CropARM: An agronomic support tool assisting Tasmanian farmers for rainfed and irrigated wheat production

Maria Eugênia Richter[1], David Phelan[1], Matthew Harrison[2], Geoffrey Dean[3], Georgina Pengilley[3], Sue Hinton[3] and Caroline Mohammed[1]

[1] Tasmanian Institute of Agriculture, Private Bag 98, Sandy Bay TAS 7001, maria.doamaralrichter@utas.edu.au
[2] Tasmanian Institute of Agriculture, P.O. Box 3523, Burnie TAS 7320
[3] Tasmanian Institute of Agriculture, Locked Bag 1375, Launceston TAS 7250

Abstract
Well-designed agricultural decision support tools (DS) equip farmers with a rapid and easy way to compare multiple scenarios as well as the influence of different management strategies on a crop production. These tools assist 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 establishes a framework for risk management given prevailing climate characteristics as determined by location. Prior to this work being undertaken, no CropARM (http://www.armonline.com.au) data was available for Tasmania. Additionally, no sites currently available in CropARM allow users to compare rainfed and irrigated wheat crops, which will likely form the basis of decisions made by many Tasmanian wheat growers. This study collated observed data from 27 sites in Tasmania, from the period 1981 to 2011; APSIM was parameterised with these field observations and the subsequent scenario simulations have populated CropARM. Wheat cultivars simulated include Brennan, Isis, Mackeller, Revenue, Tennant (winter types) and Kellalac (spring type). Soil parameters were obtained from both field observations and the APSoil database, climate data for each site was accessed historical data. The APSIM simulations were compared with the observed field data and demonstrated reliable model parameterisation, with evaluation statistics close to ideal. Approximately 200,000 simulations were undertaken and incorporated in the CropARM database for wheat cropping systems across Tasmania, enabling agronomic scenario analysis for wheat producers.

Keywords
Decision support tools, APSIM, wheat modelling, irrigated wheat.

Introduction
Agricultural decision support (DS) tools equip users with a rapid and cost effective means of contrasting multiple farm scenarios with the influence of different management farm strategies on production and profitability in conjunction with soil and climate characteristics. Providing information that complement farmer experience and establishes a framework for risk management. The data are typically collected directly from archival records, such as the national climate and soil databases available in Australia (SILO climate data, ASRIS; https://www.longpaddock.qld.gov.au/silo/, http://www.asris.csiro.au/), or it also may be generated using biophysical models, such as the Agricultural Production Systems Simulator (APSIM, https://www.apsim.info/), a modular framework that allows users to 'plug-and-play' inputs of soil and crops components in a user-friendly graphical interface. APSIM has been used to provide simulation data that supports DS tools such as NitrogenARM, CropARM (formerly Whopper Cropper) and Yield Prophet. CropARM is a DS online agricultural risk management (ARM) tool based on climate records from SILO, the soil grid by ASRIS and pre-run APSIM simulations, for use in grain production analysis (Nelson et al. 2002). The outputs include grain yield, days to anthesis, leaf area index and water-use efficiency (Jakku and Thorburn 2010). Prior to this study, there were no available data for Tasmanian farmers and CropARM did not contain sites that allows users to compare rainfed and irrigated crop yields.

Methods
Over the period of 1983 to 2010, grain yield data were obtained for 27 wheat field trials across ten sites in Tasmania and simulated using APSIM (version 7.7) (Keating et al. 2003). Field data were collected using wheat cultivars cvv. Brennan, Isis, Mackellar, Revenue, Tennant and Kellalac, and the sowing dates ranging from April to September. Nitrogenous fertiliser was applied at sowing at a rate of 25 kg N/ha, with a further topdressing of 50 kg N/ha in early spring. Half of the field trials received 24–60 mm of irrigation; two trials

received a maximum of 240 mm and the remainder were rainfed. Soil parameters were obtained from the APSoil database for Tasmania, and long-term climate data was sourced from SILO climate data 'Long Paddock' (https://www.longpaddock.qld.gov.au/silo/ppd/) (Jeffery et al. 2001). Site details for the field trials are presented in Table 1, along with annual climate statistics.

Table 1. Location characteristics and watering regimes. Abbreviations: SE, south-east; MV, Meander Valley; NM, northern Midlands. I = irrigated, R = rainfed, ELV = elevation and AR = annual rainfall. Climate statistics are the means for the period 1983 to 2010.

Site	Years	Region	System	Soil type	Lat. (°S) Long. (°E)	ELV (m)	AR (mm)	Annual mean temp (°C) Max	Min
Cambridge	1983,2007	SE	I & R	Sodosol	42.79°,147.42°	45	501	17.5	8.1
Campbell Town	2006	NM	R	Dermosol	41.92°,147.49°	209	499	17.6	5.6
Cressy	2009,2010	NM	I & R	Sodosol	41.68°,147.08°	149	628	17.2	5.1
Epping forest	1987	NM	R	Sodosol	41.76°,147.35°	195	628	17.2	5.1
Hagley	2007,2010	MV	R	Dermosol	41.52°,146.90°	149	833	16.9	4.6
Forthside	1983	NM	I	Ferrosol	41.22°,146.27°	142	965	16.1	7.4
Longford	2006	NM	I	Sodosol	41.59°,147.12°	159	628	17.2	5.1
Sassafras	1985	NW	R	Ferrosol	41.28°,146.49°	136	777	16.9	8.2
Symmons Plains	2004	NM	R	Sodosol	41.64°,147.25°	159	628	17.2	5.1
Westbury	2009	MV	R	Dermosol	41.52°,146.83°	169	833	16.9	4.6

Model performance was evaluated using a range of model statistics including coefficient of determination (r^2, ideal = 1), Pearson's correlation coefficient (r, ideal = 1), mean bias (ideal = 0), mean prediction error (MPE, ideal = < 5%), modelling efficiency (MEF, ideal = 1), variance ratio (v, ideal = 1), bias correction factor (C_b) (ideal = 1) and the concordance correlation coefficient (CCC, ideal = 1) (Cullen et al. 2008; Pembleton et al. 2013; Tedeschi 2006). For brevity, only the coefficient of determination and variance ratio will be commented on in this paper.

Batch simulations were undertaken using a variety of different soil parameters and management options for each site using the parameterised APSIM files (Table 2). The Tasmanian database for CropARM (http://www.armonline.com.au) contains approximately 200,000 simulations.

Table 2. Factors and levels used for the CropARM batch simulations.

Factors	Levels
Sowing date	15 April, 15 May, 15 June, 15 July
Seeding rate (plants/m2)	60, 80, 110, 150, 200, 250
Row spacing (mm)	250
Cultivar	Revenue, Mackellar, Tennant
Initial stored soil water	Soil profile 50%, 75% and 100% full
Initial soil N (kg N/ha)	30, 60 and 90
Sowing N applied (kg N/ha)	0,50 and 100
Within season N (kg N/ha)	60 (kg/ha) applied once, twice or thrice
System	Rainfed and irrigated
Irrigation	Irrigated in response to soil water profile light, light at flowering light SE, heavy at flowering and heavy through the growing season

Results

Parameterisation of APSIM

The parameterised outputs from APSIM are compared with the observed field data from the ten sites in Figure 1. Visual inspection indicates that the model adequately simulated grain yield, although there was a tendency of the model to over predict larger grain yields. A variance ratio of less than unity indicates that a greater level of variation existed in the simulated than the observed data, likely because simulations included multiple years of climate data (whereas measurements were conducted over only one season). The performance of the other statistical indicators were not affected by this and were deemed satisfactory. Overall, the evaluation statistics indicate that the model adequately simulated wheat grain yields under rainfed and irrigated conditions with an acceptable degree of confidence.

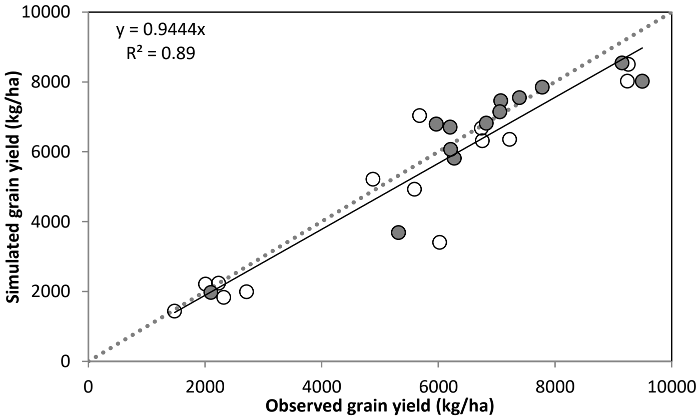

Figure 1. Simulated and observed total wheat grain yields (kg/ha) for the 27 trials in Tasmania under rainfed and irrigated conditions (open and closed circles, respectively) conditions. The regression equation and R^2 value are given for the line of best fit.

Application of CropARM

Outputs from CropARM in relation to sowing date, cultivar selection, and N applied for wheat production at Cambridge in the Tasmanian Midlands region are shown in Figure 2, as representative of south-eastern Tasmania The simulations were run as rainfed with four sowing dates (April, May, June, and July), three wheat cultivars of Mackellar, Revenue, and Tennant with 0 N, 60 kg N and 120 kg N/ha applied during the growing season. Over the 114 years of data, the sowing time did not have a significant effect on total grain yield, while there were only slight differences evident in the variation of yields between cultivars. However, there are discernible differences in the rate of N applied, particularly if no N is applied, in contrast to application rates of 60 and 120 kg N/ha respectively (Figure 2).

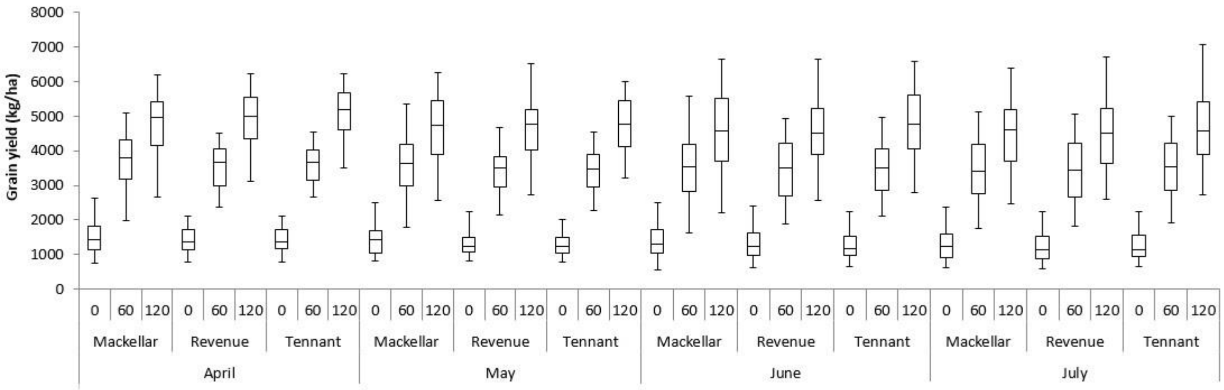

Figure 2. Simulated grain yield (kg/ha) for the sowing dates of April, May, June, and July, cultivars of Mackellar, Revenue, and Tennant at three different rates of N application (kg N/ha) for the site of Cambridge.

Discussion

Prior to this work being undertaken no CropARM data were available for Tasmania. Additionally, no sites currently available in CropARM allowed users to compare rainfed and irrigated crop yields, which 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. Current CropARM species are limited to grain crops, which could be a constraint to users aiming to contrast the yield of such crops with that of crops suitable for both grain and grazing (dual-purpose), which are relatively commonplace in southern Australia (Harrison et al. 2011).

Conclusion

The new CropARM wheat outputs will allow users to contrast relative differences in grain yield caused by management or genotypic differences in multiple regions across Tasmania. The development of CropARM incorporating multiple scenarios enabling multiple agronomic scenario analysis for wheat producers across the state is a first for Tasmanian grain producers.

References

Cullen BR, Eckard RJ, Callow MN, Johnson IR, Chapman DF, Rawnsley RP, Garcia SC, White T and Snow VO (2008). Simulating pasture growth rates in Australian and New Zealand grazing systems. Australian Journal of Agricultural Research 59, 761-768.

Harrison MT, Evans JR, Dove H and Moore AD (2011). Dual-purpose cereals: can the relative influences of management and environment on crop recovery and grain yield be dissected? Crop and Pasture Science 62, 930-946.

Jakku E and Thorburn PJ (2010). A conceptual framework for guiding the participatory development of agricultural decision support systems. Agricultural Systems 103, 675-682.

Jeffrey SJ, Carter JO, Moodie KB and Beswick AR (2001). Using spatial interpolation to construct a comprehensive archive of Australian climate data. Environmental Modelling and Software 16 (4), 309-330.

Keating BA, Carberry PS, Hammer GL, Probert ME, Robertson MJ, Holzworth D, Huth NI, Hargreaves JNG, Meinke H, Hochman Z, McLean G, Verburg K, Snow V, Dimes JP, Silburn M, Wang E, Brown S, Bristow KL, Asseng S, Chapman S, McCown RL, Freebairn DM and Smith CJ (2003). An overview of APSIM, a model designed for farming systems simulation. European Journal of Agronomy 18, 267-288.

Nelson RA, Holzworth DP, Hammer GL and Hayman PT (2002). Infusing the use of seasonal climate forecasting into crop management practice in North East Australia using discussion support software. Agricultural Systems 74, 393-414.

Pembleton KG, Rawnsley RP, Jacobs JL, Mickan FJ, O'Brien GN, Cullen BR and Ramilan T (2013). Evaluating the accuracy of the Agricultural Production Systems Simulator (APSIM) simulating growth, development, and herbage nutritive characteristics of forage crops grown in the south eastern dairy regions of Australia. Crop and Pasture Science 64, 174-164.

Tedeschi LO (2006). Assessment of the adequacy of mathematical models. Agricultural Systems 89, 225-247.