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Tactical responses to seasonal conditions in whole-farm planning in Western Australia

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ABSTRACT

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In dryland agricultural systems, efficient farm management requires a degree of flexibility according to variations in climate from year to year. Tactical adjustments to the mix of farm enterprises can capitalize on good growing conditions and minimise losses under poor growing conditions. In this paper, a discrete stochastic programming model of dryland wheat-sheep farms in Western Australia is used to identify optimal tactical adjustments to climate and to calculate the value of these tactical adjustments. The model, MUDAS, includes nine discrete season types with a wide range of options for tactical adjustments in each. In the standard model, optimal tactical responses increase expected net cash surplus by approximately 22% relative to a fixed or inflexible strategy. In most season types, changes to the long term farm strategy are made on less than 10% of the farm area, although in some seasons over 25% of the farm can require adjustments to the enterprise selected. The benefits of flexibility are not evenly distributed across different season types but occur predominantly in the best and worst seasons. The magnitude of benefits is affected differently by different commodity prices. Benefits of flexibility are due to capitalizing on knowledge about the greater volatility of profits from cropping than from livestock production. Deterministic models and even stochastic models which don't include activities for tactical adjustments miss this key feature of the system.

INTRODUCTION

Notwithstanding the high variance of world prices for most agricultural commodities (e.g. Hazell et al., 1990), climate is the major source of income

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risk faced by most dryland wheat/sheep farmers in Australia. These farmers place a high value on information about weather patterns, as indicated by the recent growth of commercial services providing them with long-term weather predictions. Even without such predictions, however, dryland farmers have access to information about climatic events in the recent past. This is important because climatic conditions prior to sowing affect subjective probability distributions of yields for alternative enterprises being considered for the forthcoming growing season. Of course climatic conditions prior to sowing are an imperfect indicator of final yield. Even so, flexibility in response to climatic conditions can improve farmers' returns in a given season and in the long term.

Antle (1983) observed that seasonal variation affects farmers' decision making in two ways:

(1) Risk-averse farmers adopt long-term farming strategies which reflect a preference for income stability as well as higher income. There is evidence that most farmers are risk-averse both in Australia (Bond and Wonder, 1980; Bardsley and Harris, 1987) and elsewhere (Binswanger, 1980; Antle, 1987; Myers, 1989).

(2) Both risk-averse and risk-neutral farmers make tactical adjustments to their farming strategies in response to short-term seasonal conditions. There are potentially two facets to the value of climatic information used to make these adjustments. They allow improvements in expected income for all farmers and they can reduce the cost of risk for farmers who are risk-averse. Australian cereal-livestock farmers display a high degree of flexibility according to climate. In Western Australia, the focus of this study, wide variations in management practices, input levels and enterprise selection are observed from year to year.

Although agricultural economists have invested much effort in studies of the longer term implications of seasonal variation for risk-averse farmers, much less emphasis has been placed on shorter term (i.e. within-season) tactical decisions. Mjelde et al. (1989) observed that "the role of time and the attendant possibility for the decision maker to gather information as the production horizon unfolds generally have not been depicted realistically" (p. 1). Even in models which allow for seasonal variation and risk aversion, the common practice has been to ignore the potential for tactical adjustments to the farming strategy according to short-term seasonal conditions.

This neglect of the role of tactical adjustments may have serious consequences. First it results in underestimation of the profitability of some strategies. For example, a strategy to continuously crop one soil type of the farm may be profitable in most seasons but very unprofitable in some poor seasons. If these poor seasons are at least partially predictable from climatic conditions prior to sowing, expected profits can be increased by choosing not to sow crops in these conditions. If tactical adjustments were not included in a model, the continuous crop strategy would be penalized by the absence of an option to temporarily abandon the strategy in some seasons.

The second consequence of ignoring flexibility in economic farm models is that statistical estimation of production function parameters will usually result in biased and inconsistent estimates (Antle, 1983; Antle and Hatchett, 1986). Thus short-term tactical adjustments to farm strategies are important for both descriptive and prescriptive studies of farmer behavior (Mjelde et al., 1989).

Analyses of tactical decision making by farmers have included studies of nitrogen inputs (Nordblom et al., 1985; Mjelde et al., 1989) and pesticides (Thornton and Dent, 1984; Antle, 1988; Stefanou et al., 1986). Adjustments to nitrogen decisions in these studies depended on observations of climate. The pesticide studies included a range of information types but primarily observations from scouting to estimate pest densities. Most studies found that flexibility in management practices led to increases in expected profits or expected utility. All of these studies employed partial farm models focusing on a specific crop and a single type of farm input. The model used in this study includes several types of tactical adjustment (changes in enterprise selection, management practices and input levels) but we focus mainly on what we consider to be the most important of these: changes in enterprise areas.

One of our aims in this paper is to identify optimal tactical adjustments for different seasonal conditions in the study region. Farmers in the region display great variability in the extent to which they change their farming practices from year to year. In our discussions with farmers we have encountered individuals who are unwilling to consider any degree of flexibility and others whose plans are very highly dependent on climate. We aim to identify the range within this continuum of behaviours which is optimal for farmers whose objective is to maximise expected returns.

Our second aim is to estimate the net benefits of tactical adjustments relative to an inflexible strategy. This is equivalent to the cost of rigidly maintaining a farm plan in disregard of actual climatic conditions. Such inflexibility is not commonly observed in Western Australia but, as noted above, it does occur.

In the following sections we briefly describe the farm system which is the subject of the analysis and present details of the discrete stochastic programming model used in the study. Results of individual model runs and sensitivity analyses are presented and discussed before some brief concluding comments.

FARM SYSTEM

Agriculture in Western Australia is largely confined to the south-west corner of the state, an area of approximately 250 000 km^2. The dryland farm system modeled is based on Merredin Shire in the eastern wheatbelt where almost all farms have a mix of crop and livestock enterprises. Annual rainfall in the region averages 310 mm, with most rain falling from May to October, followed by a summer drought from December to March. Crops are sown in May to July and harvested in November to December. Average farm size in the region is approximately 2500 hectares, most of which is cleared and arable. Farm operations are highly mechanized and most farms are owner operated with not more than one other permanent laborer. Casual labor is hired for only a few months of the year to assist in main tasks such as seeding, harvesting and shearing.

Crops include cereals (mainly wheat but also barley, oats and triticale) and the legume crop lupins. Livestock consist almost entirely of sheep for wool and meat production. Lambing is in late autumn or early spring and shearing is in spring and autumn. Sheep are run on annual pastures during winter and on a combination of crop residues and dry annual pastures in summer. The pastures contain volunteer annual grasses and herbs, with annual legumes introduced in some situations. Crops and pastures are commonly grown in rotation and a recent trend is toward cereal/lupin rotations on sandy soils.

Soils are highly weathered and infertile, with wheat yields in the Merredin Shire averaging 1.1 t per hectare. Enterprise selection and management according to soil type is a key part of the farming system. All farms include a mix of soil types with different production parameters and management requirements. Seven broad soil classes can be recognized in the region: acidic sands, good sand plain soils, gravelly sands, duplex soils, medium-heavy soils, heavy non-friable soils and heavy friable soils. Further details of the soils are presented by Abadi Ghadim and Pannell (1991).

DISCRETE STOCHASTIC PROGRAMMING MODEL

Cocks (1968) developed Discrete Stochastic Programming (DSP) as a means of using linear programming to analyze multistage stochastic problems in which the optimal activity in one period depends on events in past periods. Rae (1971a, 1971b) extended the model and applied it to a vegetable farm. After Rae's application, there was a period with few agricultural applications of the technique (Lambert, 1989) but recently it has been the subject of renewed interest from agricultural economists (e.g. Brown and Drynan, 1986; Lambert, 1989; Lambert and McCarl, 1989; Garoian et al., 1987).

MUDAS (Model of an Uncertain Dryland Agricultural System) is a DSP model developed by the Western Australian Department of Agriculture to describe a typical farm in the eastern wheatbelt of Western Australia. The following brief overview of the model can be supplemented by more detailed descriptions published by Kingwell et al. (1992). In addition, further technical information (Kingwell et al., 1991) is available from the senior author on request.

In this study the assumed objective is maximization of expected net returns. Other goals relating to leisure and soil conservation are represented implicitly as constraints. Net returns are calculated as gross cash receipts minus variable production costs, fixed production costs, living expenses and the opportunity costs of holding assets other than land.

Each solution from the model simultaneously specifies the optimal core strategy and optimal tactical adjustments for each type of season. The model handles dynamics as a timeless one-year loop, whereby parameters for a given year are based on the assumption that the same strategy was adopted in previous years. Inter-year effects on technical parameters are dependent on the solution selected for the current year, so that the model finds an optimal 'equilibrium' solution. Although the core strategy is the same every year, tactical adjustments can be made in each season type according to climatic conditions before sowing. These tactical adjustments also have carry-over effects on costs, yields and responses to inputs in subsequent years. Thus the model fully captures inter-year effects in calculating an optimal equilibrium solution. However it does not represent the time path of management adjustments in moving from a particular farming strategy to the new optimum. This approach greatly reduces model size and facilitates much greater detail in the biological constraints and tactical adjustments represented while still capturing the essential inter-year and intra-year dynamics of the farm system.

Within the year there are a number of nodes at which decisions must be made contingent on what has already occurred. There are 12 decision nodes for supplementary feeding of grain and for sheep live weight adjustments and two nodes for enterprise area and sheep agistment decisions. The model includes approximately 1400 activities and 1200 constraints and is solved on 80386 or 80486 microcomputers using the AESOP algorithm (a purely linear version of MINOS) and MARG (Pannell, 1990) for matrix generation and report writing.

A feature of MUDAS is its detailed representation of biological relationships and complex enterprise interdependencies, both beneficial and adverse, that exist in the dryland farming system. For example, the model includes representation of:

- seven distinct soil classes, each with unique input-output relationships and numerous rotation options;
- the depressing effect of cropping on subsequent pasture density and productivity;
- the supply of nitrogen by leguminous crops and pastures to subsequent cereal crops and the yield response to nitrogen of different crops on each soil class;
- the added weed burden in crops attributable to previous pasture;
- the various quantities and qualities of crop residues available for feeding sheep, and the dynamics of their deterioration;
- the use of lupin and cereal grains as sheep feed to supplement pastures and crop residues;
- yield penalties associated with late planting of crops;
- the depressing effect on pasture growth of increases in stocking rate.

MUDAS is derived from MIDAS (Model of an Integrated Dryland Agricultural System), a deterministic linear programming model which has been described in detail by Morrison et al. (1986) and Kingwell (1987) and applied to a wide range of problems (e.g. Kingwell and Pannell, 1987; Pannell and Panetta, 1986; Abadi Ghadim and Pannell 1991). MUDAS represents climatic uncertainty through the inclusion of nine discrete season types. Each of these seasons is represented by a submatrix of comparable detail to the deterministic MIDAS model.

The criteria for classifying seasons arose first, from discussions with farmers to identify which seasonal features influence their farm strategies and adjustment decisions and second, from detailed examinations of climatic characteristics of actual seasons from 1912 to 1988. This resulted in four criteria being identified: the timing of opening rains, the incidence of summer rain, the type of opening rains received and the level of spring rainfall.

The most important climatic factor influencing farm management decisions is the timing of opening rains. The later a crop is sown the shorter the growing season before rainfall ceases and the sooner it experiences unfavorable growing conditions such as shortening day length and low temperatures. Consequently late-sown crops have a relatively low yield potential and in seasons permitting early sowing, yield potential is high. Seasons in MUDAS are categorized as early, mid or late.

The amount of rainfall in summer and early autumn is also an important influence on crop area adjustment options. These rains provide reserves of stored soil moisture and increase expected crop yields. The incidence of summer rain is defined by an index to be high or low.

TABLE 1

Season types in MUDAS

Season	Sowing time	Summer rain	Spring rain	Earlier sowing on sandy soils	Season probability	Typical wheat yield (t/ha)
1	early	high	either	no	0.17	1.96
2	early	low	high	no	0.12	1.27
3	early	low	low	no	0.08	0.64
4	mid	high	either	yes	0.05	1.60
5	mid	low	either	yes	0.12	0.81
6	mid	high	either	no	0.13	1.28
7	mid	low	either	no	0.09	0.77
8	late	low	either	yes	0.14	0.61
9	late	low	either	no	0.10	0.57
Expected yield						1.09

t, metric tonne = 1000 kg.

Two types of opening rains are represented, characterized by the presence or absence of light rainfall before the main opening rains. These early rains are not sufficient to allow sowing on heavier soils but do allow earlier sowing of crops on sandier soils.

Spring rainfall is characterized as being high or low. This affects final yields but is not a major influence on decision making as it occurs after most management decisions have been made.

The four criteria allow for 24 ($= 3 \times 2 \times 2 \times 2$) possible types of season. However applying the criteria to rainfall statistics for Merredin from 1912 to 1988 showed that many of the possible seasons are yet to be observed and some have occurred so infrequently as to warrant their inclusion in closely related groups. Even where some seasons could be differentiated by these criteria, simulation modeling showed that there was little impact on crop yield, allowing further grouping of seasons. A final set of nine season types with associated relative frequencies was selected as representative of season variation in the region (Table 1).

Technical parameters (yields, growth rates, etc.) for each type of season are based on the simplifying assumption that the previous season was an 'average' or 'typical' season. This means that we do not account for the possibility of several consecutive good or bad seasons in our analysis.

Strategic activities and constraints

The strategic section of MUDAS describes management options to be undertaken in all seasons, unless a tactical adjustment in a particular season deems otherwise. The decision variables include the allocation of land to pasture and each crop, the rotational sequence of enterprises on each of the seven soil classes, livestock numbers, flock structure, feed sources and uses, machinery, labor and finance.

There is a set of global constraints which applies to all seasons (such as constraints which maintain a steady-state sheep flock) and a set which is repeated with different parameter values for each season type (such as pasture production parameters in each month for each type of season).

Parameters were obtained from a range of sources, including field trials, biological simulation models, scientific, economic and farming publications and subjective estimates made by appropriate experts. The data were reviewed in a lengthy process of consultation with biological researchers and advisers. Due to the very large number of parameters, we do not attempt here to present detailed documentation of the model. For that, the reader is referred to Kingwell et al. (1991). A broad overview of the model and its structure is contained in Kingwell et al. (1992).

Tactical activities and constraints

The short-term adjustment options represented in MUDAS arose out of discussion with farmers and from discussions with various advisors and researchers. The adjustment options represented are different for each season and for each soil type in accordance with the advice of our collaborators. They include changes in: enterprise selection on a soil type, grazing management, sheep live weights, sheep agistment and supplementary feeding of grain. All these options are available as tactical responses to climatic conditions. There are no options for tactical responses to short-term price fluctuations. We have simplified the system in this way because (a) in our experience of modelling this farm system with MIDAS, farm management strategies are far less responsive to price variation within a realistic range than they are to climatic variation, and (b) including tactical responses to price would add substantially to a model which is already very large.

Tactical adjustments to climatic conditions result in changes in inputs, costs and output in the year in which the adjustment occurs and some also have impacts on parameter values in subsequent years. Subsequent effects reflect the fact that one year's deviation from a rotation has an effect on subsequent soil fertility, weed densities and pasture availability. All adjustment activities are either specific to one season or, if the seasons cannot be distinguished at the time of the decision, to a set of seasons.

Farmers and advisors considered that alteration of crop area on heavy soils in response to seasonal conditions was highly likely to be beneficial but that such adjustments were rarely, if ever, required on light soils. Hence MUDAS includes crop area adjustments on all soils with a high clay content but only on one of the sandier soils. Area adjustment constraints limit the nature and area of adjustment permissible within a selected rotation. Area adjustment activities are specific to the phase of a rotation on each soil class and change herbicide and pesticide costs, tillage method, nitrogen and phosphatic fertilizer costs, use depreciation of crop gear, stubble handling costs, use of limited seeding plant capacity and penalties incurred for late sowing. All such changes are calculated exogenously in spreadsheets and are represented in the model as net effects (Kingwell et al., 1991).

A large set of livestock adjustments in MUDAS involves agistment (i.e. temporary removal of some sheep from the farm and their placement, at a cost, on pastures or dry feed elsewhere). Agistment is often practised in periods of prolonged feed scarcity. In MUDAS, sheep other than lambs, rams and breeding ewes can be agisted. Potential agistment periods are June to August and September to April. Each agistment activity is represented as a saving in feed requirement during the agistment, allowing a reduction in stocking rate. Costs of agistment vary according to demand and supply conditions considered likely in different periods of different types of season. These agistment activities allow deviations from the long term, steady-state flock selected by the model.

There are activities to allow deviations from standard live weight patterns depending on seasonal conditions. These affect feed transfer rows (due to changes in energy requirements and intake capacities), finance (due to changes in wool production per head) and sheep numbers (due to changes in lamb production per ewe). MUDAS includes activities for supplementary feeding of grain in each month of each season.

Runs for this study

This study focuses on tactical adjustments to enterprise areas rather than the other adjustment options relating to fertilizer use and sheep management. This is because of the over-riding importance of area adjustments and the difficulty of obtaining feasible solutions if some of the sheep adjustment options are not included. The improvement in net cash surplus resulting from adjustments to enterprise area is referred to below as the 'value of tactical adjustments'.

The model is run with area adjustment activities included and excluded from all soil types in all seasons. Changes in key variables between the two solutions are recorded. The probability distribution across seasons and the expected value of climatic information are calculated. The initial results are for on-farm prices of A$125 per t of wheat, A$145 per t of lupins and A$2.90 per kg of greasy wool. Subsequently we test the sensitivity of these results to key commodity prices.

When comparisons are made between solutions with adjustment activities included and excluded, all parameters and probability distributions are the same for both solutions. For example, the low yields due to poor finishing rains in season 3 also apply in the without-adjustment case. The difference between the models used to generate the two solutions is in the range of management options included, not in the biological or seasonal behaviour of the system.

RESULTS AND DISCUSSION

Table 2 shows a comparison of expected values for key farm variables in optimal model solutions with and without area adjustments. There is a lower emphasis on sheep and wool production if area adjustments are permitted. Expected crop and pasture areas are almost unchanged, sheep numbers are 20% lower if adjustments are allowed. The lower stocking allows greater flexibility to increase crop area in good seasons without the requirement for high levels of supplementary grain feeding or agistment.

The land use strategies and tactics which underlie the figures in Table 2 are shown in Table 3. (Note that there are also adjustments to fertilizer levels, timing of pasture consumption, agistment and animal live weights, but we focus here on enterprise areas). Rotational sequences of crops and pastures from the 'no adjustments' model are shown for each soil type. Optimal rotations are different for most soil types. This is consistent with earlier findings for this farm system using the deterministic MIDAS model (e.g. Abadi Ghadim and Pannell, 1991). Table 3 shows that when land area adjustments are allowed, the solution includes higher crop areas in seasons

TABLE 2

Expected values of key farm variables with and without adjustments to enterprise area

	Area adjustment activities	
	Included	Excluded
Crop area (ha)	1472	1475
Pasture area (ha)	828	825
Sheep numbers (head)	1539	1918
Grain fed (t)	13.1	19.5
Grain stored to feed later (t)	7.1	16.7
Wheat sold (t)	1311	1191
Wool sold (kg)	7513	9340

TABLE 3

Optimal strategic land use and tactical increase in wheat area (ha)

	Soil type						
	1	2	3	4	5	6	7
Optimal rotation sequence in model with no adjustments [a]							
	PPPP (460)	WWL (174) WLWL (286)	WWL (230)	WWL (230)	WWWW (345)	PPPP (334) PWWW (126)	WWWW (115)
Increase in wheat area (ha) *if adjustments included* [b]							
Season 1						219	
Season 2						219	
Season 3						219	
Season 4						219	
Season 5					−66	−81	
Season 6						172	
Season 7					−66	−81	
Season 8				77 [c]	−196	−94	
Season 9				77 [c]	−345	−94	−115

[a] W, wheat; P, pasture, L, lupins. Areas (ha) are in parentheses.
[b] Increase in wheat is in place of pasture unless indicated. Negative values indicate pasture replaces wheat.
[c] Wheat grown in place of lupins.

with apparently favorable climatic conditions at seeding time (seasons 1, 2, 3, 4 and 6) and lower areas in seasons with poor conditions at seeding time (seasons 5, 7, 8 and 9). In other words, the strategy which is optimal if area adjustments are not allowed is not optimal in any individual season.

Most of the area adjustments occur on medium-heavy and heavy non-friable soils (soils 5 and 6). In seasons with favorable early conditions, the only adjustments are higher crop areas on soil type 6. If the start of the season is less favorable, crop areas are reduced on soils 5 and 6 and, in extreme cases, on heavy friable soil (soil 7). In very poor seasons (8 and 9) there is also a switch of crop species on duplex soil types (soil 4) from lupins to wheat. This is due to the greater sensitivity of lupins to poor growing conditions. These changes in crop and pasture areas mean that the percentage of the farm in crop ranges from 40 to 74%. These variations occur despite constant on-farm commodity prices.

These results are consistent with common farmer behaviour in the region. Most adjustments occur on heavy soils, with replacement of lupins by wheat on some lighter soils in seasons with very poor yield prospects.

Although the inclusion of area adjustments results in differences in every season, the extent of the differences is generally not large. In seasons 1 to 7

TABLE 4

Net cash flow in each season with and without enterprise area adjustments

Season	Area adjustment activities		Difference
	Included	Excluded	
1	$236 700	$193 900	$42 800
2	$152 800	$126 300	$26 500
3	$7 500	$3 800	$3 700
4	$182 700	$153 700	$29 000
5	$42 300	$43 300	– $1 000
6	$100 200	$93 100	$7 100
7	$22 000	$21 300	$1 700
8	– $13 600	– $19 800	$6 100
9	– $35 800	– $48 000	$12 100
Expected value	$83 000	$67 800	$15 200

(76% of years) adjustments are made to less than 10% of the farm area compared to the solution with no adjustments. Only in the very worst season are there major adjustments; four soil types and 27% of the farm area are affected in season 9.

Despite the small area affected, the impact on profits can be very significant. Table 4 shows the impact of area adjustments on annual net cash surplus (gross cash receipts minus variable production costs, fixed production costs and living expenses). The difference between net cash surplus with and without adjustments represents the value of making the adjustments. The expected value of the adjustments is A$15 200 which represents a 22% increase in the expected value of net cash surplus.

In general, the benefits of this flexibility are highest in the extreme seasons: the best and the worst. The largest absolute increase of $42 800 occurs in season 1, which has the highest expected crop yield. In the worst season (9) area adjustments reduce the cash deficit from $48 000 to $35 800. For risk- averse farmers, this improvement may be of even greater significance than the larger improvements which are possible in seasons when returns would already be high without making adjustments to achieve even higher returns.

Note that although land use is the same in all seasons with a favourable start (1 to 4), the net cash surpluses and values of flexibility are very different between these four seasons. For example, although seasons 2 and 3 have identical climatic patterns until after the crop has been sown, season 3 has much lower yields due to poor finishing rains. Lower yields mean that the benefits of increasing crop area are much less (A$3700 compared with A$26 500) and in some circumstances could even be negative.

TABLE 5

Value of tactical flexibility for different wheat and wool prices

Wheat price [a] (A$/t)	85	105	125	145	165
Value of flexibility (A$1000)	10.8	13.1	15.2	17.9	21.3
Wool price [a] (A$/kg)	1.30	2.10	2.90	3.70	4.50
Value of flexibility (A$1000)	17.3	16.9	15.2	13.7	12.3

[a] Farm gate price net of all selling and transport costs. Wool price fixed at A$2.90 for wheat price sensitivity. Wheat price fixed at A$125 for wool price sensitivity.

The 'with adjustments' model does have lower cash surplus in season 5 than the 'no adjustments' model. This is partly because of the limited capacity within MUDAS to treat seasons 5 and 7 independently, and partly because of strategic changes to sheep management which have a positive impact overall but a negative impact in season 5. The model which includes area adjustments selects a lower stocking rate of sheep on pastures. This reduces feed problems in poor seasons, increases pasture production per hectare and enhances the capacity to increase crop area in good seasons. However these advantages are obtained at the cost of slightly lower returns in season 5 due to lower wool sales.

Impact of price changes

The expected value of tactical flexibility is affected by the prevailing commodity prices. Table 5 shows that the value is positively related to wheat price, but negatively related to wool price. Because cropping is a relatively more important source of income when adjustments are included (see Table 2), higher wheat prices increase the difference between expected income with and without area adjustments. Lowering the wool price also makes wheat a relatively more profitable enterprise and similarly increases the expected value of tactical flexibility. We hypothesize that if adjustments per se change the relative importance of an enterprise, price changes will affect the expected value of information used to make the adjustments.

Effect of adjustments on supply elasticities

As well as changing the expected levels of production of different commodities, tactical adjustments can also affect the responsiveness of producers to price changes. Table 6 shows own price supply elasticities estimated with the model for wheat and wool. These are obtained by

TABLE 6

Effect of area adjustments on own price elasticity of supply [a]

	Area adjustment activities	
	Included	Excluded
Wheat	0.49	0.49
Wool	0.65	0.72

[a] Based on farm gate price net of all selling and transport costs.
Elasticities calculated at wool price of A$2.90 and wheat price of A$125.

solving the model for a range of prices and regressing these prices against the expected value of quantities produced (using OLS).

The own price supply elasticity for wool is lower when area adjustments are included. However the adjustments have no impact on the own price supply elasticity for wheat. The change in elasticity for wool is not due to risk aversion; all solutions in this paper are for maximum expected profit. Rather it appears that the lower price elasticity when adjustments to season are included is due to lower stocking rate. Price changes have a smaller impact on profitability per hectare if the stocking rate is lower. In effect, the lower elasticity is due to the increased significance of climate in determining land use. The scope for price responses is less when responses to climatic conditions must also be made.

CONCLUDING COMMENTS

Simple adjustments in enterprise areas can result in substantial improvements in expected cash surplus on farms in the subject region (by approximately 22% in the standard model). Benefits are due to capitalizing on knowledge about the greater volatility of profits from cropping than from sheep production. Crops are relatively more profitable in good seasons and relatively less profitable in poor seasons. Deterministic models and even stochastic models which do not include activities for tactical adjustments miss this key feature of the system, and may incorrectly identify optimal activities (Kingwell et al., 1992).

Potential improvements to the model include representation of risk aversion (e.g. Patten et al., 1988) and inclusion of a wider range of season types. Risk aversion is likely to affect the strategies selected and may also affect the tactical adjustment activities. Inclusion of further season types would allow finer resolution in selecting tactics and would reduce problems of associating an actual season with one of the discrete season types in MUDAS for extension purposes.

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