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Economics and risk of adaptation options in the Australian cotton industry

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ABSTRACT

Economic impact and the cost and risk of adaptation from future climate change (CC) are the key concern of primary industries including the Australian cotton industry. Utilising outputs from biophysical modelling studies, this study quantifies the economic impact of future CC on irrigated and rain-fed cotton production systems and evaluates the effectiveness of adaptation options in dealing with the projected negative impacts or in capturing the opportunity of future CC for the period centred on 2030. For irrigated cotton, three key cotton production areas in eastern Australia were considered: Dalby, Narrabri and Hillston with rain-fed cotton is also analysed at the first two sites. Adaptation options considered included changing planting time, row configurations, irrigation scheduling triggers and rotation patterns. For irrigated cotton under CC, results indicated that (1) gross margin (GM) would increase or decrease depending on location and across irrigation triggers when associated with normal planting times; (2) later plantings, especially + 15 d, would have positive impacts on GMs across all locations when compared with normal planting times; (3) overall, rotations of cotton three years in and one year out would perform the best in terms of GMs when compared with other rotation patterns across all locations; (4) the least negatively affected rotation strategy would be cotton 2 years in and 1 year out in terms of profitability and risk; and (5) later planting at + 30 d would increase whole farm profitability compared with normal planting across all irrigation triggers. It was found that the positive impacts of late plantings on GM and whole farm profitability could not offset the negative impacts of CC at Narrabri and Hillston, indicating that other adaptation options are maybe needed in order to maintain current profitability.

For rain-fed cotton under CC, (1) GM would decrease or increase depending on locations when compared with the baseline and a normal planting time; (2) late plantings could compensate for the negative impacts of future CC on cotton GM at Dalby and would further enhance cotton GM at Narrabri; (3) solid row configurations would perform the best across most rotation patterns and locations; (4) cotton-long fallow would out-perform cotton-long fallow-wheat across all row configurations at Dalby; (5) in terms of whole farm profitability and risk, the adaptation strategy of 15 d later planting would further increase whole farm profitability in 2030 with reduced risk across all row configurations when compared with normal planting; and (6) the cotton-long fallow rotation system would be able to maintain higher levels of profitability and lower levels of risk than its counterpart.

The increase in the variability of returns across all systems and adaptation strategies at the whole farm level under CC, indicates that the level of debt that Australian cotton farms are carrying into the future period will need to be reduced to avoid larger fluctuations in returns to owners' equity. Cotton growers at different locations will need to adopt different management strategies to deal with the risk or in taking the opportunities of future CC.

1. Introduction

The potential impact of future climate change (CC) on cotton production has been widely reported (Mauney et al., 1994; Kimball et al., 1994; Reddy et al., 2002, 2005; Yang et al., 2014). However, there is very limited literature on the potential economic impact of future CC on cotton production worldwide, let alone adaptation economics. Haim et al. (2008) assessed the economic effects of future CC on cotton production in Israel. This study found that cotton would experience considerable decreases in yield with significant economic losses [−240 and −173% under A2 and B2 emission scenarios (IPCC, 2000), respectively]

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for the period centred on 2085 compared with the current situation. There remains a research gap in the economics of adaptation with regard to cotton production.

The Australian cotton industry generates significant wealth and is an important producer in the world cotton market, with exports in excess of A$2.0 billion annually. It also provides an important economic foundation as it employs up to 14,000 people in many regional and remote rural economies (CRDC, 2013). Cotton production is very sensitive to climate variation, including CC, especially in terms of available irrigation water for its production and its interaction with some key physiological processes.

The biophysical impacts of future CC on Australian cotton production have been reported in a number of studies. Luo et al. (2014) quantified the potential impacts of future CC in 2030 on cotton crop phenology. Luo et al. (2015) investigated the effects of future CC on cotton water use and water use efficiency of both irrigated and rain-fed cotton systems and assessed various adaptation options. In dealing with the negative impacts or capturing the opportunity of future CC different water supply levels were investigated for irrigated systems, while in rain-fed systems different plant row configurations were assessed. Following this work, the effectiveness of changing planting time and irrigation scheduling triggers was further explored (Luo et al., 2016a, summarised in Supplementary resource I). The potential impact of future CC on rotated cropping systems, in which cotton is a major component, has been examined (Luo et al., 2016b, summarised in Supplementary resource II). In addition to production quantity, the impact of future CC on cotton fibre quality was also investigated (Luo et al., 2016c). These biophysical impact assessments and adaptation evaluations have laid a sound basis for quantifying the economic impact of future CC on Australian cotton production and for prioritising adaptation options in terms of economic and risk efficiency. This research aims to contribute to the sparse literature and quantify the economic impact of future CC on cotton production in Australia and extend economic impact assessment to the economics and risk of adaptation options.

2. Methods and materials

To undertake the economic impact assessment of adaptation options, this study utilised projected cotton and wheat yields under a changing climate. These were derived from previous biophysical modelling studies that are detailed in Luo et al. (2016a) and Luo et al. (2016b). For detailed information on the construction of the local CC scenarios readers are directed to Luo et al. (2014, 2015). For each adaptation option being considered and for each general circulation model (four GCMs plus the base climate scenario), 100-year simulations were produced to provide projected cotton and wheat yields (Supplementary resource I Tables S3 and S4; Supplementary resource II Tables S4 and S5).

The economic analysis of adaptation options utilised the populations of projected yields to derive economic returns at both a Gross Margin (GM) and whole farm economic level. Base economic and financial parameters were derived from industry published crop budget tables and a defined typical farming business within the case study area. The GMs were derived using industry crop budget tables and mean expected yields. To analyse farm level profitability and risk, the predicted yield variations derived from the biophysical simulation outputs were used as inputs into a whole farm financial model using a Monte Carlo sampling approach on predicted crop yields.

2.1. Study areas

Three key cotton production areas in eastern Australia (Dalby in Queensland, Narrabri and Hillston in New South Wales) were used to quantify average crop GMs (Fig. 1). All three case study areas were used to analyse cotton production GMs under irrigated conditions with the first two (Dalby and Narrabri) were used to analyse cotton production GMs under rain-fed conditions. In undertaking whole farm profitability and risk analysis, the study focused solely on whole farm production at Narrabri under both irrigated and rain-fed production systems. These production areas represent the predominant Australian cotton production regions in terms of both geographical spread (with Dalby in the North, Hillston is the South, and Narrabri in between) and their importance to cotton production under both irrigated and/or rain-fed conditions. Table 1 shows current and future climate of these production areas.

2.2. Adaptation options considered

The economic analysis is based on two biophysical modelling studies previously completed. Daily outputs (maximum/minimum temperature, rainfall, solar radiation) of the CSIRO Conformal Cubic Atmospheric Model (CCAM) for the periods 1980–1999 and 2020–2039 were used by a stochastic weather generator: LARS-WG to derive monthly CC and to construct long time series of daily climate scenarios (CSs) for key cotton production areas in eastern Australia. The CCAM is a variable resolution model with a spatial resolution of 15 km by 15 km in Australia. It was driven by four general circulation models (GCMs, GFDL, Mark3.5, MPI, MIROC) under the Special Report on Emission Scenario (IPCC, 2000) A2 emission scenario. The CSs were then linked to process-oriented crop models such as the OZCOT (Hearn, 1994) and the Agricultural Production System sIMulator (APSIM)-Ozcot and -Wheat (Holzworth et al., 2014) to quantify the effects of future CC on cropping production systems under various management strategies for the period centred on 2030. The rationale of considering the period 2020–2039 is that growers are more interested in near future CC impact rather than far future.

The modification of the OZCOT and the APSIM-Wheat in representing the physiological effects of enhanced atmospheric CO_2 concentration on crop production can be found in Luo et al. (2015) and Reyenga et al. (1999) respectively. The Ozcot model was developed for Australian cotton production systems and has been validated for both irrigated and rain-fed cotton across a range of environments (Richards et al., 2008). O'Leary et al. (2015) evaluated the performance of the APSIM-Wheat model against Australian Grain Free Air CO_2 Enrichment experimental datasets and found that simulated crop responses to enhanced CO_2 were similar to and within the experimental error for accumulated biomass, yield and water use response.

More information on the two biophysical modelling studies can be found in Supplementary resources I and II. Of these two previous studies, one examined the effects of changing planting time and irrigation scheduling on cotton production (e.g. cotton lint yield) under future CC conditions (Supplementary resource I). Specifically, four planting times were considered for both irrigated and rain-fed cotton: being normal planting, 15 days (d) earlier than normal planting, and 15 d and 30 d later than normal planting. Two irrigation triggers (50 mm and 70 mm available soil water, below which an irrigation event is triggered) were taken into account for irrigated cotton. The current irrigation scheduling trigger typically used by the cotton industry is around 70 mm (Luo et al., 2015). The other investigated the effects of rotation patterns on crop (i.e. cotton, wheat) yields in a changing climate for the period centred on 2030 (Supplementary resource II). Cotton in a rotation with wheat (either, cotton three years in and one year out, or cotton two years in and one year out), and continuous cotton (cotton grown each season), were considered for irrigated cotton production systems. Cotton-long fallow-wheat and cotton-long fallow rotations were considered for rain-fed cotton production systems. It should be noted that wheat is continually grown under rain-fed conditions, whether it is rotated with irrigated cotton or with rain-fed cotton. Three row configurations: solid (S), single skip (SS) and double skip (DS) were considered for rain-fed cotton production systems. As a result, the economic analysis was focused on adaptation options such as changing planting time, changing irrigation schedules and rotation sequences for irrigated systems, while in rain-fed cotton systems different