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Research paper

An investigation of farm-scale adaptation options for cotton production in the face of future climate change and water allocation policies in southern Queensland, Australia

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ABSTRACT

Modelling cotton production at the farm-scale provides insight into the importance of water management options in adapting to climate change, especially given the renewed focus of government policies on irrigation water access and allocations. Using an irrigated cotton farm in southern Queensland as a case study, we investigated two possible adaptation strategies in response to changes in water resources from projected climate change (CSIRO Mk3.5, A1FI scenario). The modelled farm produced irrigated cotton, wheat, maize, and non-irrigated sorghum. The adaptation Strategy 1 allowed the substitution of current (baseline) production system with a system of less intensive cotton (2 m row spacing) and a maximum of 2 in-crop irrigations instead of 4. Whereas Strategy 2 allowed for the production option of dryland cotton in the rotation and implied as much 2 m row spacing cotton planting as possible depending on the other cropping rules regardless of the state of water storages. These two strategies were examined using a bio-economic farm enterprise model by evaluating the effects of projected changes in yield, water use and farm profitability (gross margin, GM), which resulted from crops competing for resources (i.e. irrigation water). Results showed 14% less water available in the 2030 s and 2050 s compared to the baseline (1960–2010), as a result of climate change and water policy decisions, thereby reducing the input costs. Under Strategy 1 there were 12.1% and 4.4% yield decreases in 2030 and 2050, respectively; while under Strategy 2 the inter-annual yield variability and proportion of low yields (<5 bales/ha) increased over the same periods. Without adaptation GMs were reduced by 27% and 43% in 2030 and 2050, respectively. Strategy 1 resulted in 8.8% increase and 15.8% decrease in 2030 and 2050, respectively. However with Strategy 2, GM increases were observed (49% and 12%, respectively in 2030 and 2050). Moreover, without appropriate adaptation options, the enterprise would have to reduce the area of irrigated cotton, causing reductions in farm business gross margins. Our findings suggested that decreased water availability would not significantly impact the cotton production system and profitability if suitable adaptation options are available.

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1. Introduction

Climatic variation is a fundamental determinant of cotton production in Australia (CRDC, 2011; McRae et al., 2007). The gross value of cotton produced in Australia has generally increased since 1985, except during drought years including 1986/87, 2002/03, 2003/04, 2006/07, 2007/08 and 2014/15 (Cotton Australia, 2015; McRae et al., 2007; NLWRA, 2008; van Dijk et al., 2013). Negative effects of climate change, i.e. reduced water availability and increased evaporation, are likely to exacerbate other climate-related production challenges to the Australian cotton industry through fruit loss, lower yields and reduced water use efficiencies due to higher temperatures (Bange et al., 2010; Williams et al., 2015).

The Australian cotton industry is one of Australia's largest rural export earners (Cotton Australia, 2016; Cotton Australia and CRDC, 2014). In cotton-producing regions in Australia cotton is a major component of the farming system and makes up 30–60% of the gross value of the total agricultural production (ABARES, 2012; Cotton Australia and CRDC, 2014; Roth, 2010). Most of cotton

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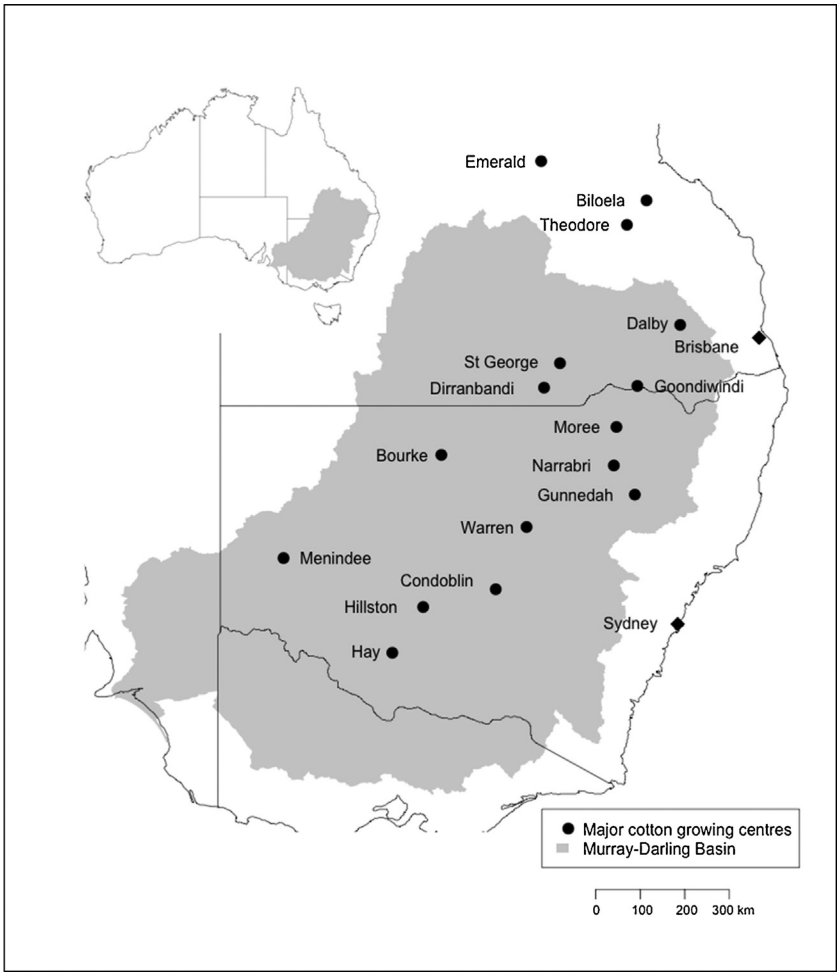

Fig. 1. Cotton growing centres in Australia in relation to the Murray-Darling Basin.

producing farms in Australia (≥80%) are irrigated. The overall production is therefore sensitive to water availability. Water resources allocation regimes vary significantly depending on the particular state or territory, the environmental conditions and water management capacities. Water resources allocations in Australian cotton producing regions (Fig. 1) depend on the Murray-Darling Basin (MDB) plan 'The Plan'. The Plan aims to ensure that water is shared between all users, including the environment, in a sustainable way (https://www.mdba.gov.au/basin-plan). However, the Plan lacks robust understanding of what is sustainable and what is not, and how to best balance and optimise the water needs of the environment, agriculture, other non-agricultural industry, and human settlements (Kiem, 2013). Under the proposed water buy-back scheme, the northern MDB region's allocation is expected to reduce by 100 GL or 14%, and to increase flows in the Murray–Darling River system (Kiem, 2013; MDBA, 2010). Together with significant and unanticipated declines in water allocations over recent years and climate change threat this will result unprecedented pressure on cotton irrigators to improve water use efficiency, productivity and adopt suitable practices to remain viable.

The sensitivity of cotton production to various key aspects of climate (such as temperature, radiation, water, CO_2) has been well documented (e.g., Bange et al., 2010; Bange and Milroy, 2004; Reddy et al., 1995; Reddy et al., 2000; Reddy et al., 2004). This knowledge has enabled the development of strategies to manage the impacts of climate variability at both farm and industry scales. In general, these strategies have focused on improving the whole farm resource and crop water use efficiencies to increase farm productivity and economic returns (Power et al., 2011; Ritchie et al., 2004). Despite this, there are still significant uncertainties surrounding the impacts of climate change on cotton production and possible adaptation options, especially in light of changing government policies on irrigation water access and allocation (Luo et al., 2013; McRae et al., 2007; MDBA, 2011; Pearson et al., 2011).

To address these uncertainties, the vulnerability and sensitivity of cotton yield to climate change has been assessed for the major cotton producing regions using a range of modelling techniques including process-based models (Doherty et al., 2003; Haim et al., 2008; Hebbar et al., 2013; Rodriguez et al., 2014; Williams et al., 2015; Yang et al., 2014) and statistical modelling (Schlenker and Roberts, 2009). Such quantifications of the risk of climate change to the cotton industry can provide the foundations for an economic analysis of climate change impacts, as undertaken for other agricultural sectors (e.g. Rodriguez et al., 2014).

Existing analyses on impacts of climate change on the yield of individual crops present considerable potential for adaptation and policy recommendation (Challinor et al., 2009; Howden et al., 2010). Suggested climate risk management strategies for Southern Queensland include water management strategies to enable better water use efficiently, improved nitrogen use efficiency, development of crop rotation systems, optimal planting configurations, the use of integrated pest and weed management systems (Bange et al., 2010; Luo et al., 2013; McRae et al., 2007). However, it is essential that the spatial scale be increased to the farm level when considering adaptation plans for cropping systems (Rodriguez et al., 2011).Working at a farm-scale will demonstrate to farm managers

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