A decision aid to assess the economic implications of ley pastures in crop rotations

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Abstract. The benefits of incorporating ley pastures into cropping rotations is becoming more relevant as soil fertility decline becomes apparent in regions where continuous cropping has been practised over the long-term. However, there has been only a limited amount of economic analysis that demonstrates the economic implications of management changes to include ley pastures. The authors have developed a whole farm economic decision aid that enables comparisons of several different cropping rotations including ley pastures to provide decision makers with information for management of their farming system. The target audience for this is farmers and their advisors.

The decision support model is a whole farm economic analysis that incorporates farm capital value, plant and machinery inventory, fixed costs, depreciation and gross margin analysis for each of the cropping rotation scenarios selected; it compares the selected crop rotation scenarios on a site specific basis, dependant upon individual farm management, marketing strategy and seasonal conditions; it incorporates risk assessment methodology so that farmers gain an appreciation of the range of possible outcomes; and provides growers with a quantitative assessment of possible changes to their farming system.

Introduction

The introduction of ley pastures into cropping rotations of grain-growing enterprises has been used for many years as a means to improve soil fertility and condition for the long term sustainable use of cropping resources (Lloyd *et al.* 1991; Hossain *et al.* 1995). Over the years there has been a significant amount of research directed towards ley pastures in the form of legume variety selection, planting information, nitrogen (N) fixation amounts, and yet there is relatively little information to determine the economic and financial implications of these changes to the farm business. Many growers acknowledge the benefits that ley pastures can provide within their farming system such as improving soil total N, improving soil organic matter, improving soil structure and infiltration, reducing weed populations and reducing some crop diseases (Lloyd *et al.* 1993; Weston *et al.* 2000; Whitbread *et al.* 2000*a*, *b*). However, they are not confident to include ley pastures into their farming system as they are concerned about the financial and management implications (Weston *et al.* 2000). Research dating back to the 1950s has proven that economic factors are the major determinants of adoption and technological change (Marra *et al.* 2003), so it is crucial that consideration be given to the economic analysis of ley pasture systems.

The benefits derived from ley pastures are site specific and dependent upon individual grower's management, marketing and the seasonal conditions encountered. Assessment of these benefits requires an economic methodology that can be tailored to an individual farm and efficiently capture the full range of possible outcomes that a farmer may encounter. Some past work (Moore and Grace 1998) has observed that "extremely high benefit: cost ratios" (21-25: 1) can be obtained in South Australian wheat-pasture (legume dominant) ley systems, but this economic assessment was based on a paddock (gross margin) level only and did not take into account the extra benefits to livestock from increasing pasture legume content.

The economic decision aid developed and discussed in this paper will assist farmers in the decision making process by enabling them to evaluate alternative cropping rotations that include ley pastures in comparison with current crop-based rotations. The decision aid determines the profitability of the selected cropping rotations on a whole farm basis and estimates the risk profile for an individual farmer. The criteria used to measure the selected options are taxable income and return on capital. Comparisons are made over the period of the selected rotations.

The model

The model has been written within a Microsoft™ Excel® spreadsheet that consists of multiple worksheets. A cover page and navigation menu is included to help the user navigate around the model. The components include rotation selection, summary sheet ("Farm analysis"), fixed costs, plant and equipment, depreciation, crop and livestock prices, yield and price scenario tables and gross margins for cropping and livestock alternatives (see Fig. 1).

The analysis compares a baseline continuous cropping rotation (this can be a rotation cycle of up to 10 years) with up to 3 scenarios of selected ley pasture and crop rotations on a whole farm basis. There is also a section that allows for the income from permanent native pasture to be included to complete the whole farm picture. The criteria used to assess the options are taxable income and return on investment.

For each of the 10 years in the baseline or alternative scenarios, summer and winter-season options may be selected. Rotation options include long and short fallow wheat (in rotation with other crops), wheat as a continuous crop, chickpea, mungbean, long and short fallow sorghum, winter and summer fallow, wheat undersown with lucerne, wheat after lucerne (year-1, year-2 and year-3), wheat undersown with grass and medic pasture, merino ewes on grass-medic pasture, lambs or steers on oats, lambs or steers on forage sorghum, merino or cross bred lambs on lucerne and lucerne hay (1 or 2 hay cuts instead of grazing). The reason for this variety of options is that the region this model applies to is the northern cereal zone (northern NSW and southern and central Queensland). In this environment, rotations are variable, as noted by Tow (1992) "rotation sequences are flexible and opportunistic in response to rainfall and market variability".

When rotations are selected in the model, the initial settings give a static comparison, using average gross margins. The user inputs information on stocking rates, wool cuts and crop yields. There is also a facility to look at 'snapshot' scenarios of different weather and output price combinations for the case study. The weather scenarios have been defined as 'poor', 'most likely' and 'good' seasons and their parameters are defined by the grower or operator, since they will vary from location to location. Default figures have been used for crop yields and livestock production, but these can be changed to suit individual growers. There is also a range of prices for each crop ($/tonne), wool ($/kg), livestock ($/kg) and hay ($/tonne). These include 'minimum', 'poor', 'most likely', 'good' and 'maximum' prices for each category. These are also in a simple table format so they can be altered from season to season.

A user of the model selects from different weather and price scenarios to compare the different rotations selected under such scenarios. For example, a 'good' weather season with 'poor' prices could be compared with a 'poor' season with 'good' prices. This is an initial way of comparing the robustness of the cropping/ley pasture scenarios being compared before going into more in-depth risk analysis.

Risk analysis

The model uses risk analysis methodology to capture and describe the possible, but unpredictable variation that exists in yields and prices due to seasonal conditions and market fluctuations. This is achieved by incorporating the expected range of possible outcomes for each of the variables used in the analysis and applying probabilities of likely occurrence in the form of a cumulative distribution. The probabilities are elicited from the grower according to their perception of the possible variation in each of the variables used. For each of the variables in the gross margin budgets a cumulative distribution is used (Table 1).

Table 1. An example of input data for crop yield

Yield category	Tonnes/ha	Cumulative probability (%)
Minimum	0	0
Poor	1.0	20
Most likely	2.5	60
Good	3.0	80
Maximum	3.5	100
Expected yield	2.0	

In the above example, the cumulative distribution of this crop yield is described as follows:

- the minimum possible yield is 0 t/ha (note: the model identifies and takes into account non-economic yields – i.e. yields that have a value less than the cost of harvesting),

- a poor yield is 1 t/ha and the probability of getting ≤1 t/ha is 20%,
- a most likely yield is 2.5 t/ha and the probability of getting ≤2.5 t/ha is 60%, thus the probability of getting >1 t/ha and <2.5 t/ha is 40%,
- a good yield is 3 t/ha and the probability of getting ≤3 t/ha is 80%, thus the probability of getting >2.5 t/ha and <3 t/ha is 20%,
- a maximum yield is 3.5 t/ha, thus the probability of getting >3 t/ha and <3.5 t/ha is 20%, and
- the expected value is the mean value of the distribution.

The yield amounts and the probabilities used to define the distributions can be varied, according to the perceptions of the model user. Figure 1 provides the distribution of the example yield in Table 1.

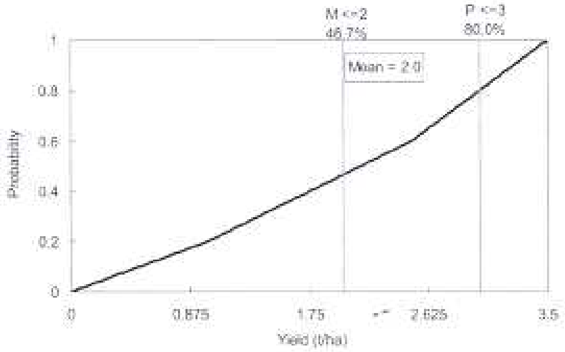

Figure 1. Distribution of the yield variable as described in Table 1

In Figure 1, the point M demonstrates that the probability of the yield being ≤2 t/ha is 46.7% and the point P shows that the probability of the yield being ≤3 t/ha is 80%.

By running the simulation, the model uses random sampling techniques to define the distribution for each of the variables throughout the spreadsheet where a cumulative distribution has been used, as illustrated in Figure 1. The distributions of variables can also be correlated either positively or negatively depending on the relationship among the variables. For example, if the price of wheat is high, it is expected that a positively correlated product would also have a high price at the same time. If one variable is high, while another is low then a negative correlation exists. These distributions are then used to define the distribution of the criteria being assessed and used to compare the selected cropping rotations.

As previously mentioned, the assessment criteria used in the model are taxable income and return on investment.

Figure 2 illustrates an example of 2 distributions of taxable income for 2 selected cropping rotations.

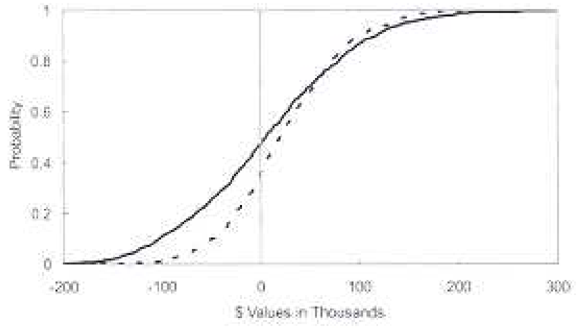

Figure 2. Distribution of taxable income for 2 cropping rotations 1 (solid line) and 2 (dashed line).

The model does 2 analyses simultaneously. Firstly, it calculates the mean value for each of the assessment criteria such as the mean taxable income value that is based on the expected values (or mean values) of each of the variables used throughout the model. For this example, (Fig. 3) the mean values or expected taxable income for the first option is $18,500 (solid line) and for the second option (dashed line) is $41,400. Both options demonstrate positive mean expected values.

Secondly, the model provides a distribution of each of the selected cropping rotations (Figure 2). These distributions are derived by randomly sampling each of the variables according to their cumulative distribution by running a simulation that re-calculates the spreadsheet a designated number of times (for example 2000). Each recalculation represents a different possible outcome for each of the selected cropping rotations and taxable income result. All of the outcomes are sorted from smallest to largest and graphed to indicate the final taxable income distribution for each cropping rotation.

The risk analysis methodology uses values from the cumulative distributions for each of the variables to evaluate the overall riskiness of the investment. Note that the distributions for this example show that the taxable income for both cropping rotations has the possibility of being negative. The full distribution of the criteria (taxable income) being assessed with the accompanying probabilities provides more information for the decision maker than simply calculating an average or expected taxable income. For the first option (solid line) the possibility of achieving a negative taxable income is estimated to be 47%, whereas for the second option (dashed line) it is approximately 33%. The analysis of this example would suggest that the second cropping rotation option has less risk. Note from the example that the lines cross over. This indicates that in years where the variables selected have high values (i.e. high prices and yields), Crop Rotation 1 has the potential to achieve higher income even though its overall risk profile is higher. It also has the potential to make substantially greater losses in years when both prices and yields are low.

The example described above demonstrates the analysis methodology; it is not a representative outcome of the viability of cropping alternatives. It is merely an example to demonstrate the use of risk analysis in crop rotation analysis. The model is designed to be used on an individual property basis, and as such will have completely differing outcomes of each farm's investment analysis and risk profile.

The data generated by the simulation allows the estimation of a range of statistical data such as the mean or expected outcomes, standard deviation, maximum and minimum values as well as an estimate of the probability of obtaining a negative outcome. These assessments provide information of a risk profile for each of the options selected. These are key considerations when considering the viability of cropping rotation alternatives when trying to achieve sustainable farm management practices.

Conclusions

The methodology used in this model gives a better indication of the overall profitability of alternative crop rotations on a whole farm basis. It provides an understanding of the full range of possible outcomes as well as a quantitative assessment of the climatic and price risks involved. It also offers a succinct summary of viability in its estimate of mean, maximum and minimum assessment criteria values as well as an estimate of the probability of achieving critical outcomes. This is vital information for decision makers seeking the best information they can obtain to help make difficult management and investment decisions, especially in a business sector that is characterised by seasonal and market variation.

Acknowledgments

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References

Lloyd DL, Smith KP, Clarkso NM, Weston EJ, Johnson B(1991) Sustaining multiple production systems 3. Ley pastures in the subtropics. *Tropical Grasslands* **25**, 181-188.

Lloyd DL, Ryley MJ, Simpson GB, Johnson B (1993) 'Crop-Pasture Rotation'. In 'Cropping Strategies for the Next Decade, Queensland Crop Production Conference Proceedings 1992'. QDPI Conference and Workshop Series QC93009, Agdex 984 (Queensland Government: Brisbane)

Hossain SA, Strong WM, Warin SA, Dalal RC, Weston EJ (1995) Comparison of legume based cropping systems at Warra, Queensland. II. Mineral nitrogen accumulation and availability to the subsequent crop. *Australian Journal of Soil Research* **34**, 289-297.

Marra M, Pannell DJ, Ghadim, AA (2003) The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve? *Agricultural Systems* **75**, 215-234.

Moore AD, Grace PR (1998) Effects of annual pasture composition on subsequent wheat yields in the Waite Permanent Rotation Trial, South Australia. *Australian Journal of Experimental Agriculture* **38**, 55-59.

Tow PG (1992) An evaluation of cereal zone rotations for achieving short-term and long-term sustainability. In 'Proceedings of the 6th Annual Australian Society of Agronomy Conference'. pp. 228-231.

Weston EJ, Doughton JA, Dalal RC, Strong WM, Thomas GA, Lehane KJ, Cooper JC, King AJ, Holmes CJ (2000) Managing long-term fertility of cropping lands with ley pastures in southern Queensland. Pastures for production and protection – Proceedings of the Sixth Tropical Pastures Conference, Emerald, Queensland'. *Tropical Grasslands*, **34**, 169-176.

Whitbread AM, Blair GJ, Lefroy,R.RDB (2000*a*) Managing legume leys, residues and fertilisers to enhance the sustainability of wheat cropping systems in Australia 1. The effect on wheat yields and nutrient balances. *Soil and Tillage Research* **54**, 63-75.

Whitbread AM, Blair GJ, Lefroy RDB (2000*b*) Managing legume leys, residues and fertilisers to enhance the sustainability of wheat cropping systems in Australia, 2. Soil physical fertility and carbon. *Soil and Tillage Research* **54**, 77-89.