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Advancing a farmer decision support tool for agronomic decisions on rainfed and irrigated wheat cropping in Tasmania

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ABSTRACT

Well-designed agricultural decision support tools (DS) equip farmers with a rapid, easy way to compare multiple scenarios as well as the influence of different management strategies on crop production. One such tool, CropARM (http://www.armonline.com.au) assists users in establishing a framework of risk, with simulations incorporating climate scenarios and management actions, such as fertiliser rates, sowing time, row spacing, and irrigation regimes. When used in conjunction with soil and climate characteristics, biophysical model-based DS tools provide information that complements farmer experience and helps establish a framework for risk management given local climate characteristics. In this study, we used the APSIM model to provide the simulation data necessary to expand CropARM for new management conditions and environments in southern Australia. Prior to this work being undertaken, no CropARM data was available for Tasmania and no sites in CropARM allowed users to compare rainfed and irrigated wheat crops. This study collated data from 27 plots across ten sites in Tasmania, from the period 1981 to 2011, under both rainfed and irrigated conditions. APSIM was parameterised with these field observations and the subsequent scenario simulations were used to populate CropARM. Wheat cultivars used in the parameterisation of APSIM include Brennan, Isis, Mackeller, Revenue, Tennant (winter types) and Kellalac (spring type). The validation showed reliable model parameterisation, with an r^2 value of close to 1, which is considered satisfactory. 670,680 simulations were undertaken and incorporated within the CropARM database for wheat cropping systems across Tasmania. With regularly updated climate streams, the free online framework provided by CropARM gives users the ability to assess downside risks associated with several different crop management alternatives, and by simultaneously comparing multiple scenarios, users can select management options that are likely to adhere most closely with their desired management objectives.

1. Introduction

Agricultural decision support (DS) tools equip users with a rapid and cost-effective means of contrasting multiple scenarios to gauge the influence of different management strategies on farm production and profitability (Nelson, Holzworth, Hammer, & Hayman, 2002; Hochman & Carberry, 2011; Rose et al., 2016). Such tools provide information that complements farmer experience and establishes a framework for risk management where declining profitability and increasing climatic variability within agriculture increasingly pose complex challenges (Hochman & Carberry, 2011; Jakku & Thorburn, 2010). Such challenges necessitate the integration of scientific knowledge into decision support tools that can assist primary producers contemplating farm management decisions (Jakku & Thorburn, 2010). Agricultural DS tools are typically software applications, commonly based on models describing various biophysical processes in farming systems and the response to varying management practices (Jakku & Thorburn, 2010; Rose et al., 2016). Decision support tools designed for assessing crop

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management often require data regarding climate, soils, farm management and crop genotype (Carberry et al., 2002; Nelson et al., 2002; Hochman et al., 2009). Data is typically collected directly from archived records, such as the national climate and soil databases available in Australia (SILO climate data and ASRIS; https://www.longpaddock.qld.gov.au/silo/, http://www.asris.csiro.au/) and is used in biophysical models including the Agricultural Production Systems Simulator (APSIM). APSIM uses a modular framework that allows users to 'plug-and-play' management as well as soil and crop components in a graphical user interface (Holzworth et al., 2006). This feature circumvents the need for model derivation from first principles or programming coding underlying mathematics in low-level programming languages, isolating execution semantics of computer architecture from users and increasing ease of use.

The APSIM model has been used to provide simulation data that underpins DS tools including FARMSCAPE (Carberry et al., 2002), Yield Prophet (Hochman et al., 2009) and Whopper Cropper (Nelson et al., 2002). The Whopper Cropper software tool was developed in consultation with public and private advisors/consultants, partly in response to demand for access to the cropping systems modelling capability of APSIM (Keating et al., 2003). Whopper Cropper provides information on the impact of climate risk on crop yields for crop management alternatives beyond the experience of individual farmers, using historical climate data to obtain seasonal cropping perspectives (Nelson et al., 2002). Recently, Whopper Cropper was transformed into the online set of tools called Agricultural Risk Management, hosted by the Queensland Government (ARM online), see http://www.armonline.com.au/#/wc. APSIM simulations have been used to provide information for the ARM tools, such as NitrogenARM and CropARM. Each tool has user-defined management options including soil type, water profile capacity at sowing, cultivar and plant density as well as sowing date and nitrogen (N), amongst others. Additionally, CropARM calculates growers' exposure to risk when comparing various management inputs such as applications of N fertiliser along with resource-based options such as stored soil water. When used in conjunction with soil and climate characteristics, biophysical model-based DS tools provide information that enhances farm manager experience and provides a framework for risk management given prevailing climate characteristics as determined by location, for example early frost incidence or the influence of heat waves during anthesis, that can severely penalise grain yield.

Effects of different management locations and cultivars in CropARM can be displayed alone or in combination with other inputs. Each simulation uses 115 years of climate records and the APSIM model to simulate year-to-year variability in yields along with related information including crop biomass, grain protein, in-crop rainfall, days to harvest, water use efficiency and minimum and maximum in-crop temperature. The APSIM model (version 7.8) (Keating et al., 2003), has been shown to competently simulate crop growth and yield, and water and nitrogen balances across a wide range of environments (Acuna, Lisson, Johnson, & Dean, 2015; Keating et al., 2003; McCormick, Virgona, Lilley, & Kirkegaard, 2015; Robertson & Lilley, 2016; Wang, Wang, & Liu, 2010). The CropARM outputs use climate records from SILO and the national soil grid provided by the Australian Soil Resource Information Systems (ASRIS) (http://www.asris.csiro.au/). This enables users to make informed decisions about the risk associated with various management conditions whilst taking account of interactions between crop biology with climate (phenology) given similar growing season conditions experienced in the past.

Like all DS tools, CropARM can only include a set number of crops types and management alternatives. Prior to this study, the DS tool only contained data from mainland Australia and excluded data for the southern-most state, Tasmania. Further, agronomic information for mainland sites contains only simulations of rainfed crops. In order to keep pace with growing dairy industry expansion in Tasmania, the Grains Research and Development Corporation (GRDC) recently invested in new research projects to double Tasmanian grain production in the next five years to approximately 160,000 t/annum (Ryan, 2015). With the rollout of new irrigation schemes across the State from a $220 million investment (http://www.tasmanianirrigation.com.au), grain is becoming commercially competitive with other high-value crops such as poppies (Ryan, 2015). Such developments mean that farmers in Tasmania may be more inclined to produce cereals and dual-purpose grain crops, which are common in high-rainfall zones of mainland Australia (Harrison, Evans, Dove, & Moore, 2011). As irrigation infrastructure becomes more available, users will require more agronomic information on irrigation and management option effects on crop yields in different locations of Tasmania.

The purpose of this study was to parameterise APSIM using observed wheat crop production data from ten sites across Tasmania, and then to incorporate this data into CropARM, since prior to this work no CropARM data were available for the State. Additionally, there were no options for comparing between rainfed and irrigated crop yields within CropARM. Effects of irrigation on crop growth will likely form the basis of decisions made by many Tasmanian farmers regarding whether to sow grain crops or to apply additional water within the growing season. The new CropARM outputs will allow users to contrast relative differences in grain yield caused by management or genotypic differences in multiple regions, allowing insights into of how crop irrigation decisions influence crop phenology and grain yield.

2. Materials and methods

2.1. Locations

Ten sites were selected as representative of the Tasmanian wheat growing regions. The ten sites span from the north-west coastal region (Forthside, Sassafras) to the Meander Valley (Hagley, Westbury), the northern Midlands (Campbell Town, Cressy, Epping Forest, Longford, Symons Plains), and into the southern Midlands (Cambridge) (Fig. 1). The soil types across the ten sites are diverse due to variations in climate, landscape and geology and include Sodosols, Dermosols and Ferrosols soils (Table 1). There is a significant gradient in average annual rainfall across the ten sites of over 450 mm per year, from Forthside in the central coast region receiving an annual rainfall of 950 mm to Campbell Town and Cambridge in the southern region of the state recording 500 mm annually (Table 1). Mean annual rainfall generally ranges from 500 to 550 mm in the Southern Midlands, although in some locations the average rainfall is 700 mm due to the impact of easterly rainfall systems. The Southern Midlands is also prone to severe frosts (Grose et al., 2010).

2.2. Parameterisation

Management and yield data of wheat from 27 field trials at 10 locations for the period of 1981 to 2011 were obtained from Acuna et al. (2015). Site details for field wheat trials are shown in Table 1, along with mean annual climate statistics. Parameterised APSIM files (version 7.8) were obtained from Acuna et al. (2015). The field trials as reported by Acuna et al. (2015) were sown with winter wheat cultivars (Brennan, Isis, Mackellar, Revenue or Tennant) and a long-season spring wheat (Kellalac), with sowing dates ranging from April to September. Typically, wheat crops in Tasmania are sown in April/May and are harvested in November/December/January (depending on seasonal rainfall and temperature). All cultivars are available in APSIM except for Isis, which was substituted with a new variety adapted to Tasmania (Mackellar_Tas). Nitrogen fertiliser was typically applied at sowing at a rate of 25 kg N/ha, with a further top-dressed application in early spring of 50 kg N/ha. Approximately half of the field trials received 24–60 mm of irrigation, and two trials received a maximum of 240 mm of irrigation while the remainder were rainfed (Acuna et al., 2015). Trials were managed to minimise losses due to weed competition and