaction, wind and water erosion, water repellence, soil structure decline, water-logging, water erosion and wind erosion (Van Gool et al., 2004). This database was based on proportional mapping, which means the database does not give the exact location of (for instance) salinity but rather gives the proportion of the soil type, which is susceptible to salinity. The soil units are generally rated as 'very low', 'low', 'high' or 'very high' for each of the variables.

For the measure of salinity hazard, the proportion of the soil unit rated as *high hazard* or *presently saline* was used (Fig. 1). *High hazard* was defined as salinity already present in limited areas or high risk from shallow saline groundwater that is close to the surface with a rising trend. Often this term refers to land with rising water tables immediately adjacent to saline land. *Presently saline* was defined as all areas where salinity status was moderate, high or extreme and includes land units with

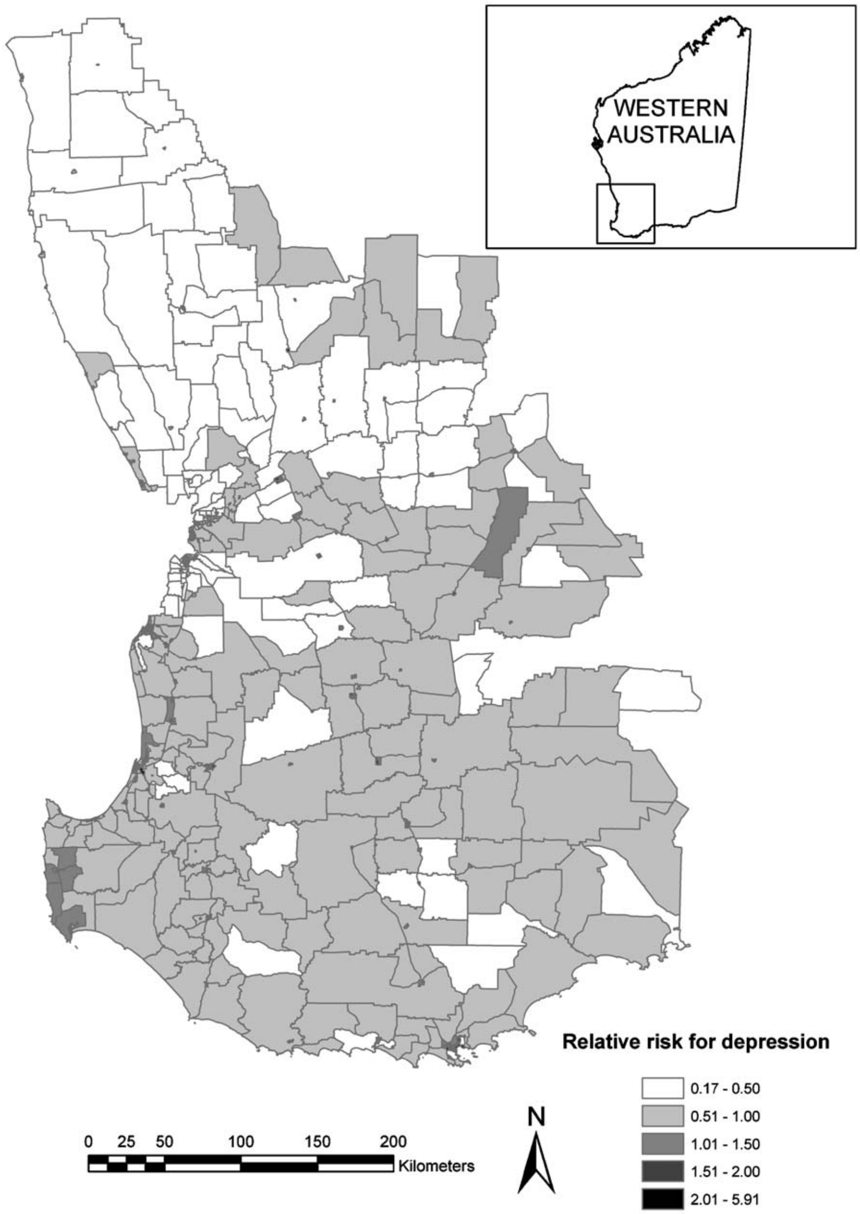

Fig. 2. Modelled relative risk for depression (RR[i] = exp(α+β1 × SEIFA[i]+β2 × ind[i]+β3 × sal[i]+b[i]+h[i]) where $\alpha = -0.991$, $\beta 1 = 0.207$, $\beta 2 = 0.039$, $\beta 3 = 0.003$).

saline wet soils and salt lake soils. The other environmental variables were similarly classified (see Van Gool et al. (2004) for definitions).

For all the environmental variables obtained from the Western Australian Department of Agriculture's soil and landscape mapping database, the method used was the same. Using ArcMap™ GIS software census collection districts were overlaid onto the soil mapping unit boundaries. For each census collection district, the proportion of the total area covered by individual soil types was calculated. Given that the area of the census collection districts was known, it was then possible to calculate the number of hectares of each soil type in each census collection districts. The proportion of each mapping unit affected by the environmental variable was known so this could be used to calculate the number of hectares within the census collection districts affected by the variable. These two estimated could then be integrated to the percentage of the census collection districts affected.

Analysis of data

Initial analyses were based upon calculation and mapping of standardised morbidity ratios (SMRs) for hospitalisation rates for depression. A more advanced spatial model was then developed based on the Besag, York and Mollie (BYM model) (Besag et al., 1991). Risk estimates using this model incorporate both a spatially correlated component and a non-spatially correlated component and is increasingly favoured for the production of disease maps (see Lawson et al. (2000) for review). The model is generally expressed as

$$\log \theta_i = \beta X_i^T + h_i + b_i$$

where θ_i is the relative risk for area i, X_i are the risk factors for area i, β is the vector of the regression parameter, b_i is the spatial heterogeneity (sometimes called correlated heterogeneity and labelled u_i in some studies) and h_i is the non-spatial heterogeneity

Table 1
Number of cases and population size for the study area by 20 year age groups.

Age class	Male cases	Female cases	Male population (average 1996–2001)	Female population (average 1996–2001)
0–19	69	138	67,049	62,547
20–39	436	705	53,479	55,064
40–59	331	518	54,435	53,439
60–79	143	222	26,265	26,340
80+	37	70	3599	5879
Total	1016	1653	2,04,827	2,03,269

(also called uncorrelated heterogeneity and labelled v_i in some studies) (Pascutto et al., 2000).

Models were run using WinBUGS (version 1.4.1)© with minimally informative priors, i.e. the models did not have a well-defined prior distribution. A 'burn in' of 10,000 iterations was used to optimise convergence, followed by a sample of 5000 iterations to calculate sample means for alpha and beta. For each WinBUGS simulation, nodes were monitored to ensure the simulation was exploring all of the possible distribution space. The history of each simulation was checked to ensure convergence, which usually occurred within 200 iterations. The effect of adding parameters were assessed for each model using the deviance information criterion (DIC) of Spiegelhalter et al. (2002). The DIC is a widely used statistic which tests the goodness-of-fit (Lawson et al., 2003) where the model with the lowest DIC value is considered the optimal model to fit the data.

Results

Summary information

The population of the study area averaged 4,08,111 over the period 1996–2001, this was distributed across 882 census collection districts. In the period 1996–2001 there were 2669 individuals with records for depression (1016 males and 1653 females) (Table 1).

Results of Bayesian modelling/spatial analysis

The optimal model for predicting the relative risk for depression included the area level parameters for socio-economic status, percentage of the population classified as Indigenous, the proportion of the area affected by salinity, as well as the standard terms for correlated and uncorrelated heterogeneity (Table 2). Improved goodness-of-fit of the model was suggested by the significant decrease in the DIC (>4 units) with the inclusion of each of these factors in the model.

The initial map of SMR showed no distinct or consistent spatial pattern, with extreme values between 0 and 9.01, indicating the relatively unstable estimate often produced by small case numbers. Poisson-gamma Bayesian smoothing reduced the variability in relative risk to between 0.27 and 4.71.

On visual examination of the risk maps, the final estimates using the BYM model (incorporating SEIFA, proportion of the population identified as Indigenous and salinity) showed no distinct spatial pattern of excess risk (Fig. 2). However, separate analysis of the salinity component indicated a pattern of increased relative risk, which ranged from 1 up to 1.3 in the more saline areas (Fig. 3). The model shows spatial clustering (i.e. correlated heterogeneity) of the relative risk for depression (Fig. 4), but no uncorrelated heterogeneity (Table 2).

Table 2
Deviance information criterion (DIC) for depression relative risk model with and without correlated (b) and uncorrelated (h) heterogeneity (SEIFA—socio-economic index, ind—percentage of population identified as Indigenous and sal—% of area classified as saline).

Model	DIC
α+SEIFA+ind+sal+b+h	3234.530
α+SEIFA+ind+sal+b	3236.080
α+SEIFA+ind+sal	3752.770

Discussion

This study found the optimal predictive model for the relative risk of depression incorporated the following variables: socio-economic status (as SEIFA), percentage of the population identified as Aboriginal, and presence of dryland salinity. This finding indicates that, adjusted for other major factors, an elevated risk of hospitalisations for depression was associated with residence in areas proportionately more affected by dryland salinity. There are a range of likely explanations for these findings. As noted above, dryland salinity can dramatically change the landscape and, in extreme cases, can leave the land unusable for farming and denuded, except for dead trees and salt pans. This level of land degradation can potentially result in mental health outcomes through a number of inter-related pathways. Firstly, dryland salinity can result in a reduction in agricultural productivity and therefore income of farms (Martin and Metcalf, 1998; Trewin, 2002). The effects of salinity can be viewed as similar to those of drought, with the ensuing loss of productivity and lowering of land values leading to an increase in financial pressures. Continuing falls in commodity prices over the past decade and loss of the capital value of assets has lead to a decrease in the ability of farmers to invest in salinity containment or prevention (Stoker, 1999).

As productivity drops and the costs of cultivating degraded land start to escalate, farms become less viable and people may move away from affected areas. As the population declines in already sparsely populated rural communities, social networks tend to fragment and decline (Jones and Tonts, 1995). Lack of social support has been documented as a contributing factor in mental illness in rural communities (Fraser et al., 2005). It should be noted that secondary salinisation is only one of a range of factors, such as lack of education and employment opportunities, commodity prices and farm amalgamation, involved in rural population decline (Jones and Tonts, 1995).

Apart from the role of salinity, the Besag, York and Mollie model used for this spatial analysis indicated the role of other important predictive factors—socio-economic factors and proportion of the population in the areal unit identified as Aboriginal—in predicting hospitalisation for depression. Socio-economic status has been shown in multiple studies to correlate with the mental health status of populations (e.g. Carstairs, 2001;

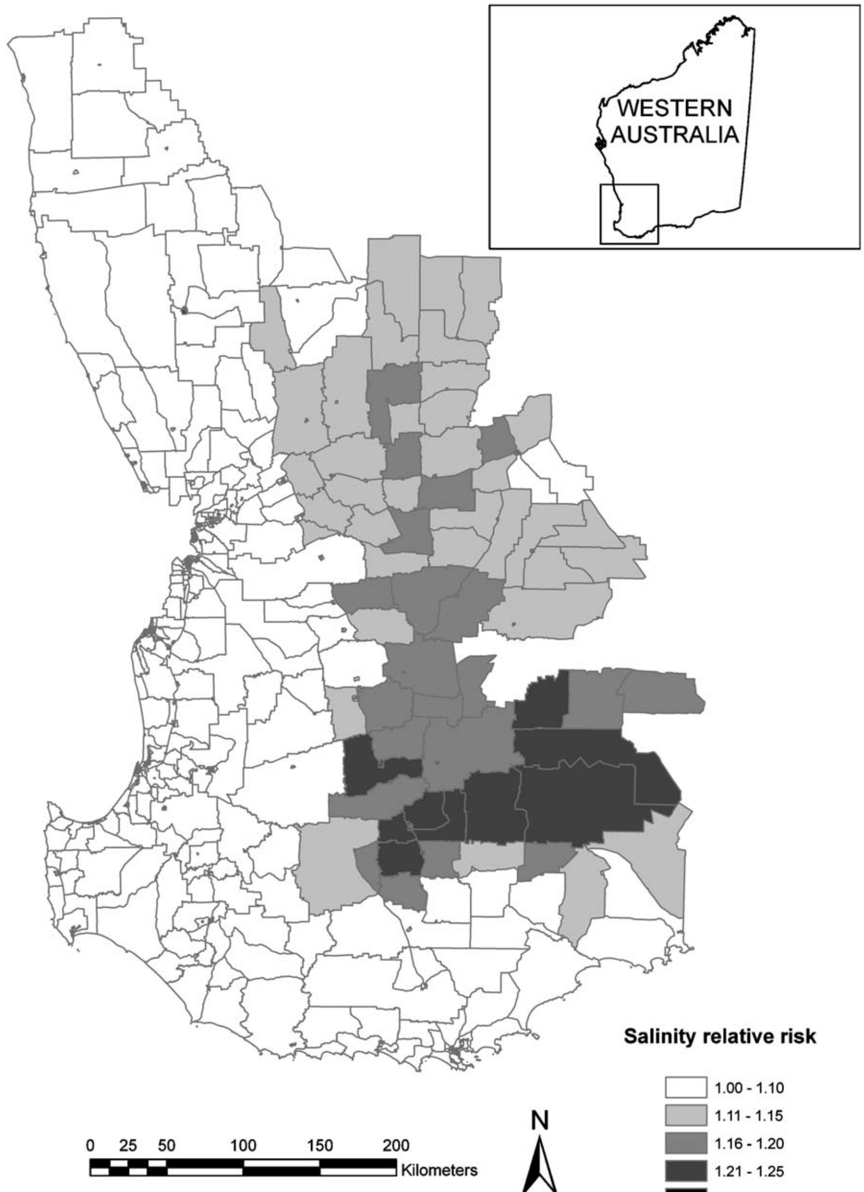

Fig. 3. Relative risk for depression based only on salinity ($RR[i] = \exp(\alpha+\beta1 \times SEIFA[i]+\beta2 \times ind[i]+\beta3 \times sal[i]+b[i]+h[i])$ where $\alpha = -0.991$, $\beta1 = 0.207$, $\beta2 = 0.039$, $\beta3 = 0.003$).

Braaten et al., 2005; Pattenden et al., 1999; Blane et al., 1996). A study by the Australian Bureau of Statistics in 2000–1 found that people in socio-economically disadvantaged areas had a higher prevalence of mental or behavioural problems (AusStats, 2004). Other studies, such as Taylor et al. (2004) found that the prevalence of affective disorders and anxiety disorders increased in lower socio-economic groups (Fryers et al., 2005; Kaplan et al., 2008; Lorant et al., 2007; Taylor et al., 2004).

This study found a correlation between the percentage of the population classified as Indigenous and the relative risk of depression. Generally Indigenous Australians have higher morbidity rates for mental illness compared with non-Indigenous Australians (Draper et al., 2005; Thomson, 1984; Trewin and Madden, 2003; Wilkinson et al., 2001). Rates of depression amongst the Aboriginal males are higher than the rest of the population (Brown and Blashki, 2005) and is one of the common problems treated by GPs in the Aboriginal population (Trewin and Madden, 2003). Aboriginal people are also more likely to be hospitalised due to mental illness than the rest of the population (Draper et al., 2005).

A strong indication of the validity of using the BYM model used for this spatial analysis was that it reliably detected the other major predictors of mental illness—SEIFA and proportion of the population identified as Aboriginal—which are known from the literature to be highly significant. This suggested that the BYM model could be confidently used to detect the effects of other variables of interest in relation to human health outcomes.

Because of the nature of the data utilised in the regional study there were a number of limitations. For most diseases the health data used from the Data Linkage Unit were hospital admission records. Thus, the estimate of incidence rates can only be used as an indication of the scale of disease, but not a true count of the number of cases. Our reported rates are an underestimation of true disease burden for depression (e.g. Draper et al. (2005)). Events such as visits to general practitioners were not recorded in the database. The dataset did not utilise records with post office

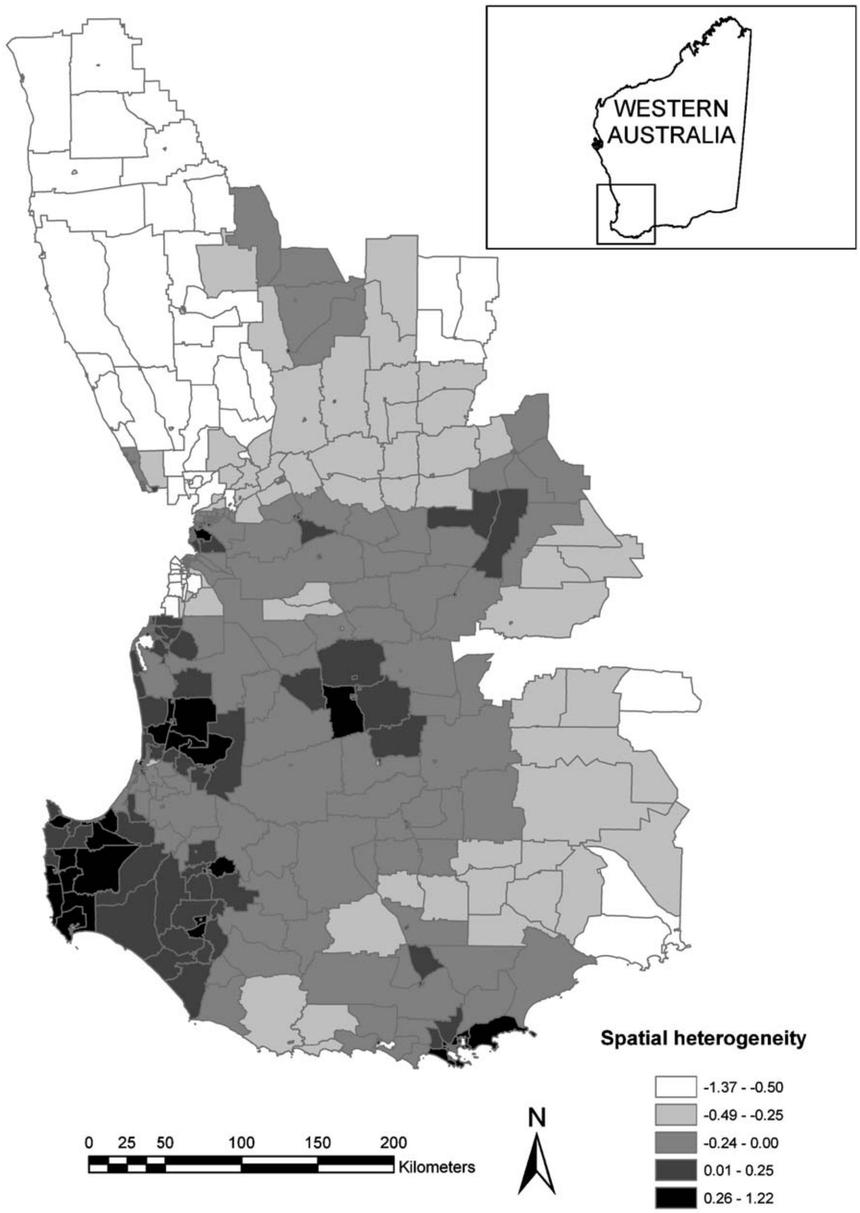

Fig. 4. Correlated spatial heterogeneity for depression.

box addresses and any patient with such a address is therefore not included. In rural areas, use of post office box addresses (rather than street addresses) are more common that in urban areas. These addresses are not geocoded in the dataset because the postcode of the post office box may differ from the postcode of the patient's residence. This exclusion of patient records with no geocode will also lead to a degree of underestimation of the true disease rate.

The soil landscape data used in this study was based on soil surveys conducted by the Western Australian Department of Agriculture. The environmental data from the Western Australian Department of Agriculture's soil and landscape mapping database used a probabilistic mapping system, which assigns the probability of a given point with particular characteristics, as opposed to producing definite measured values for that point (Schoknecht et al., 2004). This form of mapping is able to capture variability within the soil unit (that is, high versus low values) and allows the closest match between the reported information and the map (Van Gool et al., 2004). Although not providing precise information about individual points, these maps were considered sufficiently accurate for the regional scales used in this study.

Conclusion

In summary, dryland salinity was associated with increased relative risk for hospitalisation for depression. Although socio-economic status and the proportion of the population identified as Indigenous were important predictors of the relative risk for depression, dryland salinity also contributed to the relative risk independently. Given the changes in the surroundings due to dryland salinity, local residents could have experienced psychological distress through a range of mechanisms, including loss of farm income. Current predictions are of an escalation of dryland salinity both from the impacts of catchment clearing and, more recently, climate shift that has lead to a substantial reduction in rainfall and associated runoff (Horwitz et al., 2008). With the future extent of salinity-affected farmlands in Australia predicted to rise dramatically, the findings of this study would indicate a corresponding increase in reported rates of depression in rural communities.

Acknowledgements

This research was funded by the Cooperative Research Centre for the Plant Based Management of Dryland Salinity. The research was approved by the University of Western Australia's ethics committee (RA/4/3/0492).

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