ECONOMICS OF CHANGING ROTATIONS TO COMBAT HERBICIDE RESISTANCE

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Summary. The economics of altering rotations to delay the development of resistance to herbicides was investigated using a whole-farm, bioeconomic model called MIDAS. The model represents the dryland farming system in the eastern wheatbelt of Western Australia. The profitability of various cereal-pasture-lupin rotations was compared to those currently optimal in the farming system. The effect of wool and wheat prices and length of pasture phase on the profitability of the rotations was examined. Using prices expected in the medium term, altering rotations by the inclusion of pasture into cereal-lupin rotations had a significant adverse effect on farm profit. The extent of profit decline was sensitive to soil type and product prices.

INTRODUCTION

Use of Integrated Weed Management (IWM) has been widely promoted as the key to managing herbicide resistant weeds. A key element of IWM is the inclusion of pasture phases in the rotation, since this allows the use of a wider range of non-selective weed control measures, especially knockdown herbicides and grazing. However the decision to change rotation is very complex and is influenced by many factors other than herbicide resistance. These include prices, production costs, soil type, availability of adapted legume species, yields, crop disease, nitrogen fixation, machinery size, farm debt, and attitudes to risk

Because it is such a complex issue, it is not clear that it is in the best interests of farmers to change rotation before resistant weeds build up to high densities. In this paper we examine the short- to medium-term economic effects of changing rotations to delay build-up of resistance. We use a whole-farm, bioeconomic model (called MIDAS) which incorporates the main factors influencing rotation choice other than herbicide resistance. The model is used to investigate (a) the change in short-run profit resulting from the inclusion of pasture into continuous cropping rotations, (b) profitability of different lengths of the pasture phase and (c) the sensitivity of results to pasture yields and grain and wool prices.

METHODS

Model description. MIDAS is a mathematical programming model which represents a typical farm in the eastern wheatbelt of Western Australia, about 270 km east of Perth. Average rainfall is 310 mm per annum and the main products are wheat and wool. A proportion of cropping is done continuously, usually in a wheat-lupin rotation, with one or two years of wheat after the lupin crop.

The model calculates the combination of farm enterprises, rotations, sheep flock size and structure, machinery usage and sheep feeding strategies which maximises farm profit in the medium term. The model output gives details not only about the most profitable set of activities but also the profitability of activities not selected. A detailed description of the model can be found in Kingwell and Pannell (1) and Morrison and Young (2). Model data and assumptions are presented by Pannell and Bathgate (3). Only a brief overview of the model is given here.

Seven soil types are described in the model, and they are classified according to their production characteristics. Up to 20 rotations per soil type are represented in detail with allowance made for the effects of current crops and pastures on subsequent production. This is due to factors such as disease break effects, stubble for grazing, nitrogen fixation and the reduction in pasture production after crop. The impact of these factors is quantified for each rotation option on each soil type.

Analysis of rotations. The model was modified on three soil types by the introduction of pasture into the cereal-lupin rotations. The soil classes on which these novel rotations were introduced are those lighter textured soils better suited to cereal-lupin cropping. These are soil types S2 (sandplain), S3 (gravelly sand) and S4 (duplex) (3).

The new rotations were chosen in consultation with general advisors of the Department of Agriculture. For each phase of each rotation, we obtained estimates of production parameters and factors such as nitrogen fixation, soil structure effects, etc. Most of the data for these rotations had to be estimated subjectively (in collaboration with advisors) due to lack of experience with the rotations. The model was run to compare profitability of the new rotations with traditional rotations. We also tested the impact of different combinations of wheat and wool prices on the relative profitability of rotations. Finally, different levels of pasture growth were examined on one of the soil types to determine what effect it has the profitability of the rotations.

RESULTS AND DISCUSSION

Table 1 shows how much the profitability of the new rotations would have to improve for them to be as profitable as continuous cropping with wheat and lupins. These values are termed "shadow costs" and they are based on average returns per hectare over the length of the rotation. They do not directly allow for impacts of the rotation on herbicide resistance.

Table 1. Shadow costs of wheat-pasture-lupin rotations

Soil type: Rotation*	S2 ($/ha)	S3 ($/ha)	S4 ($/ha)
CPPPLCL	11.7	7.3	14.8
CPPCL	11.2	8.9	14.8
CPL	18.9	17.1	24.1

* C = cereal crop, L = lupin crop, P = pasture.

On each of the three soil types examined, CPPPLCL performs similar economically to CPPCL. The advantage which the longer pasture phase has in allowing a more thorough run-down of the ryegrass seed bank means that it is likely to be preferred from the point of view of resistance management. Thus when resistance management is considered (in addition to the many factors already considered in calculating Table 1), CPPPLCL is likely to be the best economic performer of these three rotations. Even though it is the best of the rotations we considered, CPPPLCL requires farmers to make a substantial sacrifice of short-run income compared to CL or CCL.

Given the low profit margins in the eastern wheatbelt region the decreases in profit shown in Table 1 are substantial. It seems unlikely that farmers will be prepared to introduce pasture into continuous cropping rotations unless resistance is imminent. From a long-term economic point of view, continuing to crop may well be the best decision for them to make. This is reinforced by current evidence that the number of selective herbicide applications needed to produce a herbicide resistant ryegrass population is not reduced by inclusion of a pasture phase in the rotation. Once resistance becomes a problem one of the new rotations may be adopted. Possibly, then, the best way to view the values in Table 1 is as the decline in profit which will occur after resistance has become established in the ryegrass population and the farmer has been forced to change rotation.

It is notable that on each soil type, CPL is the least profitable of the rotations we considered. This is due to the low pasture density in this rotation and to the higher cost of herbicides required to control ryegrass in the pasture prior to the lupin crop.

Effect of changing prices. The results in Table 1 are for a particular set of assumptions. It may be that different assumptions would lead to different conclusions. To investigate this possibility, we solved the model for a wide range of wheat and wool prices. The results of this exercise varied for different rotations on different soil types. An illustrative set of results for the CPPCL rotation on soil type S2 is shown in Table 2.

Table 2. Shadow prices of CPPCL rotation on soil type S2.

Wheat price ($/T n.p.r)	Wool price(c/kg greasy)			
	250	300	350	400
130	8.6	10.6	9.8	8.2
170	12.2	11.2	9.9	9.0
210	17.3	16.6	16.7	15.3

Naturally, the higher the wool price, the more profitable it is to include pasture in the rotation. Conversely, the higher the wheat price, the greater is the profit advantage of cropping. These trends are evident in Table 2 but even at the highest wool price and lowest wheat price, the CPPCL rotation is still an average of $8.20 less profitable than CL.

For the other soil types, results not presented here show that these cereal-pasture-lupin rotations can compete economically with cereal-lupins in certain circumstances. In particular if wool price is 350c/kg greasy, and the wheat price drops to $150/tonne (soil type S3) or $130/tonne (soil type S4), there is no economic advantage of CL over CPPCL or CPPPLCL even in the short term. It is anticipated that for the foreseeable future, wheat prices will remain above these levels. If the wool price is less than 350c (as it currently is), the wheat price would have to fall even further for it to be profitable in the short term to change to CPPPLCL or CPPCL.

Effect of increasing pasture growth. Apart from higher wool prices an alternative way of improving the profitability of cereal-pasture-lupin rotations is to increase pasture production. Low pasture density after cropping is a primary contributor to the relatively low profitability of cereal-pasture-lupin rotations. There are various means by which pasture production may be improved, including plant breeding, grazing management and re-seeding. Here we are not specific about the source of extra pasture production but consider hypothetical increases of 10 percent and 20 percent above current levels. Results for soil type 3 are shown in Table 3.

Prospects for these novel rotations appear best on soil type 3. Even so a 20 percent increase in pasture production on this soil type is not sufficient to make them as profitable in the short term as CCL. However the best of them (CPPPLCL) is only $2.00 per hectare per year behind CCL. It would be expected that the advantages of this rotation for resistance management would more than compensate for this small sacrifice of short-term income.

Table 3. Shadow costs of wheat-pasture-lupin rotations on soil type S3

Increase in pasture growth:	0%	10%	20%
Rotation	($/ha)	($/ha)	($/ha)
CPPPLCL	7.3	3.2	2.0
CPPCL	8.9	5.9	4.8
CPL	17.1	16.5	16.0

CONCLUDING COMMENTS

The results presented here are, of course, specific to a particular region with its own production system and production levels. Even within this region we have shown that results of adopting a new rotation are very sensitive to factors such as wheat price and wool price. Nevertheless the study has highlighted some important lessons of broader relevance.

The introduction of a pasture phase into continuous cropping rotations to delay the onset of resistance can be very costly. As unpalatable as it appears, it may be in farmers' best interests to wait for resistance to develop before responding with a new rotation, especially given wheat and wool prices expected to prevail over the next 3 to 5 years.

The profitability of altering rotations is very dependant on soil type and product price. Introducing pasture is only likely to be a viable strategy for delaying resistance on soils where the profitability of pasture is similar to that of crop. On other soils, it may be better to wait for resistance to appear before moving to adopt the rotations examined here.

Note, however, that we have not yet identified how much short-term income it is worth sacrificing in order to delay resistance, so a cautious interpretation of our results is necessary. Also note that the results do not imply anything about the costs of other management responses, such as cultivation, burning or seed catching.

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