Transformational agronomy by growing summer crops in winter: The cropping system and farm profits

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Abstract
The idea that "Yield is King" fails to acknowledge that what matters most to farmers is farm profits and risk, rather than yield. This is because decisions made in one season will affect options and crop performance over the next few years. Therefore, quantifying the longer-term impacts of innovation adoption is important. We used the Agricultural Production Simulation model (APSIM) to simulate and investigate the implications of adopting rain-fed winter sown sorghum in the Australian northern grains region. Results indicate that within a crop rotation early-planted sorghum will tend to decrease median sorghum crop yields but increase the following winter crop yields. This appears to have a marginal economic effect in Breeza and Dalby but encouraging results in Emerald. The inclusion of chickpea within the rotation increased returns in the best seasons with little change to downside risks in poor seasons.

Keywords
Gross margins, variable costs, income, system strategies, crop rotation, rainfed cropping

Introduction
Within the Australian Northern Grains Region (NGR) sorghum is typically planted in spring and summer and followed by a winter break-crops to reduce the impacts of pest and disease pressure. Therefore, when evaluating innovative crop rotations, the interaction between crops and the effects on profitability and down-side risks of poor outcomes is important, in contrast to just comparing the yield of individual crops. The transition from summer sorghum to a winter chickpea crop can be achieved with long or very-short fallows, the latter often called "double cropping". The former tends to increase the chickpea crop yields but at the opportunity cost of lower intensive-cropping (fewer crops planted over time), and the latter tends to have the opportunity cost of reduced winter yields. There may be an opportunity to plant sorghum earlier in winter with risk of reduced sorghum yield but with the benefit of double-cropping top increase cropping intensity. The expected annual gross-margins of this strategy and risk of failed plan are not well understood and requires investigation.
This is a preliminary bio-economic modelling investigation of the potential use of early-planted sorghum (sown in late winter or very early spring) within the NGR. Crop modelling was undertaken with APSIM (Holzworth et al., 2014) at Emerald and Dalby in Qld and Breeza in northern NSW.

Methods
Biophysical modelling parameters
The simulation sites were selected to be representative of low, medium, and high yielding environments within the Australian NGR from central Qld to northern NSW. The five modelled cropping systems included continuous sorghum (S-S), a chickpea crop followed by sorghum (C-S), a chickpea crop followed by early-sown sorghum (C-ES), a wheat crop followed by sorghum (W-S), and a wheat crop followed by early-sown sorghum (W-ES). The APSIM-Sorghum parameters of fertile tiller number were set at two, planting density at 6 plants/m^2, with a solid row configuration and cultivar maturity per site and system are given in Table 1.

Table 1. Geographical locations and sorghum maturating cultivar (early, medium and late) for each location and cropping system. Crops are chickpea (Cp), wheat (W) and sorghum (S). Fallows are long (xx), winter/summer (x) and very short (*). Early planted sorghum denoted by ES.

		Cropping systems				
Location	Coordinates	C_ES (x Cp x* S * Cp)	C_S (x Cp xx S Cp)	S_S (x S x S x S)	W_ES (x W x* S * W)	W_S (x Cp xx S Cp)
Emerald	-23.53, 148.16	Early	Late	Late	Early	Late
Dalby	-27.18, 151.26	Late	Late	Late	Late	Late
Breeza	-31.25, 150.46	Medium	Medium	Medium	Medium	Medium

A standard APSIM soil Black Vertosol-Waco module (Dalby No. 1012) was used for all sites and simulations. Meteorological data for each location (Table 1) was obtained from the Australian SILO database (BoM, 2020) and each 3-year crop rotation simulation was started in each of the 75 years (1940-2019). Nitrogen at the time of sowing each crop was set at a minimum of 150 kg/ha within 1 m of soil depth. Nitrate (NO_3) fertiliser was applied at a depth of 50 mm. A full soil water profile was set at the beginning of the rotation and rainfed for the remainder of the rotation.

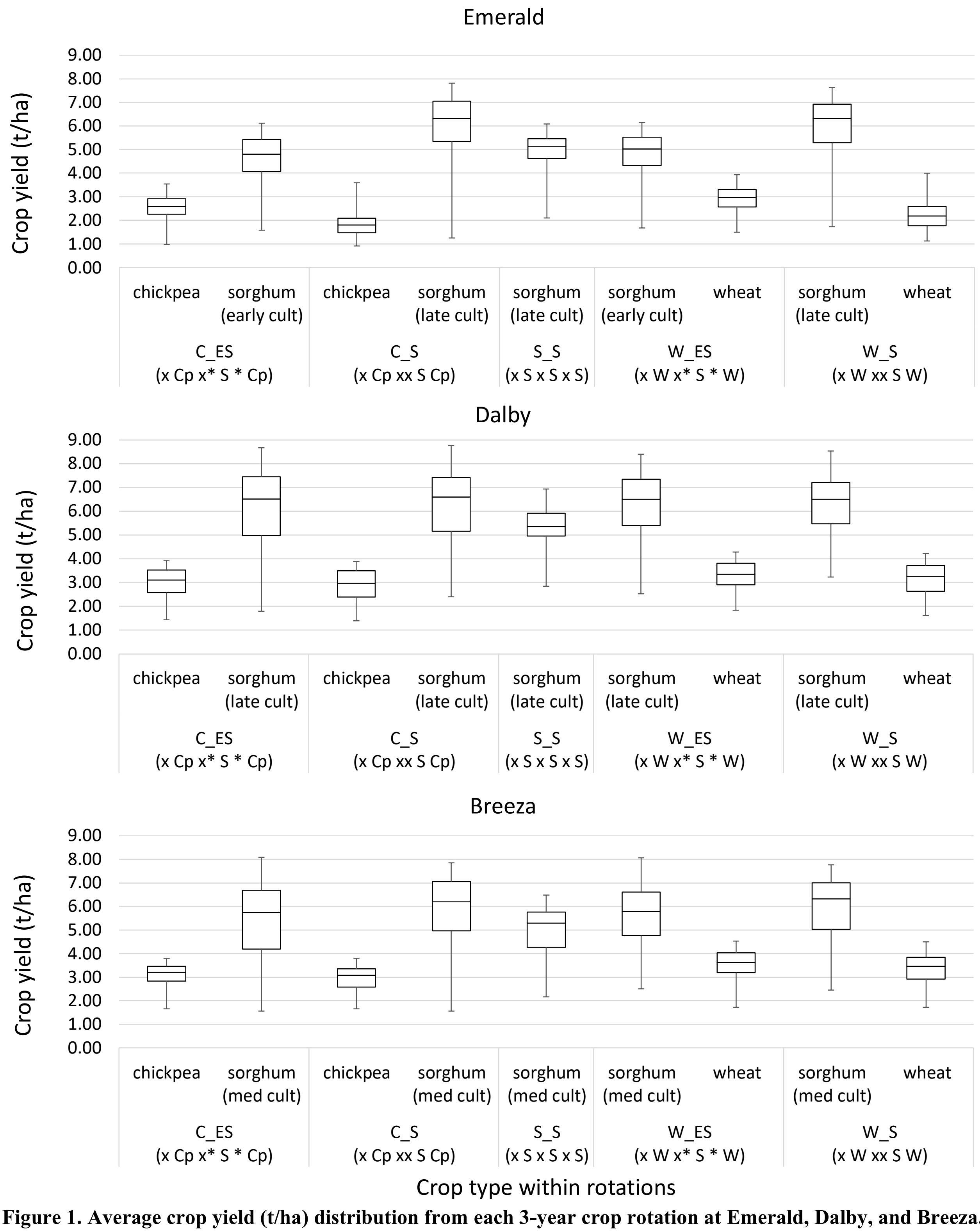

Figure 1. Average crop yield (t/ha) distribution from each 3-year crop rotation at Emerald, Dalby, and Breeza. Crops include chickpea (Cp), wheat (W) and sorghum (S) with different maturing cultivars. Fallows are long (xx), winter/summer (x) and very short (*). Early planted sorghum denoted by ES.

Economic modelling parameters

The variable costs for each of the cropping systems was taken from the AgMargins (2020) database using the 2019 gross margin reports for the darling downs, and farm gate crop prices are based on the average 2016-18 being $791/t for chickpea, $215/t for sorghum, and $247/t for wheat (Zull et al., 2020). The cost of N-fertiliser product was based on $1/kg and application rate derived from the APSIM modelling. Fixed and overhead cost were not included as they are the same for all crop rotations at each location.

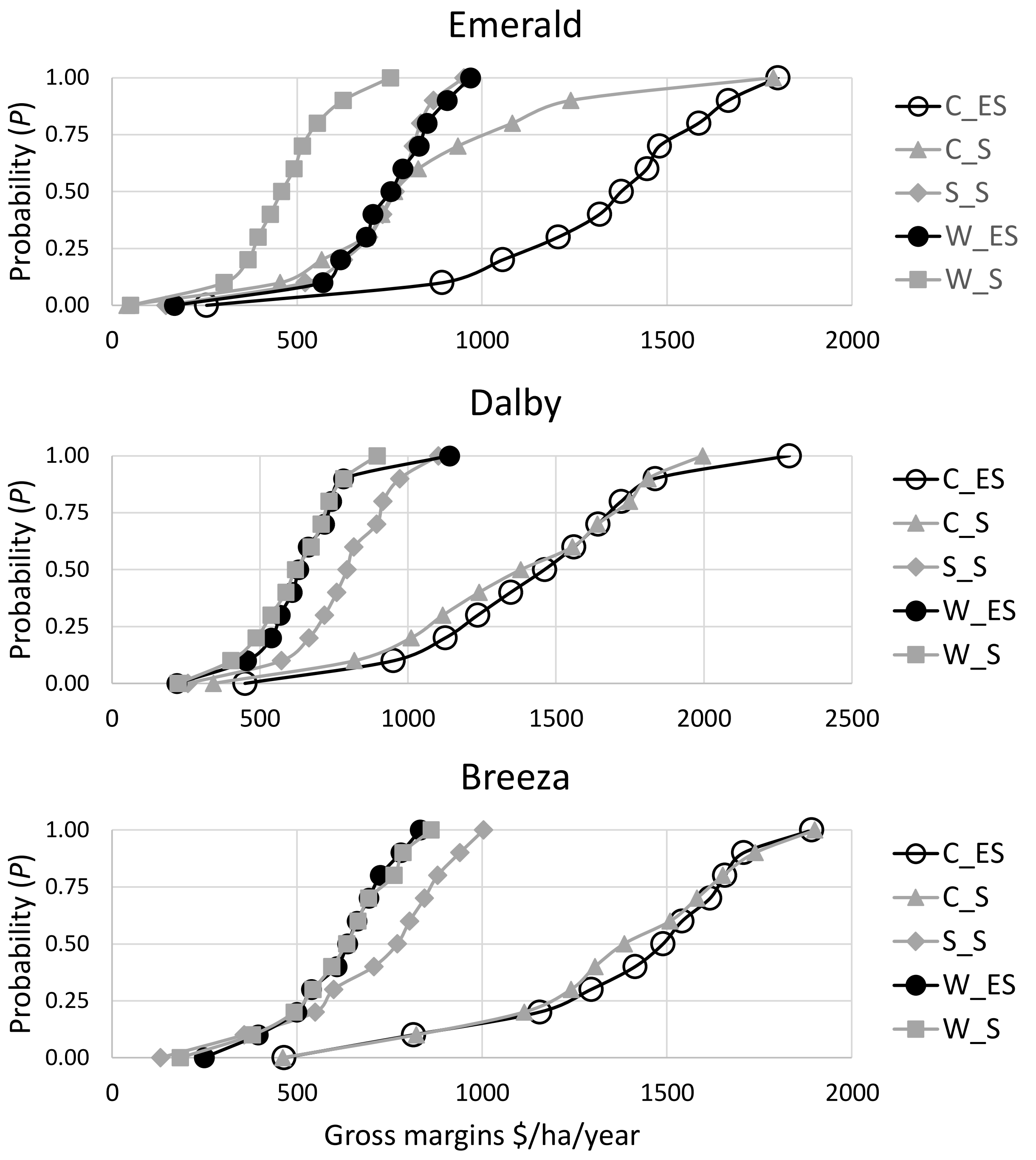

Figure 2. Cumulative probability distributions of average gross margins ($/ha/year) over 3-years for each crop rotation system. Where the expected (median) gross margin is *P* = 0.5, minimum is *P* = 0 and maximum is *P* = 1.0 at Emerald, Dalby, and Breeza.

Results

The distribution of the average yield for each crop type within the rotation is given in Figure 1. Therefore, due to the law of averages the distribution of sorghum in the S_S rotation will be lower as it has three sorghum crops than single crops within a rotation. However, the expected (median) value for all crops is comparable across rotations, as is the yield distribution between similar rotations, i.e. C_ES Vs C_S and W_ES Vs W_S. At all locations, early-planted sorghum rotations tended to result in lower median sorghum yields but increased the median winter crops (chickpea and wheat). Therefore, economic analysis is required to determine the net effect of adopting early-planted sorghum practices across locations.

The distributions of average gross margins ($/ha/year) over the 3-year rotation for each of the rotations and locations varied greatly (Figure 2). The results should not be compared between sites but rather between rotation systems at each site. For example, at Emerald the C_ES rotation system exhibits 1st-order stochastic dominance over all other rotations in that it results in the greatest gross-margins from the worst-case ($P = 0$) to best-case ($P = 1$) scenario. Therefore, it also results in the greatest expected (median, $P = 0.5$) gross margins. However, it is also the riskiest, as it has the greatest variance (range difference between the worst- and best-case scenario). The practice of early-planted sorghum also resulted in it having 1st-order stochastic dominance over the traditional W_S rotation. The economic returns of the chickpea rotations were largely driven by chickpea prices compared to both sorghum and wheat prices. Interestingly, the expected return of the C_S, S_S, and W_ES rotations were very similar ~$760/ha/year. The C_S had the greatest variance (risk) but this was primarily driven by up-side risk (doing very well in good years), and little difference in down side risk to other systems (poorer years). Whereas for Dalby and Breeza there seems to be little economic benefit of change in system risk through the adoption of early planted sorghum. At all locations the inclusion of chickpea within a rotation resulted in increased expected economic returns, and although this did increase variance this was predominantly upside or positive risk in achieving higher returns in good years.

Conclusion

The practice of early-planted sorghum within cropping systems tended to decrease the median sorghum yield but increase the following winter crop yield (wheat or chickpea). The net economic effect of shifting biophysical resources for one crop to another appears to be negligible in Dalby and Breeza but greatly improved gross margins in Emerald due to higher summer rainfall increasing the probability double cropping opportunities. With the added benefit of rotations that included chickpea having higher commodity price. Although, chickpea does increase economic risk (range between the lowest and highest gross margins) this was largely due to upside risk with higher returns in better years, but similar downside risk (poorer year) to other rotations. That is, in a run of poor years with few planting opportunities and crop yields, it does not matter what crop you choose to plant the returns will most likely be an economic loss equal to input costs.

Acknowledgements

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