# 5. Farm Models

> ***'...value choices are merely preferences that cannot be subjected to intelligent and shared examination '***
>
> *- James B. White*

## 5.1 Introduction

In this chapter, the structure of the mathematical programming models that were developed for use in this work is described. The base model is constructed to be a representation of the activities, resource constraints and input-output coefficients used on the various study farms. For each of the five case farms in this study, a variant of the basic MP model was developed. The various components of each sub-matrix of the basic model are detailed and discussed in this chapter. Section 5.2 is a description of the basic components of the risk-neutral model. Succeeding sections describe the utility-efficient model and its formulation for use in this study. Model validation and verification are also discussed.

## 5.2 Linear programming models

### 5.2.1 Model features

Figure 5.1 provides a schematic summary of the main features of the models. The schema presumes the new Linola technology being considered in this work to be incorporated in the system.

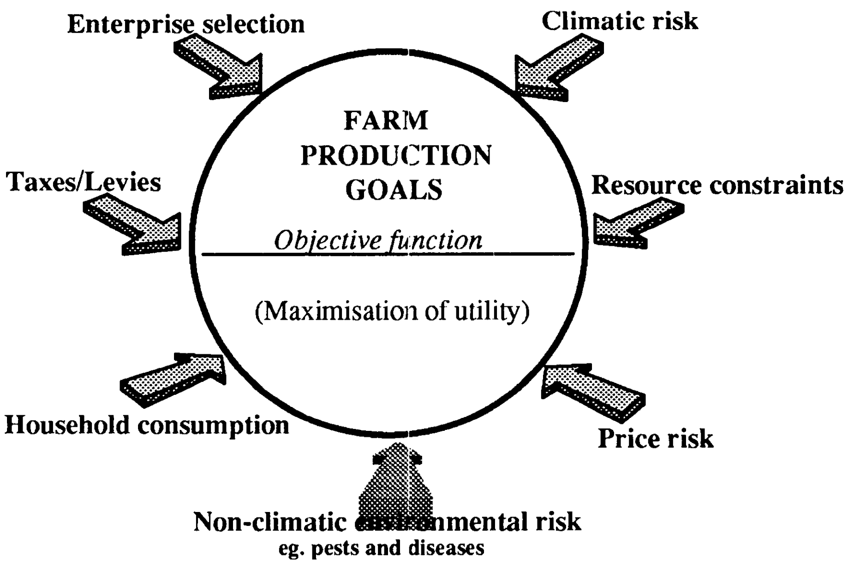

*Figure 5.1 : Main features of the farm models*

### *Farm production goals*

Farmers tend to pursue a variety of objectives simultaneously including farm profitability. In the long term, farming household welfare is affected if the farming operation is not profitable. The utility-maximising approach allows for the trade-offs in farm net revenue required to stabilise farm income.

### *Enterprise selection*

Although not all potentially feasible cropping and livestock alternatives are included in the models, there is still a wide range of activities and enterprises to impart sufficient flexibility within the models with regard to enterprise selection. Differences in the timing of planting reflected for crops including wheat, barley, linseed and canola also allows for greater flexibility within the models.

### *Resource constraints*

The key resources that may constrain production include land, labour and capital. Some flexibility is introduced into the land constraints by differentiating land into arable, native and improved pastures. Changes in the usage levels of fertilisers are assumed to be reflected in the subjective scaling procedure applied to yield data.

The sources of labour on each farm include owner/operator labour, permanent hired labour and casual labour. Allowance was made for acquiring additional labour units of labour as required.

In the computation of the farm budgets fixed capital items such as plant, machinery and buildings are accounted for as real costs apportioned to the various categories of crops, livestock and haymaking. Additional finance may be obtained from lending institutions at the prevailing market rate of interest.

### *Risk and uncertainty*

Generally, the variability of farm household income results from changes both in commodity prices and in production relationships. The former is a result of the inherent nature of agricultural commodity markets whilst the latter results from the vagaries of the climate and the influence of pests and diseases on commodity yields. These uncertainties result in a variation in the distribution of returns to the farm household. The influence of these elements of uncertainty were reflected in the models by the subjective scaling of historical price and yield data based on a triangular distribution. Each scaled data point is then considered as a state-of-nature to reflect stochastic variability.

With regard to their risk attitudes, the aversion to risk of all the respondent farmers was evident from the results of the elicited preference intervals following King and Robison (1981, see Section 4.6.1).

### 5.2.2 Matrix structure

An initial step in the development of the utility-efficient programming model used in this study was the construction of a linear programming model.

The basic mathematical programming model developed for each farm varied depending on the resource base as well as the major cropping and livestock-rearing activities on each case farm. However, the general matrix structures were similar and comprise three main segments viz. production, behavioural and finance. The matrix sizes varied from the 80 by 76 matrix of case farm three to 92 by 77 for case farm five. The basic structure of each matrix as exemplified by case farm one is depicted in Figure 5.2. The description of various aspects of each matrix follows.

#### *Objective function*

The objective function maximised in the models is the subjective expected utility of the net return to farm household resources. This income measure is equal to net farm income before tax. In essence, the models are specified to maximise the certainty equivalent of net farm income subject to various production constraints. The certainty equivalent is the certain rate of return that would make an individual indifferent between an existing farm plan and a portfolio including a risky new technology such as Linola. To handle the usual stochasticity prevalent in farm cash-flow positions through the production year, a stochastic formulation involving the cumulation of variable costs and returns in three cash flow periods was adopted. It was assumed that most of the farm costs occur in the first two periods and can be treated as deterministic given that these costs are unlikely to change significantly in the short term. However, returns in the third period, which are influenced by output price changes, are treated as stochastic and the net revenue for each activity is calculated in the model for each of the 25 states of nature assumed. The total net revenue for each state is computed through 25 counting activities which collect the net revenues for each state into the objective function. This was accomplished by multiplying all entries in the objective function by the probability of occurrence of each state. Thus, the variability in returns to crop and livestock activities on each case farm is reflected in the objective function which provides the link between the different states. Such a formulation allows the models to capture the inherent production risk in the modelled farms in a simplified DSP approach solvable via the UEP formulation .

Given that expected variable costs (here defined as cash expenses attributable to an activity excluding labour costs) are determined largely by the type of production activity

## *Figure 5.2 : Basic outline of LP matrices - case farm one*[a]

| | Production activities | | | | Other activities | | | Financial activities | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 14 cropping activities | 9 pasture and related activities | 5 livestock raising activities | 6 feed transfer activities | 9 supplementary feed buying and selling activities | 2 equipment hiring activities | 9 labour hiring activities | 3 borrowing activities | 25 income counting activities | Sign | RHS |
| *Objective function:* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | probability of occurrence of each state (.04) | | |
| *Constraints:* | | | | | | | | | | | |
| 4 land use constraints | 1 | +/- | | | | | | | | ≤ | A |
| 8 rotational constraints | +/- | | | | | | | | | ≤ | 0 |
| 2 livestock production constraints | | | + | | | | | | | ≤ | 0 |
| 8 feed supply constraints | - | - | + | +/- | | | | | | ≤ | 0 |
| 4 supplementary feed production constraints | | - | + | | +/- | | | | | ≤ | 0 |
| 3 equipment constraints | + | + | | | | + | | | | ≤ | 0 |
| 9 labour availability constraints | + | + | + | | | | -1 | | | ≤ | L |
| 6 casual labour maximum constraints | - | | - | | | | | | | ≤ | 0 |
| 2 deterministic cash balance constraints | +/- | +/- | +/- | | | | | | | ≤ | -C1 |
| 25 stochastic cash balance constraints | +/- | +/- | +/- | | | | | | 1 | ≤ | +/-C2 |
| 3 capital availability and usage constraints | | | + | | | | | +/- | | ≤ | K |
| 1 Linola constraint | (0/1 for Linola) | | | | | | | | | ≤ | 0 |

[a] + or - indicates the sign of the matrix element, A is the amount of available land, L is the available labour in the designated period, + or -C indicates a cash or borrowing requirement, and K is limit on borrowings in cash balance periods.

and farm type (bio-physical), and the earlier stated assumption about the homogeneity of the farms, it follows that unit variable costs for each activity are assumed to be similar for all farms. Variable costs enter the matrix in the cash flow segment and also in the computations of the objective function net revenues or gross margins. Fixed costs have been assumed to have no impact on production decisions though it is recognised that fixed costs will matter for non-risk neutral decision makers or those who do not exhibit constant absolute risk aversion. Crop activity net revenue budgets for each farm using the mean values of the corrected data are provided in Appendix Tables A11-A15.

### *Activities*

The unit of each production activity is a hectare for specified cropping and pasture activities and a head of stock for livestock activities. By the nature of mathematical programming, each production activity implies a fixed technology (assumed to be the common one current in the district) which is reflected as a unique combination of input-output and yield coefficients. Past changes in production technique affecting yields used to define the states of nature were assumed to be accounted for by detrending the annual historical data as described in Chapter 4. The end-product of each activity was assumed to be sold at harvest with the consequence that alternative marketing strategies are generally not provided for in the models. Options for on-farm usage or off-farm disposal are however considered with regard to hay and straw.

The enterprises and activities included in each model represent the regular cropping and stocking options on the farms under consideration. Since these vary from farm to farm, the matrices vary in size between the case farms. No consideration has been given to irregular opportunistic production of crops or livestock. Figure 5.2 is an outline of the structure of the matrix for case farm one. A listing of all activities and constraints included in the farm models is provided in Appendix Table A9.

The major crops grown include, in no particular order, wheat, ryegrass seed, barley, triticale, linseed, Canola, oats (grain and forage) and sunflower. Improved pastures are mainly sown to sub- and/or white clover and lucerne sometimes mixed with phalaris. The option of double-cropping has not been considered in the models because it is not a common practice in the district.

In each matrix, cropping and pasture activities form the first group of activities. Either early or late wheat could be grown after oilseeds. Early wheat is sown in May/June and late wheat crop sown in late July to early August. Based on the literature regarding the yield effects of oilseeds (e.g. Kearns 1991; Ralph 1992; Anderson 1992; Slatter and Good 1992; Victorian Farmers Federation 1993) and information obtained from interviewing farmers and VDA officials, the following assumptions were made: 1) historical and yield data obtained from farmers is the yield for wheat after oilseeds and legumes; and 2) wheat planted after wheat results in 10% reduction in yield. As discussed in Chapter 2, these yield effects are a result of the break provided by the oilseed and legume crops that helps to control take-all and cereal cyst nematode. These assumptions were used to compute the objective function net revenues. The technical coefficients were assumed identical for all wheat crops with the only difference being the timing of farm operations. Price correlations were not explicitly considered in the models. It was assumed that by maintaining the stochastic dependency in the historical data any inherent correlations would be maintained.

With regard to the oilseed crops, provision was also made for the early and late sowing of linseed and Canola following the usual practice of farmers in the district. Early sowings of both crops occur in April/May and late sowings in August/September. Each model was run with and without the Linola activity. Although, as discussed in Chapter 2, Linoflax has potential for use in the production of paper products, this has not been considered in the models because it is not a commercial option for the farmers at present.

GrClov1 is clover grazed in summer when its feeding value is highest and GrClov2 is clover similarly grazed in spring. HayClov1 and HayClov2 are respectively clover crops baled for hay in spring and summer.

The next group of activities is the livestock activities. All the models include some type of sheep - self-replacing Merino flock, fat lamb production and/or wether production. With beef production on case farms four and five, the main activities include vealer, weaner, steer and fattener production. Case farm one includes broiler production on an 'all-inputs-supplied' contract basis such that only the farmer's labour and management are required inputs into the enterprise. Except for case farm three that runs only annually bought-in wethers, all other farms have four sheep rearing activities: Merino, FstCrs, Wether1 and Wether2.

The representation of sheep production on each farm is based on a 'simplified' reconciliation assuming the basis of the flock to be Merino and/or first-cross ewes - simplified in the sense that wethers, hoggets, ewes and rams were not disaggregated into relevant age groupings. Production data and budgets that form the basis of each model are presented in Appendix Tables A11-A15. The Merino activity comprises a self-replacing merino ewe flock producing lambs, hoggets and wool. For the purpose of the models, the definition of 'first-cross ewe' is five-year Merino ewes transferred for breeding with mainly Border Leicester or Dorset Horn rams to produce first-cross (fat) lambs which are usually all sold. The Wether1 activity is the raising of bought-in wethers and Wether2 is the raising of farm produced wethers from a self-replacing merino ewe flock. A 50:50 ratio of wether to ewe lambs was assumed. Of the wether lambs, either they are all sold off or 75 per cent are sold with 22 per cent transferred to the wether flock. Twenty per cent of the wether flock is culled for sale annually. Three rams are run per hundred ewes. Twenty-five per cent of rams are assumed culled and replaced by bought-in stock annually. The modelled sheep enterprise relationships for self-replacing flocks on the case farms used in the computation of the activity budgets are depicted in Figure 5.3. None of the case farms produce stud rams and second-cross or prime lambs so these options were not considered in the models.

Revenue from the sheep activity comes from the sale of wool, lambs, cull ewes, cast-forage ewes and rams. Associated costs include the cost of bought-in rams, wethers and maiden ewes, stock selling costs, shearing and veterinary costs. The livestock activity budgets for each of the case farms are provided in Appendix Tables A11-A15.

The breeding cattle activity on the relevant case farms is depicted in Figure 5.4. The cattle budgets which form the basis of the cattle production activity modelling are presented in Appendix Tables A14 and A15. Breeding cows may be bred to Belgian Blue, Limousin, Hereford or Angus Bulls to produce progeny. Maintaining pure lines of stock is not a consideration in the models. A 50:50 ratio of male to female calves is assumed. Fifteen per cent of breeding cows are culled annually as are 33 per cent of bulls. Heifers may be used as replacements or sold. Replacements are usually joined at 15-18 months to calve for the first time at about 24 months. Male calves may be sold as weaner steers, vealers or store cattle. Generally, three bulls are run per hundred cows.

Beef production costs include selling costs, dipping for lice control and veterinary costs, cost of bought-in bulls and growth promotants as detailed in the relevant budgets in Appendix Tables A14 and A15. These costs were apportioned to each of the designated cash balance periods as appropriate.

Next there are feed transfer activities for the two classes of feed, high quality (G-feed) and total feed, (T-Feed). The sources of feed for these feed classes include forage, natural pasture, improved pasture (clover or lucerne), which is mainly baled for hay, and cereal stubble. Baled hay from hay making activities and forage oats supply feed to the high quality feed pool and natural pasture and cereal/legume stubble supply poor quality feed to the total feed pool. These activities allow for the inter-season transfer of feed

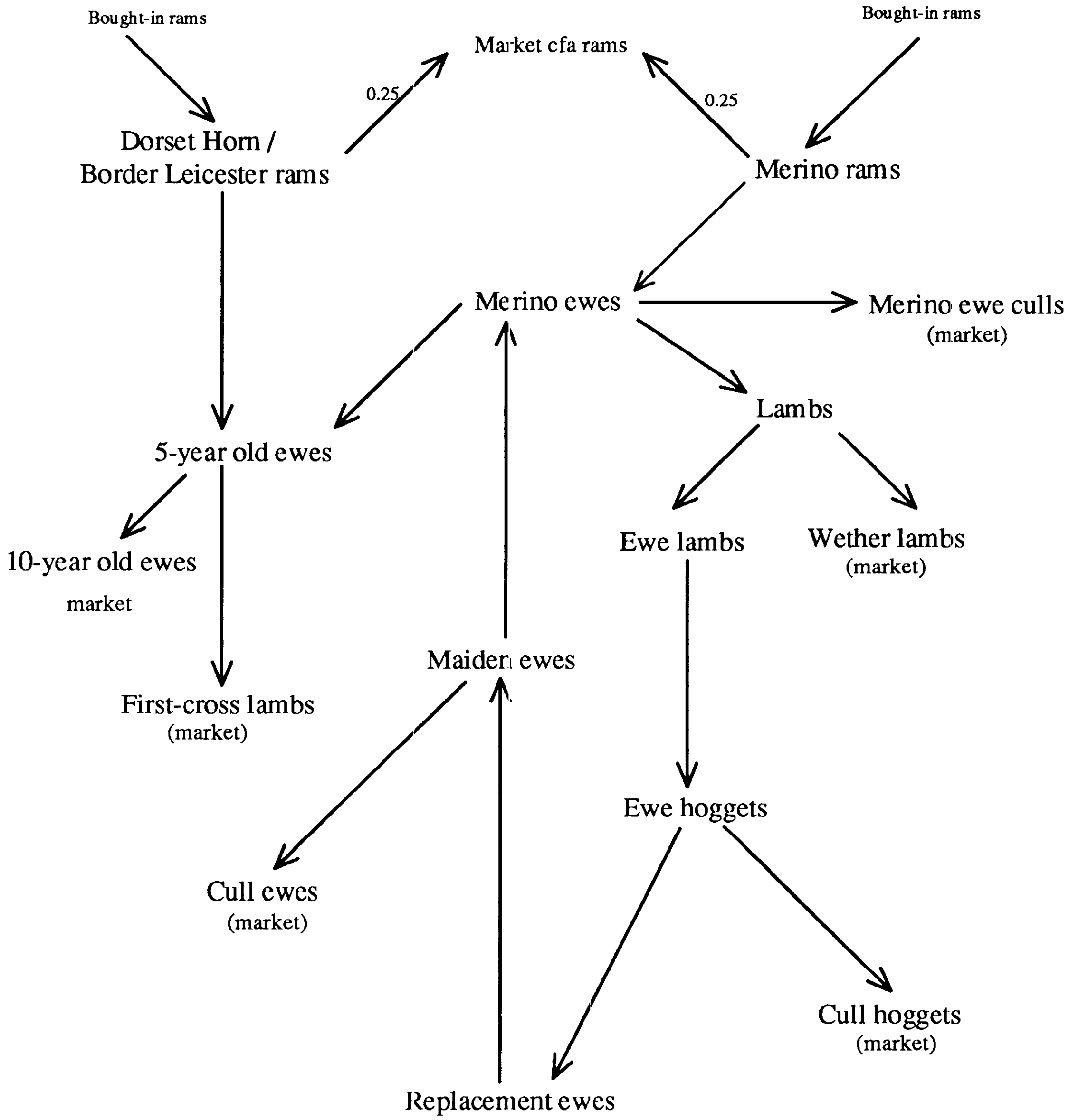

*Figure 5.3 : Schema of sheep activities on case farms*

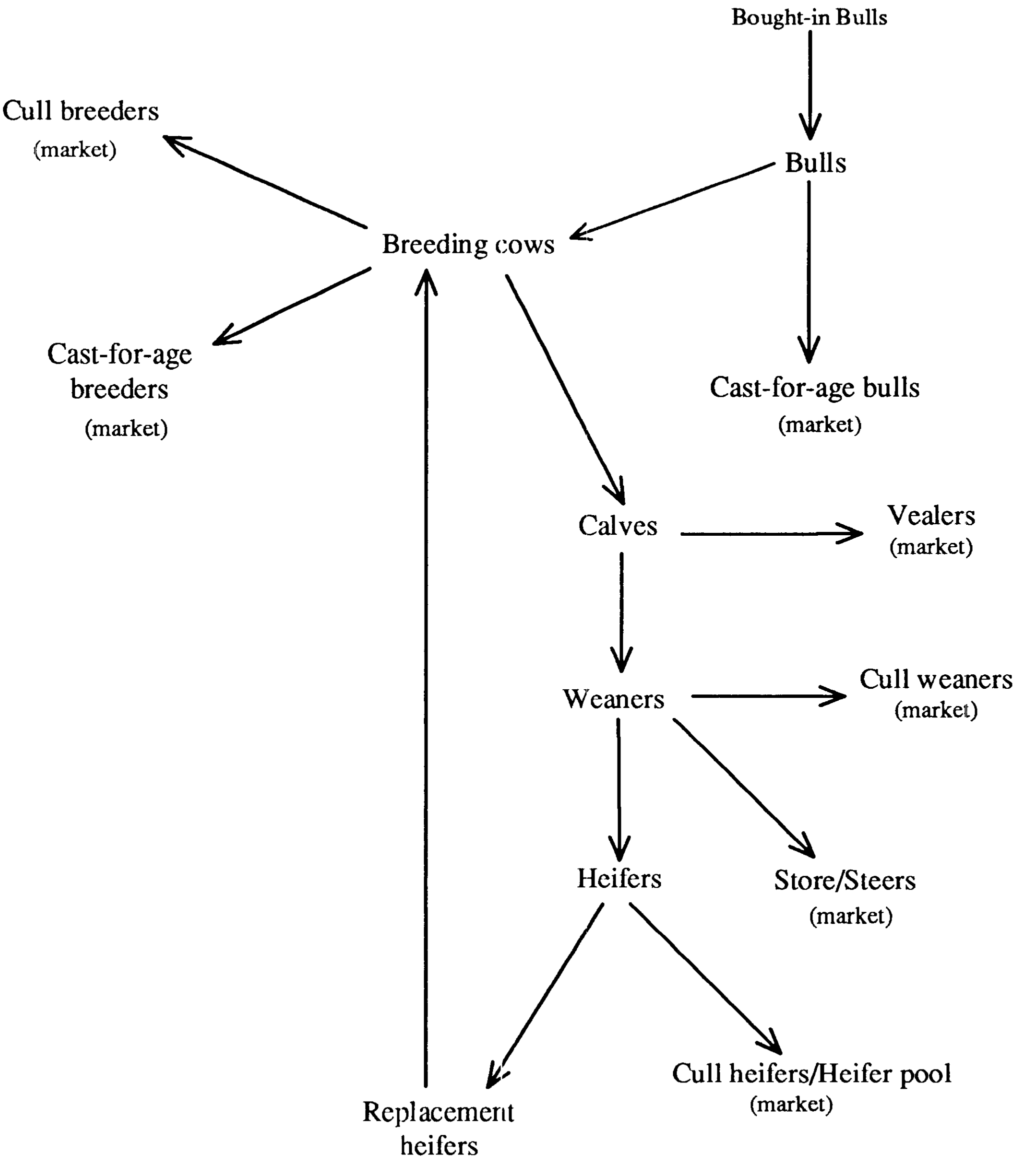

***Figure 5.4 : Schema of cattle enterprise on relevant case farms***

resources with allowances made for declines in feed quality of transferred feed. No feed was assumed transferred from the winter period, which is usually the time of greatest feed shortage.

Except for farm four, all farms have options to agist out natural pasture land via an Agistmt activity. Costs charged to this activity include labour and material costs of fence maintenance and provision of watering facilities.

Hay was assumed to be baled in spring and summer from good quality hay-producing crops, mainly clover and lucerne. It was assumed that the average bale of hay weighed 50 kg and contained 90 per cent dry matter (DM) i.e. 45 kg DM. Then, following Rickards and Passmore (1977), it was assumed that a bale of 45 kg DM provides 1.8 livestock month (LSM) of metabolisable energy. A livestock month is the feed energy requirement of a standard sheep in 30 days. A standard sheep is 50 kg dry sheep grazing medium quality pastures at maintenance.

The next group of activities relates to the buying, selling or use of straw and hay. It was assumed that the quality of bought-in hay/straw is similar to that conserved on the farms for hand feeding. Straw may be baled in summer after harvest of cereal crops. Cereal/legume stubble may be grazed in-situ by stock or baled for later feeding or sale. Cereal stubble was assumed to supply poor quality feed providing 1.27 LSM per 45 kg DM. Thus, a 50 kg bale of straw containing 90 per cent DM was estimated to provide 1.27 LSM. Allowing for mechanical losses from trampling and faecal contamination as well as due to biological decay, cereal stubble was estimated to supply on average 21.59 LSM/t. Based on the earlier yield assumption, a second wheat crop was assumed to produce 10 per cent less stubble and so supplies 19.43 LSM/t. Stubble from legumes was assumed to be medium quality feed containing 80 per cent DM and 65 per cent utilisation as a result of controlled grazing required to reduce the dangers of phomopsis-related diseases in livestock. Thus, legume stubble supplies 17.33 LSM/t. Purchase prices of hay and straw are assumed to exceed sale prices by marketing and transaction costs, to reflect normal market circumstances and to preclude unbounded solutions or solutions with the farmer simply buying and selling for profit.

Two activities are included to allow hiring-out of farm equipment in summer and winter. It was assumed that hired equipment will include the tractor. Hence tractor hours are allocated to the hiring out of equipment in summer and winter.

The next group of activities includes nine labour hiring periods. It was assumed that extra casual labour could be hired at current wage rates.

Three borrowing activities to supplement cash as needed to finance short-term operations are included in the models for the two deterministic cash flow periods (Borr1 and Borr2) and for livestock capital (LvCap). No attempt has been made to differentiate the sources of credit, hence all credit was assumed to be obtained at the same annual interest rate of nine per cent. Borrowed funds are assumed to be paid back in the following period and the trading year was assumed to start in March when preparations begin for a new production season and when most accounts from the previous year are assumed to have been settled.

The final 25 activities represent the cash balances in each of the 25 states of nature assumed for this study.

### *Constraints and RHS values*

The first three constraints represent the availability of land, described as arable, improved pasture and natural pasture. Homogeneity in the quality of each class of land was assumed. Grazing land has not been separated into sheep and cattle grazing where both types of livestock are kept, mainly because this is not a common practice but also in order to retain some flexibility in the models. The right hand side values for each of the land categories were obtained from the respondent farmers and exclude areas developed for farm buildings and other uses. One constraint, with an operator-indicated limit, is introduced to restrict the agistment of land (except for farm 4) under native pasture.

The system of crop rotation on these farms was considered a major aspect of the preservation of both the physical and chemical structures of the soil as well as the ecobiological aspects. For these reasons, the rotation system for each case farm was given careful consideration in the formulation of the farm models. The next group of constraints therefore comprises rotational constraints handled via the 'permission-to-grow' rotational constraints approach, in the manner discussed by Hardaker (1979). In consequence, the level of each cropping activity is determined in the model according to the imposed rotational constraints based on the prevalent farming system in the district. Oilseed crops are rotationally linked to cereals as are the legumes, field peas and lupins. Cereals cannot be grown for more than three successive years after oilseeds or legumes. Wheat, early or late sown, may not be grown more than two years in succession. First-crop wheat may be sown either after oilseeds or a legume. The first wheat crop permits a second wheat crop. Triticale is limited to one year in three. Oilseeds, like legumes, are limited to no more than 25 per cent of the total sown area. Canola is limited to 10 per cent of the total sown area to satisfy general contract conditions.

As appropriate, an absolute limit was imposed on broiler production for case farm one based on the maximum broiler housing capacity in the short term. Limits were also placed on livestock numbers as indicated by the farmers based on current labour and land availability. One farmer indicated the limit to be a drought stocking strategy to minimise potential stock losses should a drought occur.

There are four designated season-specific feed periods in which the supply and demand for feed by the livestock is in livestock months (LSM). In each period, the activities which directly or indirectly provide livestock feed do so through two feed pools, a good quality feed and a total feed pool. G-Feed (spring, summer, autumn, winter) is the supply of high quality feed from pasture - clover, lucerne or forage oats. These crops supply energy in LSMs to the good feed and total feed pools - GrClov1 supplies 32.92, 67.41 and 39.93 LSMs per hectare respectively in spring, summer and autumn; GrClov2 supplies 57.61, 47.19 and 39.93 LSMs per hectare in spring, summer and autumn. Feed supply to the good feed and total feed pools is on a per hectare basis.

Demand for feed was apportioned to stock on the basis of the productive state or purpose of the stock. To account for increased needs of lactating and fattening stock, their feeding is supplemented by high G-Feed. Dry sheep, wethers and store cattle are mainly fed on lower quality feed from natural pasture and stubble. The second feed pool is defined to include both high and lower quality feed. Sources contributing to total feed but not to high quality feed include natural pasture and grazed cereal/legume stubble.

The next group of rows in the models relates to hay and straw production and utilisation. The Haytie and BaledStr rows account for the supply and use of these commodities. Allowance was made for supplementary feeding in the models incorporating cattle production using bought-in hay, barley or oats as appropriate. This representation ensures sufficient flexibility and diversity in the sources of nutrition for the livestock on each farm. It was assumed that spring-baled hay produces an average 115 bales (5.75 t/ha) per hectare and summer-baled hay produces 140 bales (6.95 t/ha) per hectare with a similar LSM value of 1.8. The potential benefits of 'flushing' or strategic supplementary feeding of ewes and cows have not been considered in the models. An example of the general structure of the feed transfer sub-matrix is provided in Figure 5.5.

## *Figure 5.5 : Feed supply, transfer and usage sub-matrix*[a]

| | | | | | | | | | Feed transfer | | | | | | Feed utilisation[b] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit | Crop activity | GrClov1 | GrClov2 | HayClov1 | HayClov2 | Natpas | Livestock activity | SprSm Ft1 | SmAut Ft1 | AutWn Ft1 | SprSm Ft2 | SmAut Ft2 | AutWn Ft2 | FdHyAut | FdHyWin | SelHay | BySpWin | Sign | RHS |
| Obj. function[c] | | +$ | -$ | -$ | -$ | -$ | -$ | +/- $ | | | | | | | -$ | -$ | +$ | -$ | | |
| Constraints: | | | | | | | | | | | | | | | | | | | | |
| Arabl | ha | 1 | | | | | | | | | | | | | | | | | ≤ | A |
| Graze1 | ha | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | ≤ | B |
| Graze2 | ha | | | | | | 1 | | | | | | | | | | | | ≤ | C |
| GSprFeed | LSM | | -32.92 | -57.61 | | | | $m_{1sp}$[e] | 1 | | | | | | | | | | ≤ | 0 |
| GSumFeed | LSM | | -67.41 | -47.19 | | | | $m_{sm}$ | -0.6 | 1 | | | | | | | | | ≤ | 0 |
| GAutFee | LSM | | -39.93 | -39.93 | | | | $m_{au}$ | | -0.85 | 1 | | | | -36 | | | | ≤ | 0 |
| GWinFeed | LSM | | | | | | | $m_{wn}$ | | | -.7 | | | | | -36 | | | ≤ | 0 |
| TSprFeed | LSM | | -32.93 | -57.61 | | | -36.30 | $m_{2sp}$ | 1 | | | 1 | | | | | | | ≤ | 0 |
| TSumFeed | LSM | $-S_2$[d] | -67.41 | -47.19 | | | -19.36 | $m_{2sm}$ | -0.6 | 1 | | -.6 | 1 | | | | | | ≤ | 0 |
| TAutFeed | LSM | | -39.93 | -39.93 | | | -14.52 | $m_{2au}$ | | -0.85 | 1 | | -.7 | 1 | -36 | | | | ≤ | 0 |
| TWinFeed | LSM | | | | | | -9.68 | $m_{2wn}$ | | | -.7 | | | -.6 | | -36 | | | ≤ | 0 |
| Haytie | t | | | | -5.75 | -6.95 | | | | | | | | | 1 | 1 | 1 | -1 | ≤ | 0 |

[a] Detailed activity listing with their acronyms are provided in Appendix Table A9.
[b] Only hay and related activities are shown. Similar activities are included for straw utilisation.
[c] +, -$= net return or variable cost.
[d] $S_2$ = stubble LSM supply to total feed and loose straw.
[e] $m_1$, $m_2$= Feed demand from good and total feed pools - LSM/hd.

A single constraint is introduced for the available tractor hours to maintain the existing flexibility in the use of tractors on the study farms. The available tractor hours and usage are computed based on a single 95 kW PTO tractor taking account of down times. Two related constraints are introduced for the hiring out of farm equipment in summer and winter with operator-imposed limits as RHS values. These limits were set to prevent interference with the timeliness of farm operations on the case study farms.

Following this group are 15 labour-related constraints pertaining to the nine delineated labour periods and casual labour limits described in Chapter 4. The use of family labour is considered only to the extent of adding the estimated hours of family labour available through the production season to the total labour supply in the appropriate labour period. The labour periods, which are simple, non-nested periods, were delineated based on a Gantt-chart type representation of activities during the production year elicited via the questionnaires. The delineated periods were deliberately selected to be fairly broad so as not to unrealistically restrict the planning of the seasonal use of labour in the models. Shorter periods were chosen for critical farming operation. The delineated periods and the common activities in the case study farms are provided in Table 5.1.

While all case farms were owner-operated, the need existed for hiring labour, particularly at times of labour bottle-necks such as during harvest, planting and sheep shearing. Whilst no absolute constraints were placed on the hiring of extra labour for farming operations, a 'permission-to-hire' mechanism was introduced for some activities based on levels indicated by the operators. Wheat harvesting generally required extra labour hours as did sheep shearing and marking. Expected labour hiring costs were allocated to each period in the corresponding cash flow period.

The existence of sufficient flexibility in the use of labour to enable easy switching between crop and livestock production requirements because of a lack of specialisation was assumed, hence no attempt was made to differentiate between livestock and cropping labour.

During the course of the production year on the farm, there is a characteristic ebb and flow of capital as a result of commodity or stock sales, borrowings and the defraying of variable costs, overheads, interest and principal payments, personal and other taxes as well as household consumption. Together, these influence the operations on the farm in various ways. The next group of constraints represents the annual cash flow or cash balance which is seasonally delineated into three; Cash1 measuring the cash balance on 1

**Table 5.1 : Delineated labour periods and activities on case farms**

| Period | Span | Activity |
|---|---|---|
| 1 | April-May | Fencing, paddock preparation, sowing, lambing |
| 2 | June | Sowing, lamb marking |
| 3 | July-August | Sowing, sheep crutching, equipment/fence maintenance |
| 4 | September-October | Equipment/machinery maintenance, shearing, stock treatment for external parasites |
| 5 | November | hay baling, ewe tupping and cow servicing, harvesting |
| 6 | December (early) | Harvesting, stock sale |
| 7 | December (late)-January early | Harvesting, fly control (sheep) |
| 8 | January (late)-February (early) | Harvesting, drenching/dipping |
| 9 | February (late)-March | Stubble carting/burning, paddock preparation, shearing |

June and covering March to May, Cash2 measuring the cash balance on 1 December, covering April to November, and Cash3 measuring the cash balance on 1 March, covering December-February based on the timing of monetary transactions during the production year. The cash balance for each date also incorporates the capital required to service fixed farm resources as well as the defraying of private expenditure. The cash balance between each period is cumulated from the previous cash period, implying that the 'end of year' balance in 'period 3' equals the net return. Cash periods one and two are treated as deterministic whilst the third period is treated as stochastic in recognition of the fact that, under uncertainty, the level of cash balances at the end of the production year is dependent on the state of nature. This introduces an aspect of a simplified DSP approach that is amenable to solution via the UEP formulation since the final cash balance in period 3 equates to the net cash surplus.

The RHS values for cash period one include the funds carried over from the previous season, as estimated by the farmer, less the estimated total pre- and early-season requirement for working capital. The RHS values for the other cash constraints show the seasonally apportioned overheads for the farm (including cash drawings).

The next three rows of the matrices reflect the restriction on short-term borrowing. Rather than being set by the lending institutions, however, the borrowing limitations are based on limits set by the producers themselves. All interviewed farmers indicated that funds for carry-on finance would not be borrowed beyond 7-12 per cent of their estimated walk-in, walk-out property values excluding livestock trading capital requirements which are assumed in the models to be equal to the value of existing stock. Figure 5.6 provides a depiction of a typical example of the cash balance sub-matrix used.

Although capital items such as new farm machinery may influence production activities through the expansion of farming capacity and improvement of economic efficiency, such investment decisions are of a long-term nature and have not been included in these models which are constructed to represent the annual farm production cycle.

The final row of each matrix allows the activity, Linola, to be turned on and off.

### *Input-output coefficients*

Technical coefficients used in the models are those related to grazing land, cropped land(s) and labour/feed use in the designated labour/feed periods. All coefficients are expressed on a per unit of production activity basis. Labour is expressed in person-hours per unit and feed in livestock months (LSM) per period. While it is recognised that differences in soil characteristics and stock management expertise on farms can result in variations in the technical coefficients between farms, it was necessary for the purposes of this work, due to a lack of research resources, to assume identical technical input-output coefficients. This assumption was based on the premise that all case study farmers had been involved in farming for over 15 years and, as such, should have achieved an average level of technical efficiency.

## Figure 5.6 : Cash balance sub-matrix[a]

| | | | Production activities | | Net cash surpluses | | | | | Borrowing activity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Constraints | Unit | Sign | Crop activity | Livestock activity | CsSta1 | CsSta2 | CsSta3 | ... | CsSta25 | Borr1 | Borr2 | LvCap | RHS |
| Obj. function→ | | | -/+$ | -/+$ | .04 | .04 | .04 | ... | .04 | | | | |
| Cash1 | -$ | ≤ | $VC_1$ | $VC_1$ | | | | ... | | -1 | | | -W1 |
| Cash2 | -$ | ≤ | $-GR_2+VC1$ | $-GR_2+VC1$ | | | | ... | | 1.02 | -1 | | -W2 |
| Cash3S1 | -$ | ≤ | $+/-NR_{s1}$ | $+/-NR_{s1}$ | 1 | | | ... | | 1.02 | 1.04 | .09 | -W3 |
| Cash3S2 | -$ | ≤ | $+/-NR_{s2}$ | $+/-NR_{s2}$ | | 1 | | ... | | 1.02 | 1.04 | .09 | -W3 |
| Cash3S3 | -$ | ≤ | $+/-NR_{s3}$ | $+/-NR_{s3}$ | | | 1 | ... | | 1.02 | 1.04 | .09 | -W3 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| Cash3S25 | -$ | ≤ | $+/-NR_{s25}$ | $+/-NR_{s25}$ | | | | ... | 1 | 1.02 | 1.04 | .09 | -W3 |
| LimCap1 | $ | ≤ | | | | | | ... | | 1 | | | +C1 |
| LimCap2 | $ | ≤ | | | | | | ... | | | 1 | | +C2 |
| LivCap | $ | ≤ | | +CL | | | | ... | | | | -1 | 0 |
| LimLvCap | $ | ≤ | | +CL | | | | ... | | | | 1 | +K |

[a] Detailed activity listings with their acronyms are provided in Appendix Tables 9a and b; $GR_2$ indicates cumulative cash balance in Cash2, $VC_1$ indicates variable cost in period one, $NR_{s1}$ indicates cash surplus in Cash3, state 1, CL is stock purchase price, W1, W2, W3 are cumulative capital requirements in each stochastic cash period.C1, C2 are respectively limits on borrowings in Cash periods 1 and 2, and K is the limit on livestock trading capital.

### 5.2.3 Validation and verification of the model

Testing a developed model for functionality, reliability and accuracy in depicting the workings of the system it was intended to reflect is an important aspect of the modelling process. Since modelling of systems is not an exact science, the consistency of performance of the basic assumptions needs some scrutiny. Model verification is achieved when the result obtained from the model is consistent with certain *à priori* criteria dictated by practice and theory. In essence, the logical consistency of the model with regard to the system needs to be examined. Apart from structural 'defects' in the model, physical errors involved in data entry are also important aspects of the verification and debugging process. Although the packages used in solving the models, including GAMS (Brooke, Kendrick and Meeraus 1988) and GULP (Pannell 1993), have advanced data handling and processing facilities, certain errors, such as wrong signing or misplaced coefficients and typographics, still had to be physically verified by carefully ‘eyeballing’ and cross-checking entries.

To limit errors of data entry, all data manipulations and relevant computations were done on an Excel spreadsheet from which the matrices were then exported in text format as GAMS input files. Also, cropping options in the various solutions were verified to be consistent with permissible rotational constraints. A sensitivity analysis was performed on the value of the objective function with changes in the technical coefficients, RHS values and the objective function values to ascertain data reliability as well as the stability of the various optima.

Validation of the models depends on their validity in representing the systems they were intended to depict and their usefulness, in this instance, as decision making tools for the case farms in question. Questions need to be asked about how well the system is represented and whether or not the results obtained are logically consistent. According to Dent, Harrison and Woodford (1986), these questions are subjective and model validation has to be a continuing process that may sometimes require refinements to the original model based on its performance in achieving its fundamental goal of assisting with decision making as well as policy initiatives. Whereas verification may be measured in absolute terms, validation can only be a relative assessment of specified objectives.

Following the suggestion of Dent et al. (1986), validation of the models involved forcing into the models the current activity levels on the case farms modelled and comparing the resultant objective function and resource usage levels. This approach created infeasibility problems for models 3 and 5. This was observed to be a result of the cash constraints in the cash flow segment of the matrix. As a result, the model was reformulated with changes in the working capital requirements. These were then discussed with the relevant farmers and the necessary adjustments were made to obtain results consonant with current resource allocation patterns on the farms. To ascertain their true representation of the farms being considered, the models were constantly reviewed and adjusted in consultation with the study farmers and the expert informant until they were adjudged to be satisfactory representations of the study farms.

## 5.3 Risk programming model

### 5.3.1 Choice of model

Despite significant developments in risky decision analysis in the last couple of decades (Dillon 1971; Anderson 1977; Anderson and Dillon 1992), Anderson (1975) has tersely noted that there evidently exists no panacea in the field of mathematical programming for risky planning. Much of the work in the area has been aimed at seeking methods that identify and order efficient plans with few theoretical and practical limitations. According to Anderson (1975), realism, accuracy and adequacy of alternatives should be the paramount consideration in deciding how risk is to be specified in a programming model.

Hardaker et al. (1991) have noted that, by its very nature, agricultural production requires that sequential decisions are made on a continuing basis. This implies some level of embedded risk (Hardaker et al.) for which discrete stochastic programming (DSP) may be the better mathematical programming option (Cocks 1968; Rae 1971a,b and Hardaker 1979). However, the problems associated with the availability and collection of data (for which a full DSP specification has a huge appetite), model tractability and dimensionality often preclude the specification of a stochastic model that reflects multiple sources and timing of risk. For these reasons, model abridgments may be required, particularly when research resources for data collection are limited as was the case in this research. As a consequence, despite its inability to fully handle issues of sequential decision making consonant with the recognised embedded risk in agricultural production, a simplified, less stringent DSP formulation in the form of UEP was thought to be adequate for the purposes of this study. Whilst recognising that some of the risk faced by the farmers in this study will be embedded, it was assumed that an adequate representation can be obtained by considering the variability in activity revenues per unit level without the need to consider the variation in the levels of the farming activities.

As discussed at length in Chapter 3, utility-efficient programming (UEP) allows identification of farmer 'preference efficient' farm plans which are also stochastically dominant (SDRF) farm plans. The approach also requires less information about producer risk attitudes compared to the Lambert and McCarl (1985) approach on which it is based and it is amenable to the use of various types of utility functions although Hardaker et al. (1991) emphasise use of the so-called separable 'sumex' function because of perceived attractive properties. The next section turns to the discussion of the choice of utility functions.

### 5.3.2 Choice of utility function

The decision of whether or not a single- or multi-attribute utility function best describes the farm being modelled usually poses problems as it determines the choice of mathematical programming approach. In many instances, a single attribute such as net farm income is taken to be the main variable determining decision maker utility. Herath et al. (1982), in their work with rice farmers in Sri Lanka, report that a single-attribute utility approach out-performed the multi-attribute approach.

Obtaining the utility-efficient set of farm plans must necessarily involve the use of a utility function (or approximation thereof) which is consistent with farmer preferences. As observed by Anderson et al. (1977), Lin and Chang (1978) and Musser et al. (1984), a myriad of algebraic forms can be fitted to data on the selected attribute. However, most empirical studies have emphasised the use of quadratic, cubic polynomial and exponential functions. Rae (1971a) observed that how well the chosen functional form represents the 'true' utility function of the decision maker will depend on the sensitivity of the optimal strategies to changes in the shape of the utility function. As demonstrated by Musser et al. and Zuhair et al. (1992), the choice of functional form is important in empirical applications of the EU hypothesis in as much as it can influence the categorisation of decision makers on the basis of their attitudes to risk.

Anderson et al. (1977) indicate that an acceptable algebraic form for the utility function should logically:

1) have strictly positive marginal utility (concave, monotonic);
2) exhibit decreasing risk aversion with increasing wealth;
3) be manipulatable and easy to work with.

Contrary to what is normally expected, despite widespread use in empirical investigations, quadratic and some of the higher polynomial utility functions fall short of the above requirements by exhibiting increasing aversion to risk with increasing wealth and also by not possessing positive marginal utility throughout their range.

Hardaker et al. (1991), Zuhair et al. (1992) and Anderson and Dillon (1992) have variously demonstrated that the negative exponential utility function, despite the implication of constant coefficient of absolute risk aversion, is useful and convenient for empirical investigations. The negative exponential utility function has the general form of:

$$U(W) = 1 - \exp(-r_a W) \qquad [5.1]$$

where $r_a > 0$ is the Pratt-Arrow measure of risk aversion (Pratt 1964; Arrow 1974). Being defined by only the measure of risk aversion, $r_a$, makes this functional form convenient for use in empirical work (Anderson and Dillon 1992). Arrow and Enthoven (1961) demonstrated that the desirable properties of this functional form allow the attainment of a global optimum in NLP formulation. Also, in a study of Sri Lankan crop producers, Zuhair et al. (1992) found that the negative exponential utility function out-performed the quadratic and cubic utility functions in predicting farmer decision making behaviour.

Pratt (1964) has shown that the coefficient of absolute risk aversion, $r_a$, uniquely represents the preferences of a DM and as a consequence, a restriction on $r_a$ should correspond to a restriction on DM preferences (Meyer 1977a,b). Such restriction of DM preferences forms the basis of both SDRF and UEP. As suggested in work by Ogisi, Hardaker and Torkamani (1994), if the SDRF criterion performs as proposed by Meyer (1977a,b), then the algebraic form of the utility function should be of no consequence in UEP formulations over a specified range of absolute risk aversion.

For the above adduced reasons and the implicit assumption of this study that the case study farmers are inherently risk averse, the negative exponential utility function is selected as a satisfactory functional form for the purposes of this work.

### 5.3.3 Model formulation

In the formulation of the model for the UEP model adopted for this study, it was assumed that risk in the constraint set is transferred into the objective function. To achieve the objectives of this work, the problem is formulated as a mathematical programming problem of the form:

$$\max \quad E[U] = \sum_{k=1}^{25} p_k [1 - \exp\{-r_a z_k\}] \qquad [5.2]$$

subject to

$$Ax \leq b$$
$$c_k x - Iz_k = uf$$

and $$x, z \geq 0$$

where A is an $m$ x $n$ matrix of input-output coefficients, $x$ is an $n$ x $1$ vector of activity levels, $b$ is an $m$ x $1$ vector of resource stocks, $c_k$ is an $s$ x $n$ vector of activity net revenue for state k, I is an $s$ by $s$, identity matrix, $z_k$ is an $s$ x $1$ vector of net cash surplus for the k*th* state, $p_k$ is a $1$ x $s$ matrix of the subjective probability of state k, $u$ is a $s$ x $1$ vector of ones and f is a scalar measuring fixed costs. A general outline of the UE matrix is shown in Figure 5.6.

The relationship between $\lambda$, $r_a$ and the upper ($r_1$) and lower ($r_2$) bounds of the risk aversion range for the utility function being considered is given by:

$$r_a = (1-\lambda)r_1 + \lambda r_2 \qquad [5.3]$$

From [5.3] the value of $r_a$ should vary between $r_1$ and $r_2$ as the parameter lambda is varied from 0 to 1.

The elicitation of producer preferences was carried out using the King and Robison (1981) interval approach as detailed in the previous chapter. The reported results of the elicitation process in Table 4.3 indicate that the five farmers used in this study display varying levels of absolute risk aversion within the range 5 x $10^{-3}$ to 1 x $10^{-4}$. Whilst case farmers one and three appear to exhibit constant aversion to risk over the income levels considered, case farmers two, four and five show an apparently non-constant aversion to risk. Following the Love and Robison (1984) assertion concerning the intertemporal stability of risk preference, it was assumed that the lower and upper bounds on $r_a$ may be approximated by the exhibited preferences around the usually experienced income levels between $14 000 and $23 000. King and Robison (1981) have noted that the narrower the range of the bounds of the risk aversion function, the more discriminatory will be the approach in terms of the optimal farm plans provided.

The optimal farm plan sought with the UEP approach must maximise the producer welfare or subjective expected utility based on a single-attribute, monotonic concave utility function subject to identified constraints. For this work, it was assumed that the producer's intent is the maximisation of the subjective expected utility of net farm income subject to various technical, personal, resource and institutional constraints. The developed model is solved using the non-linear algorithm MINOS-5 - Modular In-core Non-linear Optimisation System - (Murtagh and Saunders 1977) using stepwise variation of lambda, $\lambda$.

After the linear, risk-indifferent models were verified and validated for operational consistency and efficiency, transforming them to the UEP matrix involved incorporating a utility transformation to transfer the final balances of the twenty-five subjective activity net revenue vectors for each assumed equally likely year or state of nature to the objective function. A proper GAMS statement was then written to include the negative exponential utility function assumed for this study and the elicited upper and lower bounds of the risk aversion function for each of the respondent farmers. Several solve statements were written into the model to enable variation of lambda by .05 from zero to unity. An outline of the employed UE programming matrix is shown in Figure 5.7.

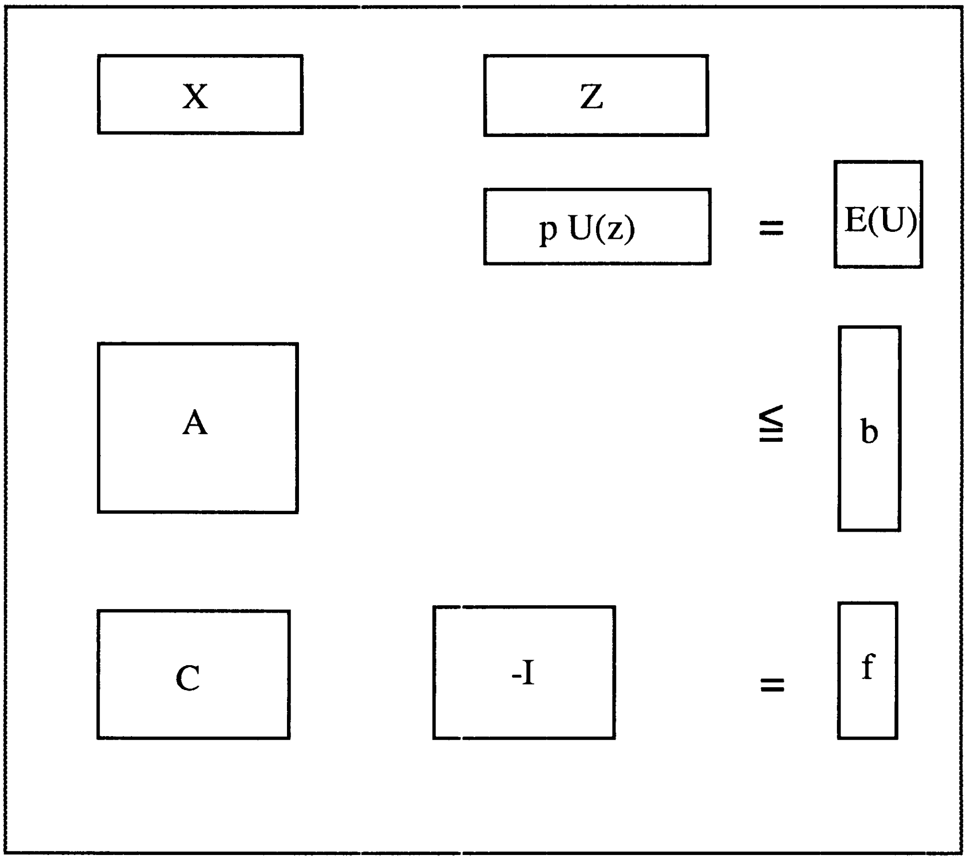

*Figure 5.7 : Schematic of the UE programming matrix*

# 6. Results

*'There is a tide in the affairs of men, which, taken at the flood, leads on to fortune'*

- W. Shakespeare

## 6.1 Introduction

The results of the models for each of the five case farms used in this study are presented in this chapter. In the first section, the result of the optimisation of each model is reported. Generally, about five groups of farm plans were generated for each study farm comprising two risk-indifferent with/without Linola, two utility-efficient with/without Linola and one run each of risk-neutral, profit maximising models using current activity levels on the farms. In the second section, the hypotheses governing the conduct of the study as indicated in the first chapter are tested on the basis of the empirical results of the risk-neutral and risk-efficient models. The reporting of results focuses on the impact of risk, as represented in the models, on the adoption of Linola technology rather than on the economic efficiency of resource allocation. Aside from the interest in whether or not Linola enters the risk-neutral and/or risk-efficient farm plans, the stability and sensitivity of the generated farm plans in each grouping are investigated. More comprehensive excerpts of the results may be found in the Appendix to this work.

## 6.2 Modelling results

The general results obtained for each of the modelled case farms are first presented in this section of the thesis. Following this, a few more specific modelling results and tests of the goodness-of-fit of some of these results are also presented. The reporting of the results concludes with the tests of the hypotheses that were set up to steer the course of the study.

### 6.2.1 General results

The modelling results from the observed, risk-neutral and utility-efficient models are reported and compared for each case farm. The emphasis of the reportage, in line with the objectives of this study, is on the potential for the inclusion of Linola in each farm plan rather than on the efficiency with which farm resources are utilised. This is because the models have not been set up for all potential activities in the district but for those being carried out currently (or in the recent past) on each case farm.

Summaries of the results of the actual strategies, risk-neutral and utility-efficient models for case farms 1 to 5 are presented in Tables 6.1 to 6.5. Based on farmer expectations and beliefs, Linola does not enter the optimal farm plan in any of the case farms in either the risk-neutral or risk programming models. For purposes of comparison, current activity levels were forced into the models. These results for each farm are also presented in Tables 6.1 to 6.5.

As expected, utility-efficient farm plans vary with the level of farmer risk aversion. Decreases in aversion to risk - equivalent to increases in the value of the parameter $\lambda$ - in the non-linear utility-efficient programming models apparently lead to the inclusion in the farm plans of risky cropping activities with higher net returns as may be observed in the risk-neutral solution.

The effect of the ranges of risk aversion used for each of the case farms is evident in the relative differences in the standard deviation and coefficient of variation of the UE payoffs compared with the risk-neutral payoff. As may be observed from Table 6.1 for farm one, as risk aversion decreases, there is a gradual increase in the expected payoff value from \$376 749 at a risk aversion level of $1.0 \times 10^{-4}$ to \$377 518 at $1.0 \times 10^{-5}$. The standard deviation of the payoffs ranged from \$30 429 to \$36 625 for the same risk aversion range. Triticale and lupins are progressively replaced by grazing oats in the optimal strategies with decreasing risk aversion up to a risk aversion level of $3.3 \times 10^{-5}$. There is a general reduction in the coefficient of variation of the payoffs (9.6 to 8.12 per cent), with increasing risk aversion which provides an indication of the payoff risk being traded off against expected income as would be expected for a risk-averse decision maker. This is true not only for farm one, but for all farms in the study except farm four in which the variation increased. As may be expected, both the observed and risk neutral solutions exhibit higher variation in the payoffs than the UE solutions over the risk aversion range considered for each study farm. In farm one, the provision of constant returns through the year leads to the inclusion of broilers up to the allowable maximum in the UE farm plans. Over the risk aversion range considered, the number of sheep tended to increase from 2444 to 2823 merino ewes with decreasing aversion to risk. For the feeding of stock, grazing clover progressively replaced clover baled for hay with decreasing aversion to risk. All available pasture land is utilised.

For case farm two (Table 6.2), a decreasing aversion to risk results in a progressive decline in the number of merino ewes raised. Spring-baled clover hay is replaced by summer-baled clover hay with decreasing aversion to risk. With crops, the areas sown to July-sown wheat, field peas and linseed generally tended to increase with decreasing risk aversion. The reverse was the case for grazing oats and canola sown in August. Up to the allowable limit of 80 h is allocated to baling hay off-farm and an increasing amount of stubble straw is baled for sale. Between the risk aversion levels of 5.0 x $10^{-4}$ and 3.04 x $10^{-5}$, up to 175 h of extra labour is employable in early December. The more risk averse strategies show a lower variation, as measured by the CVs, in the expected payoffs over the preference range considered. These range from 16.31 per cent to 19.52 per cent.

The results for farm three presented in Table 6.3 indicate that, with decreasing risk aversion between 1.0 x $10^{-4}$ and 1.0 x $10^{-5}$, barley is progressively replaced by July-sown wheat in the optimal portfolios. For this range of risk aversion, the expected payoff value ranges between $99 656 and $122 289 and the standard deviation of the payoffs between $32 413 and $41 892. For this farm, the variations of the payoffs for the observed and risk-neutral portfolios are higher than those of the UE portfolios for the risk aversion range considered. The areas sown to both linseed and lupins progressively increase with decreasing aversion to risk for the interval between 1.0 x $10^{-4}$ and 1.0 x $10^{-5}$. A decrease in the total number of sheep raised occurs with decreasing aversion to risk with a

## Table 6.1 : Case farm one - Actual, risk-neutral and utility-efficient solutions at various risk aversion levels

| | | | | Risk aversion level | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity[a] | Unit | Actual | Risk-neutral | 0.000100 | 0.000082 | 0.000064 | 0.000051 | 0.000042 | 0.000033 | 0.000019 | 0.000010 |
| WhtlEar | ha | 40.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Tritic | ha | 180.0 | 146.1 | 162.4 | 162.4 | 162.4 | 73.9 | 74.4 | 101.5 | 146.1 | 146.1 |
| Barley | ha | 120.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| GrazOat | ha | 0.0 | 113.9 | 77.1 | 77.1 | 77.1 | 112.4 | 116.7 | 120.5 | 113.9 | 113.9 |
| Lupins | ha | 0.0 | 130.0. | 119.7 | 119.7 | 119.7 | 93.2 | 95.6 | 111.0 | 130.0. | 130.0. |
| Linsed1 | ha | 60.0 | 19.6 | 20.8 | 20.8 | 20.8 | 20.5 | 0.0 | 19.9 | 19.6 | 19.6 |
| Linsed2 | ha | 0.0 | 58.4 | 51.1 | 51.1 | 51.1 | 35.4 | 57.3 | 46.7 | 58.4 | 58.4 |
| Linola | ha | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Canola1 | ha | 100.0 | 52.0 | 47.9 | 47.9 | 47.9 | 37.3 | 38.2 | 44.4 | 52.0 | 52.0 |
| GrClov1 | ha | 250.0 | 124.6 | 97.8 | 97.8 | 97.8 | 109.1 | 112.6 | 121.1 | 124.6 | 124.6 |
| HayClov1 | ha | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HayClov2 | ha | 100.0 | 255.5 | 282.2 | 282.2 | 282.2 | 270.9 | 267.4 | 258.9 | 255.5 | 255.5 |
| Natpas | ha | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 | 400.0 |
| Merino | hd(ewe) | 1200.0 | 2823.0 | 2444.0 | 2444.0 | 2444.0 | 2654.0 | 2702.0 | 2802.0 | 2823.0 | 2823.0 |
| FstCrs | hd(ewe) | 700.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Wether2 | hd(ewe) | 804.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Broiler | hd(x$10^3$) | 520.0 | 520.0 | 520.0 | 520.0 | 520.0 | 520.0 | 520.0 | 520.0 | 520.0 | 520.0 |
| SelHay1 | t | 867.5 | 1775.4 | 1961.5 | 1961.5 | 1961.5 | 1883.6 | 1858.4 | 1799.3 | 1775.4 | 1775.4 |
| BalHOff | h | 106.0 | 0.0 | 0.0 | 0.0 | 0.0 | 139.6 | 134.9 | 80.0 | 0.0 | 0.0 |
| BalCtStr | t | 186.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SelStrw | t | 186.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Borr1 | $ | 14941 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LvCap | $ | 100308 | 116685 | 101030 | 101030 | 101030 | 109690 | 111680 | 115830 | 116685 | 116685 |
| E(TNCB)[b] | $ | 303572 | 377517 | 376749 | 376749 | 376749 | 371762 | 371542 | 374376 | 377518 | 377518 |
| Std deviation | $ | 43009 | 36226 | 35789 | 35789 | 35789 | 30549 | 30429 | 32890 | 36225 | 36225 |
| CV[c] (%) | $ | 14.19 | 9.60 | 9.50 | 9.50 | 9.50 | 8.22 | 8.19 | 8.79 | 9.60 | 9.60 |

[a] A full listing of activities is provided in Appendix Table A9. [b] Expected total net cash balance.

[c] Coefficient of variation.

## Table 6.2 : Case farm two - Actual, risk-neutral and utility-efficient solutions at various risk aversion levels

| | | | | Risk aversion level | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity[a] | Unit | Actual | Risk-neutral | 0.000500 | 0.000402 | 0.000304 | 0.000231 | 0.000182 | 0.000133 | 0.000059 | 0.000010 |
| Wht1Lat | ha | 40.0 | 107.7 | 61.4 | 61.4 | 61.4 | 56.3 | 68.8 | 60.3 | 68.8 | 107.7 |
| Wht2Lat | ha | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 26.1 | 0.0 |
| Barley | ha | 84.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| GrazOat | ha | 0.0 | 59.5 | 144.9 | 144.9 | 144.9 | 150.0 | 137.5 | 145.9 | 111.4 | 59.5 |
| GrainOat | ha | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SunFlow | ha | 50.0 | 68.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 41.3 | 68.8 |
| Linsed2 | ha | 41.0 | 0.0 | 41.3 | 41.3 | 41.3 | 41.3 | 68.7 | 47.6 | 0.0 | 0.0 |
| Canola2 | ha | 0.0 | 0.0 | 27.5 | 27.5 | 27.5 | 27.5 | 0.0 | 21.1 | 27.5 | 0.0 |
| Linola | ha | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Fldpea | ha | 30.0 | 39.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 39.0 |
| GrClov1 | ha | 79.5 | 0.0 | 19.0 | 19.0 | 19.0 | 17.8 | 20.7 | 18.8 | 19.5 | 0.0 |
| HayClov1 | ha | 0.0 | 0.0 | 273.5 | 273.5 | 273.5 | 208.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| HayClov2 | ha | 213.5 | 293.0 | 0.0 | 0.0 | 0.0 | 0.0 | 272.3 | 274.3 | 273.5 | 293.0 |
| Natpas | ha | 182.0 | 60.6 | 182.0 | 182.0 | 182.0 | 182.0 | 182.0 | 182.0 | 157.0 | 60.6 |
| Merino | hd(ewe) | 1400.0 | 292.0 | 1112.0 | 1112.0 | 1112.0 | 1112.0 | 1112.0 | 1112.0 | 959.0 | 292.0 |
| Wether1 | hd | 0.0 | 122.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 122.0 |
| Agistmt | ha | 0.0 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 25.0 | 25.0 |
| FdHyAut | t | 24.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FdHyWin | t | 134.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SelHay1 | t | 1325.5 | 2036.4 | 1576.2 | 1576.2 | 1576.2 | 1832.2 | 1892.5 | 1906.1 | 1900.5 | 2036.4 |
| BalHOff | h | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 |
| BalCtStr | t | 90.7 | 71.2 | 30.7 | 30.7 | 30.7 | 28.1 | 34.3 | 30.1 | 47.4 | 71.2 |
| FdStrWin | t | 90.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SelStrw | t | 0.0 | 71.2 | 30.7 | 30.7 | 30.7 | 28.1 | 34.3 | 30.1 | 47.4 | 71.2 |
| Hireq-w | h | 51.5 | 56.1 | 46.6 | 46.6 | 46.6 | 32.6 | 28.0 | 28.0 | 35.4 | 56.1 |
| Hireq-s | h | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 | 50.0 |
| Employ6 | h | 0.0 | 0.0 | 175.1 | 175.1 | 175.1 | 0.0 | 0.0 | 0.0 | 0.0. | 0.0 |
| Borr1 | $ | 9203 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LvCap | $ | 32662 | 9241 | 25948 | 25948 | 25948 | 25948 | 25948 | 25948 | 22384 | 9241 |
| E(TNCB)[b] | $ | 92339 | 116937 | 86652 | 86652 | 86652 | 105990 | 109008 | 110542 | 114575 | 116233 |
| Std deviation | $ | 17357 | 22746 | 14543 | 14543 | 14543 | 17291 | 17960 | 18105 | 19911 | 22683 |
| CV[c] (%) | $ | 18.80 | 19.54 | 16.78 | 16.78 | 16.78 | 16.31 | 16.48 | 16.38 | 17.38 | 19.52 |

[a] A full listing of activities is provided in Appendix Table A9. [b] Expected total net cash balance.
[c] Coefficient of variation.

**Table 6.3 : Case farm three - Actual, risk-neutral and utility-efficient solutions at various risk aversion levels**

| | | | | Risk aversion level | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity[a] | Unit | Actual | Risk-neutral | 0.000100 | 0.000082 | 0.000064 | 0.000051 | 0.000037 | 0.000028 | 0.000019 | 0.000010 |
| Wht1Lat | ha | 75.0 | 312.1 | 34.5 | 58.4 | 122.8 | 186.2 | 245.8 | 269.3 | 272.7 | 272.7 |
| Tritic | ha | 155.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Barley | ha | 60.0 | 44.0 | 214.6 | 192.3 | 139.2 | 89.1 | 37.4 | 44.6 | 52.7 | 52.7 |
| Linola | ha | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Linsed2 | ha | 20.0 | 106.8 | 74.8 | 75.2 | 78.6 | 82.6 | 85.0 | 94.2 | 97.6 | 97.6 |
| Canola2 | ha | 165.0 | 71.2 | 49.8 | 50.2 | 52.4 | 55.0 | 56.6 | 62.8 | 65.1 | 65.1 |
| Lupins | ha | 122.0 | 178.0 | 124.6 | 125.4 | 131.0 | 137.6 | 141.6 | 157.0 | 162.7 | 162.7 |
| GrClov1 | ha | 10.4 | 20.5 | 0.0 | 1.9 | 8.8 | 13.6 | 19.8 | 19.8 | 19.8 | 19.8 |
| HayClov2 | ha | 64.7 | 54.5 | 75.0 | 73.1 | 66.2 | 61.4 | 55.2 | 55.2 | 55.2 | 55.2 |
| Natpas | ha | 158.0 | 158.0 | 173.0 | 173.0 | 173.0 | 173.0 | 173.0 | 173.0 | 173.0 | 173.0 |
| Wether1 | hd | 625.0 | 556.0 | 845.0 | 882.0 | 698.0 | 747.0 | 609.0 | 609.0 | 609.0 | 609.0 |
| Wether2 | hd | 780.0 | 1544.0 | 0.0 | 139.0 | 660.0 | 1022.0 | 1491.0 | 1491.0 | 1491.0 | 1491.0 |
| Agistmt | ha | 15.0 | 15.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FdHyWin | t | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SelHay1 | t | 349.3 | 378.9 | 521.3 | 508.4 | 460.4 | 427.0 | 383.8 | 383.8 | 383.8 | 383.8 |
| BalHOff | h | 94.0 | 36.5 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| BalCtStr | t | 128.6 | 59.4 | 191.9 | 191.8 | 138.2 | 54.7 | 25.7 | 48.4 | 57.0 | 57.0 |
| FdStrWin | t | 0.0 | 0.0 | 0.0 | 20.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SelStrw | t | 128.6 | 59.4 | 191.9 | 171.1 | 138.2 | 54.7 | 25.7 | 48.4 | 57.0 | 57.0 |
| Hireq-w | h | 0.0 | 0.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 0.0 | 0.0 | 0.0 |
| Hireq-s | h | 0.0 | 0.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 0.0 | 0.0 |
| Employ6 | h | 0.0 | 90.3 | 0.0 | 0.0 | 0.0 | 12.2 | 68.1 | 75.9 | 77.9 | 77.9 |
| LvCap | $ | 27323 | 38419 | 19441 | 22603 | 27001 | 34141 | 38757 | 38757 | 38757 | 38757 |
| E(TNCB)[b] | $ | 116095 | 122995 | 99656 | 100999 | 106580 | 111881 | 115753 | 120653 | 122289 | 122289 |
| Std deviation | $ | 46485 | 45729 | 32413 | 32448 | 33605 | 35242 | 36436 | 40360 | 41892 | 41892 |
| CV[c] (%) | $ | 40.04 | 37.18 | 32.53 | 32.13 | 31.53 | 31.50 | 31.48 | 33.45 | 34.26 | 34.26 |

[a] A full listing of activities is provided in Appendix Table A9. [b] Expected total net cash balance.
[c] Coefficient of variation.

## Table 6.4 : Case farm four - Actual, risk-neutral and utility-efficient solutions at various risk aversion levels

| Activity[a] | Unit | Actual | Risk-neutral | Risk aversion level | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.0006 | 0.000512 | 0.000423 | 0.000305 | 0.000217 | 0.000099 | 0.000069 | 0.000010 |
| BarlEar | ha | 29.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.3 | 18.6 | 12.2 |
| Bar2Ear | ha | 0.0 | 0.0 | 46.2 | 46.2 | 46.2 | 46.2 | 46.2 | 30.2 | 0.0 | 24.0 |
| BarlLat | ha | 0.0 | 70.9 | 70.3 | 70.3 | 70.3 | 70.3 | 70.3 | 70.2 | 73.6 | 66.8 |
| CanSeed | ha | 10.0 | 59.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| GrazOat | ha | 90.0 | 2.7 | 17.7 | 17.7 | 17.7 | 17.7 | 17.7 | 17.9 | 54.1 | 38.0 |
| Linsed1 | ha | 35.0 | 33.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 32.6 | 33.0 | 33.0 |
| Linsed2 | ha | 0.0 | 0.0 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 | 0.0 | 0.0 | 0.0 |
| Linola | ha | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Canola1 | ha | 56.0 | 22.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 | 22.0 |
| Canola2 | ha | 0.0 | 0.0 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 21.7 | 12.3 | 0.0 |
| Fldpea | ha | 0.0 | 15.9 | 46.2 | 46.2 | 46.2 | 46.2 | 46.2 | 30.2 | 18.6 | 24.0 |
| GrClov1 | ha | 210.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 159.7 | 21.4 |
| GrClov2 | ha | 0.0- | 69.3 | 51.9 | 51.9 | 51.9 | 51.9 | 51.9 | 68.8 | 0.0 | 39.3 |
| HayClov2 | ha | 273.0 | 502.7 | 520.1 | 520.1 | 520.1 | 520.1 | 520.1 | 503.2 | 412.4 | 511.3 |
| Natpas | ha | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 |
| Merino | hd(ewe) | 830.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FstCrs | hd(ewe) | 620.0 | 233.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 0.0. | 780.0 | 241.0 |
| BfYear | hd(cow) | 56.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BfVeal2 | hd(cow) | 0.0 | 140.0 | 150.0 | 150.0 | 150.0 | 150.0 | 150.0 | 152.0 | 111.0 | 139.0 |
| BfFatSum | hd | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FdHyAut | t | 45.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FdHyWin | t | 200.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SelHay1 | t | 1654.0 | 3493.7 | 3615.9 | 3615.9 | 3615.9 | 3615.9 | 3615.9 | 3497.3 | 2865.8 | 3553.7 |
| BalHOff | h | 183.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 129.0 | 0.0 |
| FdStrAut | t | 0.0 | 0.0 | 57.5 | 57.5 | 57.5 | 57.5 | 57.5 | 0.0 | 0.0 | 0.0 |
| FdStrWin | t | 0.0 | 0.0 | 91.5 | 91.5 | 91.5 | 91.5 | 91.5 | 88.8 | 0.0 | 0.0 |
| BuyStrw | t | 0.0 | 0.0 | 149.0 | 149.0 | 149.0 | 149.0 | 149.0 | 88.8 | 0.0 | 0.0 |
| BuyOats | t | 0.0 | 90.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 61.9 |
| Hireq-w | h | 110.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 | 0.0 | 0.0 |
| Hireq-s | h | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Employ2 | h | 135.0 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 22.2 | 22.5 |
| Employ4 | h | 0.0 | 0.0 | 80.5 | 80.5 | 80.5 | 80.5 | 80.5 | 75.9 | 0.0 | 0.0 |
| Employ5 | h | 0.0 | 0.0 | 30.1 | 30.1 | 30.1 | 30.1 | 30.1 | 30.4 | 0.0 | 0.0 |
| Borr1 | $ | 38421 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LvCap | $ | 79802 | 80000 | 80000 | 80000 | 80000 | 80000 | 80000 | 80000 | 80000 | 80000 |
| E(TNCB)[b] | $ | 130696 | 249202 | 243948 | 243948 | 243948 | 243948 | 243948 | 243344 | 237328 | 248746 |
| Std deviation | $ | 24538 | 43655 | 39826 | 39826 | 39826 | 39826 | 39826 | 38750 | 31937 | 39896 |
| CV[c](%) | $ | 18.77 | 17.52 | 16.33 | 16.33 | 16.33 | 16.33 | 16.33 | 15.92 | 13.46 | 16.04 |

[a] A full listing of activities is provided in Appendix Table A9. [b] Expected total net cash balance.

[c] Coefficient of variation.

**Table 6.5 : Case farm five - Actual, risk-neutral and utility-efficient solutions at various risk aversion levels**

| | | | | Risk aversion level | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity[a] | Unit | Actual | Risk-neutral | 0.00010 | 0.000086 | 0.000072 | 0.000062 | 0.000051 | 0.000044 | 0.000037 | 0.000030 |
| Wht1Lat | ha | 0.0 | 52.7 | 52.2 | 52.4 | 52.7 | 52.7 | 52.7 | 52.7 | 52.7 | 52.7 |
| Wht2Lat | ha | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Barley | ha | 19.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RyeGrSeed | ha | 0.0 | 4.6 | 0.0 | 2.3 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 |
| Turnip | ha | 0.0 | 0.0 | 4.7 | 2.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| GrainOat | ha | 44.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Linsed2 | ha | 22.0 | 16.5 | 15.8 | 16.2 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 | 16.5 |
| Canola2 | ha | 25.0 | 11.0 | 10.5 | 10.8 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| Linola | ha | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Fldpea | ha | 0.0 | 25.2 | 25.9 | 25.5 | 25.2 | 25.2 | 25.2 | 25.2 | 25.2 | 25.2 |
| GrLucn1 | ha | 96.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| GrLucn2 | ha | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HayLucn2 | ha | 0.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 |
| Natpas | ha | 1240.0 | 1067.6 | 1055.6 | 1061.6 | 1067.6 | 1067.6 | 1067.6 | 1067.6 | 1067.6 | 1067.6 |
| Merino | hd(ewe) | 1558.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BfWean | hd(cow) | 307.0 | 448.0 | 438.0 | 443.0 | 448.0 | 448.0 | 448.0 | 448.0 | 448.0 | 448.0 |
| BfYear | hd(cow) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BfVeal1 | hd(cow) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BfVeal2 | hd(cow) | 71.0 | 0.0 | 8.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FdHyWin | t | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SelHay1 | t | 0.0 | 667.2 | 666.5 | 666.8 | 667.2 | 667.2 | 667.2 | 667.2 | 667.2 | 667.2 |
| BalHOff | h | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 |
| BalCtStr | t | 35.0 | 40.1 | 37.6 | 38.9 | 40.1 | 40.1 | 40.1 | 40.1 | 40.1 | 40.1 |
| SelStrw | t | 35.0 | 40.1 | 37.6 | 38.9 | 40.1 | 40.1 | 40.1 | 40.1 | 40.1 | 40.1 |
| Agist | ha | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 |
| Hireq-w | h | 66.0 | 81.6 | 82.8 | 82.2 | 81.6 | 81.6 | 81.6 | 81.6 | 81.6 | 81.6 |
| Hireq-s | h | 50.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 |
| Employ2 | h | 76.0 | 89.7 | 89.2 | 89.4 | 89.7 | 89.7 | 89.7 | 89.7 | 89.7 | 89.7 |
| Borr1 | $ | 9288 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Borr2 | $ | 66360 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LvCap | $ | 0.0 | 187500 | 187500 | 187500 | 187500 | 187500 | 187500 | 187500 | 187500 | 187500 |
| E(TNCB)[b] | $ | 19677 | 87845 | 87427 | 87638 | 87845 | 87845 | 87845 | 87845 | 87845 | 87845 |
| Std deviation | $ | 11473 | 7203 | 6881 | 7034 | 7203 | 7203 | 7203 | 7203 | 7203 | 7203 |
| CV[c] (%) | $ | 58.3 | 8.20 | 7.87 | 8.03 | 8.20 | 8.20 | 8.20 | 8.20 | 8.20 | 8.20 |

[a] A full listing of activities is provided in Appendix Table A9. [b] Expected total net cash balance.
[c] Coefficient of variation.

consequent reduction in the required capital investment in the livestock enterprise. At the lower bound of the interval considered, only wethers intended for the domestic market are kept. There is a progressive decline in the amount of straw baled for sale with decreasing aversion to risk as increased crop production makes higher demands on the available resources, particularly labour. Farming equipment may be hired-out in winter and summer for a combined period of 110 h up to the risk aversion level of 3.7 x $10^{-5}$ without affecting on-farm usage.

For farm four (Table 6.4), for a risk aversion range between 6.0 x $10^{-4}$ and 1.0 x $10^{-5}$, the payoff values ranged between $243 948 at the lower end to $248 746 at the upper end with corresponding standard deviations of $39 826 and $39 896. Although it may be observed that increasing aversion to risk results in increased variability of returns as measured by the coefficient of variation, the predicted portfolios are SDRF as evident in the CDF of payoffs (see later). With decreasing aversion to risk for this farm, an increasing area is sown to March-sown linseed, barley, field pea and canola sown in April with a corresponding decrease in the areas sown to August-sown canola. Similarly, clover hay is increasingly baled for sale. At the most risk-averse solution, some 93 per cent of the available arable land area is cropped with the remaining seven per cent being left to fallow. Decreasing risk aversion results in the increased level of diversification of livestock production with varying combinations of first cross sheep and vealers from cross-bred cows. By the perception of this farmer, under his current production environment, it is a more utility-efficient option to keep a combination of cattle and sheep. Straw fed to stock in autumn and winter is bought-in rather than baled on-farm implying that the burning of stubble is the more economic option. The risk-averse enterprise combinations require the hiring of extra labour in September/October and also in November.

For case farm five, the payoffs ranged from $87 427 at a risk aversion level 1.0 x $10^{-4}$ to $87 845 at an aversion level of 3.0 x $10^{-5}$ (Table 6.5). The variations in the expected payoffs were not significantly different over the preference range considered. The variation of returns for the observed cropping plan on the farm at 58.3 per cent was significantly higher than either the risk-neutral solution or the UE solutions with a maximum variability of 8.2 per cent. The process of optimisation of the models allows the selection of such minimal land areas as 2.3 ha for ryegrass seed and turnips. However, in practice, such small areas are unlikely to be grown by farmers except perhaps for experimental crop trials. The areas sown to wheat, August-sown linseed and ryegrass seed increased with decreasing risk aversion. As with the other four farm models, Linola does not enter the risk-neutral or UE portfolios for farm five. Increasing aversion to risk resulted in a progressive increase in the number of beef weaners. Despite the availability of a large area of natural pasture, it is not an economic option, according to this farmer's beliefs, to raise sheep of any sort at the present time. At the lower bound of the risk aversion range of $3.0 \times 10^{-5}$, while all arable land is cropped, only about 70 per cent of the available area of natural pasture is used. In the observed farm plan, some 72 per cent of the total area of natural pasture is in use for raising both sheep and cattle.

The influence of risk aversion on farming strategies for case farms one to five over the relevant ranges of risk aversion is shown in Figures 6.1 to 6.5. The risk-neutral strategies are also shown under zero risk aversion levels. In most cases, there is a greater diversification of farming strategy under the UE solutions than under the risk-neutral solutions if the number of included activities is used as a measure of diversification to take advantage of beneficial interrelationships between enterprises. Increasing trends towards specialisation would make such a measure a plausible indicator.

As previously noted, the crop of interest in this study, Linola, did not feature in any of the optimal farm plans for these five farms. Whilst the results for the case farms are not strictly comparable given the differences in the beliefs and preferences of the farmers, the results of each model are, nevertheless, indicative of the potential benefits of the new crop as assessed using different farmers' perceptions.

As was to be expected, based on *a priori* theoretical considerations, the narrower the elicited range of risk aversion, the fewer were the feasible utility-efficient production strategies open to the farmers. Differences in the expected payoffs, expected total net cash balance, due to risk aversion for each of the farm operators relative to the risk-neutral solution are provided in Table 6.6. The expected payoff reductions of the UE solutions relative to the risk-neutral solutions (Table 6.7) were highest for case farm three where they ranged from 2.02 to 25.90 per cent. The lowest variations in expected payoffs were observed for farm five.

The relevant cumulative distribution functions (CDFs) for each of the study farms are presented in Figures 6.6a to e. They all conform to *a priori* expectations based on the SDRF evaluative criterion. However, the gap between the observed and predicted strategies for farms four and five indicates that either the farmers' preference intervals were wrongly coded or that the farmers behaved contrary to their expressed preferences. These gaps may also be due to the fact that the operational models for these farms were wrongly specified.

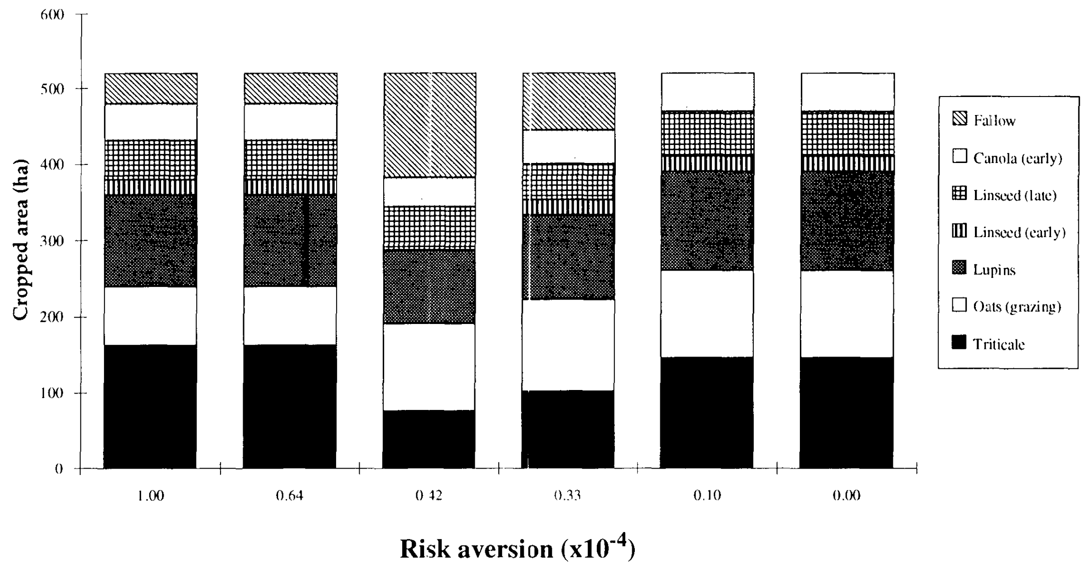

*Figure 6.1 : Case farm one: Influence of risk aversion on relative crop combinations*

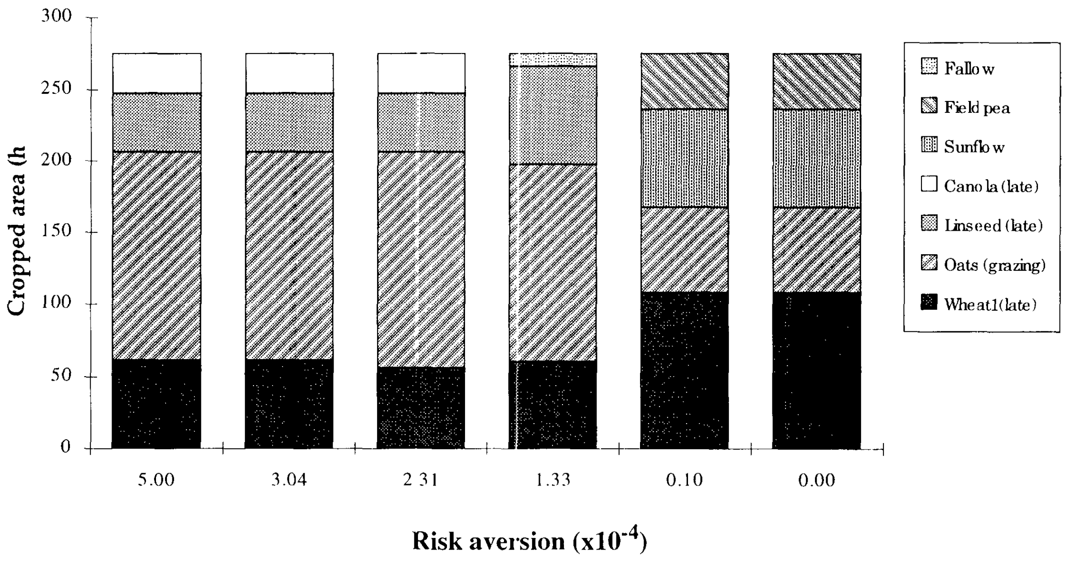

*Figure 6.2 : Case farm two: Influence of risk aversion on relative crop combinations*

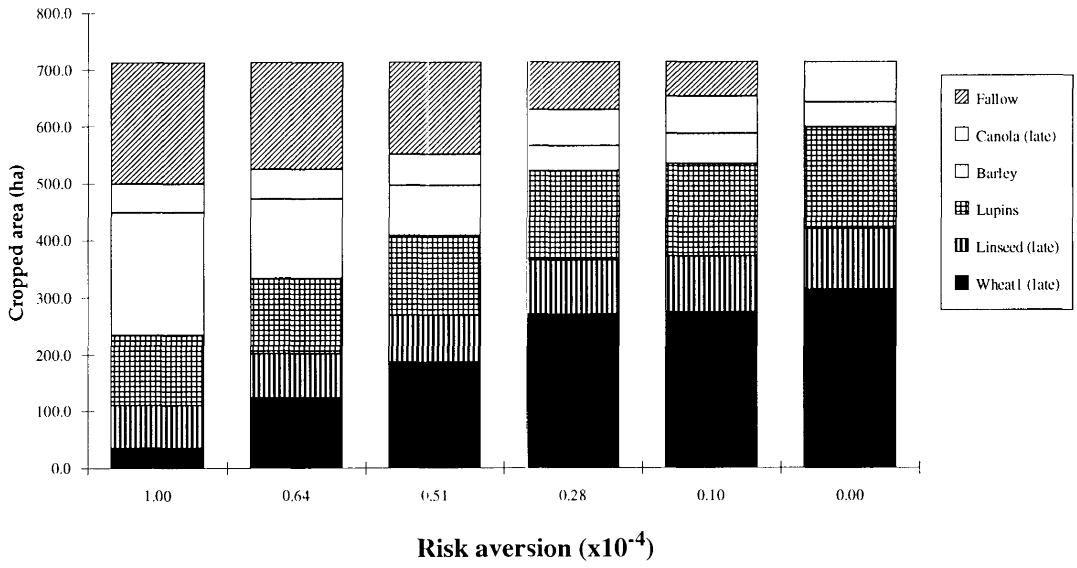

***Figure 6.3 : Case farm three: Influence of risk aversion on relative crop combinations***

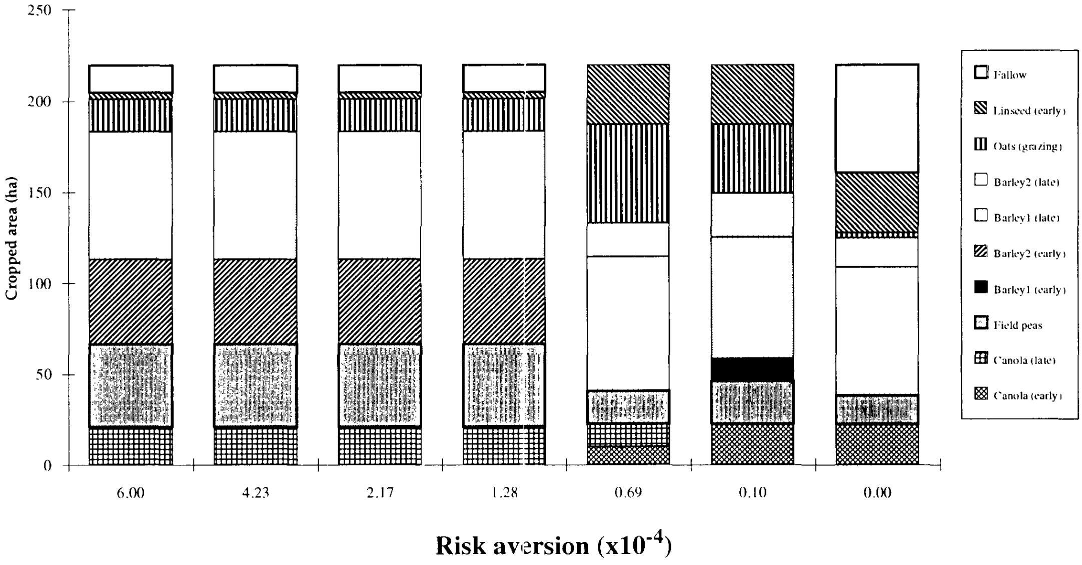

***Figure 6.4 : Case farm four: Influence of risk aversion on relative crop combinations***

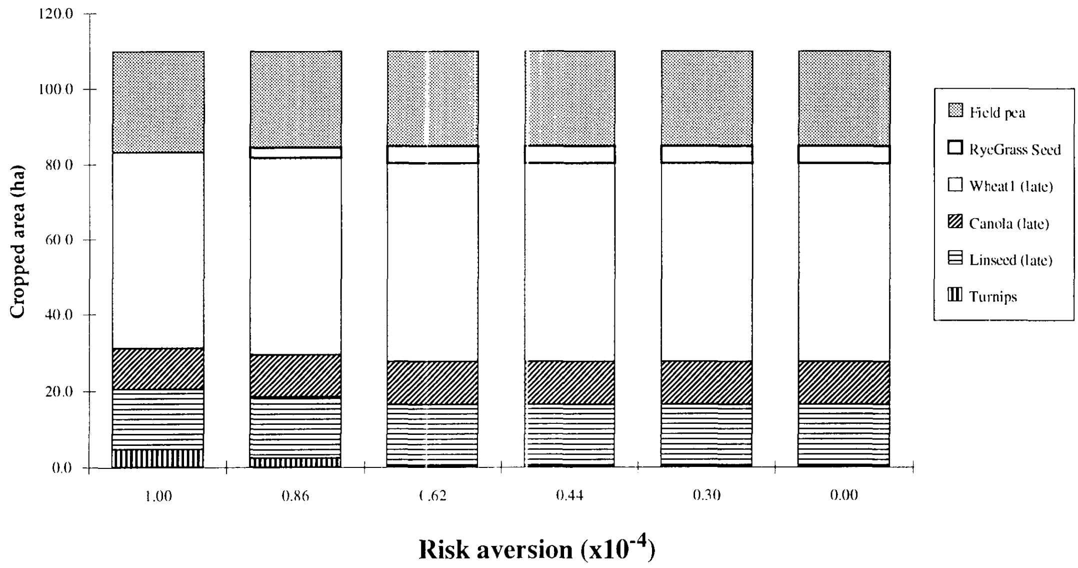

***Figure 6.5 : Case farm five: Influence of risk aversion on relative crop combinations***

**Table 6.6 : Ranges of reduction in expected payoffs due to risk aversion**[a]

| Case farm: | Range of payoff reductions \$ (x$10^3$) |
|---|---|
| One | 0.77 - 3.14 |
| Two | 5.86 - 29.75 |
| Three | 0.71 - 23.34 |
| Four | 0.46 - 5.26 |
| Five | 0.12 - 0.42 |

[a] difference between risk-neutral and UE strategies. Refer to Tables 6.1 - 6.5

**Table 6.7 : Effect of farmer aversion to risk on expected payoff and standard deviation of payoff relative to risk-neutral strategies**

| | Per cent difference in: | |
|---|---|---|
| Risk aversion | expected payoff | standard deviation of payoff |
| *Farm One:* | | |
| 0.000600 | 0.20 | 1.21 |
| 0.000425 | 0.20 | 1.21 |
| 0.000325 | 0.20 | 1.21 |
| 0.000250 | 1.50 | 15.67 |
| 0.000150 | 1.58 | 16.00 |
| 0.000125 | 0.83 | 0.92 |
| 0.000100 | 0.00 | 0.00 |
| *Farm Two:* | | |
| 0.00500 | 25.90 | 36.06 |
| 0.00402 | 25.90 | 36.06 |
| 0.00304 | 25.90 | 36.06 |
| 0.00231 | 9.36 | 23.98 |
| 0.00182 | 6.78 | 21.04 |
| 0.00133 | 5.47 | 20.40 |
| 0.00010 | 2.02 | 12.46 |
| *Farm Three:* | | |
| 0.001000 | 18.98 | 29.12 |
| 0.000730 | 17.88 | 29.04 |
| 0.000415 | 13.35 | 26.51 |
| 0.000325 | 9.04 | 22.93 |
| 0.000235 | 5.89 | 20.32 |
| 0.000190 | 1.90 | 11.74 |
| 0.000100 | 0.57 | 8.39 |
| *Farm Four:* | | |
| 0.000600 | 2.11 | 8.77 |
| 0.000450 | 2.11 | 8.77 |
| 0.000325 | 2.11 | 8.77 |
| 0.000250 | 2.11 | 8.77 |
| 0.000200 | 2.11 | 8.77 |
| 0.000150 | 2.35 | 11.24 |
| 0.000100 | 4.76 | 26.84 |
| *Farm Five:* | | |
| 0.001000 | 0.48 | 4.47 |
| 0.000825 | 0.24 | 2.35 |
| 0.000685 | 0.00 | 0.00 |
| 0.000615 | 0.00 | 0.00 |
| 0.000510 | 0.00 | 0.00 |
| 0.000405 | 0.00 | 0.00 |
| 0.000300 | 0.00 | 0.00 |

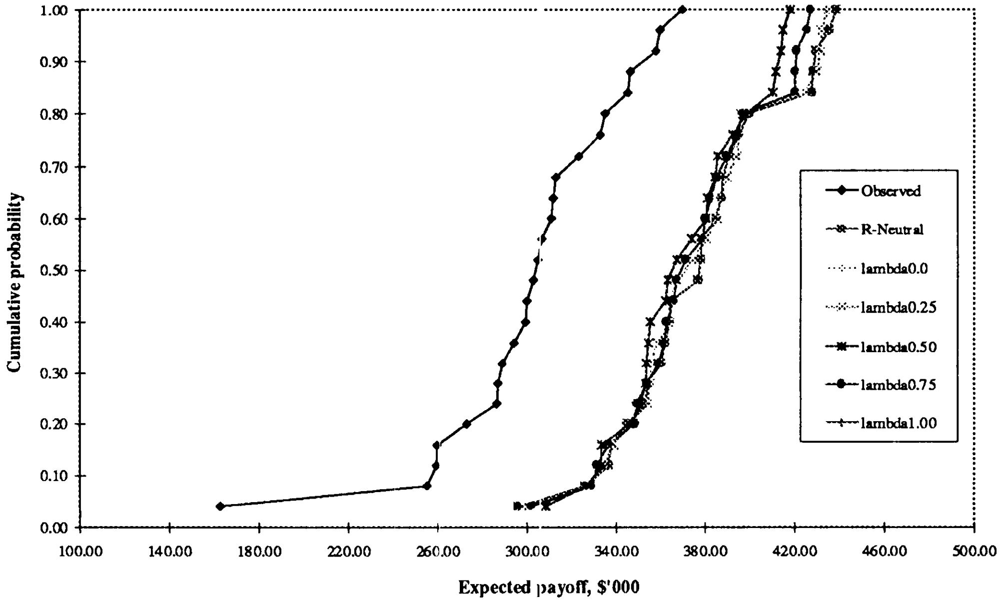

***Figure 6.6a : Cumulative distribution functions of expected payoffs for case farm one***

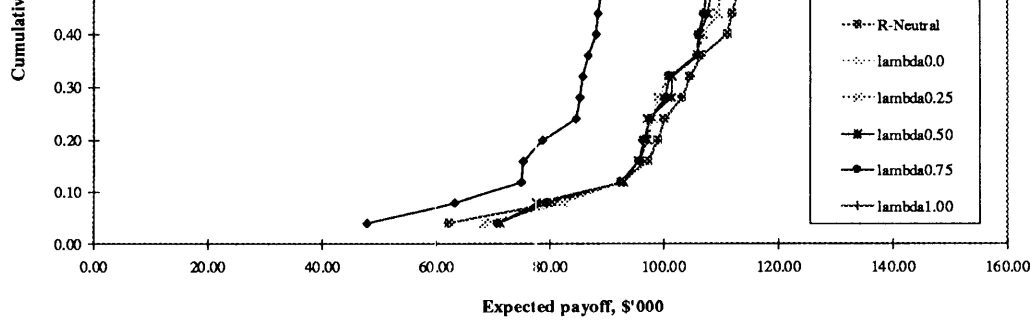

***Figure 6.6b : Cumulative distribution functions of expected payoffs for case farm two***

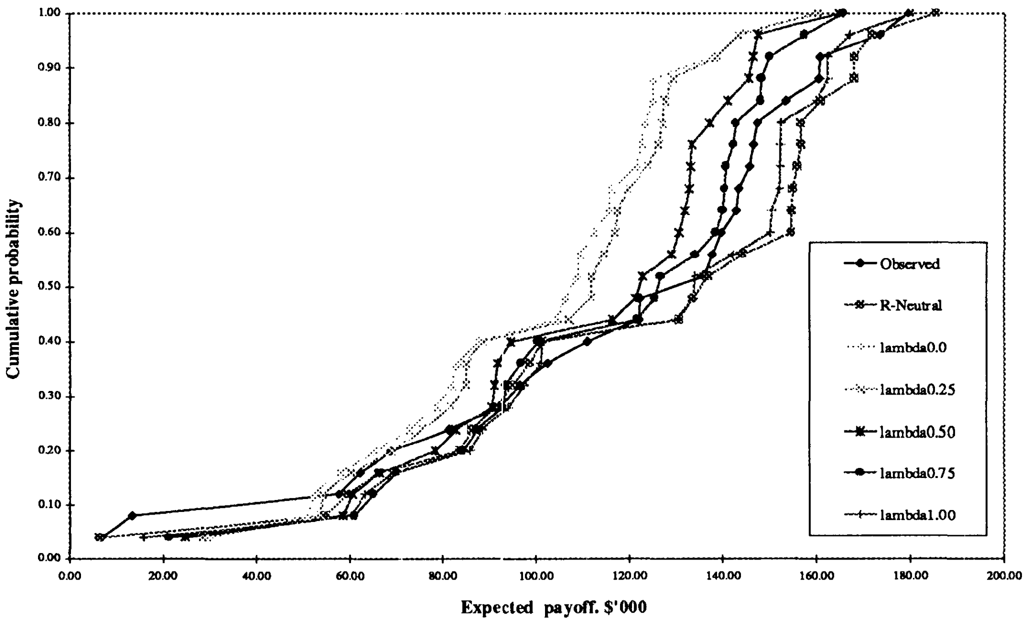

***Figure 6.6c : Cumulative distribution functions of expected payoffs for case farm three***

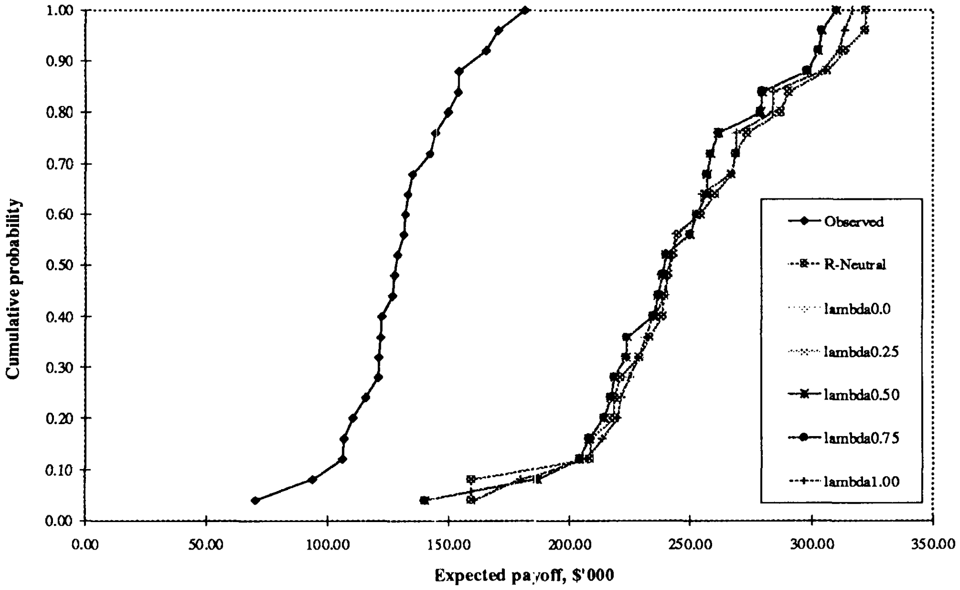

***Figure 6.6d : Cumulative distribution functions of expected payoffs for case farm four***

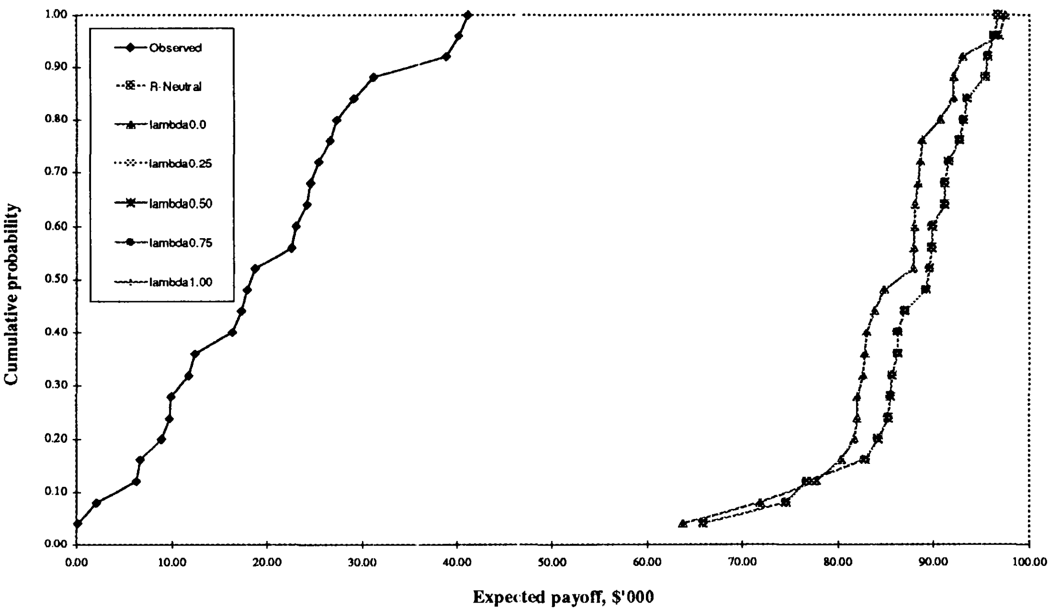

***Figure 6.6e : Cumulative distribution functions of expected payoffs for case farm five***

### 6.2.2 Extension agent and researcher perceptions

Incorporating the perceptions of the extension agent and those of the oilseed researcher about Linola with the assumed 'public' perceptions (see Section 4.4) regarding the production of customarily sown crops for each case farm provided the results reported in Tables 6.8, 6.9 and 6.10, for case farms one, two and three. For case farms four and five there was no change in the risk-neutral solutions with either extension agent or researcher perceptions incorporated. In case farm one (Table 6.8), there was no observed difference when the extension agent perception was incorporated in the model. However, the researcher's perception resulted in the substitution of Linola for May-sown linseed in the risk-neutral solutions.

**Table 6.8 : Influence on risk-neutral optimal portfolio of incorporating extension agent and researcher perceptions - farm one**

| Activity | Farmer | Extension agent | Researcher |
|---|---|---|---|
| Tritic | 146.06 | 146.06 | 146.06 |
| GrazOat | 113.94 | 113.94 | 113.94 |
| Linola | 0.00 | 0.00 | 19.88 |
| Linsed1 | 19.59 | 19.59 | 0.00 |
| Linsed2 | 58.41 | 58.41 | 58.12 |
| Canola1 | 52.00 | 52.00 | 52.00 |
| Lupins | 130.00 | 130.00 | 130.00 |
| GrClov1 | 124.55 | 124.55 | 124.55 |
| HayClov2 | 255.45 | 255.45 | 255.45 |
| Natpas | 400.00 | 400.00 | 400.00 |
| Merino | 2823.25 | 2823.25 | 2823.25 |
| Broiler | 520.00 | 520.00 | 520.00 |
| SelHay1 | 1775.40 | 1775.40 | 1775.40 |
| LvCap | 116684.79 | 116684.79 | 116684.79 |
| **Mean** | **377517.25** | **377517.25** | **377777.76** |
| **Standard Deviation** | **36225.55** | **36225.55** | **35442.76** |
| **Coefficient of Variation (%)** | **9.60** | **9.60** | **9.38** |

## Table 6.9 : Influence on risk-neutral optimal portfolio of incorporating extension agent and researcher perceptions - farm two

| Activity | Farmer | Extension agent | Researcher |
|---|---|---|---|
| Whtl1Lat | 107.74 | 107.74 | 116.46 |
| GrazOat | 59.52 | 59.52 | 42.08 |
| SunFlow | 68.75 | 68.75 | 0.00 |
| Linola | 0.00 | 0.00 | 68.75 |
| Fldpea | 38.99 | 38.99 | 47.71 |
| HayClov2 | 293.00 | 293.00 | 293.00 |
| Natpas | 60.55 | 60.55 | 42.81 |
| Merino | 292.05 | 292.05 | 206.46 |
| Wether1 | 122.23 | 122.23 | 86.41 |
| Agistmt | 25.00 | 25.00 | 25.00 |
| SelHay1 | 2036.35 | 2036.35 | 2036.35 |
| BySpAut | 0.00 | 0.00 | 0.00 |
| BalHOff | 80.00 | 80.00 | 80.00 |
| BalCtStr | 71.18 | 71.18 | 79.43 |
| SelStrw | 71.18 | 71.18 | 79.43 |
| BuyStrw | 0.00 | 0.00 | 0.00 |
| Hireq-w | 56.07 | 56.07 | 49.46 |
| Hireq-s | 50.00 | 50.00 | 50.00 |
| LvCap | 9241.05 | 9241.05 | 6532.98 |
| **Mean** | **116397.35** | **116397.35** | **125798.52** |
| **Standard Deviation** | **22746.28** | **22746.28** | **22034.85** |
| **Coefficient of Variation (%)** | **19.54** | **19.54** | **17.52** |

**Table 6.10 : Influence on risk-neutral optimal portfolio of incorporating extension agent and researcher perceptions - farm three**

| Activity | Farmer | Extension agent | Researcher |
|---|---|---|---|
| Wht1Lat | 312.05 | 312.05 | 356.00 |
| Barley | 43.95 | 43.95 | 0.00 |
| Linola | 0.00 | 0.00 | 106.80 |
| Linsed2 | 106.80 | 106.80 | 0.00 |
| Canola2 | 71.20 | 71.20 | 71.20 |
| Lupins | 178.00 | 178.00 | 178.00 |
| GrClov1 | 20.48 | 20.48 | 7.06 |
| HayClov2 | 54.52 | 54.52 | 67.94 |
| Natpas | 158.00 | 158.00 | 173.00 |
| Wether1 | 556.16 | 556.16 | 1195.55 |
| Wether2 | 1543.84 | 1543.84 | 532.53 |
| Agistmt | 15.00 | 15.00 | 0.00 |
| FdHyAut | 0.00 | 0.00 | 0.00 |
| FdHyWin | 0.00 | 0.00 | 0.00 |
| SelHay1 | 378.91 | 378.91 | 472.15 |
| BalHOff | 36.50 | 36.50 | 35.47 |
| BalCtStr | 59.40 | 59.40 | 0.00 |
| SelStrw | 59.40 | 59.40 | 0.00 |
| Employ6 | 90.32 | 90.32 | 27.14 |
| LvCap | 38419.42 | 38419.42 | 36337.56 |
| **Mean** | **122994.89** | **122994.89** | **132621.37** |
| **Standard Deviation** | **45729.41** | **45729.41** | **45359.71** |
| **Coefficient of Variation (%)** | **37.18** | **37.18** | **34.20** |

For case farm two, as with farm one, extension agent perception did not influence the risk-neutral optimum but researcher perception resulted in the substitution of Linola for sunflower. In addition, there were changes in the amounts of late sown wheat, grazing oats and field peas included in the optimal portfolio (Table 6.9). Also, fewer livestock were included with merinos decreasing from 293 ewes to 206 and wethers decreasing to 86 from 122. The coefficient of variation of the payoffs were lower (17.52 per cent) with the inclusion of Linola.

For farm three, as may be observed in Table 6.10, while extension agent perception did not influence the optimal farm plan, the researcher's perception resulted in the substitution of late sown linseed with Linola. Aside from the additional influence of more late wheat being included, there were also fewer sheep with more bought-in wethers (1196) being kept compared with the previous 556. However, fewer farm-raised wethers (532) are included compared with the previous 1544. Also, less labour is employed (*cf* 90.3 h vs 27.1 h) in labour period six.

### 6.2.3 Goodness-of-fit tests of predicted portfolios

It was considered useful to test whether the payoff distributions of the predicted risk-neutral and UE porfolios were identical to those of the observed farm plans by other than chance. As noted by Lin, Dean and Moore (1974), there are many dimensions to an actual farm plan such as the types of crops grown, types and numbers of livestock, input levels and average income. However, these authors also observed that the best single characterisation of a farm strategy is its income distribution. On this basis, testing the resultant risk-neutral and UE farm plans generated in this study for goodness-of-fit involved comparison of the predicted portfolios with the actual ones based on the distribution of payoffs.

The comparisons, were based on the Chi-square goodness-of-fit test on the strength of the hypothesis that the distribution of the payoffs of the predicted farm plans was identical to the distribution of payoffs of the actual farm plans. The test involved ranking the payoffs and defining appropriate intervals from which the Chi-square statistic was computed. The computed Chi-square values are given in Table 6.11. The p-values computed indicate that the probability of the distribution of the predicted payoffs being identical to the observed payoffs was close to zero in all cases. Therefore, it may be concluded that any similarities or dissimilarities in the distributions of the predicted and observed payoffs are unlikely to be due entirely to chance.

**Table 6.11 : Calculated Chi-square values for observed and predicted farm strategies**

| | | | UE strategies at lambda equal to: | | | |
|---|---|---|---|---|---|---|
| Case farm | No of intervals | Risk-neutral | 0.00 | 0.50 | 0.75 | 1.00 |
| One | 6.0 | 193.92 | 192.42 | 172.20 | 213.92 | 193.92 |
| Two | 7.0 | 76.64 | 76.64 | 26.53 | 25.53 | 76.83 |
| Three | 6.0 | 38.90 | 44.45 | 37.48 | 35.53 | 36.23 |
| Four | 6.0 | 191.00 | 191.09 | 189.09 | 189.09 | 191.00 |
| Five | 5.0 | 286.50 | 286.50 | 286.50 | 286.50 | 286.50 |

### 6.2.4 Modelling experiments

#### *Experiment one*

To investigate how much the subjective Linola price or yield expectations of each of the respondent farmers will have to change before the crop is included in the risk-neutral portfolios, various spread-preserving shifts in the elicited expectations were used in resolving the models repeatedly, *ceteris paribus*, until Linola entered the risk-neutral solutions. The results of the required percentage increases in Linola yield and price expectations relative to the scaled mean values for each of the case farms are given in Table 6.12. If the required increase in Linola yield/price were used as a measure of perception then it is obvious that the farmer with the most pessimistic perception about the potential performance of Linola on his property is case five with farm one being the most optimistic. However, when the required Linola gross margin is used as a measure of perception there is a reversal in the ordering of perceptions and farmer two becomes the most optimistic regarding Linola and farmer one, the most pessimistic. From both Table 6.12 and Figure 6.7, it would appear that an inverse relationship exists between the required increase in the yield or price of Linola and the required Linola gross margin for the farms used in this study. Also, from Table 6.12 and Figure 6.8, it is evident that the farms with higher expected payoffs for the risk-neutral models would appear to require a lower percentage increase in Linola yield/price for its inclusion in the farm plans.

### *Experiment two*

To obtain a best-bet strategy it was assumed that the true potential of Linola on the five study farms should necessarily lie between the perceptions of the researcher, extension agent and farmers. On the basis of this assumption, the mean of the subjective means of yields and prices for the farmers, extension agent and researcher was used in re-running the risk-neutral and UE models. There were no observable changes in the predicted portfolios compared with those obtained using only the farmers' subjective means, i.e., Linola did not enter any of the solutions.

**Table 6.12 : Required percentage increases in yields and prices of Linola, *ceteris paribus*, for inclusion in the risk-neutral solutions**

| Case farm | Risk-neutral shadow cost ($/ha) | Required increase in Linola yield/price (%) | Required Linola gross margin ($/ha) |
|---|---|---|---|
| One | 19.46 | 14.69 | 357.73 |
| Two | 123.78 | 70.14 | 187.84 |
| Three | 48.03 | 32.67 | 245.89 |
| Four | 141.77 | 52.80 | 252.06 |
| Five | 409.80 | 86.67 | 206.26 |

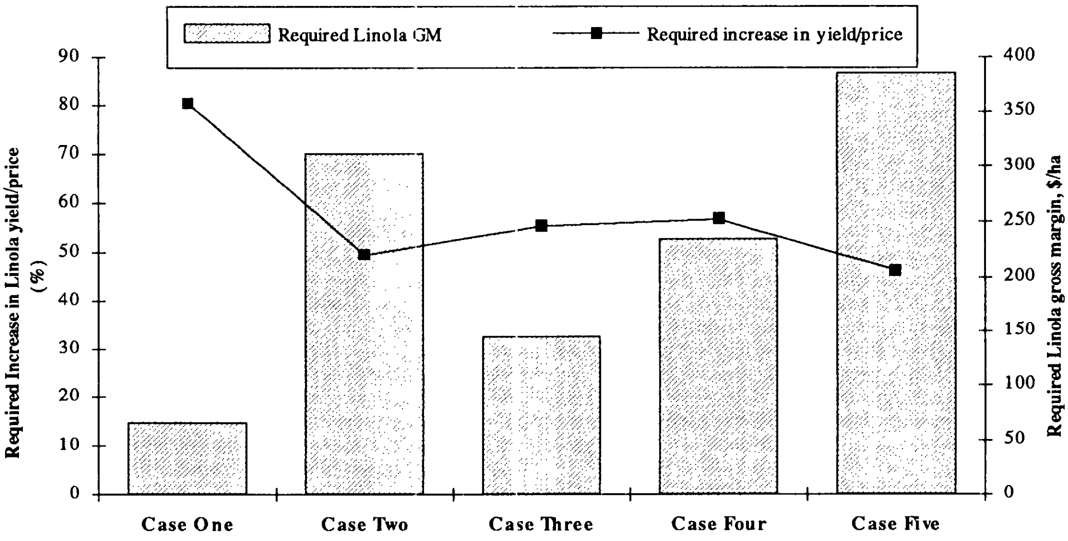

***Figure 6.7 : Relationship between required increase in Linola yield or price and the required Linola gross margin***

**Table 6.13 : Respondent farmer yield and price expectations about Linola[a]**

| | Yield | | | Price | | |
|---|---|---|---|---|---|---|
| Case farm | Mean t/ha | Standard deviation t/ha | Coefficient of variation | Mean $/t | Standard deviation $/t | Coefficient of variation |
| One | 1.50 | 0.48 | 0.320 | 330.01 | 22.73 | 0.068 |
| Two | 0.67 | 0.21 | 0.313 | 350.00 | 22.74 | 0.065 |
| Three | 1.01 | 0.27 | 0.267 | 326.77 | 25.97 | 0.079 |
| Four | 0.84 | 0.29 | 0.345 | 339.15 | 30.90 | 0.091 |
| Five | 0.63 | 0.18 | 0.286 | 325.19 | 21.10 | 0.065 |

[a] Based on an assumed triangular distribution.

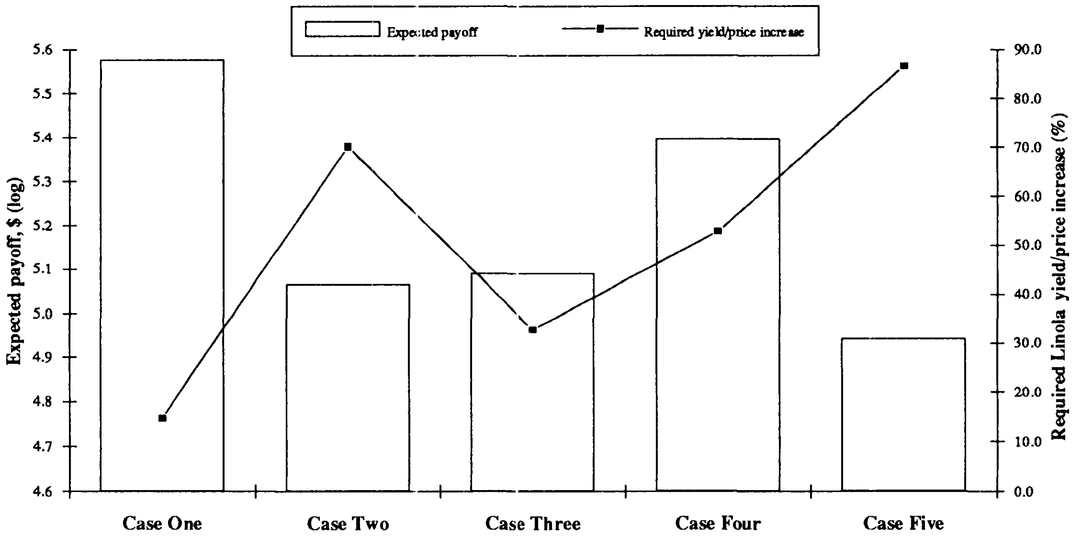

***Figure 6.8 : Relationship between risk-neutral expected payoff and percentage yield required for inclusion of Linola in farm strategies***

### 6.2.5 Testing the study hypotheses

In testing the hypotheses specified in Section 1.4, recourse needs to be had to the results presented earlier in this chapter. The first guiding hypothesis formulated for the study was that the adoption of Linola into cropping systems in the Barwon would not increase the certainty equivalent of farmer incomes. For all case farms considered, since Linola does not enter either the risk-neutral or UE farm plans generated (Tables 6.1 - 6.5), it is to be concluded that the hypothesis cannot be rejected for respondent farmers. Thus, the analysis in the current study suggests that the adoption of Linola into their cropping systems would not increase the certainty equivalent of the farm incomes of the study farmers.

The second hypothesis is that 'the relative attractiveness of Linola as a regular part of cropping rotations of farmers in the Barwon is unaffected by their aversion to risk'. The results presented in Tables 6.1 - 6.5 indicate that Linola enters neither the risk-neutral nor the UE solutions. If aversion to risk were a major factor in the decision of the respondent farmers, then the crop should be selected in one or more of the risk-neutral farm strategies. This is not the case, however. It may be concluded, therefore, that the second hypothesis cannot be rejected on the basis of these results. In consequence, for the five case study farms used in this work, the attractiveness of Linola production cannot be concluded to be affected by the expressed aversion to risk by the farmers.

For the third hypothesis which states that 'there is no difference in the scope for adoption of Linola into prevailing crop systems in the Barwon district, regardless of the source of information used to judge performance,' recourse is had to the results presented in Tables 6.8 to 6.10. The incorporation of extension agent and researcher perceptions in the risk-neutral models, assuming that farmer perceptions of traditionally grown crops fall in the public domain, indicate that, while the perception of the extension agent did not influence the optimal strategies, those of the researcher did in three of the five case farms. In consequence, it is to be concluded that in three of the study farms - farms one, two and three - the third hypothesis is to be rejected. For farms four and five, however, the hypothesis cannot be rejected. This implies that for farms four and five, the source of the information about Linola did not significantly influence its attractiveness for these farms.

# 7. Discussion and Conclusions

> ***'We should all be concerned about the future because we will have to spend the rest of our lives there'***
>
> \- C. F. Kettering

## 7.1 Introduction

The contents of this chapter focus discussion on the impact of risk, as represented in the models, on the adoption of Linola technology based on the results presented in Chapter 6. Aside from the interest in whether or not Linola enters the risk-neutral or risk-efficient farm plans, the stability and sensitivity of the generated farm plans in each grouping were also worthy of interest. Section 7.3 provides a summary of the main conclusions that may be drawn from the work specifically with respect to the technology of Linola production, and oilseeds production generally, on the case farms. Some conclusions are drawn with respect to technology assessment generally.

The risk efficiency analysis approach adopted in this work is focused on whether or not the adoption of Linola into traditional cropping systems has perceived benefits for the adopting farmer given prevailing uncertainties about its on-farm performance and the farmers' attitude to risk. Various policy implications of the results presented in Chapter 6 are examined with regard to the impacts on producer welfare of a new technology such as Linola. Section 7.4 is a presentation of some of the possible areas for future research. A brief concluding commentary on the study is provided at the end of the chapter.

## 7.2 Discussion of empirical results

The objectives of this research as stated in Chapter 1 include *a*) the assessment of the potential of oilseeds as broadacre crops and the impact of a new variety of oilseed, Linola, on the certainty equivalent of producer incomes; *b*) the comparison of actual, risk-neutral (profit-maximising) and risk-averse (utility-maximising) farm plans; *c*) the determination of a 'best bet' set of farm plans based on the combined perceptions of the producer, extension worker and researcher; and *d*) analysis the policy implications to both the State and Commonwealth governments in terms of improving the flow of information regarding new methods of production and offering research assistance to farmers so that farmers' production decisions are not biased away from areas of comparative advantage.

Attaining these objectives necessitated the application of a whole-farm modelling approach to farming operations on five case farms in the Barwon district of Victoria. Emphasis was on the risk attitudes of the operators and on their subjective assessments of the potential of a new oilseed crop, Linola, to increase the welfare of their farming households. The study has been an attempt at the characterisation of the potential of a new technology, Linola, based on the beliefs and risk preferences of case study farmers.

### 7.2.1 Potential for oilseeds

From the reported results in Tables 6.1 to 6.5, it is observed that oilseeds always formed a part of the optimal farm portfolio, usually to their allowable maximum, in both the risk-neutral and UE programming solutions for all of the five case farms. The potential of oilseeds in their complementary traditional role of disease-break crops is clear from these results since all the farm plans include one oilseed type or another. As seen in the Appendices (3-8, 16) to this work, oilseeds are generally high-return, high-variability cropping activities that it might have been supposed would be considered too risky by the risk-averse producer. However, such a supposition is not supported by the results presented in Tables 6.1 - 6.5 as only in farm one was no oilseed included as part of the risk-efficient stratagem for the risk aversion range considered. Generally, there was a tendency for a reducing level inclusion of oilseeds with increasing aversion to risk, reflecting the relatively risky nature of these crops. However, the complementarity effects that oilseeds exhibit with cereal crops, particularly wheat and barley, would appear to ensure the continued inclusion of significant areas of oilseeds in most of the farm plans of the study farms. This notion of complementarity between oilseeds and cereals is supported by the fact that cereals not grown after an oilseed crop did not usually feature in the farm plans obtained for the study farms.

### 7.2.2 Potential for Linola

Despite currently touted advantages of Linola (see Chapter 2), based on the perceptions of the five study operators, this crop does not appear to possess the potential to impact positively on the certainty equivalents of producer incomes in the Barwon. No Linola was present in any of the farm plans based on farmers' beliefs about returns from the inclusion of the crop in their farm plans though oilseeds, as earlier discussed, possess the potential for increased production in the study area. Thus, whilst the available technical information (see Section 2.6.6) indicates tremendous potential for Linola in the Barwon region, the perceived production risks by the study farmers appear to be a significant disadvantage at the present time. As more information about the crop becomes available to farmers these perceptions about Linola may change.

### 7.2.3 Comparisons between observed, risk-neutral and risk-averse farm plans

The non-inclusion of Linola in any of the farm plans modelled led to the non-rejection of the hypothesis that the attractiveness of Linola is unaffected by farmer aversion to risk. Buschena and Zilberman (1994) have observed that the behaviour of affluent farmers is likely to be less affected by risk avoidance considerations. The respondent farmers in this study may be classified as affluent considering the value of the resources/assets they control. Therefore, the conclusion that their behaviour as regards Linola adoption is unaffected by their risk attitudes is not too surprising.

More generally, on mixed farms of the type studied, a relatively high degree of diversification is readily achieved because of the need for balanced crop rotations to spread labour peaks and to balance cash inflows with outflows over the production year. If one particular crop or group of crops is particularly risky, it may well be readily possible to change an already diversified plan only marginally to limit the impact of risk. Significantly, arable land was allocated to fallow in several instances as depicted in Figures 6.1 - 6.5. This may have been a result of the deliberately limited options within the models to diversify sources of risk in other potential enterprises. Various other risk-reducing strategies that allow operational adjustment with changing risk aversion such as crop/livestock insurance and alternative marketing strategies were not included in the models.

As a rule, the basis of a rigorous comparison of the predicted strategies that include the new technology should be the CDFs of the payoffs (see Figure 6.6) for the different strategies. However, the non-inclusion of the new technology in any of the risk-neutral or risk-averse strategies makes such a comparison superfluous.

Conflicting results have emerged in decision analysis literature about the influences of farmer risk aversion on resource allocation decisions. Roumasset (1976), Smith and Umali (1985), Rosegrant and Roumasset (1985), among others, have found in their studies with rice production that risk aversion does not significantly influence resource allocation decisions by farmers. Other authors including Just (1974), Moscardi and de Janvry (1977), Dillon and Scandizzo (1978), Foster and Rausser (1991), Harper et al. (1991), Crisostomo, Burton, Featherstone and Kelly (1993) have indicated that aversion to risk plays an important role in farmer decision making. Based on an econometric analysis involving subjective evaluation of selected characteristics of various crops, Adesina and Zinnah (1993), Lin and Milon (1993) and Adesina and Baidu-Forson (1995) have concluded that farmers' subjective preferences for characteristics of new agricultural technologies are very important determinants of adoption behaviour. The results of this work provide support for this claim and therefore emphasise the need for consideration of the subjective perceptions of farmers about new production methods more than their aversion to production or other risk in the process of information dissemination concerning new technologies such as Linola.

Based on the results of the farm situation modelled in this study, the conclusion may therefore be drawn that, while risk aversion may be important in the determination of enterprise combinations, it may not be an overly important factor in technology assessment for technologies that affect only part of farming system, such as a break crop. Possibly more significant are the subjective beliefs of farmers which are influenced by their level of 'informedness'.

Such a conclusion seems to suggest that a 'package' approach to technology transfer is unlikely to be successful, at least for these case farmers, given the variety of beliefs concerning the potential of Linola on their farms. Rather, what they appear to need is information about Linola that they perceive as relevant to their needs and circumstances. The transmission of such material would mean using the information sources that these farmers currently attach high priority to. It may also be possible to work to change the perceptions of these farmers about the reliability and relevance of information sources that they may currently discount.

### 7.2.4 Best-bet farm plans based on farmer, extension agent and researcher perceptions

As noted in Chapter One, in the context of this work, a best-bet farm plan is one that is expected to give the best payoff based on the differing perceptions of the technology in question. The technology under consideration in this instance is Linola. The results reported in Tables 6.8 - 6.10 indicate that the extension agent's belief about the performance of Linola is sufficiently identical to that of the farmers to produce identical risk-neutral strategies. However, in three out of five cases, the perception of the researcher resulted in the inclusion of Linola in the risk-neutral farm strategies. As reported in Section 6.2.4, a simple combination of the perceptions of farmer, extension agent and researcher did not visibly alter the predicted portfolios. Although aspects of supply and demand for Linola have not been explicitly handled in the farm models, these were discussed at length in Chapter 2. At the present time Linola is grown under contract to Seedex at pre-season guaranteed prices. These prices are already at relatively competitive levels compared with other oilseeds as may be seen from Table 6.14 and Appendix Tables 3-8. Thus, it would appear that the research emphasis should be geared towards improving the expected yield of the crop to make it more attractive to farmers. Such emphasis would require that consideration be given to the technical competence of the farmer. Such competence is dependent on both experience in growing of the crop and received information concerning the crop.

Based on the perceptions of the extension agent about Linola, the expected net revenue per hectare of Linola and its standard deviation were computed to be \$172.96 and \$81.11 respectively. For the researcher, the corresponding statistics were \$316.87 and \$109.42. These divergent perceptions may be indicative of a communication problem between researcher and extension agent. Moreover, the fact that the extension agent's beliefs were broadly in line with those of the farmers, at least as judged by the farm plans generated, makes it clear that the seeming breakdown in the transfer of information is between the researcher and people with a more applied orientation. An indication of this limited interaction is borne out by the responses of the farmers to questions regarding their most important source of information regarding innovations in agriculture. All five respondent farmers indicated one form or other of the media as their primary source of information when the responses were ranked. Next in the rankings were field days followed by extension officers. Researchers did not feature in the responses.

Current technology adoption literature emphasises the need for a two-way flow of information between farmers and researchers so that experiences and beliefs may be 'traded'. Such coming together of the various agents - users and developers of technology - provides the communication vehicle required to reduce any gaps in perceptions as well as a better understanding of the distribution of potential returns. Given the obviously poor perceptions of the studied farmers concerning the performance of Linola, in contrast to researcher perceptions, there is an apparent need for more farmer-oriented research and development of the technology of Linola if it is to be widely adopted in the Barwon district. In this regard, there would appear to be a need for better coordinated on-farm trials to provide more 'useable' information to farmers. Such information should directly influence their subjective assessments and reduce the gap between researcher, extension agent and farmer perceptions regarding the potential of Linola as a regular inclusion in cropping systems in the Barwon region.

### 7.2.5 Policy implications

The results of the current analysis have implications for agricultural policy in relation to both the adoption of new technologies and the dissemination of information about these technologies. The development, dissemination and adoption of new methods of production by Australian farmers is a major necessity in the search for increasing productivity to allay the effects of the prevalent cost-price squeeze faced by these farmers. The fact that the development of Linola has been ongoing since 1975 attests to the fact that the development of a totally new crop, however considered, is not an easy undertaking.

It is often argued that the required outlay of capital and other resources in the endeavour to obtain the necessary information creates a possible market failure in agricultural research and development that justifies the intervention of the government on the basis of welfare considerations. Dillon (1979) and Byerlee (1987) have argued that the cost of acquiring quality information regarding new technologies is likely to be much higher than the benefits that accrue for individual farmers. This form of market failure may be supposed to lead to under-investment in agricultural research and development. Further market failure may result from distortions caused by taxes and subsidies. While this latter aspect was not investigated, the relatively deregulated market faced by Australian farmers suggests that there is unlikely to be any significant difference between private and social comparative advantage. With respect to Linola development and uptake, the main possible market failures include:

a) risk aversion by farmers working as a 'friction' that militates against socially optimal allocation of resources. According to McArthur and Dillon (1971), the government can take a long-term view with regard to research and development and be indifferent to risk. In consequence, according to this line of argument, it is a rational interventionist approach for the government, based on welfare considerations, to invest in research and development. However, this argument may not engender support in the instance of Linola since risk aversion has been revealed at present, not to be a factor in its adoption. It is arguable whether the presence of production risk is sufficient reason for government intervention. In any case, it is doubtful whether intervention would be a worthwhile policy option for the government given that, as noted by Hazell et al. (1986) and Hazell (1992), the gathering and dissemination of the relevant information can be not only demanding and administratively difficult, but also expensive;

b) a prevailing level of under-investment in agricultural research and development as a result of the fragmented nature of agricultural production and the supposed lack of a market for agricultural innovations. Again, this is a moot point in the case of the technology considered in this study. The company charged with marketing and distributing the crop, Seedex, has Plant Variety Rights (PVR) to the crop which makes the non-exclusivity of research findings a non-issue. The company can maximise the rent value of Linola should its development be successful under PVR protection. Allowing that funds already invested by the Commonwealth are considered sunk costs of research, the option exists now for Seedex to share the risks associated with the further development of Linola by raising more development capital on the equity markets. Scope also exists for obtaining institutionalised research and development from such bodies as the Australian Oilseeds Federation and Grains Research and Development Corporation which already collect R&D levies from oilseed and coarse grain producers.

Australian farmers may be supposed to be receptive to information concerning new production techniques given the continuing phenomenon of the cost-price squeeze. Such information, which plays a major role in the formulation of farmer beliefs concerning the new technology, needs to be packaged and presented in a form that is accessible and easily digested by the end-users, i.e., the farmers. The wide gap in perceptions about Linola between farmers and the extension officer on the one hand and the researcher on the other has already been noted. Moreover, the need to make research (and to a lesser extent, extension) more responsive to farmers' needs and circumstances has also been discussed. In so far as the organisation and management of agricultural research and extension is a policy matter, there are obvious policy implications from the findings of this study.

## 7.3 Conclusions

The case study approach adopted in this study precludes any broad generalisations of the results obtained with regard to general resource allocation decisions made by farmers in the Barwon region. However, given that these farmers are a significant proportion of the farmers who have grown Linola on a trial basis in the Barwon district at the time of the study, certain broad categorisations concerning the potential of Linola in the district can be distilled.

On the basis of the results obtained in this study, several pertinent conclusions may be drawn. In the first instance, the non-inclusion of Linola in either the risk neutral or UE solutions leads to the conclusion that, at the present time, for the five respondent farmers, Linola would not contribute to farmer certainty equivalent. In other words, based on the subjective assessments of the case farmers used in this study, it is not currently worthwhile to grow Linola. The implications of this result are 1) abandon Linola research; 2) improve Linola technology; 3) conduct on-farm research elsewhere that may be more suited to the technology; or 4) attempt to correct any mis-perceptions of the technology by farmers through a better flow of information regarding its potential so that a significant right-ward shift of the cumulative distribution function of payoffs occurs to make it more appealing to farmers.

The non-inclusion of Linola in any of the farm plans may not, however, be an indication of the actual worth of the technology but more a result of the information currently available to the respondent farmers. This fact was reflected in the expressed fears of a few of the farmers about their technical competence to grow the crop. In time, as more information becomes available about Linola, it is likely that a reduction in the level of pessimism associated with the management expertise of the farmers should see their perceptions of its potential performance improve.

Second, in terms of resource allocation decisions modelled for the five farmers in the study, the results of the various models presented in Tables 6.1 - 6.5, suggest that farmer aversion to risk is apparently not the reason for the predicted non-adoption of Linola under the uncertain production environment in Barwon. The divergence between the results obtained for the deterministic risk-neutral models and those for the UE programming models is, however, suggestive of the influence of risk in farmer resource allocation decisions and on the farmer certainty equivalents. The implication of this result is that the goal of extension in the transfer of technology should be the alteration of farmer beliefs through the timely provision of pertinent and useable information. It would not appear to be a legitimate option to seek to change a decision maker's personal attitude to risk.

Third, the unique optimal solution obtained for each assumed utility-maximising farmer based on his beliefs and preferences, suggests that general and stereotyped prescriptions by extension agents have to be considered as unsatisfactory. There is the need to avoid the 'packaging' of information approach in favour of a more interactive one that is tailored to the needs and circumstances of farmers. Such interaction would allow the coming together of the various agents involved to foster better communication and the reduction in perceptual gaps that may exist concerning the new technology.

Fourth, it would appear that oilseed production in the Barwon has recognisable potential since oilseeds are in most of the predicted strategies as well as in most actual farm plans. This indicates that the non-inclusion of Linola in the solutions is probably because the crop is not yet perceived by the respondent farmers to be competitive with other oilseeds.

Fifth, the different solutions obtained with farmer and researcher perceptions indicates the possibility that the source of information may influence the scope for the adoption of Linola given the apparent gap in perceptions. In consequence, the emphasis by researchers should be to seek to narrow the existing gap in perception by better interaction between researchers, extension agents and farmers, especially through interactive on-farm research in which learning is a two-way process.

Sixth, while the necessity for some interventionist policy by government to reduce the burden of acquiring 'quality' information by producers may be argued, such intervention is not considered necessary in this instance given that an avenue exists for CSIRO, through Seedex, to share the risk associated with the further development of Linola. Investment in agricultural research will not achieve the desired results on the farm if effective mechanisms of transmitting research information to farmers are not in place. Rötter and Dreiser (1994) have noted that the provision of effective decision making support to farmers can significantly influence adoption rates for new technologies. Applied agricultural research can be regarded as having some potential value only when it results in new farming practices which are stochastically efficient relative to prevalent practices. Thus, there is an obvious need for more research to improve the profitability of Linola in the Barwon district or, perhaps, the crop could be introduced to another part of the country more suited to its production.

## 7.4 Study limitations and scope for further research

Although every effort was made to ensure the quality of the data used in the models, some of the assumptions made to aid computations because of financial constraints faced by the author may have created elements of bias in the models. For instance, the assumption of similar technical coefficients - excepting yields and prices - in all five farms modelled may have led to either an over- or under-estimation of the model objective functions. The uniqueness of the terrain and soil structure on individual farms may cause technical coefficients to vary from one farm to another. It might be useful to obtain farm-specific data for the modelling to allow more specific analysis and modelling.

A possible major limitation of this work is the use of a single attribute utility function. This has led to other non-monetary factors that could influence production decisions being ignored. For instance, the possible effects of a farmer's preference for leisure have not been considered in the models. It is possible that such assessment of new technology should be based on a multi-attribute utility function. Whilst most of the interviewed farmers saw farming as a business, they also thought of it as a way of life and, for a few, it was seen as a family tradition. In essence, a multi-attribute approach to the problem might provide more insights into subjective technology assessment by producers.

The severe financial constraints that faced the author limited the time spent in the field collecting the data for this study. The one-off interview procedure adopted for the work for measuring the range of risk aversion may be fraught with problems as Binswanger (1980) has observed. Such problems associated with the elicitation of individual preferences include changes in expressed preferences over time and interviewer biases. The problem of changing preferences would probably be less with the interval approach relative to the more commonly applied equally likely certainty equivalent (ELCE) and equally likely but risky outcome (ELRO) approaches. However, a better measurement of preferences might have been obtained with a drawn-out series of multiple elicitations to ascertain that true producer preferences have been coded correctly. The results obtained for farms four and five, for instance, indicate that either the producer preference intervals were not correctly elicited or that the producers behave differently to their expressed preferences (see Figures 6.6d and 6.6e).

Another possible limitation of the study is the use of regional historical yield and price data as the basis of the data used in the models. The biases in regional data relative to actual farms data have been recognised by various authors (e.g., Bessler 1984; Gommes 1993; Penning de Vries 1994; Rasmussen 1996). Although the scaling procedure adopted for the study should preserve the stochastic dependencies and the historical distribution of the data, it is possible that the covariances may not be a true reflection of actual covariability of the expected outcomes. According to Rasmussen (1996), modest differences in the correlations between yields and prices may significantly influence the variability observed for expected outcomes. In recent times, crop growth models have been widely applied in studies of agricultural production. These models have been used to simulate time series data for crop yields (Dillon, Mjelde and McCarl 1989; Crisostomo et al. 1993) and could be an option for generating yield data for an analogous study.

To maintain simplicity and focus on the main objective of the assessment of the potential for Linola adoption in cropping practices, the study has neglected consideration of many of the risk management strategies open to farmers. A more complex modelling procedure could be adopted to include all feasible diversification options in the district, insurance and hedging options and various marketing options including various contracting alternatives such as forward and futures contracting or guaranteed minimum price options. The benefits of such added complexity will, of course, have to be weighed against the value of the additional information provided with regard to the assessment of a new technology.

The objective function in this study was defined as the pre-tax net farm income. However, recognising that changes in the context in which individual risk preferences are elicited can have significant influences on the exhibited preferences, it is possible that the use of post-tax net farm income could yield different results from that obtained in this work.

Byerlee and Anderson (1982) developed a model that provides a decision theoretic framework for the analysis of the role of the farmer risk attitudes in the acquisition of information regarding an existing technology. It would be interesting to see how, within such a framework, producer risk preferences influence their decisions concerning the use of information about new technologies such as the one that formed the focus of this work. A comparison between the way non-risk neutral farmers process received information concerning existing and new technologies would be illuminating for the design of effective extension programs.

The contention in much of this work is that, under uncertainty, the risks associated with a new technology are a result of imperfect knowledge and since there is no 'correct' measure of risk under such circumstances, individual perceptions become central. In the final analysis, despite the enumerated limitations, the author believes the intended objective of analysing the influence of farmer perceptions of the worth of a new technology as an addition to their farming systems has been achieved.

Finally, the issue of economic efficiency was not explicitly considered in the analysis. It is possible that the existence of economic inefficiencies in resource use on the studied properties could influence technology adoption decisions. A study of the relationship, if any, between technical or allocative efficiency and technology adoption could also provide results useful for the design of extension programs.

## 7.5 Concluding comments

Despite the differing goals of agricultural producers within an uncertain production environment, the achievement of these goals requires sound management of available resources with the implication that good decisions are necessary. The adoption of a new technology poses additional risks to the producer that further emphasise the need for good decision making to ascertain and maintain the welfare of the farm family.

It is clear that the research method used in this study is not without shortcomings. The case study approach using five producers effectively limits the general applicability of the results. Further studies in this area would, no doubt, improve the quality and applicability of these results. Nonetheless, the study has provided useful insights into the impact of farmer risk attitudes on decisions concerning the adoption of a new technology. The subjective nature of farmer perceptions about the riskiness of a new technology indicates the need for the realistic characterisation of farmer beliefs before any worthwhile evaluation of the potential value of a new technology can be undertaken. The study has clarified the fact that, in technology assessment in commercial agriculture in Australia, the focus ought to be less on the aversion to risk by farmers and more on their expressed beliefs about yields and prices of a new crop which appear to have significant influence on their resource allocation decisions. Although the subjectively perceived riskiness of a new method of production may well exceed the actual risks associated with the technology, in the final analysis, it is the strength-of-conviction of the farmers concerning the potential performance of a new method of production that influences their adoption of new technologies within the limits of their resource endowments. Also, the study indicates that insufficient and inappropriate interaction between farmers and researchers can only serve to bias negatively farmer perceptions of a new technology. Finally, the study demonstrates the practicality of using the SDRF evaluative criterion in a whole-farm planning context to subjectively assess the potential for the adoption of a new technology.