DISCUSSION PAPER

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The Profitability of Green Manuring

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Executive summary

Recently interest in the role of renovation cropping in the farming systems of the Western Australian wheatbelt has increased. It has been proposed as a means of addressing the apparent decline in soil quality in some intensively cropped areas and the increased incidence of herbicide resistance.

Renovation cropping involves either turning a crop into the soil at flowering or cutting the crop and leaving it on the soil surface. This is done to maximise the amount of organic matter added to the soil and to control weeds most effectively. In the Western Australian wheatbelt the focus has been on using pulses, although a range of crops can be used. The pulse phase of a rotation is favoured as pulses improve the nitrogen status of the soil. In addition the returns to pulses are lower relative to cereals and canola, so the forgone profit in the year of renovation cropping is lowest.

Renovation cropping leads to changes in soil conditions that persist for at least the following season. It reduces weed numbers in the following crop by reducing seed set, increases the availability of nutrients and may improve soil structure. Lower weed numbers reduce the carry-over of root diseases thus providing a disease break for the following cereal crop. Recent trials have shown likely yield increases of 20-30% above those after a pulse crop and increased grain protein levels in the following cereal.

The main cost of green manuring is the income lost by sacrificing grain production. The loss in income plus any additional costs associated with soil renovation need to be recouped in the following season(s). Therefore the income from the yield increase(s) in the subsequent year(s) needs to be equal to or greater than the total costs of renovation, including the income forgone.

Despite the increase in interest in renovation cropping, no comprehensive economic analysis has been undertaken to determine its role in Western Australian farming systems. This study investigates circumstances under which renovation cropping is likely to be profitable and estimates the needed increase in farm profit, given the variability of yields that result from seasonal influences.

To investigate the consequence of risky yields historical rainfall data was used to generate yield distributions for different rainfall zones, soil types and crops. The yield distributions were used as input to a simulation model to determine the distribution of income, resulting from renovation cropping, in a lupin:wheat:wheat rotation. The mean yield boost resulting from renovation cropping was estimated to be 3% based on trial results (F. Hoyle, pers. comm.).

The results of the analysis showed that there is a 30-40% chance of increasing profit if yield is increased by 30% on average. However, the results were very sensitive to the average increase in yield. The probability that profit will be increased was halved when yield boost was reduced to 20%.

The yield increase required to make renovation cropping profitable can vary between 100% under the worst case and below 10% under the best case. The variability depends on grain prices, grain yield in the renovation phase (if a commercial crop had been was harvested), and the cost of renovation and grain yields in the following crop phase.

The likelihood that profit will be increased depends largely on minimising income forgone relative to the increase in income in the following years. Therefore green manuring will be most profitable when done in years when the grain yield of the pulse crop is low, and/or when the following cereal yield is very high.

Weather forecasts are not yet sufficiently developed to predict potentially good years over 12 months ahead, so renovation needs to be undertaken in poor years to maximise the chances of increasing profit.

Identifying poor yielding years prior to renovation does present some difficulty although weather forecasts may improve the chances of undertaking renovation in the 'right' year. . Also yield potential is determined directly by biomass of the crop, so this may be used as an early indicator of yield. Where waterlogging or disease has caused low vegetative growth, resistant weeds are widespread in a paddock, or where frost has damaged the crop green manuring is more likely to be a profitable option.

This suggests a role for tactical use of renovation cropping so that it is undertaken in years where the forgone income is minimised (i.e. it is done in poor yielding years). The results of the analysis show that only small yield increases in the following cereal crop are necessary to break even in these circumstances.

The analysis highlighted gaps in the knowledge of the impact of renovation cropping that may be important for more comprehensive economic analysis, or information that may improve the grower’s ability to undertake the practice profitably. Further research into green manuring could include:

- Determining whether the profitability of green manuring can be increased using long term weather forecasts. Improving the estimates of the probability of achieving different yields may allow farmers to renovate soils in years that have lower risk.
- More information on the effects of green manuring on yield and protein for different crops under different conditions is required to better assess the economic advantages of green manuring
- The profitability of green manuring relative to other methods of improving sustainability of cropping also needs to be addressed.

1. Introduction

Intensive cropping in the wheatbelt of Western Australia has lead to a number of problems that may threaten long-term sustainability. The most immediate is the increase in weed resistance to herbicides, as it has the largest impact on crop yield in the short-term. Managing resistance to herbicide may require substantial changes in agricultural practices.

Also anecdotal evidence suggests that lupin yields are declining on some soils that are used for continuous cropping. This appears to be associated with a decline in the chemical and physical fertility of the soil. Renovation cropping is one treatment that may provide a profitable means overcoming these problems.

Farmers, who have adopted renovation cropping in Western Australia, have done so primarily to control herbicide resistant weeds. However many of those growers who have adopted it are impressed with the improvement of soil fertility, and subsequent increases in cereal yield and grain protein[1].

Despite large apparent gains in yield and protein, few growers appear willing to adopt the practice. One possible explanation for low adoption is the uncertainty of its profitability. While cereal yield is often higher after green manuring, the increase has to be large enough to cover the loss of income when a crop is sacrificed to renovate the soil.

Where there are large densities of resistant weeds the loss in income in a renovation phase is likely to be minimal, and therefore it may be the best strategy. In the absence of resistant weeds the loss in income in the year of green manuring is dependent on seasonal conditions. Farmers' decisions to renovate will depend on the likelihood of poor yields in the year after manuring, particularly if it is being done strategically to improve soil fertility.

This paper assesses the economic benefits of green manuring and the potential costs. It also investigates the circumstances in which green manuring will be profitable and those that result in losses to growers.

2. Description of green manuring

Renovation cropping involves turning a crop into the soil at flowering or cutting and leaving it on the soil surface. This increases soil organic matter and may increase soil nitrogen if a legume crop is used. Organic matter improves soil structure, which can lead to improved infiltration of water, higher water holding capacity and increased aeration of the soil. Nitrogen from a manured

1 W. Anderson (pers. comm.).

legume crop may be available to the following crop thereby reducing the need for applied nitrogen.

The benefits of renovation depend on climatic conditions, soil type and on the problems being addressed[2]. The specific problems green manuring may address are:

- herbicide resistance,
- soil structural decline,
- chemical infertility, or
- disease levels[3].

2.1. Management of green manure crops

A range of crops may be used but in Western Australia pulse crops are favoured. This is because renovation is likely to be done as part of an existing rotation, in the place of a pulse crop. The loss in income associated with renovation will be lowest if done in the pulse phase. There is also the additional benefit of improved soil nitrogen. Other crops commonly used are mixtures of oats and vetches, oats and peas, medics, clover and brassica crops[4].

Renovation is done at or just prior to flowering to ensure the biomass of the crop is at a maximum and thereby maximising the organic matter added to the soil

The suitability of a particular crop depends on the problem being addressed. While legume crops are most suitable to increase nitrogen levels, non-legume crops are best used where improving organic carbon levels is a priority. This is due to their higher biomass. Cereal crops such as oats are most used for this purpose[5].

In the renovation phase the crop is sown and managed as a normal crop. A knockdown spray is generally used prior to sowing, but spraying during the growing season is likely to be unnecessary[6]. In early spring the crop is turned in, usually with an offset disc drill, sprayed with herbicides or it is cut using a slasher. The preferred method depends on rainfall and soil type. Under dry conditions spraying or brown manuring may be less attractive to methods that mulch or turn the green manure crop in. . Spraying may also be less attractive the sandier the soil[7].

2 Wal Anderson (pers. comm.).

3 Zaicou-Kunesch et al (1998) suggest that inclusion of oilseed (canola) and/or chickpeas is necessary for proper disease break and weed control.

4 Wal Anderson (pers. comm.). In the South Australian agriculture green manure usually takes the form of vetch but medics and subterranean clover is also used (Amato (1998) and Mayfield (1995)).

5 Amato (1998) found that there is no clear winner comparing yield boost, grain protein increase and nitrogen fixation, whereas Mayfield (1995) suggests that vetch seem to give the highest grain protein increases, while medic has a longer lasting effect on yield; Appendix I summaries a number of green manure trials (Tables 6 to 11 effects on yields and Table 12-14 for effects on grain protein).

6 Wal Anderson (pers. com.)

7 As Table 7 and Table 13 seem to suggest (Appendix), and Fran Hoyle (pers. comm.).

However, spraying is favoured if it is a wet spring. In wet seasons spraying reduces water erosion as the crop is left on the top of the soil, leaving the soil undisturbed[8]. Rain will also improve decomposition of crops on the top of the soil and leach nutrients into the soil and Yield increases resulting from ploughing and spraying in the following season are likely to be equivalent in this case[9].

The frequency of renovation will depend on soil and weed conditions, ranging from 1 in 3 to 1 in 9 years[10]. It can be used either strategically or tactically. For strategic use a crop suitable for increasing soil fertility is grown specifically for the purpose of green manuring.

Tactical management implies that a decision is made during the course of the season to renovate the soil. This would happen if it were likely to fail, for example, as a result of an infestation of herbicide resistant weeds or because seasonal conditions are very poor, resulting in an expected poor yield. This increases the likelihood that the expected increase in yield in the following crops will compensate for the loss in income in the year of renovation. Tactical use of green manuring implies that cost is the same as for a cash crop whereas there may be scope for reducing cost for a planned (strategic) green manure crop.

2.2. Climate and organic matter

It is unclear what climatic conditions are best for renovation cropping. Organic matter content of soil depends on mean annual temperature (MAT) and mean annual precipitation (MAP). The organic content is at the highest at about 800mm (MAP) and at the lowest at about 18C MAT[11].

On one hand, this suggests that green manuring works best under moist conditions where dry matter is higher and decay is enhanced. Further, the lower production of dry matter in drier areas would increase the need for bulk and the frequency of renovation. On the other hand, the relative benefit of renovation may be highest in dry areas where there is less soil organic matter, and slower rates of decay. This may also distribute the benefits more evenly over the season and reduce the likelihood of leaching of nutrients[12].

2.3. Herbicide resistance

While there are many possible benefits of renovation, the primary reason for its adoption in Western Australia has been to combat weed resistance to herbicide. It is one method of controlling resistant weeds by preventing seed set. Reductions in weeds from thousands to less

8 Wal Anderson (pers. comm.). Experiments are undertaken by some farmers, first to flatten the crop (windrower or slasher) and then to run lightly over it (with a disc-plough); Amato 1998.

9 Amato (1998).

10 Amato (1998), Zaicou-Kunesch, et al (1998) used 1 in 3 phases, Darryl Abbott used green manure 1 in 6 and 1 in 9.

11 In-sang (1990).

12 Wal Anderson (pers. comm.).

than 10 seeds/m^2 have been observed [13] following the year of renovation. Resistance is developing rapidly[14] and has become a major management issue in Western Australia over the last 10 years. Resistance has developed to all major selective herbicide groups in all cropping areas. Estimates of herbicide resistance range from less than 10% of paddocks to 50% of farms for group A and B chemicals[15].

3. Potential Benefits

3.1. Yields

Yield increases resulting from renovation cropping depend on soil structure, fertility and the extent to which they can be improved, the presence of herbicide resistant weeds, disease, water logging and weather[16]. Consequently, yield boosts can vary considerably between different locations and years. This variability is increases the risk of low or negative benefits of renovation and is likely to adversely affect its adoption.

Trials (Appendix I: Tables 4-7) have shown increases in subsequent cereal yields between -26 and 257% above that of cereals following a pulse crop. However, the average increase in yield is around 30%. Yield increases have commonly been measured in the first and second crops after manuring, similar to the increase in cereal yields following lupins[17].

3.2. Grain protein

Increases in grain protein, like yield, vary markedly. The trials summarised in Appendix I (Table 7-10) have shown increases in grain protein content between 0-2.7% with average increases of around 1%. There is no evidence that green manuring leads to increase grain protein beyond the first year after renovation.

Protein benefits seem more uncertain than yield boost, and are likely to be below 1%-point, demanding higher carry-overs of dry matter. Protein boosts also seem less likely on sandy soils where there is more leaching[18].

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13 Wal Anderson (pers. comm.). Amato (1998) finds that ryegrass is reduced with 90-95% .

14 Often herbicide resistance arises after only 3-4 applications for some herbicides; Gill (1996) referring Gill (1995) and Martin et al (1993). Gill (1993) finds that 7-8 years of application of several herbicides result in high level risk to herbicide resistance. In continuous cropping systems in Southern Australia 4000-5000 farmers had herbicide resistant populations in 1991, and in 1994 40% of all fields had herbicide resistant ryegrass, L. Rigum. Initial resistance or background resistance is often as high as 2%. Gill (1993) finds that resistance can develop extremely fast with the entire weed population being resistant within one or two years of appearance.

15 Dave Bowran, Agriculture Western Australia; Wal Anderson (pers. comm.); (pers. comm.), Gill (1995).

16 Wal Anderson (pers. com.)

17 Darryll Abbot (pers. com.).

18 Fran Hoyle (pers. comm.)

3.3. Cost savings

When undertaken strategically the costs of establishing the renovation crop will be less than that for a crop sown for grain production. Herbicide and fertiliser rates can be reduced, as weed control and crop biomass is not critical. However, trials have not been conducted to determine the optimal input levels.

When a cash crop is used to renovate the soil as a tactical response, there are no cost savings. This is because tactical management implies changes are made in response to seasonal conditions. Therefore the manured crop would be intended for grain production and input levels would reflect this intention. Table 1 gives an overview of representative cost savings.

Table 1 – Cost savings of a green manure treatment

Year	Item	Cost savings of variable cost
1	Spray	Halved spray cost [19]
	Fertiliser	80% reduction of N or 10 kg/ha [20]
	Other	Some/marginal
2	Spray	Halved spray cost [21]
	Fertiliser	Some/nil depends on whether boost effect is due to nitrogen or soil structure improvement or weed/disease
	Other	Nil
3	Spray	Nil
	Fertiliser	Nil
	Other	Nil

4. Cost of green manuring

The main cost associated with green manuring is the loss of income from the forgone crop. The loss is likely to be high when green manuring is replacing a cash crop in a good season or when the price of the crop is high. However, if renovation is adopted as a response to a problem that has already reduced the profitability of the paddock the loss in income will be much less.

5. Method of analysis

5.1. Method

Firstly an investment analysis was undertaken. For a range of costs, grain prices and grain protein boosts the break-even yield increase after renovation was determined. (I.e. the increase in yield of subsequent cereal crops to cover the costs of renovation.) It was assumed that the yield boost would occur in the following 2 years with two thirds of the boost in the first year (so that a 30% boost is split into a 20% in the first year and 10% in the second). .

19 David Bowran, Agriculture Western Australia.

20 Wal Anderson (pers. comm.).

21 David Bowran, Agriculture Western Australia.

To investigate the consequence of yield variability a spreadsheet model was developed. TACT[22] was used to generate yield probability distributions [23] for high, medium and low rainfall areas and two soil types. Yields where assumed to be normally distributed, and yield boosts were assumed to be a fixed percentage of yields.

The yield distributions were linked to budget spreadsheets for 8 crops using the computer program @Risk - a simulation program for risk analysis. For each combination of crops, rainfall region and soil type 500 simulations were run varying yield. This provided a probability distribution of net income. From this the likelihood of achieving particular levels of income could be determined. .

6. Results

6.1. Break-even yield boost

The results of the investment analysis are shown in Table 2. The increase in cereal yields required to break-even after a renovation phase is given for 8 scenarios. Break-even yield boost ranged from 6% in total to 100% for the scenarios examined[24].

The factors that most influenced the break-even yield increase were pulse yield and cereal yield. This can be seen by comparing Scenarios 2 with 3 and 7 with 8. The break-even yield increase in Scenario 2 is over 80% while in Scenario 3 it is around 50%. The main factor affecting this difference is the pulse yield. The break-even yield increase in Scenario 7 is around 20% and nearly 40% in Scenario 8. Cereal yield is the major factor affecting this difference.

A comparison of the different scenarios also shows pulse price has a significant impact on the break-even yield. When the pulse price is low the yield increase required to break-even is also low. The influence of pulse yield and pulse price implies that the opportunity cost of sacrificing grain yield in the year of renovation is the major factor affecting profitability. That is, if a high value crop is sacrificed to undertake renovation then the loss in income in that year is high. This has to be recouped by higher yields in subsequent crops. The break-even yield increase is proportional to the loss in income in the year of renovation. This may have implications for management of and potential research.

It is important to note that the scenarios with the lowest break-even yield increase are the most profitable. This is because where yield increase required to break-even is lowest then the costs of

[22] A model that uses historical rainfall data to generate a sequence of likely yields for different rainfall areas and soil types.

[23] Average yields, legume and green manure boosts.

[24] The 100% scenario is not illustrated. It is of course the situation where everything is equal between years except for the lost crop in year 1. The necessary yield boost would be higher if the values were discounted.

renovation are more likely to be covered. Any income over and above that required to break-even is profit.

. While the selection of scenarios for analysis were somewhat arbitrary the results indicate that the only in the most favourable circumstances is the break-even yield increase below 30%, which is the average of a number of trials undertaken in WA.

Therefore if renovation cropping is to be profitable it appears that in addition to yield increases, benefits need to be achieved through cost savings and protein increases, even though these only have small effects on profitability on their own.

Table 2 – Break-even yield boost

Scenario	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cost savings year 1($/ha)	**20**	0	0	**0**	0	**20**	**10**	**10**
Cost savings year 2 ($/ha)	**20**	0	0	**0**	0	**20**	0	0
Pulse price year 1($/t)	160	**130**	160	**140**	160	**100**	**140**	**140**
Cereal price year 2 ($/t)	160	160	160	160	160	160	160	160
Cereal price year 3 ($/t)	160	160	160	160	160	160	160	160
Pulse yield year 1(t/ha)*	2	2	**1**	**1**	2	**1**	**1**	**1**
Cereal yield year 2 (t/ha)*	2	2	2	2	2	**3**	**3**	**2**
Cereal yield Year 3 (t/ha)*	2	2	2	2	2	**3**	**3**	**2**
Protein premium ($/%)	-	-	-	0	**5**	**5**	**5**	**5**
Protein boost (%-point)	0	0	0	0	**2**	**2**	**2**	**1**
TOTAL break-even yield boost**	**92%**	**81%**	**50%**	**44%**	**90%**	**6%**	**20%**	**37%**

*) Yields are yields that would have been achieved without green manuring. Green manuring takes place in year 1. Break-even yields are calculated relative to yields in year 2 and 3.
**) The total yield boost is assumed to materialise in the two following wheat crops with two thirds of the boost in the first year

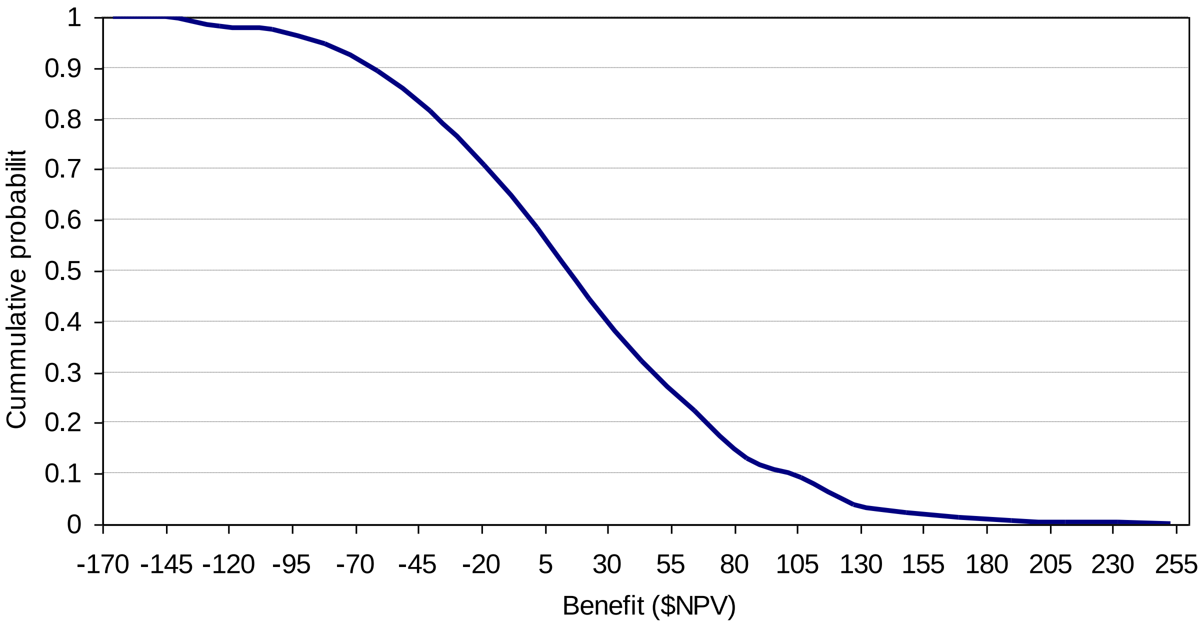
6.2. Impact of yield variability

Table 4 shows the net benefits of renovation in a lupin-wheat-wheat rotation on sandy soils in different rainfall zones assuming an average yield increase after green manuring of 30%. Given the assumptions used in the analysis the results indicate that renovation cropping would reduce profit inn 60% of seasons, and increase profit in only 40%. There is also a large variation in the net income from renovation cropping.

Table 4 – Green manure simulation for a Lupin-Wheat-Wheat

Rain-	**Soil**	**Min. gross**	**Max gross**	**Mean gross**	**Stand.**	**Prob. less**	**25%**	**75%**

Fig. 1 - Cumulative net benefit of green manuring, Year 3



fall		margin	margin	margin	dev.	than zero	percentile	percentile
H	Sandy	-$163	$139	-$13	$51	60%	-$48	$23
M	Sandy	-$147	$127	-$12	$46	60%	-$42	$20
L	Sandy	-$91	$97	-$5	$32	57%	-$26	$18

The results are similar for heavier soils. Under the most optimistic assumptions the likelihood of breaking even is about 60%. Figure 1 illustrates the cumulative probability distribution of the benefits of renovation. It shows that there is a 30% chance of achieving a benefit of around $50. However, there is also a 30% chance of losing $20/ha or more.

Generally the results of the analysis show that where cereal yields are increased by a total of 30%, the likelihood of a net benefit is between around 30-40% for all rainfall areas and soil types. That is, on average renovation is unlikely to be profitable.
The probability of a profitable outcome is halved where yield is increased on average by only 20%

6.2.1. Strategic use of green manuring

It is reasonable to conclude from the results that the strategic use of green manuring is unlikely to be profitable in the long term. Increases in yield of the following cereal crop need to be much higher than the average increases measured in trials. .

Strategic use of green manuring may be profitable where low yields could be anticipated either in the year of renovation or in the following crops. For example, monitoring of herbicide resistant weeds may lead to an expectation of reduced crop yields. Provided renovation provides good weed control it may be profitable. However this was not explicitly examined and further work is required in this area

Also, where the value of subsequent crops is high there is a higher likelihood of that a year of renovation will be profitable. For example, if durum wheat or canola is grown following a renovation phase increases in yield or quality will be worth relatively more than other cereals. Therefore the break-even yield increase will be less.

6.2.2. Tactical use of green manuring

The analysis did not look specifically at the issue of using green manuring tactically. However, with appropriate information on seasonal conditions and crop development renovating tactically is more likely to increase farm profit than it is applied strategically. Poor seasonal conditions, such as low rainfall or frost, or a large weed infestation in a crop will reduce potential income in that season. Where costs are unlikely to be recouped from harvesting, using the crop to renovate the soil may be the best option. That is renovation is undertaken when the forgone income is low, thereby reducing the subsequent yield increase required to break-even. However, profits will depend very much on seasonal conditions in the following season. Ideally, long range weather forecasts could provide information to predict subsequent crop yield. This would further improve the likelihood of increased profit by renovating. Such forecasts are apparently too unreliable for this to be practical, although some work is being done in this area.

Using renovation cropping to control resistant weeds may also been seen as tactical, as in the example above where a weed infestation reduces the yield potential of a crop. The case for using this approach is strengthened by considering the costs of other methods of controlling the resistant weeds. If a crop is not turned in or cut when weed number are very high the costs of alternative methods of control will be incurred and these are likely to be substantial.

7. Conclusions

The role of green manuring in Western Australia is unclear at this point given that relatively few trials have been conducted. However, it is more likely be profitable if used tactically, depending on the seasonal conditions and the presence of problems such as herbicide resistance.

Strategic use of green manuring to ameliorate poor soil conditions is unlikely to be profitable in the majority of seasons. This is because the expected increase in yield is generally insufficient to cover the costs of manuring and the forgone income. An exception to this may be where subsequent crops are high value.

To further clarify the role of green manuring in the wheatbelt the following data and information is required:

- The effects of green manuring on yield and protein for different crops under different conditions.
- Determining whether the profitability of green manuring can be increased using long term weather forecasts. Improving the estimates of the probability of achieving different yields may allow farmers to green manure in years that have lower risk. This study suggests that this is an important factor for use of green manuring.
- The profitability of green manuring relative to other methods of improving sustainability of cropping.

Appendix I

Yield and yield boost of green manure

Table 4 – Wheat yields (t/ha)

	Treat-ment	Hal-bury	Blyth	Cun-liffe 'grazed	Cunliffe ungrazed	Ka-punda	1) Ave-rage	2) Mid-North SA	3) Mul-lewa
Vetch	**Harv.**	1.9	3.1	2.3	1.8	3.2	2.5	2.1	2.6
	Plow.	2.8	3.8	2.7	1.9	4.0	3.2	2.7	
	Spray.	2.1	1.7	2.6	1.6	4.3	3.1	2.4	2.7
Medic	**Mown**	2.1	3.1	2.0	1.1	3.0	2.4	2.1	
	Plow.	3.1	3.6	2.5	1.9	3.7	3.1	2.8	
	Spray.	2.5	1.3	1.3	1.5	3.9	2.8	2.2	
Vetch/ Canola									2.4
Vetch/ Chick pea									2.6

Source: Kunesch CM,et al (1998) Amato (1998) and Mayfield (1995)
Notes: Kapunda resown with clover in 1994. 'In Amato (1998) and Mayfield (1995) Janz wheat is used. Vetch mown at Blyth during 'harvesting treatment; Mown medic was removed at Harbury and Blyth; Cunliffe was grazed 'before spraying; Vetch was mown at Blyth due to weed infestation. For Western Australia, Wal Anderson suggests that wheat yield increases are between 0.2 to 1.2t/ha – depending 'on how deteriorated the soil was prior to the green manure treatment

Table 5 - Wheat boost (percentage)

	Treat-ment	Hal-bury	Blyth	Cunliffe grazed	Cunliffe ungrazed	Ka-punda	1) Ave-rage	2) Mid-North SA	3) Mul-lewa	Total average
Vetch	**Plou.**	**46%**	**20%**	18%	3%	27%	29%	31%		30%
	Spray.	12%	-45%	15%	-13%	**35%**	24%	16%	5%	15%
Medic	**Plou.**	**46%**	15%	**26%**	**70%**	25%	31%	**36%**		34%
	Spray.	16%	-57%	-35%	33%	32%	17%	6%		12%
Vetch/ Canola									-9%	-9%
Vetch/ Chick pea									1%	1%
										14%

Source: Kunesch CM,et al (1998) Amato (1998) and Mayfield (1995)
Note: Boost are relative to harvest/ mown crops and un-weighted. Kapunda resown with clover in 1994.

Table 6 - Wheat yield and boost

Lamroo (SA), 1993	Yield (t/ha)	Boost (%)	Moora (WA), 1996	Yield (t/ha)	Boost (%)	Salmon Gums, 1997	Yield (t/ha)	Boost (%)	Total average	Avg. excl. values less than zero and
Cereal	0.7	N/A	**Volunteer pasture – N**	2.99	NA.	**Harv. peas**	2.21	N.A.		
Grassy pasture	1.1	57%	**Volunteer pasture + N**	2.79	NA.	**GM peas**	2.75	24%		30%
Medic pasture	1.3	86%	**Green manure – N**	4.27	43%					
Harvested vetch	1.7	143%	**Green manure + N**	3.94	41%					
Green manure	2.5	**257%**								Ploughed
Boost average		136%			42%			24%	93%	30%

Note: Lameroo: Low fertility soil with 0.6% organic carbon; +N indicates that 30kg/ha was added.

Sources: Mayfield (1995); Darryl Abbott (pers. com.); Seymour (1997)

Table 7 - Barley yield and boosts

	Treat-ment	Halbury	Boost	Blyth	Boost	Cunliffe 'grazed	Boost	Cunliffe 'un-grazed	Boost	Boost aver
Vetch	**Harv.**	3.48	na.	3.02	na.	3.11	na.	3.26	na.	
	Plow.	3.59	3%	2.41	-20%	3.03	-3%	3.14	-4%	-6%
	Spray.	3.74	7%	2.24	-26%	3.14	1%	3.26	0%	-4%
Medic	**Mown**	3.34	na.	3.11	na.	2.97	na.	3.08	na.	
	Plow.	3.15	-6%	3.08	**-1%**	3.1	**4%**	3.03	-2%	-1%
	Spray.	3.66	**10%**	2.8	-10%	3.05	3%	3.16	**3%**	1%
										-2%

Notes: Blyth was sown with Schooner while Halbury and Cunliffe were sown with Galleon

Source: Amato (1998)

Protein

Table 8 - Grain protein percentage

	Treat-ment	Hal-bury	Blyth	Cun-liffe 'grazed	Cunliffe ungrazed	Ka-punda	1) Ave-rage	2) Mid-North SA	3) Mul-lewa
Vetch	**Harv.**	10.9	13.0	10.8	11.0	10.7	10.8	10.9	9.4
	Plow.	12.7	13.1	11.5	11.1	12.4	12.2	12.1	
	Spray.	12.0	15.1	11.5	11.3	12.2	11.9	11.8	12.3
Medic	**Mown**	10.9	12.2	12.4	11.4	11.7	11.6	11.7	
	Plow.	11.2	12.2	12.7	11.2	12.0	11.9	12.0	
	Spray.	12.1	14.6	11.8	11.2	11.9	11.9	12.0	

Source: Amato (1998) and Mayfield (1995)
Notes: Kapunda resown with clover in 1994. Vetch mown at Blyth during harvesting treatment; Mown medic was removed at Harbury and Blyth; Cunliffe was grazed before spraying; Vetch was mown at Blyth due to weed infestation.

Table 9 - Grain protein percentage-point increase

	Treat-ment	Hal-bury	Blyth	Cun-liffe 'grazed	Cunliffe ungrazed	Ka-punda	1) Ave-rage	2) Mid-North SA	3) Mul-lewa
Vetch	**Plow.**	**1.8**	0.1	**0.7**	0.1	**1.7**	1.4	**1.2**	
	Spray.	1.1	2.1	**0.7**	**0.3**	1.5	1.1	0.9	**2.9**
Medic	**Plow.**	0.3	0.0	0.3	-0.2	0.3	0.3	0.3	
	Spray.	1.2	**2.4**	-0.6	-0.2	0.2	0.3	0.3	
							0.8	0.7	2.9

Source: Amato (1998) and Mayfield (1995)
Notes: Kapunda resown with clover in 1994. Vetch mown at Blyth during harvesting treatment; Mown medic was removed at Harbury and Blyth; Cunliffe was grazed before spraying. Vetch was mown at Blyth due to weed infestation.

Table 10 - Protein boost

Lamroo (SA), 1993	Protein (%)	Boost (%-point)	Moora (WA), 1996	Protein(%)	Boost (%-point)
Cereal	8.7	NA	**Volunteer pasture – N**	8.6	NA.
Grassy pasture	8.6	-0.10	**Volunteer pasture + N**	10.7	NA.
Medic pasture	8.8	0.10	**Green manure – N**	11.3	**2.70**
Harvested vetch	9.4	0.70	**Green manure + N**	12.1	1.40
Green manure vetch	9.8	**1.10**			
Boost average		0.45			2.05

Note: Lameroo: Low fertility soil with 0.6% organic carbon; +N indicates that 30kg/ha was added.
Sources: Mayfield (1995); Darryl Abbott (pers. com.); Seymour (1997)

Net return

Table 11 - Net return

SA		Gross margin ($/ha)	Moora	Gross margin year 1 ($/ha)
Vetch	Harvested	410	Volunteer Pasture – N	322
	Ploughed	343*	Volunteer Pastrue + N	300
	Sprayed		Green Manure – N	606
Medic	Harvested		Green Manure + N	468
	Ploughed			
	Sprayed			

Source: Mayfield (1995), Darryl Abbott (pers. com.). *) If durum wheat had been used the net return would be 381$/ha
Note: Neither include any cost savings. Mid North South Australia (sand clay loam soil); Green manure in 1993/ Janz Wheat in 1994.

Table 12 - Gross income ($/ha), Mullewa trial

1996 Crop	1997 Crop	Gross income
Chickpea	Wheat	541
Chickpea	Canola	317
Canola	Chickpea	391
Canola	Wheat	365
Vetch	Wheat	420
Wheat	Vetch	
Wheat	Wheat	477

Source: Zaicou-Kunesch CM, et al (1998)

8. Literature

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