Impact of changing climate on cereal productivity in Queensland

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Abstract

This study aimed to understand the impact of recent climatic conditions on productivity of cereals in Queensland. Changes in solar radiation, rainfall, maximum and minimum temperature were analysed on data since 1900 to 2008, and further relationships were developed between pan evaporation, from available data since 1975, with rainfall, maximum and minimum temperature in order to understand the effect and cause among climatic parameters. Overall, solar radiation increased from 1900 to 1940 thereafter from 1940 to 1980 it decreased below 1900 level. Since 1980 solar radiation has been stabilised similar to 1900 level, or slightly below, as assessed in 4 key cereal production regions in Queensland. As expected from the rising global temperature, maximum and minimum temperatures have increased substantially, whereas rainfall and pan evaporation did not show any significant trend, particularly since 1975 to 2008. Cereal productivity (t/ha) in Australia has significantly decreased since 1990 particularly for winter cereals, with no change in productivity for summer cereals. On the other hand, productivity of summer cereals in Queensland has increased significantly (R^2=0.41, P<0.001)) from about less than 2 t/ha to more than 2.5 t/ha. There was also a slight increase in winter cereal productivity in Queensland. Substantial increases in cereal productivity per unit of rainfall indicate changing climatic conditions, particularly rising maximum and minimum temperature with no impact on overall evaporative demand (pan evaporation did not change) and this appears to have a positive impact on summer cereal productivity in Queensland.

Introduction

There is a need to develop adaptation and adoption strategies for cereal productivity in response to changing climatic conditions for the future. However, it is important to understand the impact of current changes in climatic parameters before developing any adaptation strategies or recommendations. In particular, cereal productivity in Queensland is likely to be influence by the two key components of climate, mean temperature and rainfall. In recent decades, from 1970 to 2008, there have been increases in mean maximum and mean minimum temperatures (BOM, Australia). During this period mean temperature (average of maximum and minimum) has been risen between 0.5 C and >1.5 C in various parts of Queensland. However, the trend in the rainfall pattern is not as clear as the mean temperature, though long-term trend from 1900 to 2008 indicates slight increase in the rainfall whereas a short-term from 1970 to 2008 indicates significant decrease in the rainfall in various parts of Queensland. Forecasts in the future (2030-2070) from various models indicates there will be increases and/ or decreases in rainfall in various regions of Queensland. Nevertheless, current increases in the mean temperature and frequent droughts with likely increases in the evaporative demand may have already impacted on the cereal productivity over the recent decades (1970-2008).

In this study, changes in solar radiation, rainfall, mean maximum and mean minimum temperatures were analysed for the available data from 1900 to 2008 for cereal growing belt in Queensland at specific locations (St George, Roma, Emerald and Goondiwindi). Further relationships were developed between open pan evaporation, and rainfall, mean maximum and mean minimum temperature in order to understand the effect and cause among climatic parameters from reliable data since 1975 for open pan evaporation. Cereal productivity (t/ha) in Queensland was analysed from the reliable data available from 1994 to 2008 (ABS 2007/08). Cereal productivity per unit rainfall was also determined to help understand the impact of current changes in climatic parameters, mostly warmer and drier conditions.

Materials and Methods

Weather data for specific locations (St George, Roma, Emerald and Goondiwindi) and Queensland was collected from SILO website. Cereal productivity data for Queensland and Australia was collected from ABS sources (ABS 2007/08). Solar radiation data was analysed as the decadal pattern (10 year trend) from 1900 to 2008, whereas a trend line was used to analyse the rainfall, mean maximum and minimum temperatures, open pan evaporation, cereal productivity, and cereal productivity per unit of rainfall, from 1975 to 2008.

Results

Rainfall pattern and open pan evaporation did not show any significant changes, whereas mean maximum and minimum temperatures increased significantly over the same period (from 1975 to 2008) (Fig. 1). Extremely dry conditions were recorded in the years 1994, 2002, and 2005 with rainfall below 400 mm compared with the long-term average (1900-2008) of about 600 mm for Queensland.

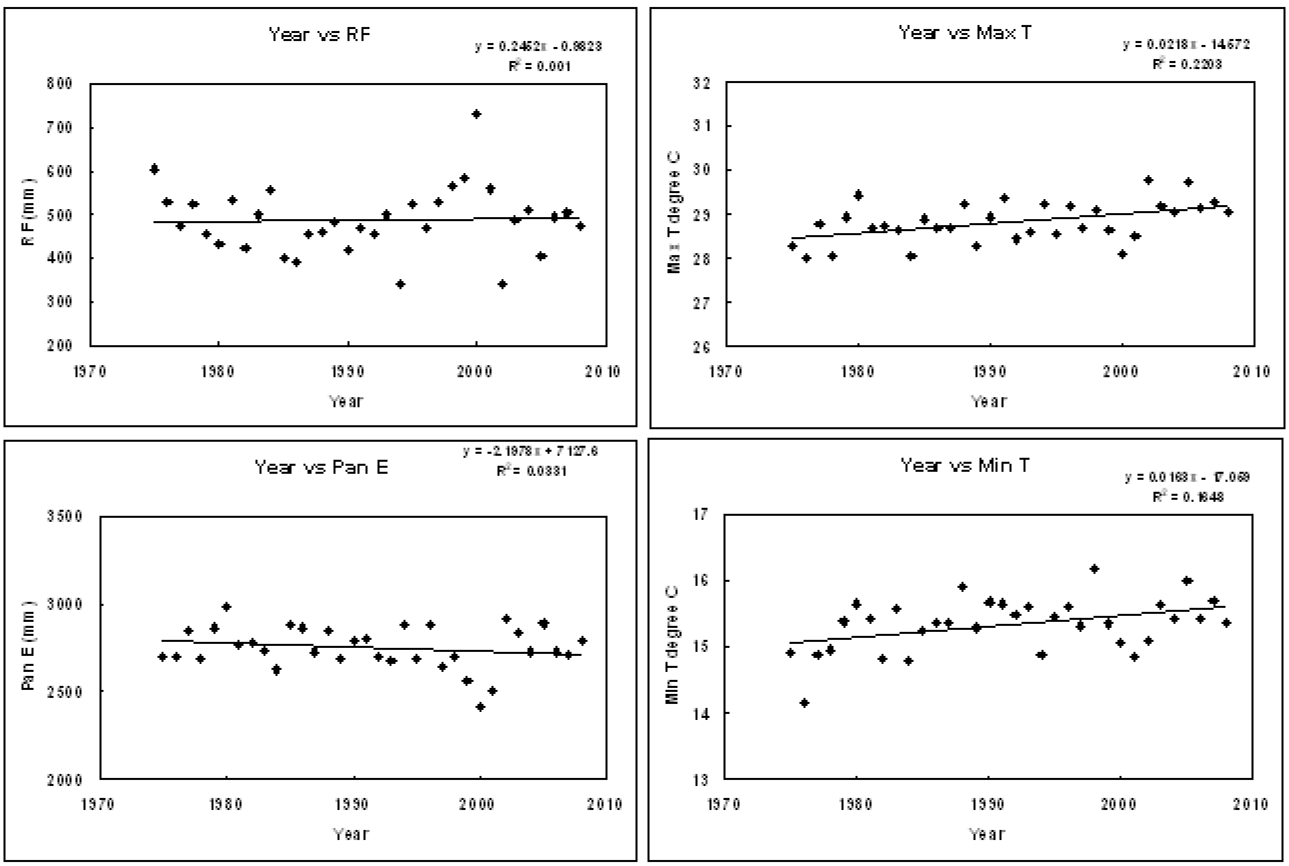

Figure 1. Trends in rainfall pattern, open pan evaporation, mean maximum and mean minimum temperature from 1975 to 2008 for Queensland (source: SILO, Bureau of Meteorology)

Summer cereal productivity did not change, whereas winter cereal productivity decreased significantly for Australia (Fig. 2). On the other hand, for Queensland, summer cereal productivity increased significantly from about 2.0 t/ha to 2.5 t/ha, and there was also a slight increase for the winter productivity (Fig. 2).

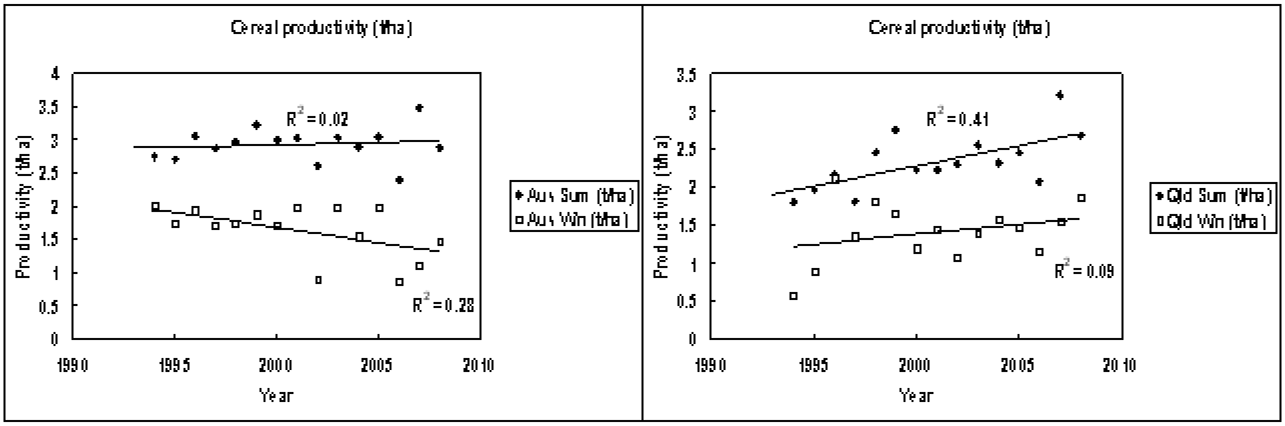

Figure 2. Trends in summer and winter cereal productivity (t grain/ha) from 1994 to 2008 for Australia (Aus) and Queensland (Qld) (source: ABS 2007/08)

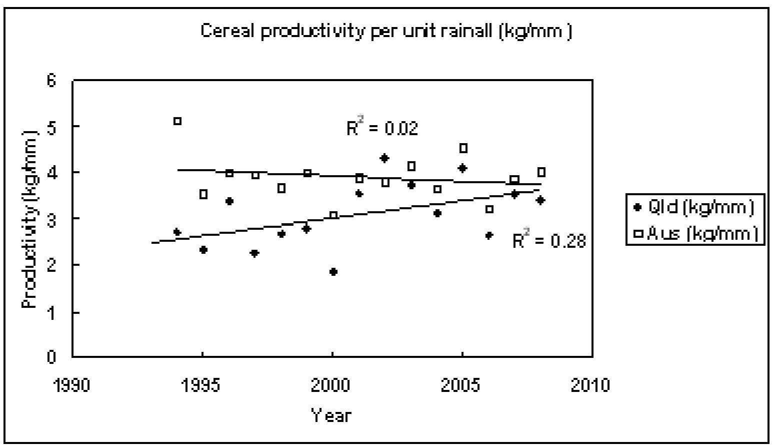

Figure 3. The trend in annual cereal productivity per unit of rainfall for Queensland (Qld) and Australia (Aus) from 1994 to 2008.

Annual cereal (average of winter and summer) productivity per unit of rainfall increased for Queensland, whereas it did not change for Australia (Fig. 3).

Discussion

Australian cereal production is dominant in southern Australian states mostly with winter production of wheat and barley, whereas Queensland (northern Australia) produces most of the summer cereals (mostly sorghum) due to its summer dominant rainfall. However, amount of total winter cereal production in Queensland can be greater than the sorghum production due to larger and preferred planting of wheat during winter. Since significant variability occurs in the planting area from season to season, therefore it was necessary to analyse cereal productivity per unit of planted area, in order to understand the impact of changing climatic conditions in this study.

Analysis of climatic parameters from 1970 to 2008 apparently indicated warmer and drier climate with increasing mean maximum and minimum temperatures, and frequent droughts, in the last couple of decades for Queensland (Fig. 1). However impact of warmer and drier conditions was not reflected upon the cereal productivity. Analysis of cereal productivity per unit of planted area indicated significant increase from 1994 to 2008 irrespective of warmer or drier conditions in Queensland (Fig. 2). It should be noted that this increase in productivity could be also due to improved agronomic management techniques and varieties. In contrast, winter cereal productivity decreased for Australia over the same period though improved management and varieties have been adopted across Australia.

Cereal productivity per unit of rainfall had an increasing trend since 1994 for Queensland compared with Australia (Fig. 3). This was surprising and unexpected while considering warmer and drier climatic conditions for the same period. Warmer and drier conditions should have increased the evaporative demand and evaporation with reduced efficiency of rainfall for cereal production. This poses a fundamental question of our understanding and assumptions of current climate change and its impact on agricultural production and likely adaptive strategies in future.

Open pan evaporation indicates evaporative demand resulting from interaction of various climatic parameters (rainfall, temperature, vapour pressure deficit, solar radiation, and wind speed). Unchanged or slight trend of decreasing open pan evaporation until 2000 highlighted other climatic factors might be interacting and negating the impact of increasing mean temperature on the evaporation. In particular, increases in rainfall and/or cloud cover, or decreases in wind speed or solar radiation might be influencing the open pan evaporation. Solar radiation analysis though suggests that overall decrease in the radiation since 1950 as shown for the four regions in Queensland (Fig. 4). This trend was similar for the other regions in Queensland (data not presented). However, during the period of open pan evaporation analysis there was not much change in the solar radiation between 1970 and 2008 (Fig. 4).

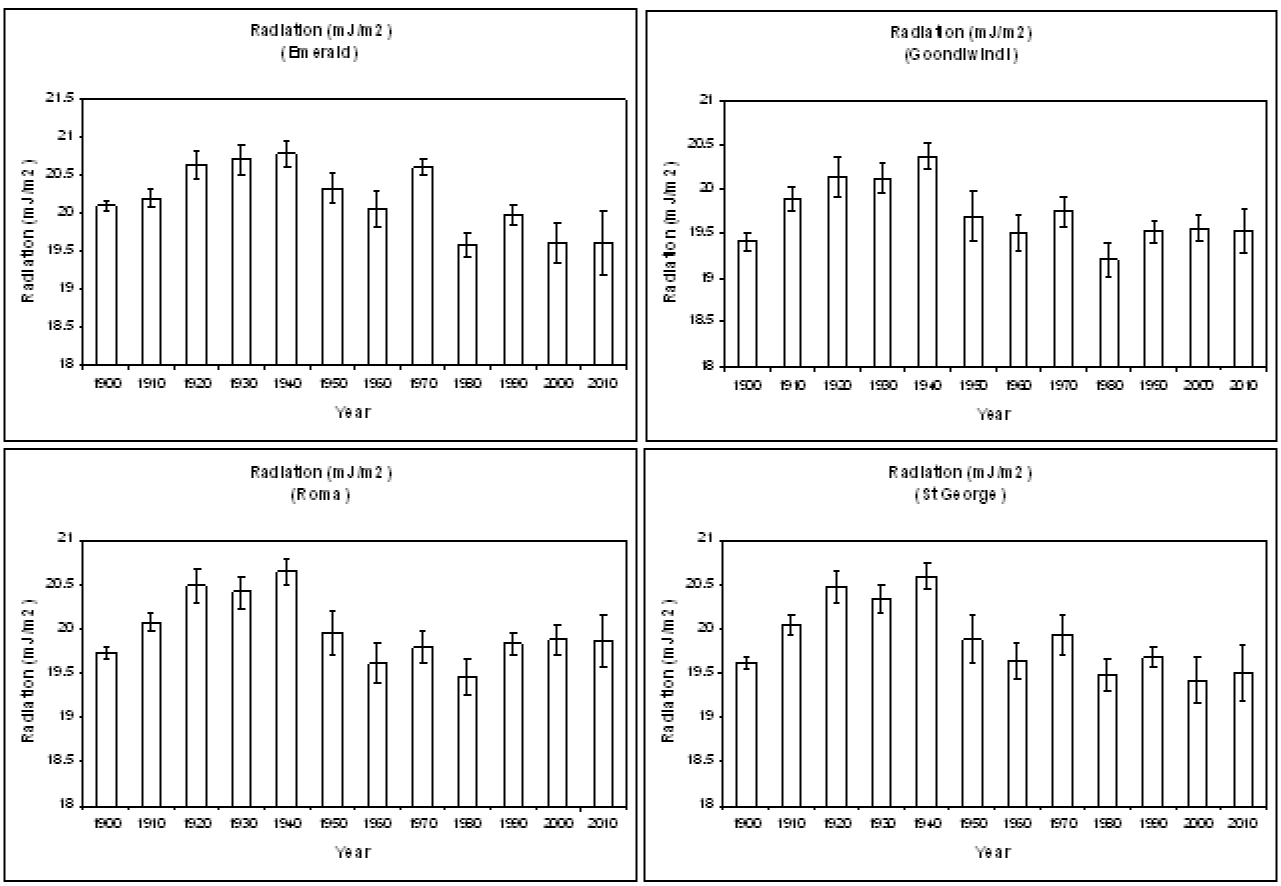

Figure 4. Decadal trends in the solar radiation for Emerald, Goondiwindi, Roma and St George, Queensland.

There was no authentic data available for wind speed or cloud cover to be analysed, and the reliability and quality of solar radiation data pre-1950 can be a concern in this study. However, long-term trend in rainfall, from 1900 and 2008 suggests that there has been increase in the total annual rainfall for

Queensland. This may also suggest that cloud cover might be increasing thus impacting on the open pan evaporation. This ‘evaporation paradox’ has been seen for other regions and countries and debated in the literature vigorously in recent years (Peterson et al. 1995; Brutsaert and Parlange 1998; Roderick and Faraquhar 2002; Cong et al. 2009). Some of these studies around the world did include wind speed and cloud cover data to understand the ‘evaporation paradox’ which has complicated the understanding of relationship between CO_2 and temperature increases and impact on evaporation and increasing water vapour in atmosphere.

In conclusion, current changes in the climatic conditions (warmer, not necessarily drier conditions) do not indicate any negative impact, rather it has been beneficial for cereal production or productivity in Queensland. A cautious approach is required for suggesting recommendations for likely adaptive changes based on the current impact of climate change on cereal productivity in Queensland. However, if the climate continues to change with further increases in the mean temperature as well as elevated atmospheric CO_2 the impact and outcome can be expected to be different.

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