

Whole farm analysis-Fertiliser nitrogen can reduce deep drainage and increase profitability.

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Abstract

Opportunity cropping has been shown to reduce mean annual deep drainage compared to long fallow systems. A question that remained was the effect of added fertiliser nitrogen under each of the cropping systems and whether it would make a significant difference to amounts of deep drainage and to profitability. Estimates of crop yield and deep drainage results were generated using the APSIM (Agricultural Production Systems Simulator) cropping systems model, to compare long-fallow wheat/sorghum and two opportunity-cropping scenarios on a vertosol on the Liverpool Plains using rainfall data from 1958 to 1997. The results showed that fertiliser nitrogen did have a significant effect on deep drainage and gross margin under each cropping system. However, higher rates of nitrogen only produced small marginal benefits.

Key words: cropping systems, profitability, modelling, variability, whole farm budgeting

1. Introduction

The Liverpool Plains catchment of northwest NSW (Figure 1) covers 1.24 million hectares bounded to the south by the Liverpool Ranges (part of the Great Dividing Range), to the east by the Melville Ranges and to the west by the Warrumbungle Range. Two rivers, the Mooki and Cox's Creek, drain northwards into the Namoi River, a tributary of the Murray-Darling river system (Ringrose-Voase *et al.*, 2003). Gunnedah is the largest town (pop. 10,000) and is located in the north of the catchment. Approximately 1.1 million hectares are managed for agricultural production of which about 36% is under dryland cropping, 4.5% under irrigation, 7.5% is under improved pasture, 35% is under native pasture and 17% is under timbered native vegetation (URS, 2001). More than 80% of dryland cropping is practised on cracking clay soils (Vertosols) of basaltic origin which generally have very high plant available water holding capacities of around 150-300 mm.

Figure 1: Map of the Liverpool Plains, NSW



The Liverpool Plains catchment faces a number of natural resource problems including dryland salinity, soil erosion, flooding and reduced soil organic matter fertility. Currently the severely salinised area (more than 80% yield reduction) is estimated to be 1,000 hectares (Ringrose-Voase *et al.*, 2003). Current projections indicate the area that will be salinised to some degree will reach 175,000 hectares by 2025, with \$80 million lost in production between 2000 and 2025 (URS, 2001).

Long fallow wheat/sorghum rotations became common in the late 1960s and early 1970s on the Liverpool Plains due to wheat quotas, an increasing demand for grain sorghum for stock feed, reduced organic matter fertility requiring longer fallows to mineralise nutrients and to control wild oats (a major crop weed). In addition, the long fallow periods of up to 15 months, if well managed, almost guaranteed a full profile of available soil water at planting, thus overcoming much of the variability of rainfall which characterises the Liverpool Plains and most dryland cropping regions of Australia.

However, increased deep drainage below the root zone resulting from the replacement of perennial native vegetation with annual crops and fallows is believed to be the major cause of secondary dryland salinity. Long fallow cropping systems in the Liverpool Plains have been shown to be especially 'leaky', allowing large amounts of water to infiltrate past the root zone late in the fallow period (Abbs and Littleboy 1998; Ringrose-Voase *et al.* 2003; Young 1999). This means that more precipitation infiltrates into subsoil zones, rather than being used by vegetation (this is 'deep drainage'). When deep drainage exceeds the outflow from either local or regional groundwater systems, the water table will rise (often in different parts of the catchment) bringing dissolved soil salts closer to the surface in lower parts of the landscape and into the root zone of pastures and crops. Productivity then falls as the salinity levels rises beyond their tolerance. Long periods under fallow also expose the soil to risk of erosion due to wind and intense summer storms which are common in the region.

Natural resource management strategies to address a number of issues in the catchment, including salinity and soil erosion, have been outlined in the Liverpool Plains Catchment Investment Strategy (URS, 2001). A classification of Land Management Units based on geology, soil type, landscape position, and rainfall was developed. Changes in land use for each land management unit were then recommended in the Catchment Investment Strategy including a shift towards opportunity-cropping from long-fallow. The latter recommendation was based on research that showed that opportunity-cropping (using both winter and summer crops) resulted in less surface runoff and less deep drainage than conventional cropping such as short fallow winter cropping or the long-fallow rotation (URS, 2001; Young, 1999). For example, Abbs and Littleboy (1998) applied a cropping systems model (PERFECT) to determine deep drainage under different cropping systems. They found that for one black earth soil type, a long fallow rotation showed an annual average deep drainage of 48mm, compared to 22mm for opportunity cropping. Also, the model estimated that deep drainage events occurred in 50% of years under a long fallow system, compared to 29% of years under opportunity cropping. However, crop yields and profitability issues were not mentioned in the Abbs & Littleboy study.

One of the most important questions that remain concerns the effects of opportunity-cropping on profitability, year to year cash flow and deep drainage compared to long-fallow. Farmers require that proposed changes to the cropping system are profitable, and it has been shown in past studies that perceived profitability and financial considerations is a key, if not the most important factor in adoption of 'conservation' and/or new practices (Cary and Wilkinson, 1997; Sinden and King, 1990; Cary *et al.*, 2002; Marra *et al.*, 2003). In the mid-1990's, a survey showed that 56% of farmers were still using the long fallow wheat-sorghum rotation on the Plains, with 35% undertaking opportunity cropping (McLeish and Flavel, 1996).

2. Methods

2.1 Field Experiments and Simulation Modelling

APSIM was verified against 5 years of comprehensive production and water balance data collected from on-farm experiments in the upper Liverpool Plains catchment (Ringrose-Voase *et al.* 2003). The sites were typical of the highly productive Vertosols and the light textured soils on outcropping sandstone ridges in the catchment. They were representative of areas previously identified as being significant sources of recharge of groundwater which resulted in raised watertables and associated soil salinity problems on the alluvial plains (Paydar *et al.* 1999; Ringrose-Voase *et al.* 2003; Young 1999). The project also involved adapting and validating the APSIM model (McCown *et al.* 1996; Paydar *et al.* 1999) to represent the soil types and rainfall patterns of various locations across the Liverpool Plains. The aim was to quantify the production, nutrient movement and water balance of cropping systems with varying lengths of fallow and perennial pastures. The result is a comparative prediction of agronomic and deep drainage outcomes for the different cropping systems over a range of climatic zones and soil types. Local farmers and advisers 'sensitivity tested' APSIM output, resulting in appropriate changes to model specification, and were also consulted regarding details of model specification such as crop varieties and planting times relevant to representative areas within the catchment.

Estimates of the long term productivity and water balance of alternative cropping systems were made using APSIM specified for crop agronomy, soils and climate zones relevant to the Liverpool Plains. The hydraulic properties of 20 soil types suitable for cropping were determined and historic weather data for 9 representative climate zones were downloaded from ‘Data Drill’ (Queensland Centre for Climate Applications, 1998) from Bureau of Meteorology data (Ringrose-Voase *et al.* 1999).

Agronomic, deep drainage and runoff results were generated from the APSIM cropping systems model to compare different crop rotations in the Liverpool Plains using rainfall data between 1958 and 1997. The reason for using this time span was that reliable temperature data was collected from 1958 onwards.

Agronomic results were generated from APSIM to compare long-fallow wheat, continuous (short fallow) wheat, continuous sorghum and opportunity-cropping systems (defined by a wheat/sorghum rotation) on a large range of soil types and climatic zones within the catchment. The continuous wheat and continuous sorghum were included to try to gauge the relative impact of each crop on drainage and runoff, rather than as realistic crop options. Some form of rotation is necessary to reduce disease and weed risks, especially in wheat.

Opportunity cropping was modelled using two different sowing rules as a follow on to the modelling results published in Ringrose-Voase *et al.* (2003). Set rates of nitrogen were used in the APSIM model for that exercise and it was determined that a further research question of interest was the impact that different target rates of soil nitrogen had on both profitability and other key parameters such as drainage and runoff. The sowing rules related to depths of moist soil required for a crop to be planted, provided that the date is within a ‘sowing window’ (period for sowing suitable for that variety to yield adequately). The rules were 50 cm – 70 cm (winter – summer respectively) derived from discussions with local farmers in the mid-1990’s (Ringrose-Voase *et al.*, 2003) and 50 cm – 100 cm (from recent discussions with local growers (R. Young, pers. comm.) available water capacity¹ triggers for planting. The nitrogen target rates of interest were 10 kg N/ha, 50 kg N/ha, 100 kg N/ha, 150 kg N/ha and 200 kg N/ha. These rates were applied to both the opportunity cropping and the long fallow simulations. The targets were the preferred rate of available nitrogen rather than a set rate of fertiliser, so the amount of fertiliser added would ‘top up’ the soil nitrogen to that level. The required amount of fertiliser nitrogen would depend on the yield and protein of the previous crop, or whether there was a long fallow to allow for natural nitrogen accumulation. Both experimental and simulated long fallow consisted of three phases to emulate the strip cropping systems commonly used for long fallow in the Plains (Table 1).

Table 1: Long fallow phases

<i>Sub-system</i>	<i>Year 1</i>	<i>Year 2</i>	<i>Year 3</i>
Strip 1	Fallow	Wheat	Sorghum
Strip 2	Wheat	Sorghum	Fallow
Strip 3	Sorghum	Fallow	Wheat

This analysis focuses on ‘Lever Gully’, a self-mulching, black vertosol found on the lower slopes of the Liverpool Ranges. It has a very high clay content throughout the profile, good water entry properties and a high available water capacity. It covers approximately 483 square kilometres of the Liverpool Plains region (Banks, 1995; Banks 1998). Six climatic zones were suitable for cropping. This paper focuses on the climatic zone that represents the greatest proportion of the catchment, the Gunnedah zone. Mean annual rainfall is 626mm per year, with a mean evapotranspiration of 1,884 mm per year and 11.9 frost days on average. Elevation is 306m above sea level on average and the zone represents 31.7% of the catchment (Ringrose-Voase *et al.*, 2003).

¹ A soil’s ‘available water capacity’ is water held between the wilting point and the field capacity (drained upper limit). Water that is held in the soil below the wilting point (lower limit) is unavailable to plants.

2.2 Data Analysis Methods

The initial analysis uses the mean values of these distributions in making comparisons of alternative management strategies. Gross margin budgets were developed based on annual outputs (yield, protein content) and inputs (fertiliser, other inputs). These were compared with average deep drainage figures and a simple classification of win-win cases is made. This is a deterministic or average-value evaluation of crop alternatives.

The next stage of analysis involved looking at the distributions of gross margins and the resultant spread of financial returns using Mean-Standard deviation (or *E,S*) analysis (one alternative dominates another if it has a higher mean and lower standard deviation) (Hardaker *et al*, 1998).

2.2.1 Derivation of gross margins

The budget results for one of the trial sites from 1995 to 1999 were used to estimate the average wheat and sorghum variable costs (excluding nitrogen fertiliser and contract harvesting) as well as summer and winter fallow costs (Table 2). For example, the average cost of all of the winter fallow periods during the trial was used for winter fallow costs. Machinery assumptions and costs and levies are those appropriate to each enterprise under commercial conditions as outlined in Scott (1997 a, b). A gross margin is the gross income from an enterprise less the variable costs incurred in achieving it. Variable costs are those costs directly attributable to an enterprise and which vary in proportion to the size of an enterprise. The gross margin is not gross profit because it does not include fixed or overhead costs such as depreciation, interest payments, rates or permanent labour which have to be met regardless of enterprise size (Scott 1997 a, b).

Table 2: Variable costs used in the budgets

<i>Costs, \$/ha</i>	<i>Harvest</i>		
	Basic	Up to 2.5 tonnes grain/ha	Increase per tonne grain/ha over 2.5
Wheat	126.34	35.00	15.00
Sorghum	141.80	40.00	6.30
Winter fallow	39.70		
Summer fallow	45.50		

Source: Ringrose-Voase *et al*, 2003.

The same commodity and individual input prices were used over the whole period. This was to prevent fluctuations in commodity prices and input prices obscuring rotation effects on the gross margins. Wheat prices used were \$144 per tonne for 10% protein, \$150 per tonne for 11.5% protein, and \$188 per tonne for 13% protein with an increment of \$0.50 per tonne for every 0.1% increase in protein within each class. Wheat with less than 10% protein was classed as feed wheat with a price of \$117 per tonne. The sorghum price used was \$130 per tonne. Wheat prices were based on averages from AWB Ltd and the sorghum price was based on a 10 year average sourced from ABARE (ABARE, 2001).

Nitrogen fertiliser and contract harvest costs were added separately as part of the gross margin calculation process. Additionally, a rule was used that if the yield was so low that income would be less than the cost of harvest, then the crop would not be harvested. The costs incurred (ie. the resultant negative gross margin) would only include the basic costs (Table 2).

2.2.2 Mean- Standard Deviation Analysis

Mean-standard deviation (*E,S*) analysis is a variant of mean-variance efficiency analysis; both are applicable since the standard deviation is the square root of the variance (Hardaker *et al*, 1998). Mean-standard deviation analysis was used to compare the variability of financial returns once they had been selected by a win-win condition. The *E,S* efficiency rule states that, when the degree of risk aversion isn't known, the alternative that has a greater or equal expected value with a lower standard deviation is the dominant or preferred choice. In other words, an alternative is preferred for a given mean (or expected value) if its standard deviation is less than that of another alternative with the same mean

(Hardaker *et al*, 1998). The advantage of using this technique is that only information on the means and standard deviations (or variances) are needed. A requirement for the *E,S* efficiency rule to be exact is that the distribution of outcomes (in this case, gross margins) should follow a normal (bell-curve) probability distribution centred around the mean, and 99% of values will fall within 3 standard deviations of the mean. When the sample outcomes do not best fit a normal probability distribution, the *E,S* efficiency rule is not invalid but it can only be approximate (Hardaker *et al*, 1998).

2.2.3 Whole Farm budgets

A steady state whole farm budget was used to estimate the effect upon whole farm returns. The budgets are deterministic and static, similar to a linear programming model, in that the selected rotation crops and fallow periods are distributed proportionally across the cropping area. Capital investment in land and machinery is incorporated, as well as variable and fixed (overhead) costs and an estimation of rates of return to capital invested.

The budgets show profit measures such as net farm income and rate of return on assets and operator labour, but are not optimising. The profit results of all rotations are listed, rather than the model determining the most profitable rotation. The budget depicts returns and enterprise mix for a one year period. The rotation selected determines the amount of tractor use per year, which in turn influence tractor life and overhead costs.

A combination of improved and native pastures are common on most properties on the Plains (L. Serafin, pers. comm. 2003), so for the budget it was assumed that 20% of the farm area would be under native pasture (@ 4 DSE/ha) and 40% would be under improved/introduced pasture (@ 8 DSE/ha), which would be resown every eight years. Pasture maintenance assumed was 125 kg/ha of single superphosphate every two years.

Liabilities included are of three types. For each budget, the tractor is assumed to be 3 years old and paid off over 10 years. Also, it is assumed that a seasonal loan is required to cover 50% of crop variable costs, the amount of this varies from rotation to rotation. Lastly, a term loan amount is assumed. A debt per hectare figure was calculated (\$325/ha) using ABARE survey data for mean farm size and "Farm business debt at June 30". The debt per hectare figure was multiplied by farm area used and the amount owing on the tractor and the seasonal loan for crop variable costs was subtracted to determine the term loan amount.

The budget reports various measures such as;

- Total farm gross margin
- Net farm income (total farm gross margin less overhead costs)
- % operating return on total assets and operator labour
- % business return (net farm income less interest and loan repayments) on equity

Operating return on total assets and operator labour shows the earning rate on all funds and management skill, and so provides a guide to the expected earning rate of all resources.

The analysis package @RISK was used to derive distributions of best-fit for wheat and sorghum yields from the APSIM output for each cropping system. The distributions were then used in the whole farm budgets to determine an estimate of the variability in whole farm returns under the cropping and fertiliser systems under comparison. A large number of iterations (5000) of the model were required for the results to converge- that is, for the results statistics to change by less than 1.5% between iterations.

3. Results

3.1 Gross margin and drainage results

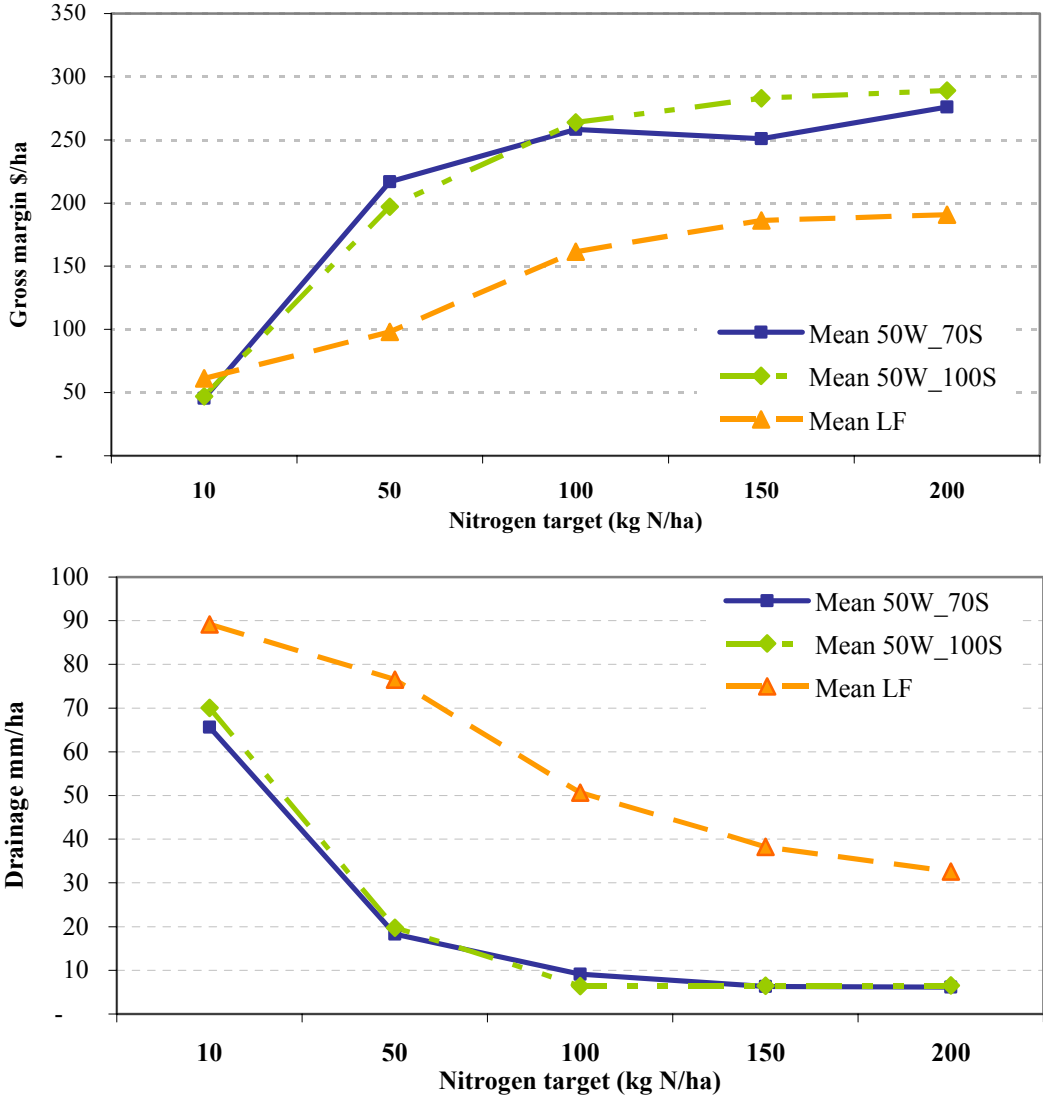
The results show that most of the opportunity cropping options for each nitrogen target rate have a greater mean gross margin than long fallow, and lower mean annual combined deep drainage and runoff. A 'win-win' comparison table (Table 3) showed that for rates of target nitrogen from 50 to 200, the opportunity cropping options both increased mean annual gross margin and reduced mean annual drainage and runoff compared to long fallow. The 10 kg N/ha nitrogen target doesn't meet the 'win-win' criteria.

Table 3: Mean gross margin and deep drainage comparison

Mean gross margin	10 N	50N	100N	150N	200N
Long fallow	61	98	161	186	191
50W-70S	45	197	264	283	289
50W-100S	47	217	258	251	276
Drainage	10 N	50N	100N	150N	200N
Long fallow	89	76	51	38	33
50W-70S	66	18	9	6	6
50W-100S	70	20	6	6	7
Win-win?	10 N	50N	100N	150N	200N
50W-70S	no	yes	yes	yes	yes
50W-100S	no	yes	yes	yes	yes

Figure 2 shows the comparison of mean gross margin and drainage figures. There is a moderate reduction of deep drainage for the opportunity cropping options with a 10 kg N/ha nitrogen target and substantial reduction for those nitrogen targets including and above 50 kg N/ha. The two opportunity cropping options appear to be reasonably similar in terms of average gross margin and deep drainage. Further criteria, such as a comparison of variability and of costs outlined in following sections allows additional refinement of the options.

Figure 2: Mean gross margins and deep drainage

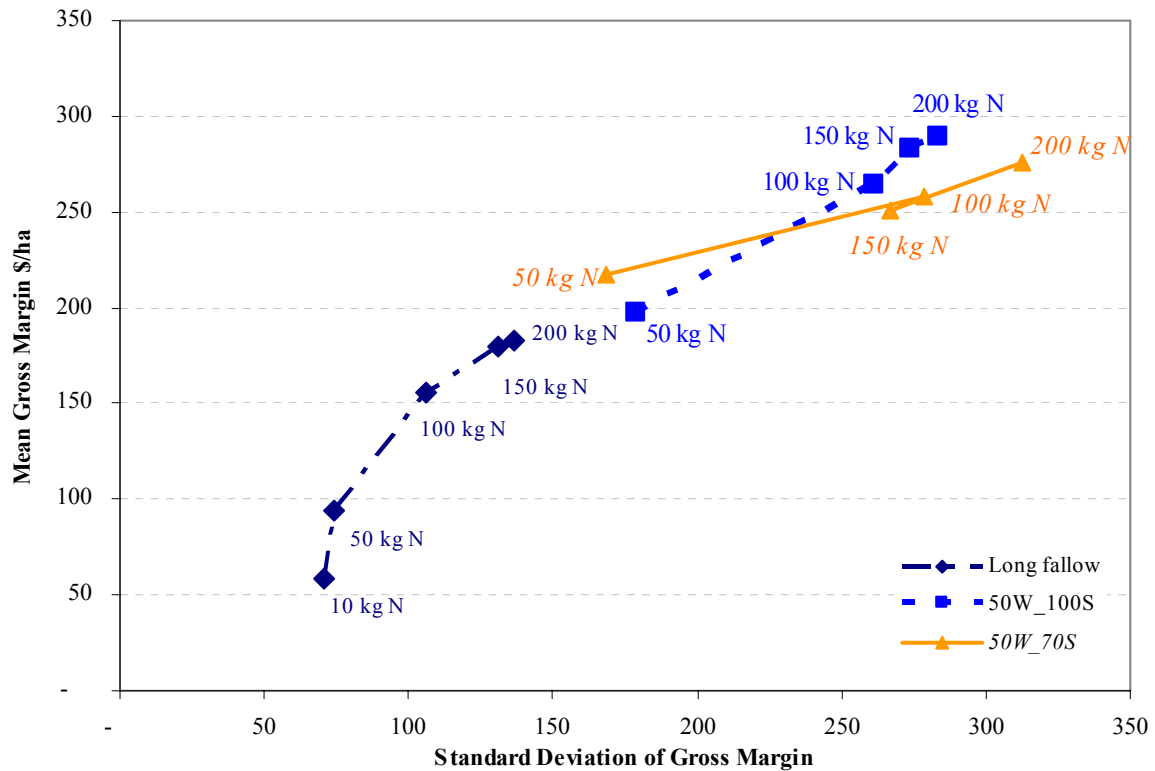


3.2 Variability

A key concern of farmers in the region is that opportunity cropping has more variability in gross margin returns. Once opportunity cropping options had been chosen using the ‘win-win’ criteria, Mean-Standard deviation (*E,S*) analysis was used as a rule to choose between them. This measure is based in the principle that if the expected value of choice X is greater than or equal to choice Y, and that the standard deviation of X is less than that of Y, then X is preferred to Y (Hardaker *et al*, 1998). The rule states that one alternative dominates another if it has a higher mean and a lower standard deviation. Mean annual gross margin was graphed against standard deviation (Figure 3). Application of the *E,S* efficiency criterion indicates that the *E,S* efficient set is:

- 50W-70S 50 kg N/ha target
- 50W-100S 100 kg N/ha target
- 50W-100S 150 kg N/ha target
- 50W-100S 200 kg N/ha target

Figure 3: Mean-standard deviation analysis



A comparison of the E,S efficient set of opportunity cropping options with long fallow (Table 4) shows that the means for all opportunity cropping options are higher than long fallow for all N targets. A t-test was also undertaken to test there is a statistical difference between the long fallow and opportunity cropping mean gross margins.

The null hypothesis used is $H_0 = \mu_{OC} \leq \mu_{LF}$, that is the mean of the opportunity cropping option for a particular N target rate is less than or equal to that of the corresponding long fallow option. The alternative hypothesis is $H_A = \mu_{OC} > \mu_{LF}$, that is that the mean gross margin opportunity cropping rotation is greater than that of the corresponding long fallow. Using the test statistic for each N target rate;

$$t^* = \frac{\bar{X} - \mu_0}{s / \sqrt{n}}$$

where X = mean gross margin for each N target rate, s = standard deviation, n = number of years

Using $\alpha = 0.025$, null hypothesis will be rejected if the test statistic t^* is greater than the critical value of 2.021

The results for each N target rate were;

- 50 kg N/ha $t^* = 5.36$, reject H_0
- 100 kg N/ha $t^* = 2.81$, reject H_0
- 150 kg N/ha $t^* = 2.15$, reject H_0
- 200 kg N/ha $t^* = 2.28$, reject H_0

So we can conclude from this that the opportunity cropping options do have a statistically higher average gross margin than the long fallow options.

When the coefficients of variation are compared (Table 4), the opportunity cropping options for 100, 150 and 200 kg N/ha show a higher relative variation than the corresponding long fallow options, with the coefficient for opportunity cropping with 50 kg target N/ha being very similar to the one for long

fallow. This indicates that the variability of opportunity cropping gross margins is higher on average for N target rates including and above 100 kg N/ha. However, profitability is also substantially higher.

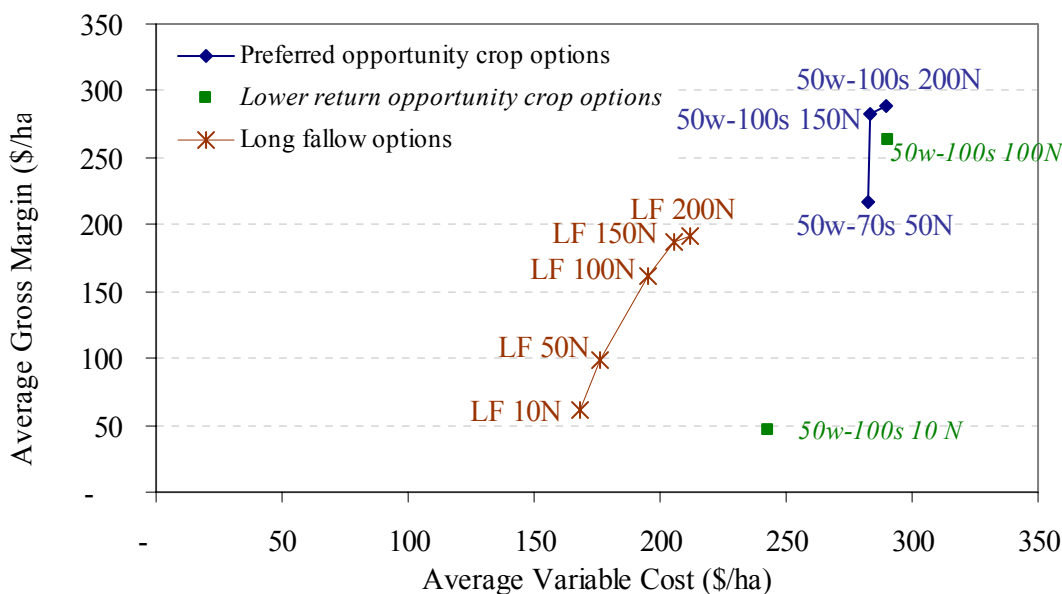
Table 4: Comparison of E,S efficient set with long fallow

N target	Long fallow			E,S efficient set of opportunity crop options			
	Mean	SD	Coefficient of variation	Planting Rule	Mean	SD	Coefficient of variation
50	94	74	79%	50W-70S	217	168	77%
100	156	106	68%	50W-100S	264	261	105%
150	179	131	73%	50W-100S	283	274	104%
200	183	137	75%	50W-100S	289	284	111%

3.3 Costs

Another area of concern for growers is the higher variable costs of opportunity cropping systems. Figure 4 shows a comparison of average gross margin against variable cost as adapted from methodology on marginal and dominance analysis used by CIMMYT (1988). Dominance analysis compares the variable costs with the gross margin, showing the increase in costs required to gain a given increase in gross margin. Treatments were first listed in order of increasing variable costs. Any treatment that had a total gross margin less than (or equal to) those of a treatment with lower total variable costs is dominated. Therefore, dominated treatments have a lower extra gross margin per unit of extra costs than other treatments (CIMMYT, 1988).

Figure 4: Comparison of gross margins against variable cost



The higher input costs though are mainly attributable to a higher cropping frequency. The crop frequency (Table 5) of opportunity cropping is almost double that of long fallow wheat/sorghum. Also as discussed in the previous section, the standard deviations of the gross margins for opportunity cropping were lower than those for long fallow.

Table 5: Cropping frequency over 40 years (crops in 40 years)

<i>Treatment</i>	<i>10</i>	<i>50</i>	<i>100</i>	<i>150</i>	<i>200</i>
Mean 50W_70S	50	48	48	46	44
Mean 50W_100S	47	49	44	39	39
Mean LF	25	25	25	25	25

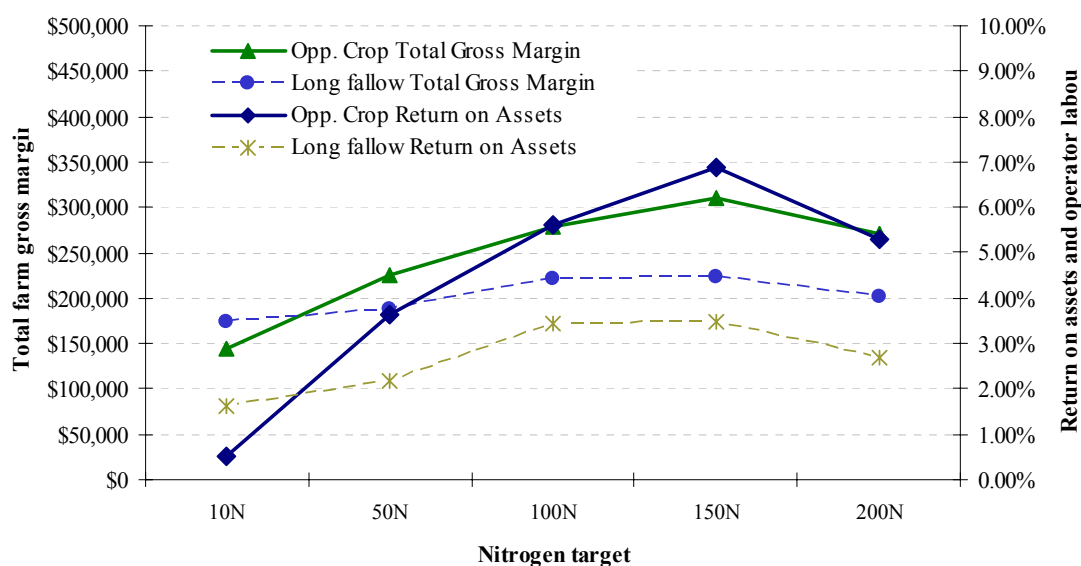
3.4 Whole Farm analysis

The opportunity cropping rotations in the whole farm budget were set at the proportion of two-thirds sorghum/one third wheat.

Wheat and sorghum yields and wheat proteins for both the opportunity cropping and long fallow options were taken from distributions derived from the APSIM yield output. The analysis package @RISK was used to derive the distribution that best fit the yield and protein output data according to the Chi-square test (Palisade, 2000). These distributions were then truncated so they could not return a value below zero since a negative yield or protein would be nonsensical. A simulation of 5000 iterations was run for each opportunity cropping and long fallow options. This was required to ensure the descriptive statistics of the output distributions did not vary more than 1.5% from one iteration to the next, indicating the results were stable.

The results are summarised in Figure 5. The opportunity cropping options showed better returns on a whole farm basis for all nitrogen targets except for the 10 kg N/ha target. The E,S analysis and a comparison of variable costs against gross margin didn't show much difference between the 150 and 200 kg N/ha nitrogen targets, but the whole farm budget showed lower returns for the 200 kg N/ha target. The reason for the lower returns appears to be a combination of higher costs and slightly lower crop frequency for the 200 kg N/ha target. On this basis it appears as though the 150 kg N/ha target would be the most profitable option in the long term.

Figure 5: Whole farm results using derived yield distributions



The software package also returned probability distributions for each result. One set (for the 50w-100s rule for the 150 kg N/ha target) is shown in Figure 6 as an example. There is only a 5% chance of obtaining a zero return on assets and operator labour in this case.

Figure 6: Probability Distributions for opportunity cropping 50W-100S, 150 kg N/ha

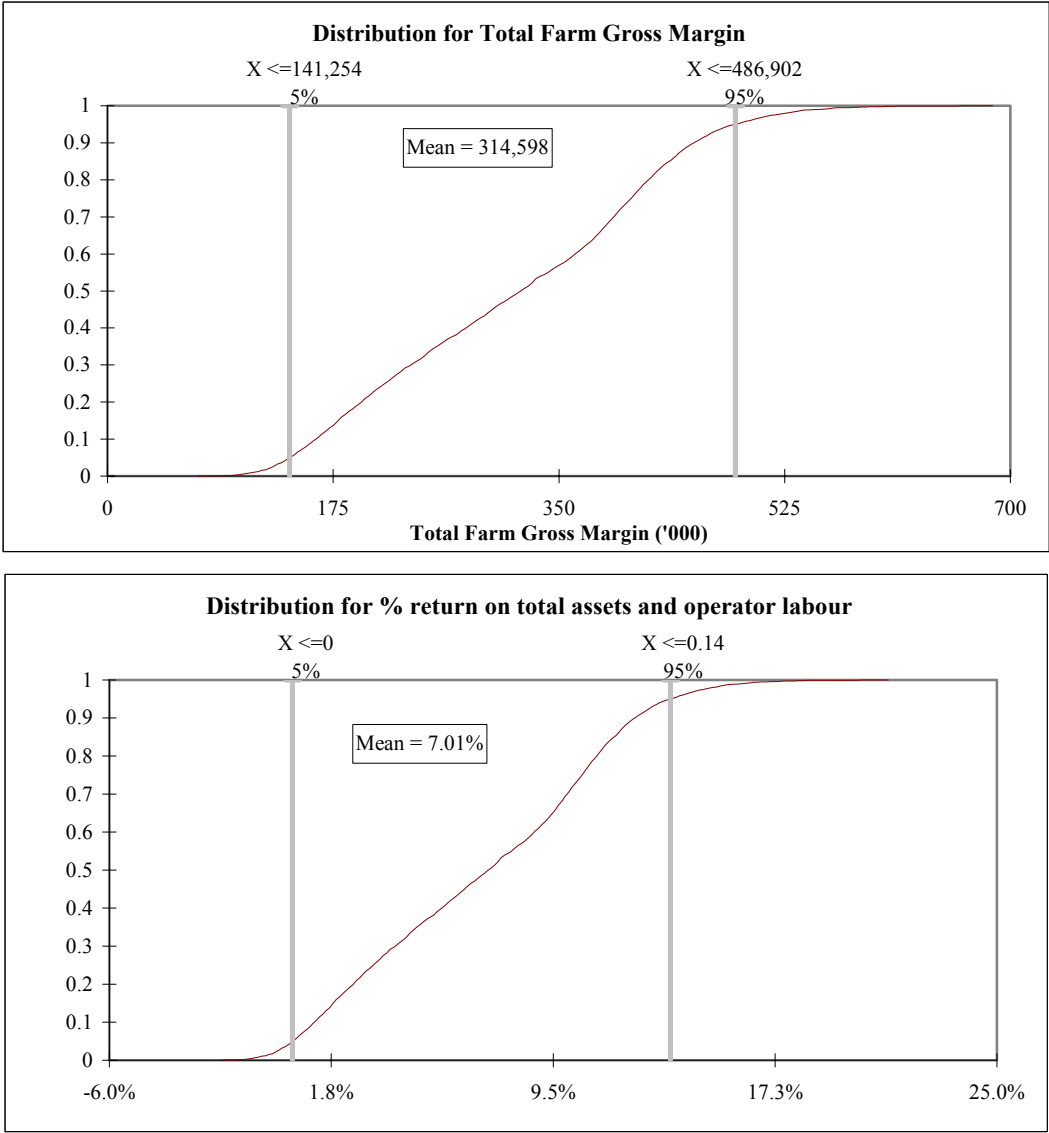


Figure 7 shows the underlying probability distribution, this was a BetaGeneral (Palisade, 2000) distribution, slightly skewed to the left. The distributions of return for the 150N opportunity cropping option compare favourably to the equivalent long fallow system (Figure 8). The averages for the opportunity cropping option were considerably higher than for the long fallow option.

Figure 7: Underlying distribution for OC 150N for return on assets

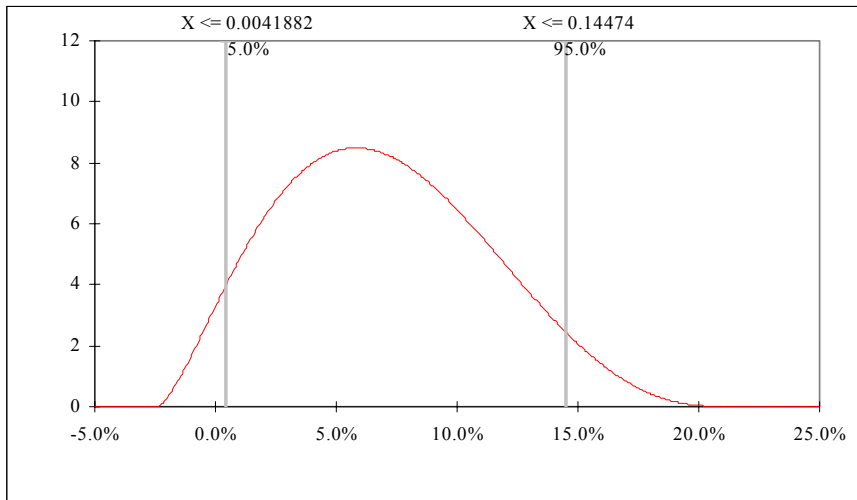
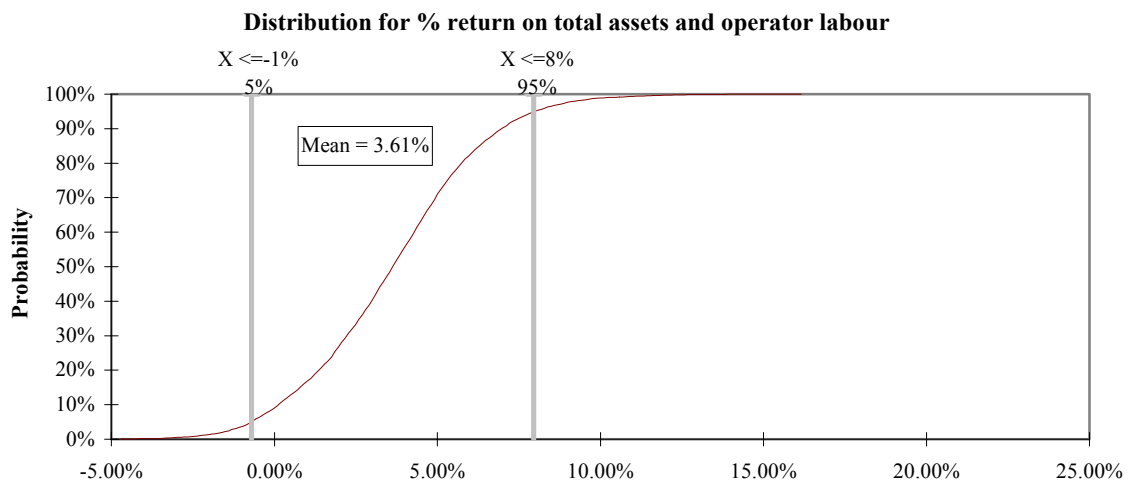
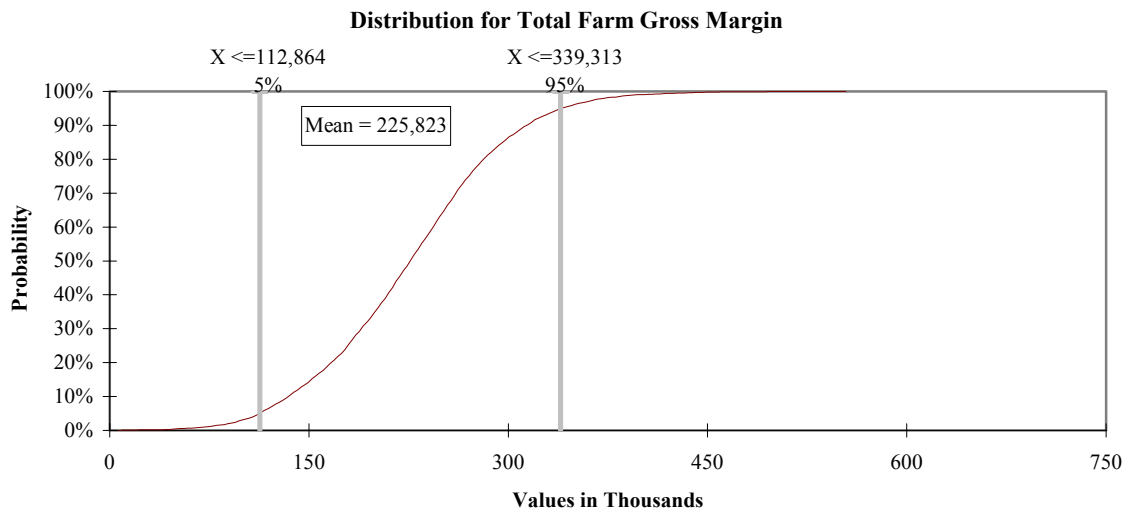


Figure 8: Probability Distributions for Long Fallow, 150 kg N/ha target



4. Discussion

Several opportunity cropping and nitrogen target scenarios were found that improved mean annual gross margin and reduced mean annual deep drainage when compared to long fallow. Basic gross margin and drainage comparisons and mean-standard deviation analysis were used to select a set of four opportunity cropping/nitrogen target options. There were 50W-70S 50 kg N/ha, 50W-100S 100 kg N/ha, 50W-100S 150 kg N/ha, and 50W-100S 200 kg N/ha. A t-test was used to confirm that these four options did have statistically higher mean gross margins than the equivalent long fallow options.

A comparison of the coefficients of variation showed that the opportunity cropping rotation for the 50 kg N/ha target was similar to that of the long fallow. The other opportunity cropping options showed larger coefficients of variation than that of the long fallow options, hence they have a higher relative variation than that of long fallow. This indicates that the concerns of growers about opportunity cropping being a more variable option than that of long fallow have validity.

Most opportunity cropping scenarios also had higher mean annual variable costs than long fallow, although this was driven by a higher cropping frequency.

This approach shows that for this hypothetical farm, the change to opportunity cropping using the 50W-100S planting rule and nitrogen target of 150 kg N/ha would be the most profitable and reduce deep drainage significantly.

An evident occurrence in these results is the relative flatness of the whole farm returns near the maximum (Figure 5). This implies there may be a reasonably wide margin of error and that a nitrogen target rate of between 125 kg and 175 N/ha would capture 90% of the benefits from the change to an opportunity crop planting rule of 50 cm soil moisture for winter crops and 1 metre for summer crops.

Ultimately, it is the individual grower's attitude to risk that will determine whether they decide to make the change from the traditional long fallow wheat-sorghum strip cropping system to opportunity cropping based on soil moisture and soil nitrogen levels. The results shown here do provide useful information to growers about the likely variability of each system compared to the other. The issue remains that these results are drawn from yields generated by a computer model as opposed to real world measurements. Therefore results such as this should be combined with some case study data from growers' experiences in the field to deliver a comprehensive extension message.

5. Conclusion

Opportunity cropping as represented by a wheat/sorghum rotation had improved profitability and reduced drainage and runoff compared to a set long fallow strip cropping system. Added fertiliser nitrogen to achieve a soil nitrogen target amount also had a positive impact on returns. The optimal amount appeared to be 150 kg N/ha for this soil type.

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