Dominance Analysis of Crop Rotation Trials

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Abstract

Much of the recent and current agricultural productivity research is concerned with the sustainability of cropping systems. Paddock level gross margin (ie financial) analysis is usually used to get the message across to farmers about the profitability of different crop rotations, but a system with a high gross margin may also have high costs. This can have implications at the farm level in terms of seasonal borrowing requirements, machinery (and therefore capital) and labour requirements. This paper takes gross margin analysis a step further and applies dominance analysis principles to gauge the returns per dollar invested. The paper concludes by outlining further work needed to conduct more complete economic analyses of sustainable cropping systems.

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1. Introduction

The concern over the sustainability of farming systems in northern NSW in recent years had led to several farming systems projects being undertaken in the region. Growers are interested in both new technologies (crop varieties, disease and weed management) as well as longer term sustainability issues (soil health, profitability). The emphasis of farming systems research in general in the region is on changing the winter cereal-based rotations by inclusion of pulse crops, lucerne and pasture phases to achieve these objectives. This paper demonstrates dominance and marginal analysis principles to compare the profitability of cropping systems trials undertaken on the north western plains and north-east slopes of NSW in the 1990's.

The basis of analysing the profitability of crop rotation trials is the use of gross margins. The role of budgeting (eg Makeham and Malcolm, 1991) has been retained in day to day extension activities. Simple gross margin analysis on a per hectare basis gives total gross margin earned from each treatment. Yet this cannot be used to rank between treatments, since each treatment has a different level of variable costs invested to produce that return. The application of dominance and marginal analysis allows ranking of cropping system treatments which have trialed a range of crops and as a result have different variable costs. There are two northern plains sites (still in operation as of early 2002) located at Coonamble and Cryon (50 km east of Walgett). There were also two sites on the north-east slopes at Warialda and Croppa Creek, operated from 1993 to 1999.

2. Methodology

The financial returns of experimental treatments can be compared using gross margin and dominance analysis (CIMMYT, 1988). 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, such as seed, fertiliser and so on. A gross margin doesn't represent gross profit because it does not include fixed or overhead costs such as depreciation, interest payments or permanent labour which have to be met regardless of enterprise size.

Gross margins were drawn up for each season using input operations conducted on the trial plots and output income. Fallow and crop operations at each trial site were used to calculate variable costs. Other costs such as tractor running costs are taken from NSW Agriculture machinery cost estimations. Prices used for both inputs and outputs were drawn from Scott (2001). For example, the same price is used from season to season for a particular wheat grade or a particular input. This is to avoid any confounding effects of price changes from year to year and to enable the comparison of the different rotations on the same basis.

Dominance and marginal analysis compares the variable costs with the gross margin, showing the increase in costs required to gain a given increase in gross margin (CIMMYT, 1988). 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.

Once the set of dominant treatments have been determined, they may be examined more closely using marginal analysis. The net benefit curve is used to illustrate the preferred treatments. A marginal analysis of the dominant treatments indicates the rates of return from one treatment to the next along the net benefit curve.

3. Western Farming Systems

The GRDC project DAN266NR, 'Sustainable rotations and cropping practices for the marginal cropping areas of north west NSW and south west Queensland' began in 1995 to investigate the sustainability of different cropping systems on the north-western plains of NSW. The economics component of the project aims to address concerns by grain growers that proposed changes in the cropping systems will be profitable. Growers are interested in both new technologies (crop varieties, disease protection, management practices) in the short term and longer term sustainability issues (soil fertility, structure decline, sodicity and salinity). In particular the emphasis is on changing the winter cereal-based rotations by inclusion of pulse crops, lucerne and pasture phases to achieve these objectives.

3.1 Trial outline

There are two core trial sites in operation in NSW. Each is managed by a committee made up of local grower representatives and NSW Agriculture staff. One is at “Cryon Station” at Cryon (50km east of Walgett), the other is located at “Willmon”, 12km east of Coonamble in north-western NSW. Both operate in an environment where average monthly evaporation is above average monthly rainfall, so soil moisture management is very important in order to grow annual crops in these areas.

The average annual rainfall at Walgett is 479mm with a significant proportion of rainfall occurring in the spring/summer months (Figure 1a). The soil type on “Cryon Station” is a Myall brown clay, cropped since the 1970’s (Edwards, 2000). The mean annual rainfall for Coonamble is 503 mm per year with a similar rainfall pattern to that at Cryon. The soil type on “Willmon”, Coonamble is a grey clay, cropped continuously since 1962 (Edwards, 2000).

The continuous cropping trial plans are outlined in Tables 1 and 2. There are ten continuous cropping treatments at both trial sites. Within each treatment, there are two added nitrogen fertiliser options, with and without. In the first three years at Cryon and the first two years at Coonamble, the rates were 50 kg and 100kg of nitrogen per hectare respectively, and from 2000 the nitrogen rates were varied according to yield and wheat protein targets set by each site’s management committee.

Whilst the rotations on both sites have a similar design, there are differences in the crops grown (particularly the opportunity cropping sequences) due to different preferences of the growers on the site management committees. Therefore the data from this trial are of limited use for more formal simulation modelling, since a response function for yield (or protein) in relation to nitrogen fertiliser cannot be ascertained when there are insufficient data points to determine the functional form. It may be useful for validation of a detailed biological simulation model, such as APSIM, which may then be used to provide data for budgeting over a longer period of time.

3.2 Gross margin analysis

This analysis is a method of comparing the trial plot results for extension purposes. Gross margins were drawn up for each season using input operations conducted on the trial plots and output income. Overhead costs have not been included at this stage nor the implications of zero/reduced till systems on resource degradation and any economic gain or losses involved from resource preservation or degradation. For example, the risk of soil erosion under a cultivated system compared to a zero till system, and the subsequent influence on land value, has not been quantified in these particular trials.

Contract rates were used to estimate harvesting costs. The gross margins do not include transport costs from farm to silo, as these vary between farms (Edwards, 2000). Crop prices used were $300 per tonne for chickpeas, $180 per tonne for fababeans, $110 for barley, $125/tonne for ASW (Australian Standard White) grade wheat, $155/tonne for AH (Australian Hard) grade wheat and $175/tonne for PH (Prime Hard) grade wheat. For wheat, an increment of $0.50 per 1% increase in protein within the grades was assumed.

Treatment 22 returned the total highest gross margin at Cryon followed by treatments 25, 22 with added nitrogen (plus-N), 26 plus-N and 27 (Table 1). Treatment 6 plus-N returned the highest total gross margin at Coonamble, followed by treatments 4, 6, 5 and 1 (Table 2).

The reasons for relatively low (on some cases negative) total gross margins included a low fertility paddock, problems with fallow weed control in some years reducing the amount of soil moisture available to subsequent crops and high grain screenings in the plus-N treatments causing downgrading of wheat to feed grade prices.

3.3 Dominance Analysis

In order to undertake a dominance analysis, the cumulative costs and gross margin data are sorted by increasing costs per hectare (Table 3). A treatment is dominated if it has a gross margin per hectare equal or less than a treatment whose total variable costs are lower.

The dominance analysis shows that in the six years of the trial at Cryon Station so far, the dominant treatments are (in order of increasing costs) treatments 20 (long fallow/wheat, zero-till (ZT)), 20 plus-N, 28 (continuous winter cereal, cultivated till (CT)), 27 (opportunity crop, ZT) and 25 (opportunity winter crop, CT) and 22 (pulse/wheat, ZT). These treatments have given the highest total return on the total variable costs invested in them and are shown as the net benefit curve in Figure 2.

The marginal analysis results are shown in Table 3. A marginal analysis of the dominant treatments indicates the rates of return from one treatment to another. The marginal rate of return is expressed as a percentage and is the marginal net benefit (ie difference in gross margin between one treatment and another) divided by the marginal costs (ie difference in variable costs). For example, the marginal rate of return of changing from treatment 20 (ZT, long fallow/wheat) to 20 plus-N is;

$$\frac{\$1125-\$1064}{\$606-\$558} = \frac{\$61}{\$48} = 1.27 = 127\%$$

So compared to the ZT long fallow/wheat rotation without nitrogen, for every extra $1 invested in the nitrogen fertiliser, a grower would have recovered the $1 and obtained an extra $1.27. So the marginal benefits of nitrogen fertilizer (in this case extra grain protein) were enough to cover the extra nitrogen purchase costs.

The minimum rate of return required is likely to vary between growers, since attitudes to risk as well as requirements for cash flow, debt servicing/repayments and capital replacement differ between farms. On the basis of a required minimum rate of return of 100% (CIMMYT, 1988), further refinement of rotation selection may be made. Since the difference between treatments 20 plus-N and 28 is below the selected 100% rate, we can exclude treatment 28 and compare treatments 27 and 20 plus-N. Comparing these two, the marginal rate of return is 51% (Table 4). So therefore, in the six years of the trial so far, treatment 27 (ZT, opportunity crop) had a marginal return of 51% over treatment 20 plus-N (ZT, long fallow wheat) and returned an extra $0.51/ha for every extra $1 required to be spent on variable costs. This is below our 100% minimum marginal return rate, so we can then compare treatments 25 (CT, opportunity winter crop) and 20 plus-N. Comparing these two, the marginal rate of return is 162% (Table 4) which is more acceptable.

The difference between treatments 22 and 25 is 37%, below the 100% return rate assumed to be required, hence, even though the gross margin of treatment 22 is the highest, it wouldn’t be selected on the basis of the marginal analysis.

A dominance analysis (Figure 3) shows that for the trial results so far at Coonamble, treatments 4 (long fallow/wheat, ZT) and 6+N (opportunity winter, ZT) are dominant. A marginal analysis shows that the marginal rate of return between treatments 6+N and 4 is quite low (Table 5). Assuming a minimum marginal rate of return of 100% is required, the choice wouldn’t be made to go from treatment 4 to 6 plus-N.

Both long fallow treatments (3 and 4) have had six seasons of fallow and two under crop. However, treatment 3 has lower total gross margins than treatment 4 due to relatively low proteins for the first crop and a downgrading to feed grade due to high screenings for the second wheat crop. The total fallow costs for treatment three were about $30/ha lower than those for treatment 4 to date. The trial on this site has only been going 4 years and because of this would not be representative of the longer term. Table 6 shows pairwise marginal comparisons at Coonamble.

It is apparent that at Cryon there have been distinct benefits between the dominant opportunity cropping treatments compared with the continuous cereal crop treatments. The ‘optimal’ treatment from the dominant set depends on which rotation being compared against another and the individual growers willingness and ability to outlay any extra variable costs required. So using a dominance analysis approach is a useful basis upon which to compare treatments and determine the optimal treatments in terms of returns invested in a particular level of variable costs. Of the five treatments that returned the highest gross margin, treatments 22 plus-N and 26 plus-N were excluded by the dominance analysis. Also, for a grower who had been undertaking an opportunity cropping rotation such as treatment 25, it would not have been worth shifting to treatments 22 (wheat/pulse) if the required minimum marginal rate of return was above 37%.

At Coonamble, treatment 6 plus-N has returned the highest total gross margin but the dominance analysis shows this is also a relatively high cost option. Dominance analysis has revealed this and would allow growers to assess the results according to their own risk preferences in this light.

4. Wheat/Chickpea Rotations on the north-east slopes

The north-east NSW trial at Warialda and Croppa Creek was part of a long term farming systems experiment funded by GRDC (project DAN 23) and began in the 1980's. This analysis examines the phase from 1993 to 1999 (at Warialda) and 1993 to 1998 (at Croppa Creek) which dealt with rotations of wheat, barley, chickpea or faba beans under three different fallow management practices. The average annual rainfall at Warialda is 689mm with a significant proportion (59%) occurring from September to February (Figure 1b).

4.1 Trial outline

The three fallow management practices were stubble burnt (SB, crop residue burnt and fallow cultivated), stubble retained (SR, crop residue incorporated with cultivation) and no-till (NT, crop residue retained, no fallow cultivation) at Warialda and Croppa Creek. There were eight crop rotation sub-treatments within each fallow treatment. The crop sequences are listed below, with the crop rotation plan shown in Table 7;

A. Continuous wheat, no nitrogen fertiliser applied
B. Continuous wheat, 150 kg N/ha applied annually
C. Wheat/chickpea, no nitrogen fertiliser applied
D. Wheat/chickpea, 150 kg N/ha applied annually to wheat
E. Wheat/barley/chickpea, no nitrogen fertiliser applied
F. Wheat/barley/chickpea, 150 kg N/ha applied annually to cereals
G. Wheat/faba bean, 150 kg N applied annually to wheat
H. Wheat/barley/faba bean, 150 kg N/ha applied annually to cereals

4.2 Gross margin analysis

Gross margins were also drawn up for each season using input operations conducted on the trial plots and output income. Crop prices used were the same as those used for the Western Farming Systems analysis. All crops were sown with 65 kg/ha of Starter Z fertiliser. Within each treatment, there are two added nitrogen fertiliser options, with and without. The added nitrogen treatments at both sites were the same, 150 kg of nitrogen per hectare (the equivalent of 326 kg/ha of urea) applied to all cereal crops.

Typical crop variable costs are shown in Table 8. Wheat variable costs included one pre-sowing herbicide and three in-crop herbicides. Barley variable costs included one pre-sowing and two in-crop herbicides. Chickpea costs included one pre-sowing herbicide, seed treatment, a pre-emergent herbicide for grass and broadleaf weeds, two grass herbicide herbicides, one fungicide and one insecticide application. Faba bean costs were the same as for chickpeas but omitted the insecticide. Faba beans costs were slightly higher than for chickpea due to higher seed and harvesting costs. Winter fallow costs for the no-till system included three herbicide applications. There were two knockdown herbicides and one cultivation for the stubble retained and stubble burnt systems. Summer fallow under no-till included four herbicide applications, under stubble burnt and retained there were three cultivations and two herbicides. Total gross margins are shown in Table 8.

At Warialda, the no-till chickpeas/wheat (NT-C) rotation returned the highest gross margin. The barley/chickpeas/wheat rotation (E) returned the highest gross margin in the stubble burnt and stubble retained tillage systems. It is often difficult to compare treatments under different tillage systems, since the costs involved are often different. Total gross margin may be high, but the variable costs may have been high as well.

Gross margins at the Croppa Creek trial site were lower because this was a generally lower yielding site. The chickpeas/wheat rotation without added nitrogen (C) returned the highest gross margin for the no-till system. The chickpeas/wheat rotation with added nitrogen (D) returned the highest gross margin for the stubble burnt and stubble retained tillage systems.

4.3 Dominance Analysis

Figure 4 shows the graphical results of a dominance analysis of all treatments at Warialda, with those to the right of the net benefit curve being dominated. The dominant low cost options are continuous wheat (A) under stubble retained and stubble burnt at around $1300 over the seven years or an average of $188 per year. The barley/chickpeas/wheat rotation without added nitrogen (E) retuned similar results under all tillage systems. No-till chickpeas/wheat without added nitrogen (NT-C) gave the highest gross margin.

Table 10 shows the dominant treatments from the Warialda trial site. The marginal rate of return is expressed as a percentage and is the marginal net benefit (ie difference in gross margin between one treatment and another) divided by the marginal costs (ie difference in variable costs). For example, the marginal rate of return of changing from SB-A (stubble burnt & cultivated, continuous wheat) to SR-E (stubble retained, barley/chickpeas/wheat) is 562%. So compared to the stubble burnt, continuous wheat rotation, for every extra $1 invested in the stubble retained- barley/chickpeas/wheat rotation, a grower would have recovered the $1 and obtained an extra $5.62.

None of the dominant treatments can be excluded on a 100% minimum marginal rate of return basis. But, some of the large percentage figures are due to only relatively small numbers, particularly over a six year time span. When comparing the stubble retained, continuous wheat sequence (SR-A) with the no-till chickpeas/wheat sequence (NT-C), the marginal rate of return was 343%. So from 1993 to 1999, each extra $1 in variable costs invested in a no-till chickpeas/wheat sequence (compared to stubble retained, continuous wheat sequence) would have recovered the $1 and obtained an extra $3.43.

Figure 5 shows the graphical results of a dominance analysis of all treatments at Croppa Creek, with those to the right of the line (the net benefit curve) being dominated. The dominant low cost options are continuous wheat under stubble retained (SR-A) and stubble burnt (SB-A). The dominant higher cost options were wheat plus added nitrogen under stubble retained (SR-B), followed by no till chickpeas/wheat without added nitrogen (C) under stubble retained and no-till.

Table 12 shows the dominant treatments from the Croppa Creek trial site. One of the dominant treatments, (SM-C) could be excluded on the 100% minimum marginal rate of return basis. Comparing no-till chickpeas/wheat (NT-C) with stubble retained wheat plus nitrogen (SR-B) the marginal rate of return is 48% (Table 10). This doesn’t meet the 100% minimum marginal rate of return either. The pairwise comparisons in Table 13 could be used when comparing each rotation against another.

5. Conclusion

Both of these trials used limited fertiliser treatments, zero additional nitrogen fertiliser and one other rate, although the rate at Cryon varied from 2000 based on nitrogen budgeting to reach target yields and wheat protein. Even though the plus nitrogen treatments were dominated in most cases, this doesn’t mean that additional nitrogen in general is uneconomic. The set rates of fertiliser, particularly that on the Warialda and Croppa Creek sites at 150 kg/N/ha, for instance may have been too high, in that the plants had enough nitrogen but were limited by available moisture. Or alternatively, the rate may have been too low in some cases and the cereal crops still had a nitrogen limitation. Further analysis would be required from trial or APSIM modelling results with different nitrogen rates to determine profitable rates of nitrogen.

The use of dominance and marginal analysis makes further use of the information used in standard gross margin budgeting and addresses the concerns of growers about the costs associated with altering a cropping system from continuous cereal based to cereal/pulse or cereal/pulse/oilseed rotation based. It shows that simply ranking treatments by gross margin can give a misleading picture about what is the financially preferable treatment.

The analyses discussed in this paper are useful for financial analysis of crop rotation trials and has met with a positive response from researchers. However, given that trials of this nature are aimed at finding sustainable rotations, the economic analysis needs to go beyond the simple financial analysis discussed. The next step is whole farm analysis on a financial basis followed by, or along with, economic analysis that assesses the change in the value of the natural resource base (land and water) due to the introduction of the cropping systems under investigation.

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Table 1: Cryon Station trial rotation plan **F= fallow**

													Total gross margin	
No	Tillage	Rotation	1996	96-97	1997	97-98	1998	98-99	1999	99-00	2000	00-01	2001	Zero N	Plus N
19	zero till	Continuous cereal	wheat	F	wheat	F	barley	F	wheat	F	wheat	F	barley	$ 839	$ 899
20	zero till	Long fallow-wheat	F	F	wheat	F	F	F	durum	F	F	F	wheat	$1064	$1125
21	zero till	Wheat-long fallow	wheat	F	F	F	wheat	F	F	F	wheat	F	F	$503	432
22	zero till	Pulse-wheat	chickpea	F	wheat	F	chickpea	F	durum	F	chickpeas	F	wheat	$1580	$1485
23	zero till	Wheat-pulse	wheat	F	chickpea	F	wheat	F	fababeans	F	wheat	F	chickpeas	$929	$876
24	cultivated	Winter/summer exploitative	wheat	sorghum	F	sorghum	F	sorghum	wheat	F	wheat	F	barley	$748	$746
25	cultivated	Opportunity winter crop	chickpea	F	wheat	F	canola	F	wheat	F	chickpeas	F	wheat	$1564	$1148
26	zero till	Opportunity winter crop	chickpea	F	wheat	F	canola	F	wheat	F	chickpeas	F	wheat	$1224	$1248
27	zero till	Opportunity winter/summer	wheat	F	F	sorghum	F	F	durum	F	chickpeas	F	barley	$1233	$1053
28	cultivated	Continuous cereal	wheat	F	wheat	F	barley	F	wheat	F	wheat	F	barley	$1164	$1052

Table 2: Coonamble trial rotation plan

										Total gross margin	
Treatment	Tillage	Treatment name	1997-98	1998	1998-99	1999	1999-00	2000	2000-01	2001	Zero N	Plus N
1	zero till	Contin. Wheat	F	wheat	F	wheat	F	wheat	F	wheat	$236	-$6
2	cultivated	Contin. Wheat	F	wheat	F	wheat	F	wheat	F	wheat	-$27	-$124
3	zero till	Wheat-Long fallow	F	wheat	F	F	F	wheat	F	F	-$86	-$189
4	zero till	Long fallow-Wheat	F	F	F	wheat	F	F	F	wheat	$290	$54
5	cultivated	Opportunity winter crop	F	canola	F	wheat	F	chickpea	F	safflower	$237	$224
6	zero till	Opportunity winter crop	F	canola	F	wheat	F	chickpea	F	safflower	$261	$329
7	zero till	Opportunity winter/summer	F	canola	F	durum	F	chickpea	F	wheat	-$12	$107
8	zero till	Wheat/pulse	F	wheat	F	fabas	F	wheat	F	chickpea	-$26	-$60
9	zero till	Pulse/wheat	F	chickpea	F	wheat	F	chickpea	F	wheat	$50	$142
10	cultivated	Winter/summer exploitative	F	canola	F	durum	sorghum	wheat	F	durum	$126	-$79

Table 3: Marginal Analysis for Dominant Treatments at Cryon

Treatment	Tillage	Total variable costs $/ha	Total Gross Margin $/ha	Extra Costs $/ha	Extra gross margin $/ha	Marginal rate of return
20	ZT	558	1,064			
20+N	ZT	606	1,125	48	61	127%
28	CT	785	1,164	179	39	22%
27	ZT	819	1,233	34	69	203%
25	CT	877	1,564	58	331	571%
22	ZT	920	1,580	43	16	37%

Table 4: Marginal comparisons of all treatments at Cryon

From

To	19	19+N	20	20+N	21	21+N	22	22+N	23	23+N	24	24+N	25	25+N	26	26+N	27	27+N	28
19																			
19+N	33%																		
20	-71%	-32%																	
20+N	-107%	-49%	127%																
21	124%	86%	-1122%	-31100%															
21+N	295%	142%	-347%	-517%	-54%														
22	1730%	-457%	143%	145%	345%	638%													
22+N	503%	-930%	94%	90%	247%	396%	-110%												
23	65%	-60%	-29%	-47%	104%	178%	-658%	-4277%											
23+N	15%	-33%	-32%	-47%	70%	112%	-323%	-461%	-45%										
24	4400%	78%	-100%	-140%	92%	234%	1849%	563%	126%	49%									
24+N	-42%	-729%	-60%	-78%	50%	90%	-491%	-880%	-258%	271%	-1%								
25	0%	-346%	157%	162%	394%	826%	37%	-61%	-447%	-264%	40800%	-384%							
25+N	256%	-356%	19%	6%	165%	276%	-547%	4814%	-1095%	-196%	323%	-442%	-341%						
26	554%	-266%	41%	29%	213%	383%	-1319%	442%	-410%	-182%	661%	-334%	-486%	-146%					
26+N	217%	-17450%	36%	27%	162%	250%	-226%	-389%	665%	-524%	260%	-2183%	-166%	147%	20%				
27	-684%	-134%	65%	51%	346%	1014%	344%	135%	-152%	-112%	-866%	-180%	571%	-47%	-7%	6%			
27+N	201%	-183%	-3%	-19%	146%	253%	-811%	2057%	-365%	-116%	277%	-292%	-473%	679%	-450%	238%	-108%		
28	-357%	-93%	44%	22%	373%	1627%	308%	145%	-100%	-82%	-462%	-137%	435%	-7%	37%	30%	203%	-56%	
28+N	240%	-150%	-3%	-20%	153%	273%	-1123%	1110%	-237%	-103%	330%	-249%	-569%	300%	-860%	196%	-122%	6%	-62%

Table 5: Marginal Analysis for Dominant Treatments at Coonamble

Treatment	Tillage	Total variable costs $/ha	Total Gross Margin $/ha	Extra Costs $/ha	Extra gross margin $/ha	Marginal rate of return
4	zero till	638	290			
6+N	zero till	1222	329	584	39	7%

Table 6: Marginal comparisons of all treatments at Coonamble

	From																		
To	**1**	**1+N**	**2**	**2+N**	**3**	**3+N**	**4**	**4+N**	**5**	**5+N**	**6**	**6+N**	**7**	**7+N**	**8**	**8+N**	**9**	**9+N**	**10**
1																			
1+N	-87%																		
2	774%	7%																	
2+N	-147%	358%	-35%																
3	143%	16%	31%	-8%															
3+N	405%	48%	228%	19%	-86%														
4	-21%	-56%	-144%	-83%	-1297%	-321%													
4+N	147%	-15%	-90%	-48%	139%	-1279%	-182%												
5	-108%	-90%	-1684%	-140%	220%	927%	1%	337%											
5+N	25%	-403%	132%	-1030%	87%	154%	0%	71%	-2%										
6	134%	-157%	350%	-253%	141%	299%	11%	142%	28%	-28%									
6+N	53%	804%	121%	631%	90%	138%	21%	79%	31%	99%	33%								
7	-143%	-39%	49%	-151%	39%	104%	-62%	0%	-133%	305%	-448%	178%							
7+N	-12%	183%	52%	224%	45%	77%	-16%	27%	-24%	-54%	-43%	-404%	53%						
8	-1048%	8%	2%	-45%	24%	125%	-113%	-54%	-409%	174%	838%	144%	77%	60%					
8+N	-204%	41%	-18%	-64%	7%	52%	-88%	-42%	-178%	580%	-495%	255%	-665%	104%	-28%				
9	-291%	-26%	79%	-96%	47%	141%	-75%	-2%	-208%	169%	9200%	136%	5%	44%	195%	-136%			
9+N	-55%	-138%	82%	-359%	58%	120%	-35%	30%	-67%	429%	-177%	170%	207%	22%	115%	777%	86%		
10	0%	-74%	671%	-133%	128%	371%	-35%	119%	-174%	42%	187%	64%	-116%	-3%	-908%	-180%	-236%	-35%	
10+N	-80%	250%	11%	341%	19%	51%	-52%	-11%	-84%	-353%	-146%	876%	-28%	179%	14%	50%	-19%	-118%	-68%

Table 7: Warialda/Croppa Creek Crop Rotation Plan

	1993	1994 (drought)	1995	1996	1997	1998	1999
A	Wheat	Fallow	Wheat	Wheat	Wheat	Wheat	Wheat
B	Wheat + N	Fallow	Wheat + N	Wheat + N	Wheat + N	Wheat + N	Wheat + N
C	Chickpea	Fallow	Wheat	Chickpea	Wheat	Chickpea	Wheat
D	Chickpea	Fallow	Wheat + N	Chickpea	Wheat + N	Chickpea	Wheat + N
E	Barley	Fallow	Chickpea	Wheat	Barley	Chickpea	Wheat
F	Barley +N	Fallow	Chickpea	Wheat + N	Barley +N	Chickpea	Wheat + N
G	Faba bean	Fallow	Wheat +N	Faba bean	Wheat + N	Faba bean	Wheat + N
H	Faba bean	Fallow	Wheat + N	Barley +N	Faba bean	Wheat + N	Barley +N

Table 8: Typical crop variable costs for Warialda/Croppa Creek ($/ha)

Crop	no N	+150 kg N	Fallow costs	$/ha
Wheat	177	245	Summer fallow NT	43
Barley	168	235	Winter fallow NT	23
Chickpeas	299	N/A	Summer fallow SM/SB	32
Faba beans	308	N/A	Winter fallow SM/SB	21

Table 9: Total Gross Margins for Warialda and Croppa Creek ($/ha)

Code	Rotation	Warialda			Croppa Creek		
		NT	SR	SB	NT	SR	SB
A	W	506	812	842	-136	20	243
B	W+N	762	1220	1531	79	635	547
C	CpW	2387	1976	1976	755	686	629
D	CpW+N	2385	1904	1985	721	744	741
E	BCpW	2134	2006	2084	326	285	282
F	BCpW+N	2158	1956	1943	488	315	243
G	FbW	1700	1184	1700	535	511	545
H	FbWB+N	1110	1132	1194	437	244	315

Table 10: Marginal Analysis for Dominant Treatments at Warialda

Dominant treatments	Total variable costs $/ha	Total Gross Margin $/ha	Extra Costs $/ha	Extra gross margin $/ha	Marginal rate of return
A: SR-W	1,324	812			
A: SB-W	1,327	842	3	30	1000%
E: SR-BCpW	1,534	2,006	207	1164	562%
E: SB-BCpW	1,537	2,084	3	78	2600%
E: NT-BCpW	1,552	2,134	15	50	333%
C: NT-CpW	1,783	2,387	231	253	110%

Table 11: Marginal comparisons of all treatments at Warialda

	From																						
To	NT: A	SB: A	SR: A	NT: B	SB: B	SR: B	NT: C	SB: C	SR: C	NT: D	SB: D	SR: D	NT: E	SB: E	SR: E	NT: F	SB: F	SR: F	NT: G	SB: G	SR: G	NT: H	SB: H
SB: A	-700%																						
SR: A	-600%	1000%																					
NT: B	63%	-18%	-11%																				
SB: B	289%	171%	177%	-1569%																			
SR: B	202%	94%	101%	-898%	15550%																		
NT: C	461%	339%	343%	40625%	1615%	2122%																	
SB: C	476%	318%	323%	-1278%	-967%	-1718%	415%																
SR: C	468%	313%	319%	-1349%	-1085%	-1938%	437%	0%															
NT: D	351%	264%	268%	1230%	472%	637%	-2%	180%	184%														
SB: D	290%	205%	209%	1154%	293%	487%	-394%	4%	5%	1538%													
SR: D	271%	189%	193%	1029%	233%	422%	-451%	-35%	-36%	2290%	-1620%												
NT: E	920%	574%	580%	-604%	-339%	-519%	110%	-120%	-115%	70%	-45%	-68%											
SB: E	974%	591%	597%	-546%	-287%	-452%	123%	-73%	-71%	80%	-28%	-51%	333%										
SR: E	943%	562%	569%	-508%	-242%	-405%	153%	-20%	-19%	101%	-6%	-29%	711%	2600%									
NT: F	236%	176%	179%	470%	181%	270%	-78%	46%	47%	-138%	91%	137%	5%	14%	28%								
SB: F	237%	168%	172%	582%	163%	285%	-223%	-11%	-11%	-623%	-43%	42%	-44%	-32%	-14%	229%							
SR: F	238%	170%	174%	585%	168%	289%	-216%	-7%	-7%	-596%	-30%	56%	-41%	-29%	-11%	217%	1300%						
NT: G	312%	199%	205%	-4467%	604%	1600%	2748%	-373%	-400%	448%	224%	155%	-211%	-174%	-137%	144%	108%	114%					
SB: G	312%	199%	205%	-4467%	604%	1600%	2748%	-373%	-400%	448%	224%	155%	-211%	-174%	-137%	144%	108%	114%	0%				
SR: G	193%	86%	93%	-796%	8675%	1800%	2111%	-1886%	-2141%	649%	504%	439%	-546%	-476%	-428%	278%	296%	300%	1613%	1613%			
NT: H	95%	39%	44%	151%	-151%	-39%	-565%	-266%	-271%	-1301%	-706%	-667%	-224%	-206%	-189%	1564%	-3085%	-3254%	-235%	-235%	-26%		
SB: H	108%	51%	55%	185%	-119%	-9%	-519%	-238%	-241%	-1168%	-618%	-577%	-204%	-187%	-170%	1530%	-2416%	-2540%	-198%	-198%	3%	2100%	
SR: H	101%	43%	48%	170%	-149%	-33%	-586%	-270%	-274%	-1457%	-762%	-721%	-225%	-207%	-189%	1299%	-5407%	-5886%	-238%	-238%	-19%	-183%	388%

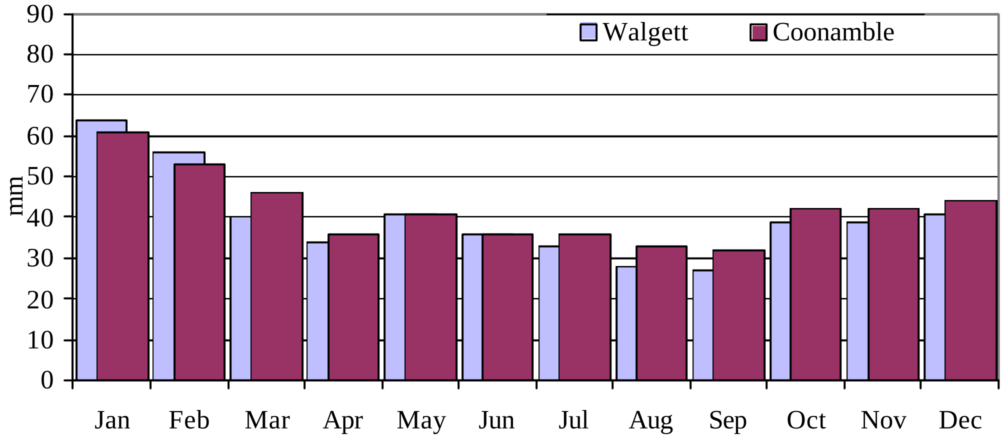
Table 12: Marginal Analysis for Dominant Treatments at Croppa Creek

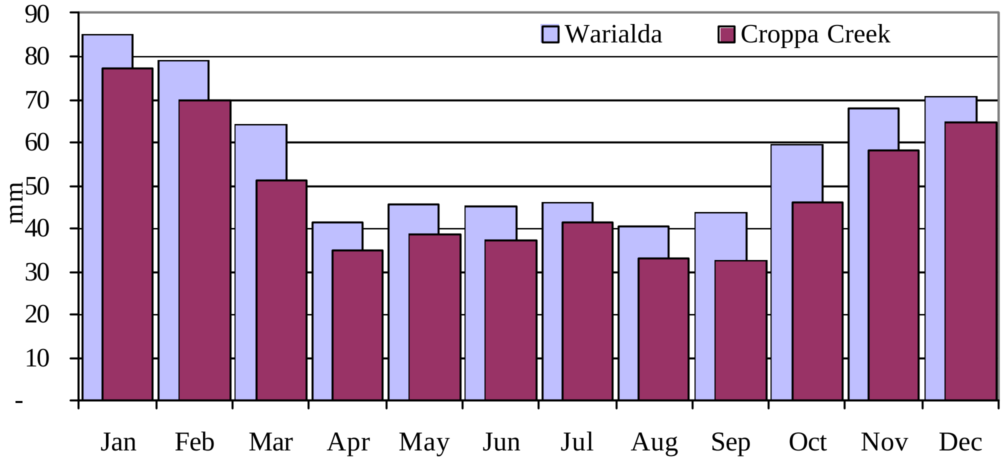
Dominant treatments	Total variable costs $/ha	Total Gross Margin $/ha	Extra Costs $/ha	Extra gross margin $/ha	Marginal rate of return
A: SR-W	1,217	20			
A: SB-W	1,221	243	4	223	5575%
B: SR-W+N	1,378	635	157	392	250%
C: SR-CpW	1,579	686	201	51	25%
C: NT-CpW	1,630	755	51	69	135%

Table 13: Marginal comparisons of all treatments at Croppa Creek

	From																						
To	NT: A	SB: A	SR: A	NT: B	SB: B	SR: B	NT: C	SB: C	SR: C	NT: D	SB: D	SR: D	NT: E	SB: E	SR: E	NT: F	SB: F	SR: F	NT: G	SB: G	SR: G	NT: H	SB: H
NT: A																							
SB: A	-758%																						
SR: A	-289%	5575%																					
NT: B	53%	-36%	13%																				
SB: B	194%	76%	130%	-918%																			
SR: B	721%	250%	382%	-188%	-36%																		
NT: C	248%	125%	178%	-1536%	2971%	48%																	
SB: C	250%	108%	169%	-567%	-178%	-3%	238%																
SR: C	267%	124%	184%	-639%	-316%	25%	135%	2850%															
NT: D	153%	78%	114%	409%	84%	19%	-17%	36%	14%														
SB: D	173%	89%	129%	637%	125%	27%	-9%	56%	28%	-38%													
SR: D	173%	89%	128%	621%	125%	27%	-7%	56%	29%	-46%	100%												
NT: E	217%	32%	115%	-130%	159%	-292%	294%	326%	379%	114%	141%	141%											
SB: E	268%	19%	125%	-82%	135%	-720%	233%	231%	266%	109%	131%	131%	77%										
SR: E	272%	20%	127%	-83%	133%	-729%	230%	228%	262%	108%	130%	129%	71%	-300%									
NT: F	113%	41%	77%	273%	-29%	-33%	-138%	-57%	-81%	3329%	-550%	-595%	48%	52%	51%								
SB: F	77%	0%	41%	182%	-216%	-102%	-382%	-206%	-239%	713%	3557%	2947%	-30%	-12%	-12%	408%							
SR: F	90%	13%	53%	243%	-157%	-81%	-312%	-162%	-193%	677%	6086%	4290%	-4%	10%	9%	326%	1029%						
NT: G	162%	63%	110%	3800%	-19%	-32%	-393%	-86%	-141%	128%	224%	220%	103%	98%	96%	-34%	-374%	-259%					
SB: G	188%	73%	126%	-1137%	-20%	-35%	-7000%	-150%	-261%	89%	135%	134%	147%	128%	126%	-30%	-231%	-167%	-19%				
SR: G	200%	72%	130%	-547%	129%	-57%	697%	-656%	-1094%	89%	126%	125%	167%	136%	134%	-10%	-159%	-111%	26%	89%			
NT: H	105%	32%	69%	249%	-56%	-45%	-169%	-80%	-104%	2185%	-760%	-830%	33%	40%	39%	850%	359%	260%	-74%	-58%	-33%		
SB: H	93%	13%	55%	288%	-174%	-85%	-349%	-175%	-210%	541%	1936%	1716%	-4%	10%	9%	254%	-900%	0%	-314%	-187%	-122%	197%	
SR: H	85%	0%	45%	359%	-312%	-114%	-568%	-269%	-313%	430%	857%	820%	-35%	-13%	-14%	235%	-2%	139%	-856%	-346%	-214%	197%	197%

Figure 1: Mean monthly rainfall





Source: Australian Rainman, v3.3.

Figure 2: Net benefit curve and dominated treatments- Cryon

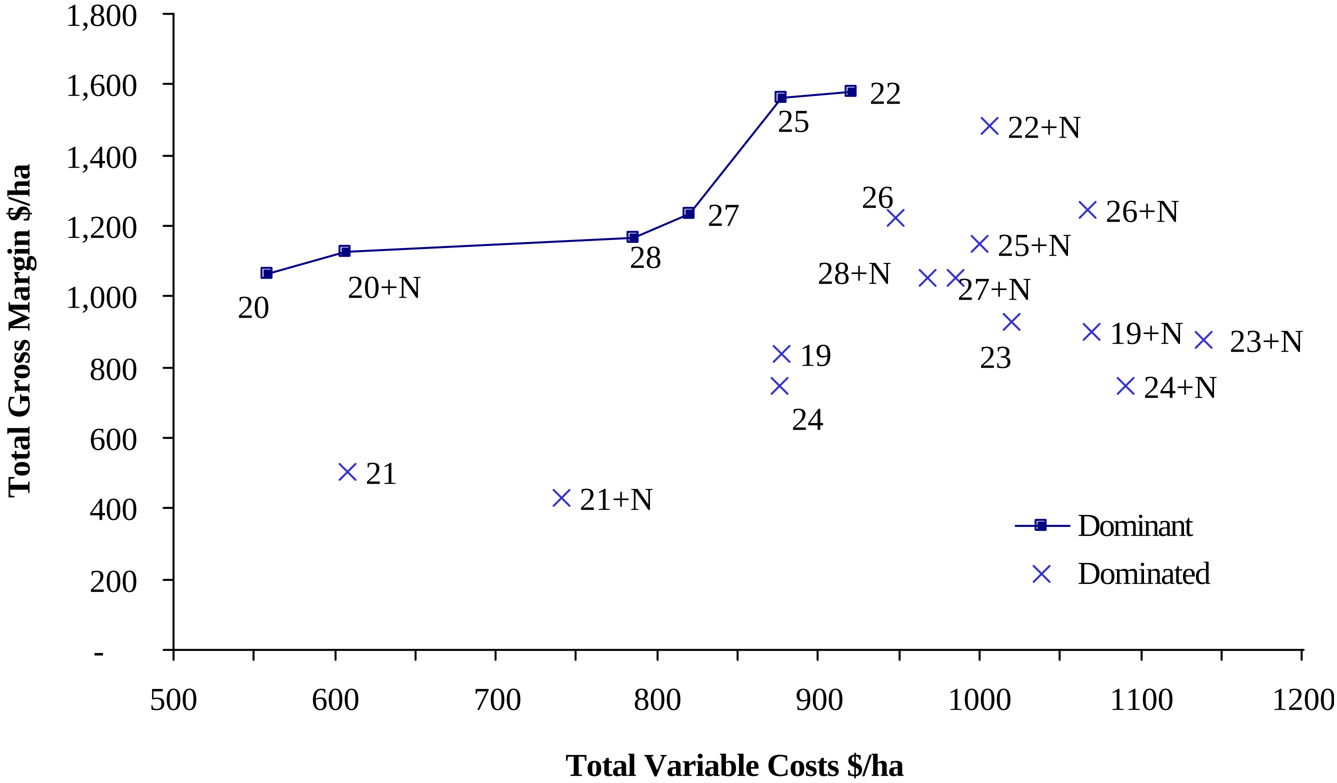


Figure 3: Net benefit curve and dominated treatments- Coonamble

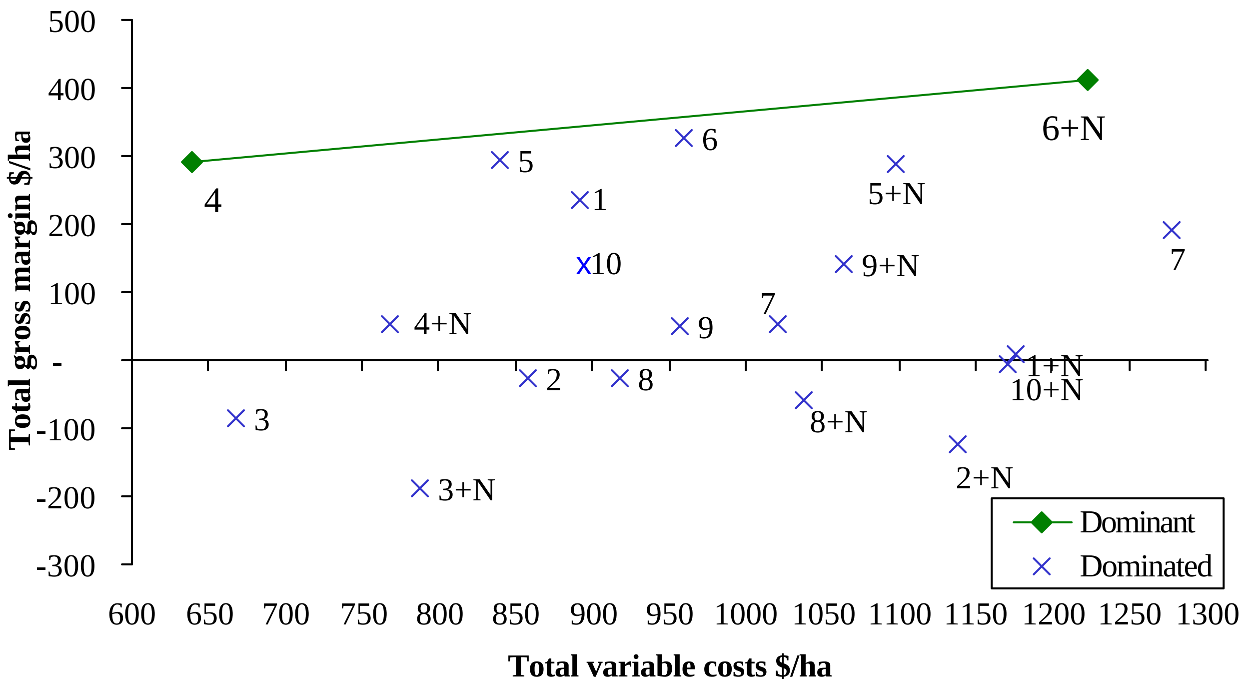


Figure 4: Net benefit curve and dominated treatments- Warialda

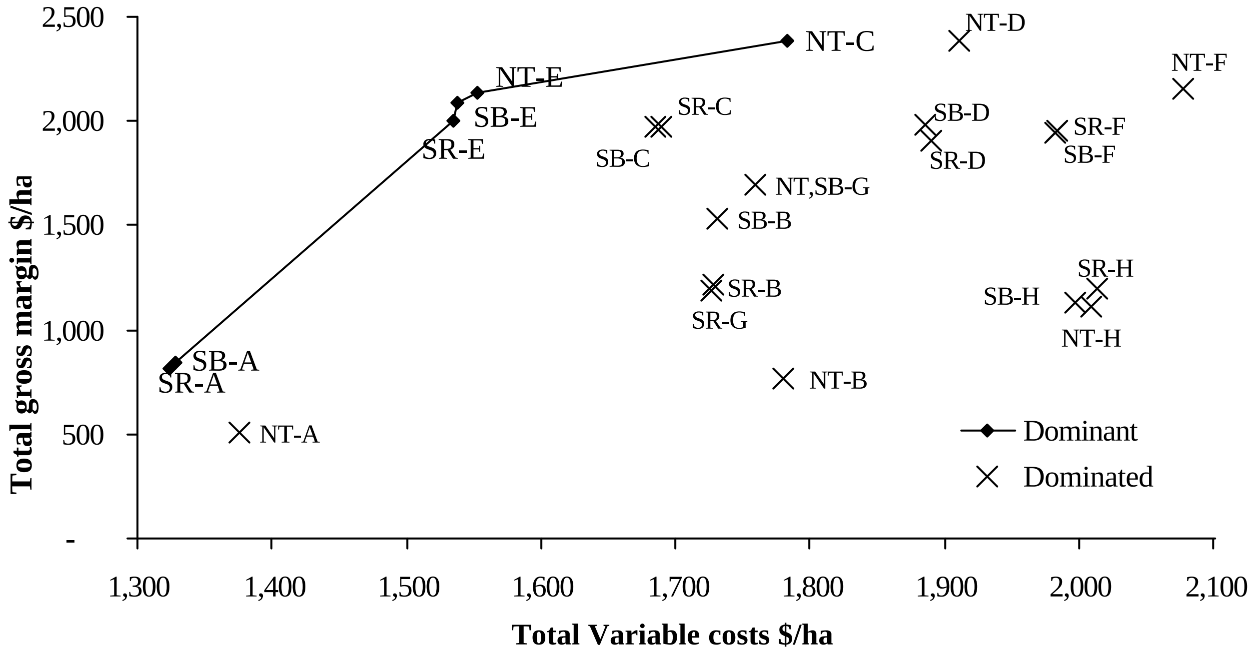


Figure 5: Net benefit curve and dominated treatments- Croppa Creek