Analysis for optimal water use in grain cropping systems of North-Eastern Australia

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Summary. A systems model is used to simulate the water use of alternative winter/summer cropping strategies at three sites in sub-tropical Queensland and northern New South Wales. The productivity and economic performance of the cropping strategies were assessed using 100 years of simulated grain yields. The long term analysis showed that opportunity cropping increases mean annual grain production and in summer dominant rainfall regions is more profitable than monoculture wheat.

Introduction

Variability of water supply and management of stored soil moisture to maximize profits are perennial problems for farmers practising dryland cropping in Australia. The last decade has seen a major shift away from the traditional and more conservative cropping strategies using long fallows to more intensive cropping systems. In considering the decision to plant more crops, a farmers' task would be made easier if information was available on expected level of production along with some estimate of the risk involved, especially for regions which experience highly variable rainfall.

Traditional experimentation is not expedient for providing this strategic information. A systems model (1,2), which is able to simulate multiple cropping sequences using long term weather data and is able to be easily modified for rotation crop sequence, soil, and nutritional factors, offers an efficient means of assessing these complex interactions with respect to productivity. Issues pertaining to sustainability can be considered in the analysis when processes for organic matter decomposition, runoff, deep drainage and soil erosion are included in the model.

In this paper, we describe the results of a study in which alternative summer/winter cropping systems were simulated for variable soil and climatic environments in the grain cropping regions of N.E. Australia. Model outputs are analysed for maximium crop use of rainfall and an economic analysis applied to assess the long term profitability of the alternative cropping strategies.

Methods

The system model

The simulation model PERFECT (2) was used in this study. This model has been developed and validated for cropping systems utilizing Vertisols in the sub-tropical regions of Queensland and northern New South Wales (3). The model simulates water balance, soil erosion, crop growth and yield in daily steps using long term climatic data. Model outputs are sensitive to parameters describing topography, soil properties, fallow management and cropping strategy. Crop simulation models for wheat, sorghum and sunflower are included in the systems model.

Application of model

The model was used to simulate three cropping strategies - monoculture wheat, a wheat/sorghum rotation and opportunity cropping using wheat, sorghum and sunflowers - at Emerald. Dalby and Gunnedah. Planting criteria for planting individual crops, along with soil and climatic information for the three locations are given in Table I. In all cases, 20mm of rain in 6 consecutive days and 75mm of PAW in the profile (0-60cm) were needed for the model to open the planting 'window'. For all sites, a fallow management strategy of stubble retention was simulated.

Daily rainfall data (1889 to 1988) and mean weekly pan evaporation and temperature for each site were used in each simulation. Output for the 100 years was analysed for mean monthly rainfall and mean monthly simulated evapotranspiration for each cropping strategy and site. The number of crops planted, planting soil water, grain yield and number of tillage operations per crop were also assessed. The economic analysis assumed prices for wheat of $140/t, sunflowers $300/t and sorghum $1 10/t. Planting operation, fertilizer, insecticide and harvest costs were fixed at $85 per crop. Seed costs varied with crop type planted (wheat $25/ha,sunllowers $30/ha and sorghum $16/ha) and tillage operations were $5 each.

Table 1. Descriptive information for location. climate, soil and planting windows used in analysis.

1. Location	Emerald	Dalby	Gunnedah
Latitude (^{o}S)	23.5	27.2	30.6
2. Climate			
Mean annual rainfall (mm)	647	688	607
Annual rainfall c.v. (%)	32	24	28
May - Oct rainfall (% of annual)	28	35	43
Av. ann. pan evaporation. (mm)	2096	1893	1840
3. Soil	Vertisol	Vertisol	Vertisol
Depth (mm)	750	1200	1200
Plant available water content (mm)	150	237	237
4. Planting Windows			
Wheat	1 Apr - 30 Jun	20 May - 31 Jul	20 May - 31 Jul
Sorghum	25 Dec - 31 Jan	2 Oct - 31 Dec	27 Oct - 31 Dec
Sunflower	1 Feb- 15 Mar	1 Jan - 15 Mar	1 Jan - 15 Mar

Results

Water use patterns

This analysis was performed to achieve the closest possible matching of water use to water supply in variable climates. Figure I shows the mean monthly precipitation and estimated transpiration for the three contrasting cropping systems at Dalby. There is a large disparity between use and supply for monoculture wheat, thus a need to store water in [allows. However, rainfall during the summer fallow far exceeds the storage capacity of the soil (439 vs 237mm), and this generally contributes to higher runoff/erosion and drainage/salinity hazards (data not shown) in this cropping system. In contrast, the use and supply of water are better matched in the other two systems, with opportunity cropping the best system overall. The question is: Will this be more productive and profitable?

Grain production.

Mean grain yield per crop and cropping intensity averaged over 100 years for three cropping systems at Emerald. Dalby and Gunnedah are shown in Table 2. The wheat/sorghum rotation and the wheat monoculture systems were on a par for the number of crops planted over 100 years. For opportunity cropping, the average cropping intensity was in excess of one crop per year at all sites, with the highest (1.5 crops/year) achieved at Dalby.

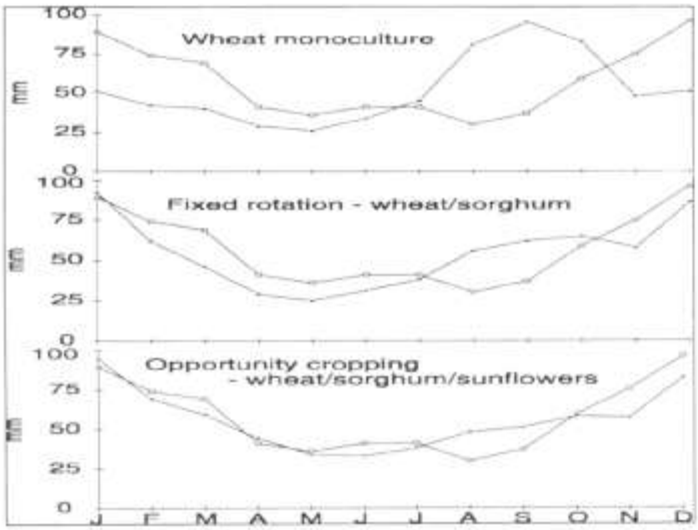

Figure 1. Mean monthly rainfall (1889 - 1988,□) and simulated mean monthly evapotranspiration (■) for three cropping systems at Dalby.

Across all sites, there is a trend for mean wheat yields to decrease as cropping intensity increases. This is related to lower mean soil water storage at planting of the wheat crops in the rotational systems (up to 45% less at Dalby) as well as delay in the sowing of the wheat crop (up to 22 days at Emerald). However, across all sites, the more intensive cropping strategies had higher mean total grain yields per year compared to the wheat monoculture production. The margin of increased production varied between 0.3 t/ha/yr for wheat/sorghum at Emerald to 1.1 t/ha/yr for opportunity cropping at Dalby (Table 2).

Table 2. Mean yield (t/ha) for each crop planted, percentage of years cropped and mean annual yield over 100 years (bold type) for 3 cropping systems at Emerald. Dalby and Gunnedah. Mean (bold type) and median gross margins ($/ha) are included.

Cropping system	Emerald	Dalby	Gunnedah
Wheat			
Yield/crop	2.3	2.5	2.5
% years planted	76	90	83
Av. annual yield	**1.8**	**2.3**	**2.1**
Av. annual Gross Margin	**148**	**209**	**194**
Median Gross Margin	115	178	168
Wheat / Sorghum			
Yield/crop	2.1/3.2	2.1/4.0	2.4/3.4
% years planted	40/39	56/55	43/42
Av. annual yield	**2.1**	**3.4**	**2.5**
Av. annual Gross Margin	**160**	**277**	**207**
Median Gross Margin	135	243	131
Wheat / Sorghum / Sunflower			
Yield/crop	1.7/3.0/1.0	1.6/3.7/1.0	1.8/3.2/1.0
% years planted	25/63/18	49/58/44	46/41/38
Av. annualyield	**2.5**	**3.4**	**2.5**
Av. annual Gross Margin	**206**	**309**	**224**
Median Gross Margin	211	310	185

Economic performance.

The mean and median gross margins for the respective sites and cropping systems are shown in Table 2. The trend in the two northern regions where summer rainfall is more dominant clearly shows that the inclusion of summer crops in a cropping system is more profitable than wheat alone. On average. opportunity cropping is also more profitable at Gunnedah, however, based on the median value, the likelihood of the return being lower than the long term average is also quite high. The cumulative probability distribution for gross margins for wheat and opportunity cropping at Gunnedah (data not shown) were quite close except for the top ten percent of years and suggest that the decision to plant more crops at Gunnedah will be price sensitive. When the economic analysis was performed with a wheat price of $160/t, (a $20 increase in price *to* reflect a protein premium) the average gross margin for wheat became equal to that of opportunity cropping ($235 vs $237). Significantly. this higher price for wheat did not change the trend for the Dalby and Emerald scenarios because the higher level of sorghum productivity dominates in these environments .

Discussion

Figure 2 summarises the relationships and consequences (risks) shown by this study when more crops are introduced into a cropping system. Analysis of model outputs may provide insights into short and long term climate variability, and provide a rational basis for comparing cropping systems. Also, the breadth of issues evident in Figure 2 would be daunting for any experimental programme to tackle in an affordable time frame. This study has demonstrated how the application of a systems model provides an effective and efficient research tool for dealing with the productive potential and economics of complex systems.

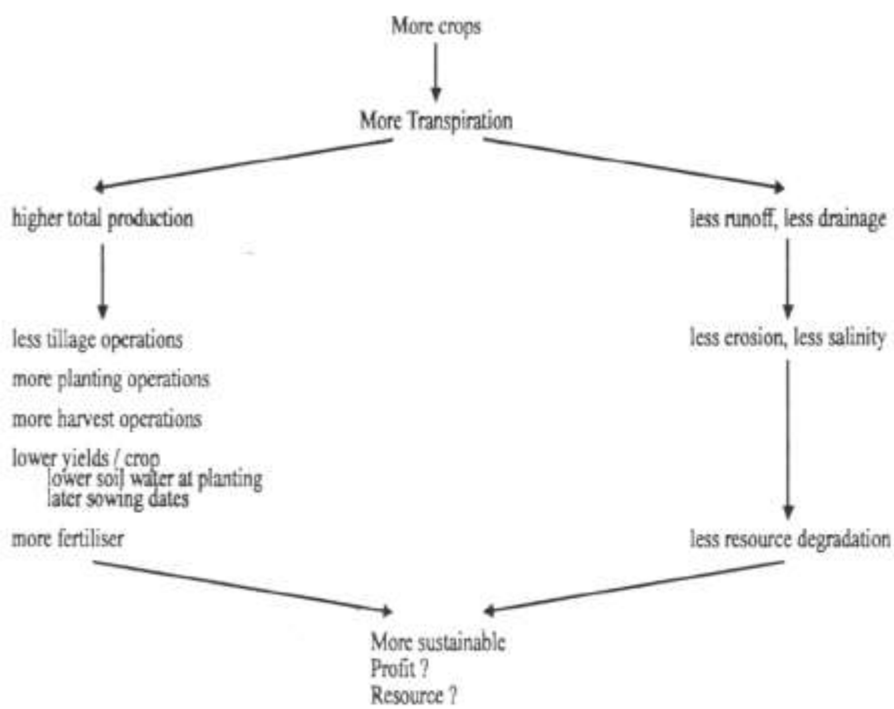

Figure 2. Schematic for relationships and consequences for increased cropping intensities.

References

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