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IMPACT OF AGRONOMIC AND ECONOMIC FACTORS ON FARM PROFITABILITY - MODEL SPECIFICATION AND APPLICATION (TARLEE TRIALS)

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A multi-period mathematical programming model capable of representing cereal/grazing farm firms in South Australia is developed to determine the likely impact on farm profitability of alternative rotational sequences. Historically, crop rotations have been modelled using explicit predetermined rotations. In this study the model freely determines the optimal rotation over the designated planning horizon.

Empirical results indicate that the complex inter-relationships involved in a mixed crop/livestock farming operation plays a major role in determining the optimal farm plans. The model develops a plausible set of farm plans under various price and yield assumptions, though somewhat different from traditional farm practices. Preliminary analysis of tillage techniques suggest the selection of tillage practice did not have a significant effect on the final selection of rotations.

1. INTRODUCTION

The Australian rural sector's terms of trade are expected to continue falling during the remaining years of this decade (BAE (1986)). The real net value of rural production is close to the lowest level recorded in Australia, even though the Australian dollar has depreciated significantly over the last 18 months. South Australian cereal/sheep farmers, are experiencing an improved outlook for wool, but continued depressed prospects of overseas cereal markets. Also aggravating farmers' terms of trade is the continual rise in farm costs, much being attributed to rising interest payments and higher input costs which have imported components.

Farm incomes, then, especially for cropping specialists are at low levels, though mixed cereal/livestock enterprises are probably relatively better off than their cropping counterparts (Trengove, 1986). Hence, identifying factors which improve productivity and facilitate structural change on farm firms, thereby improving farm incomes, becomes an important area for research (Kingma (1977)). In particular, the examination of how farm resources, agronomic production systems and investment behaviour, can be altered to improve farm incomes, while economic forces continue inducing change.

For farm-firms to survive unfavourable terms of trade, they need to adopt both (1) cost-saving innovations such as those being offered by recent innovations in tillage techniques and (2) to adjust their enterprise mix and size to account for changing price relativities and new production technology which give new cropping alternatives and higher-yielding varieties. Any adjustment of farm operations affects other aspects of the farm plan, because

expansion of one enterprise will affect resources available to other enterprises. This is accentuated when changes occur in both crop and livestock enterprises or where the farmer is considering the purchase of more land. For example, any change in the farm plan such as crop/livestock mix has both an immediate and longer term impact on farm performance. This is clearly seen when changing a wheat/barley/feed rotation to all wheat, which not only affects immediate farm profits, but influences the longer term feed availability for grazing, and decreases wheat yields over time due to cereal root diseases and soil fertility factors.

Different Tillage Techniques also affect both the feed availability and yield of crops in proceeding years, though the effects would appear to be much less significant than those of changing rotations (Krause, 1985). Farquharson et al., (1984) and Godyn (1984) have studied the impact of direct drilling at the farm level showing farm profitability can be improved by altering traditional farming practices to direct drill, by allowing improved soil management, weed control and increased crop production. These results are dependent on many variables such as product price relativities, soil types and rainfall.

2. MODEL BACKGROUND

The combination of farm enterprises is important in exploiting the jointly beneficial inter-relationships among different crops/livestock and tillage techniques. These inter-relationships include the effects of soil productivity through weed control, breaking of root disease cycles embedded in soils, moisture retaining ability of different soil types and soil fertility through retention of organic matters. Literature shows that the modelling of these

rotational/tillage aspects has been handled by explicit rotation definitions being included in farm-firm models as discrete activities. However this method of rotational modelling limits the choice of rotation to the combinations selected by the modeller.

In Australia, Johnston and Matuska (1985) developed a farm-firm model using a recursive programming algorithm embedded in a simulation framework, to study the economic potential for new grain legumes and oilseeds to enhance on-farm profitability and/or reduce income variability in the wheat-sheep zone of N.S.W. Morrison et al. (1984) developed a linear programming model of the Eastern and Central wheat belt farms in Western Australia. Their aim was to determine relative profitability of cropping and livestock enterprises and the most profitable crop pasture rotation. Pearce and Cowie (1986) have developed a polyperiod linear programming farm-firm model which is being used to study the economics of on-farm soil conservation.

Of these Australian studies, only Pearce's model allows rotations to be determined within the model, without specifying a number of fixed rotations. Although, to overcome the large number of rotation possibilities annual cropping land becomes land of a given fertility for production of either crops or livestock in the following year, thus aggregating the impact of past paddock history regarding crop and feed yields.

Talaat and McCarl (1986) have developed a farm-firm model which allows for rotations to be developed within the model, with the aims of identifying an optimum long-run crop rotation strategy and its sensitivity to risk attitude. They used an annual, timeless, equilibrium model formalized by Throsby (1967) instead of the; (1) multiyear linear programming model based on firm growth

work by Loftsgard and Heady (1959) and used in Australia by Farquharson et al. (1984); and (2) the dynamic programming approach used by Burt (1982) and Johnston (1985). The annual equilibrium approach assumes that the present farming environment should not influence rotation choice, that inter-relationship data is not readily available and that the switch to the optimal rotation was short enough to neglect the time path of adjustment.

The present study differs from the above studies in that rotations (including livestock enterprises) are wholly determined within the model, allowing for all rotation possibilities except where obvious agronomic practises prevent consecutive plantings of certain crops. This allows for all the inter-dependencies between cropping and livestock to be considered when determining the optimal rotation or combination of enterprises of farm-firms given differing soil types and management practices. Such a model requires large inputs of data thus highlighting the availability or otherwise of sound technical research and on-farm data.

Multiperiod linear programming is used to represent the agronomic and economic environment of farm-firms in this study where the agronomic history of the farm is considered important, considerable crop/livestock inter-relationship data is available (though some deficiences still exist) and where the multiperiod aspect of the model is important because the time taken to reach the optimal rotation is unknown and in-need of experimentation. Further, multiperiod linear programming was chosen because of the comprehensive specification of the problem being faced and the availability of a number of suitable algorithms able to solve large linear/non-linear programming problems (APEX IV and MINOS/AESOP).

The aim of this paper then is to describe the specification, verification, validation and application of a multiperiod linear programming model capable of representing farm firms in the cereal/grazing regions of South Australia and applied to determine the most profitable use of farm resources that highlights appropriate rotational sequences.

3. MODEL FRAMEWORK

As previously discussed, the model for the study of optimal rotation and tillage techniques is a multiperiod linear programming model, which produces an optimal solution over each and all years. The solution in any year depends on what is known about preceeding and succeeding years. By definition, multiperiod linear programming implies that activities must be additive and linear, inputs and outputs are divisable and coefficients are known with certainity. These assumptions can be relaxed when necessary by approximating proceedures, sensitivity analysis and use of non-linear algorithms.

Many studies discuss various ways of including multiple goals into multiperiod linear programming models (see studies such as Cocks and Carter (1968), Boehlje and White (1969), Boussard (1971), Rae (1970), Barnett (1982) and many more). Models range from maximizing a profit objective function to the addition of goals as sectors in the constraint sets of linear programming models, through to including multiple goals in the objective function by specifying weights to these goals according to prior information about their relative importance given them by the decision markers (Norton (1979)). (Note that the linear programming formulation of a single objective function problem is a subset of the more general multiple objective (Flinn (1980)).

In setting goals in this study, short to medium term (3-5 years) farmer goals where considered, including maximizing profit and maintaining a satisfactory standard of living. The main purpose of this model is to study crop/pasture rotations within the confines of present farm size, removing additional complications attached to long term activities such as buy/sell land and valuing land to determine a farms terminal net worth.

This leads us to the important question of the length of the planning horizon in multiperiod linear programming models. The optimal long term growth path of farm-firms is secondary in this study to the medium term decision making at the farm level. Consequently, the planning horizon should at least ensure that the correct planning decision is made in the first period and perhaps the second period (Barry (1972)). Rae's (1970) suggestions are taken in this study of both; (1) extending the time period until investment decisions in the first year become insensitive to further extensions of the planning horizon; and (2) extending further to more accurately determine second and subsequent year investment decisions. This is in line with the aims of this study of determining optimal rotations which need three to five years to allow for yield and feed availability differences to influence model solutions. It is envisaged that the planning horizon be large enough to allow rotations to move from being paddock specific rotations (due to previous farmer decisions) to a whole farm plan which balances economic and agronomic information. The final planning horizon length will be constrained by the model size and related costs of computing. When necessary, to increase the length of the planning horizon, the optimal solution will be used to initiate a further optimal solution for subsequent years with associated input data changes.

Uncertainty in activity costs, yields and prices should theoretically be included in linear programming models, as optimal farm plans will depend not just on expected net incomes but also on the riskiness inherent in the plan and on the decision makers aversion to risk (Norton (1979)). Incorporating risk into multiperiod linear programming analysis increases the complexity of determining an optimal solution. One method of incorporating risk is using quadratic programming to derive expected income variance frontiers (Barry and Willmann (1976)). An alternative formulation of handling risk within the conventional linear programming framework include Hazell's (1971) MOTAD and its subsequent modification (Harel and Scandizzo (1974) (see also Held (1982) and Wicks (1978)) through to Thomas's et al. (1972) seperable programming techniques.

In this study, risk between enterprises (cost, yield and price) is assumed constant and thereby ignored in the model structure. However, a series of alternative plans are developed which contain varied input coefficients which help to subjectively determine the optimal plan's sensitivity to variations in various input factors. Solutions are considered normative; the optimum set of farm activities given a set of assumptions (Blyth (1982), Farquharson (1984)).

4. SPECIFICATION OF THE MODEL

4.1 Introduction

In this study it is assumed that farm-firm management is seeking to maximise profits (cumulative net operating surplus) through efficient resource allocation. Profit is defined as income for re-investment (onfarm or otherwise) after all variable costs, fixed costs, tax and private consumption expenditures

Figure 1: Aggregated Representation of Farm-Firm Model

Activities / Contraints Year 1 to ... Year N	Cropping	Feed Transfer	Sell Crop	Produce Sheep	Sell Sheep/Product	Buy Sheep	Buy Hay	Buy Machinery	Sell Machinery	Buy Labour	Taxation	End Year	Cash Transfer	Cropping	Feed Transfer	Sell Crop	Produce Sheep	Sell Sheep/Product	Buy Sheep	Buy Hay	Buy Machinery	Sell Machinery	Buy Labour	Taxation	End Year	Finish Cash	Cash Transfer	RHS
Crop Area	+																											0
Grain Production	-		+																									0
Feed Production	-	+/-		+			-																					0
Sheep Reconciliation				+/-	+	-																						+
Hay Reconciliation																												+
Machinery Constraint	+							-	+																			+
Machinery No.								-																				0
Labour Constraint	+									-																		+
Borrowing Constraint								+																				+
Taxation Constraint											+	-	+															0
Gross Margin Constraint	+		-	+	-	+	+	+	-	+		+/-																0
Crop Transfer	-			-										+														0
Sheep Transfer																	+											0
Cash Transfer													-														+	0
Crop Area														+														0
Grain Production														-		+												0
Feed Production														-	+/-		+			-								0
Sheep Reconciliation																	+/-	+	-									+
Hay Reconciliation																												+
Machinery Constraint														+							-	+						+
Machinery No.																					-							0
Labour Constraint														+									-					+
Borrowing Constraint																					+							+
Taxation																								+	-	+		0
Gross Margin Constraint														+			+	-	+	+	+	-	+		+		-	0
Final Revenue (Objective function)																										+		MAX

have been deducted. This profit maximizing goal is subject to many resource use, availability and finance constraints designed to reflect actual farm-firm operations. The model represents the farm-firm over a planning horizon of as many years that can practicably be handled. The farming year is assumed to begin in mid May, at the break of the season as any changes in farm plans can most effectively be achieved at this time.

The activities in the model fall basically into the following categories: (1) crop production, (2) feed production and transfer through periods, (3) sheep and sheep product production, (4) crop, sheep, sheep product and machinery selling, (5) sheep, hay, feed concentrates, labour and machinery purchasing, (6) taxation and other financial activities, and (7) crop, sheep and financial transfers.

The constraint and row transfers in the model are as follows: (1) resource constraints, (2) cashflow and credit constraints, (3) taxation constraints, (4) cash, feed, sheep and crop transfers, and (5) disposible income constraints.

Table 1 presents an aggregated representation of the model which will be broken down into submatries covering a single period in the following sections for further explanation. Many of the activities and rows shown represent numerous activities and rows in the model. Though Table 1 represents two years of the model the multiperiod linear programming model includes four time periods. Crops produced are sold as grains, their paddock history is transfered to become part of an activity in the following year and feed availability for sheep consumption is supplied. The sheep enterprises require feed produced either on the farm or through purchases of hay and feed concentrates. Buying and selling of machinery, and financial activities also occur. Sales revenue

are accumulated, from which total production costs (variable and fixed), taxation and living expenses are deducted. Resulting cash supply is transferred into the following years cash flow. At the end of each year certain cropping land, livestock and cash are transfered into the following year.

4.2 Crop and Pasture Submatrix

Table 2 depicits the year 1 cropping and pasture submatrix of the model, though reduced in size from the eight possible cropping alternatives to four, representing the farm-firm being modelled in the Lower North of South Australia. (Appendix I provides row and column name definitions). In the first year, only wheat, barley, beans and clover pasture reflect last years paddock history. However, the first year's rotation alternatives on each of these paddocks include wheat, barley, peas, volunteer pasture, beans, oilseeds, fallow and clover pasture, eight possibilities in total. Crops grown (measured in hectares) produce varying tonnages per hectare of grain depending on crop type and paddock history. They also produce stubble which has a certain energy equivalent for use as stock fodder. Pasture, on the other hand provides stock fodder in various periods throughout the year, in quantities also dependent on paddock history. This information has been collected from Departmental crop rotation and tillage trials over many years (Schultz (1985)). The cropping and pasture activities use various hours of tractor, cultivator, harrow, spray, sowing and harvesting equipment, figures again collected from resource personel within the Department and leading farmers such as Rohde (1985). (The above data is available upon request). These activities also require labour, superphosphate[1],

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[1] In the model application, superphosphate was incorporated into the gross margin removing the super constraint and activity from the model.

Table 2: Cropping and Pasture Submatrix

ROWS \ COLUMNS		1-WTWT	1-WTBA	1-WTPE	1-WTVP	1-WTBE	1-WTOS	1-WTFA	1-WTMP	1-BAWT	1-BABA	1-BAPE	1-BAVP	1-BABE	1-BAOS	1-BAFA	1-BAMP	1-BEWT	1-BEBA	1-BEPE	1-BEVP	1-BEOS	1-BEFA	1-BEMP	1-MPWT	1-MPBA	1-MPPE	1-MPVP	1-MPBE	1-MPOS	1-MPFA
1*CASHAVLE	LE																														
1*FARMAREA	EQ	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1*WTAREA	LE	1								1								1							1						
1*BAAREA	LE		1								1								1							1					
1*PEAREA	LE			1								1								1							1				
1*VPAREA	LE				1								1								1							1			
1*MPAREA	LE								1								1							1							
1*BEAREA	LE					1								1															1		
1*FAAREA	LE							1								1							1								1
1*OSAREA	LE						1								1							1								1	
1*WTLYR	EQ	1	1	1	1	1	1	1	1																						
1*BALYR	EQ									1	1	1	1	1	1	1	1														
1*PELYR	EQ																														
1*VPLYR	EQ																														
1*MPLYR	EQ																								1	1	1	1	1	1	1
1*BELYR	EQ																	1	1	1	1	1	1	1							
1*FALYR	EQ																														
1*OSLYR	EQ																														
1*PRODWT	LE	-A								-A								-A							-A						
1*PRODBA	LE		-A								-A								-A							-A					
1*PRODPE	LE			-A								-A								-A							-A				
1*PRODBE	LE					-A								-A															-A		
1*PRODOS	LE						-A								-A							-A								-A	
1*P1FEED	EQ	-D	[illegible]			-D	-D			-D	-D	-D		-D	-D			-E	-D	-D		-D			-D	-D	-D		-D	-D	
1*P2FEED	EQ																														
1*P3FEED	EQ																														
1*P4FEED	EQ																														
1*P5FEED	EQ				-D				-D				-D				-D				-D			-D				-D			
1*P6FEED	EQ				-D				-D				-D				-D				-D			-D				-E			
1*P7FEED	EQ				-E				-D				-D				-D				-D			-D				-E			
1*P8FEED	EQ				-D				-D				-D				-D				-D			-D				-D			
1*P9FEED	EQ																														
1*CONFEED	LE																														
1*TRACHR	LE	A	A	1		1	A	T	T	A	A	1		1	A	T	T		A	1		A	T	A	A	A	1		1	A	T
1*CULTHR	LE	T	T	T		T	T	T		T	T	T		T	T	T		T	T	T		T	T		T	T	T		T	T	T
1*WIDEHR	LE																														
1*NAROHR	LE	U	U	U		U	U			U	U	U		U	U			U	U	U		U			U	U	U		U	U	
1*SPRAHR	LE	T	T	T		T	T			T	T	T		T	T			T	T	T		T			T	T	T		T	T	
1*SOWGHR	LE	T	T	T		T	T		T	T	T	T		T	T		T	T	T	T		T		T	T	T	T		T	T	
1*HEADHR	LE	T	T	T		T	T			T	T	T		T	T			T	T	T		T			T	T	T		T	T	
1*TRACHO	EQ																														
1*CULTHO	EQ																														
1*WIDENO	EQ																														
1*NAROWO	EQ																														
1*SPRANO	EQ																														
1*SOWGNO	EQ																														
1*HEADNO	EQ																														
1*SUPER	LE	T	T	T	U	T	T	T	U	T	T	T		T	T	U	U	T	T	T	U	T	T	U	T	T	T	U	T	T	T
1*NITROGEN	LE	B	B				B			B	T				B							B								T	
1*WOOLREC	LE																														
1*MUTONREC	LE																														
1*LAMBREC	LE																														
1*EW1REC	LE																														
1*EW2REC	LE																														
1*WETHEREC	LE																														
1*HAYREC	LE																														
1*LABOUR	LE	A	A	A		A	A	T	T	A	A	A		A	A	T	T	A	A	A		A	T	T	A	A	A		A	A	T
1*MACH$$	LE																														
1*DDRAFT	LE																														
1*GROSMARG	LE	C	B	C	B	C	C	A	B	C	B	C	B	C	C	A	B	C	B	C	B	C	A	B	C	B	C	B	C	C	A
1*TAXY	EQ																														
1*TAXES	EQ																														
1*DISPY	LE																														
1*TAXCOM	LE																														
1*NETAXY	EQ																														
REVEX	FR																														

ROWS \ COLUMNS	1-WTAREA	1-BAAREA	1-PEAREA	1-VPAREA	1-MPAREA	1-BEAREA	1-FAAREA	1-OSAREA	1-SELLW"	1-SELLBA	1-SELLPE	1-SELLBE	1-SELLOS	1-BUYSUPER	1-BUYNITRO	RHS1
1*CASHAVLE																
1*FARMAREA																C
1*WTAREA	-1															
1*BAAREA		-1														
1*PEAREA			-1													
1*VPAREA				-1												
1*MPAREA					-1											
1*BEAREA						-1										
1*FAAREA							-1									
1*OSAREA								-1								
1*WTLYR																C
1*BALYR																C
1*PELYR																
1*VPLYR																
1*MPLYR																C
1*BELYR																B
1*FALYR																
1*OSLYR																
1*PRODWT									1							
1*PRODBA										1						
1*PRODPE											1					
1*PRODBE												1				
1*PRODOS													1			
1*P1FEED																
1*P2FEED																
1*P3FEED																
1*P4FEED																
1*P5FEED																
1*P6FEED																
1*P7FEED																
1*P8FEED																
1*P9FEED																
1*CONFEED																
1*TRACHR																F
1*CULTHR																F
1*WIDEHR																F
1*NAROHR																F
1*SPRAHR																F
1*SOWGHR																F
1*HEADHR																F
1*TRACHO																
1*CULTHO																
1*WIDENO																
1*NAROWO																
1*SPRANO																
1*SOWGNO																
1*HEADNO																
1*SUPER														-1		
1*NITROGEN															-1	
1*WOOLREC																
1*MUTONREC																
1*LAMBREC																
1*EW1REC																
1*EW2REC																D
1*WETHEREC																
1*HAYREC																
1*LABOUR																D
1*MACH$$																C
1*DDRAFT																
1*GROSMARG									-C	-B	-C	-C	-C		T	-E
1*TAXY																
1*TAXES																
1*DISPY																1
1*TAXCOM																-E
1*NETAXY																-E
REVEX																

nitrogen fertilizer and finance, the latter costings appearing in Appendix II-B. The labour activity is designed to measure peak labour demand occurring during the crucial period of soil preparation and crop planting.

Initially, the cropping/pasture submatrix was to include tillage technique differences highlighting conventional and minimum till. The conclusion of Farquharson (1984) and Godyn's (1984) work indicate that the difference between these tillage practices is small though the possibility of easing restraints on crop production does exist. Limitations of this potential must be recognised. For example, Krause (1986) has concluded from his whole farm analysis of major tillage trials in South Australia that under good management both costs and yields are similar and that one system does not have major advantages over the other, though under some weather conditions, one tillage system may prove advantageous over the other. Given past experience and Departmental trial results, tillage techniques were not included in this segment of the overall study. Their inclusion in the model, however, is simple in that the crop/pasture matrix would double in size to represent two tillage techniques, with some data differences being included.

The important aspects of the model development are both the yield of grain and pasture from different rotations and the use of paddock history in determining future rotations. In the following years, rotation possibilities balloon out to a maximum of 2048 possibilities in the third year though this number is marginally reduced by removing unrealistic rotations on agronomic grounds.

4.3 Livestock Feed Submatrix

Various livestock activities covering the traditional sheep products of wool, lamb and mutton are incorporated into the multiperiod linear programming model. The self replacing merino sheep enterprises, designed to reflect different management strategies open to South Australian farmers, are included in this model. The major difference between the two sheep enterprises being the time of lambing and lambing percentage; spring lambing (100 percent marking) versus the traditional autumn lambing (90 percent marking) strategy.

Table 3 describes the livestock and feed transfer submatrix of the model for year 1. For both flock types, sheep can be purchased, sold or grazed as part of an overall farm plan. Lamb, wool and mutton are sold as products of these livestock enterprises, while hay and feed concentrates are used to supplement livestock diets when grazing supply is inadequate to meet grazing demand and to supplement ewe diets to enhance lambing percentages.

Feed for grazing (pasture and stubble) is made available over nine periods in each year, which match ewe feed requirements. Any feed remaining at the end of each of these nine periods is determined and a portion is transferred (allowing for spoilage in the paddock) into the following period as available feed for continued grazing.

Purchasing of additional ewes is financed by an overdraft, with the interest cost being included in the determination of net operating surplus. Revenue from sheep sales is used to reduce the overdraft while interest on this money is included as income when determining net operating profit. In this

Table 3: Livestock and Feed Transfer Submatrix

ROWS \ COLUMNS		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		FEEDDIS	FEEDDIS	FEEDDIS	FEEDDIS	FEEDDIS	FEEDDIS	FEEDDIS	FEEDDIS	FEEDDIS	UTLYRHUS	UTLYRHUS	UTLYRHUS	UTLYRHUS	UTLYRHUS	UTLYRHUS	UTLYRHUS	UTLYRHUS	UTLYRHUS	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH	DOTAGRICH
		2	3	4	5	6	7	8	9	10	8	9	10	11	12	13	14	15	16	1	2	3	4	5	6	7	8	9	10	11	12	13
1*CASHAVLE	LE																															
1*FARMAREA	EQ																															
1*WTAREA	LE																															C
1*BAAREA	LE																															
1*PEAREA	LE																															
1*VPAREA	LE																															
1*HPAREA	LE																															
1*BEAREA	LE																															
1*FAAREA	LE																															
1*OSAREA	LE																															
1*WTLYR	EQ																															
1*BALYR	EQ																															C
1*PELYR	EQ																															C
1*VPLYR	EQ																															
1*HPLYR	EQ																															
1*BELYR	EQ																															C
1*FALYR	EQ																															S
1*OSLYR	EQ																															
1*PRODWT	LE																															
1*PRODBA	LE																															
1*PRODPE	LE																															
1*PRODBE	LE																															
1*PRODOS	LE																															
1*P1FEED	EQ	1									-T	C	C							-D												
1*P2FEED	EQ	-T	1									C	C								-D											
1*P3FEED	EQ		-T	1								C	C									-D										
1*P4FEED	EQ			-T	1							C	C										-D									
1*P5FEED	EQ					1						C	C											-D								
1*P6FEED	EQ				-T		1					C	C												-D							
1*P7FEED	EQ					-T		1				D	D													-D						
1*P8FEED	EQ						-T		1			C	D														-D					
1*P9FEED	EQ							-T		1		C	C															-D				
1*CONFEED	LE								-T		1	C	C																-D			
1*TRACHR	LE											S	A																	-1		
1*CULTHR	LE																															F
1*WIDEHR	LE																															F
1*HAROHR	LE																															F
1*SPRAHR	LE																															F
1*SOWGHR	LE																															F
1*HEADHR	LE																															F
1*TRACWO	EQ																															F
1*CULTWO	EQ																															
1*WIDEWO	EQ																															
1*HAROWO	EQ																															
1*SPRAWO	EQ																															
1*SOWGWO	EQ																															
1*HEADWO	EQ																															
1*SUPER	LE																															
1*NITROGEN	LE																															
1*WOOLREC	LE																															
1*MUTOWREC	LE										-A	-A					1															
1*LAMBREC	LE										-T	-T						1														
1*EWIREC	LE										-T	-T							1													
1*EWZREC	LE										1		-1		1																	D
1*WETHEREC	LE											1		-1		1																
1*HAYREC	LE																															
1*LABOUR	LE																			1	1	1	1	1	1	1	1	1				D
1*MACHSS	LE																															C
1*DRAFT	LE																															
1*GROSHARG	LE												B	B	-B	-B																E
1*TAXY	EQ										A	A	B	B	-B	-B	-A	-B	-B	B	B	B	B	B	B	B	B	B	C	T		
1*TAXEB	EQ																															
1*DISPY	LE																															
1*TAXCON	LE																															1
1*METAXY	EQ																															-E
REVEX	FR																															-E

manner, assets converted to cash are not considered as increasing the operating surplus.

4.4 Labour, Machinery and Financial Submatrix

Table 4 describes the hire labour, buy/sell, machinery, taxation and other financial activities of the multiperiod programming model for the first year of the analyse. The planting season has been designated as the period of peak labour demand for farming operations, becoming a major production constraint when labour supply is lower than labour requirements to plant the seasons crop. In this period labour usage is measured in man hours per hectare whether contributed by the owner, operator, owner/operator or family labour. Once this usage exceeds predetermined supply the model allows for additional labour units to be hired. Labour demand is important when considering its supply price and the cost of labour saving technology (bigger machinery for example).

Machinery can be purchased or sold for the purpose of up-grading existing machinery. At all times the farmer is restricted to one of each type of machinery by various constraint equations. However, where large farms require more than one of each machine, coefficient adjustments are made to allow for this possibility prior to searching for an optimal solution. Monies can be borrowed to cover machinery purchased and these medium term machinery loans are charged the amortised value of the loan which reflects its annual capital costs. The assumption has been made that the farmer will at all times keep his machinery, even if producing livestock without the cropping enterprise. It is unrealistic to consider farmers selling their machinery at low prices when many farmers are facing this option due to low product prices. And further, movements in livestock/crop price relativities could induce a sudden swing back

Table 4: Labour, Machinery and Financial Submatrix

ROWS \ COLUMNS		1-BUYLABOR	1-BUYTRA	1-BUYCUL	1-BUYWID	1-BUYHAR	1-BUYSPR	1-BUYSOW	1-BUYHED	1-SELTRA	1-SELCUL	1-SELWID	1-SELHAR	1-SELSPR	1-SELSOW	1-SELHED	1-CASH	1-ENDYR$$	1-NETAXY	1-TAXYNE	1-TAX0	1-TAX1	1-TAX2	1-TAX3	1-TAX4	1-FINCASH	RHS1
1*CASHAVLE	LE																1										
1*FARMAREA	EQ																										C
1*WTAREA	LE																										
1*BAAREA	LE																										
1*PEAREA	LE																										
1*VPAREA	LE																										
1*MPAREA	LE																										
1*SEAREA	LE																										
1*FAAREA	LE																										
1*OSAREA	LE																										
1*WTLYR	EQ																										C
1*BALYR	EQ																										C
1*PELYR	EQ																										
1*VPLYR	EQ																										
1*MPLYR	EQ																										C
1*SELYR	EQ																										B
1*FALYR	EQ																										
1*OSLYR	EQ																										
1*PRODWT	LE																										
1*PRODBA	LE																										
1*PRODPE	LE																										
1*PRODSE	LE																										
1*PRODOS	LE																										
1*P1FEED	EQ																										
1*P2FEED	EQ																										
1*P3FEED	EQ																										
1*P4FEED	EQ																										
1*P5FEED	EQ																										
1*P6FEED	EQ																										
1*P7FEED	EQ																										
1*P8FEED	EQ																										
1*P9FEED	EQ																										
1*CONFEED	LE																										
1*TRACHR	LE		-E																								F
1*CULTHR	LE			-B																							F
1*WIDEHR	LE				-B																						F
1*HARDHR	LE					-B																					F
1*SPRAHR	LE						-B																				F
1*SOWGHR	LE							-B																			F
1*HEADHR	LE								-B																		F
1*TRACNO	EQ		-1							1																	
1*CULTNO	EQ			-1							1																
1*WITENO	EQ				-1							1															
1*HARDNO	EQ					-1							1														
1*SPRANO	EQ						-1							1													
1*SOWGNO	EQ							-1							1												
1*HEADNO	EQ								-1							1											
1*SUPER	LE																										
1*NITROGEN	LE																										
1*WOOLREC	LE																										
1*MUTONREC	LE																										
1*LAMBREC	LE																										
1*EW1REC	LE																										
1*EW2REC	LE																										D
1*WETHEREC	LE																										
1*HAYREC	LE																										
1*LABOUR	LE	-1																									D
1*MACH$$	LE		E	E	E	E	E	E	E																		C
1*ODRAFT	LE																										
1*GROSMARG	LE	C	B	B	B	B	B	B	B	-D	-D	-D	-D	-D	-D	-D	-1	1									E
1*TAXY	EQ																		-1		E	E	E	F	F		
1*TAXES	EQ																				1	1	1	1	1		1
1*DISPY	LE																	-1				D	E	E	F	1	-E
1*TAXCON	LE																			1							
1*NETAXY	EQ		B	B	B	B	B	B	B									-1	1	-1							
REVEX	FR																									1	-E

into cropping after only one year of all livestock. Machinery then comes under the asset fixity definition as does land in this model.

Other constraints set limits on total debt. Provision is not made for investment in more land, or for off-farm investment other than capital attracting an interest, as the study is aimed at existing farms and rotational sequences which optimize farm profits of the existing farm size. Capital expenditure on machinery/ livestock is made available from bank funding.

An allowance for a negative profit in the early years of the farm plan can be built into the model if expenditure on improving the livestock enterprise and machinery upgrading is profitable in latter years. However, this option has not been used in the model at this stage of development because the planning horizon is only medium term (due to matrix size), and a negative first year income is an unlikely event to arise from machinery purchases as expenditure on machinery is deducted in equal annual installments.

Throughout the year, the farmer is required to make certain fixed payments. These include overheads, debt repayments, family living expenses and taxation expenditure. The latter expenditure is modelled using Vandeputte's (1970) proceedure which allows for the Australian progressive taxation structure to be modelled. For reasons of simplicity provisional taxation and income tax averaging were not incorporated into this model.

The model manipulates farm finances to maximise profits, defined as the remaining annual finance after overheads, debt repaymnents, family living expenses (plus basic salary), tax commitmenmts and variable production costs are deducted from gross income from the cropping and livestock enterprises. The surplus is used for reinvestment into the farm covering short-term production

expenditure in the following year or allowed to accumulate and attract an interest rate attributable to short-term capital.

5. MODEL APPLICATION

5.1 Farm Background

The model was built using data from the Tarlee Rotation Trial (Schultz (1985)), the property of Mr. and Mrs. I.J. Rohde at Tarlee (sight of the Tarlee Rotation Trial) and expectations of the mid north region's departmental extension and research staff.

The farm consists of 730 hectares of fertile red brown earth with a rotation history of wheat/sown clover/barley/sown clover over most of the property and a small area having a barley/beans rotation. The property is known to have a low cereal cyst nematode bioassay rating, resulting in high cereal yields. Last season the enterprises consisted of 170 hectares of wheat, 140 hectares of barley, 50 hectares of beans and 370 hectares of improved pasture which carried two thousand ewes that lamb in autumn. (Throughout this study this plan is known as the initial farm plan). The sheep enterprise is self replacing. With the use of concentrated feeding the current carrying capacity of 5.4 ewes/ha is relatively high when compared to district averages. The property is run as a partnership of three people.

The model was built to accompany this property's farming practices of the last season, however, for subsequent years eight cropping alternatives exist. They are wheat, barley, peas, beans, oilseeds, fallow, volunteer and improved, clover pastures. For the next three years the model determines the most profitable rotations for the property from over 2000 rotation options, each allowing for paddock history. Consequently, paddock rotations are highlighted

as distinct from a whole farm plan particularly in the first few years of the planning horizon. Eventually the effects of paddock history brought into the model are removed and a time related farm plan begins to appear, thus showing the importance of paddock history and its interplay with economic trends (cereal/livestock prices for example) in determining an optimal farm plan.

5.2 Agronomic Assumptions - Summary

While the agronomic assumptions of the model are described in detail in a forthcoming publication, a brief outline is given below.

5.2.1 Cropping

Both cereal, grain legumes and oil seed rape can be growing in various rotation combinations but restrictions are put on continuous grain legumes and oil seed rape due to disease difficulties. Continuous wheat and/or barley is possible however yields are decreased and nitrogen fertilizer requirements are increased accordingly. Nematocide is applied with more than two consecutive years of wheat is grown.

5.2.2 Feed Availability

The year has been divided up into 9 periods to coincide with different stubble and pasture availability periods and varying sheep requirements. Sheep feed is supplied from pastures, stubbles and purchased hay.

There was little evidence to determine the amount of uneaten feed that could be transferred from one pasture period to the next. While paddock feed spoilage occurs because of stock trampling and weather conditions, there is no research available to help quantify this loss. An estimate of 40% feed loss was used between stubble feed periods as this gave realistic carrying capacities.

From local farmer experience, it was also assumed that a volunteer pasture following a sown pasture year produced high levels of dry matter. This type of pasture produced fifty percent more matter than a volunteer pasture that had not followed a sown pasture. This assumption had a significant influence on the amount of pasture grown in the farm plan.

5.2.3 Sheep Enterprise

Two lambing periods were tested to determine which self replacing ewe flock management strategy best suited the feed availability. Autumn lambing is most common for the mid-north district and a lambing percentage of 90 percent was used. The second lambing percentage of 100 percent was used for the less common spring lambing time.

5.3 Model Vertification and Validation

Verification is defined as the process of ensuring the model performs the way the modeller intended. This process was performed by entering appropriate data and generating a solution. The solution was examined against economic and agronomic principles and against the long hand method of determining a solution. On both accounts the model structure was proven sound.

The checking of the model to ensure the system has been adequately simulated is called validation. This process was performed by entering the model farm's data and constraining the model to a one year planning horizon in order to check the result agains the current plan. The outcome of this process was discussed with the appropriate extension and research officers to compare the results with their expectations. This consultation also occurred during the testing of the three year planning horizon model, and again the results reflected largely the expectations of the modellers, and appropriate research and extension staff. During the process of validation some coefficient estimates were adjusted to

allow the results to more accurately reflect the system. An example was the quantity of pasture transfer from one period to the next within a season.

6. MODEL RESULTS

6.1 Detailed Discussion of the Original Optimal Farm Plan

The cropping/grazing results of the model farm using 1986 prices are given below in table 5, to be described as the original farm plan throughout this study.

Table 5: Original Optimal Farm Plan

Farm Plan (Hectares)			
Initial Farm Plan	Year 1	Year 2	Year 3
Wheat 170 →	Beans 170 →	Wheat 170 →	Wheat 170
Barley 140 →	Beans 140 →	Wheat 140 →	Wheat 140
Beans 50 →	Wheat 50 →	Wheat 19 →	Wheat 19
		Clover Past 31 →	Volunteer Past 31
Clover Pasture 370 →	Wheat 180 →	Beans 180 →	Wheat 180
	Volunteer Past 190 →	Volunteer Past 140 →	Volunteer Past 104
		Clover Past 86 →	Volunteer Past 86
Ewe Numbers (ewes)*			
2000	1341	1211	964

* The model chose spring lambing instead of the traditional practise of autumn lambing.

6.1.1 Year One of Farm Plan

The initial plan's 170 hectares of wheat stubble and 140 hectares of barley stubble were first planted to beans and then to wheat in the following two years, whereas the 50 hectares of bean stubble were firstly planted to wheat and then followed by a wheat/clover pasture mix and subsequently a wheat/volunteer pasture mix in the final year of the farm plan. The 370 hectares of clover

pasture were set aside for wheat and volunteer pasture in the first year, followed by beans, volunteer pasture and clover pasture in the second year and in the final year a wheat/volunteer pasture mix. This meant that 230 hectares of wheat, 310 hectares of beans and 190 hectares of pasture were grown in the first year of the farm plan. This crop/pasture combination resulted in 1341 ewes being run over the whole farm, a reduction of 659 from last years numbers and an increase in cropping area from 360 hectares to 540 hectares, the larger increase occurring in bean acreage. About 28 tonnes of hay were fed out to the sheep in the period late october to mid December, allowing 7 ewes per hectare of pasture to be carried. Although this figure is high compared to actual farm practices it is not beyond expectations and represents the economic use of stubbles, improved panture production (50 percent greater growth than volunteer pasture) and purchased hay.

Income is derived from the sale of 516 tonnes of wheat, 527 tonnes of beans, 10,068 kgs of wool clip, 322 cast for age ewes, 965 lambs and any accumulated interest on proceedes of capital derived from sheep sales. Once variable production costs are deducted, total gross margin amounted to $103,479. Following the deduction of allowable tax deductable items amounting to $64,819, tax was paid on a net income of $38,660. This amount, fixed costs and living expenses of $20,000 meant a net operating surplus of $9,921 resulted after the first years farming. This money represents the farmers profit and is reinvested into the farm or placed into interest bearing investments.

In comparison, the initial farm plan (paddock history) generated a total gross margin of $89,672, meaning tax was paid on $24,853, yielding a net operating surplus of $-530. That is, living expenses would have dropped by $530 to break even, assuming no off-farm income was generated. This comparison

highlights the models power in choosing the optimal farm plan because of its capability to logically and objectively consider more information than other means of farm planning. This model has not considered subjectivity (risk), such as the possibility of seasonal variations.

6.1.2 Year two of farm plan

In the second year of the plan a total of 329 hectares of wheat, 104 hectares of volunteer pasture, 117 hectares of clover pasture and 180 hectares of beans were grown. This represents a drop in cropping acreage from the first years high of 540 to 509 hectares, still a major increase on the initial farm plans cropped area of 360 hectares. Because volunteer pasture on improved pasture paddocks produce 50 percent more feed than volunteer pasture without this history or improved pasture following crops, pasture area increased from the first year low of 190 to 221 hectares. However, less feed was produced in total, requiring 81 tonnes of hay to be purchased. This allowed 1211 ewes to be carried, a decrease of 130 from the first year. The carrying capacity of 5.5 ewes per hectare was maintained.

In the second year, the net cumulative operating surplus was $21,249, giving a net operating surplus for the second years operations of $11,328.

6.1.3 Final year of farm plan

For the final year of the plan 613 hectares were cropped to wheat and 117 hectares were under volunteer pasture with a clover pasture history (giving high feed values). This allowed 964 ewes to be carried, significantly fewer than the previous year, giving a carrying capacity of 6.2 ewes per hectare. This high carrying capacity was maintained by both the stubbles and pasture production and the 64 tonnes of purchased hay. Because the cropping program has been significantly increased, 13 hours of labour was purchased to make up the deficit

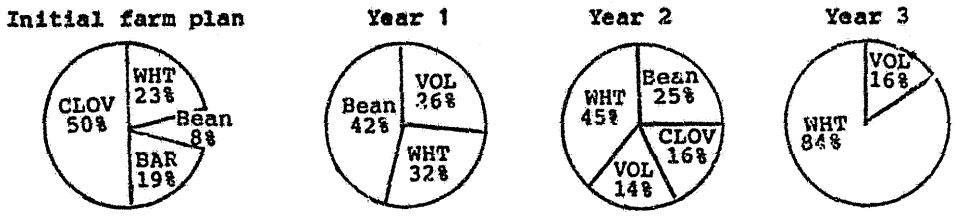
in owner/operator labour availability. Cumulative net operating surplus amounted to $47,440 in the final year of the farm plan.

If the planning period was extended another one or two years, crop acreage, in the third year would possibly be less than that reported above. This depends on the influence of interrelationships and paddock history over the longer time period. An estimate of the level of this influence has not been included as terminal conditions in the three year planning model of this study (see section 3 for a discussion on length of planning horizons).

6.2 Summary of Original Optimal Farm Plan

Figure 1 below provides a summary of table 5 above, showing the percentage area of each enterprise, hay requirements per ewe and the annual cash surplus for three years of the farm plan.

Figure 1: Summary - Enterprise Area (%)*



	Initial farm plan	Year 1	Year 2	Year 3
Hay/Ewe (kg)		20.5	67.2	66.6
Annual Cash surplus $	$-530	$9920	$11329	$26190

* WHT - area sown to wheat; BAR - area sown to barley; Bean - area sown to beans; CLOV - area sown to sub-clover pasture and VOL - area of volunteer pasture.

In summary, annual surplus increased from $-530 in the initial farm plan to $26,910 in the third year of the optimal farm plan. A major trend of increased cropping and reduced sheep numbers has occurred on this farm. This is despite

low grain prices (1986) of $100, $75, $135 and $170 for wheat, barley, grain legumes (peas/beans) and oilseeds, relative to previous years prices, and improved wool prices of $3.20/kilogram compared to past years. Although profit margins have increased in the sheep enterprise, they were not large enough to warrant a decrease in the initial cropping area. In addition, the increase in cropping area was also attributable to new break crop technologies giving higher cereal yields and improved gross margins over the planning period. Though planning initially consisted of traditional paddock rotations, it is turning into a whole farm plan as extending the time horizon reduces the importance of a paddock's history in future years.

6.3 Major Features of the Farm Plan

6.3.1 Wheat Selected as Main Enterprise

Wheat was selected as the main enterprise because the high gross margin attributed to wheat was maintained over the three years under study due to the improved yields encouraged by break crops. Beans were the major break crop used because of combined high bean returns and the significant yield lift given to next years wheat crops. Consequently, the optimal farm plan (table 5) shows two to three consecutive wheat crops following a bean crop, this cropping regime meant nitrogen fertilizer was applied at 20 kg and 40 kg/hectare, given two or three years of consecutive wheat cropping respectively, to replace the nitrate removed from soils due to continuous cereal cropping. Because the planning horizon including paddock history only covers four years, it is difficult to determine whether consecutive wheat plantings would continue.

The model has selected a wheat/bean cropping pattern supplemented with applied nitrogen. This approach is in contrast to the traditional practice of farmers in the area who grow barley and often fallow in addition to growing wheat. The optimal plan rejects these options because barley gross margins are inferior to those of wheat, and the profits forgone in the fallow year are not recouped in the following cropping years.

6.3.2 Tradition Rotation Method not use to Select Enterprise Mix

The common practice in South Australian cereal/sheep farming is for crop/pasture selection to follow a well established rotation pattern. The ley farming system established over the last three to four decades has acted as a buffer to farmers incomes against weather vagarities and major movements in crop/livestock price relativities. The riskiness attached to farming was subsequently reduced. Results in this study suggest profits can be increased by not maintaining traditional rotation patterns at least within the models planning horizon. This can be achieved by altering annual farm plans to reflect changing commodity prices and resource costs, and by incorporating the latest agronomic technology available (break-crops to manage soil born diseases for example) into present farm practices. In effect, enterprises are selected after balancing economic considerations against agronomic technology and paddock cropping/ pasture history.

Though this study does not explicitly incorporate the riskiness of farming into the model farm, due to the high associated computing expenses, the conclusions are still valid. Enterprise selection is still best determined by considering all relevant factors (new and past) at the point of decision making, not necessarily by following a past rotational pattern. The inclusion of risk

would see the spread of enterprise mix increase, depending on the degree of risk each decision maker is prepared to carry. Some indication of riskiness of the optimal farm plan is given in section 7.5, where major price variations and their impact on enterprise mix are summarized.

6.3.3 No Supplementary Feeding of Sheep Suggests Under-Stocking

With cropping areas increasing, total ewe numbers declined and over the three years studied, the average ewe carrying capacity per pasture area was around 25 percent higher than the initial stocking rate. These rates occurred because as shown in diagram 6 the hay feed per ewe rose to 67.0 kg per ewe. Results indicate then that even at a hay price of $80/tonne it is profitable to supplement paddock feed with hay, to maximise stocking rates. These stocking rates also depend on the quantity and quality of stubble feed available after harvest. In all examples, supplementary feeding was part of the optimal plan, indicating that no such feeding of sheep suggests under-stocking.

Though traditional practise is autumn lambing, the optimal farm plan preferred spring lambing. This result was expected as improved feed quality and availability resulted in a higher lambing percentage, making spring lambing more profitable.

6.3.4 Pasture and Cropping Area Becomes Segregated Over Time

The assumption that the first volunteer pasture following a sown clover generates 1.5 times the dry matter production of the initial sown clover is crucial to the selection of pasture areas in the farm plan. This assumption came from local farmer observation. The model uses the sown clover pasture

enterprise as a pasture regenerator rather than a break crop for wheat production, which is contrary practise to the traditional farm practice. The results indicate that when wheat is the main cereal crop chosen, a grain legume break crop (beans) is preferred over a pasture legume. As seen in table 5, a separation of the cropped area from the pasture area occurs, with the initial 370 hectares of clover pasture providing 88 to 100 percent of the land to pasture in future years. Other optimal plans generated, as commodity prices varied, also support this conclusion (see chapter seven). Area set aside purely for pasture over the planning period became more pronounced as sheep enterprise profitability improved relative to grains.

6.3.5 Paddock History is Critical to Enterprise Selection

Because the case study property was initially managed to carry sheep on over half the farm, the optimal plan (see figure 1) is biased in the direction of higher sheep numbers than would occur if pastures were not established. However, if the improved pasture was infact voluntary pasture at the beginning of the planning period then over the three years of planning, sheep numbers would average 1113 ewes on an average pasture area of 163 hectares (6.8 ewes per hectare) compared to 1172 ewes run at a carrying capacity of 6.7 ewes per hectare in the optimal plan (see table 5). Average cropping acreages remain virtually constant. The major differences in the two plans lies not in longer term trends but in the path toward these trends. For example, in the orginal plan 310 hectares of beans were planted in year one compared to 170 hectares in the present plan under discussion. Similarly, in the original optimal plan volunteer pasture in the first year followed improved pasture meaning 1341 sheep were carried in the first year of the plan compared to 829 sheep in the present optimal plan. Over the three years though cumulative net operating surplus in

the second plan is $3463 lower, representing a 7.3 percent decline in cumulative net operating surplus.

Where soil fertility was low and incidence of root diseases high, meaning poor cereal yields, the optimal plan would select a greater area of breakcrops in the first few years of the planning horizon. This is supported by the present study scenario, where soil fertility is high and root disease incidence is low, giving relatively large cereal areas compared to break crop areas.

6.3.6 Higher Annual Cash Surplus Generated

The additional cash surplus (see figure 1) generated by the model's farm plan indicates the greater profitability in grain production than in the sheep enterprise. While the annual cash surplus has increased to $26,190 in year 3, it indicates a low 2.6 percent return to the $1,000,000 farming asset, which is typical of farming businesses in general. This illustrates the mounting pressure for farmers to adopt improved technologies, farming practices and management to continue to maintain viable rural businesses.

7. SENSITIVITY ANALYSIS

To test the optimal solution's sensitivity to a changing economic environment, wool, feed and cereal prices and price relativities are varied. Major changes to enterprise mix and cumulative cash surpluses are discussed in detail in a forthcoming Departmental Technical Bulletin. What follows is a brief summary of estimated farm plans in relation to the initial farm plan.

Grain (including grain legumes) and wool prices were varied up and down by 20 percent from 1986 commodity prices and new farm plan solutions were obtained.

Table 6 illustrates the cumulative cash surplus's generated by these farm plans. As shown, the financial results are sensitive to large fluctuations in commodity prices from being non viable when grain prices are decreased by 20 percent to a cummulative cash surplus of $115,917 when both grain and wool prices increased by 20 percent.

Table 6: Commodity Price Variations and Associated Cumulative Cash Surplus

		WOOL PRICE VARIATIONS		
		-20%	BASE	+20%
Grain Price Variation	+20%	$108 532	$108 548	$115 917
	BASE	$ 35 319	$ 47 439	$ 61 022
	-20%	$-49 785	-$ 15 117	-$ 3 655

Figure 2 shows more clearly the differences in the cumulative cash surplus comparisons. The histograms highlight the greater sensitivity of cumulative cash surplus to grain price movements than to wool price movements. This characteristic is also shown in the small pye diagrams which indicate the areas to crop and pastures for each year of the model's farm plans. It shows that cropping always remains the major enterprise and sheep the minor enterprise with regard to land use, within the 20 percent price range shown. At a combined 20 percent rise in grain prices and a 20 percent fall in wool prices, all livestock are sold. At no stage does the model return to the pasture area or sheep numbers of the initial farm plan.

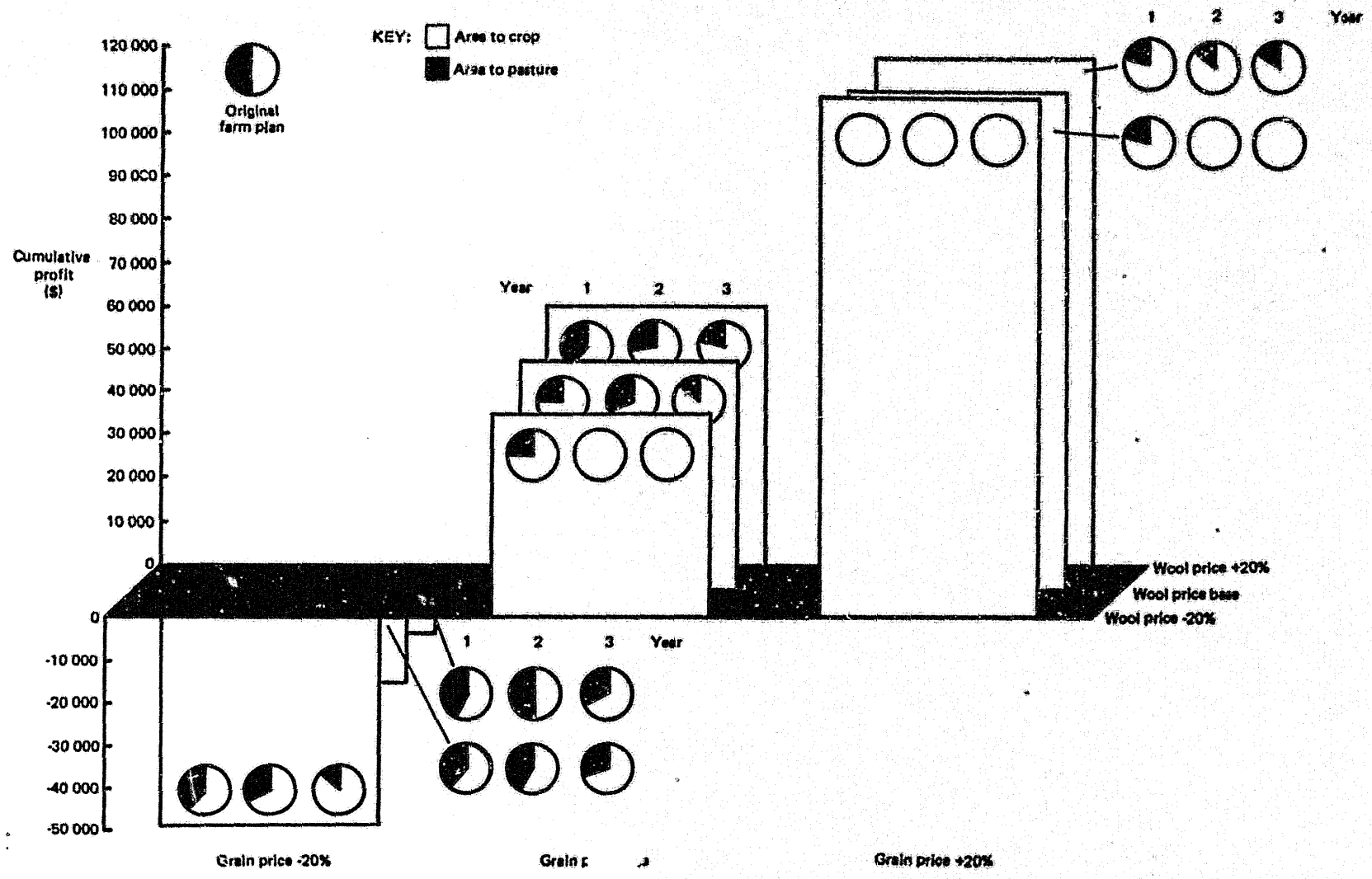


Figure 2: Cumulative Profit Comparison Between Farm Plans At Different Commodity Prices.

By simulating a 20 percent rise in wool prices the model indicates that some cropping area should be put back into pasture, with sheep numbers increasing by 400 ewes, from 964 in year 3 of the original optimal plan. However, despite this shift the total cropped area is still far in excess of the initial farm plan.

The pattern of enterprise selection does not alter greatly as the commodity prices are varied. In all the commodity price shift solutions, the patterns of enterprises chosen to follow the initial wheat (170 ha) and barley (140 ha) did not change from those of the original solution summarized in Table 5. Changes did occur with those enterprises that followed the initial sown clover (370 ha) and to a smaller extent the initial beans area (50 ha). As the relative returns from wool increase the area of pasture increases (both sown clover and volunteer pasture). This occurs on the land that had the initial sown clover pasture, and not on the 360 hectares that had a cropping paddock history.

Figure 2 can also be used to gain insight into the riskiness of different enterprise mixes. Farmers who are risk adverse would spread their enterprise mix more evently between crop and sheep enterprises than those farmers who are less risk adverse. The farm plans given in figure 2 would be very useful for individual farm decision making, given the decision makers personal choice of price and yield levels for the coming season. Even in the worst scenerio, regarding the cropping enterprise, of a 20 percent fall in cereal prices and a 20 percent rise in wool prices, does the average enterprise mix become 50/50 crop/pasture, as is commonly practised on some of the red brown soils in South Australia. When considering risk, farm plans could be updated from 50/50 crop/sheep to something approaching the 75/25 crop/sheep enterprise mix.

Since the model's solutions show greater sensitivities to grain price movements, than to wool price movements, more detail is now given to these results. Figure 3 shows the total gross margins comparisons from each years plan for the three grain prices tested (+20%, base, -20%) while holding the wool price stable. The cumulative cash surplus figures are given at the bottom of the diagram and the pie diagrams at the top show the total gross margin percentage attributed from grain and sheep for each year of the farm plan. The two lines across the page show, firstly the level of overhead costs, loan repayments and the living costs required, and secondly the dashed line indicates the level of tax that is required to be paid. The portion of the histograms that are above the dashed line indicate the amount of surplus cash (profit).

Figure 3 highlights more clearly the sensitivity of grain price changes to this farms business viability. If grain prices were to fall by 20 percent the farming operation becomes non-viable. At the base run only the third years plan develops a substantial cash surplus. If grain prices improve by 20 percent, all years in the farm plan develop cash surpluses of more than 2 percent of total farm assets.

All farm plans selected by the model regardless of the commodity price fluctuations develop improved total annual gross margins compared to the initial farm plan under 1986 commodity prices.

10. SUMMARY AND CONCLUSION

The points below relate to the case study farm in particular, though the summary and conclusions are applicable to similar farms, regarding soil type, yields and possible crop type and sheep enterprise mixes.

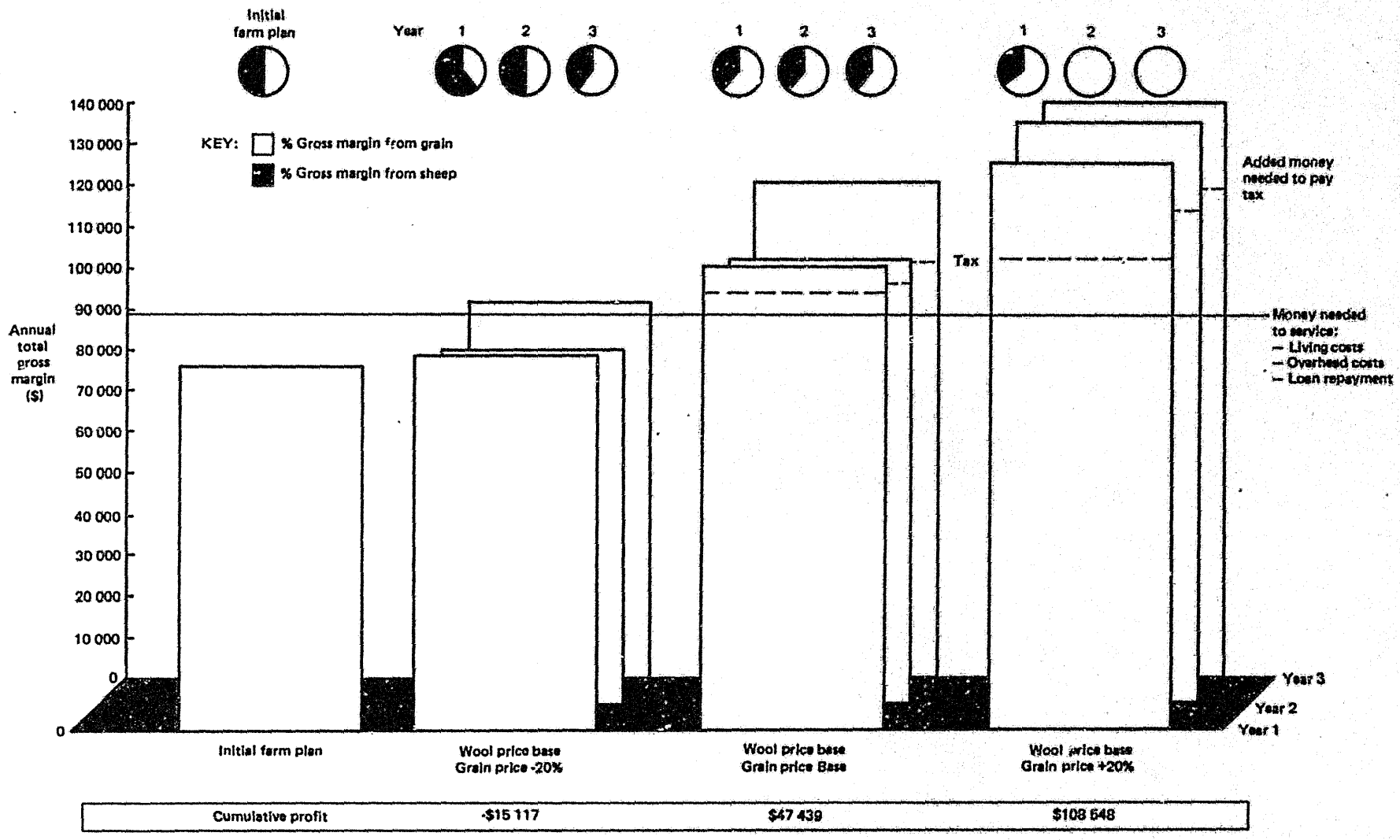


Figure 3: Farm Plan's Annual Profit Sensitivities To Grain Price Changes.

1. Results in this study indicate that farm profits can be increased by not maintaining traditional rotation patterns. Enterprise mix should be selected after balancing economic considerations against agronomic technology and paddock history.

2. The initial farm-plan could be updated from 50/50 CROP/SHEEP to a 75/25 CROP/SHEEP enterprise mix for the first years farm plan, yielding an increase of $10451 in operating surplus. Over the planning horizon of three years the increase in cumulative operating surplus amounts to around $49,000 compared against the initial farm plans negative operating surplus.

3. The optimal plan does not formally consider riskiness of increasing the cropping enterprise relative to sheep, though sensitivity results suggest the 75/25 crop/sheep enterprise mix would closely approximate the optimal mix when riskiness of different enterprises were considered.

4. The optimal plan averaged over the three years of the planning horizon was 163 hectares of beans, 355 hectares of wheat and 212 hectares of pasture carrying 1172 sheep per year. Wheat was selected as the main enterprise, with beans primarily used as a break-crop.

5. Over the three year planning period, pasture and crop area clearly become segregated with 88 to 100 percent of annual pasture being a continuous pasture rotation. Legumous pastures were utilized for their feed value, not for their impact on soil fertility.

6. Results suggest that the starting paddock history does have a significant impact on the choice of enterprises over the planning period. Initial paddock history wains in importance as the planning horizon increases.

7. At present prices for wool and cereals, rising wool prices and falling cereal prices, sheep are an important component in the enterprise mix of traditional cereal/sheep farms. However, as (1) cereal prices increase and wool prices remain constant and where (2) significant falls in wool prices together with significant rises in cereal prices occur, sheep numbers drop significantly and eventually have no role in farm plans for the case study.

8. Whereas gross-margin comparisons would suggest wheat as the only crop to grow, this model utilizes the feed value of crops and their contribution to the sheep enterprise and selects a combination of the crop and sheep enterprises as the optimal farm plan.

9. Changing feed costs have a direct impact on cereal acreages and sheep numbers. For example, rising costs of feed initially induce a reduction in both cereal acreages and sheep numbers as more pasture land is required to carry the sheep at a lower carrying capacity. Rising feed costs result in lower quantities of hay being purchased. Alternatively, falling feed costs induce very high stocking rates, declining pasture area and rises in the area cropped.

10. In all plans where sheep were part of the enterprise mix, supplementary feed was necessary to maintain maximum stock numbers, indicating that if no supplementary feeding exists, the farm plan is not optimal and the farm is therefore understocked.

11. Grain price relativities[1] are important in determining the mix of grains as well as the mix of enterprises (cereal/sheep) because each crop produces

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1 Summary and conclusion points 11 to 13 are based on experiments not reported in this document but in a forthcoming Departmental publication.

different amounts of feed for sheep consumption. For example, decreasing bean prices cause falling bean acreages, rising wheat acreages and falling sheep numbers.

12. Increasing barley prices (10 percent) induce increases in barley acreages in the optimal farm plan, substituted in the place of both wheat and bean acreages. Sheep numbers only marginally decline.

13. Varying prices of a given product (wheat in particular) within the farm planning horizon affects the optimal enterprise mix significantly, indicating the need for farm managers to constantly update their farm plans in response to new pricing information.

14. Different tillage techniques were considered insignificant in their affect on financial outcome of the farm plans under responsible management. Consequently, tillage plays no part in determining optimal farms in this study where surplus labour and machinery capacity exists.

15. This work yields results which are specific to farms of a given soil type and cannot be generalized across South Australia. This highlights the need for similar economic and agronomic research, as used in this study, to cover other soil types and different production areas within South Australia. This would give a broad picture of South Australian agriculture and its response to changing economic environments particularly on rotations and enterprise mix.

16. Financially viable farm plans require consideration of numerous variable economic and agronomic factors, as does sound departmental extension advice. A need for micro-computer based analytical economic/agronomic based models and programs is highlighted by this study and the complicity of results generated.

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Appendix I

ROW AND COLUMN NOTATIONS FOR MODEL MATRIX - ONE YEAR

Row name	Comment
CASHAVLE	Available farmer cash
FARMAREA	Total farm area
WTAREA	Area planted to wheat
BAAREA	" " " barley
PEAREA	" " " peas
VPAREA	" " " volunteer pasture
MPAREA	" " " medic/clover pasture
BEAREA	" " " beans
FAREA	" " " fallow
OSAREA	" " " oilseed rape
WTLYR	Last year's wheat area
BALYR	" " wheat area
PELYR	" " peas area
VPLYR	" " volunteer pasture area
MPLYR	" " medic/clover pasture area
BELYR	" " bean area
FALYR	" " fallow area
OSLYR	" " oilseed rape area
PRODWT	Wheat production
PRODBA	Barley production
PRODPE	Peas production
PRODBE	Beans production
PRODOS	Oilseed rape production
P1 Feed - P9 Feed	Nine periods of feed availability and use
Confeed	Concentrate feed
TRACHR	Hours of tractor use
CULTHR	" " cultivator "
WIDEHR	" " wideline "
HAROHR	" " harrow "
SPRAHR	" " spray boom "
SOWGHR	" " combine "
HEADHR	" " header "
TRACNO	Number of tractors
BULTNO	" " cultivators
WIDENO	" " wide li ss
HARDONO	" " harrows
SPRANO	" " spray booms
SOWGNO	" " combines
HEADNO	" " headers
NITROGEN	Nitrogen application rate
WOOLREC	Wool reconciliation
MUTONREC	Mutton "
LAMBREC	Lamb "
EW1REC	Autumn lamb ewe reconciliation
EW2REC	Spring " " "
WETHREC	Wether " " "
HAYREC	Hay " " "
LABOUR	Labour requirements
MACH$$	Machinery expenditure
ODRAFT	Overdraft finance
GROSMARG	Unit costs/returns
TAXY	Taxable income
TAXEQ	Tax equality
DISPY	Disposable income
TAXCON	Negative income taxation
NETAXY	Net Taxable income
REVEX	Objective function

Column name	Comment
WT	Wheat area planted
BA	barley " "
PE	peas " "
VP	Voluntary Pasture area planted
MP	Medic/Clover Pasture area planted
BE	Bean area planted
FA	fallow area planted
OS	Oilseed/rape area planted
WTWT	Wheat planted on wheat stubble
BAWT	Barley " " " "
PEWT	Peas " " " "
VPWT	Volunteer Pasture planted on wheat stubble
MPFA	Fallow on medic/clover pasture
WTAREA	Total wheat area planted
BA "	" barley area planted
PE "	Total pea area planted
VP "	" voluntary pasture area planted
MP "	" medic/clover pasture area planted
BE "	" bean area planted
FA "	" fallow area planted
OS "	" oilseed area planted
SellWt	Sell wheat production
SellBa	" barley "
SellPe	" pea "
SellBe	" bean "
SellOs	" oilseed "
Buynitro	Buy nitrogen
Feed 1-2 ... Feed 9-1	Feed transfer activities over 9 periods
Ew1S	Running Ewes - Autumn lambing
Ew2S	Running Ewes - Spring lambing
Buyew1S	Buy Autumn lambing ewes
Buyew2S	" Spring " "
Sellew1S	Sell Autumn " "
Sellew2S	Sell Spring " "
Sell wool	Sell wool
Selmuton	Sell mutton
Sellamb	Sell lambs
Buy Hay 1 - Buy Hay 9	Hay purchases by period
Buycon	Buy feed concentrates
Buylabour	Hire labour
Buytrac	Buy tractor
Buycul	" cultivator
Buywid	" wideline
BuyHar	" harrow
BuySpr	" spray boom
Buysow	" combine
BuyHed	" header
Sell trac - Sell Hed	Selling the above farm machinery
ODRAFT	Overdraft finance used
CASH	Cash used
ENDYR$$	End year gross margin
NETAXY	Net taxable income
TAXYNE	Negative income taxation
TAXO-TAX4	Taxation brackets
FINCASH	Final disposable income net of taxation overheads and living expenses.