1 Introduction

Learning Objectives

- Discover the nature of farm decision problems and learn about the choices that farmers are faced with.
- Consider how to represent decision problems using symbolic models.
- Discover and recognize that farmers have varying levels of managerial ability.
- Learn about the topics the book covers and analytical methods for farm business management. What is the road ahead?

Introduction to Problem Solving

All farmers like to think they operate an optimal farming system, a system that is likely to be different from that of other farmers. Each farm is unique in its set of resources (quantity and quality) and the objectives held by the farmer and his family (note: in this book, farmers are referred to as men only in the interests of simplicity and it is acknowledged that many farmers are women). This means a particular farm's best plan and system will be unique. For each farmer, and his advisers, the challenge is to work out this unique optimal system. Given the nature of farming and primary production, there could well be a number of near-optimal systems that for all intents and purposes can be called optimal alternatives.

This book is about the methods, techniques and ideas useful in developing improved farming systems and in improving the outcomes from the system through better managerial skills. Most of the procedures can be used by farmers themselves, and all by farm advisers and consultants.

Discussions also cover the conditions and situations that are part and parcel of farm management. The decision procedures, in general, are all about problem solving, because any decision situation implies choice and, therefore, requires a method for deciding which alternative maximizes or improves the objectives. The book does not consider the practical and technological aspects of carrying out the optimal plans, other than through considering methods of understanding and improving managerial ability.

Some decision situations might not involve risk (or more correctly, involve little risk – almost all decisions involve some degree of risk) and so the analytical method used can ignore risk. This is a much less complex approach than directly allowing for risk and therefore costs less to implement. However, in general, many farmers will want to actively allow for risk, given its intrusion into most decision problems.

While the range of potential analytical techniques available is extensive, only the commonly used approaches will be discussed. At one extreme an individual farmer might make decisions based solely on intuition, and at the other might employ someone to create complex computer-based simulation systems. In most cases, however, the latter will be too costly relative to the benefits over intuition, or over simple budgeting (a budget is an estimate of farm output from a series of farm inputs, all converted from physical terms, such as kilograms or number of animals, into costs and returns). In a budget, both the quantities and values are presented to give the net return from the particular farming system.

Problem solving can be divided into two classes: evaluative and developmental. Evaluative refers to situations in which known courses of action are being evaluated to select the best. For example, cash crop farmers might currently implement a range of crop rotation systems and need to know which is best. A farm survey might be used to solve this problem. In contrast, when new systems are being developed and tested, a developmental research situation exists. For example, the problem might be deciding how best to incorporate soybean production into a mixed cropping system in a new farming area. As known systems do not exist, these would have to be developed.

The steps to be performed in solving a problem include:

- Formulating the problem (e.g. is it one of the best stock replacement systems, or the best breed of stock, or both?).
- Constructing the model to represent the problem (e.g. developing budgets of the alternatives).
- Testing the model (e.g. comparing budget prediction with actual).
- Deriving a solution from the model (e.g. comparing budgeted profit of alternatives).
- Testing and controlling the solution (e.g. trying out the solution on part of the farm).
- Fully implementing the solution.

The rest of this immediate discussion revolves around the first two issues, after discussing the objectives in problem solving. The other steps will be covered throughout the rest of the book to a greater or lesser extent.

Optimal Solutions to Problems

A problem can be described as a situation with the following conditions:

- A farmer who has the problem: the decision maker.
- An outcome that is desired by the decision maker. If there is not a desired outcome, there is no problem because, presumably, he already has what he wants.
- At least two courses of action that have some chance of yielding the desired objective or outcome.
- An initial state of doubt in the decision maker's mind as to which is the best course of action.
- An environment or context of the problem. The environment consists of all factors that can affect the outcome, including those not under the decision maker's control.

Problems can be more complex than the description above. For example, perhaps the decisions taken may cause a counter reaction by others (e.g. take out a contract to capture the market), or objectives may be multi-dimensional involving several outputs (e.g. leisure hours, cash profit, environmental impacts).

Further, the answer required may not be a simple 'do this (e.g. apply 120 kg nitrogen (N) fertilizer per hectare)', but rather what is referred to as a strategy. This involves a rule telling the decision maker to follow one of a range of actions depending on the current state of the farm and prices (e.g. if the N price drops 10%, apply 130 kg, if it increases 15%, apply 100 kg). Similarly, a wool producer should perhaps shear his sheep in a certain month if wool prices are falling, or at a later date if they are rising. The decision depends on the current state of the environment in all senses of the word.

Formulating the Problem

One of the first steps must be to study the environment, or context, in which the problem exists. Producing a general diagram, or a description of the whole system in which the problem is embedded, can be helpful. The system will consist of objectives and potential activities satisfying these. The components are then connected by a flow of information, which leads to decisions on a choice of system or, in other words, a set of production activities.

To enable analysis, a problem must be formulated in detail. Consider each factor.

The decision maker's objectives

Formulating objectives is difficult because farmers can seldom clearly articulate their requirements. If asked, farmers often provide general comments such as '(I) enjoy the farming way of life'. Such statements have little operational significance.

Thus, a consultant will have to discover the objectives and in doing so may well provide a useful service. Often a good approach is to present alternative 'solutions' to the problem and note the farmer's reactions. This often reveals previously unmentioned objectives.

Sometimes, however, answers to especially prepared questions will provide a starting point (see Appendix 4) and an avenue through which to discuss objectives.

Alternative courses of action

Establishing the possibilities largely consists of:

- Identifying the variables (the factors for which decisions are required) that significantly affect the outcome of the problem (e.g. time of weaning, time of shearing, price of wool, the amount of N fertilizer to apply in a particular month).
- Determining which of the variables can be controlled directly, or indirectly, by the farmer (e.g. the price of wool cannot be controlled but time of shearing can).

In some cases none of the obvious courses of action may seem to solve the problem, and so the farmer must look for new courses of action.

Using the objectives for choosing between courses of action

Ideally, it would be good to quantify the objectives so that alternative courses of action can be given a value; choice is then easy. However, this is seldom possible for other than profit and leisure measurement. For example, the value of clearing up a stream is difficult to measure. In this case offering a range of efficient solutions to the farmer will help choice. Another example: in choosing between buying or breeding replacement stock, an adviser could estimate the cost of the best way of achieving each method and let the farmer decide on the basis of the cost and other factors, such as the risk and workload.

Models

Models of farming systems are simplified representations of the real world (Swinton and Black, 2000) in the form of numbers and symbols. Their advantage is they are easier and less costly to manipulate and experiment with than the real world. In farm management 'symbolic models' are used in contrast to physical models; that is, the real world is represented with symbols. For example, a simple budget.

Symbolic models

Symbolic models consist of variables representing output (e.g. profit) and input (feed, fertilizer, etc.). Thus we have, for example, a production function:

$$Y = f(X_i)$$

Output (Y) is some function (f) of inputs (X_i), where a value for i represents each input (e.g. X_1 might represent the kg of fertilizer per hectare, X_2 = irrigation level, and so on).

Models of problem situations will always take the following form:

$$Y = f(X_i, W_j)$$

where Y = measure of the value of the decisions made (the output, e.g. net income, yield of crop per hectare); X_i = the variables under the control of the decision maker: the decision variables (e.g. the quantity of fertilizer/ha, the lambing date); W_j = the factors (variable or constant) that affect performance but that are not controlled by the farmer (e.g. the wool price); f = the relationship tying the variables together.

As a very simple example, the yield of wheat might be:

Yield (kg) = 5600 + 25 N, where N is the kg of nitrogen applied.

In this example it is assumed the yield will be 5600 kg/ha if no N fertilizer is used, with the yield increasing 25 kg for each kg N. In reality the relationship would be more complicated and include other variables.

In most problems there will be restrictions on the decision variables. There is, for example, usually a limited supply of fertilizer, land, working capital and all the other resources. Thus, the problem is constrained.

In constructing models, each variable has to be defined so it can be measured. Further, once the model has been constructed and validated, a method of analysis must be designed. Finally, results must be interpreted.

Considerable time may need to be spent on determining the functional relationships because these tie the model (budget) together and determine the optimal values of the decision variables. For example, how will altering the lambing date affect the lambing percentage? In budgeting the experience of the 'budgeter' is usually critical because this person estimates the output from the input levels assumed.

Constructing and Using Models

Models are approximations

Because of the complexity of real life, most models will only be approximations of reality. Furthermore, models need to be manageable (capable of being solved), so sometimes simplifications are necessary. (A budget is an example of a very simple model.) The problem is to decide what simplifications are reasonable. Experience helps to decide the best approach.

Possible simplification methods

Possible simplification methods include:

- Omitting decision variables (e.g. assume all lambs will be given selenium when comparing alternative stock systems).
- Simplifying uncontrolled variables (e.g. assume a given lamb price in a budget, whereas it might be any one of many prices).
- Changing the nature of variables (e.g. assume all labour comes in whole units, thus ignoring casual or part-time labour).
- Changing the constraints to a simpler form (e.g. ignoring the limitations on a cropping system imposed by having two tractors of different sizes. Simply assume the average size when developing a new programme).

Sequential decision models

Sometimes decisions are considered for a range of actions that do not all have to be implemented at once and may not need to be done for a few months (time-based models). When it comes to making some of these decisions, some of the assumptions may have changed. Thus, reconsideration may be important just before the decision is made so that all relevant up-to-date information can be used (e.g. do not decide on how much hay to sell until well into the winter).

Deriving solutions from models

- Trial and error methods are often used to converge on a solution (e.g. a series of budgets, each one being developed on the basis of the conclusions suggested by the previous one).
- Evaluating *all* alternatives so the best can be selected (e.g. a series of budgets that have been calculated concurrently for all the alternatives).

The Manager (Decision Maker)

Some farmers achieve much better outcomes than others, even though they are working in the same physical environment and facing the same prices, costs and regulations. Somehow the good manager knows what to do, and when. A group of farmers might make the same decisions, but the better ones carry out the decisions at the right time. For example, they spray for a disease problem at the right time, while others spray too early, or more likely, too late. Some call this situation the '2-week' rule: the less able managers seem to be roughly 2 weeks behind.

All farmers strive to be good managers. If you can get greater output from the same resources with less effort simply by making the right decisions at the right time, then any farmer would choose to select this option. But how can they do this?

To understand farmers, you need to know something about their 'management style', experience and intelligence, and how these factors impact on managerial skill. It is all very well for a farmer to know what, when and how to produce, but if he cannot carry out the plans appropriately, he will not be successful. The skill of the manager is critical, so any prospective farmer needs to know about the factors affecting skill. In the end the farmer wants to know how he can improve his skills, so the discussion offers procedures to follow that are based on research.

A farmer also needs to know about the specific skills he should have, and how his proficiency can be improved. Skills fall into the general areas of observation, anticipation and risk management. Right at the beginning is observation, because all the relevant up-to-date data and knowledge (current prices, feed inventory levels, animal health, soil moisture, and so on) is required before any kind of decision can be made. Then, in assessing possible decisions, the farmer must be able to anticipate the likely outcomes if he were to make a particular decision. And because most factors in farming are not certain, a farmer must be versed in the techniques available for mitigating uncertainty, leading to optimal decisions and protection from extreme outcomes.

The Road Ahead

Farm systems analysis is about creating models of alternative systems to allow comparison and analysis, leading to conclusions about improved farm production plans or systems. However, it is not always appropriate to conduct quantitative research, for example when little information and data are available for solving a problem. For these cases the solution might be to produce qualitative information, which might lead to acquiring numeric data that can be used to quantify the problem. For example, when exploring a new development it might be appropriate to ask other farmers, extension workers and commercial managers what their views are on possible costs and returns, conditions and problems. The qualitative conclusions might then be used in farm trials with recording systems to provide data for future quantitative work. Thus, while most of the systems analysis discussions are about numeric methods, some thought is given to qualitative approaches.

In Chapter 3 the decision-making environment in primary production is discussed because it must be understood in order to allow good decisions. A strong feature of the environment is its uncertain and risky nature, so Chapter 6 is devoted to decision making under risk and uncertainty. A discussion on measuring outputs is also included, because in real life objectives are multi-dimensional (Chapter 13). Profit is seldom the only objective. Indeed many farmers will tell you profit is secondary to 'enjoying farming as a way of life'.

Farm production is long term; in many cases, production systems require several years to generate saleable products. Clearly forestry is the extreme, but even stock systems can take more than 1 year to produce: an example is beef production in which 2-year-old animals are sold. And it is certainly true that farm development takes several years to reach an equilibrium following change.

If, for example, a block of land is cleared and sowed to pasture, it might be as long as 10 years before the pasture is producing to its potential. This all means that in analysing problems the timing of costs and returns must be taken into account, for there is an opportunity cost (return from an alternative use) of the committed funds before output occurs. Funds invested could have been put into the bank and returned the going interest rate. Thus, farm investment must return at least this rate to be worthwhile.

When time is involved, factors such as the compound interest rate must be allowed for. Chapter 7 covers all the formulae and methods to be used in these time-dependent projects: these are called investment analyses, or sometimes cost–benefit analyses. Furthermore, it is not always easy to decide which costs and returns to include in these analyses, so discussion on the choices is provided.

Chapter 14 discusses farm surveys and their use in comparing farming systems. Every farm can be viewed as an experiment and, consequently, provides information useful in comparing systems and in coming to conclusions about optimal systems. Furthermore, survey data are often used in the formation of benchmark data. These data can be used to guide farmers on how to improve their farming system through comparing the case farm's data with the benchmarks of the better farms. While these applications generally rely on using farm survey data, in contrast, specific recording systems can be used. With the modern computers found on most farms, it is not difficult to set up schemes that record data that can then immediately be fed into a central computer system designed for group analyses and comparisons.

A basis for much of the analysis mentioned is production economics. There are many texts on production economics, so the full details are not covered in this book. However, it is useful to summarize the conclusions because they provide decision rules. These are conditions that, if attained, provide optimality. One such rule is to invest in increasing quantities of an input until the cost of the last unit invested just matches the profit increase that results from this last input. This is the 'marginal cost equals the marginal return' rule. Chapter 2 provides a synopsis of the basics of production economics for students new to the area, and revision for others.

Overall, the survey techniques mentioned rely on historical records and, consequently, provide answers about improved systems that can be no better than the best in the population of farmers surveyed. In contrast, it is possible to use a range of analytical techniques to discover systems that are improvements on the existing systems. These rely on having technical information that defines physical input–output relationships, which can then be used to create 'optimal' systems.

Note, however, that the technical information for analyses (e.g. the relationship between animal growth and the intake of protein and energy) can only come from historical studies using experiments and farm observations. The main analytical method discussed, using the technical information, is forecast budgeting.

In reality there are a whole range of analytical techniques that might be used in advanced farm systems analysis. Chapter 15 contains a brief description of some of these techniques to ensure students are aware of the possibilities. This information might be used by a student hoping to proceed to more advanced study. The more advanced systems analysis techniques benefit from access to a computer because the calculations and comparisons can be time consuming. Consequently, Chapter 16 contains a discussion on farm computers and the all-important software that controls their use.

The book also introduces a number of analytical models that are commonly used in urban business. Even though they are less important in primary production, they are still worth outlining. One model is inventory analysis, where the problem is to determine the optimal level of inventory to hold. For example, how much hay and silage should be held to minimize the cost of providing a particular level of stock feed? Another 'problem' is replacement analysis. When is the optimal time to replace productive assets such as a header harvester or even an animal? With time, productivity and costs change, leading to an optimal replacement time to minimize the costs of providing the services of the asset.

Two other decision problems are also mentioned. These are critical path analysis and queuing analysis. Critical path analysis is about working out the task sequence in any operation that is critical in determining the completion time, and thus, cost (such as building a major dairy milking parlour). Queuing analysis is about providing sufficient resources so that an uneconomic queue does not form: an example is providing harvesting resources to avoid overly expensive crop loss from a queue of ready-to-harvest crops sitting in the field losing grain and quality.

Along the way in explaining methods of analysing and creating farming systems, a number of side tracks appear. For example, how to measure which farms are efficient is discussed because sometimes analysts get confused over this issue. Similarly, comments on cost accounting are offered because this is a common approach to determining the profit contribution of alternative enterprises (Chapter 14).

The chapters in Part 3 (The farmer's skills) cover the manager 'as a person', with his various skills. First, the discussion covers the factors defining a manager and his abilities, and provides experimental data that show just how important 'experience' is in developing an excellent manager. Information on farmers' views about the skills needed to be a good manager is also discussed. This leads on to the component skills associated with good observation, anticipation and risk management. Skills like listening and reading capability, developing imagination to allow successful anticipation, and many others are covered because they all lead to creating a competent manager.

Thought is also given to 'informed intuition' because many successful managers often do not revert to calculations when making decisions, but rather use their intuition. If the intuition has come from experience, and is well 'informed', the decisions and outcomes will be successful.

The term 'farm system' has been used regularly, but has not been well defined. A farm system is a plan or blueprint for operating a primary production unit, whether it is a farm, horticultural unit or any other form of primary production. This plan, or system, includes a list of the products produced, the area/quantity of each, a list of the inputs used for each product and a description of how the inputs should be used in terms of timing, quantity and application method.

A farm system plan also includes details of the associated financing set-up, and instructions for management aspects such as the strategies for handling uncertainties. In theory, a manager should be able to take up the blueprint and follow the guidelines it provides to produce maximum profit, assuming this is the objective. This book covers the main methods available to an analyst in creating these blueprints (starting with Chapters 4 and 5 on budgeting, going through to Chapter 15 on farm systems analysis). Clearly it is not possible to discuss every possible method available, but with a full understanding of the contents of the book an analyst/researcher should have a sound basic knowledge that will lead him to seek further refinements when necessary.

It is also critical that a farmer knows what is happening both financially and physically around his farm. Both financial and physical recording and analysis arrangements can be critical to good management. They are all discussed in some detail in Chapter 8.

And, overall, a strong emphasis is placed on explaining and discussing improving a manager's skills. For, in the end, it is the manager's ability that determines the outcomes (Chapter 13).

Questions and Exercises

- List and explain the major decision problems a farmer faces in a farming type you are familiar with.
- Thinking about one of the farm production systems you are familiar with, write a symbolic representation of the structure of the overall decision problem. Be sure to carefully define all the variables in the model and list the ones the farmer can control.
- For the farmers/managers you have had contact with, compare and contrast their characteristics that might influence their attitude to decision making.
- Explore and discuss the nature of quantitative analysis relative to qualitative approaches. You may find searching the Internet will help you to understand the two approaches.
- List the topics covered in the book and consider whether any other important farm decision aspects/methods might also have been included. Give reasons.
- Consider the factors highlighted in Chapter 1, and compare them with the features of Ben's scenario in the case study below. Which factors are covered in both the chapter and the case study?

Focus Study Exercise: Ben Rochester and his Dilemma

Ben was a reasonably experienced mixed farmer, producing both beef and a range of crops. He had inherited the farm from his father, who had been relatively conservative and minimized investment in the land, buildings and equipment, often acquiring what he needed second-hand. He had found a conservative approach gave him the best chance to pay off debts (such as a high mortgage) quickly.

When Ben took over, the farm was somewhat run down. Despite this, he agreed to a high valuation when becoming the owner to ensure his parents had a reasonable nest egg. He borrowed money and had his parents provide a second mortgage, both of which involved repayments.

Ben worked long hours to knock the farm back into shape, intensifying production with labour-intensive crops such as grapes and acquiring contracts to produce vegetable plant seeds for the home market. The prices were exceptional, but so was the management intensity required to get a good yield. His machinery was somewhat lacking, requiring skill and many repairs to keep it running.

Some years turned out exceptionally well, when the season produced good yields and prices were high, but unfortunately such years were rare. If he could find the money to invest in irrigation, he would remove one of the unknowns. Then one of those rare events occurred: a sequence of years combining good yield with high price. He continued meeting his debts with ease, but also paid off more of the mortgage debt, improving his equity.

He had always dreamed of using the stream water on his property. As he sat on the tractor for hours on end, he imagined well-watered and perfectly even crops. But how could this come about? There were restrictions on using the water, and getting into irrigation would be a massive investment.

The stream was reliable, but, with the restrictions in place, it would be necessary store large quantities of water after intensive rain for use at later times. Given the terrain, a spray system would also be necessary. What would it all cost? What would be the yield and quality impacts? What were the longer term product prices likely to be? Ben's mind went round in circles with the enormous number of issues he knew little about.

After thinking about the problem, he realized there were many levels of irrigation system, not just all or none. But he couldn't even start simple calculations given the diversity of knowledge required. There were engineering questions, water storage system problems, piping questions, hydraulic issues: it was daunting. After talking it over with friends and family, he reckoned the only thing to do was approach a consultant for advice.

He asked around the neighbourhood with no luck, before his spouse suggested that the lecturers at the local agricultural college might have some ideas. Ben made an appointment, then, impressed with their information and understanding, decided to ask them for help. They agreed, keen to have another farm to use for student visits and case study exercises. They would visit with one of the classes for an initial inspection and then ask the students to assess the problem. Once the assignments were handed in, the lecturers could pick the best and update them using their knowledge. This way the cost to Ben would be kept to a minimum.

In the end Ben received a report listing possible designs, costs and returns. The lecturers had enlisted the help of an agricultural engineer, and a civil engineer for the earthworks. They had also approached the local authority that controlled the uptake of the stream water, which also gave permission for earthworks.

Continued

Focus Study Exercise. Continued

The last chapters of the report presented budgets for four different levels of irrigation. They pointed out that responses would depend on each season and the prices expected. They also considered the timing, with both slow and fast development, because it would take many years for a new equilibrium of soil fertility and plant regimes to develop. As one of the possible programmes took over 10 years, they had used investment analysis methods to produce the net present value (NPV) of each alternative. This produced a single return figure summarizing the many year cash flows so the systems could be compared. The calculations allowed for the borrowing costs as well as the impacts on taxation.

The consultants made it clear the simplifications they had used. For a start, they only compared four policies, whereas in reality there were many irrigation levels possible. They also noted they had taken the expected long-term price of the products proposed using a marketing group's view, simplified because in the real world prices would vary year by year. The consultants also noted they had limited the products to just three possibilities. They noted that if Ben went ahead, he should always watch the contracts available and adjust accordingly.

The net outcome was that three of the possible systems showed a positive NPV, covering all the costs as well as providing a profit over and above the opportunity cost of the investment. One system, the most intensive irrigation option, was not profitable. But, Ben noted, the increase in debt level was daunting. Should he go ahead with the option with the greatest NPV?

Ben consulted his spouse and retired parents. His spouse pointed out they would soon need to find school fees if the children were to have the best education possible. And, she pointed out, they hadn't had a holiday for many years. They decided to bite the bullet and proceed as quickly as possible; the sooner the irrigation was underway, the sooner they could have a family holiday. The plan, given the increased intensity of system, had budgeted in extra help, so holidays were possible.

The next day Ben visited the bank manager with the report. He pointed out it provided many strategies depending on the yearly product price outlook and the seasonal outcomes. The bank manager realized Ben had done his homework and was not just a 'fixed' system farmer who might end up in dire financial straits. Ben went home with a signed contract, as well as brochures from the local travel agent!

Reference

Swinton, S.M. and Black, J.R. (2000) Modelling of agricultural systems. Staff paper 11581, Michigan State University, Department of Agriculture, Food and Resource Economics, East Lansing, Michigan.