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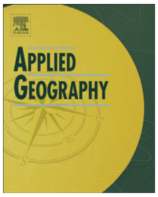

Estimating the spatial and temporal impacts of climate change on rainfall reliability: An example in a Mediterranean agricultural region

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ABSTRACT

Rainfall is the major driver of crop growth in Mediterranean agricultural regions and its spatial and temporal distributions determine yield potential. This study uses a long term spatial archive of rainfall observations for the Eyre Peninsula (South Australia) to estimate the spatial and temporal impacts of climate change on wheat yield. The three step process involved: (1) cluster analysis and statistical comparison to spatially distinguish heterogeneous "hazardscapes" (places that represent the physical susceptibility to hazards (Khan, 2012)); (2) using historical rainfall reliabilities to estimate the probability of receiving rainfall within a range of predefined thresholds and season for each hazardscape; (3) applying 2030 and 2070 climate change projections to determine the potential future impacts on rainfall. Nine hazardscapes were spatially differentiated each having temporally different historical seasonal rainfall reliabilities. Variations over space and time mean that the impacts of climate change will be spatially explicit. Projected rainfall reductions for 2030 showed marginal impact on hazardscapes with low seasonal reliabilities, primarily in winter and spring. The 2070 projections showed that some hazardscapes were unlikely to receive past rates of rainfall thus limiting the ongoing prospects of current and perhaps the potential adoption of alternative rain-fed land uses. Reductions in rainfall for hazardscapes with higher historical rainfall reliabilities will cause negative impacts on crop development. The ability to quantify the potential spatial and temporal impacts of climate change on seasonal trends will inform land managers' climate change mitigation and adaptation pathways.

Introduction

Estimating the potential impacts of climate change on places within a landscape provides an evidence base for both its belief, since most environmental perception is local rather than global (Brondizio & Moran, 2008), and the appropriate adoption of mitigation and adaptation options (Cutter et al., 2008; Smith, Anderson, & Moore, 2012; Yarnal, 2010). Conceptually, place can be defined in a hazard context as a "hazardscape"; a dynamic scape that reflects the physical susceptibility of a place, human life and assets to various hazards within a given human ecological system (Khan, 2012). Several climate change studies have utilised spatially variable climate and environmental information at a regional level (Jongman et al., 2006; Metzger, Bunce, Jongman, Mücher, & Watkins, 2005; Ortega et al., 2012) to spatially differentiate heterogeneous regions (hazardscapes). The approach of stratifying larger regions into smaller climate specific hazardscapes reduces information complexity and estimation uncertainty which is inherent in utilising high resolution interpolated climate datasets. This is especially the case in rural areas where the numbers of climate observation sites are limited both spatially and temporally.

Fusion of spatially distinct hazardscapes and moderate resolution climate change projections can provide an assessment of each hazardscapes climate change vulnerability (Metzger, Bunce, van Eupen, & Mirtl, 2010; Metzger & Schroter, 2006) and an identification of the spatial variation associated with deteriorating agroclimate conditions (Trnka et al., 2011). These studies can help both farm and environmental land managers to evaluate region specific climate change impacts by highlighting future repercussions to traditional agriculture and prospective mitigation and adaptation opportunities based on future climate scenarios.

In Mediterranean agricultural regions, such as those in southern Australia, rainfall is the most limiting factor for crop growth (Turner & Asseng, 2005) and the most commonly measured and archived. While rainfall variability is commonly expressed as annual or seasonal totals, Steffen, Sims, Walcott, and Laughlin (2011) found that the reliability of rainfall was important to guide agricultural decision making in response to climate change.

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This paper will focus on determining both the historical and future rainfall reliability under climate change scenarios for defined hazardscapes within the Eyre Peninsula natural resource management region. The study has three objectives, the first to explore the use of high spatial and temporal resolution rainfall datasets, cluster analysis and a post-hoc statistical test to stratify a large agricultural area into distinct hazardscapes. The second, is to utilise the long historical archive to determine the past rainfall reliability of these hazardscapes and thirdly to apply climate change projections onto these distributions to determine their potential future rainfall reliabilities.

Eyre Peninsula study area

The region covers over 80,000 km^2 of land typified by low topographic relief. Climate is characterised as Mediterranean with cool, wet winters and warm, dry summers. Due to the proximity to the coast, areas in the south experience a cooler, wetter climate than regions in the north. Mean annual rainfall ranges from 250 mm in the north to more than 500 mm in the south (Eyre Peninsula Natural Resource Management Board, 2009).

Dry land agriculture is the major land use which is dominated by cereals such as wheat and barley and the area provides significant economic returns, producing 33% of South Australia's grain harvest. Other agricultural activities include grazing and horticulture. Despite the land dominance of agriculture, 45% of original vegetation is still intact (Fig. 1).

The study area encompasses the majority of agricultural land uses held within the boundaries of the Eyre Peninsula natural resources management area. However, for the cluster analysis this boundary was extended inland by 50 km to reduce potential edge effects (Fig. 1).

Climate change projections for the Eyre Peninsula

A range of climate change projections have been estimated for the Australian continent (CSIRO and Bureau of Meteorology, 2007) depicting results from Global Circulation Models (GCMs) based on IPCC emission scenarios. Sensitivity analysis of these models have shown that the impact on rainfall differs between models (Vaze, Teng, & Chiew, 2011) and that their accuracy is better for predicting minium and maximum temperature than rainfall (Perkins, Pitman, Holbrook, & McAneney, 2007). Given this uncertainty, climate change projections for the Eyre Peninsula were based on outputs from 11 out of 24 models (Suppiah et al., 2006, 82pp.). These models had the highest accuracy when predicting rainfall, temperature and mean sea level pressure for South Australia over the 1960 to 1990 time period and followed the IPCC SRES emission storylines (Suppiah et al., 2006, 82pp.). A percentile distribution was created from the resultant model outputs (Table 1) with 10th, 50th and 90th percentiles estimated (Department of Environment and Natural Resources, 2010). The best estimate (50th percentile) of this distribution was chosen as the projections used in the analysis in order to provide a set of consistent storyline examples. These represent projections for rainfall for the years 2030 and 2070. Here, the Low emission scenario is modelled on the IPCC B1 SRES scenario, the Medium modelled on the A1B and the High on the A1F1 SRES scenarios.

Method

A comprehensive archive of spatially interpolated daily rainfall datasets calculated from ground based observational sites (Jeffrey, Carter, Moodie, & Beswick, 2001) was utilised to address the study objectives. This archive represented continuous daily rainfall surfaces generated at a 5 km grid across the Australian continent using an optimised Barnes successive correction technique that applies a weighted averaging process to the station data. The technique provides an objective average for each grid square and enables useful estimates in data-sparse areas such as parts of rural and central Australia. In data rich areas, data smoothing will occur resulting in grid-point values that may differ slightly from the exact rainfall amount measured at the contributing stations. These datasets have been used before as inputs to create and test spatially

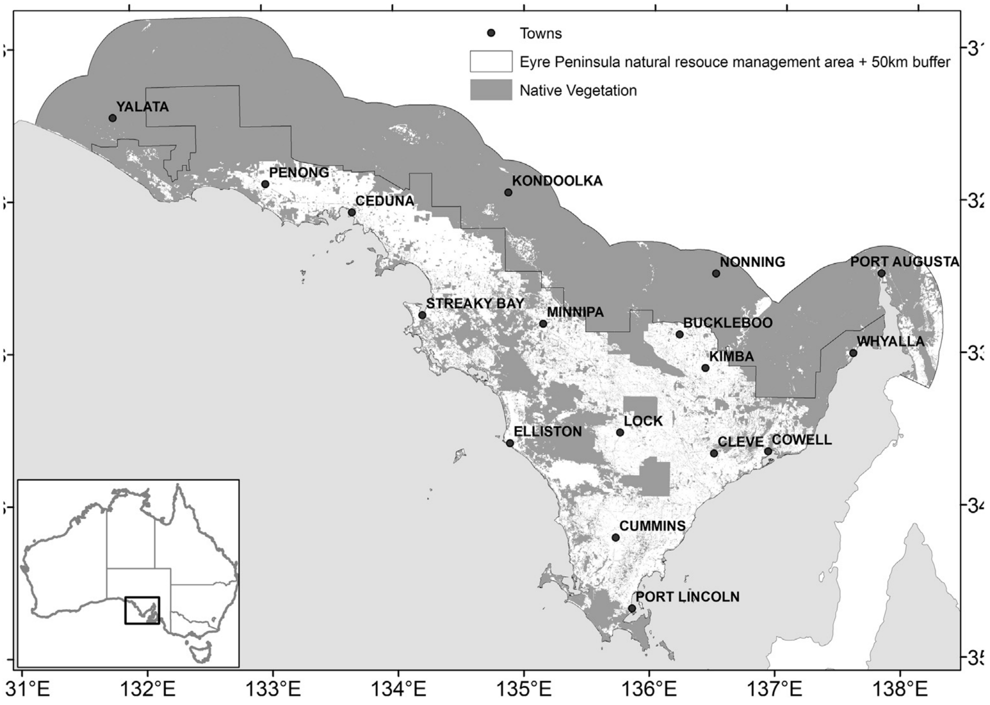

Fig. 1. Eyre Peninsula study region made up of the Eyre Peninsula natural resource management area plus a 50 km inland buffer.