Chapter 6

HOLISTIC STOCHASTIC MODELLING: AN ON-FARM DECISION-MAKING APPLICATION

6.1 Introduction

This study examines a stochastic whole-farm plan, and the theory behind this exercise is outlined in Chapters 2, 3 and 4.

Chapter 5 described the mathematical programming components of the whole-farm model. A stochastic programming model was built for a simulated small farm to demonstrate how this type of modelling affects farm planning, by making the planning outcomes a more reliable decision-making tool than deterministic methods. Appendix 5.4 contains the input and output files of this demonstration exercise.

This chapter compares a benchmark on-farm plan under two scenarios (i.e. deterministic and stochastic) in order to evaluate the influence of the hard system component on the overall holistic farm planning exercise. Finally it closes with an analysis of the specific and general conclusions of the study and a discussion on the critical achievements of the HSM exercise.

6.2 Deterministic and Stochastic Optimal On-farm Planning Scenarios

Scenario analysis was used in this study as per Wossink (1993). The first scenario presents a deterministic environment, where the whole system variables are deemed to be deterministic, while the second scenario includes selected variables deemed to be stochastic. For the latter scenario, the input-output coefficients of these variables reflect the stochastic dynamics describing *technical risk*; the objective function reflects the *attitudinal risk* component which affects system performance. The computations performed examine the implications of optimisation and stochastic criteria applied to combining farm resources.

The multi-activity farm models in this study are created applying deterministic and stochastic versions of the analytical model. These quantitative models are progressively constructed from the individual-enterprise models (i.e., beef, meat and wool). The individual enterprises were evaluated with a total use of the farm resources, in order to test the accuracy and effectiveness of the model. The way each individual enterprise was likely to contribute to the overall optimal plan was also evaluated using this method.

The following analysis of results is descriptive, and these optimal outcomes should be considered only as global indicators of enterprise performance. These values should not be taken as the definitive response to the system's performance, since farming system conditions might unexpectedly change. The descriptive comparison of results is undertaken below in order to establish the relative benefits of deterministic and stochastic analysis.

6.2.1 The deterministic scenarios

Table 6.1 gives an overview of farm performance for the *deterministic* scenarios. Further information about the input and output files is found in Appendix 6.1.

Analysing the results for the individual farm plans it may be observed that the beef farm plan (BEEFDM) reports the largest value for the optimal solution ($3036600), compared with the meat farm plan (MEATDM) ($2239392), and the wool farm plan (WOOLDM) ($2260895).

BEEFDM considers trading steers only in the optimal solution of the farm system. Parameterisation of costs was done to evaluate introducing breeding cows into the optimal solution, but the results described completely unrealistic cost levels. BEEFDM uses the loan option and integrates this loan investment capital with the cash available for purchasing trading steers (1327 head) and land (451 ha) after paying farm costs.

MEATDM makes full use of the available land (1111 ha) and indicates the purchase of additional land for breeding activities (311 ha). The MEATDM model buys breeding ewes (3451 head) which, at a lambing rate of 100 per cent, produce 3451 prime lambs to sell. When the breeding ewes are culled at a rate of 20 per cent, 691 cast for age (cfa) ewes are available for sale. A supply of wool types A, B and C, as described in the code variables, is sold to improve cash flow. The farm plan allocates resources to purchase land (311 ha).

Table 6.1 Deterministic Decision Making Farm Plans

ACTIVITIES	BEEF (BEEFDM)	MEAT (MEATDM)	WOOL (WOOLDM)	HOLISTIC (HDM)
Farm Assets	3036600	2239392	2260895	3037592
Pasture land	1562	1422	1464	1562
Fodder land	150	150	150	150
Buildings	155000	155000	155000	155000
Machinery	85200	85200	85200	85200
Buy trading Steers	1327			1327
Sell trading steers	1327			1327
Meat ewes		3451		
Buy meat ewes		3451		
Prime lambs		3451		
Sell culled ewes		691		
Sell prime lambs		3451		
Sell wool type A		12082		
Sell wool type B		3452		
Sell wool type C		3452		
Buy land	451	311	353	451
Bank loan	100000	100000	100000	100000
Pay bank loan (i = 0.09)	109000	109000	109000	109000
Pay fixed costs	71400	71400	71400	71400

WOOLDM does not choose any animal activity. Rather, it selects an investment in land (353 ha) as the only profitable activity, investing to the extent of the available financial resources. This type of outcome demonstrates the need for caution in using optimal solutions. In this particular case, 12444 DSE of grazing capacity are available. The land resource is fully covered by the model's specifications, but the slack grazing capacity is not taken into account. This example provides a good justification for running multi-activity models.

The multi-enterprise deterministic farm plan (HDM) reports an optimal farm assets value of $3037592 and chooses the beef enterprise resource combination as the most suitable to fulfil the objective function criterion. There are no significant differences between BEEFDM and HDM.

When comparing the previous analyses with the values reported in the output files of Appendix 6.1 it should be noted that in the different scenarios one (1) animal is run for the different animal categories. This is an artificial value, set to test the programming matrix (RHS) to ensure that the model is operational at all levels, and these values are not considered in the analysis of the optimal solutions.

6.2.2 The stochastic scenarios

Table 6.2 gives an overview of farm performance for the *stochastic* scenarios. Further information about the input and output files is found in Appendix 6.1.

Analysing the individual farm plans it may be observed that the beef farm plan (BEEFSM) reports the largest value for the optimal solution ($2885200) compared with the meat farm plan (MEATSM) ($2315713), and the wool farm plan (WOOLSM) ($2182458).

As with the deterministic scenarios, the stochastic model pays farm costs, transfers values of the total assets to the farm assets account and uses a term-loan option for making cash available, once the initial RHS cash value is assigned to the three individual-enterprise farm plans.

BEEFSM differs from the deterministic scenario in relation to the final number of trading steers (1108 head) and land purchased (407 ha), with an optimal assets value of $2885200, compared to the values (1327 steers; 451 ha of land and $3036600 optimal assets value) derived from the deterministic exercise.

MEATSM reports a farm assets value of $2315713 and uses the available investment capital, including the term-loan option, for buying breeding ewes (3326 head) and purchasing land (358 ha). A stochastic lambing rate (84 per cent) is chosen by the model to produce 2788 prime lambs which are sold together with 666 cfa ewes. The purchase of land is considered within this farm plan (358 ha), and the wool production from the meat sheep is also included in the optimal solution. This model has a similar outcome to the stochastic beef farm plan, where the optimal solutions of the stochastic scenario produce lower nominal values.

WOOLSM, as in the wool plan in the deterministic scenario, does not include any animal activity in the optimal solution but uses investment resources to purchase land (294 ha): in the deterministic scenario the proposed land purchase is larger (353 ha).

The multi-enterprise stochastic farm plan (HSM) reports an optimal farm assets value of $2262814 and adopts the beef enterprise activities in its optimal solution, reducing the land purchase by 44 ha, and stocking 219 steers less.

Table 6.2 Stochastic Decision Making Farm Plans

ACTIVITIES	BEEF (BEEFSM)	MEAT (MEATSM)	WOOL (WOOLSM)	HOLISTIC (HSM)
Farm Assets	2885200	2315713	2182458	2262814
Pasture land	1518	1469	1405	1518
Fodder land	150	150	150	150
Buildings	155000	155000	155000	155000
Machinery	85200	85200	85200	85200
Buy trading Steers	1108			1108
Sell trading steers	1108			1108
Meat ewes		3326		
Buy meat ewes		3326		
Prime lambs		2788		
Sell culled ewes		666		
Sell prime lambs		2788		
Sell wool type A		11644		
Sell wool type B		3327		
Sell wool type C		3327		
Buy land	407	358	294	407
Bank loan	100000	100000	100000	100000
Pay bank loan (i = 0.09)	109000	109000	109000	109000
Pay fixed costs	71400	71400	71400	71400

6.2.3 A comparative analysis between deterministic and stochastic scenarios

A comparison between the deterministic and stochastic scenarios is undertaken at two levels:

(a) a discrete comparison between the values of the different farm plans; and

(b) a comparison of parameterised optimal solutions between the deterministic farm plan (HDM) and the stochastic farm plan (HSM).

The discrete comparison between the values of the different scenarios indicates:

(a) The activities adopted in the optimal solutions of the different farm plans are not substantially different between the deterministic and stochastic scenarios; rather there is a difference in the degree to which each activity is used in the optimal solution.

(b) For most of the farm plans, the stochastic scenarios offer lower values for the objective functions and activities than the deterministic scenarios, except for the meat farm plans, where the objective value of MEATSM is slightly larger ($76231) than the MEATDM value, since the stochastic scenario indicates a larger purchase of land than the deterministic scenario. This outcome is not seen in the remaining scenarios.

The comparison of parameterised optimal solutions between the deterministic and stochastic scenarios is shown by Table 6.3, Table 6.4 and Figure 6.1. As indicated in the above mentioned tables, the models were parameterised in a discrete manner for the stochastic variables that entered the optimal solution. The average optimal value of farm assets for the deterministic farm plan is $3254690, with a standard deviation of $1523061 and a coefficient of variation of 46.8 per cent in the domain of the function for which the parameterisation exercise was done. This indicates that there may be a high level of variability of the optimal solution when deterministic values are used in the setting of the planning model. The average optimal value of farm assets for the stochastic farm plan is $2262659, with a standard deviation of $570 and a coefficient of variation of 0.025 per cent indicating a minimal level of variability of the optimal solution in the domain of the function for which the parameterisation exercise was done. It can be argued, then, that the domain of the stochastic farm plan function offers a minimised variability pathway when compared with that of the deterministic farm plan, and therefore the application of stochastic programming fulfils the objective of managing the technical and attitudinal risks embedded in the operation of the farm system. An aspect that remains for further discussion is how realistic the values of stochastic optimal solutions are for practical farm planning processes: how useful and relevant are these results when the conceptual mapping exercises indicate a massive influence of stochastic factors in the overall performance of the farm system ?

6.3 Conclusions

The conclusions of this study are presented in two major areas. The first refers to how the components of the quantitative farm model integrate with the components of the conceptual farm system. The second is related to the validity of the HSM outcomes of the study and their implications for the on-farm application of strategic management.

6.3.1 Specific conclusions

The specific conclusions about the on-farm application of the quantitative programming model are as follows:

Table 6.3 Parameterisation of the Deterministic Farm Plan

ACTIVITIES	HOLISTIC DOWN (HDM1)	HOLISTIC STAND. (HDM)	HOLISTIC UP (HDM2)
Farm Assets	1507377	3037592	5219101
Pasture land	1111	1562	1611
Buy land	NIL	451	500
Buy trading Steers	471	1327	2052
Sell trading steers	471	1327	2052
Bank loan	NIL	100000	100000
Pay bank loan (i = 0.09)	NIL	109000	109000
Pay fixed costs	71400	71400	71400
Saving Account	215340		485200

Critical variables: Steer prices, Stocking rate & Land Prices
(Discrete variation 50 % down and up)
Average Assets Value = $ 3254690
Standard Deviation = $ 1523061
Coefficient of Variation = 46.8 %

Table 6.4 Parameterisation of the Stochastic Farm Plan

ACTIVITIES	HOLISTIC DOWN (HSM1)	HOLISTIC STAND. (HSM)	HOLISTIC UP (HSM2)
Farm Assets	2261896	2262814	2263266
Pasture land	1518	1518	1518
Buy land	407	407	407
Buy trading Steers	1108	1108	1108
Sell trading steers	1108	1108	1108
Bank loan	100000	100000	100000
Pay bank loan (i = 0.09)	109000	109000	109000
Pay fixed costs	71400	71400	71400

Critical variables: Steer prices, Sustainability Index & Land Prices
(Discrete variation of target values 50 % down and up)
Average Assets Value = $ 2262659
Standard Deviation = $ 570,00
Coefficient of Variation = 0.025 %

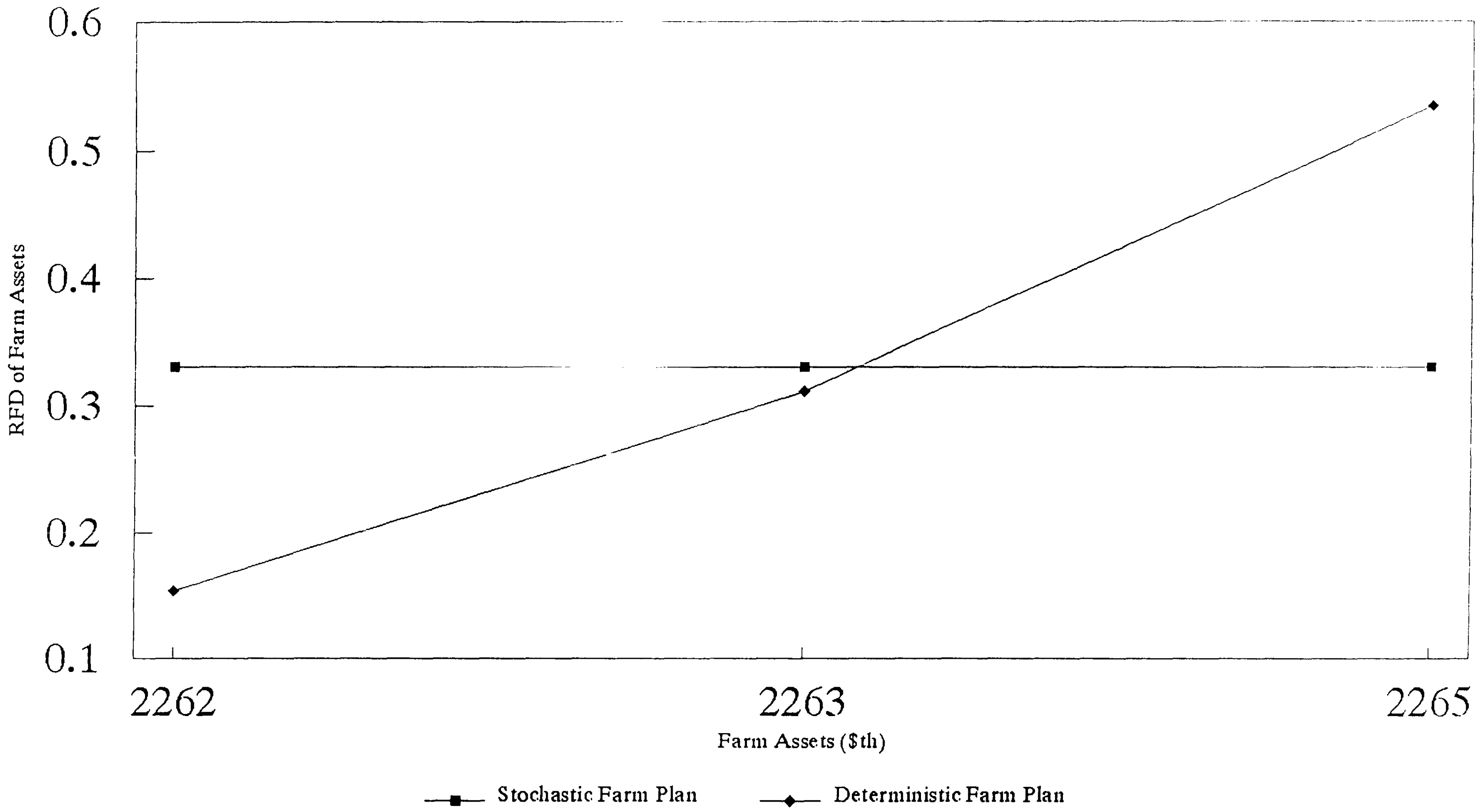

Figure 6.1 Deterministic and Stochastic Farm Plans

(a) The optimal solutions of the individual farm enterprises showed the relative weighted value of each enterprise in the operation of the farm system. The multi-activity model used the inter-relationships amongst these enterprises (physical and financial) to find the combination most suited to the optimal condition established by the decision criterion of the objective function. It is not surprising to find that the wool enterprise does not enter the optimal solution, given the current cost and commodity-price structure input into the model. Similarly the meat sheep enterprise is not considered in the optimal solution when the multi-activity model is implemented.

These results from the quantitative models confirm the farmer's view on enterprise combination. However, for farm planning purposes, the discrete values of the optimal solutions should not be considered apart from the changing context of the farm system. Conceptual mapping showed the multiple factors internal to the farm system that embed variability in the system operation and subject the farm system to a permanent process of change and adjustment (i.e. dynamics and feedback processes). In other words, conceptual mapping ensured a cautious and more informed basis for the interpretation of the quantitative results in the light of the more complex reality of any farming system.

(b) The sequential running of the different farm plans has a two-fold purpose. Firstly, the exercise validates the consistency of each individual enterprise and each enterprise's importance in the optimal solution; and secondly it tests the structure of the analytical model. When cash flow alone was considered in the initial stages of defining the model setting, the level of participation of the animal activities in the optimal solution revealed a low financial performance for the whole-farm plans. When the optimal criterion was upgraded to include whole-farm assets valuation, the optimal solution always highlighted land purchase as a major investment for optimal financial farm performance, but it was not always possible to stock the farm land appropriately. While this can be pre-arranged, artificially, in the programming matrix, the current model structure did not consider this option, and left this decision to the model to resolve, using merely financial arguments, as the objective function defined. The analysis of the optimal solutions of this model, where no conditions for land purchase decisions were established, other than return of the activity by itself, caution is needed in the interpretation of optimal solutions, since the carrying capacity of the farm system is not fully exploited by the optimal model, mainly because of financial constraints to the farm operation in terms of available resources and profitability of complementary activities to land purchase.

Throughout the exercise, the model consistently used the marginal animals allocated in the RHS section of the programming matrix, paid costs, variable and fixed, used the loan facility, sent the cash-flow balance to a savings account and afterwards to the final farm assets balance: all are consistent with realistic farm management practice.

(c) The comparative analysis between the discrete scenarios and the stochastic scenarios of the programming exercise shows the advantage of the stochastic models in the management of risk in the farm business. The stochastic plan of this study offers a way to plan farm activities with a more realistic accounting of risk, representing, as it does, dynamic system components for strategic management. Information on the trends in the combination of activities and resource trading is important, but it is the farmer who must, in the end, decide how to implement the plan, considering how the conditions underlying the operation of the farm system are going to change through its internal dynamics or outside factors.

(d) The stochastic planning scenarios, did not select an entirely different set of activities, but modified the balance of these activities to conservative levels in order to minimise risk.

(e) Traditional MP techniques, built on gross margins or similar techniques, add theory-driven inflexibility to the overall farm plan. By contrast, the criteria generated by embedding cash-flow and assets valuation into the system's dynamics seem to suit the strategic planning model better, when the overall decision criterion is operational financial performance. Strategic management can be better undertaken at the farm level since the information provided by the quantitative exercise enables the decision maker to preview the system operation before implementing his/her own decisions.

(f) The stochastic programming model of this study is an integration of an array of stochastic management criteria, and aims to make decision making in FBM more useful through developing a more realistic stochastic representation of system performance. The incorporation of various traditionally "soft" system variables in the programming matrix has extended the interface between soft and hard systems analysis, and this was a major objective of this study.

(g) The stochastic programming technique of this study offers flexibility in risk management. It allows easy modifications of its components at the levels of model structure, technical risk management and attitudinal risk management. Also, it facilitates the inclusion of any new components at the level of technical risk which may arise through subsequent research on the farm system.

(h) The stochastic programming model itself has proven to be simple to use though it initially requires laborious setting of the programming matrix. Technically it runs as a representation of a total farm system, involving hard system and some soft system aspects. This allows the management of both financial and non-financial variables in the same framework.

The farmer's financial objective is progressively handled by cash flow and assets valuation accounts that map the system's operation in accordance with the pre-established objective function. The stochastic effect of the technical variables of the farm system affects farm cash flow, and the attitudinal risk of the decision maker affects the final farm value.

(i) Stochastic programming, from a prescriptive perspective, is a technique that generally results in lower values than deterministic programming. The stochastic model minimises the negative deviations (i.e. downside risk) of the effects of technical risk factors embedded in the farm operation below the values of reference defined by the farmer's minimal expectations. It also uses probabilistic parameters for the stochastic technical variables of the farm system. Therefore the stochastic results are more realistic, since they represent the true variability of the farm system operation.

6.3.2 General Conclusions

The wider conclusions to address the overall objectives of the study are outlined in this section.

(a) The deterministic and stochastic programming models of the study are efficient in deriving an effective combination of farm resources, a combination which generates the best whole-farm assets valuation at the end of the exercise. A flexible approach, as outlined by the conceptual maps related to resource usage and objectives definition, should be paramount in striving for sustainable outcomes from the farm. However, stochastic quantitative programming results should be considered primarily as a reference point for organising resources, implementing enterprise activities, and developing contingency schemes to increase the scope of success in decision making. Decision making, in soft systems methodologies, is mainly a subjective process, guided by empirical and intuitive perceptions of reality. Quantitative programming, on the other hand, holds that decision making is a pre-established process with pre-determined outcomes and achievements. The truth requires a balanced integration of these two theoretical perspectives. Adjusting pre-conceived system performance, by highlighting the independent decisions of the decision maker, and giving due weight to his/her individual expertise, beliefs and expectations, will lead to the achievement of holistic sustainable farm outcomes.

(b) It is important to realise that HSM does not only derive the value of the optimal solution, but also generates information on the interplay of resources, considering the soft and hard constraints imposed on the farm model through the planning scenarios. In this way, operational decision making is strengthened with more accurate information. This approach can accommodate the consideration of the diversity of real life situations, within which a cautionary analysis of results will provide a valuable management tool to be used in enterprise organisational processes.

(c) When the quantitative component of the modelling exercise is integrated with the conceptual modelling exercise, this integration is broadly consistent with HSM. Thus it may be concluded that HSM minimises the riskiness of the whole-farm plan by ensuring the application of a broader context for farm planning; one which explicitly encourages the cross-referencing of hard and soft system influences, and one which facilitates system learning on the part of both, the farmer and the adviser/analyst.

(d) The mathematical models, and specifically the stochastic models, were structured around elements derived from a conceptual mapping exercise of the farm system. Identifying interrelationships between hard and soft system elements, and tracing feedback processes that define the management strategies for combining resources, were both important steps towards defining a more holistic farm decision model that reflects the reality of managing the farm business.

(e) Chapter 2 demonstrated the multiple conceptual maps which may be derived for a farming system. Under the framework of HSM this multiplicity of system mapping, rather than creating conflicting system objectives, reinforces the unity of the system's action. When provided with different perspectives of the same system, the decision maker has a better range of possibilities, an array of methods for gaining information about the system, and therefore a number of ways to engage the management process on controlling the factors considered critical. The end point of any conceptual mapping exercise is integration towards a common broad objective, but as the level of mapping is taken to higher definitions, the system's purpose becomes more explicit/specific. By maintaining an holistic perspective, the integrated views of the system which the decision maker possesses will avoid potentially misleading bias when considering quantitatively designed advice.

(f) The inter-relationships between resources, activities, decision management factors and objectives influencing a farm system management environment may be better captured through holistic exercises that deal with soft and hard systems environments. Conceptual mapping of farming systems, a soft systems tool, and quantitative modelling, a hard systems tool, may be progressively integrated in the planning process, using conceptual mapping as an information tool and the quantitative modelling component as an operational research tool. This should produce a decision planning model which can contribute to better information management.

(g) HSM shows that some soft systems variables (e.g. sustainability, experience, intuition) can be represented in an optimal decision model, and that their impact can be quantified through specific relationships within a framework of short-term objectives.

(h) Short-term planning models able to incorporate cash-flow and assets analyses enable the decision maker to make informed decisions with longer term implications. Since the financial conditions of managing on-farm production processes are in a permanent flux, short-term stochastic decision planning models are a suitable tool to improve the tractability of holistic farm planning and to support the provision of better information.

(i) HSM is a simple tool for operational decision making in farm planning given the constraint of system variability (i.e. stochastic influences). Employing available on-farm and regional data will make HSM a more effective tool, reducing the variation between business plans and real-life performance.

(j) Using HSM, farmers can better understand the impact of the farm system's instability on their farm income, the influence of technical factors (i.e. ecological, production, financial and market) and attitudinal factors (i.e. the farmer's risk perception) in the farm operation.

(k) Risk management is one of the challenges facing professional farmers and farm consultants. Practical opportunities to incorporate risk in whole-farm planning from the perspective of the decision maker are urgently needed. This study presents a simple but not insignificant approach to the consideration of on-farm risk management. Farmers can define the variables which they consider critically influence farm performance, facilitated by a conceptual mapping exercise. Analysts can use real farm data and input the information through the data entry set as used for this generic model. Using the essential elements of the model of this study a farm programming matrix will advise on the best combination of resources while managing the variability of the farm system as seen by the farmer. Furthermore, the chance to use target values of reference for critical variables has proven to be a suitable criterion to differentiate domains of risk aversion and risk taking attitudes, at the operational farm management level.

(l) Carrying out formal on-farm stochastic modelling exercises for different scenarios does not necessarily make decisions about farming less risky or objective, but it does make them more tractable. The formal optimal and stochastic framework facilitates the investigation of alternative scenarios for farm performance, but does not replace the decision maker's experience of the farm organisation. HSM builds upon the farmer's managerial and technical background, enhancing his/her decision making process under the influence of perceived technical and attitudinal risks. The process also increases the understanding of farm consultants and analysts who use it. In summary, the integrated procedure facilitates all round learning and improves the mutual understanding between analyst and farmer.

(m) The analytical results of whole-farm planning scenarios should be used as inputs for setting decision priorities, after carefully considering the limits to the accuracy of those decisions. If used with caution, the simulated farm performance can provide valuable information about the advantages of prospective plans, therefore making the decision making process in the farm business more effective. The quantitative exercise will sharpen the farmer's perceptions by helping him/her learn about the impact of various strategic opportunities. What is further needed is good communication and co-operative learning between modeller/analyst and farmer.

(n) Soft systems and hard systems techniques were used to identify the system components and its internal dynamics before the system's objectives were defined. There was therefore an element of system learning that framed HSM as an inductive exercise rather than deductive. A major contribution may well be the better understanding of the dynamics of the system and its complexity. HSM allows effective consideration of environmental instability engendered through the analytical process outlined in this study, and the easy management of non-traditional planning variables, thereby widening the scope of successful decision making in a short-term framework.

6.4 General Discussion

There are four aspects that are considered relevant to this general discussion of the achievements of this research:

6.4.1 The farming systems research approach

The scope of farm business management is increased when FSR principles are used. This study presented a typical FSR, on-farm exercise, where holism was considered to generate farming system information that would enhance the decision-making process.

In the holistic approach of this study, resource identification, resource integration and resource management combined to create an operationally manageable dimension for sustainability.

When learning methods are applied to farming systems (as in HSM) the expertise, outlook and intuition of the farmer and the analyst interact and combine to redefine more precisely the system's components, and its dynamic relationships, feedback processes and purpose, producing an enriched map of the farm system. This process of refining and redefining might continue indefinitely, making on-farm research a valuable tool of information.

6.4.2 Integrating farming systems analyses

This research was an exercise on hard and soft systems integration, where a quantitative programming model and conceptual mapping at different levels of resolution were put together in order to achieve a better analysis of the farm system, its components, interrelationships, internal dynamics, feedback processes and stochastic system behaviour. One outcome of the exercise was a more informed and purposeful whole-farm system where the relevance of the decision maker's action is pre-eminent in the system's performance. Thus this exercise demonstrates that hard systems programming techniques are useful for planning purposes as long as they are complemented by approaches which ensure a realistic and holistic perspective of management and decision making.

Though the integration between the soft system and hard system components of the farm in analysis was pursued through a realistic and practical farm planning approach, it was not possible to include several soft system elements into the formal modelling exercise, and their relevance and influence can only be incorporated into the decision framework through reference to the conceptual mapping component. It is legitimate to combine the programming approach with conceptual mapping in order to more completely address the realistic concerns of farmers who always will be driven by more complex concerns than those that can be represented in any formal programming model. In this particular on-farm study, personal values, such as leisure, social pride, political implications of the farming status, management of sources of finance, marketing opportunities, information management and family participation, are some examples of variables not included in the analysis, although worthy of consideration.

6.4.3 The strategic management framework

The challenge in farm resource management is to find an approach that treats people, resources and environment as a whole; one that recognises the human purposiveness of the system and that uses available organisational techniques to optimise resource usage. Management studies suggest the concept of *strategic management* as a solution to this concern. Though there are many perspectives on strategic management, this research was framed under the philosophy of holistic dynamics and organisational management supported in Stacey (1993), where strategic management is a decision-making exercise with holistic dynamic management characteristics that recognises the system purposiveness in the short-term; the changing nature of the system (embedded stochastic processes); the natural and induced adjustment processes (feedback processes); and the continuous looping of *choice* - *action* - *reaction* with dynamic changes in time and in purpose. Conventional wisdom suggests some acceptable principles for understanding the system, but the analysis of the system and its action is framed towards the crucial role of the human component of the system, i.e. the decision maker. It is the decision maker who finally defines system purposiveness and sets the strategic holistic management of the system to achieve his/her particular perception of the system's purpose.

6.4.4 The interaction between farmer and analyst

Conceptual mapping, when conducted by an analyst willing to incorporate the complexity of resource management and decision making, can convey without analyst bias the reality of the farm from the farmer's perspective. By contrast, a traditional hard systems approach to systems analysis and planning determines the hypotheses to be tested before hand. In HSM there are no pre-conceived models or solutions. The system is there, encompassing resources, including the decision maker, that act in a holistic manner, and the analyst has to become part of that system at a particular point in time of the analysis if he/she wants to understand the system. If this happens, the decision maker (i.e. the farmer) will dictate and highlight the relevant components and the analyst will embody them using the algorithms and methods of HSM.

6.5 Summary

A descriptive analysis of the programming models, applied to the case-study farm, was undertaken, highlighting the advantage of stochastic modelling in terms of more realistic quantitative information. However it should be remembered that the results of this type of model must be evaluated within the whole context of the system and the value of its outcomes considered against a constantly changing environment. The versatility of conceptual mapping in capturing this changing environment is highlighted by its capacity to allow the decision maker to analyse the system from multiple perspectives, depending on his/her particular perceptions of risk and of the system's purposes.

The conclusions were listed in two groups: specific conclusions, the quantitative outcomes of the MP exercise, and the general conclusions, which refer to the broader objectives of the study.

Finally, using conceptual mapping, an overall perspective of the relevant achievements of this research are presented in Figure 6.2. The holistic stochastic modelling exercise, under the framework of Farm Business Management, constitutes the environment of this systematic definition of the research results. The integration between conceptual decision models and optimal decision models encompasses the resources side of this system description. The process component is how the analyst learns about the system, a learning process which enhances decision making and directly adds value to strategic management.

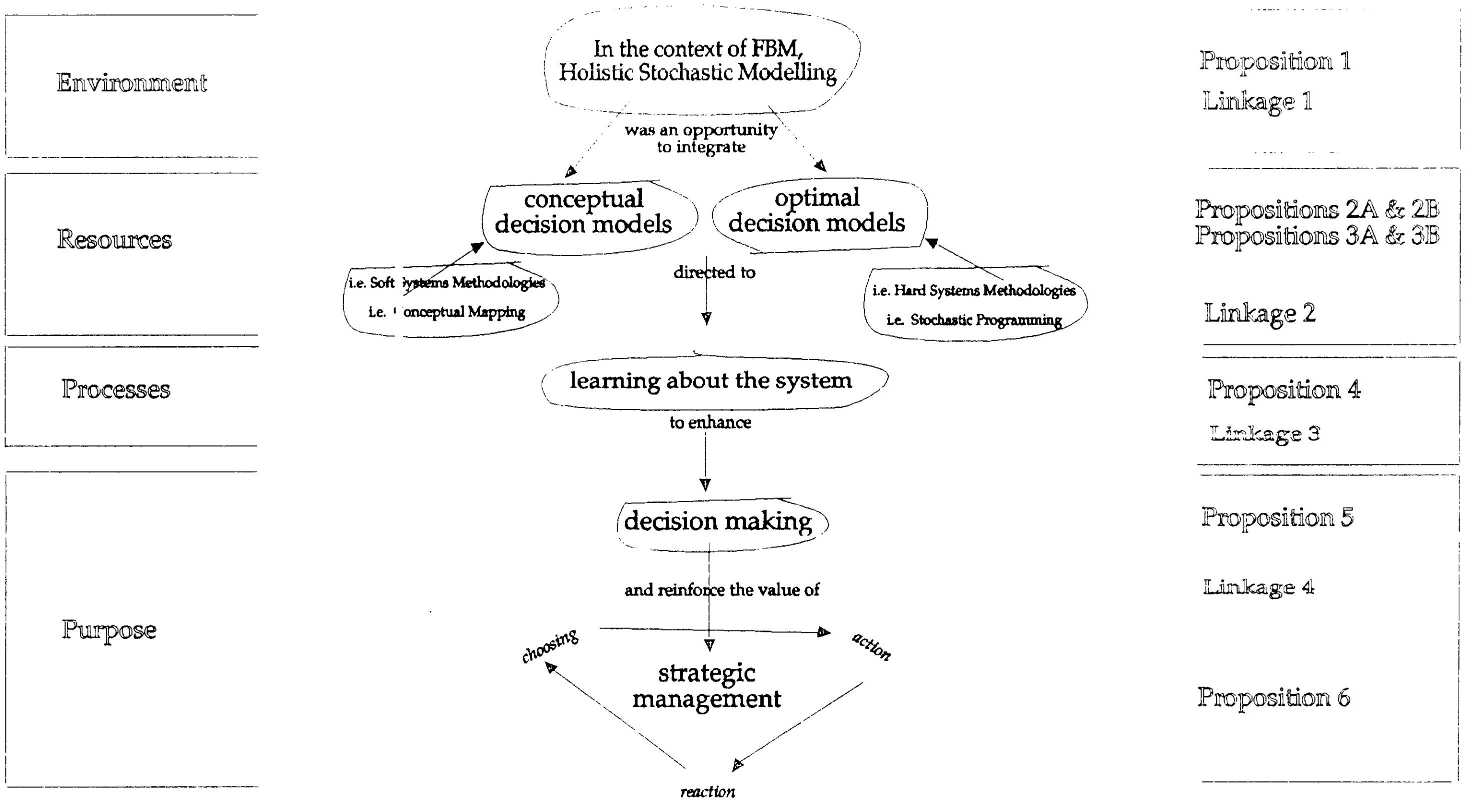

Figure 6.2 Conceptual Map of Research Achievements

Chapter 7

IMPLICATIONS AND LIMITATIONS

7.1 Introduction

This chapter provides a critical assessment of the study's structure, its achievements, its implications and limitations. Recommendations for further research and related extension work are also discussed. Finally the chapter assesses the merits of learning processes when integrated within the framework of strategic FBM.

7.2 Review of the Study

7.2.1 The basic problem statement

The study has indicated that using the holistic management framework to enhance sustainability, both financial and ecological, in planning is not the end point of the exercise, yielding solutions to be implemented, but is simply an information process, aimed at better organising the system's interrelationships and system's dynamics towards objectives identified in farm systems management.

The holistic perspective, focusing on financial and on other objectives not normally considered in formal farm planning processes, captures the system's dynamics better, recognises the internal feedback mechanisms of the system and identifies the sources and consequences of instability.

An HSM that is not immutable and which offers scope for adjustment according to how the decision maker perceives the realities of the farm business is one which integrates hard systems thinking with soft system processes to better define management problems.

This research aimed to test how a practical combination of hard and soft systems modelling techniques might assist farm planning and enable the decision maker to implement better informed decisions in a risky environment. The qualitative modelling exercise, using conceptual mapping, extends the model developed by Novak and Musonda (1991) because of the incorporation of new logistical and operational components. A functional programming farm model, using quantitative algorithms flexible enough to allow for compromise between predetermined financial objectives and the human issues of decision making at the farm level, fulfilled, in part, one objective of this research. The quantitative model and the conceptual mapping to describe the system were integrated in the end within the overall HSM.

The thesis is an integrative exercise of qualitative (soft systems) and quantitative (hard systems) modelling techniques, currently a difficult marriage to attempt. Hard systems thinkers undervalue the information that empirical conceptual analysis can provide, though they use it in an intuitive manner; and soft systems thinkers consider that, since any system is in constant flux, systems do not have end points that can be categorically described. An approximation, which integrates these two schools of thought, such as the one developed in this research, is a contribution to building better information models for decision making.

The integration of stochastic criteria allowed the construction of a model which using components from recent approaches, allows for the independent management of the technical and attitudinal risks affecting the farm system. This does not feature in the available literature on stochastic programming. The method developed in this research allows the analyst to incorporate, without difficulty or computational limitations, as many stochastic technical variables as necessary in the programming matrix, and to manage the stochastic effect directly in the technical coefficients of the model. The available techniques convert the stochastic effect to financial values, since the setting of the programming matrix is always dependent on the integration of the objective function, which defines the nature and characteristics of the decision criterion.

7.2.2 The role of HSM in FBM

The conceptual framework of the study is based on the view that a suitable integration through a FSR approach to agricultural technology, business management techniques and the socio-economic aspects of the farm environment constitutes a sound approach for FBM. The components of strategic management (i.e. choosing, action, reaction) are implemented to achieve the system's objectives in a dynamic and permanently changing environment, through holistic modelling exercises which encompass deterministic and stochastic scenarios. An holistic stochastic model constructed from an integration between conceptual mapping and deductive techniques was developed to enhance decision making by providing information, and an improved understanding of the variability of final farm outcomes.

A farm case study was used to generate the relevant components of the farm system through conceptual mapping. Conceptual mapping is an appropriate way of developing an holistic context for subsequent quantitative modelling. The concerns identified were then integrated through coefficients into a programming matrix. A sequence of on-farm programming scenarios was developed where the sequential incorporation of analytical components was evaluated using systematic reference to the holistic context established through conceptual mapping.

Though the results from on-farm case studies of this nature are mostly confined to the farm(s) under analysis, this should not exclude the use of available inferential statistical techniques through a two-fold approach:

(a) Upgrade FBM research from the individual case-study to representative group case-studies using the theory of finite populations (Keller et al. 1990).

(b) Develop a simple approximation to the riskiness of the critical variables using confidence analysis.

7.3 Applicability of Results

There are general and specific components presented in the FBM model developed in this study which are likely to be applied in the context of on-farm planning. Its general applicability relates to FBM developments in terms of research, and in consultancy and education. Its specific application is to the system analysis method for stochastic whole-farm planning in order to improve decision-making. The integrated approach has the capacity to derive suitable alternative farm plans that may be compared to previous exercises, benchmark opportunities and new plans.

HSM, while it uses quantitative algorithms, is not a conventional hard modelling exercise. It is different in that conditions of system analysis and system understanding are established through soft techniques (i.e. conceptual mapping). HSM requires additional quantitative information to round out the quantitative model design, information related mainly to defining inter-relationships, the inter-dependency of resources and activities, and the system's stochastic elements and purposes. The farmer plays the paramount role of defining the system's purposiveness according to his/her view on strategic management, where technical and attitudinal critical constraints are identified.

HSM allows the management of any type of variable considered to be stochastic. Taking into account that probability distribution functions and soft systems indexes may be generated from historical records or by weighting subjective probabilities, there is no limit to how the model might be applied in managing stochastic farming systems.

HSM represents a step forward in the design of planning techniques that better approach the operational reality of farming systems. Integrated farm analysis is a valuable guide to improving the management of resources, the combination of activities and the identification of the ever-present risks of the farm enterprise. It would be fair to say that when holistic stochastic planning is adopted, instead of giving fixed guidelines for actions, it presents the options for decision-making with the flexibility that every experienced farm business manager claims is essential for matching plans to reality. The holistic context is important as a guide to any formal modelling activity, as a context for the assessment of results and as a mechanism to facilitate farmer's and consultant's learning.

It is not only historical data which describes how the farm and farm outcomes evolve over time. Expertise is a distillation of history and adds a valuable component of experience and intuition that decision makers should not underestimate. Therefore, as improvements to whole-farm planning techniques are developed, the farmer's expertise, subjective assessment and intuition must be taken into account for optimal decision-making under risk. Decision models such as the one outlined in this study encourage these developments.

The model cannot account for every likely activity or any farmer's individual management system, but modifications can be incorporated without losing the basic structure of the model. The important feature of the model is that it reveals to the analyst and the farmer the logical readjustments to the farming system that can be made in order to make better investment decisions and enhance a sustainable farm business performance.

In spite of advances in functionality and simplicity, MP decision-models continue to be highly sophisticated tools, too complex for practical planning purposes. To avoid this complexity, training for farm business managers requires a shift in emphasis towards both formal and informal educational processes. Similarly extension packages should be made available in a way that simplifies the process of adoption. Purdue University is a successful example of this philosophy in action (Doster 1995) with the establishment of the Annual Top Farmers Planning Workshops using different levels of budgeting and MP packages.

While the method of this research was developed for specific on-farm purposes, it does not preclude its use for stochastic decision-making in other sectors of the economy, if suitable adjustments are made to the programming matrix. The powerful combination of MP and conceptual mapping as a way of exploring system relationships will provide a sound framework for informed decision making in any business context.

7.4 Implications for Future Research

New operational components should be added to the model in order to make its results more consistent with reality. For instance, consideration of mortality effects, interrelationships amongst animal categories, and better use of the fodder option are aspects that need improvement.

The index method used to implement ecological sustainability effects may be further developed to implement other soft system variables. The integration between weighted indexes and an elicitation of subjective probability distributions may be used to incorporate a wider range of the individual strengths and vision the farmer can bring to the farm system operation. It should be noted, however, that the complete integration of soft and hard system components within a single analytical framework embodying feedback is only feasible using the system dynamics simulation procedure. The transition from the integrated process outlined in this study to a system dynamics modelling approach is a very worthy subject for further research.

Further testing is required to enhance the validity of the programming matrix. This could done by running the model on a large number of case-studies. The results could then be used to facilitate better decision-making for farm planning, sustainability and environmental issues and policy planning purposes.

Adopting stochastic programming methods for on-farm decision making basically requires an attitudinal shift in management organisation, and an upgrading of skills. This is the challenge faced by farmers and farm consultants who are increasingly becoming aware that business survival needs a professional approach to the management of the farm system.

7.5 The Learning Experience of this Research

The learning experience of this research focused on the integration of conventional methodologies of deductive modelling into a more flexible approach. The traditional rigour of deductive techniques was used to explore not just the prediction of future outcomes but, and in the main, to improve information on the system to enhance decision making.

The reason why this argument was followed in this research is partly explained by the personal position of the author, who sees his strong belief in the value of farming as an important socio-economic structure for future generations threatened by reductionist perceptions of resource management and short term profitability. Only decision makers with a professional perspective of farming will be able to implement farm resource management where the farming activity continues to exist in its own right, competing with the other sectors of the economy and ensuring long term sustainable FBM to safeguard inter-generational equity. Reaching this level of management of the natural resources may only be achieved by an inductive process of learning about the whole system, rather than through prescriptive models of behaviour. The approach the author recommends emphasises rather ignores the complexity of farming systems and translates the significance of this complexity into a practical planning context. This realistic complexity is best considered and represented through an holistic perspective, and this research has created an integrated approach that works within this perspective.

Since the core understanding of FBM is a balance of knowledge and fulfilment of individual and social rewards, the challenge for the future is to integrate knowledge coming from research and experience, education and extension to the benefit of the overall development of the farming sector.

Studies like this one, which are basically management decision-making exercises, need to have a well-defined framework. FBM provided the most suitable framework for this study. Because the study enhances the body of systematic knowledge for consultancy and educational purposes, it is a contribution to better FBM, and may be a means by which farm business managers will gain professional recognition.