The Tactical Management Processes used by Pastoral-Based Dairy Farmers:

A Multiple-Case Study of Experts

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The Tactical Management Processes used by Pastoral-Based Dairy Farmers:

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Abstract

A competitive advantage of the New Zealand dairy industry is the ability of its farmers to produce milk from "*low-cost*" pastoral-based systems. Despite the importance of these systems to the New Zealand economy little is known about how farmers actually manage them. It has long been recognised that considerable variation exists between farmers in terms of milksolids production. An important reason for this is management capability. Some farmers have greater expertise in the management of pastoral-based dairy systems than others. Analysis of the management processes used by "*expert*" dairy farmers may help identify management practices "*less expert*" farmers could adopt to improve productivity. Such research would provide a cornerstone for maintaining the competitive advantage of New Zealand's dairy industry.

A particularly important period in relation to the management of a pastoral-based dairy farm is summer-autumn. Management decisions made during this time affect milksolids production in both the current and subsequent lactations. Management is also particularly difficult during this period because pasture growth, the farmers' primary source of feed, is highly variable. Therefore, this study set out to develop a model to explain the tactical management processes used over the summer-autumn by "*expert*" pastoral-based dairy farmers.

From a review of the normative and descriptive farm management literature, important concepts relevant to research into tactical management were identified. A longitudinal (three years), embedded multiple-case study approach was used to investigate the tactical management processes used by selected "*expert*" dairy farmers. From this investigation, a general model of tactical management was developed and compared to the literature. Importantly, the adoption of a suitable theoretical framework for case selection allowed more consistent and effective cross-study comparisons within the farm management discipline.

Several theoretically important findings were identified through the study. Factors that determined the case farmers' choice of planning horizon were identified, as were the termination targets they used to overcome the planning problems of interdependency and consequences. The case farmers used both qualitative and quantitative planning processes. A model of the informal planning process was developed that demonstrated how the case farmers modified their "*typical*" or predefined plan in response to prior learning, strategic and tactical decisions made previously, and the farm state at the start of the planning period. The importance of targets (standards) and contingency plans (components of the plan) for control was confirmed. New typologies for classifying targets and contingency plans were also generated.

A more refined model of the control process was developed. This focused on models of the important sub-processes: monitoring, decision point recognition, control response selection, opportunity recognition and selection, diagnosis, evaluation and learning. Similarly, typologies for classifying aspects of these sub-processes were developed or extended. Differences between "*structured*" and "*unstructured*" decisions were identified. The next challenge is to find ways to effectively transfer the practices of "*expert*" farmers to their less proficient colleagues.

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CHAPTER 1 INTRODUCTION

1.1 Background

The New Zealand dairy industry, a farmer owned cooperative, is one of the cornerstones of the New Zealand economy contributing around one fifth of all export receipts (NZDB, 2000a). More than 90% of New Zealand's milk production is exported and this accounts for about 30% of the world trade in dairy products (NZDB, 2000b). A competitive strength of the New Zealand dairy industry is that its dairy exports are produced from pastoral-based systems where animals graze pastures *in-situ* year-round (Holmes, 1990; Guy, 1993; Mitchell, 1993).

Several factors have encouraged the strong reliance on pasture as the primary source of feed. A small internal market for liquid milk and distance from trading partners has required milk to be sold in a processed rather than liquid form (Bryant, 1993). Transport costs to distant markets and the absence of government subsidies (Camoens, 1993) mean New Zealand dairy farmers receive a low return for their milk relative to those in other more populated countries in Europe and North America (Hurley, 1995; Howse, 1997). For example, in 1993, New Zealand farmers received 30 cents/litre for their milk in comparison to 53 cents/litre, 63 cents/litre, 71 cents/litre, 108 cents/litre, and 149 cents/litre for farmers in the United States, Canada, Sweden, Switzerland and Japan respectively (Howse, 1997). New Zealand dairy farmers do not have access to cheap grain or large quantities of bi-products like their counterparts in Australia, Europe and North America (Leaver and Weissbach, 1993). Therefore, low milk returns and lack of cheap external feed sources have forced New Zealand farmers to take full advantage of year-round grazing (Mitchell, 1993).

In Europe and North America, a harsher winter climate, strong demand for year-round milk production and high milk prices, have enabled dairy farmers to adopt confined feeding systems under which all or a large proportion of the herd's diet is provided through conserved supplements and bought-in feed (Holmes, 1990; Leaver and Weissbach, 1993; McCall and Sheath, 1993; Tie *et al.,* 1993; Hurley, 1995). In contrast, the temperate climate in New Zealand enables animals to be kept outdoors on pasture year-round (Holmes, 1990). Although pasture provides a cheap feed source, its sensitivity to climate means seasonal rather than year-round calving allows least cost milk production. Consequently, nearly all (*ca.* 97%) herds are calved in early spring so that their pattern of feed demand coincides with that of pasture growth (Bryant, 1993). For the same reason, herds are dried off during the autumn so that feed demand is reduced during winter when pasture growth rates are at their lowest (Holmes and Brookes, 1993). Over time, and through research and extension, New Zealand dairy farmers have developed a competitive advantage (Porter, 1990) in the management of pastoral systems (Mitchell, 1993). The grazing systems and the technologies that support these systems such as pasture monitoring, feed budgeting, electric fencing, use of phosphatic fertiliser and white clover, new pasture species and the tactical use of nitrogen have made New Zealand dairy farmers world leaders in pastoral farming (McCall and Sheath, 1993; O'Connor *et al.*, 1993).

However, this leadership is under threat as farmers in countries such as Australia and Ireland, which can also produce pasture year-round, have entered dairy export markets (Parker, 1998). In addition, threats to New Zealand's low cost system also come from biotechnology which has the potential to dramatically improve the cost efficiencies of its competitors (Parker, 1998). Importantly, productivity on New Zealand dairy farms has declined 2% per annum since 1993 despite extensive research and development and the best efforts of an industry funded extension agency (Dairy Exporter, 2000a).

With declining real returns from milk over the last forty years, New Zealand dairy farmers have been forced to increase farm and herd size and productivity to remain viable (Parker and Holmes, 1997). Two main strategies can be undertaken to maintain or improve living standards in response to reduced prices, namely intensification and/or expansion (Van Der Ploeg, 1985). Data from the New Zealand dairy industry indicates farmers have adopted both options (Macmillan and Henderson, 1987; LIC, 1996; NZDB, 2000b).

To enhance the international competitiveness of on-farm production, the New Zealand dairy industry funds research and an extension service (NZDB, 2000a). Despite this long-term investment, and a long-established advisory service (Stitchbury, 1995), considerable variation still exists in production and profitability between farms (McRae and Townsley, 1980; Deane, 1993; Holmes *et al.*, 1993; Howse and Leslie, 1997). Such data suggest some farmers have more efficient management practices and more effective use of technology in producing milk (McRae and Townsley, 1980; Howse and Leslie, 1997).

Thus, a further means to improve New Zealand's competitive advantage in milk production is to study the management practices of the country's best farmers to identify how the practices of poorer performing farm businesses can be improved (McRae and Townsley, 1980). Such research could identify the practices undertaken by "*high performing*"[1] dairy farmers and then make this information available through extension to "*less expert*" farmers.

While the benefits of investigating the practices of high performing dairy farmers has long-been identified, little formal research on how New Zealand dairy farmers manage their pastoral systems has been published (e.g. Crawford *et al.*, 1995ab). In contrast, a substantial body of literature exists on the factors that influence milk production (e.g. Campbell *et al.*, 1977; Grainger and Wilhelms, 1979; Bryant and Trigg, 1982; Grainger and McGowan, 1982; Holmes and Macmillan, 1982; Bryant, 1990; McDougal, 1993) and prescriptive advice on how dairy farm management should be practiced has been synthesised from experimental work, simulation modeling and demonstration farms (e.g. Hill, 1982; White, 1982; Ridler and Hurley, 1984; Bryant and Macdonald, 1987; Brookes *et al.*, 1992; Holmes and Brookes, 1993). Similarly, studies have been undertaken to identify the factors that influence dairy farm productivity and/or profitability (Neutze, 1956; McRae and Townsley, 1980; Valentine *et al.*, 1993). These studies either correlated easily measured factors such as farm and herd size, resource efficiency measures, resources, level of inputs, and socio-demographic parameters to farm productivity and/or profitability (e.g. McRae and Townsley, 1980), or describe the use (or non-use) of specific management practices (e.g. Crawford *et al.*, 1995a). However, they provide little information on how farmers manage their pastoral systems in terms of decision-making. Interestingly, the dairy farm extension service has recently been restructured to combine the research and extension arms of the industry under one organisation, Dexcel (Boedeker, 2000; Dairy Exporter, 2000abc, 2001). The focus of this new organisation is to increase dairy farm productivity by 4% per annum, and one of the mechanisms they will use to achieve this goal is to identify the management practices of high performing farmers (Boedeker, 2000; Dairy Exporter, 2000abc, 2001).

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[1] In this study "*high performing*" is defined as "*achieving high levels of milk production per hectare from a specific bundle of resources in a cost effective way*".

Research into the management practices used by high performing dairy farmers provides access to a source of knowledge that has been little researched, namely, the 13,800 dairy farmers (NZDB, 2000b) that make up the New Zealand dairy industry. The results of this research could also be used to identify the reasons why some farmers are not achieving high levels of production. It could also be used by extension services to help farmers improve productivity and profitability. Fundamental to this research is the belief that management is an important determinant of farm productivity and profitability.

1.2 The relationship between management and farm performance

The implicit assumption that management plays a crucial role in enabling farmers to reach their goals is central to the farm management discipline. In relation to management education, Loftus (1980) asked two key questions: first, Can management overcome the problems confronting farmers? and second, What management skills do farmers lack? Researchers often overlook these questions to the point where Nuthall (1999, p.1) stated that "*Managerial skill is almost a forgotten resource*". In answer to the first question, farmers face a number of problems (e.g. external trade barriers, changing world markets), which cannot be solved through the application of on-farm management skills. Although there are numerous studies on farm performance, few have attempted to link this to management ability. There is however, some evidence that farm management is an important determinant of farm performance. Driver and Onwona (1986), for example, found that the management skills of farmers and their willingness to accept risks were important determinants of farm business performance. Van der Ban (1969) observed large differences in income on farms that operated under similar resource constraints, and attributed these differences primarily to variation in the farmers' managerial ability. Similarly, Campbell (1955) in a paper on agricultural efficiency, argued that the skill with which resources are allocated on individual farms has an important bearing on the aggregate efficiency of agriculture. Olsson (1988, p.248), after reviewing several studies on success in farming, concluded, "*the success of the firm depends on the leadership qualities of management*".

Most studies of farm performance tend to define success in relation to the achievement of financial goals (Neutze, 1956; Driver and Onwona, 1986; Hayden and Johnson, 1989; McGilliard *et al.*, 1989; Wadsworth and Bravo-Ureta, 1992; Boland and Patrick; 1994; McGregor *et al.*, 1995). However, farmers usually have other goals (Gasson, 1973;

Harper and Eastman, 1980; Cary and Holmes, 1982; Schroeder *et al.*, 1985; Gasson *et al.*, 1988: Valentine *et al.*, 1993; Fairweather and Keating, 1994), and success may be defined by their achievement rather than by financial criteria.

The concept of farm efficiency is inescapably evaluative (Pasour, 1981) and cannot be defined and measured independently from the goals and knowledge of the decision maker. Hence, the definition of "*success*" is critical to the design, analysis and interpretation of studies of farmer behaviour (Olsson, 1988). In this thesis, the term "*successful*" is defined as "*a farmer's ability to produce high levels of milk per hectare relative to their resource bundle, in a cost effective way*". The definition also incorporates a caveat that "*the level of production must be relative to the farmer's bundle of resources*". An implicit assumption in most investigations into farm performance is that the resource bundle available to farmers is relatively homogeneous. However, within most farming regions there is considerable variation in physical (such as soils and micro-climate) and capital resources (such as farm size, machinery, stage of development, quality of livestock), and the quantity and quality of labour employed. The heterogeneity of farmers' goals and their access to resources make the study of "*successful*" farmers an area that can be fraught with pitfalls. For example, McRae and Townsley (1980) reanalysed cross-farm data that showed milkfat production per hectare was a function of stocking rate and demonstrated that milkfat production per hectare increased as land value (a proxy measure for the productive potential of a farm) increased.

This leads to the second question posed by Loftus (1980, p.1) "*What management skills do farmers lack?*" In the business literature, Katz (1974) defined the concept of skill as an ability to translate knowledge into action. He also made the important distinction that skill is an ability which can be developed (rather than something that is innate) and that it is manifested in performance, not merely in potential. After reviewing the literature on the management skills of farmers, Lees and Reeve (1991) concluded that little had been written on this subject. In a study of Australian farmers, they identified the following areas of management skill:

- establishing aims,
- identifying and assessing resources and constraints,
- assessing risks,
- assessing and deciding among options,
- developing long, medium and short term plans,

- carrying out plans, and
- assessing achievement of aims and business plans.

Although this list corresponds closely with the management process described in most farm management textbooks, Lees and Reeve (1991) expressed surprise that given their importance (to farmers) they did not feature more strongly. Driver and Onwona (1986) also investigated the management skills of farmers; however, they used simple indicators to measure these and provided little information on the management process. In contrast to this quantitative approach, Loftus (1980) suggested that one means of assessing the management skills required by farmers was to investigate their management processes. Similarly, Nuthall (1999) suggested that research into the decision making processes of experts would be a useful starting point for identifying the skills used in management. Despite its recognised importance, empirical research into the management processes used by farmers remains scarce (Loftus, 1980; Howard and MacMillan, 1991; Rougoor *et al.,* 1998; Nuthall, 1999).

1.3 The management process: Reasons for the paucity of empirical research

In a recent review of the literature on studies of farmer decision-making, Rougoor *et al.* (1998, p. 270) concluded that the area was "*underexposed*". Two inter-related factors stand out as possible reasons for the lack of empirical research into the management processes used by farmers. First, the adoption of economics as the underlying theoretical framework for the discipline and second, the emphasis placed on quantitative research methods. At the famous Black Duck workshop in 1949, the role of economic theory in farm management research was debated and the proponents of economic theory set the methodological foundations that would dominate farm management research during the 1950's and 1960's (Jensen, 1977; Malcolm, 1990). The primary focus through this period was production economics and mathematical programming (Jensen, 1977; Malcolm, 1990) but little work was undertaken in relation to the critical success factors for exceptional farm performance (Howard and MacMillan, 1991). Ulf Renborg echoed this view when he stated: "*in the short space of twenty or thirty years, from the sixties to the eighties, farm management as an academic discipline has seemed to stray from the needs of farm management as a practice*" (Giles and Renborg, 1990, p.100). This was despite the criticism of researchers' preoccupation with an economic framework for studying management (Johnson, 1957, 1963; Gasson, 1973; Andison, 1989; Giles and Renborg, 1990). In economics, emphasis is placed on the criteria by which a choice is made or the way in which a choice is made (Gasson, 1973), rather than the "*process of making the choice*" (Andison, 1989) or "*why*" it was made (Gasson, 1973). Further, an economics paradigm leads to the presumption of homogeneity in production technology, management and behaviour (Driver and Onwona, 1986).

After reviewing the contributions that various disciplines might make to farm management research, Johnson (1957) concluded that economics provides a necessary, but not sufficient framework for the study of management in farming. Other authors (Williams, 1957; Wright, 1985; Andison, 1989; Giles and Renborg, 1990; Harling and Quail, 1990) reached the same conclusion. Several authors (Wright, 1985; Renborg, 1988; Andison, 1989; Harling and Quail, 1990; Martin *et al.*, 1990) also made a case for the integration of management science with farm management, particularly because of its focus on the management process (Andison, 1989). The call for further research into the decision-making processes used by farmers has been reiterated through the history of farm management research (see Johnson, 1957, 1963; Plaxico and Wiegman, 1957; Williams, 1957; Burns, 1973; Jackson, 1975; Andison, 1989; Howard and MacMillan, 1990; Rougoor *et al.*, 1998; Nuthall, 1999). Andison (1989) discussed the need for farm management researchers to identify the factors that make managers successful, and the separation of these into those that can and cannot be taught. The former can then be passed onto the farming community and strategies can be developed to minimise the impact of the latter.

The second factor that has limited research into farmers' management processes is the emphasis placed on quantitative research. These methods can be usefully separated into modeling and survey-based approaches. The development of prescriptive models (linear programming and simulation modeling) dominated the farm management literature through the 1960's and 1970's (Malcolm, 1990). This prescriptive approach in effect ignored the effect of the farmer in farm management.

Where empirical research into farmers' management processes has been undertaken, these studies have been dominated by survey-based cross-sectional research approaches (Howard and MacMillan, 1991; Rougoor *et al.*, 1998). Howard and MacMillan (1991) were critical of the studies on farm performance undertaken in the 1980's because they were based on easily measured "*historical phenomena*" but failed to investigate "*how*" farmers achieved high levels of performance. The criticisms identified by Howard and MacMillan (1990) also applied to many of the studies on farm performance undertaken in the 1990's which investigated the relationship between farm, farmer characteristics and farm performance (Rosenberg and Cowen, 1990; Tarabla and Dodd, 1990; Cruise and Lyson, 1991; Wadsworth and Bravo-Ureta, 1992; Jordan and Fourdraine, 1993; Jose and Crumly, 1993; Boland and Patrick, 1994; McGregor *et al.*, 1995). Interestingly, the distinction between the characteristics of successful managers and what they do was made as early as 1955 in the business literature (Katz, 1974). Katz (1974) argued that to study what managers do (i.e. the kinds of skills they exhibit when carrying out their job effectively), rather than their innate traits and characteristics would provide more useful research results in relation to the selection and development of managers.

Howard and MacMillan (1991) advocated a shift in emphasis away from quantitative surveys to qualitative case studies so that the management processes that farmers use to achieve various levels of performance could be identified. Rougour *et al.* (1998) after reviewing 28 management process studies also concluded that longitudinal rather than cross-sectional survey-based research methods were more suitable for the study of management because of its continuous and on-going nature. Although limited case study and/or longitudinal research has been undertaken by English-speaking farm management researchers, French researchers (e.g. Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) have undertaken a number of such studies in recent years. Over the last twenty years, several management- related disciplines have shifted towards this type of research in order to reduce the gap between theory and practice. These include operations management (Miller *et al.*, 1981; Meredith *et al.*, 1989; Flynn *et al.*, 1990), accountancy (Christenson, 1983; Morgan, 1983a; Tompkins and Groves, 1983; Kaplan, 1984; Chua, 1986) and organisational sciences (Mintzberg, 1973, 1975, 1979; Burrell and Morgan, 1979; Van Maanen, 1979; Morgan and Smircich, 1980; Morgan, 1983b; Yin, 1984, 1993; Lincoln, 1985; Archer, 1988; Eisenhardt, 1989, 1991; Easterby-Smith *et al.*, 1991; Guba and Lincoln, 1994). The argument for using these methods in management research is based on the belief that they provide a better understanding of the complex processes used by managers than traditional quantitative research approaches (Mintzberg, 1975, 1979; Morgan and Smircich, 1980; Yin, 1984). In contrast, the "quantitative-qualitative" debate has not featured strongly in the mainstream farm management literature. A few qualitative studies have been published (e.g. Fleury *et al.*, 1996; Dore *et al.*, 1997; Aubry *et al.*, 1998) and the use of case studies has been advocated (e.g. Maxwell, 1986;

Doorman, 1990; Howard and MacMillan, 1991), but these are in the minority, suggesting that these methods have yet to gain widespread acceptance amongst farm management researchers.

In summary, although numerous farm management studies have investigated the factors associated with farm performance, most have used surveys and focused on the statistical analysis of easily measured socio-economic variables to define the characteristics of successful farmers. Few studies have investigated how successful managers manage their farms to achieve high levels of performance. Thus, in the context of the present study, the literature provides limited insight into the management practices used by dairy farmers achieving consistently high performance from pastoral-based systems.

1.4 A framework for considering the research question

When studying a field of interest, a framework is required to organise the information collected (Anthony, 1965). In this study, a framework for investigating the management processes used by high performing pastoral-based dairy farmers is required. This means that it is necessary to distinguish between, and integrate three separate but interrelated processes: management, decision-making, and problem-solving (Scoullar, 1975). The terms "*management process*", "*decision-making process*", and "*problem-solving process*" are used interchangeably in the literature (Scoullar, 1975; Cary, 1980) and all three have been used to describe the management practices of farmers.

Numerous authors (Johnson, 1954; Koontz, 1962; Anthony, 1965) have suggested "usefulness" is an important criterion for evaluating the quality of theory. Given the above problem, fundamental questions can be asked such as what is the usefulness to management research of distinguishing between the processes of management, decision-making and problem-solving, and how might the literature on these three processes be best organised in the context of a management study? A framework is developed in the following section on important theoretical concepts relevant to the study of the management processes used by farmers.

1.4.1 Management process

The literature on the management process has developed from the seminal work of Bradford and Johnson (1953), Johnson and Haver (1953), Johnson (1954), Johnson *et al.* (1961), Lee and Chastain (1960), and Nielson (1961) (Table 1.1). A six-function model (Johnson *et al.*, 1961) of the management process emerged from this research that has dominated farm management theory for the last forty years, although the model was simplified during this time from six (*problem recognition/definition, observation, analysis, decision, action, responsibility bearing*) to three functions (Table 1.2): planning, implementation and control (Boehlje and Eidman, 1984; Kay and Edwards, 1994). A major advance occurred during the early 1970's when Barnard and Nix (1973) introduced these functions into the farm management literature. However, the evolution of the management process model has not been straightforward (Table 1.2). Researchers have failed to: build on preceding theory, cite sources when modifying existing theory, provide definitions of key concepts, or adopt recognised definitions and terms. They have also altered the position of various sub-processes within functions without justifying such changes. These inconsistencies are often associated with relatively new disciplines that have had limited theoretical development (Kuhn, 1962) and may also reflect a general lack of empirical research into the management process. With the exception of the 1961 study by Johnson *et al.* (1961), few of the models proposed for farm management have been empirically tested.

A comparison of the models of management process in Tables 1.1 and 1.2 highlights several inconsistencies. First, several authors (Nielson, 1961; Suter, 1963; Calkin and Di Pietre, 1983; Renborg in Giles and Renborg, 1990) believed that goal formulation was a function of the management process while others (Barnard and Nix, 1973; Scoullar, 1975; Kay, 1981; Dalton, 1982; Boehje and Eidman, 1984; Buckett, 1988; Giles in Giles and Renborg, 1990; Kay and Edwards, 1994) thought it was a separate and higher level process. Despite its importance and unlike the other management functions, little has been written on goal formulation or its sub-processes. For the purposes of this study, it is assumed that goal formulation is separate to and outside the management process, but that its products, goals and objectives are key drivers of the process.

Table 1.1. Components of models within management process theory as proposed by different authors in the 1950's - 1960's.

Model 1	Model 2	Model 3	Model 4
Bradford & Johnson (1953) Johnson & Haver (1953) Johnson (1954)	**Lee & Chastain (1960)**	**Johnson *et al.* (1961)**	**Nielson (1961) Suter (1963)**
			Goal formulation
	Problem recognition	Problem definition	Problem and opportunity recognition and definition
Observation	Information gathering	Observation	Observation and information gathering
Analysis	Recognition of alternative solutions and opportunities Analysis of alternative solutions	Analysis	Specification of alternative solutions and opportunities Analysis of alternative solutions
Decision	Decision	Decision	Decision-making
Action	Action or inaction	Action	Action-taking or implementation
Responsibility bearing	Responsibility bearing	Responsibility bearing	Responsibility bearing
			Evaluating the outcome

Table 1.2. Development of management process theory as proposed by different authors in the 1970's - mid-1990.

Barnard & Nix (1973)	Kay (1981)	Dalton (1982)	Calkin & Di Pietre (1983)	Boehlje & Eidman (1984)
			Goal formulation	
Compilation Planning	Planning	Forecasting Planning	Compilation Planning	Planning
Implementation	Implementation	Implementation	Implementation	Implementation
Control	Control	Recording Control	Evaluation	Control

Buckett (1988)	Giles in Giles and Renborg (1990)	Renborg in Giles and Renborg (1990)	Kay and Edwards (1994)
		Setting objectives	
Forecasting			
Planning	Planning	Information collection Analysis Planning	Planning
Implementation	Decision-making	Implementation	Implementation
Recording Analysis and appraisal of results Control	Control	Control Correction	Control

It is generally accepted that management comprises three functions: planning, implementation and control (Boehlje and Eidman, 1984; Kay and Edwards, 1994) and these appear to have been derived from the six functions proposed by Johnson *et al.* (1961). However, there are discrepancies in terms of what constitutes the management process (Table 1.2). For example, some authors (Bamard and Nix, 1979; Dalton, 1982;

Calkin and Di Pietre, 1983; Buckett, 1988; Renborg in Giles and Renborg, 1990) separate out functions while others (Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994) subsume these under the major functions of planning (forecasting, compilation, information collection, analysis), implementation and control (recording, analysis and appraisal, correction) (Table 1.2).

Some aspects of the earlier models of management are omitted in later models. For example, evaluation, identified as critical for learning by Nielson (1961) is implied, rather than included in most models of the control process. Few authors (e.g. Mauldon, 1973) explicitly mention evaluation in relation to control. Similarly, recent management process models omit the function "*responsibility bearing*" (Table 1.2). This may be because it is assumed or because it is not a process: managers either accept or do not accept responsibility for their actions. Different views are also held on what the function *implementation* comprises. The majority of authors view implementation as the process of putting a plan into action (Dalton, 1982; Calkin and Di Pietre, 1983; Kay and Edwards, 1994). However, Barnard and Nix (1973) considered that it also included the process of selecting the best plan to implement.

The above examples show that although the management process has evolved from common roots over the last forty odd years, this has not always been consistent. Inconsistencies included the carryover of additional functions from earlier models of management (Table 1.1) and the naming and definition of functions.

Most of the management process models prescribe the functions a farm manager must undertake. Scoullar (1975) took a different view and considered management from the point of view of the knowledge and skills a farmer might need to run a farm business. This allowed Scoullar (1975) to cleave the management process into two distinct types on the basis of the manager's knowledge level. The first, termed the "*goal achievement process*", is applied when managing situations where s/he has a full knowledge of the situation and the management actions required. Here the manager can draw on routine management procedures that they have used in the past. This model is similar to others of the management process.

The second, the "*problem solving process*", was developed by Scoullar (1975) to describe how managers operate when faced with novel situations and therefore have no prior knowledge upon which to draw. Here the manager needs to use quite different knowledge and skills. This view is similar to Simon's (1960) cleavage of "*programmed*" and "*non-programmed*" decisions, and Gorry and Morton's (1971) "*structured*" and "*unstructured*" decisions. Unstructured decisions do not have ready-made solutions (Simon, 1960) and because the decision-maker has no experience with such decisions, no pre-defined procedures exist for their execution (Gorry and Morton, 1971). Unstructured decisions also require more steps, with feedback between steps and may involve delays or interruptions (Gorry and Morton, 1971; Mintzberg *et al.,* 1976). Mintzberg *et al.* (1976) also reported that unstructured decisions required more rigorous diagnosis, search, design, screen and choice sub-processes than structured decisions. "Structured" and "unstructured" decisions identify two points on a continuum, and therefore, Gorry and Morton (1971) proposed a third category, "semi-structured" decisions. This distinction is useful for researchers when investigating different management situations, or for considering the skills and knowledge required by a manager to cope with distinct management situations. For example, tactical decisions, and decisions made by experienced managers (experts), which is the focus of this study, could be expected to fall predominantly in the "*programmed*" or "*structured*" decision category. In contrast, decisions made by inexperienced managers, or strategic decisions, by their very nature, could be expected to fall into the "*non-programmed*" or "*unstructured*" category. This taxonomy provides guidelines to researchers studying the management processes used by farmers. What then is the difference between the management and decision-making processes in farm management?

1.4.2 Decision-making process

The confusion surrounding the difference between the management and decision-making processes is not surprising when the literature is analysed (Hardaker *et al.*, 1970; Castle *et al.*, 1972; Osburn and Schneeberger, 1978). As Table 1.3 illustrates, the concepts evolved from common roots, namely the work on management functions undertaken by Bradford and Johnson (1953), Johnson and Haver (1953), Johnson (1954), Johnson *et al.* (1961), Lee and Chastain (1960) and Nielson (1961). Because many of these models formed the basis for the management process model, similar issues can be therefore expected to arise in the decision-making literature such as whether *goal formulation* is part of decision-making (See Tables 1.3 & 1.4). Castle *et al.* (1972) and Osburn and Schneeberger (1978) viewed *goal formulation* as part of decision-making, but later authors (Kay, 1981; Boehlje and Eidman, 1984; Makeham and Malcolm, 1993; Kay and Edwards, 1994) viewed it as separate from, but important to, decision-making.

Table 1.3. The roots and component elements of decision-making process theory.

Lee & Chastain (1960) Johnson *et al.* (1961)[2]	Nielson (1961)	Brannen (1961)	Thornton (1962)
	Goal formulation		
Problem definition	Problem recognition and definition Opportunity recognition	Defining the problem Goal orientation	Problem recognition
Observation	Observation and information gathering	Recognising alternatives Recognising and collecting information	Preparation
Analysis Recognition of opportunities	Specification of alternative solutions and opportunities Analysis of alternative solutions	Evaluating alternatives	
Decision	Decision-making	Selecting an alternative Making a decision in terms of a plan of action	
Action	Action-taking or implementation		Action
Responsibility bearing	Responsibility bearing		
	Evaluating the outcome		

Debate also exists in the literature about what constitutes a decision, i.e. is it the process of making a decision or does it extend further than this and include implementation, evaluation and responsibility bearing. Authors such as Brannen (1961), Nielson (1961), Thornton (1962), Scoullar (1975), and Dryden (1997) have argued that decision-making should be viewed solely as the act of making a decision. Brannen (1961) stated that a decision was final when expressed in action and thus the outcome of the decision-making process was a plan of action. Cary (1980) adopted the perspective of cleaving "*reflection*" from "*action*" and accordingly, he viewed decision-making as primarily a mental process that formed the link between thinking and doing. He argued therefore that researchers could not fully comprehend the behaviour of a decision maker until they understood their mental models and perception of reality at the time the decision was made. Consequently his view of decision-making incorporates all steps except *action*. This may be a more useful view because it explicitly incorporates evaluation and failure to undertake this function limits learning.

[2] Also based on Bradford and Johnston (1953), Johnson and Haver (1953) and Johnson (1954).

Table 1.4. Alternative models and elements of the decision-making process proposed in the farm management literature.

Hardaker *et al.* (1970)	Castle *et al.* (1972)	Osburn & Schneeberger (1978)	Kay (1981)	Boehlje & Eidman (1984)	Makeham & Malcolm 1993	Kay & Edwards (1994)
	Setting goals	Formulating goals and objectives				
Recognising a problem or situation where a decision should be made	Recognising the problem	Recognition and definition of problems	Identify and define the problem	Define the problem or opportunity	Recognising the problem and the need for action	Identify and define the problem
Collect relevant facts and opinions	Obtaining information	Gathering and organisation of facts	Collect information		Making observations, collecting facts, getting ideas	Collect data and information
Specify and analyse possible alternatives or courses of action	Considering the alternatives	Analysis of alternative courses of action	Identify and analyse alternative solutions	Identify alternative courses of action Gather information Analyse the alternatives	Analysing observations and testing alternative solutions to problems	Identify and analyse alternatives
Decide on the most appropriate solution or courses of action	Making the decision	Decision-making based on sound criteria	Make the decision	Make the decision and take action	Making the decision	Make the decision
Implementing the decision	Taking action	Implementation	Implement the decision		Implement the decision	Implement the decision
Observing and evaluating the consequences of the action taken Bearing responsibility for the consequences	Accepting responsibility Evaluating the decision	Acceptance of responsibility Evaluation of the outcome of the decision	Observe the results and bear responsi-bility for the outcome	Accept the consequences and evaluate the outcome	Controlling the implementation Taking responsibility for the decision Reviewing the outcome and adapting the intended and expected to the actual Doing it better next time, i.e. learning from one's mistakes	Monitor and evaluate the results Accept responsibility for the decision

As mentioned previously, responsibility bearing, unlike the other decision-making steps, is not a process, but rather an attitude that is assumed to be held (or not held) by the decision maker. The existence of this attitude however is important. Without it, managers would most likely forego *evaluation* in the belief that poor outcomes from decisions were due to chance rather than their own actions. As a result, limited learning would occur. In contrast, *action* or *implementation*, although it is seen to be critical for effective decision-making, has not traditionally been the focus of management research.

Management researchers' bias has been towards the cognitive aspects of decision-making, the actions managers take and the outcomes that result from those actions, rather than the action-taking process itself.

The final issue raised in the decision-making literature, and the most relevant to this study, is whether decision-making and management processes differ and if so whether this distinction is useful. The fact that the two processes emerged from common roots, as illustrated earlier (Table 1.3), indicates that there may be grounds for considering them as versions of the same process. Dryden (1997) viewed decision-making to be isomorphic with the management process. He considered that the steps *problem recognition* or *definition*, *observation*, *analysis* and *decision* were equivalent to *planning*. *Action* was synonymous with *implementation*, while the *acceptance of responsibility* and *evaluation* were equivalent to *control*. In contrast, Thornton (1962) believed that the steps *observation*, *analysis* and *decision* were synonymous with planning. He (therefore) differed from Dryden (1997) in that he viewed *problem recognition/definition* as being distinct from *planning*. This view may be more logical because *problem recognition/definition* is similar to the *control* process except that the steps by which the choice of corrective action is chosen is missing.

A useful distinction made by Thornton (1962) was that managers made two types of decisions: detailed and infrequent decisions and simpler routine decisions. This may be useful for differentiating between less frequent "*planning*" decisions that involve a detailed planning process and more frequent "*control*" decisions where a deviation is identified, diagnosed and a suitable control response selected to minimise the impact of the deviation. This view is similar to that held by Boehlje and Eidman (1984) who believe that decision-making occurs across the three functions of management. As such, both decisions (planning and control) would incorporate a "control" aspect because a planning decision is normally triggered by the identification of a "problem".

The decision-making models have been criticised by Cary (1980) because of their simplistic nature and the lack of detail at the sub-process level. He argued that to understand how farmers manage and make decisions, researchers must understand how farmers perceive the world in which they operate and the mental models they use to do this. The majority of decision-making models provide limited insight into the cognitive processes used by farmers. A taxonomy of the sub-processes (or decisions) used by farm managers has been developed to varying degrees by several authors (Lee and Chastain, 1960; Scoullar, 1975; Boehlje and Eidman, 1984).

Some progress has been made in identifying the sub-processes used in decision making through the recent work of Ohlmer *et al.* (1998). They developed a matrix model of the decision-making process from a case study of Swedish farmers. In one of the few recent in-depth qualitative case studies of farmer decision-making they investigated primarily unique (as opposed to repetitive) strategic decisions. The matrix model (Figure 1.1), although similar to most models of decision-making (Johnson *et al.*, 1961; Hardaker *et al.*, 1970; Kay, 1981; Boehlje and Eidman, 1984; Makeham and Malcolm, 1993; Kay and Edwards, 1994), has some important differences and is influenced by decision-making research outside the discipline of farm management (e.g. Newell and Simon, 1972; Mintzberg *et al.*, 1976; Hogarth, 1981; Beach, 1993; Klein *et al.*, 1993; Lipshitz, 1993).

	Sub-process			
Phase	**Searching & paying attention**	**Planning**	**Evaluating & choosing**	**Bearing responsibility**
Problem detection	Information scanning Paying attention		Consequence evaluation Problem?	Checking the choice
Problem definition	Information search Finding options		Consequence evaluation Choose options to study	Checking the choice
Analysis & choice	Information search	Planning	Consequence evaluation Choice of option	Checking the choice
Implementation	Information search Clues to outcomes		Consequence evaluation Choice of corrective action(s)	Bearing responsibility for the final outcome Feed Forward information

Figure 1.1. Conceptual model of the decision-making process (Source: Ohlmer *et al.*, 1998).

Ohlmer *et al.* (1998) separated the step *problem recognition and definition* (Tables 1.3 & 1.4) into two phases, *problem detection* and *problem definition*. *Identification and analysis of alternatives* and *decision* are combined into one phase, called *analysis and choice*. The steps *information collection*, *evaluation* and *bearing responsibility* have been redefined as sub-processes that occur across the four phases. *Observation* has been renamed as *searching and paying attention* and *evaluation* as *evaluating and choosing*. A new sub-process, *planning*, has been introduced within the *analysis and choice* phase. They also argued that decision makers collect information at each phase of the decision-making process rather than just at the *information collection* step. The sub-process, *searching and paying attention*, may be different from the *information collection* step in the decision-making process, because it includes both the external search for information and the internal search for information stored in the memory of the decision maker. Further, Ohlmer *et al.* (1998), on the basis of their work and that of Lipshitz (1993), argued that option generation should occur within the problem definition phase rather than during *analysis* as had been the case historically. The naturalistic decision-making models of the problem-solving processes used by experts reviewed by Lipshitz (1993) suggested that option generation was strongly linked to problem definition.

Although it could be argued that the changes Ohlmer *et al.* (1998) made to the decision-making model could have been deduced logically from the existing literature, the model attempts to make more explicit, the sub-processes that comprise the decision-making process of farmers. Empirical information on the nature of these sub-processes remains scant.

Management and decision-making processes, according to the literature, are essentially the same. Both incorporate, to varying degrees, steps that involve the generation, analysis and selection of alternatives, the development and implementation of plans, and the identification, diagnosis and evaluation of problems or deviations from the plan, and some form of correction, whether it is through the development of a new plan or the introduction of a contingency plan. Interestingly, one process starts with planning while the other starts with control or the identification of a problem. This has important implications for researchers reporting empirical work under the banner of "decision-making". For example, depending on the magnitude of the problem, the decision maker may undertake either a relatively simple corrective process or a more detailed planning procedure (Thornton, 1962). Researchers, when reporting on such decisions, could usefully classify them as either simple control, or more complex planning decisions.

If the management and decision-making processes can be considered synonymous, then it would be sensible to adopt the management process as the model under which management is researched. This is because management rarely comprises a single decision (Brannen, 1961; Thornton, 1962), rather it is an ongoing cyclical process of planning, implementation and control, where *planning* decisions tend to be much less frequent than *control* decisions (Thornton, 1962). A planning decision will comprise a sub-set of lower level decisions or sub-processes as suggested by Cary (1980), e.g. what information to obtain, how long to search for this, what options to investigate, and so on. For this study, the farm management of dairy farmers was viewed from a management process perspective of planning, implementation and control, and the decisions made by the farmers were broadly classified (as either planning, implementation or control) under these headings.

In any decision making study, the classification of decisions is important. Castle *et al.* (1972) classified decisions on the basis of: importance, frequency, imminence, revocability and available alternatives. The usefulness of this classification schema is not clear since few, if any, researchers have reported using it when analysing farmers' decisions. There may also be some fundamental problems with such a schema. For example, *importance* and *imminence* may be time dependent and inter-related. In contrast to Castle *et al.* (1972), the schema originally proposed by Gorry and Morton (1971) and introduced to farm management by Dryden (1997) appears to provide a more useful way of classifying the decisions of farmers. Gorry and Morton (1971), drawing on the work of Simon (1960) and Anthony (1965), classified decisions by level (strategic, tactical and operational), and "*structuredness*" (structured, unstructured). By their nature, operational decisions tend to be structured and strategic decisions unstructured. Experienced (or more knowledgeable) farmers tend to make more structured decisions than inexperienced (or less knowledgeable) farmers. This latter distinction ties in with Scoullar's (1975) distinction between "*routine decision making*" (goal achievement) and "*problem solving*". Empirical research of decision-making could usefully be classified and reported using this matrix.

1.4.3 Problem-solving process

The final consideration in this section is how problem-solving is related to the management and decision-making processes. The problem-solving process was derived from the same roots as the decision-making process. Johnson (1976) developed a model of problem-solving (Table 1.5) from his model of the management process (Johnson *et al.*, 1961). It is therefore not surprising that the terms management process, decision-making process, and problem-solving process are used interchangeably (Scoullar, 1975; Cary, 1980). Cary (1980) thought there was little point in distinguishing between decision-making and problem-solving because they appeared to be synonymous in the literature. It is not difficult to see how problem-solving fits into the management process. A problem is traditionally defined as a gap between actual and desired performance (Cary, 1980) and therefore problem-solving is the process used to minimise that gap in much the same way as the management process is used to progress a manager from his/her current state to some future desired state.

Table 1.5. Early research related to elements in the problem-solving and management functions.

Model of Managerial Adjustment Lee & Chastain (1960)	**Management Functions** Johnson *et al.* (1961)	**Problem-Solving Process** Scoullar (1975)	**Problem-Solving Process** Johnson (1976)
Problem recognition 1. Difficulty is felt. 2. Gather information. 3. Recognise alternative problem definitions. 4. Analyse alternative. 5. Problem definitions. 6. Define the problem. 7. Accept responsibility for the definition.	Problem definition	Problem recognition 1. Recognising the problem. 2. Recognising a 'model' under which the problem will be studied 3. Recognising all important variables within the 'model' 4. Knowledge of methods needed to investigate the variables within the 'model' 5. Knowledge of principles and generalisations. 6. Comprehension of accumulated facts 7. Recognising the interrelationships between variables 8. Recognising the causes of the problem	Problem definition
Gather information about the problem	Observation		Observation
Recognition of alternative solutions and opportunities Analysis of alternative solutions	Analysis	Recognition of the possible solutions to the problem	Analysis
Decision	Decision	Recognition of the most practical and economic solution Planning to carry out the solution	Decision
Action or inaction	Action		Action
Acceptance of responsibility	Responsibility bearing		Responsibility bearing

As previously mentioned, the process of problem recognition and definition is similar to the monitoring, comparison and diagnosis aspects of the control process. Problems as such, could be classified into a hierarchy comprising those that require the introduction of contingency plans due to an aberration in the environment (i.e. control problems), those that are significant enough to require the introduction of a new planning process (i.e. planning problems) or the reformulation of the manager's goals (goal formulation problems) due to long-term changes in the environment, and those that require the development of a new planning and/or control system due to fundamental problems with the planning model and/or the control system (i.e. management control problems). These planning and control problems are synonymous with planning and control decisions. They also reflect the various corrective actions open to a manager in relation to control (Barnard and Nix, 1973; Boehlje and Eidman, 1984). Problem-solving can therefore also be viewed as a broader form of control, in much the same way as Anthony (1965) viewed the management process.

From Scoullar's (1975) perspective (Table 1.5), problem-solving is synonymous with unstructured decision making and requires a quite different set of processes than those used for structured decision making. A problem, as defined by Scoullar (1975) is the result of a knowledge, not a performance, gap. As such, "problem-solving" in this context is synonymous with learning. This may provide a useful framework for considering unstructured decisions.

1.4.4 A framework for studying farmers' management practices

Critical to any classification schema for management is the level of decision making (Anthony, 1965). Management decisions can be classified as strategic, tactical or operational. The degree of "*structuredness*" of decision-making, however, will be dependent on the farmer's knowledge and the number of new situations s/he has encountered. The other aspects of management that must be considered are the functions (planning, implementation and control) and the fields of management (production, finance and marketing) (Boehlje and Eidman, 1984). From the above discussion, a classification schema based on the management "cube" (Boehlje and Eidman, 1984) can be derived as shown in Figure 1.2. Thus, farm management decisions could be classified by level, structuredness, primary function and field. Equally important, as discussed by Cary (1980), is the identification of the detailed sub-processes that comprise the decision-types within this taxonomy. This classification schema is almost identical to that developed by Boehlje and Eidman (1984) except that it distinguishes between structured and unstructured decisions, but does not classify decisions by placement on the farm family life cycle. The latter is not included here because it does not classify the decisions, but rather the decision-maker. The schema is also similar to that provided by Dryden (1997) except he did not include the fields of management.

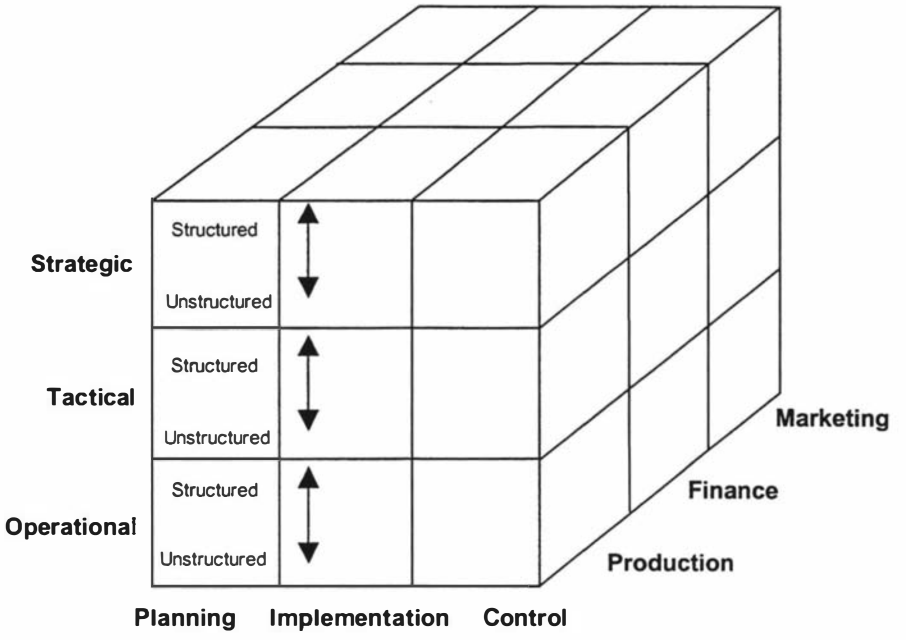

Figure 1.2. A classification schema for decisions (Derived from Boehlje and Eidman, 1984 and Dryden, 1987).

1.5 Scoping the study

An important aspect of any research design is the scoping of the research (Booth *et al.*, 1995). The general topic of interest in this study is the management processes used by high performing pastoral-based dairy farmers. However, issues in relation to the field (production, finance, marketing) (Boehlje and Eidman, 1984), and level (strategic, tactical, operational) (Anthony, 1965) of management must be decided along with the focus (time frame, livestock classes) within the chosen field. The field is production, the level is tactical and the focus is the "summer-autumn" period management of the milking herd. Strategic decisions in pastoral systems, such as stocking rate, calving date and level of intensification, although critical to farm performance, relate more to the profitable matching of feed supply and feed demand, as opposed to the on-going management of the pastoral resource. Such decisions are made in response to major changes in the external environment and therefore tend to be infrequent and irregular (Gorry and Morton, 1971). This may limit the number of observations given the limited time frame set aside for fieldwork (3 years). In contrast, tactical decisions tend to be regular, ongoing and repetitive (Gorry and Morton, 1971).

The milking herd was chosen as a focus to simplify data collection and analysis. Besides, most New Zealand dairy farmers run their young stock and milking herd on separate areas. The choice of time frame was more difficult. Because the study was part-time, it was not possible for the author to investigate farmers' management processes for a complete year. The summer-autumn period was chosen because it was believed to provide the most "profitable" insight into the management processes of high performing pastoral-based dairy farmers.

Decisions made over the summer-autumn have a major impact on milk production in both the current and subsequent production cycles. In order to best utilise spring pasture growth, New Zealand farmers calve their herds two to three months before peak spring pasture growth rates occur (Grainger and McGowan, 1982; Macmillan and Henderson, 1987; McCall and Sheath, 1993). The downside to this approach is that a feed deficit situation[3] is experienced during the first one to two months of the spring. In order to minimise the impact of this feed deficit situation on milk production, farmers calve onto pasture reserves accumulated during the autumn and winter and feed supplements, use nitrogen to increase feed supply, and draw on cow body reserves (Bryant, 1990). Failure to ensure the herd is in good condition (i.e. condition score $\leq$ 5.0 condition score units[4]) and provided with sufficient feed at calving, can have a major impact on herd productivity (milk production and reproductive performance) in the current and subsequent seasons (Grainger and Wilhelms, 1979; McGowan, 1981; Bryant and Trigg, 1982; Macmillan *et al.*, 1982; Phillips, 1983; Morton, 1991). Production data and comparisons with North American and European herds suggest that a large proportion of New Zealand herds are underfed in early lactation and for a large part of the remainder of lactation (Bryant, 1993; Murphy, 1993; Edwards and Parker, 1994).

Winter management and the drying off decision are two important determinants of a farmer's ability to achieve adequate pasture cover and cow condition at calving (Holmes and Brookes, 1993). The drying-off decision is particularly important because it determines the amount of feed and the condition of the herd going into the winter (Campbell *et al.*, 1977; Holmes and Macmillan, 1982; Bryant and Macdonald, 1987; Holmes and Brookes, 1993). Despite its importance, there has been limited empirical

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[3] Animal feed demand (kg DM/ha/day) exceeds pasture growth rates (kg DM/ha/day).

[4] Condition score is a subjective measure of body fatness based on the amount of fat over the loins, hips, area above the tail, and thighs. A 1-10 scale is used and a score of 1 denotes cows in very poor body condition.

research (Parker *et al*., 1993) into this decision although a few papers have described the prescriptive process ("recipes") farmers should undertake in relation to drying off (Bryant and Macdonald, 1987; Holmes and Brookes, 1993).

In a survey of 250 New Zealand dairy farmers, Parker *et al*. (1993) found that farmers considered that the pasture available and cow condition at calving had a larger influence on milk production during the first 8 weeks of lactation than the drying off decision or winter management. However, despite the lesser ranking of the drying off decision in relation to milk production, some 74% of respondents dried their herd off in response to cow condition, pasture cover, some combination of the two, or a combination of pasture cover, weather and milk production. Data from the survey also suggested that farmers would need to increase pasture cover on average by 334 kg DM/ha and cow condition by 0.5 - 1.0 condition score units over the winter period. Without the use of an extensive period of grazing off, it is unlikely that this could be achieved. About one fifth of the farmers used feed budgeting over the autumn-winter period to monitor their progress towards planned targets. Parker *et al*. (1993) concluded that given the farmers' limited use of formal planning techniques (i.e. feed budgeting) and the magnitude of the required increase in both pasture cover and cow condition over winter, it was unlikely that they would achieve their targets. In this context, the poor early lactation performance of New Zealand dairy cows on pasture diets (LIC, 1993) is not surprising.

The drying off decision also impacts on the current season's production (Holmes and Brookes, 1993). The seasonal nature of pasture production means New Zealand herds tend to have relatively short lactation lengths (220-250 days) (Bryant, 1993), especially in regions where summer-autumn moisture stress causes feed restrictions (Edwards and Parker, 1994). Autumn rains usually improve pasture growth rates and farmers therefore adopt a range of strategies to bridge the summer feed deficit and keep the herd lactating. These strategies delay the drying off of the herd and allow advantage to be taken of the flush of autumn feed. Therefore the decision to dry off the herd cannot be considered in isolation. It involves a series of tactical and operational decisions made through the summer-autumn period (January 1st until the herd is dried off) in relation to the allocation of resources (pasture, supplements, crops, cows) (Campbell *et al*., 1977). Research that identifies management techniques that can extend the lactation length of New Zealand dairy herds will benefit not only farmers but also dairy companies that are seeking to improve the utilization of processing plant (Paul, 1982; Paul, 1985; Macmillan and

Henderson, 1987; Gray *et al.*, 1994). For example, if a typical 200[5] cow herd was milked for an extra 15 days at 0.9 kg MS/cow/day, an extra 2700 kg MS/herd would be produced for income of $10,206 (assuming a milk price of $3.78/kg MS[6]). At the national level[7], this is equivalent to an extra 37.4 million kilograms of milksolids or, assuming the same milk price, $142 million to the New Zealand dairy farming community.

The drying off decision made at the end of the summer-autumn provided a definite terminating point for the study. The summer-autumn is also the period of greatest variability in terms of pasture growth, the primary feed resource used by New Zealand dairy farmers and the driver of this, rainfall (Campbell and Bryant, 1978; Baars, 1981). Martin (1994) reported that New Zealand dairy farmers ranked highly the risk associated with variable rainfall. Given an important aspect of management is control (Kennedy, 1974; Barnard and Nix, 1979; Boehlje and Eidman, 1984; Wright, 1985), a study period that exposes farmers to extreme variation in relation to their primary feed source should provide useful insights into their tactical management. Strategic management decisions such as stocking rate and calving date are based on "*average conditions*" and cannot be easily changed within a given year. Therefore, variable pasture growth must be addressed through the use of tactical and operational decisions that fine-tune the relationship between feed supply, essentially pasture growth, and animal requirements. The identification and application of tactical management processes that minimise the impact of highly variable summer-autumn pasture growth rates should benefit all pastoral-based farmers.

In summary, the focus of this study will be the tactical production management decisions related to the milking herd made by high performing pastoral-based New Zealand dairy farmers. The study was conducted over the summer-autumn, a period that has critical impact on production in both the current and subsequent seasons and in which pasture growth rates, the primary source of feed, are most variable.

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5 Based on the 1999/2000 average herd size of 236 cows (NZDB, 2000b) where it is assumed that 15% of the herd has been culled to this point in time.
6 Based on the average dairy payout for the 1999/2000 season (NZDB, 2000b).
7 Based on the 1999/2000 figure of 13,861 herds (NZDB, 2000b).

1.6 Purpose and scope of the investigation

The dairy industry contributes some 20% to New Zealand's export receipts. Central to the success of the New Zealand dairy industry is production of low cost milk from pastoral-based dairy systems. Despite the importance of 'low cost' pasture to the competitive advantage of the New Zealand dairy industry, little is formally known about how dairy farmers manage this vital resource. An especially critical period in a seasonal dairy system is the summer-autumn period when pasture growth rates are highly variable. Tactical management decisions made during this period importantly influence production in both the current and forthcoming seasons. A study of the management practices used by high performing dairy farmers over the summer-autumn period could identify practices that can be adopted by less expert farmers to improve the productivity of their farms and provide results that are relevant to the management of dairy farms at other times of the year, thereby enhancing New Zealand dairy farmers' competitiveness in producing milk for export markets.

The fundamental assumption central to this thesis is that the management of "average" farmers could be improved by studying and transferring the management practices of "high" performing farmers. Therefore, the overall aim of this thesis was to develop a theory to explain the tactical management practices used by high performing dairy farmers. This was achieved by addressing the following objectives:

1. To describe how high performing dairy farmers tactically manage their farms through the summer-autumn period.

2. To explain why high performing dairy farmers tactically manage their farms in the way they do during the summer-autumn period.

3. To compare the results of the study to the literature.

4. To develop theory to explain how high performing dairy farmers tactically manage their farms through the summer-autumn period.

1.7 Outline of the study

The justification and purpose for the study has been set out in this chapter along with the conceptual framework within which the phenomenon of interest was investigated. In Chapter Two, the normative literature on the management process is reviewed while in Chapter Three the descriptive literature on both the management and decision-making processes is discussed. The method used to investigate the management processes used by high performing pastoral-based dairy farmers over the summer-autumn is described in Chapter Four. Case reports on the management processes used by the case farmers over the summer-autumn across three years are presented in Chapters Five and Six. The results of the cross-case analysis are presented in Chapter Seven. In Chapter Eight, a model of the tactical management processes used by the case farmers is compared to the literature. In Chapter Nine, the conclusions drawn from the study, an evaluation of the method, and areas for future research are presented.

CHAPTER 2 THE MANAGEMENT PROCESS

2.1 Introduction

A question often raised is "*What is the difference between farm management and business management*?" A primary difference is that farmers manage biological systems, whereas business managers operate manufacturing or servicing businesses. The farm business also usually has fewer personnel in relation to staffing. The early organisational management literature viewed management as comprising five functions: planning, organising, staffing, directing, and control (Koontz, 1962). More recently, *'directing'* has been renamed as *'leadership'* (Koontz and Weihrich, 1993). The difference between the functions defined in the organisational and farm management literature highlight an important conceptual difference between the two disciplines. In organisational management, managers manage people (Anthony, 1965) and they, unlike most farm managers, do not physically participate in the physical implementation of plans. Managers in large organisations make decisions and persuade others to implement them (Anthony, 1965; Simon, 1997, pp. 1-2). Hence, in the organisational literature, planning and control are separated from implementation. Simon (1997, p. 23) coined the phrase "*vertical specialisation*" to describe the division of decision making duties between management and non-management personnel. Such structures allow personnel to develop expertise at the various levels within the organisational hierarchy. The scope and family-based nature of most farm businesses precludes the development of *vertical specialisation* (Blackie, 1971). However, as farm size continues to increase (Guy, 1993) this distinction becomes more blurred. Given that the tactical management of small owner-operator dairy farms is the focus of this study, the business literature will not be drawn on, except where it has direct relevance to the issues raised.

Management can be studied from two viewpoints in the context of farming: normative and descriptive (Ilbery, 1978; Klein and Methlie, 1990). Normative studies seek to determine how a rational person would make decisions in a given situation and to provide prescriptive advice on how best to make decisions. In this chapter, the normative literature is reviewed. The role of goals and values in the management process, and the process itself are discussed including the interdependency between planning and control and the relationship between the environment and the management process is reviewed.

2.2 Goals and values and their role in the management process

The farm management literature on goals and goal formulation is scant, and even less has been written about these at the tactical level of management. As such, information about this area can only be inferred from the more general literature. The literature is unequivocal on the role of goal formulation in management. Buckett (1988), Giles and Renborg (1988) and Olsson (1988) all wrote that goal formulation is separate to, but drives the management process. In contrast, Calkin and Di Pietre (1983) considered goal formulation to be a function of management, while Boehlje and Eidman (1984) and Dalton (1982) saw it as part of the planning process. Dalton (1982) however, later stated that goal formulation was part of a "higher process". Castle *et al.* (1972) and Osburn and Schneeberger (1978) viewed goal formulation as part of the decision making process while Thornton (1962), Kay, (1981), Boehlje and Eidman (1984) and Kay and Edwards (1994) articulated a contrary view. Scoullar (1975) viewed management as two interrelated processes: goal achievement and problem solving. He separated the process of goal formulation from goal achievement and identified two other processes: goal evaluation, and goal modification and reformulation. Trip *et al.* (1996) viewed goal formulation to be outside the management process and saw goals as the motivational and "guiding" force to planning, implementation and control. Thus, there is a diversity of views on the process of goal formulation and its relationship with management processes and decision making.

The *economic* and *empirical* views of goals in farm management also conflict. Nielson (1961) challenged the traditional view of the farmer as "*economic man*" with a single goal of short-term profit maximisation. He believed farmers held multiple goals that changed through time and argued that methods could be developed to improve farmers' ability to formulate appropriate goals. This was confirmed by Gasson's (1973) study and it is now generally accepted that farmers have multiple goals (Boehlje and Eidman, 1984; Kay and Edwards, 1994).

Makeham and Malcolm (1993) stressed that the goals of the farm family ultimately determine how a farm is managed. These goals change through time and depend on an individual's circumstances and stage in the family firm life cycle (Bennet, 1980; Boehlje and Eidman, 1984). Bennett (1980) suggested several changes in the farm family firm through time. These changes were associated with the farmer's management of the enterprise, the development of the enterprise, the phases of the farm family and the formation of associated networks. The farmer's goals may be complementary or in conflict (Kay, 1981; Kay and Edwards, 1994). Further, because of the farm family's direct involvement in the farm business, the goals of a farmer may be classified as business or personal, although these tend to be inter-linked (Rushton and Shaudys, 1967; Kay and Edwards, 1994). Goals and their ranking not only change with time, but also in response to circumstances (Boehlje and Eidman, 1984; Kay and Edwards, 1994).

Goals can be conceptualised in a structure with the higher level goals representing the farmer's needs and motives and the lower level goals, the means to the ends (Trip *et al.*, 1996; Ohlmer *et al.*, 1997). In other words, objectives (or goals) can be broken down into sub-objectives that need to be realised in order to achieve the primary objective, and these sub-objectives can be further subdivided through several levels of a hierarchy (Dalton, 1982). This suggests the time frame used by the manager determines whether a goal takes on the attributes of a means or an end.

Petit (1977) and Dalton (1982) both identified that a hierarchical goal structure is useful for diagnosing problems in a farm business, as they can show the tasks and sub-tasks that need to be undertaken in order to achieve a higher level goal. Similarly Gasson (1973, p. 524) stated that "*A course of action may be viewed as the achievement over time of a connected series of goals where attainment of one satisfies an immediate need and also provides a stepping-stone to a more ultimate goal.*" Olsson (1988) also believed that goals drive a farmer's choice of strategy, which ultimately leads to action. Petit in an earlier paper (1976) described the relationship between goals and actions as dialectical i.e. a relationship between what an individual thinks the situation should be like and what s/he can do about it. The actions an individual can take to improve a situation will depend on his or her perceptions of the situation and power to modify the situation. Therefore, goals are influenced by an individual's earlier performance and feedback, as well as reference groups or reference data, which show what is possible. Where individuals have limited experience, then these latter factors may have a greater influence. Importantly, Petit (1976, p.300) also proposed that the choice of strategy "defines a whole array of goals for tactical decisions".

The hierarchical nature of goals is important for maintaining integration and consistency of behaviour (Simon, 1997). If the goals within a hierarchy are fully integrated then decision making should be efficient because goal conflict is removed and goal congruence is achieved. However, Simon (1997) noted that in reality, a high degree of conscious integration may seldom be attained. Interestingly, various methods have been introduced from the business literature into farm management to assist in ensuring goal congruence. In the late 1960's, management by objectives was introduced (Boyer, 1969). More recently, the balanced scorecard (Kaplan and Norton, 1992, 1993, 1996a,b,c) has been advocated as a means of ensuring goal congruence (Parker, 1999). This method uses a multi-dimensional performance measurement system that is logically derived from strategy to ensure lower level goals are congruent with the overall thrust of the organisation (Dinesh and Palmer, 1998).

Goals are often viewed as the drivers of management in that they provide the direction for the entire management process (Boehlje and Eidman, 1984; Kay and Edwards, 1994). Goals influence the management process in two ways (Boehlje and Eidman, 1984). First, in a planning context, they provide the criteria by which the desirability of alternative plans can be judged. Second, also in a planning context, they form the basis from which standards are derived. These standards are central to the control process. Kay and Edwards (1994) recommend that for goals to be useful to a farm business they should be written, specific, measurable and specified for a precise time period.

Petit (1977) asked the question, "*Where do goals come from?*" His answer is that they clearly come from an individual's higher level goals and their perception of the environment and ability to modify it. If “goals” depend on higher level goals, then such a hierarchy can go on *ad infinitum*. However, Petit (1977) postulated that in reality, given the impossibility of formulating an infinite hierarchy of articulated goals, individuals have a temporary, revisable set of goals and some general rules of behaviour which guide their goal setting. Although little is written on tactical goals, their hierarchical nature and the recommendation that lower level goals be logically derived from higher level goals to ensure congruence, suggest that tactical goals are derived from a farmer’s strategic goals. Given the repetitive nature of tactical management, the work of Simon (1960) and Gorry and Morton (1971) implies that farmers’ tactical goals may remain relatively constant until their strategic goals change.

An individual's choice of goals reflects their values (Petit, 1977; Olsson, 1988). Values are cultural products learned through social interaction (Gasson, 1973). They serve as standards and influence a farmer's selection of the mode[1], means[2] and ends for plans ranging from the most grandiose through to the most trivial (Gasson, 1973, p. 525; Petit, 1977). Because values shape farmers' goals (Olsson, 1980), differences in values may contribute to variation in goal ranking. Research into "*management style*" (Bennett, 1980; Van der Ploeg, 1985; Olsson, 1988; Cruise and Lyson, 1991; Fairweather and Keating, 1994) provides a possible way of characterising farmers on the basis of an amalgam of factors such as values, goals and means and modes of operation. Cruise and Lyson (1991) also suggested that "*management style*" is moderated by the macroeconomic and physical environment.

While goals tend to be situation specific, values transcend situations (Petit, 1977). Although some values may be common across individuals within a population, value systems differ between individuals (Gasson, 1973). Olsson (1988) distinguished between individuals who had their own clearly defined values, and individuals who had poorly defined values that were common to society in general. The literature suggests that in order to understand the behaviour of individuals, an understanding of their value systems and goals is necessary (Gasson, 1973; Cary, 1980; Olsson, 1988).

2.3 The normative view of the management process

Goals and values drive the management process. The modern normative view in farm management is that this process comprises three functions: planning, implementation and control (Kay and Edwards, 1994; Parker *et al.*, 1997). Implementation receives scant attention in the literature, although it is critical to the performance of farms and non-farming organisations. There appears to be a fundamental assumption that its nature is so basic that it is not worthy of scientific investigation in contrast to the planning and control functions. This study on dairy farm management incorporates aspects of implementation.

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[1] Manner of acting or doing, method - Random House Dictionary (1967).
[2] Method used to attain an end - Random House Dictionary (1967).

2.3.1 The interdependence of planning and control and the hierarchical nature of the management process

Although the inter-dependence of planning and control is recognised (Boehlje and Eidman, 1984; Wright, 1985; Kay and Edwards, 1994), this is not reflected in the normative literature which has been criticised for its emphasis on planning and planning techniques to the detriment of control (Kennedy, 1974; Jolly, 1983; Wright, 1985; Parker, 1999). In this respect, Kennedy (1974, p. 416) considered that farm management research has "*lacked balance*". The danger of separating these functions for research purposes is that they are then viewed in isolation. This appears to be the case in farm management where the development of normative planning has dominated the literature (Wright, 1985). Planning and control, although often discussed separately, are aspects of the same problem and must be fully integrated (Kennedy, 1974; Barnard and Nix, 1979; Wright, 1985; Kaplan and Norton, 1996abc). This point is best made by Anthony (1965, p. 27) in the business management literature who stated that planning and control, although recognisable as "*definable abstractions*" that represented "*different types of mental activity*" are not separate activities in reality.

Several authors (Blackie, 1971; Barnard and Nix, 1979; Boehlje and Eidman, 1984; Shadbolt, 1997; Parker, 1999) believe planning is a prerequisite for the effective accomplishment of the implementation and control functions of management. Without a plan, farmers do not know what resources they need to achieve their goals. Activities cannot be controlled because a central aspect of control is the comparison of actual with planned outcomes. Plans provide the standards used in the control process. Conversely, in an uncertain environment, plans cannot be effectively implemented without control .

Wright (1985, p. 16) differentiated between a narrow view of control i.e. a process that "*ensures plans are implemented and pursued properly*", and a broader view of control which is "*the continuous identification of appropriate combinations of organisational activity based on observed or forecasted relations between an organisation and its environment*." This broader view places planning as a subset of control. Wright (1985) believed that planning and control are practically identical concepts. Given farmers plan in an uncertain environment, one would expect the decision to replan (control) to be an important aspect of the farm management literature (Wright, 1985). However, few papers (e.g. Kennedy, 1974) focus specifically on control (Kennedy, 1974; Wright, 1985; Parker, 1999). Similarly, most planning models focus on the initial plan and no mention is made of subsequent plans, the timing of these or the associated analysis (Wright, 1985). Exceptions to this include Blackie (1971), Kennedy (1974) and Darkey (1989).

Planning aids used in farm management were reviewed by Wright (1985). He found that none aided the generation of new plans nor did they provide advice for the development of plans subsequent to the original plan. Wright (1985) also criticised these planning aids because they summarised environmental uncertainty in the form of probability distributions rather than the variety of responses a manager might use to keep a plan on course as it unfolds. Therefore, these planning aids or models, provide only a *partial* view of the management process.

The role of control in the management process depends on the strength of the relationship between plan implementation and plan performance (Wright, 1985; Kaine, 1993). If plan implementation has little impact on plan performance, then the requirement for control is minimal and greater emphasis should be placed on plan reformulation. Alternatively, if the environment is highly unpredictable such that planning is of limited use, then greater emphasis will be placed on control and adapting to changes in the environment. Few other authors have made this distinction in the literature. Interestingly, the emphasis by researchers on planning implies that farmers operate in a stable and relatively predictable environment. The artificial separation of the concepts of planning and control may explain why farm management has often been criticised for the gap between theory and practice and the paucity of useful farm management theory based on empirical studies of practitioners (Plaxico and Wiegmann, 1957; Williams, 1957; Johnson, 1957, 1963; Burns, 1973; Jackson, 1975; Musgrave, 1976; Jensen, 1977; Petit, 1978; Nix, 1979; Wright, 1985; Andison, 1989; Harling and Quail, 1990).

The belief that planning and control are interdependent, led Anthony (1965) to propose that it is more useful to conceptualise them within a hierarchy that reflects the management structure of an organisation. In other words, it is more useful to compare the planning and control processes used by senior managers with those used by other senior managers, than with those used by lower level managers. On this basis, Anthony (1965) proposed a taxonomy for planning and control where these interdependent functions are separated into a hierarchy of strategic planning, management control and task control: strategic planning is the process of deciding on the goals of the organisation and the strategies for attaining these goals; management control is the process by which managers influence other members of the organisation to implement the organisation's strategies; task control is the process of ensuring that specific tasks are carried out effectively and efficiently. The terms management control and task control have since been modified and are now known as tactical management and operational management. Anthony (1965) stressed that the boundaries between these three categories are not sharp. Gorry and Morton (1971), for example, viewed the taxonomy as a continuum from strategic planning to operational management.

In the farm management literature, planning hierarchies "*receive scant attention*" (Wright, 1985, p. 182). Prominent farm management texts (Barnard and Nix, 1979; Dalton, 1982: Boehlje and Eidman, 1984; Buckett, 1988; Kay and Edwards, 1994) barely touch on the concept of hierarchies of management (i.e. strategic, tactical and operational management), except Barnard and Nix, (1979) and Buckett (1988) who distinguished between strategy and tactics in terms of both planning and control, and Dalton (1982, pp. 126-127), who differentiated management tasks on the basis of time scale. There may be two reasons for the lack of focus on the hierarchical nature of the management process. First, farm size prevents vertical specialisation on most farms and therefore, farmers do not develop distinctive competencies in strategic, tactical or operational management that could form the basis of a research focus. Second, the development and application of quantitative planning techniques have been preferred to the study of the management processes actually used by farmers. Because one individual manages across the strategic-operational spectrum (Blackie, 1971), the planning horizon associated with the farmer's goals dictates the nature of the management process used, not the individual's management position as is in a large organisation.

Since the late 1980's, strategic planning has been the topic of a number of farm management papers (e.g. Renborg, 1988; Martin *et al.*, 1990; Rasmussen *et al.*, 1990; Attonaty and Soler, 1991; Harling, 1992; Hemidy, 1996; Parker *et al.*, 1997). However, these papers tend to focus on the application of strategic planning to farm businesses, although the hierarchical nature of planning is often mentioned in passing (e.g. Parker *et al.*, 1997). Few papers explicitly address tactical management. Those that do, tend to describe prescriptive decision support systems for use in tactical management (e.g. Gold *et al.*, 1990; Kingwell *et al.*, 1992; Stafford Smith and Foran, 1992). The following review of planning and control is therefore of a general nature rather than specific to tactical management.

2.3.2 Planning

The traditional farm management view of planning is summarised by Barnard and Nix (1979, p. 3) who defined the planning problem as "*allocating scarce resources amongst various uses in a way that best satisfies the wants of the individual.*" Therefore, in farm management, a plan is deemed to comprise three elements (Barnard and Nix, 1979; Kay and Edwards, 1994): one or more goals (or objectives), scarce resources, and alternate ways of using these resources to achieve the goal(s). Wright (1985, p. 16) suggested that the business management literature was a better source of information on planning than its farm management equivalent. Drawing on this literature, he defined planning as "*a programme or set of activities decided to be appropriate at and for some period of time, in the pursuit of some level of organisational performance*". While a plan was defined as "*a statement of objectives to be attained in the future and an outline of the steps necessary to reach them*". Similar definitions have been provided by other farm management authors (Reisch, 1971; Boehlje and Eidman, 1984; Kaine, 1993). Plans must also have a time horizon within which the objectives are to be satisfied (Wright, 1985). The concept of a planning horizon is important to the planning process. For planning to be a rational activity, an individual or organisation must have an objective and the means to influence outcomes (Kaine, 1993). The type of planning that is undertaken is dependent on the decision maker's ability to control outcomes and this determines the nature of the objectives that may reasonably be set by a decision maker (Kaine, 1993). As such, the identification of the limits of control a manager has over outcomes is a crucial step in identifying objectives and associated plans.

2.3.2.1 Planning horizon

The role of time in the planning process, or the 'planning horizon' was highlighted by Wright (1985). Earlier, Hanf and Schiefer (1983) had argued that the time dimension of managerial decisions is not considered adequately. They believed that because the management process is a continuous series of decisions, it is difficult to incorporate time into mathematical planning models. Several problems were highlighted in the literature in relation to the specification of a suitable planning horizon. First, decisions that comprise the management process are interdependent through time, i.e. a decision is not only dependent on the preceding decisions made by the manager, but also influences subsequent decisions (Hanf and Schiefer, 1983). Second, the implementation of a decision also takes time, and in a changing and uncertain world, this has implications for subsequent decisions, i.e. the optimum sequence of decisions identified at a point prior to the implementation of the plan, may not be the optimum plan post-implementation due to changed circumstances (Kennedy, 1974; Hanf and Schiefer, 1983).

Hanf and Schiefer (1983) made some useful comments about the interdependency of decisions within a plan and the effects of time on the length of the planning horizon for a specific plan. They argued that it should be "*as long as there are interdependencies between decisions to be made now and the present and future consequences which follow from the implementation of these decisions*". This is a useful guideline provided there is a point in time where the interdependencies cease to exist, but as they pointed out, such points in time do not normally exist and interdependencies, although they diminish over time, tend, in principle, to continue, indefinitely. However, for practical purposes a "cut" has to be made at some point in time, which then becomes the planning horizon. Hanf and Schiefer (1983) and Reisch (1971) leave this decision to the judgement of the decision-maker.

Alternatively, the place the plan holds in the planning hierarchy can be used as the determinant of the planning horizon (Reisch, 1971; Wright, 1985). In essence, a strategic plan will be of much greater duration than that of a tactical plan in the same hierarchy (Reisch, 1971; Wright, 1985). However, the choice of planning horizon rests with the manager. Hanf and Schiefer (1983) discussed the trade-off a decision-maker must consider when selecting a planning horizon. A longer planning horizon provides the decision-maker with a greater appreciation of the consequences of their decisions, but increases uncertainty. The converse applies to a shorter planning horizon. Again however, this provides limited practical guidance about how to set a planning horizon for a specific plan.

A third alternative is to have a rolling planning horizon (Kennedy, 1974; Hanf and Schiefer, 1983). It has been argued that because uncertainty increases with time (Reisch, 1971; Wright, 1985), only the initial decision in a plan can be considered optimal, while later decisions must be considered preliminary (Kennedy, 1974). Plans therefore, must be revised regularly in response to changed conditions to ensure later decisions are optimised (Kennedy, 1974; Hanf and Schiefer, 1983). Once the initial decisions have been implemented, the planning procedure is repeated before implementation of the next set of decisions. The "*rolling time horizon*" means the horizon for each successive plan is of the same length. Hanf and Schiefer (1983, p. 19) referred to this process as "*rolling planning*".

2.3.2.2 Hierarchies of plans

The hierarchical nature of plans is covered only briefly in prominent farm management texts (Barnard and Nix, 1979; Boehlje and Eidman, 1984; Kay and Edwards, 1994). An exception to this is Dalton (1982, pp. 126-127) who viewed management in terms of a hierarchical structure and classified, with examples, management tasks as short-term tactical decisions, medium-term tactical/strategic decisions, and long-term strategic decisions. He believed that the type of information used at the various levels of management changes. The degree of quantification and specification of information declines as one moves from short-term tactical decisions through to long-term strategic decisions. This has important implications for the precision of both planning and subsequent control.

Reisch (1971) also viewed planning as a multi-level information and control system which produces and controls a system of sub-plans over various future time spans, the length of which depends on the level of the decision. He classified three levels of planning: high level, long run plans (10 year time frame), intermediate level plans (two year time frame) that convert high level plans into more practical plans, and lower level or production plans that cover a single production period. Businesses have multiple plans and these are interconnected by the constraints and/or objectives one plan imposes on another. The effectiveness of lower level plans influences the outcome of higher level plans. A taxonomy of plans has been developed to distinguish plans at different levels in the hierarchy according to the source of its objectives (Wright, 1985). To efficiently use resources to achieve a common set of objectives, lower and higher level plans should be consistent (Wright, 1985). Anthony (1965) discussed the different knowledge and skills required for planning at different levels in the hierarchy, but this area has not been developed in the farm management literature, although several authors (Wright, 1985; Dryden, 1997) have drawn on Anthony's (1965) work.

2.3.2.3 Objectives and the planning process

The traditional view that farm plans seek profit maximisation has been criticised by numerous authors (Nielson, 1961; Reisch, 1971; Gasson, 1973; Wright, 1985) on two grounds: first, farmers normally have multiple goals, and second, profit maximisation is often secondary to non-economic goals. Other goals can be incorporated into the planning process in the form of constraints or a utility function (Reisch, 1971). Reisch (1971) argued that these approaches are not satisfactory and that the aspiration levels and the relationships between farmers' goals should be defined both quantitatively and qualitatively. He also noted that goals may change over time and such changes should be incorporated into the planning process. In any planning exercise, attainable objectives should be set because failure to do so can create fundamental problems for control (Wright, 1985).

2.3.2.4 Planning process

The farm planning literature is dominated by budgeting, linear and other programming techniques (Wright, 1985) that are primarily focused on whole farm planning (Trebeck and Hardaker, 1972; Anderson *et al.*, 1977). Typically, three problems are addressed simultaneously: "*(1) which enterprises to adopt on the farm, (2) what method of production to employ in each enterprise, and (3) what amount of resources to allocate to each enterprise*" (Anderson *et al.*, 1977, p. 195). Wright (1985) was critical of this partial view of farm planning because it fails to incorporate such areas as firm farm growth, degree of short term production flexibility, financial plans, strategies to cope with variability in output or income, and employment plans. He also criticised farm management researchers for not adopting planning theory from the business management literature. Since then some of Wright's (1985) concerns have been addressed. For example, the broader perspective offered by the business management literature on strategic planning has now been incorporated into farm management (e.g. Renborg, 1988; Harling and Quail, 1990; Martin *et al.*, 1990; Rasmussen *et al.*, 1990; Attonaty and Soler, 1991; Harling, 1992; Parker *et al.*, 1997).

The whole farm planning literature is dominated by planning algorithms and as a result decisions on plan selection take a pivotal role in the conceptual framework (Wright, 1985). However, this is only one of the steps in the planning process (Wright, 1985). Other steps such as the decision to plan or the search for alternative plans may be more important. Other authors (Reisch, 1971; Nix, 1979; Malcolm, 1990) have been equally critical of the mathematical planning techniques used in farm management noting that their use in practical farming is limited. Reisch (1971) believed that the pre-decisions made before the mechanical process of computation are much more critical than the process of plan selection. Pre-decisions include the choice of objectives, the identification of constraints and coefficients, the forecasting of costs and prices and production levels, and the specification of other assumptions about the farming system to be modeled. Wright's (1985) thoughts echo Reisch (1971) who also advocated a shift in emphasis in the farm management from mathematical modeling to the process and structure of planning.

The farm management literature has also been criticised for its static approach to planning (Reisch, 1971; Mauldon, 1973; Hanf and Schiefer, 1983; Wright, 1985). It is often assumed that an optimal plan, once devised, will hold for the duration of the planning period. The inherent uncertainty of agricultural systems means it is doubtful an optimal plan can ever be specified (Mauldon, 1973). Several authors have emphasised the dynamic nature of the planning process and the need for control and revision of plans (Reisch, 1971, Mauldon, 1973; Kennedy, 1974; Hanf and Schiefer, 1983; Jolly, 1983; Boehlje and Eidman, 1984; Wright, 1985). Reisch (1971) described planning as a flowing process because as one moves from one planning period to the next, future events come closer, irrelevant events become relevant, uncertain information or forecasts become more certain, the planning horizon is extended and the planning process is repeated with new and more accurate information. Blackie (1971, p. 29) stated "*Planning is thus removed from its pedestal as a special and infrequent function of management and is regarded in its true role as a continuing series of short-run tactical decisions influencing long-run strategy.*" Blackie (1971) believed that the failure to consider planning as a routine management function had created a defective link between planning and control, and had ignored the need for feedback through control.

In open loop (Mauldon, 1973) or rolling/adaptive planning (Reisch, 1971; Hanf and Schiefer, 1983), all current and future decisions are specified. However, only the current decision is implemented. Results from this are then used to undertake another open loop planning exercise. Planning should shift emphasis to the development of procedures for transforming one provisional plan into another (Mauldon, 1973). Planning is then viewed as another means of control rather than as a technique for developing a predefined course of action (Mauldon, 1973) and learning then becomes an important aspect of the process as it can be used to enhance farmers' control (Mauldon, 1973).

In recent years, new methods of performance measurement (total quality management, the balanced scorecard and benchmarking) that link planning and control have been introduced to the farm management discipline from the business literature (Shadbolt, 1997; Ferris and Malcolm, 1999; Parker, 1999). Financial-based performance measurement systems have been criticised for being one-dimensional and not providing an holistic view of the business (McNair *et al.*, 1990; Zairi, 1994; Kaplan and Norton, 1996a). As such they ignore important measures such as quality, timeliness, skill enhancement, and useful knowledge work. These are primary sources of competitive advantage (Vollman, 1991).

The historical lack of congruence between strategy and performance measures has implications for both strategy implementation and evaluation (Glaser, 1991; Sieger, 1992; Zairi, 1994). In relation to implementation, the traditional measures are output-based indicators and are therefore of little use for carrying out corrective action in relation to tactical decisions (McNair *et al.*, 1990; Vollman, 1991; Zairi, 1994). Similarly, the traditional "static" performance measures do not encourage a strategy of continuous improvement (McNair *et al.*, 1990) and, because they are "generic" in nature, are of little use in communicating to employees what they need to excel at to remain competitive (Kaplan and Norton, 1996a). McNair *et al.* (1990) noted that conflict could occur between financial and physical performance measures and this encouraged the wrong behaviour. This point has previously been stressed by Chandler and Sargeant (1962, p.285) who highlighted the dangers of *"making management recommendations on the basis of technical information only"*. However, even when financial and physical performance measures are selected from a holistic view of the business, they may not agree under certain conditions.

Traditional performance measurement systems are not well suited to evaluating strategy in the modern business environment (Sieger, 1992; Zairi, 1994). Financial measures tend to be "lagging" or historical indicators that measure how well an organisation performed in the previous year (Kaplan and Norton, 1996a). This may be appropriate for a static business environment but in today's rapidly changing world, businesses need "leading" indicators to predict how an organisation will perform in the future (Glaser, 1991; Sieger, 1992; Kaplan and Norton, 1996).

The planning process is poorly described in the literature, (Reisch, 1971; Wright, 1985). The best representation is that provided by Boehlje and Eidman (1984) who specified eight major activities that comprise the planning process (Table 2.1). The first step is the determination and clarification of goals. Calkin and Di Pietre (1983) also viewed this step as part of the management process, while others (Buckett, 1988; Giles and Renborg, 1988; Olsson, 1988; Trip *et al.,* 1996) viewed it as a separate process. Goals play an important role in the planning process as they determine the choice between alternative plans and are used to derive standards for control purposes (Boehlje and Eidman, 1984).

Forecasting is an essential step in the process because planning involves predictions with respect to future events (Boehlje and Eidman, 1984). Because planning involves uncertainty, expectations and forecasts guide planning rather than facts (Reisch, 1971). Identification of the available resources as well as the restrictions imposed by the external environment allows the manager to specify the constraints within which the plan must be developed (Boehlje and Eidman, 1984).

Although budgets are widely recognised for their role in determining the allocation of resources (Barnard and Nix, 1979; Harsh, *et al.,* 1981; Calkin and Di Pietre, 1983; Osburn and Schneeberger, 1983; Makeham and Malcolm, 1993; Kay and Edwards, 1994), Boehlje and Eidman (1984) are one of the few references to specify the role of budgets, along with written policy and procedure statements in the planning process. In fact, they (1984, p. 16) refer to budgets as *"the fundamental planning tool used by farm managers"*. They suggest that policy and procedure statements are important in repetitive problem areas, such as might occur in relation to tactical management, because they avoid the need for repeated analysis. Written policies and procedures can also be used for implementation (Boehlje and Eidman, 1984), therefore forming the link between planning and implementation.

Table 2.1. Major activities of the planning function of management (Source: Boehlje and Eidman, 1984).

1. Determine and clarify goals and objectives.
2. Forecast prices and production.
3. Establish the conditions and constraints within which the firm will operate.
4. Develop an overall plan for the long run, intermediate run, and the current year.
5. Specify policies and procedures.
6. Establish standards of performance.
7. Anticipate future problems and develop contingency plans.
8. Modify plans in the light of control results.

Boehlje and Eidman's (1984) general planning model, and those of Barnard and Nix, (1979) and Kay and Edwards, (1994) imply plan generation and selection occur but do not outline these as specific steps in the planning process. In contrast, these are seen as important steps in the more specific whole farm planning process (Calkins and Di Pietre, 1983; Osburn and Schneeberger, 1983; Kay and Edwards, 1994).

The establishment of standards is critical for control and demonstrates the interdependence between planning and control. Most standards described in the literature refer to financial control rather than tactical production management (Barnard and Nix, 1979; Kay, 1981; Osburn and Schneeberger, 1983; Boehlje and Eidman, 1984; Buckett, 1988; Kay and Edwards, 1994). Further, standards tend to be for historical, rather than concurrent control. Budgets are recommended as sources of standards for control purposes (Mauldon, 1973; Osburn and Schneeberger, 1983) and the cashflow budget provides a mechanism for concurrent financial control (Mauldon, 1973; Boehlje and Eidman, 1984). Other sources of standards are goals (Boehlje and Eidman, 1984), historical records of the business' previous performance, and performance levels of farm businesses that operate under similar conditions (Osburn and Schneeberger, 1983). In relation to tactical production management, Boehlje and Eidman (1984) recommended the use of biological growth charts and lactation curves as sources of standards.

Recent papers (Hemidy, 1996; Shadbolt, 1997; Parker *et al.,* 1997; Parker, 1999) have stressed the need to link business strategy to performance measures. Central to the problem of implementing strategy is the choice of indicators (Hemidy, 1996). Logic and knowledge of cause and effect relationships is used to link strategy to performance indicators (Hemidy, 1996; Parker, 1999). Critical success factors are identified which will determine the success or failure of the strategy. These are then used to derive key performance indicators (both leading and lagging as described earlier) that enable the performance of the business to be determined in a timely and cost-effective manner (Shadbolt, 1997).

Developing contingency plans is important because forecasts may prove to be erroneous (Boehlje and Eidman, 1984). Contingencies allow managers to change plans if conditions change or if control results (Barnard and Nix 1979; Boehlje and Eidman, 1984) indicate the need for a plan change.

Some guidance is given in the literature about the derivation of standards and "in-control" levels. Osburn and Schneeberger (1983) specified three sources of standards: historical records of the business' previous performance, performance levels of farm businesses that operate under similar conditions, and realistic budgets and projections for the farm business. Goals are an alternative source of standards (Boehlje and Eidman, 1984). In relation to production systems, since these are based on biological processes, the control standards should be stated as a rate per unit of time or a quantity over time (Boehlje and Eidman, 1984).

Wright (1985), despite his criticism of existing planning models, made only one important addition, situation assessment of the external environment, to create a six step model which is less detailed than that of Boehlje and Eidman (1984). Information from the situation assessment is used to decide whether or not it is worthwhile to undertake a new planning exercise. Barnard and Nix (1973) incorporated this aspect into the control process. Interestingly, Wright (1985), unlike other authors, included implementation within the planning process rather than as a separate function of management because he considered it as the final step in planning.

2.3.2.5 Effort in the planning process

The amount of effort a manager should apply to the planning process is probably related to the net benefit perceived to be associated with it (Wright, 1985). If the net benefits are thought to be low, the manager will probably be indifferent to alternative plans (Wright, 1985). In uncertain environments, managers will adopt strategies that minimise commitment and maximise their ability to adapt to changing conditions. In other words, in these circumstances, control may be relatively more important than planning, a view supported by Reisch (1971, p. 205), who argued that the greater the level of uncertainty in the environment, the less chance an optimum plan has of being realised once implemented.

The ideas of Simon (1960), Gorry and Morton (1971), and Koontz and Weihrich (1988) suggest that effort is also a function of the plan's location within the planning hierarchy and the “structuredness” of the decision. Thus, strategic planning could be expected to require considerably more effort than operational planning because of the importance, uniqueness and complexity of the problem and associated lack of management experience. In contrast, at the tactical and operational planning level, managers are likely to have developed a range of predefined planning procedures by dealing repetitively with similar problem situations.

2.3.2.6 Planning aids

A distinction between the planning process and "*planning aids*" was made by Wright (1985). The planning process can be considered the cognitive process the manager undertakes when developing a plan. In contrast, Wright (1985, p. 76) defined planning aids as "*external technologies related to any of*" the steps within the planning process. This definition encompasses planning techniques such as budgeting and mathematical programming, simulation models and decision support systems, management information systems and the various devices used to monitor farm performance (Wright, 1985;

Attonaty and Soler, 1991). Planning aids are useful provided they enhance a manager's planning process and resultant plans (Attonaty and Soler, 1991). As with other types of models, the effectiveness of a planning aid depends on how isomorphic it is with reality (Petit, 1977). Kelly and Malcolm (1999) were also critical of planning aids, in this case technical models, which had built-in economic and financial analytical methods. Their criticism was that the model then determined the analytical method rather than the problem confronting the manager. Instead, they recommended that farm management analysis remain outside the operation of the technical model.

Planning aids can enhance farmer learning (Petit, 1977; Wright, 1985; Attonaty and Soler, 1991; Cox, 1996). However, such learning will only be effective if the planner understands the model and this may be a problem with particularly complex models (Cox, 1996). A model built by an outside agency may not reflect the farmer's reality or understanding (Wright, 1985; Attonaty and Soler, 1991). Researchers often believe that more advanced planning aids lead to better management and therefore better financial performance (Kaine, 1993; Cox, 1996). This belief may be misplaced (Kaine, 1993; Cox, 1996). Planning aids have the potential to induce decision makers to make organisationally irrational plans (Wright, 1985) such as:

1. the aid uses an invalid model of the organisation or environment,
2. the aid is incorrectly assumed to be using data in ways consistent with decision maker objectives,
3. the information from the aid is misunderstood by the decision maker, and
4. the aid fails to have all available relevant data provided to it.

Wright (1983) recommended that planning aids should be evaluated in relation to the above four areas before they are used by decision makers.

2.4 Control

Few farm management publications focus specifically on control. One exception, Kennedy (1974) stated that given the complex, dynamic and uncertain nature of the planning environment in farming, one could question first, whether it is possible to develop an "*optimal*" plan, and second, in the event that one could, the duration over which such a plan would remain "*optimal*". Drawing on cybernetics, Kennedy (1974) proposed a framework in which an optimal plan is developed, implemented, monitored and if the actual outcome deviates from predicted outcome, can be recast. This framework, is consistent with Hanf and Schiefer (1983) who believed that due to uncertainty, planning is only relevant to the initial decisions specified in the plan.

Boehlje and Eidman (1984, p. 684 – 685) also discussed control in relation to production management. They proposed that a farmer use six steps to develop a control system for their production system:

1. Delineate the production system and break this into subsystems that are meaningful for the identification of the important inputs and outputs to monitor.
2. List the inputs and outputs to monitor for each subsystem in their approximate order of importance.
3. Specify the monitoring time interval for each selected input or output.
4. Identify the appropriate means of monitoring each input and output selected.
5. Specify the standard and the "in-control" range for each variable being monitored.
6. Establish rules for action to apply when the observed variable is outside the "in-control" range.

They then illustrated the application of these six steps to two production systems (livestock and crop). They also stressed that to develop effective control systems managers must have a thorough understanding of the production system. On a similar note, Makeham and Malcolm (1993, p. 23) stated that "*skill at managing the fluctuations about the normal pasture supply is one of the main requirements for the successful running of pasture-based animal production enterprises*". Therefore, they emphasized the importance when analysing such systems, of identifying the measures the farm manager adopts for coping with variability of feed supply. They believed the general aim of such measures is to minimise the impact of adverse situations and exploit favourable circumstances.

In general, most definitions of control, explicit or implicit, are encompassed by that provided by Dalton (1982, p. 87) who described the purpose of control as to "*confine systems performance within preferred limits*". Wright (1985, p. 16) believed that this view was too narrow and proposed a broader definition of control as "*the continuous identification of appropriate combinations of organisational activity based on observed or forecasted relations between an organisation and its environment.*" This definition encompasses the original definition of control and also incorporates changes in plans.

The extent to which plans contribute to organisational performance will be a function of the control farmers can exert over performance (Wright, 1985; Kaine, 1993). Control also comes at a cost, and an important consideration for management is whether the cost of control outweighs the benefits (Dalton, 1982).

More recently, farm management researchers have discussed the role of control, and in particular the performance monitoring system, in relation to strategy (Hemidy, 1996; Shadbolt, 1997; Ferris and Malcolm, 1999; Parker, 1999). In particular, performance measures should link to the farm business goals (Shadbolt, 1997).

2.4.1 Types of control

Four types of control can be identified from the farm management literature (Mauldon, 1973; Dalton, 1982; Boehlje and Eidman, 1984):

1. Preliminary or compensatory control.
2. Concurrent control or equalisation of deviations.
3. Elimination of disturbances.
4. Feedback, historical or adaptive control.

Preliminary or compensatory control is used to prevent deviations from the plan before they occur (Dalton, 1982; Boehlje and Eidman, 1984). Unlike preliminary control, concurrent control (or equalisation of deviations) is used to make adjustments during the event (Dalton, 1982; Boehlje and Eidman, 1984). The process of *elimination of disturbances* requires the manager to eliminate the external disturbance by initiating control over aspects of the environment (Dalton, 1982). In contrast, historical or adaptive controls are designed to improve the next decision making cycle i.e. the control method is based on historical data as opposed to real time data (Mauldon, 1973; Dalton, 1982; Boehlje and Eidman, 1984). This method is reliant on learning (Mauldon, 1973) and may result in the derivation of a new plan, the incorporation of new methods of preliminary or concurrent control, or the development of an improved control system (Boehlje and Eidman, 1984).

An important aspect of control is the ability to differentiate between a short-term aberration due to environmental instability and a longer-term change (Wright, 1985). Failure to differentiate between these two could result in costly and inefficient resource use, or suboptimal system performance due to failure to take corrective action when required. Feedback is used to ensure a system achieves its objectives in an uncertain environment (Kennedy, 1974).

Each method of control requires a different form of systems analysis to be undertaken by the manager (Dalton, 1982). The choice of control method or combination of methods is based on the net benefits of each method and risk considerations (Boehlje and Eidman, 1984). Although four methods of control can be identified from the literature, only one general model of the control process is reported. This may be because preliminary control and elimination of disturbances can be incorporated into the planning process as opposed to the control process *per se*. Similarly, although the processes of concurrent and historical control differ in relation to the time frame over which important parameters are monitored, the general process is similar.

2.4.2 Levels of control

Although management is hierarchical in nature, there is little differentiation between the control process at the operational, tactical and strategic levels. Rather, control is classified by field (financial, marketing and production) (Boehlje and Eidman, 1984), or in terms of financial or physical control (Barnard and Nix, 1979). Financial control can be differentiated on the basis of level where the cashflow budget is used to monitor the financial performance of the business at a tactical level (Barnard and Nix, 1979; Boehlje and Eidman, 1984), and various financial indicators are used to monitor the financial performance of the business on an annual or longer-term basis (Barnard and Nix, 1979; Boehlje and Eidman, 1984; Boehlje, 1994). Information used at the tactical level is more specific and quantifiable than that used at the strategic level (Dalton, 1982). Buckett (1988) distinguished short-term information used for control at the tactical level, from end of year and longer-term information used for control at the strategic level. Boehlje and Eidman (1984) realised that control can occur at a meta-level and recommended that the control system should be evaluated in terms of accuracy and usefulness.

2.4.3 The control process

The control process in the farm management literature consists of three basic steps: the establishment of standards which normally occurs during planning; the monitoring of actual performance and comparison with standards; and the correction of deviations from the plan when necessary (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994; Parker, 1999). The last usually encompasses the decision of whether or not to depart from the current plan (Mauldon, 1973). Once data is monitored, it is assumed to be recorded. Normally, recording is viewed as a sub-step in the control process (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994), but some authors (e.g. Dalton, 1982) view this as a separate function of management. Once recorded, data is analysed or processed into information that can be used for making control decisions, hence only data useful for decision-making should be collected (Boehlje and Eidman, 1984).

Once a deviation from a plan is detected, a decision must be made as to its significance. Boehlje and Eidman (1984) recommended that managers specify an "in control" range for standards, that if exceeded, identifies the need for remedial action. A critical step in the control process is the evaluation of the reasons for the difference between actual and planned performance (Calkin and Di Pietre, 1983; Parker, 1999). Barnard and Nix (1979) identified four reasons why actual performance might deviate from the plan:

1. Plans are developed with imperfect knowledge, therefore some of the underlying assumptions within the plan may be incorrect.
2. Targets set in the plan may not be fully achievable.
3. Changes in the socio-economic environment (e.g. prices, technology) may occur which render the plan obsolete.
4. Changes in the biophysical environment (e.g. weather, pests and diseases) may occur which render the plan obsolete.

Mauldon (1973) and Barnard and Nix (1979) believed that it is important for farmers to determine if the deviation is due to factors within or beyond their control. Such information will determine the nature of the manager's response.

The "evaluation" aspect of control is a basis for learning (Parker, 1999) and it is surprising therefore that little has been written on this aspect of control. Mauldon (1973, p. 42) believed that the control process is essential for farmer learning and that control systems have "*an important educational role to play in raising the managerial skills of farm people*". In effect, the control system teaches farmers what they can control (Mauldon, 1973). Petit (1977) suggested that farmers' mental models are revised as they adapt to changes in the environment, but he provided no further insight into how the learning process occurs. The balanced scorecard developed by Kaplan and Norton (1992, 1993 1996abc) emphasised the need to identify important "cause and effect" relationships between business strategy and operational measures. Specification of these relationships allows the manager to evaluate the validity of the strategy on the basis of operational measures. Similarly, Shadbolt (1997) emphasised the role indicators play in assisting farmers understand farming systems. Such learning better allows farmers to more effectively control their systems.

Once a deviation from the plan is detected, it can be corrected in one of four ways: by modifying the plan, by adjusting the implementation, by developing a new plan, or by changing the farmer's goals (Boehlje and Eidman, 1984; Parker, 1999). Alternatively, the farmer may change the standards (Boehlje and Eidman, 1984). Barnard and Nix (1979) noted that in some situations where factors are beyond the manager's control, the manager may have to accept this as the case and continue to implement the current plan. If longer-term factors have brought about the deviation, farmers may need to change the plan, or in an extreme case, their goals, rather than introduce a contingency plan (Barnard and Nix, 1979; Boehlje and Eidman, 1984; Parker, 1999). In the following sections, the steps in the control process are discussed in more detail.

2.4.3.1 Monitoring

Drawing on the work of Blackie (1971), Parker (1999) classified monitoring techniques as formal and informal. A formal monitoring technique is one that is structured and formally recorded, as opposed to an informal monitoring technique which is a haphazard accumulation of knowledge over time that is normally stored in the manager's memory. Boehlje and Eidman (1984) believed that informal systems should be replaced by formal systems only where the benefits exceed the costs of the change, and therefore formal systems are only developed for areas that have an obvious benefit for the firm.

Several important questions must be answered if a manager is to design an effective monitoring system. These include what data to monitor, the frequency with which the data is monitored, the method of data collection, and the sources of error (Kennedy, 1974; Boehlje and Eidman, 1984; Parker, 1999). One means of determining what factors to monitor for the control of a farm business is to consider the various areas of control within the business. Boehlje and Eidman (1984) distinguished between enterprise or activity control[3] and financial control. They identified four types of enterprise or activity: production, service, marketing, and investment and development activities. Once identified, these can be decomposed into meaningful subsystems to determine which inputs and outputs should be monitored (Kennedy, 1974; Boehlje and Eidman, 1984). Alternatively, and as outlined earlier, the goals or the business strategy can be used to determine what factors to measure (Boehlje and Eidman, 1984; Hemidy, 1996; Shadbolt, 1997; Parker, 1999).

Osburn and Schneeberger (1983) discussed the dangers of misinterpreting measures of performance and relying on one measure of performance. Performance can be influenced by a range of factors that are often inter-related, e.g. farmers may substitute labour for capital or *vice versa*. Therefore, a farmer should view a mix of performance indicators before deciding on corrective action. It follows that the use of the "*wrong*" performance measures in decision making can have a "*catastrophic*" impact on the farm business (Shadbolt, 1997). The balanced scorecard (Kaplan and Norton, 1992, 1996abc), as indicated by its name, provides a balanced view of the business by using a combination of measures, long- and short-term, leading and lagging, financial and non-financial. Therefore, no one single measure is used to assess the performance of the business, and factors other than financial results are taken into account. This provides a more holistic view of the business and reduces the danger of relying on one type of measure to assess business performance.

The frequency of monitoring is influenced by a number of factors. Data are not only monitored on the output from a process, but also on the progress towards such output through time (Blackie, 1971). Leading and lagging indicators provide concurrent and historical control respectively (Parker, 1999). Buckett (1988) argued that the "*interval of control*", that is, the time between measurements, should be determined by the usefulness of such information in the control process. The delay or lag between recording and receiving information for decision making must also be taken into account when considering the monitoring interval. Generally, the older the information, the lower its value to management for decision making (Beetley and Gifford, 1988; Lokhorst *et al.*, 1996)

The optimum monitoring frequencies for various types of information are an important issue for management. Mauldon (1973) believed that monthly monitoring is optimal in relation to the use of a cashflow budget for financial control but did not indicate how to

[3] Major profit or cost centres within the business.

assess the optimal monitoring frequency for other data. Boehlje and Eidman (1984) stated that the monitoring interval should allow time for effective intervention if required. Kennedy (1974) argued that the frequency of monitoring affects the stability and accuracy of the system over time and monitoring has a cost associated with it. The more unstable a system, the greater the need for intervention and hence the greater the cost (Kennedy, 1974). A number of factors influence the accuracy of a control system (Kennedy, 1974). Accuracy increases as the monitoring interval declines because the system is able to respond more quickly to changes in the environment (Kennedy, 1974) but there is a trade-off against the increased cost of monitoring and a relative increase in measurement error (Kennedy, 1974). Accuracy improves with time as more data is collected from which to devise probabilities of estimates (Kennedy, 1974). The ultimate test is whether the benefits of more frequent monitoring outweigh the associated costs (Boehlje and Eidman, 1984). Benefits are not just associated with the control of the system but also with the learning that can accrue from the process, a factor that is difficult to evaluate (Johnson, 1954).

Three sources of error in a monitoring system were identified by Parker (1999): environmental change, sensor or instrument error, and imprecision in plan implementation. Improving instrument error cannot overcome the other two. For example, Barioni *et al.* (1997) demonstrated that farmers gained no economic advantage by improving the accuracy of pasture mass measurement to a coefficient of variation of less than twenty percent. Since pasture measuring devices already exceed this level of accuracy, future research should focus on reducing data collection time and improving data interpretation rather than on improving instrument accuracy. Barioni *et al.* (1997) did point out that if farmers fail to measure pastures accurately for control purposes, significant costs may be incurred.

Once the monitoring interval is determined, the method of measurement is specified (Boehlje and Eidman, 1984). Parker (1999) distinguished between objective data collection where some form of instrument is used to measure the data, and subjective data collection that is collected through the senses of the individual. He noted that objective measures tend to be univariate whereas subjective measures were normally a composite of several factors. Objective measures have an advantage in that they are repeatable (Boehlje and Eidman, 1984), provide clarity of communication, and can be calibrated against standards (Parker, 1999). However, there is a trade-off against instrument failure and greater direct costs, especially time when compared to subjective monitoring systems (Boehlje and Eidman, 1984; Parker, 1999). This might explain farmers' preference for more subjective visual measures (Paine, 1997). Factors such as social values and personal satisfaction are best expressed and monitored in qualitative terms.

The normative literature emphasises the role monitored information plays in problem recognition during the control phase (Barnard and Nix, 1973; Boehlje and Eidman, 1984; Kay, 1981; Kay and Edwards, 1994; Parker, 1999). Other roles have been identified for information, primarily in the decision-making literature. For example, several authors identified information gathering as an important step preceding option generation, analysis and selection (Bradford and Johnson, 1953; Johnson and Haver, 1953; Johnson, 1954; Lee and Chastain, 1960; Johnson *et al.,* 1961; Nielson, 1961; Suter, 1963). Similarly, Harsh *et al.* (1981) discussed the role of information in making predictions to identify problems in advance. Although evaluation is recognised as an important function in the management process, the role of information in this process is implicit in the normative literature (Barnard and Nix, 1973; Mauldon, 1973; Boehlje and Eidman, 1984; Parker, 1999). However, Harsh *et al.* (1981) discussed the role of diagnostic information in identifying the cause of a problem and identifying opportunities for improvement in farm performance.

2.4.3.2 Recording, data processing and analysis

Data and information are not the same (Boehlje and Eidman, 1984). Data is defined as the raw input collected by the management information system, whereas information is data that has been processed in some way for use in decision making. Thus, once the type, frequency and method of data collection have been determined, a decision must be made as to how the data will be recorded (or stored) and how it will be processed. Storage systems may be formal (written or computer-based) or informal (memory of manager) (Boehlje and Eidman, 1984; Parker, 1999). Data may also need to be stored until required for decision making at a later date (Boehlje and Eidman, 1984). Although recording is a recognised component of the control process, Hardaker and Anderson (1981) believed that much of production management control can be undertaken without the need for formal recording systems.

For control purposes, Boehlje and Eidman (1984) suggest means and ratios (plus and minus) be calculated. Barnard and Nix (1979) also included the calculation of gross margins. Most farm management texts (Barnard and Nix, 1979; Kay, 1981; Dalton, 1982; Boehlje and Eidman, 1984; Kay and Edwards, 1994) include a section on recording or farm records which specify the range of relevant data that can be collected both on and off-farm and methods for recording such data. These texts also list and describe ratios that can be calculated for control purposes.

2.4.3.3 Comparison to standards and decision point recognition

Standards and the "in-control" range for each control variable must be specified and then compared to actual performance levels (Boehlje and Eidman, 1984). The choice of the "in-control" range can have serious implications for systems performance but its specification is dependent on the judgement of the manager (Boehlje and Eidman, 1984). Little guidance is given about the derivation of in-control levels in the literature. The derivation of standards has been previously discussed in Section 2.3.2.4 under planning. If a significant deviation from the plan is identified, then the reason for the deviation should be evaluated and a control response selected and implemented (Barnard and Nix, 1979; Boehlje and Eidman, 1984).

When actual performance is compared to standards, the manager must decide between continuing to implement the current plan or implementing a control response. Mauldon (1973) recognised this decision point but other authors (Barnard and Nix, 1979; Boehlje and Eidman, 1984; Kay and Edwards, 1994) have focused on problem recognition (deviation from the plan) and the selection of a suitable control response. Although a distinction is made between problem and opportunity recognition in the decision making literature (Lee and Chastain, 1960; Nielson, 1961; Suter, 1963; Boehlje and Eidman, 1984), this distinction is not made in relation to the management process and there is no discussion about the difference between these two processes. More recently Renborg, (1988), Martin *et al.* (1990) and Parker *et al.* (1997) have highlighted the importance of identifying threats and opportunities to the farm business from the external environment, but this is from a strategic planning, rather than a tactical control focus.

2.4.3.4 Evaluation and control response selection

The final step in the design of a control process is the specification of decision rules about what corrective action to take when actual performance is outside the "in-control" range (Boehlje and Eidman, 1984). The size of the deviation between actual and planned performance as well as the circumstances that have changed since the plan's inception should be taken into account before deciding upon a control response (Mauldon, 1973). Barnard and Nix (1979) identified four reasons why actual performance might deviate from the plan (see Section 2.4.3).

Several authors (Mauldon, 1973; Bamard and Nix, 1979; Boehlje and Eidman, 1984) stress that the reasons for a deviation (between actual and planned performance) should be determined. However, few authors (Calkin and Di Pietre, 1983; Parker, 1999) refer to this process explicitly as evaluation. This is interesting given most models of decision making (Nielson, 1961; Hardaker *et al.*, 1970; Harsh *et al.*, 1981; Osbum and Schneeberger, 1983; Castle *et al.*, 1987; Makeham and Malcolm, 1993; Kay and Edwards, 1994) include an evaluation step. Calkin and Di Pietre (1983), and later Boehlje and Eidman (1984), indicated that the evaluation process should include the revision of the steps in the management process and whether they accomplished what the manager planned.

In the normative decision making literature, evaluation is seen as an important step in leaming from experience and improving decision making (Nielson, 1961; Hardaker *et al.*, 1970; Harsh *et al.*, 1981; Boehlje and Eidman, 1984; Castle *et al.*, 1987; Makeham and Malcolm, 1993; Kay and Edwards, 1994). Similarly, Nielson (1961) hypothesised that better managers would evaluate both the outcome of their decisions and their decision making processes. He believed that such managers would develop mental feedback systems to ensure the improvement of their managerial processes. Similarly, Makeham and Malcolm (1993 p. 18) include the step of "*doing it better next time, i.e. learning from one's mistakes*" in their model (of decision making). Osbum and Schneeberger (1983) developed a set of questions to help a manager evaluate their decision making (Table 2.2). These questions are similar to the control process, but the focus of this evaluation "process" is on the identification of factors not incorporated into a farmer's model of the situation rather than the evaluation of the decision making process *per se*.

Table 2.2. Questions to ask when evaluating a decision (Source: Osburn and Schneeberger, 1983, p. 14).

Evaluation questions
1. What were my expectations when I made the decision?
2. Did the outcome approximate or approach my expectations?
3. Were my expectations consistent with the reality of the situation?
4. If not, what factors might explain the difference between what I predicted and what actually happened?
5. Did I include those factors in my analysis?
6. Are they sufficiently important that I include them the next time I come to a similar decision?
7. Am I satisfied, or is a new activity called for?

Osburn and Schneeberger (1983, p.183) used a decision tree approach to decompose farm performance into its sub-components to identify the reasons for low farm profitability but they referred to this process as “trouble shooting" or "problem solving”, not evaluation. Dalton (1982) used the same process to identify the factors that influenced return on capital, but in relation to planning, not control. Alternatively, the decision tree approach has also been used to diagnose the cause of poor farm performance (Barnard and Nix, 1979; Kay, 1981; Osburn and Schneeberger, 1983; Buckett, 1988; Kay and Edwards, 1994), an aspect of control normally termed farm business analysis. Evaluation is against a range of standards such as those described by Boehlje (1994). He stressed the importance of not just calculating the financial ratios but interpreting what they mean to the business. Therefore, although there are processes available for evaluation, little has been written on how to (i) diagnose the reasons for a deviation between planned and actual performance, or (ii) evaluate the management process used to determine such performance. The focus on historical financial control is interesting, given Hardaker and Anderson’s (1981, p.200) view that “*...it is in the physical rather than the financial aspects of production where most scope for control exists*”.

A deviation from the plan can be corrected in one of five ways: by modifying the plan, by adjusting the implementation, by developing a new plan, by changing the (farmer's) goals (Boehlje and Eidman, 1984; Parker, 1999), or by changing standards (Boehlje and Eidman, 1984). The choice of corrective measure will depend on the situation and the cause of the deviation (Boehlje and Eidman, 1984). For example, the standards chosen by the manager may be inappropriate. Identification of whether the deviation is due to factors within, or beyond, a manager’s control will also determine the nature of the response (Mauldon, 1973; Barnard and Nix, 1979). Barnard and Nix (1979) advocate that where the cause (of the deviation) is within the control of the farmer, a suitable contingency plan be implemented. However, where it is due to a short-term seasonal factor that is outside the farmer’s control, then s/he may have to accept this as the case and continue to implement the current plan. If longer-term factors such as prices have brought about the deviation, farmers may need to change the plan or in an extreme case, the goals, rather than introduce a contingency plan (Barnard and Nix, 1979; Boehlje and Eidman, 1984; Parker, 1999). Boehlje and Eidman (1984) also specify that decision rules can be used to select appropriate control responses, but did not enlarge on how to do this.

2.4.3.5 Learning

Cameron (1993) believed that farm management practitioners require an education that develops their cognitive ability so that they can continually improve their acquired "tools" and apply them to creatively solve problems and exploit opportunities. Mauldon (1973, p. 42), and earlier Johnson (1954), believed that the control process was essential for farmer learning and that learning would then enhance control i.e. control systems have "*an important educational role to play in raising the managerial skills of farm people*". Similarly, Burnside and Chamala (1994) proposed that managers use the management process for learning and that this process is synonymous with the experiential learning process of planning, acting, observing and reflecting (Kolb, 1974, 1984; Wilson and Morren, 1990). The balanced scorecard developed by Kaplan and Norton (1992) emphasises the importance of learning as a driver and lead indicator of strategy implementation. Likewise, Shadbolt (1997) highlighted the role indicators play in assisting a farmer to understand how their farming system functions.

Farmers' mental models are revised as they adapt to changes in the environment (Petit, 1977). When new knowledge is produced, by correcting old mistakes, model validation occurs (i.e. learning), and this has greater value to management than the "valid" model. Petit (1977) argued that a decision-maker should assess three criteria (logical consistency, consistency with experience and workability) to determine a model's validity. He stated that for a model to be valid it had to produce results consistent with the decision-maker's previous knowledge upon which the model was based. Importantly, Petit (1977) stressed that knowledge must be viewed more as a process rather than a state because models are unlikely to be valid "*once and for all*". Therefore, invalidation and rejection of hypotheses lead to the correction of a decision-maker's errors, an essential step in the learning process.

2.4.4 Limits to control or the law of requisite variety

For planning to be a rational activity, an individual or organisation must have an objective and the means to influence outcomes (Kaine, 1993). Therefore, the type of planning that is undertaken and the nature of the objectives are dependent on the farmer's ability to control outcomes. As such, identification of the limits of control is critical to effective management (Kaine, 1993). Similarly, the concept of system's stability[4] is important when considering control (Dalton, 1982) as is Ashby's (1961) law of requisite variety (Kennedy, 1974; Dalton, 1982; Wright, 1985) which states that the variety within the environment consists of all the factors that can potentially *disturb* the system's outcome. The degree of control over outcomes depends on the extent to which an organisation can respond to the variety in its environment. Where an organisation cannot match the variety in the environment, control over the achievement of outcomes will be limited. Management must cope with variety (in the environment) by either reducing it or developing management procedures that have equal and opposite variety (Dalton, 1982). Control over outcomes is therefore a function of (i) the farmer's capacity to create sufficient system variety to offset the variety in the environment, a function of his or her knowledge, and (ii) the variety inherent in the environment in which he or she operates (Wright, 1985). If a manager's repertoire of management responses has insufficient variety, then system's performance will be variable (Wright, 1985). In such cases, managers are likely to accept that variability in performance is inevitable so objectives become broad and imprecise (Wright, 1985; Kaine, 1993). In an uncertain environment, objectives that are precise or involve profit maximisation would be viewed as somewhat irrational as they are unlikely to be attained except by chance (Kaine, 1993).

In New Zealand, dairy farmers face considerable variety in the environment at the tactical level as a result of a climate-driven feed source (pasture), and must (according to Ashby's (1961) law of requisite variety) set imprecise production objectives and/or develop system variety to offset the variety in the environment.

The degree to which systems variety is developed for the purpose of control before the marginal cost of this variety outweighs the benefits is an important question for management (Kennedy, 1974). The other important implication is that the greater the need for systems variety, the more complex and costly the control system required to manage such variety. Kennedy (1974) believed that feedback control systems should be used in situations where: the cost of error in forecasts and estimates is high, and frequent monitoring of forecasts and estimates as well as intervention to take corrective action are possible and relatively cheap. Knowledge and learning are obviously important factors in determining the effectiveness of a good control system which requires a detailed understanding of the system and its environment (Kennedy, 1974; Wright, 1985).

[4] Defined as the association between the desired system output and actual performance.

2.5 The environment and control

The degree of control a farmer has over farm business performance is a function of the inherent uncertainty in the environment and the variety within his or her system (Ashby, 1961). Any study of the management practices of farmers requires some appreciation of the environment in which those farmers operate, which using systems theory, can be classified as those factors outside a farmer's control that impact on farm performance (Dalton, 1982). As such, the environment is subjective and dependent on a farmer's perception of what s/he can and cannot control (Petit, 1977). Only a small proportion of the universe (the environment) is relevant to a farmer at any one point in time (Petit, 1977). This also changes through time in response to learning, changes in the universe, and the farmer's goals and perceptions of the objective environment (Petit, 1977). The systems perspective on the environment is therefore knowledge-based.

Wright (1985) renamed the environment "*operating environment*" and then suggested that a sub-set of this is the "*planning environment*", which a farmer considers when developing a plan. He argued that the most critical element of the planning environment is variability and that where elements in the environment are important determinants of an organisation's performance, planners must include options within their plans to minimise the impact of such variability. The degree to which planners need to do this depends on the predictability of these variable elements within the environment. Wright (1985) therefore believed that any taxonomy for classifying the operating environment should provide information on its predictability. He (1985, p. 30) advocated the taxonomy developed by Emery and Trist (1965; Emery *et al.*, 1977) for the environments encountered by business organisations. They classified the organisational environment on the basis of their inherent stability, predictability and the existence or non-existence of competitive systems. This was used for selecting strategy. They did not comment on its application to tactical management.

An alternative approach to classifying the environment comes from the risk management literature in farm management. This classification schema evolved from the initial work of Johnson and Haver (1953) and Johnson (1954) and Johnson and Lard (1961). They realised that managers have to plan in an environment of imperfect knowledge and that an important aspect of planning is forecasting future expectations. Managers need to make forecasts for decision making in relation to price and market conditions for inputs and outputs, production responses, new techniques, actions and attitudes of people, and conditions of the institutional environment (political, economic and social). These five areas represent the major sources of business risk later described by Sonka and Patrick (1984). They combine with financial risk to describe the total risk faced by a farm business (Sonka and Patrick, 1984; Barry *et al.*, 1995).

While risk can be formally classified, it does not account for the decision-maker's perceptions of uncertainty relative to the actual levels in the environment. Wolpert (1964) noted that a farmer's perceptions of the variability of the environment is a function of its inherent instability (objective environment) and the farmer's knowledge. The greater a farmer's knowledge of the farming system and its environment, the less variability s/he perceives in the environment. Therefore, farmers who through their knowledge of both their system and the environment have developed strategies or tactics to minimise such risks, will probably perceive the risk source as less important than a counterpart with a lesser level of knowledge.

In more recent years, Wilson *et al.* (1993) advocated the adoption of a theoretical model developed by Van Raaij (1981) to explain decision-making behaviour in relation to the adoption of risk management activities. This model states that the risk perceptions of a farmer are a function of the objective environment and socio-economic variables that relate to the individual and his or her farm business. For example, a farmer with high debt levels may perceive financial risk differently from a farmer with minimal debt. The interaction between the objective environment, a farmer's perception of the environment, their personal and farm attributes, and their knowledge make it difficult to develop a useful taxonomy for classifying the environment. An alternative may be to combine the ideas from Wright (1985), the sources of risk literature, and the work of Van Raaij (1981) to develop a system that describes the context in which a farmer operates. Although the development of such a system is beyond the scope of this study, defining the environment is important for describing the context in which decisions are made.

Generally, the level of uncertainty in the environment increases as the planning horizon is extended (Wright, 1985). As such, tactical management can therefore be expected to address a lower level of risk and primarily relate to climate and market spot prices. Farmers have mechanisms such as forward contracts and joining a cooperative to manage price risk. Nevertheless, defining uncertainty at the tactical level would help in understanding why particular management decisions are made. Emery and Trist's (1965; Emery *et al.,* 1977) classification schema does have something to offer in this context because one of their environmental characteristics was the level of competition between systems. Farmers faced with a high level of inter-farm competition could be expected to adopt different risk management strategies and/or tactics than those who face minimal competition, such as in a dairy cooperative in New Zealand.

2.6 Summary and conclusions

The normative literature suggests management comprises three inter-dependent functions: planning, implementation and control, but planning has been the focus to the detriment of control. Values and goals drive the management process but there is debate within the literature as to whether they are part of, or separate to, the management process. Management can be viewed within a hierarchy ranging from long-term or strategic decisions to medium-term or tactical decisions through to day to day or operational decisions. Theory on strategic management has only been developed in farm management since the late 1980's and there is a paucity of normative theory on tactical management. Strategic goals and associated decisions tend to define and constrain tactical goals and decisions. The literature provides a reasonably detailed general model of how managers should plan. Less well developed is how best to determine specific components of the plan such as the planning horizon, targets, contingency plans and associated decision rules. Similarly, several authors have been critical of the discipline's focus on plan selection through mathematical modeling rather than the process and structure of planning.

Control is essential for coping with uncertainty in the environment. The literature provides alternate means of classifying the environment, providing a context for understanding the management decisions made by farmers. Four types of control are identified in the literature: preliminary, concurrent, elimination of disturbances, and historical control. However, only one general control process is described in the literature. It can be separated into the sub-processes of monitoring, recording including data processing and analysis, decision point recognition, evaluation and control response selection. The literature provides limited guidance on determining what, how and how often to monitor specific factors. Similarly, little is written about evaluation and control response selection. A critical outcome from the evaluation process is learning, but again little is written about this area in the normative literature.

In conclusion, the normative literature provides a useful framework for thinking about the tactical management processes used by expert dairy farmers. However, because of the literature's focus on planning and limited reference to tactical management, the applicability of this material to this study is open to conjecture. An important contrast to the normative literature is the descriptive literature. Descriptive (or behavioural) studies seek to understand how people actually make decisions. Such studies are "*concerned with what is, not what ought to be*" (Ilbery, 1978, p. 451). The following chapter reviews the descriptive literature on management and focuses on the tactical level where possible.

CHAPTER 3 DESCRIPTIVE STUDIES

3.1 The requirements for a more balanced research focus

Normative research on the management and decision-making processes has dominated the farm management literature over the last forty years (Jacobsen, 1993; Ohlmer, 1998; Ohlmer *et al.*, 1998; Rougoor *et al.*, 1998). During this time, numerous authors have argued that greater emphasis should be placed on descriptive research and that until this occurs, and the gap between theory and practice closed, farmers will continue to view much of the farm management research as irrelevant (Ohlmer, 1998; Rougoor *et al.*, 1998; Nuthall, 1999). For example, Nielson (1961) was concerned that much of the theory in farm management was based on agricultural economics, and that this had resulted in a largely normative research approach, that is, the focus was on what managers *ought to do* given a specific predefined objective, rather than what they *actually do*. Despite this, and other similar criticisms (Williams, 1957; Johnson, 1957, 1963; Eisgruber and Nielson, 1963; Burns, 1973; Jackson, 1975; Musgrave, 1976; Jensen, 1977; Nix, 1979; Cary, 1980; Andison, 1989; Harling and Quail, 1990; Malcolm, 1990) made throughout the history of the discipline, little is yet known about the processes used by farmers to make management decisions (Jacobsen, 1993; Ohlmer, 1998; Rougoor *et al.*, 1998; Nuthall, 1999). Although the early descriptive work of Johnson *et al.* (1961) challenged some of the normative views of management at the time, the impact of this study on United States agriculture was not great. In fact, farm management research in the United States has remained predominantly normative in nature (Jacobsen, 1993). European researchers, in contrast, initiated descriptive studies in farm management in the late 1970's (Jacobsen, 1993) and this area has since developed through the 1990's (Attonaty and Soler, 1991; Ohlmer *et al.*, 1996, 1997, 1998).

The findings from descriptive research, both within and outside farm management, have challenged many of the underlying assumptions found in the normative literature. Gladwin (1989, p. 33) criticised the normative models of decision-making because they were not tested against empirical data to see how well they predicted the choices of individuals or groups. Single-objective decision models such as profit maximisation and the expected utility model have been used to predict behaviour successfully at the macro-level (Van Kooten *et al.*, 1986; McGregor *et al.*, 1995, 1996). However, their predictive capability at the micro-level has been less satisfactory (Van Kooten *et al.*, 1986; McGregor *et al.*, 1995, 1996). Van Kooten *et al.* (1986) believed this could be explained because farmers have multiple goals and the expected utility model is an invalid representation of real world decision-making.

Empirical research has shown that farmers have multiple goals rather than a single objective of profit maximisation (Hobbs and Warrack, 1968; Harman *et al.,* 1972; Gasson, 1973; Patrick *et al.,* 1983; Van Kooten *et al.*, 1986; Mills, 1995; McGregor *et al.*, 1995, 1996). Early work by Simon (1957) suggested that decision-makers attempt to attain satisfactory levels of each objective rather than to optimise for a single objective. He termed this "satisficing" as opposed to "optimising" behaviour. The failure of the economic approach to explain farmer behaviour has seen a number of researchers move towards a descriptive approach (McGregor *et al.*, 1995).

Descriptive research in cognitive science during the 1970's found that decision makers did not select alternatives using criteria such as expected utility (Gladwin, 1989). The assumption that decision makers maximise utility is not empirically sensible because it requires computations that they do not ordinarily carry out (Plattner, 1974). Instead, due to their limited computational capabilities, decision makers tend to decompose decisions into simpler components (Gladwin, 1989). They do not weight variables and then calculate the values for various alternatives to determine which is best (Tversky, 1972; Gladwin, 1989). Rather, alternatives are compared one dimension at a time. Decision makers have been found not to use a quantitative approach, but instead, convert continuous variables into discrete constraints that must be satisfied, or orders or semi-orders of alternatives on aspects. An alternative is assumed to comprise a set of aspects (Tversky, 1972).

Cognitive research has also shown that the decision process is deterministic rather than probabilistic where an alternative either passes the criteria or constraint, or it does not (Quin, 1978; Gladwin, 1989). "*A decision tree is thus a sequence of discrete decision criteria, all of which have to be passed along a path to a particular outcome or choice*" (Gladwin, 1989, p. 34). As such, decision makers use heuristics in order to eliminate the need for recall, summarisation and computation (Quinn, 1978).

Attonaty and Soler (1991) stated that in contrast to the underlying assumptions of the normative approach to decision-making, under situations of uncertainty, farmers find it difficult to identify the alternatives open to them, let alone the consequences of such choices so that they can be ranked to allow the identification of the best solution. Instead, under situations of uncertainty, farmers tended to make unstructured sequential decisions based on partial and incomplete information.

Researchers have also criticised the focus of the normative literature on the "decision event" (Gasson, 1973; Johnson, 1987; Ohlmer *et al.*, 1998). Ohlmer *et al.* (1998), drawing on the work of Orasanu and Connolly (1993), believed that this focus, while an important part of decision-making, was somewhat narrow and required the following assumptions: decision makers clearly understand their goals and values, these are transparent and stable over time, and they are faced with a fixed set of alternatives for which the consequences, and risks, are known. Descriptive research has shown that decision-making is more complex than this and involves: assessment of the situation, context, and nature of the problem, sequential evaluation of each option rather than several options simultaneously, the use of mental simulation for evaluation of outcomes, and the selection of options that are 'satisfactory' as opposed to 'optimal' (Ohlmer *et al.*, 1998). Ohlmer *et al.* (1998, p. 274) stated that "*Dynamic real time decision-making is more accurately described as a matter of directing and maintaining the continuous flow of behaviour towards some set of goals rather than as a set of discrete episodes involving choice dilemmas*". They identified studies in other disciplines that have challenged the normative view of decision-making (e.g. Newell and Simon, 1972; Mintzberg *et al.*, 1976; Hogarth, 1981; Beach, 1993; Klein *et al.*, 1993).

Descriptive research has also shown that farmers do not use the prescriptive processes reported in the normative literature. For example, rather than undertake the detailed planning process as reported in the normative literature, farmers use predefined tactical plans that specify the sequence of actions that must be undertaken to achieve a goal (Gladwin *et al.*, 1984; Gladwin and Butler, 1984; Attonaty and Soler, 1991; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). These plans are similar in nature to the scripts defined by Schank and Abelson (1977). This approach appears to be used where planning is repetitive (for example, an annual cycle). Therefore, farmers routinize the planning process, reducing their mental processing requirement by making the process subconscious. When the actual outcome deviates from the plan, heuristics are used rather than detailed computations to analyse which contingency plan to implement for a particular situation (Gladwin *et al.*, 1984; Gladwin and Butler, 1984; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). Such results may explain why survey-based studies (Lockhart, 1988; Parker *et al.*, 1993; Nuthall, 1996; Nuthall and Bishop-Hurley, 1999) show limited farmer adoption of the formal planning techniques (e.g. cashflow, cash forecast and feed budgeting) advocated by researchers.

The relevance of the normative planning literature has also been questioned in relation to strategic management (Wright, 1985; Renborg, 1988; Attonaty and Soler, 1991; Kaine, 1993). Classical decision aids were designed for repetitive, ongoing, well-structured and reasonably certain decisions (Wright, 1985; Attonaty and Soler, 1991). They are not suited to poorly structured, and highly uncertain decisions. Uncertainty at the strategic level makes it difficult to project a future programme of action. It is therefore necessary to develop procedures that allow farmers to operate proactively in the face of such uncertainty (Attonaty and Soler, 1991). The aim then, is not so much to develop a plan, but rather a set of decision rules, information and learning processes that can be used to interact with an unpredictable and changing environment in real time. Emphasis then shifts away from planning towards the cognitive dimension of decision-making. Key requirements in such a management approach are: methods of anticipating changes in the external environment, decision-making rules that provide flexibility, learning rules that can be used to chart a course through events, and indicators that guide reactions in real time to largely unpredictable events (Attonaty and Soler, 1991). Levels of attention or vigilance of the environment become important, as do coordination and negotiation with outside firms, questions of choice, evaluation of the criteria for evaluation, representation, models of action, and interpretation of the environment.

Recent empirical work by Kaine (1993) supports the views of Wright (1985) and Attonaty and Soler (1991), that the low adoption of normative planning aids by farmers is rational in an uncertain environment. The applicability of Attonaty and Soler's (1991) view on strategic management to tactical management is open to conjecture. Wright (1985), for example, thought that the normative planning aids were more suited to tactical as opposed to strategic management because the level of uncertainty is less. However, recent research (Parker *et al.*, 1993; Nuthall, 1996; Nuthall and Bishop-Hurley, 1999) suggests that this is not the case as few farmers have adopted normative planning aids for tactical management.

In management, there is a need for both normative and descriptive research approaches. The normative approach allows researchers to think about how farmers should manage given particular objectives. However, this approach must be balanced with the findings from descriptive research. This section has identified several areas where normative models fail to incorporate important assumptions about farmers' decision-making processes and their environment. A consequence of an unbalanced research focus is that researchers continue to focus on normative models that have little relevance to practitioners. The following section reviews important descriptive research in relation to tactical management in farm management.

3.2 Descriptive studies in farm management

Despite the importance of the management process in farm management, few descriptive studies are reported in the anglophile[1] literature on this topic. Exceptions include Gladwin and Butler (1984), Gladwin *et al.* (1984), and Crawford *et al.* (1995ab). In recent years, most descriptive research of the management process has been undertaken in France (Landais and Deffontaines, 1989; Mathieu, 1989; Papy and Mousset, 1992; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). Interestingly, much of this has focused on decision-making (e.g., Gladwin, 1976, 1979ab, 1980, 1983, 1989; Fairweather, 1992; Fairweather and Campbell, 1996; Jacobsen, 1993, 1996; Jangu *et al.,* 1995; Ohlmer *et al.,* 1996, 1997, 1998; Dryden, 1997; Ohlmer, 1998) rather than the management, process. One might hypothesise that this has occurred because it is simpler and more cost effective to study a single decision as opposed to multiple decisions that occur over several months or years. Many decision-making studies do not extend to the entire process, but focus on particular aspects of it. For example, Ohlmer (1998) investigated only the "problem definition" element of the decision-making process and Gladwin (1976), and researchers who subsequently adopted her approach (Murray-Prior and Wright, 1994; Jangu *et al.*, 1995; Murray-Prior, 1998), limited their investigation to the analysis and decision-making steps. Alternatively, researchers investigate the factors that influence farmer decision-making and/or farm performance rather than the process itself (e.g., Bigras-Paulin *et al.,* 1985ab; Tarabla and Dodd, 1990; Cruise and Lyson, 1991; Wadsworth and Bravo-Ureta, 1992; Jose and Crumbly, 1993; Boland and Patrick, 1994; Crawford, *et al.*, 1995b; McGregor *et al.,* 1995, 1996; Sutherland, *et al.,* 1996; Austin *et al.,* 1998ab). Consequently, these studies provide little insight into the actual management processes used by farmers, the focus of this study.

3.2.1 Descriptive studies of the tactical management process

Descriptive research into the tactical management processes of farmers has largely originated from concern about the adoption, or more precisely, the non-adoption of technologies developed on research stations (e.g. Gladwin *et al.*, 1984; Papy, 1994). Gladwin (1976, 1979a, 1980, 1983, 1989) provided some insight into the management processes used by farmers during the 1970's and 1980's, but during the last decade, French agronomists and farm management researchers have provided new understanding of the tactical management processes used by farmers (e.g. Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998).

Third world farming systems research identified the need to understand the farming practices of farmers if they were to develop innovations that were useful (Gladwin *et al.*, 1984). In this respect, local or indigenous knowledge of farmers is now recognised as being critical in understanding why they adopt or do not adopt certain innovations (Portela, 1994). An ethnoscientific approach was advocated where the local or indigenous knowledge used by farmers was investigated in order to understand why certain practices were used. Ethnographers use taxonomies to show the structure of knowledge used by farmers (Gladwin *et al.*, 1984).

The French initiated in-depth longitudinal research studies into the management processes used by farmers as a result of the systems philosophy that has been adopted by their research agencies (Brossier *et al.*, 1993; Papy, 1994). Agronomists and economists in particular, believed that the existing development models were inappropriate because they failed to consider farmers' goals and their actual situation in relation to the development of innovations (Papy, 1994). Farmers have reasons for not adopting new technology, and these need to be understood if researchers are to develop useful innovations.

Experimentation has long been considered the sole scientific means for acquiring agronomic knowledge, and the only valid basis for technical innovation (Deffontaines, 1993). A turning point in agronomic research occurred when observation (of farmer practice) was given the same scientific status as experimentation and thus became a valid source of scientific knowledge (Deffontaines, 1993). Consequently, a model was proposed where experimentation provided the knowledge for the development of innovative farming techniques, which farmers then adopted and put into practice through action (Figure 3.1). Analysis of the practices of farmers provided further knowledge for the development of improved techniques. Deffontaines (1993, p. 22) observed that "*Recognition of the scientific value of on-site observation puts agronomy on the same footing as non-experimental science and is conducive to closer connections with ethnologists, or even anthropologists*".

[1] Sourced from English speaking countries such as the United States of America, United Kingdom, Canada, Australia and New Zealand.

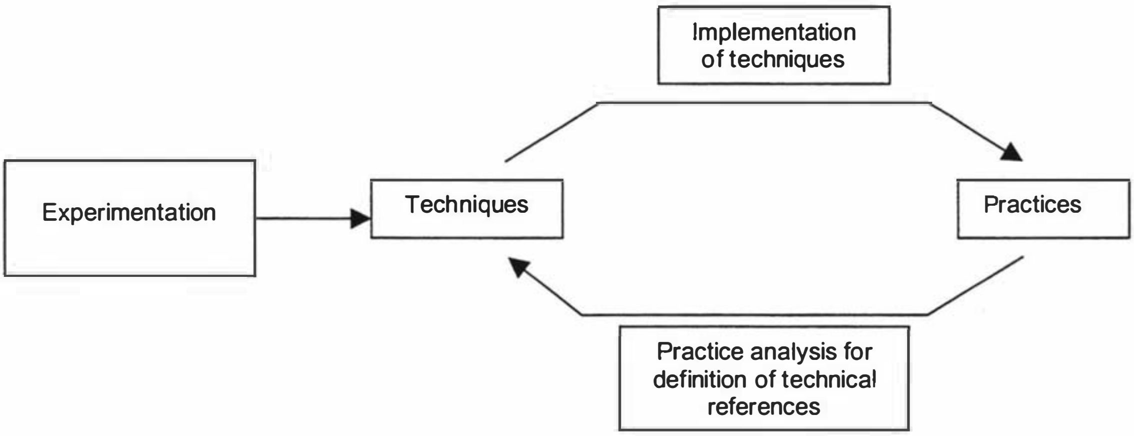

Figure 3.1. Connections between techniques and practice (Source: Deffontaines, 1993).

The French researchers distinguished between "*techniques*" and "*practices*". Techniques are formulated independently of the farmer and are based on scientific theory. In contrast, practices are the ways farmers work and these are influenced by their particular situation. Papy (1994, p. 223) stated that "*Practices are assumed to be the result of a direct intention, which in turn depends on objectives set by the farmer in a context of constraints and effectiveness*". By analysing practices, an understanding of why farmers act as they do can be obtained. The French developed typologies of farm types to classify their production systems and methods of management (Jeanine and Cristofini, 1989; Perrot and Landais, 1993). This classification schema is useful to advisory staff for identifying likely farm problems and solutions, while researchers can use it to investigate and develop tailored solutions for problems specific to farm-types.

The French approach overcomes one of the major limitations to technology adoption, poor communication between researchers and farmers (Darre, 1989). Researchers and farmers construct their realities differently as a result of their different peer groups and employment (Darre, 1989; Chambers, 1997; Paine, 1997; Parker, 1999). In the French case, agronomists tended to focus on forage production without considering other aspects of the farm business that influence forage use (Jeannin and Cristofini, 1989). The French argue that it is only through an understanding of the reality of farmers, that researchers can develop technologies that will be readily adopted.

An important aspect of the French agronomist's approach is to understand the indicators farmers use which "*express the perception they have of a specific situation*" because this perception will determine their decisions (Deffontaines, 1993, p. 23). Using a systems approach, they view the field as a sub-system within a hierarchy of systems (Deffontaines, 1993; Dore *et al.*, 1997). For example, a field can be viewed as a sub-system of the farm, the ecological system (e.g. catchment), a geographical space (the landscape), a social system (local or regional level), or an industry (Deffontaines, 1993). As such, the results from studies at the field level can be applied to a range of problems at higher levels in the systems hierarchy e.g. farm, catchment, local community, regional, and industry. However, although the field is the unit of analysis, Sebillotte (1990) stressed that its management must be understood in the context of the whole farm since its management impacts on that of an individual field.

The French and some other researchers who have investigated the tactical management processes of farmers (eg., Gladwin and Butler, 1984) do not describe the results of their studies in terms of the traditional management process of planning, implementation and control. It is necessary to relate this work back to the normative farm management literature as described in the following section.

3.2.1.1 The tactical management process

Farmer tend to use pre-defined tactical plans at the start of each planning period (Aubry *et al.*, 1998) rather than work through a detailed planning process as described in the normative literature. A farmer's plan specifies *a* schedule of events or activities that must be implemented to achieve the goal(s) for the planning period (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998).

A relatively simple process is used to control the implementation of the plan. Farmers monitor actual performance and compare this to intermediate objectives or standards specified in the plan (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). When actual performance equals or exceeds a standard, this identifies a "decision point" (Gladwin and Butler, 1984), at which point the farmer must decide between continuing the current plan or implementing a control response. If actual conditions are as expected, then a farmer will implement the next event or activity in the plan (Gladwin and Butler, 1984). However, if conditions deviate from those predicted, an appropriate contingency plan or "embedded sub-plan" may be selected (Gladwin and Butler, 1984; Gladwin *et al.*, 1984) in order to minimise the impact of the deviation in conditions, not performance. The French researchers (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) refer to these decision rules and contingency plans as "regulations".

The French researchers did not comment on the role of evaluation in relation to the control aspect of the tactical management process. A few researchers have commented on learning in relation to the control process. Aubry *et al.* (1998) mentioned that farmers refined their plans between years as a result of learning and Papy (1994) stated that there is an interaction between the tactical management process (action model) and a farmer's knowledge model (model of the production system). The management of the production system is not only the product of the farmer's knowledge system; it also helps to refine the knowledge model.

French researchers proposed a "cognitive action model" (Hubert, 1993; Papy, 1994) to explain the above mentioned tactical management behaviour of farmers. More commonly this is known as a representation of "*the mental image a farmer has of the actions required to attain certain objectives*" (Sebillotte, 1993, p. 285). The cognitive action model has been used to investigate both cropping (Cerf *et al.*, 1993; Aubry *et al.*, 1998) and livestock (Mathieu, 1989; Fleury *et al.*, 1996) farming systems in France.

3.2.1.2 The planning process

Unlike managers in large organisations who are required to provide well documented plans for lower level management to implement, the planning processes of the managers of small family farms tend to remain internal and implicit and are rarely documented (Jacobsen, 1994; Aubry *et al.*, 1998). Farmers, rather than develop a plan at the start of each planning period, as proposed in the normative literature, have pre-defined plans that they use every year (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). These predefined plans are refined incrementally through learning (Chibnik, 1981; Aubry *et al.*, 1998). Chibnik (1981) reported that farmers incrementally test new methods and use the results of such "experiments" to develop new decision rules to guide future behaviour. Such plans may become part of the farming culture to the extent that the reasons for the practice and the decision criteria may be forgotten (Gladwin *et al.*, 1984). Thus, farmers may only undertake detailed (normative) planning in the early years of their farming life, or when external factors require them to adopt a more formal process. A longitudinal study over several years would therefore be required to obtain a detailed understanding of the planning processes used by farmers. Consequently, most empirical research reports on the product of the planning process, the plan, rather than the process itself.

3.2.1.3 The plan

Empirical research suggests the plans used by farmers comprise four main components: an overall objective(s), a predictive planning schedule of events or operations for the planning period, a set of intermediate objectives or standards that are used to control the implementation of the plan, a series of decision points, a set of embedded sub-plans or "regulations" (contingency plans) and associated decision rules to be applied when actual conditions deviate from those predicted in the plan (Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998).

Objectives

In the action model (Hubert, 1993; Sebillotte, 1993; Papy, 1994), objectives are considered to be a component of the plan. Fleury *et al.* (1996) argued that to understand the tactical management of French livestock farms, it was necessary to understand farmers' broader business goals, because these impact on their tactical decisions. The objectives used in the tactical management of farms can be represented in a hierarchical structure (Mathieu, 1989; Crawford, 1996; Fleury *et al.*, 1996) as illustrated by Mathieu (1989) for French livestock farms. She found that farmers have production goals, which determine objectives in relation to animal requirements, which in turn determine objectives for the state of forage (quality and quantity) at different times of the year. Intermediate objectives or targets specify the desired states for pasture and livestock in order to meet production goals. These states are used as "*indicators*" to determine when regulatory decisions will be used, which is critical, because livestock farmers have limited control over forage production (Mathieu, 1989). Crawford *et al.* (1997), in a study of the management practices of New Zealand dairy farmers that achieved high per cow production, also found that the farmers' goals could be represented in a hierarchical structure where lower level goals represented tasks that had to be achieved in order to realise higher level goals.

Livestock farmers in the French alps were found by Fleury *et al.* (1996) to have a hierarchy of objectives for the planning period, as well as for each field for a given period in the animal or hay production process. Cerf *et al.* (1993) and Aubry *et al.* (1998) reported similar results for French cropping farmers. Fleury *et al.* (1996) distinguished between practices and goals. The same goal could be achieved by different practices, and the same practices might be used to achieve different goals. Crawford *et al.* (1997) also found that farmers used a range of practices to achieve a common goal of high per cow production. Individual farmer goal hierarchies could be used to represent alternate means (or tasks) to attain the same ends (high per cow production) despite differences in the resource base.

There is some evidence that farmers' goal hierarchies ensure goal congruence. Fleury *et al.* (1996) found that farmers' broader *long-term* business goals influenced their tactical decisions. In livestock farming, farmers regularly face the decision of whether to utilise the forage now or conserve it for later use (Landais and Deffontaines, 1989). In an Australian study of farmers' tactical management during drought, Buxton and Stafford Smith (1996) reported that farmers sought to minimise financial and livestock losses whilst attempting to minimise the damage to land and pastoral resources. These two goals are often in conflict. Farmers therefore consider both the short- and long-term implications of actions on their production systems.

The planning horizon

Little is known about the planning horizon used by farmers. They appear to separate the year into different periods according to the tasks or options required for production (Cerf *et al.*, 1993). Aubry *et al.* (1998) mentioned that farmers use activation and termination decision rules, but this was only in relation to operations or tasks, not planning itself. From a study of French alpine dairy farmers, Mathieu (1989) reported that the spring period could be separated into three periods on the basis of the physiological state of the pastures and the balance between feed demand and pasture growth.

The predictive planning schedule

The predictive planning schedule specifies the operations the farmer must undertake to achieve objectives. Mathieu (1989, p. 130) stated that it is independent of events in any one year. That is, it is a general plan, the outcome of which will be modified in response to between-year variation. Empirical research on this topic can be classified into two main areas: factors that impact on the nature of the predictive planning schedule, and the nature of the plan derived through the planning process.

An important thrust of the French work is the classification of farming systems into a typology that is useful for research and extension purposes. The basis of this typology is the production system. A key descriptor of the production system is the planning schedule used by farmers (Mathieu, 1989; Theau *et al.*, 1993; Fleury *et al.*, 1996). The planning schedule is a function of the "strategic organisation" of the farm (Fleury *et al.*, 1996), and farmers' production goals, level of intensification, and resource constraints (Mathieu, 1989; Fleury *et al.,* 1996; Crawford *et al.*, 1997). Research into decision-making has shown that values influence the mode of operation farmers choose when attempting to achieve a particular goal (Gasson, 1973, Ohlmer *et al.,* 1998).

In relation to the resource-base used by farmers, climate appears to play a critical role in determining the exact nature of the predictive planning schedules used by farmers (Gladwin, 1979a; Mathieu, 1989; Cerf *et al.*, 1993; Siddiq and Kundu, 1993; Fleury *et al.*, 1996). Mexican farmers developed cropping calendars in response to the climatic patterns and soil types on their farms (Gladwin, 1979a). Similarly, Siddiq and Kundu (1993) found that farmers used their understanding of crop production and the weather, to develop "*optimum crop calendars*" that allowed them to maximise the use of rainfall, minimise crop damage as a result of weather extremes and the use of irrigation, and optimise cropping intensity and the use of solar radiation. They also observed that farmers acquire a "*remarkable weather wisdom*" through close observation of weather events over many years (p. 156). Similar observations have been made by other authors (Gladwin, 1979a; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996).

Knowledge of the nature of farmers' plans has come primarily from the work of Christina Gladwin in the 1980's (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984) and more recently from research in France (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). Gladwin and Butler (1984), defined the product of a farmer's planning process, the plan, as a sequence of mental instructions or rules that specifies who does what, when and for how long. Alternatively, it can be viewed as a sequence of actions or tasks that must be undertaken to grow a crop or operate a livestock enterprise. The plan can be represented by researchers as a series of decision rules, however, the decision maker is not aware of these "rules" or of having made a decision (Gladwin and Butler, 1984). Repetitive routine decisions may become "automatic" to the decision maker and thus become part of a pre-attentive (subconscious) plan or "script" (Gladwin and Butler, 1984).

A plan, like a script, tells the actor what to say and do (Schank and Abelson, 1977). Such scripts allow farmers to grow crops or farm livestock without having to consciously make a large number of decisions. "*Such unconscious processing serves not only to call attention to events of importance; it also can control some apparently complex activities when performed by experts. ... experts use conscious attention judiciously, at the most difficult moments of their performance, while pre-attentive processes handle routine behaviour*" Gladwin and Murtaugh (1980, p. 118). Scripts are used when decision makers must make a large number of decisions quite frequently. Planning is a complex cognitive activity and farmers avoid the stress and cognitive "effort" it involves by adopting a predefined plan developed through experience (Gladwin and Murtaugh, 1980; Gladwin *et al.*, 1984). The rules of their plan or script are followed except where unexpected events force them out of "plan mode" into "decision mode" to choose between alternative plans or sub-plans.

A few studies (Cerf *et al.*, 1993; Aubry *et al.*, 1998) have considered the decision rules contained within farmers' pre-defined plans. Cerf *et al.* (1993) identified two key decision areas cropping farmers had to consider in their general plan: the time spent working on different crops and in different fields, and the sequence of operations. They found that the priority of resource use (labour, machinery, other inputs) in the plan was determined by the gross margin of the crop, that is, the most profitable crop received first priority. Similarly, operations that had the greatest impact on final yield, were given priority. Some assessment of risk was made in determining the sequence of operations, e.g. the risk of cultivating under humid conditions versus the risk resulting from delayed sowing date.

In a later study, Aubry *et al.* (1998) reported that the predictive planning schedule used by cropping farmers can be described in terms of two main factors: the order and timing of technical operations, and the modes of operation. Five rule types were identified from this work: *sequencing*, *activation* (and *termination*), *mode establishment*, *arbitration*, and *grouping*. *Sequencing rules* determine the chronological order of operations in each field. They distinguished between "*obligatory*" (must be undertaken in order for the next operation to proceed) and "*non-obligatory*" operations in a cropping farmer's predictive planning schedule. The farmers' objectives, constraints and risk perceptions determined non-obligatory operations. As such, some sequencing rules were obligatory e.g. harvest before sowing, and others were determined by site-specific factors. *Activation rules* determine when an operation is initiated and there are also corresponding *termination rules*. These set the time range for each operation and the timing and number of sessions per operation. A range of indicators are used to trigger these rules including *benchmark* dates and the state of the land and crop.

Mode establishment rules are used to determine what combination of equipment (tractors and implements), labour to use for a particular operation, and the type(s) and amount(s) of inputs to use. *Arbitration rules* specify the priorities a farmer establishes between sets of fields when resource constraints result in competition for labour and machinery. This occurs at several levels: between crops, between within-crop fields, between within-crop operations. The between crop decision rules determine which crops take priority at different times of the year. They also determine the timing and number of sessions for a specific operation. The between within-crop fields decision rules determine for a given crop which fields are given priority for the completion of a specific operation. The between within-crop operations decision rules are used to determine priorities in terms of machinery use, where the same machinery is required to undertake different operations e.g. apply nitrogen versus weed control. *Grouping rules* allow farmers to apply other rules to sets of fields as well as an individual paddock. This simplifies management and reduces the heterogeneity of the farming system. The rules identified by Aubry *et al.* (1998) represent important components of a plan that should be considered by a manager. Consideration of these components could provide a powerful tool for the evaluation of plans.

The standards

The standards farmers use in their plans are briefly referred to by Gladwin and Butler (1984), Mathieu (1989), Cerf *et al.* (1993), Fleury *et al.* (1996) and Aubry *et al.* (1998). Often the standards used by farmers appear to be visual images of ideal farm states at particular times in relation to crop, forage, soil and animal attributes. For example, Cerf *et al.* (1993) reported that farmers used factors such as soil colour and stage of crop growth to determine when to initiate a regulation process.

Decision points

Plans can be thought of as a sequence of actions or a set of decision processes or decision rules that result in action (Gladwin and Butler, 1984). Any step within the plan can in itself, be a complicated decision sub-routine (Gladwin and Butler, 1984). A plan will also have sub-plans embedded within it including decision rules to choose between them (Gladwin and Butler, 1984). Such points along a plan are known as decision points. The first decision point is when the decision is made whether to implement the plan; subsequent decision points exist at any point in the plan where more than one sub-plan is embedded and a choice must be made (Gladwin and Butler, 1984).

The contingency plans

Contingency plans are implemented if conditions vary from those predicted in the plan (Mathieu, 1989; Fleury *et al.*, 1996; Aubry *et al.*, 1998) and are designed to cope with inter-year variations in climate and production (Fleury *et al.*, 1996; Aubry *et al.*, 1998). They provide the farmer with several choices of action in any particular period (Gladwin and Butler, 1984; Mathieu, 1989). However, Mathieu (1989) pointed out that such choices are normally limited because they are time-of-year dependent. For example, a dairy farmer will only consider drying the herd off early near the time that it is normally dried off.

Contingency plans for a pastoral livestock farm were classified into five categories by Mathieu (1989). These were those that modified the grazing interval, the order in which fields were grazed, the area that was grazed, the number of grazing animals, and the amount of external feed introduced into the system. In contrast, most of the decisions made by cropping farmers relate to changes in the sequence and timing of operations, and the mode of operation including the type and quantity of inputs (Cerf *et al.,* 1993). Similarly, Papy and Mousset (1992) separated the *modus operandi* used by French cropping farmers into three levels: the operational level that comprised the field operations (choices about combinations of manpower and equipment), the sequencing level (choices about what sequence to perform the operations in), and the temporal level (problems where two operations are incompatible or in conflict). The tactical decisions made on livestock farms could also be classified in relation to the sequence and timing of events, and the quantity and level of inputs. For example, Mathieu (1989) discussed the impact on feed supply of changing the sequence in which fields are grazed and the quantity of feed provided to livestock.

Farmers use a wide range of contingency plans in their tactical management due to the diversity of their production objectives and resource constraints (Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.,* 1998). Buxton and Stafford Smith (1996) found that small adjustments in tactics can have major financial implications, but that it was inappropriate to generalise across farms because these adjustments are situation and location specific.

Critical events

"*Key*" or "*critical*" periods were identified by Mathieu (1989) and Fleury *et al.* (1996) as an important component of a farmer's plan for meeting production targets. These are either periods that are difficult to manage, or important in terms of determining the *long-term* productivity of the system (Fleury *et al.*, 1996). They often reflect important resource constraints on the farm (Mathieu, 1989) and may be managed through a combination of strategic choices and regulation processes (Fleury *et al.*, 1996). The gap between actual and targeted system states at these times of the year must be minimised to ensure high levels of performance. During these critical periods, it is important that farmers have sufficient flexibility in terms of contingency plans to manage variation.

3.2.1.4 The interdependence between planning and control

A plan, by itself is of little use to managers due to uncertainty in the environment, particularly climate. Climate impacts on the growth of crops and forage (Mathieu, 1989, p.130), and other farming operations such as cultivation and spraying. This means only the general direction of the outcome can be predicted, e.g. the application of nitrogen will increase pasture growth. It is not surprising then the farmers believe they have limited control over their farming systems because of uncertainty in relation to climate and product prices (Kaine, 1993; Kaine *et al.*, 1993).

Uncertainty may explain why farmers use the planning process and types of plans they do. Experientially-based predefined plans designed for a "typical" season are used in preference to formal plans (Mathieu, 1989). This coincides with Wright's (1985) view that farmers may limit their planning "effort" under conditions where the level of uncertainty is high. Farmers also try to ensure a large number of contingency plans are available around "*critical events*" to cope with uncertainty because these events have a major impact on the productivity of the farming system.

3.2.1.5 The control process

Interestingly, and this may reflect the background of the researchers, few descriptive papers on the tactical management process mention the term control, or have separated control into the monitoring and evaluation functions. Rather, the major emphasis in these papers is the role of the "embedded sub-plans" or "regulation" processes in control, and the role of decision rules in determining which sub-plan to implement (Gladwin and

Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). While the importance of indicators in relation to the "regulation" process is recognised, little is written about the nature of the indicators, or their use with decision rules in the monitoring process. None of the above authors mention an evaluation sub-process, although both Papy (1994) and Aubry *et al.* (1998) mention that learning occurs as a result of the tactical management process.

3.2.1.6 The monitoring process

With the exception of Landais and Deffontaines (1989) few studies report on the factors monitored by farmers. Cerf *et al.* (1993) mentioned three indicators used by French cropping farmers: soil colour as an indicator of soil moisture for cultivation decisions, benchmark dates for key decisions such as sowing, and the "apex" crop growth stage for straw shortener application date decisions. Milk yield was identified by Napoleone (1993) as a factor monitored by French goat farmers, while Aubry *et al.* (1998) and Fleury *et al.* (1996) did not provide specific information about indicators. More has been written about the development of simple and effective indicators that scientists can use to monitor the management practices of farmers, particularly by French researchers (Mathieu and de Vaubernier, 1988; Gilbert and Mathieu, 1989; Havet and Lafon, 1992; Napoleone, 1993; Osty *et al.*, 1993). However, the purpose of this research was to develop a methodology for investigating the management practices of farmers rather than to improve management *per se*. Landais and Deffontaines (1989), provided a detailed description of the indicators used by shepherds grazing animals in the southern French Alps. They concluded (p.205) that the study "*highlighted the richness of indicators drawn by the shepherd from the animals' behaviour, these allow the shepherd to manage the pastoral system in the absence of direct and precise indicators in the form of animal performance on the different pastures or the development of the grazed vegetation*".

The studies referred to above suggest that farmers tend to use primarily subjective as opposed to objective measurement systems and that dates play an important role in the control process. However, little is understood about the frequency of monitoring, sources of error, and the time and cost associated with farmers' monitoring systems. Some measures are taken daily (e.g. milk yield) (Napoleone, 1993), while others are less frequent and influenced by conditions rather than time interval (e.g. soil colour) (Cerf *et al.*, 1993).

Monitoring can be applied to problem identification and option selection (Cerf *et al.,* 1993). Interestingly, no mention is made in any of the empirical studies of the management process on the role of information in the diagnosis of problems, or about the diagnostic process itself. There is also minimal reference to data processing or storage with the exception of Napoleone (1993), who briefly reported that French goat farmers used a log book to daily record production related information, and Parker (1984) who found that farmers weighed sheep, but did not calculate means or refer to a plan (standard) to assess progress. No other empirical studies on data processing and storage were identified.

3.2.1.7 Decision point recognition

The point when a farmer must choose between sub-plans within the plan was termed the "*decision point*" by Gladwin and Butler (1984). These sub-plans include both the planned activity or event, and alternative, contingency plans. A decision point is identified by comparing an indicator to an intermediate objective (Gladwin and Butler, 1984; Mathieu, 1989; Fleury *et al.*, 1996). Once a decision point is identified, a farmer must then choose between implementing the current plan or a suitable control response.

3.2.1.8 Plan implementation and control response selection

Gladwin and Butler (1984) described the process farmers use to decide whether to implement the next activity in the plan or an alternative sub-plan. They found that each sub-plan, including the next planned activity, has a set of "entry conditions" associated with it. When a decision point is reached, the actual conditions at the time are compared subconsciously with the entry conditions associated with the next activity in the plan. If these match, the next activity is implemented as planned. However, if they do not match due to external factors, this forces the farmer to shift from subconscious "*plan mode*" into conscious "*decision mode*". The farmer then compares the actual conditions to the entry conditions of the alternative sub-plans or contingency plans. The sub-plan that passes all the entry conditions is then implemented. Gladwin and Butler (1984) stated that farmers conserve mental energy by moving from plan mode to decision mode only when conditions deviate from that predicted in the plan.

The French researchers (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) reported that farmers use "*regulations*" (i.e. contingency plans) to cope with inter-year variations in climatic conditions. Decision rules are applied to choose between alternative "regulations" and this is dependent on the state of specific farming system components at the time (Mathieu, 1989: Fleury *et al.*, 1996), and the stage of the production cycle (Mathieu, 1989).

Most control responses used by farmers (Gladwin and Butler, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) can be classified as contingency plans. However, farmers may continue with the basic plan and accept reduced short-term production objectives in order to obtain longer-term production gains (Mathieu, 1989). Control responses such as changing plans or goals (Barnard and Nix, 1979; Boehlje and Eidman, 1984; Parker, 1999) were not reported in the descriptive literature. It appears that in farming, most control responses can be classified under the heading "concurrent control". There is some indication of learning and the adjustment of the management process or plans or historical control (Papy, 1994: Aubry *et al.*, 1998). To date, research has not commented on the normative model of preliminary or compensatory control or elimination of disturbances control responses.

A key aspect of any control system is the criteria used by managers to decide between contingency plans. Cerf *et al.* (1993) reported that farmers used two criteria, crop gross margins and impact on final yield to select between alternative options within a plan. These criteria may also be used to determine the most suitable contingency plan.

Effective control is dependent on farmers having a good understanding or "knowledge model" (Papy, 1994) of the cause and effect relationships within their farming system (Landais and Deffontaines, 1989; Mathieu, 1989; Cerf *et al.*, 1993). Any control decision has associated costs and benefits that can be both short- and long-term. For example, livestock farmers routinely face the decision on whether to utilise forage now or conserve it for later use (Landais and Deffontaines, 1989). Such decisions require a good understanding of the full consequences of an action. The development of an effective cause and effect or "knowledge" model, is dependent on the evaluation phase of the control process.

3.2.1.9 Evaluation process

Problem diagnosis, a step in the normative management model (Mauldon, 1973; Barnard and Nix, 1979), has not been reported on in empirical studies. This may suggest that farmers use a process akin to situation assessment (or awareness) (Klein, 1993, 1997; Lipshitz, 1993; Endsley, 1997) where they subconsciously classify the situation on the basis of particular set of state variables and then pattern match the classification to a specific option rather than work through a conscious process of diagnosis and option evaluation/selection. According to Gladwin and Butler (1984), Mathieu (1989), Cerf *et al.* (1993), Fleury *et al.* (1996), and Aubry *et al.* (1998), farmers use heuristics or decision rules to select an option or course of action from a set of embedded sub-plans that will best resolve a problem or deviation. These results support the view that farmers use a process similar to situation assessment (Klein, 1993, 1997; Lipshitz, 1993; Endsley, 1997). However, it is probable that farmers confront unusual situations where some form of diagnosis is undertaken to assess the reasons for an "*unexpected*" deviation from the plan.

Similarly, little mention is made of evaluation or learning in the descriptive literature. Papy (1994) stated that interaction occurs between a farmer's "*action model*" (management system) and his/her "*knowledge model*" of the production system. The knowledge model determines the nature of a farmer's management practices, while an output from the action model, learning, validates and refines the farmer's knowledge model. Refinement to the knowledge model will result in refinements to the action model and corresponds to Burnside and Chamal's (1994) view of ground-based monitoring as a learning mechanism for rangeland managers. They believed the management process could be viewed as analogous to the experiential learning cycle of planning, acting, observing and reflecting (Kolb, 1974, 1984).

Between-year variation in the implementation of plans was found by Aubry *et al.* (1998) to be attributable to one of four factors: the weather, the activation of alternative solutions not previously used, adaptations that were implemented on the spur of the moment, and year to year changes in the farmer's planning model. Variations in the weather caused most changes to plans. Spur-of-the-moment adaptations were implemented in response to practical considerations (e.g. plough a field because it is convenient) or unusual events (e.g. severe disease outbreaks). However, the most important source of variation, from the perspective of improving farmers' management practices, resulted from the introduction of new techniques learned through the evaluation of practices.

3.3 The non-adoption of formal planning and monitoring systems

Surveys of New Zealand farmers over the last decade suggest that few of them use the formal feed planning and monitoring systems advocated by researchers and consultants (Parker, 1999). Several studies (Nuthall, 1992, 1996; Parker *et al.,* 1993; Nuthall and Bishop-Hurley, 1999) have reported that between 60-80% of the pastoral farmers surveyed did not use formal feed planning and/or monitoring methods. Parker *et al.* (1993) found that only 35% and 16% of farmers estimated pasture growth rates and used objective methods to measure pasture mass, respectively. In contrast, 90% of farmers reported using visual assessment to measure pasture mass.

Nuthall and Bishop-Hurley (1999) identified, in order of importance, time and resource requirements, difficulty in predicting weather and inaccuracy associated with estimating dry matter yield of pasture and forage crops, as the main reason why farmers did not use formal feed planning and monitoring techniques. Some 60% of farmers did not perceive feed budgeting to be beneficial, while the level of uncertainty (10%) and lack of knowledge (10%) were other reasons given for not undertaking feed budgeting. In contrast, the main benefits associated with feed budgeting were from efficiency improvements (24%), determining when to make critical feeding decisions (31%), prediction of feed surpluses and deficits (18%) and the provision of a sense of security (11%).

Commonly held beliefs as to why farmers should adopt formal monitoring systems were challenged by Parker (1999) and he proposed six main reasons why farmers do not adopt formal monitoring despite considerable efforts in this area by scientists, consultants and extension agents. These were:

1. Visual assessment has proven adequate for achieving production and financial goals.
2. Formal monitoring is discontinued once the skills are learnt.
3. No clear link exists between the formal indicators and farm business strategy or the farmer's goals.
4. The economic benefits of monitoring are unclear.
5. There is inadequate data processing and interpretation support.
6. The individuals who propose formal monitoring systems and associated decision support systems often have a poor appreciation of a farmer's world view.

According to Parker (1999), from a farmer's perspective, visual assessment is faster, more convenient, and acceptably accurate when calibrated against standards. He noted that written records of visually assessed data are not normally kept. Parker (1999) also suggested that a proportion of farmers replaced objective measures with subjective measures once they had learnt how to measure the relevant indicators. Thus, objective measures are used to identify and learn visual "cues" associated with system performance. Once such indicators are identified and validated, they replace the objective measures.

If the linkage between performance measures and a farmer's strategy or higher levels goals is unclear, then they are unlikely to adopt such measures. Parker (1999) drew on Kaplan and Norton's (1992, 1993, 1996abc) work on the balanced scorecard to suggest that if better techniques were developed to demonstrate the linkage between operational measures and farmers' strategies, more farmers might adopt formal monitoring in order to drive business strategy. Similarly, Parker (1999), like Hardaker and Anderson (1981) believed that if the economic benefits of formal monitoring were made more explicit, more farmers would adopt the approach. The majority of farms are family owned and operated and as such, farmers must undertake tasks that range from strategy through to operations (Blackie, 1971). In terms of time, many of these tasks are non-negotiable (e.g. milking), whereas task such as monitoring are important, but negotiable (Parker, 1999). Therefore if time is short, monitoring can be relegated to periods when time is available. Empirical research supports this: around one third of the farmers in Nuthall's (1992) and Nuthall and Bishop-Hurley's (1999) survey stated that they did not feed budget due to the time and resource costs associated with the practice.

There is limited data on the costs associated with formal monitoring systems. de Freitas *et al*. (1993) estimated the annual costs of a pasture monitoring system that used indicator paddocks would be about 15% of the annual animal health budget for the case farm. However, little is written on the explicit financial benefits of formal feed budgeting, although de Freitas *et al*. (1993) suggested monitoring can be inexpensive relative to its benefits. Where the economic benefits are obvious, farmers have adopted formal monitoring systems such as with milk quality and somatic cell counts in the New Zealand dairy industry (Paine, 1997).

Inadequate data processing and interpretation support is another reason advocated by Parker (1999) for the non-adoption of formal monitoring. One study (Parker, 1984) found that of those sheep farmers who weighed sheep (60%) most did not process that data to calculate a mean, and nor did they have a plan against which actual measures could be compared.

The final reason given by Parker (1999) for the non-adoption of formal monitoring is that researchers do not appreciate the world view of farmers. Paine (1997) found that the information priorities set by dairy farmers were consistent within their group, but differed from those of non-farmers. Similar results were reported by Burnside and Chamala (1994) for farmers and advisers. Paine (1997, p. 143) reported in one case study that the information system provided to farmers had been "*framed to norms of researchers and professionals and failed to appreciate the world of the farmer*." Scientists involved in this work were surprised at the holistic way farmers used information. Likewise, Burnside and Chamala (1994) recommended that the developers of monitoring systems acquire a deeper understanding of how farmers would effectively use these in practice.

Given the preceding discussion it is not surprising then that the expectation that farmers will use decision support systems to improve the productivity and profitability of their farms is seriously flawed (Cox, 1996). This is because such systems need considerable technical support to operate effectively, require monitoring data which farmers often find difficult to collate, and are based on information platforms (computers) which (at that time) few farmers have access to. Cox (1996) viewed the gulf between the scientific knowledge of researchers and the practical knowledge of practitioners as one of the primary reasons for the low adoption of formal decision support systems. Similar conclusions were drawn by Hardaker and Anderson (1981) in relation to the adoption of farm recording systems.

3.4 Empirical studies of decision-making from a management process perspective

In this section, the literature on decision-making is examined from a management process perspective. Unfortunately, as outlined below, a distinction between tactical and strategic decisions is sometimes not made. Where possible, the author differentiates the findings on this basis.

Two main sources of descriptive literature on farmer decision-making have developed since the late 1970's. First, from European research (Attonaty and Soler, 1991; Jacobsen, 1993, 1996; Ohlmer, 1998; Ohlmer *et al.*, 1998), and second, from farming systems research in third world countries on the adoption or non-adoption of improved technology by local farmers. The hierarchical decision tree modeling used by Gladwin (1975, 1976, 1979ab, 1980; 1983; 1989) to represent farmer decision-making in developing countries has since been adopted by researchers in developed nations (Fairweather, 1992; Fairweather and Campbell, 1992; Murray-Prior and Wright, 1994; Jangu *et al.*, 1995; Murray-Prior, 1994, 1998). All of these studies have tended to focus on strategic decisions that are primarily of a planning[2] nature.

In a recent review, Rougoor *et al.* (1998, p. 270) concluded that research into the decision-making process was "*under-exposed*" and that useful research would only eventuate if longitudinal as opposed to survey-based methods were adopted. This view is reinforced by the paucity of studies on the entire decision-making process used by farmers (Johnson *et al.*, 1961; Jacobsen, 1993, 1996; Ohlmer *et al.*, 1998; Catley *et al.*, 2000). Other studies are partial in nature. For example, at the simplest conceptual level, decisions made by managers have been classified (e.g. Dryden, 1997). At a more advanced level, specific phases of the decision-making process have been investigated such as problem definition (e.g. Ohlmer *et al.*, 1996; Ohlmer, 1998), and analysis and choice (e.g. Gladwin, 1976, 1979ab, 1980, 1983, 1989; Fairweather, 1992; Fairweather and Campbell, 1992; Murray-Prior and Wright, 1994; Jangu *et al.*, 1995; Murray-Prior, 1998) and the factors that influence farmer decision-making and/or farm performance (e.g. Bigras-Paulin *et al.,* 1985ab; Tarabla and Dodd, 1990; Cruise and Lyson, 1991; Wadsworth and Bravo-Ureta, 1992; Jose and Crumbly, 1993; Boland and Patrick, 1994; McGregor *et al.,* 1995, 1996; Sutherland, *et al.,* 1996; Austin *et al.,* 1998ab). However, such studies shed little insight into the decision-making process(es) used by farmers.

3.4.1 Goals and values

Important drivers of decision-making are goals and values (Ohlmer *et al.,* 1998; Catley *et al.,* 2000). Farmers' are conscious of their goals and values, especially in strategic decision-making[3] (Ohlmer *et al.,* 1998). Values influenced the choice of options considered (Ohlmer *et al.*, 1998) and the mode of operation (Gasson, 1973). Ohlmer *et al.* (1998) distinguished between *"analytical"* and *"intuitive"* farmers on the basis of

[2] Because strategic and tactical decisions occur along a continuum, and planning and control are interdependent, it is often difficult to decide if a decision should be classified as a planning decision or a control decision at the strategic level. For example, the development of a new enterprise mix may be viewed as a planning decision within an intermediate (1-2 year) time frame, but it could also be viewed as a control decision in response to cyclical changes in relative product prices over a longer-term time frame.

whether they quantified and documented their goals. Importantly, the latter group, which constituted the majority of farmers, had qualitative goals and derived these from earlier performance, reference points and other farmers. Goals were relatively stable over time as might be expected at the strategic level. Generally only 1-3 high level goals associated with the problem area of interest were identified by Ohlmer *et al.* (1998) and no hierarchy was developed for lower level goals. They also reported that farmers normally expressed their objectives in terms of the direction of change they desired.

3.4.2 Planning Process

In the decision-making literature it is difficult to distinguish between the process of developing a new plan and the control process of selecting a suitable contingency plan. This is because no distinction is made between generating and analysing options to develop a plan versus generating and analysing options to decide upon which contingency plan to implement. Thus, the types of decision investigated by researchers need to be specified.

Farmers find strategic planning difficult (Catley *et al.,* 2000) and prefer quick and simple, rather than detailed, elaborate planning approaches (Jacobsen, 1993; Ohlmer *et al.,* 1998). They tend not to use planning aids or written plans (Jacobsen, 1993; Ohlmer *et al.* 1998; Catley *et al.,* 2000) because they are perceived to be difficult to revise (Ohlmer *et al.,* 1998).

Farmers also believed that the effort required for formal planning approaches cannot be justified given the level of uncertainty. However, Jacobsen (1993) found that the mental estimates used by farmers had deficiencies in relation to economics. Ohlmer *et al.* (1998) also reported that farmers' planning processes could range from adopting or revising previous plans through to a detailed formal planning process. The latter was used for more complex opportunities such as those involving a large investment.

Most decision-making studies tend to focus on the option generation, and option selection aspects of the planning process (eg., Gladwin, 1976, 1979ab, 1980, 1983, 1989; Fairweather, 1992; Murray-Prior and Wright, 1994; Jangu *et al.,* 1995; Fairweather and Campbell, 1996; Ohlmer *et al.,* 1996, 1997, 1998; Murray-Prior, 1998). Other planning

[3] Some tactical decisions were investigated, but the primary focus of the study was at the strategic level.

steps such as forecasting, resource audit, situation assessment, policy and procedure development, specification of standards or the development of contingency plans are rarely mentioned. For example, Ohlmer *et al*. (1998) reported that farmers undertake a planning process that involves six steps: a search for options, estimating the consequences of each option, a screening or evaluation process that reduces the initial set of options down to a smaller set of 1 - 3 "good" options, and then an evaluation process in which these "screened" options are analysed in more detail before the "best" option is selected, a plan is developed for the chosen option and then an "intention" is made to implement the plan. The first three steps in this process are termed the problem definition phase by Ohlmer *et al*. (1996) and Ohlmer (1998).

3.4.2.1 Option generation

Detection of a problem induces a decision maker to search for information about options (Ohlmer *et al*., 1996; Ohlmer, 1998). The intensity with which farmers search for options at the strategic level was found to be determined by the seriousness of the problem, (i.e. its impact on their long-term goals), and the certainty with which they believed a problem existed. Similarly, the more capable, highly motivated farmers who applied a quantitative approach, spent more time searching for information on options than other farmers. Options were obtained from both internal (memory) and external sources.

Ohlmer *et al*. (1998) found farmers simultaneously made a preliminary estimate of the consequences and the factors associated with each option during the search. Problems associated with an option were identified and if surmountable, the farmers continued their evaluation. However, options associated with insurmountable or too many problems, and those not deemed as "good" as others, were screened out. Normally only one option was selected for further evaluation. Where more than one option was selected, this was normally because the options were not satisfactory. This process is similar to the first phase of the hierarchical decision tree model developed by Gladwin (1976, 1979ab, 1980, 1983, 1989) to describe the option selection phase of the decision-making processes used by farmers. She proposed that farmers described the options they considered in terms of a set of aspects[4]. These aspects are then used to screen potential options. A normally large set of options is reduced down to a much smaller set of feasible options for analysis in phase two. This first phase is normally undertaken subconsciously. Catley *et al*. (2000) reported that cutflower growers used up to 12 criteria for screening potential

[4] An aspect is an attribute or characteristic (e.g. profitability, labour requirement, risk) of the option and is assumed to be discrete. Continuous variables are converted into discrete variables that are treated either as a constraint, or categorised in such a way that they can be rank ordered.

new crops. They identified that growers used formal or informal methods and that the pros and cons of each crop were assessed in an iterative fashion.

3.4.2.2 Option evaluation and selection

Once farmers have screened possible strategic options these are evaluated in more detail (Ohlmer *et al.*, 1998). Additional information may be collected on these options and used to develop a plan, and estimate consequences for evaluation purposes. However, Ohlmer *et al.* (1998) found that farmers did not use probabilities to assess the risk associated with an option, instead, they only assessed whether the farm could survive a "bad" outcome.

Flexibility was also considered when evaluating strategic options, particularly where a large capital investment was involved (Ohlmer *et al.*, 1998). Farmers were willing to pay a cost (i.e. accept options with a lower return or higher cost) to maintain this flexibility. A lower level of performance would also be accepted if they believed that management could not compensate for the variability that had occurred in the environment. Jacobsen (1993) found that farmers appeared to use economic principles such as marginality when making decisions. Catley *et al.* (2000) reported that the evaluation and selection process used by cutflower growers to select a new crop ranged from an almost "instantaneous" decision, to one that involved detailed quantitative analysis.

Gladwin (1976, 1979ab, 1980, 1983, 1989) developed a more detailed six step process to describe the option evaluation and selection process used by farmers. Unlike the option screening process, this process is undertaken consciously by the farmer. During step one, all the aspects of the options are listed. Then heuristics are used to eliminate aspects that are not relevant to the decision. One aspect from this "reduced" set of aspects is chosen, normally the most important one, to order the options on. The alternatives are then ordered according to the chosen aspect. The minimum condition that must be met by the options is specified. Constraints are formulated from the remaining aspects and if the option that is ranked first on the ordering aspect passes all the constraints, it is accepted. If the first ranked option does not pass all the constraints, the second ranked option is tested, and so on until a suitable option is identified. If none of the options pass the test, another strategy is adopted to identify a suitable option.

The hierarchical decision tree model has been applied to a range of decisions (Fairweather, 1992; Murray-Prior and Wright, 1994; Jangu *et al.*, 1995; Fairweather and Campbell, 1996) and found to predict farmer behaviour to a high degree of accuracy.

However, it has also drawn some criticism. For example, several authors (Franzel, 1984; Fairweather, 1992; Murray-Prior, 1998) claim it was less useful in determining what factors dictate the quantity of an option chosen by the farmer. Franzel (1984) believed that this problem could be overcome where farmers could convert continuous variables into discreet variables. Murray-Prior (1998) also criticised the model because it did not explain (i) how the decision-maker chose the aspects used in the decision-making process, (ii) why decision makers behave in the way predicted by the model, (iii) the motivation for such decisions, or (iv) how learning takes place. He proposed the incorporation of personal construct theory (Kelly, 1955) into the model as a way to overcome these problems.

Murray-Prior (1998) argued that the constructs a person uses in a particular decision are a function of their perception of the current situation, and their experience with similar situations. Therefore, both context and experience are important in decision-making. Similarly, changing environments require individuals to reassess their decision rules and time is necessary before they learn which rules are most appropriate for the new conditions. Learning may result in a change in the hierarchical position of constructs, or the addition of new constructs. Murray-Prior (1998) therefore believed that Gladwin's (1976) hierarchical decision tree models would lose their predictive capability during periods of change.

The effort farmers put into planning is a function of the complexity of the plan (Ohlmer *et al.*, 1998). Some plans require almost no effort or are derived from previous plans and adjusted to suit the situation, while others require considerable input. Unfortunately, Ohlmer *et al.* (1998) did not specify the nature of these different plans.

In summary, the decision-making literature provides some insight into the planning process used by farmers, primarily at the strategic level, but little on the nature of the plans produced by this process or of its application to control. This may be because the focus is not on planning, but decision-making.

3.4.3 Control

Management control can be related to the steps in the decision-making process. The identification of deviations from the plan through monitoring, for example, is synonymous with problem detection or recognition. Diagnosis corresponds with problem definition. The selection of a response to a significant deviation from the plan (problem) is more difficult to match to the decision-making literature because normally no distinction is made between the selection and implementation of contingency versus new plans. However, in the context of strategic decisions, the control response could be expected to be the development of a new plan. These matches were used when reviewing the decision-making literature from a management control perspective.

3.4.3.1 Monitoring and problem detection

In the context of decision-making, the first step in the control process is problem detection. Two recent studies (Ohlmer *et al.,* 1997, 1998) identified several factors that influenced the timeliness of problem detection. These included: education, farm size, farmer ability and motivation, perceived importance of the problem, quantitativeness, and avoidance behaviour. Ohlmer *et al.* (1997) proposed that farmers use a three phase process for problem detection comprising information scanning, consequence estimation and consequence evaluation.

Although information scanning is an important step in problem detection, Ohlmer (1998) and Ohlmer *et al*. (1997, 1998) did not detail the factors farmers scan or monitor to identify problems. Catley *et al.* (2000) reported that cutflower growers monitored price trends through several sources (publications, internet, direct observations of markets and other growers). They also reported that the degree to which these growers monitored and recorded the profitability of their businesses ranged from intensive computer-based systems through to completely informal systems with no recording. However, little other information was provided on the growers' monitoring processes. Similarly, in a paper on problem detection, Ohlmer *et al*. (1997) identified the factors that influenced the process, but did not describe the type of information, method and frequency of data collection. Ohlmer *et al.* (1998) reported that farmers compared observations to expectations and if a significant difference was identified, "attention" was paid to the problem area. However, "attention" was also a function of the uncertainty of the information, farmer confidence in the information source, and triangulation with other information sources. Where a significant difference was identified and the uncertainty level of the information was low, greater attention was paid by farmers to the problem. Farmers initiate a new cycle of decision-making when information suggests that their goals or expectations are not likely to be met, that is, they detect a problem (Ohlmer *et al.*, 1998).

It is more common for decision-making studies to report on the sources of information used by farmers (e.g. Jacobsen, 1996; Ohlmer *et al.*, 1997; Ohlmer, 1998). Although this information may be useful, it provides little insight into the actual information farmers use to make decisions and in relation to the control process, how a deviation from the plan is identified. This is particularly important when numerous studies (Lockhart, 1988; Nuthall, 1992, 1996; Parker *et al.*, 1993; Nuthall and Bishop-Hurley, 1999) have shown that the majority of farmers tend not to use the formal monitoring and planning processes recommended in the management literature. Ohlmer *et al.* (1997) shed some light on this by noting that information provided to farmers is often in a quantitative form whereas most farmers think qualitatively (also confirmed by Paine (1997)). This may explain why farmers make limited use of this information. Alternatively, if important information is identified by farmers for decision-making, it is often for one-off strategic decisions such as investment, where monitoring post-investment is not discussed. For example, Jacobsen (1996) identified the factors that initiated a farmer's decision to make an investment in new machinery.

Catley *et al.* (2000) distinguished between problem detection and prospecting. Prospecting was equivalent to opportunity recognition, as previously defined in the normative literature (Lee and Chastain, 1960; Nielson, 1961), and involved the on-going search for new crops and technologies that could improve business performance. However, they did not elaborate on either of these processes.

3.4.3.2 Diagnosis and evaluation

The search processes to detect a problem can be distinguished from those used to diagnose the cause of a problem (Ohlmer *et al.*, 1998). Farmers either know the cause of a problem, or undertake a search to diagnose the cause. Given the repetitive nature of tactical decisions, the cause of a deviation (whether random or non-random) is likely to be known to the decision maker. Therefore, diagnosis would only be used by farmers when a novel problem was encountered. Ohlmer *et al.* (1998) made an important distinction between identifying random and non-random deviations from the plan. The outcome of the diagnosis determined the nature of the control response. No information was provided on how the farmers distinguished between random and non-random factors.

Few references are made about learning (or evaluation) in the descriptive decision-making literature. Farmers in a study by Ohlmer *et al.* (1998) continually updated their problem perceptions, ideas of options, plans and expectations when new information was obtained. The same farmers also introduced changes incrementally to learn from them before committing to a larger change as proposed by Chibnik (1981).

An alternative form of diagnosis is *ex-post* evaluation, although Ohlmer *et al.* (1998) reported that few farmers used this. Instead farmers used concurrent control to adjust their expectations for final outcome as new information became available. As a result of this feed forward and compensation approach, the farmers understood the reasons for a deviation from the plan before it occurred. Ohlmer (1998) found that farmers used *ex-post* evaluations when a decision was repetitive, e.g. the growing of a small experimental area of a new crop. However, only one out of the eighteen farmers in this study actively used the evaluation process to improve farm performance.

3.4.4 Control responses

Farmers appear to respond to problems in three ways: modify the existing plan, initiate a new planning process, or change goals (Ohlmer *et al.*, 1997). If a deviation from the plan was due to random factors, farmers initiated the modification of an existing plan and the implementation of a contingency plan. However, if a deviation from the plan was due to a non-random factor, the heuristics or planning method used to develop the plan were updated and a new plan developed. Aspiration levels or goals were adjusted through time in response to performance information and changes in the environment (Ohlmer *et al.*, 1998). Where poor conditions could not be compensated for, the farmers' performance aspirations were adjusted downwards. The main control response used by cutflower growers to the problem of declining profitability was the development of a new plan and the introduction of new crops (Catley *et al.,* 2000). Farmers also continually updated their problem perceptions, ideas of options, plans, and expectations as new information was obtained (Ohlmer *et al.*, 1998). Risk was also managed through the use of "experimental" incremental changes to learn about new options (Catley *et al.,* 2000; Ohlmer *et al.*, 1998) and through concurrent control (Ohlmer *et al.*, 1998).

3.5 The descriptive risk literature

The risk management literature also provides some insights into the management processes used by farmers. In the 1980's a number of authors began to question farm management research into risk (Jolly, 1983; Boggess *et al.*, 1985; Patrick *et al.* 1985). To make risk analyses "*manageable and mathematically tractable*", the majority of risk modeling work undertaken by farm management researchers only incorporated yield and price risk (Patrick *et al.*, 1985, p. 231). This narrow view ignored other important sources of risk that were more difficult to quantify and raised questions about the usefulness of such models irrespective of the validity of expected utility theory (Patrick *et al.*, 1985). These concerns prompted empirical research into farmers' perceptions of the sources of risk and the management strategies to cope with these (Boggess *et al.*, 1985; Patrick *et al.*, 1985). The sources of risk on farms have since been investigated in detail (Wilson *et al.*, 1993; Martin, 1994, 1996; Patrick and Ullerich, 1996; Martin and McLeay, 1998) (Table 3.1).

Table 3.1. A comparison of the ranking placed on different risk sources by livestock farmers in different studies.

Study	**Boggess *et al.* (1985)**	**Patrick *et al.* (1985)**	**Wilson *et al.* (1993)**	**Martin (1994, 1996)**		
Farm Type	Livestock	Livestock	Dairy[5]	Dairy	Sheep & Beef	Deer
Risk Source						
Market						
Product prices	1	1	2	1	1	1
Input costs	4	2	1	5	2=	8
Global economy	7	7	-	3	2=	2
National economy	-	-	-	4	2=	6=
Inflation	6	6	-	-	-	-
Capital equipment	8	9	-	-	-	-
Production						
Weather[6]	2	3	3	2/11	5=/11	10/13=
Pests and diseases	3	4	9	10	9=	4
Disasters	-	-	-	15=	16	17
Financial						
Interest rates	13	8	7	8=	8	9
Changes in land prices	-	-	-	13=	14	15
Credit availability	16	13	6	-	-	-
Use of leverage	14	12	10	-	-	-
Leasing of land	18	17	-	-	-	-
Human risks						
Labour/contractors	15	16	5	17	18	18=
Accidents or health problems	5	5	-	6=	5=	5
Changes in family situation	11	10	-	13=	12	13=
Theft	9	-	-	15=	15	11
Social and Legal risks						
Changes in government laws and policies	10	11	8	8=	7	3
Changes in local body laws and regulations	-	-	-	12	13	12
Changes in producer board policies	-	-	-	6=	10=	6=
Inability to meet contracts	-	-	-	19	19	18=
Changes in Government Agr programs	17	14	4	-	-	-
Technological risks						
Changes in technology	12	15	-	18	17	16

[5] Large-scale dairy farms milking on average 613 cows/day.
[6] Martin (1994) separated weather into variation in rainfall and variation in other weather factors. Thus on this row, the first figure separated by the slash represents rainfall and the second figure represents other weather factors.

Several of these studies are relevant to this thesis because they reported on farmers' perceptions of the sources of risk associated with livestock farming as summarised in Table 3.1. The early work of Boggess *et al.* (1985) and Patrick *et al.* (1985) reported that the four most important sources of risk to livestock farmers were product prices and input prices (sources of market risk), and weather and pests and diseases (sources of production risk). In contrast, financial risk was not ranked as an important source of risk by livestock farmers in these studies (Table 3.1). The studies by Wilson *et al.* (1993) and Martin (1994, 1996) both illustrate (Table 3.1) that perceptions and ranking of risk change with farm scale, external circumstances and farm/industry type. Farmers are also shown to be more concerned with business than financial risk.

Of particular relevance to this study, given the production focus, is how livestock farmers respond to production risk. Table 3.2 shows farmers' ranking of alternative risk management responses in relation to production risk. Unfortunately, the consistency of risk response categories between studies is poor and this limits the usefulness of the comparison. Boggess *et al.* (1985) and Patrick *et al.* (1985) reported identical rankings for production risk responses except that practice diversification and maintaining feed reserves were reversed in order. In these studies the preferred responses to production risk were enterprise diversification, production practice diversification and maintaining feed reserves and flexibility. Less preferred responses were idling capacity and geographic dispersion. For large-scale dairy farms, (Wilson *et al.,* 1993) only three risk management responses were identified (in order of ranking): using consultants, management information systems, and maintaining feed reserves.

Martin's (1994, 1996) studies of the risk responses used by New Zealand pastoral farmers indicated that the highest ranked risk management response across all farm types (dairy, sheep and beef, deer) was routine spraying and drenching, a response not mentioned in the other studies (Table 3.2). Maintaining feed reserves was ranked highly (1st or 2nd) as reported in other studies (Boggess *et al.*, 1985; Patrick *et al.*, 1985; Wilson *et al.*, 1993). With the exception of breed and production practice diversification in dairying, risks were ranked consistently across farm types. Martin (1994) concluded that New Zealand pastoral farmers preferred to cope with variation in climate by adapting to the changing conditions through feed reserves and short-term flexibility rather than by using irrigation. No mention was made of enterprise diversification or geographic dispersion in Martin's (1994, 1996) studies despite the former being the most important risk management response in both Boggess *et al.'s* (1985) and Patrick *et al.'s* (1985) studies.

Table 3.2. A comparison of the ranking of alternative risk management responses used by farmers to manage production risk.[7]

Study	Boggess *et al.* (1985)	Patrick *et al.* (1985)	Wilson *et al.* (1993)	Martin (1994, 1996)		
Farm Type	Livestock	Livestock	Dairy[8]	Dairy	Sheep & Beef	Deer
Production risk responses						
Enterprise diversification	1	1	-	-	-	-
Breed &production practice diversification	2	3	-	6 (39)	4= (69)	3= (74)
Maintaining feed reserves	3	2	3	2 (96)	1= (94)	2 (92)
Maintaining flexibility	4	4	-	3 (80)	3 (80)	3= (71)
Idling production capacity	5	5	-	5 (43)	4= (63)	5 (51)
Geographical dispersion	6	6	-	-	-	-
Use of consultants	-	-	1	-	-	-
Management information systems	-	-	2	4 (49)	5 (47)	6 (39)
Routine spraying and drenching	-	-	-	1 (92)	1= (95)	1 (94)
Irrigation	-	-	-	7 (10)	6 (15)	7 (14)

3.5.1 Tactical versus strategic responses to risk

Management responses to cope with risk at the strategic or tactical level is not differentiated well in the literature. Wright (1985) suggests that uncertainty should decline as the planning horizon shifts from longer-term to shorter-term. He therefore noted that it may be possible to use deterministic optimising models for tactical planning. Most prescriptive risk modeling papers analyse enterprise mix choices for a one year time frame (e.g. Trebeck and Hardaker, 1972; Mapp *et al.*, 1979; Pederson and Bertelsen, 1986; Darke, 1994; Teague *et al.*, 1995) although some studies have analysed longer time frames and looked at additional factors such as leverage and rental arrangements (e.g. Parton and Cumming, 1990). Risk management at the tactical level is rarely discussed. Exceptions to this were Darkey's (1989) conceptual paper on the use of decision support systems for tactical risk management and more recent investigations of risk modeling at the tactical level (Kingwell *et al.*, 1992; Stafford Smith and Foran, 1992). Decision analysis is also suitable for use in tactical decision-making and numerous papers have been written on its application to short-term decisions (e.g. Anderson, 1974; Gold *et*

[7] The figures in brackets are the percentage of respondents that claim to use the risk management response.
[8] Large-scale dairy farms.

al., 1990), although in most cases, no comment is made as to the tactical context of such decisions.

In general, the literature on risk management does not distinguish between strategy and tactics. Rather, responses are differentiated on the basis of the source of risk (market, production or finance) that they are designed to mitigate. Martin (1994), however, did differentiate between long- and short-term flexibility. She defined short-term flexibility as "*the ability to adjust quickly to changes in weather, prices and other factors*" (p. 366). This definition is synonymous with tactical management. Interestingly, Martin (1994) found that over 70% of the pastoral farmers surveyed used short-term flexibility to manage risk. Despite its apparent importance, analysis of the risk management responses cited in the literature (see Table 3.2) shows that the majority of these responses are medium- (≥ 1 year) to long-term in nature e.g. enterprise diversification, maintenance of feed reserves, use of futures contracts, maintaining low debt levels, rather than tactical. The emphasis on medium- to long-term risk management activities may reflect the influence of the whole farm planning literature. However, it does identify an area for future research.

3.6 Summary and conclusions

This chapter has provided a brief critique of the normative literature and identified areas where findings from the descriptive literature are in conflict with normative theory. Important descriptive studies into the tactical management practices used by farmers were then reviewed. These studies suggest that at the tactical level farmers do not use the formal quantitative planning processes advocated in the normative literature. Instead, pre-defined plans, developed over time and based on experience are used. These comprise an overall objective, a predictive planning schedule, intermediate objectives (or standards) and a set of contingency plans and associated decision rules. The latter two are essential for control. Heuristics within the plan determine the structure of the predictive planning schedule. The control process is essential for plan implementation and the intermediate objectives and contingency plans play an important role in minimising the impact of variation in the environment. However, despite the importance of the control process, little is written about monitoring or evaluation.

Survey data suggests that the adoption of formal planning and monitoring techniques by farmers has been limited and possible reasons for this were identified. The descriptive literature on decision-making was reviewed. This highlighted that few descriptive studies had been undertaken, and that the focus of these had been at the strategic as opposed to tactical level. The results of these studies also suggested that farmers tend to use informal heuristic-based planning processes rather than the formal quantitative planning processes advocated in the normative literature. As with the descriptive management literature, little was written on control in the decision-making literature.

Finally, the descriptive literature on risk was reviewed. Important sources of risk were identified. Farmers' perceptions of risk were a function of their socio-economic characteristics, the instability of their objective environment, the type and size of farm, and the industry to which they belonged. A farmer's choice of risk management strategies was also related to these factors. Little mention was made of risk management at the tactical level in the descriptive risk management literature although short-term flexibility was identified as an important risk management response. The literature in this chapter and in Chapter Two has identified concepts relevant to a longitudinal study into the tactical management processes used by high performing dairy farmers. The next chapter outlines the research method used in this study.

CHAPTER 4 METHOD

4.1 Introduction

Farm management has been criticised for its lack of relevance to practitioners and the gap between theory and practice (Sections 2.3.1 and 3.1). These problems are largely attributed to the normative nature of mainstream farm management research, the artificial cleavage of planning and control, and the undue influence of production economics. Consequently, empirical research into the management processes used by farmers has been scarce. The paucity of empirical research is also reflected in the use of inappropriate research methods. Management is a complex process that occurs through time. An investigation of tactical management would incorporate timeframes of between three to twelve months, while strategic management might involve a period of two to ten years. Surveys have traditionally been the primary means for data collection in studies of the management capacity of farmers (Howard and MacMillan, 1991; Rougoor *et al.*, 1998). Such studies tend to be executed without repetition and for a single point in time. They also tend to relate farmer success to easily measured variables such as age, experience and education (Howard and MacMillan, 1991; Rougoor *et al.*, 1998). As Howard and MacMillan (1991, p. 3) noted what remains "*Uninvestigated is the 'how' of decision making.*" Alternatively, the management capacity of farmers can be studied in laboratory settings using computer simulations. However, the validity of this approach is open to question due to the artificial nature of the setting (Rougoor *et al.*, 1998).

To investigate farmers' management processes effectively, longitudinal research techniques such as case studies that enable the planning, implementation and control processes used by farm managers to be recorded are required (Howard and MacMillan, 1991; Rougoor *et al.*, 1998). They provide insight into the management processes used by successful farmers (and farmers in general), and serve as the basis for improving the management practices of farmers (Rougoor *et al.*, 1998). At the time this study was initiated (late 1991), few studies of the management processes used by farmers had been reported. Similarly, little was written on the most effective methods for investigating the processes of farm management. This suggested that one of the constraints to the theoretical development of the discipline resided in the area of methodology. Literature from a range of other disciplines was therefore drawn on for this chapter on potential methods (Howard and MacMillan, 1991). First, the research method used in this study is described. Second, the means by which the rigour of the research method was maintained are explained.

4.2 Choice of research strategy

Five research strategies were identified by Yin (1989): experiment, survey, archival analysis, history and case study (Table 4.1). He then defined three criteria by which the choice of research strategy can be decided: the type of research question, the degree of control over behavioural events and the temporal focus of the research. Yin's (1989) typology of research strategies suggests that the research objectives of this study would be best met through case studies (Table 4.1). The focus of the investigation is about how and why dairy farmers manage tactically. Control over behavioural events is not required because management is best investigated in a natural setting. Contemporary as opposed to historical events are the subject of the investigation.

Table 4.1. Criteria by which to select an appropriate research strategy (Source: Yin, 1989).

Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	how, why	yes	yes
Survey	how, what[1], where, how many, how much	no	yes
Archival analysis	who, what[1], where, how many, how much	no	yes/no
History	how, why	no	no
Case study	how, why	no	yes

[1] "What" questions, when asked as part of an exploratory study, pertain to all strategies.

4.3 Definition of a case study

A case study is "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident and in which multiple sources of evidence are used.*" (Yin, 1989, p.23). Data must be collected on both context and the phenomena, unlike experiments that attempt to divorce phenomena from their contexts so that attention can be focused on a few important variables (Yin, 1993). Similarly, the survey researcher's desire to limit the number of variables means that context is only investigated to a limited degree (Yin, 1989). Thus the case study design suits research questions where there are a large number of variables and a small number of data points (or units of analysis) (Yin, 1993). A case study is characterised as an investigation that is conducted in great detail and often uses multiple sources of data (Yin, 1984, 1989, 1993; Berg, 1990; Orum *et al.*, 1991). The need to study phenomena in-depth presupposes the use of qualitative data collection methods (Orum *et al.*, 1991). Others (Eisenhardt, 1989; Yin, 1989, 1993) however, believe that the case study method can use qualitative or quantitative data. Aternative case study designs are described in detail by Yin (1993) and Eisenhardt (1989) and are elaborated on by Gummesson (1991) and Strauss and Corbin (1990). For the purposes of this research it was concluded that a theory building or theory elaboration case study approach was best suited to obtaining the empirical data required (Eisenhardt, 1989; Vaughan, 1992).

4.4 Research design - an overview

A research design is a logical sequence that links the empirical data to the research questions of the study and ultimately to its conclusions (Yin, 1984, 1989). Important factors to consider in a case study research design include a study's questions, the role of extant theory, its unit(s) of analysis, the method of data collection and the data analysis procedure (Kaplan, 1964; Nachmias and Nachmias, 1976, 1996; Philliber *et al.,* 1980; Yin, 1989; Gummesson, 1991; Eisenhart and Howe, 1992; Lockhart, 1997).

Four types of case study design (Figure 4.1) were identified by Yin (1989). A researcher may choose between an embedded or holistic design and between a single- or multiple-case study design. This study is embedded because the focus of the study or units of analysis are the planning, implementation and control decisions made by the cases at the tactical level. A holistic design does not have embedded units of analysis. The multiple-case design has a number of advantages and disadvantages when compared to the single-case design (Yin, 1989; Eisenhardt, 1991). These essentially relate to time and resource requirement versus robustness of data. For this study an embedded multiple-case study design was adopted to allow comparison (Berg, 1990) of the tactical management processes used by "expert" dairy farmers in different locations. Cases were chosen that would provide literal replication between cases and across years (Yin, 1989; Eisenhardt, 1991). Each case comprises the tactical management decisions made by an "expert" dairy farmer over the summer-autumn and these cases were studied over three years.

	Single-Case Designs	Multiple-Case Designs
Holistic (Single unit of analysis)	Type 1	Type 3
Embedded (Multiple units of analysis)	Type 2	Type 4

Figure 4.1. Basic types of designs for case studies (Source: Yin, 1989).

An overview of the embedded multiple-case study research design is provided in Figure 4.2. During the design phase, once the research problem was clarified, an initial review of the extant theory or literature was undertaken to identify important concepts and relationships. This provided the basis for the design of the data collection protocol which was tested in a pilot study and refined. The theory was then used to develop criteria for the selection of the case studies. During the second phase, data was collected from each of the case studies in tandem rather than in sequence as advocated by Yin (1989) because the cases were to be compared in the same years. Data in the form of interviews, field observations and documents was collected for three years. In total some 30 interviews were undertaken over the period of the study. Preliminary data analysis was undertaken after each interview but in-depth analysis was not completed until after the fieldwork. During the theory building process overlap between data collection and data analysis is common (Eisenhardt, 1989).

For each year, each case study was analysed in-depth using qualitative data analysis techniques and the results were summarised as case reports (Figure 4.2). A within-case, cross-year analysis was completed using the years one-to-three case reports. From this analysis a single-case report was written for each case study. The literature review was on-going over the period of the data collection and analysis to keep abreast of developments in management theory and methods (Patton, 1990; Strauss and Corban, 1990; Gummeson, 1991). Findings from the data also pointed to additional areas in the literature that needed to be pursued and highlighted concepts that differed between cases and required further investigation. Finally, a cross case analysis was completed, and results from this were compared to the extant theory which was adjusted accordingly.

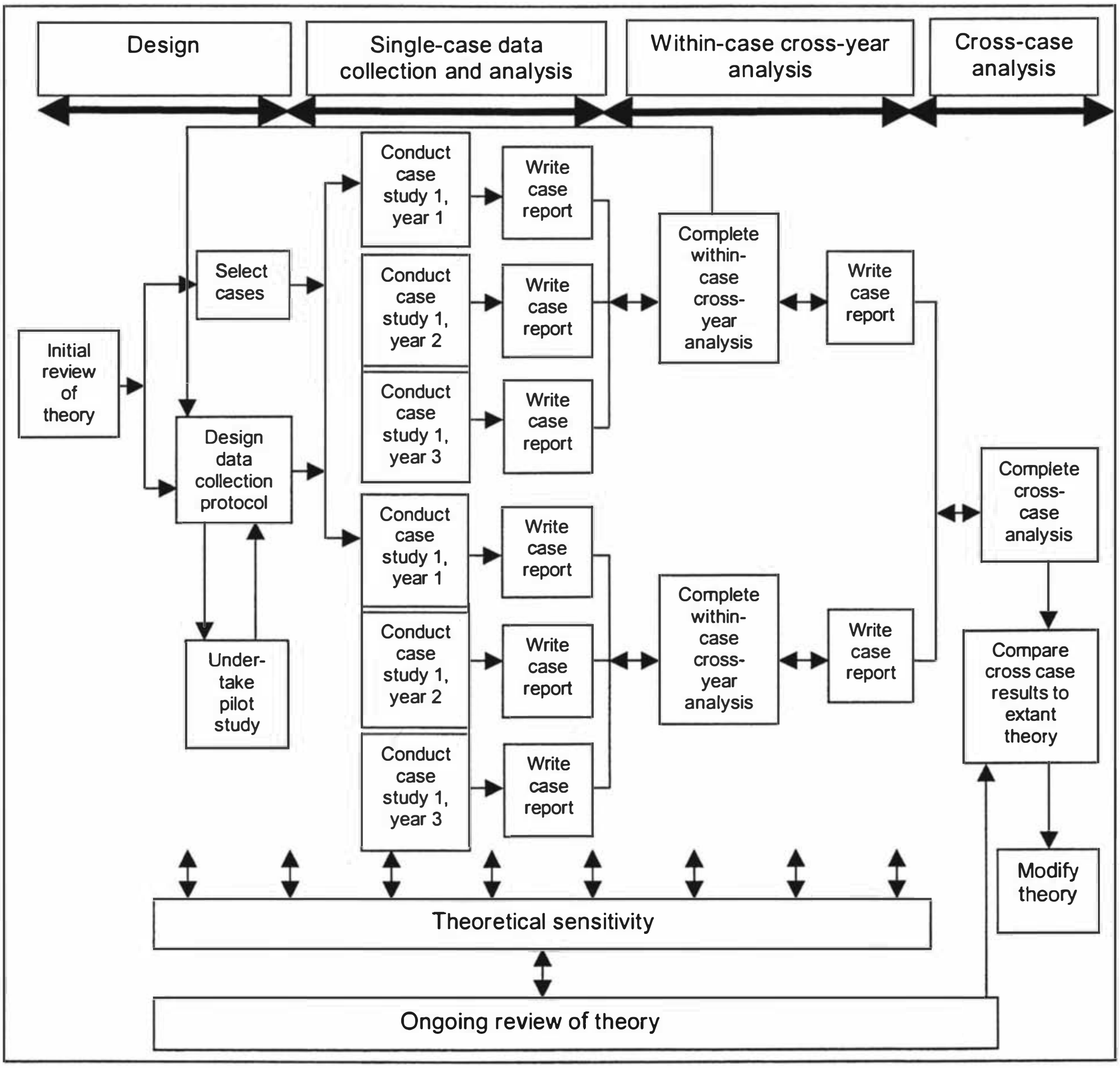

Figure 4.2. Case study method (Adapted from Yin, 1989).

4.4.1 Case selection

Case selection involves two key questions: (i) what criteria are used to select the case and (ii) how many cases should be studied. Decisions about sample size and sampling strategy depend upon prior decisions about the appropriate unit of analysis, a critical component of any research design (Yin, 1989, Patton, 1990). In case study research, the unit of analysis is the researcher's basic definition of the case (Yin, 1989). A case can be defined as an instance of a broader phenomenon or as part of a larger set of parallel instances (Orum *et al*., 1991). Cases are of little use unless they are incorporated into some typology of general processes, made causally explicit and related back to some universe of cases they represent (Walton, 1992). Therefore, typological distinctions must be made so that cases can be fairly compared within a study (Ragin, 1992).

The aim of a case study is to generalise beyond the specific case (Walton, 1992). Case definition should therefore cover three important areas (Vaughan, 1992). First, the similarities and differences between the cases must be specified. Second, the impact of these on the case study findings must be explained and third, the theoretical consequences for comparison between cases should be specified. Failure to publish this information makes it difficult for other researchers to build on the work (Vaughan, 1992). Similarly, researchers should define their unit of analysis in such a way that it is consistent with other studies in the literature so that they can be compared (Yin, 1989).

The sampling logic for a case study is quite different from that used in a survey. Purposive or theoretical sampling as opposed to statistical sampling procedures are used (Glaser and Strauss, 1967; Yin, 1984; Patton, 1990; Gummesson, 1991). The objective is to select "information-rich" cases, that is those from which a great deal can be learnt about issues central to the research purpose. The sampling strategy adopted for this study was an extreme or deviant case sampling (Patton, 1990). Here cases are selected because they are unusual or special such as displaying outstanding success in the area of interest. For this study the farmers had to be recognised as "experts" in the tactical management of a seasonal supply dairy farm over the summer-autumn period and capable of articulating that "expertise" (Hoffman, 1992). They also needed to be within the Manawatu region to allow ease of access by the researcher. Finally, they had to be comfortable with divulging information during a two to three hour visit every two to four weeks over the summer-autumn period for three years. The focus of the study was at the tactical, as opposed to strategic or operational level, and because "expert" farmers were selected, the decisions they make were assumed to be structured as opposed to unstructured in nature. The planning, implementation and control decisions made by the case farmers are the embedded units of analysis for this study and the management field relates primarily to production management as opposed to finance or marketing. In relation to the level of uncertainty faced by the case farmers, production risk is high primarily due to the influence of climate on pasture growth, but other sources of risk (market and financial) are low. Important theoretical characteristics of the case study also emerged during the investigation (Walton, 1992; Ragin, 1992ab, Vaughan, 1992). For example, multiplicity of enterprises[2] was identified as a theoretically relevant characteristic during analysis.

An experienced local consultant, an "informal gatekeeper" (Seidman, 1998), short-listed 10 possible case farmers. Each was reviewed by the author and two cases were selected and observed over three years to obtain information on between-year variation. This in effect provided six case studies (two cases by three years) and was within the range of four to 10 cases recommended by Eisenhardt (1989).

In early October 1991, the case farmers were contacted by telephone and asked if they would be willing to discuss their involvement in the study. A document outlining the purpose of the study, the method, time frame and time commitment was sent to them in preparation for a pre-study interview and briefing (Kvale, 1996; Seidman, 1998). Once they had agreed to be involved in the study, permission was obtained to tape and transcribe the interviews and their commitment to a three year study was confirmed.

4.4.2 Data collection

Data collection in case study research requires the answers to two important questions (Maxwell, 1986): what data to collect, and how often to collect it. The method of data collection is also an important issue. Little guidance is provided in the literature on the frequency of data collection, but Maxwell (1986) recommended 10 daily intervals for studies of farming systems. Logistically, this was not possible with the current study, and fortnightly intervals were trialed initially. This was then extended out to monthly intervals as it became clear that the case farmers could remember their tactical decisions over this longer time frame. Mintzberg *et al.* (1976) also reported that managers could accurately recollect recent important managerial decisions. The semi-structured interview or

2 Both case studies were single as opposed to multiple enterprises. Therefore, tactical decisions that determined resource priority between enterprises were not identified.

interview guide approach was deemed to be the most appropriate data collection method for this study (Cordingley, 1989; Patton, 1990; Scott *et al.,* 1991). This was because little was known about the nature of the phenomena, the case farmers' tactical management processes. Secondary data was collected through field observations and documents (Yin, 1984, 1989; Patton, 1990).

A data collection protocol was designed based on a high level model of the management process of planning, implementation and control, developed from the normative literature review in Chapter 2 (Yin, 1984, 1989). This study was initiated in the second half of 1991, and at that stage, little had been written on the management processes used by farmers. The majority of the French work was not published until after the first two years of data collection had been completed. Prior to selecting the three case farmers, a pilot study (Yin, 1989) was undertaken to test the feasibility of obtaining detailed information about the tactical management process used by farmers over the summer-autumn. The farmer used for this pilot study was recognised in the district as a "good" farmer. The data collection protocol was refined during the pilot study, which comprised four, two hour semi-structured interviews. The pilot study demonstrated that it was possible to obtain an in-depth understanding of a farmer's tactical management process through interviewing.

The two case studies were investigated in tandem over the three years. This enabled observations of how each case farmer managed the same changes in climatic conditions. In November 1991, each case farmer was visited and interviewed to obtain basic descriptive data on the case farm before the in-depth study was initiated. This included the case farmer's background, family situation, resource base, production levels, and an overview of their farming system. An overview of their summer-autumn management was also obtained. This confirmed that the data collection protocol, developed during the pilot study, was suitable. A farm walk was undertaken to view the farm and livestock. This information provided a context for understanding the case farmers' responses (Patton, 1990).

The time frame for the interviews was set for between early January through until drying off (April/May). The initial interviews had suggested that the case farmers' planning horizons went from late December/early January through to mid March, and then from mid March to calving or early lactation. Thus, data could be captured for a full planning period over the summer, the transition from one planning period to the next, and part of a second planning period that terminated with drying off in late autumn. The drying off date was a clear terminating point.

The first in-depth interview with the case farmers was undertaken in early January, 1992. A semi-structured (Scott *et al.*, 1991) or non-scheduled standardised interview was used (Denzin, 1989), i.e. the author had a list of the information he required from the case farmers, but the sequence and way in which questions were asked to obtain this information was tailored to the specific case farmer and situation. Prior to the visit they were briefed, over the telephone, on the question areas they would be asked, which were then sent in the post for their perusal prior to the interview. The broad set of questions covered is illustrated in Figure 4.3. The case farmers were also asked to explain the reasons behind their management practices.

Planning

1. What is your planning horizon?
2. How did you plan for this period?
3. What were your goals and targets for the planning period?
4. What was the state of the case farm at the start of the planning period and what resources were available throughout the planning period?
5. What is your plan for the next period?
6. What contingency plans might you use during the next period?

Implementation and Control

1. What are your current cow numbers and how has this changed since the last visit?
2. What are your current cow condition and how has this changed since the last visit?
3. What is your current milk production and how has this changed since the last visit?
4. What is the reproductive status of the herd and how has this changed since the last visit?
5. What is your current average pasture cover and how has this changed since the last visit?
6. What is your current pasture growth rates and how has this changed since the last visit?
7. What is pasture quality like and how has this changed since the last visit?
8. What is your current rotation length and how has this changed since the last visit?
9. What is the current level of supplement (hay, grass, silage, maize silage) on the farm and how has this changed since the last visit?
10. What is the current state of your crop and how has this changed since the last visit?
11. What has the climate (rainfall, temperature, wind, cloud cover) been like since the last visit?
12. What information was monitored over the last period (including method and monitoring interval)?
13. How was this information used in decision making?
14. What decisions did you make since the last visit and how were these made?
15. Which decisions differed from those specified in the plan and why?
16. What evaluations did you undertake since the last visit and how were these made?
17. What learning has occurred since the last visit?

Figure 4.3. Broad question areas covered on planning, implementation and control, respectively, during interview one.

Simple non-threatening closed questions about the state of the farm were asked first to relax the interviewee (Patton, 1990). These were followed by more detailed open questions once the case farmers were relaxed. Probing and follow up questions were used to obtain more information on each of the important areas (McGraw and Harbison-Briggs, 1989; Patton, 1990; Scott *et al.*, 1991). Other techniques such as clarifying and confirmatory questions were also used to develop understanding of important areas (Scott *et al.*, 1991). The case farmers were also asked to explain the reasons behind particular activities, targets or goals. Although the author had a reasonable knowledge of dairy farm management, it was sometimes necessary to clarify concepts used by the case farmer to ensure a common vocabulary. Decisions were made about which areas to pursue in more depth during the interviews. Active listening was critical for identifying such areas (Denzin, 1989; Scott *et al.*, 1991). The interview was taped and transcribed (Patton, 1990; Scott *et al.*, 1991). A summary was made of the interview and sent to the case farmer for verification along with an outline of the questions for the next interview (Scott *et al.*, 1991).

Multiple forms of evidence other than interviews were used in this study as a form of triangulation to confirm findings. When time allowed, a field inspection would follow the interview to verify the state of the farm and discuss the case farmers' monitoring systems. They could demonstrate exactly what they were monitoring, and occasionally because of the tacit nature of their knowledge, these sessions would identify important points not covered in the interviews. This new information was either discussed in the field using a hand-held tape recorder, or notes were taken and key points were discussed back at the house or at the next interview. Some secondary data (Yin, 1989) such as copies of the case farmers' feed budgets were collected. Other secondary data including the farmers' diaries, dairy company milk production dockets, herd test results, and pregnancy test results were observed at the farm, but not copied.

Information from the first interview, once summarised, provided an overview of the case farmers' goals, their planning process and plans for the summer-autumn, the factors they would monitor, the targets they would use for control, and the contingency plans they might activate. This information formed the basis for the subsequent interviews through the summer-autumn period. The structure of the subsequent interviews followed a fairly standard protocol. First, the case farmers were asked if there was anything in the summary from the previous interview that had been misinterpreted. If this was the case, these areas were clarified. They were then questioned about the state of the farm and changes that had occurred since the last visit. The farm state included the feed, livestock, and climatic information (Figure 4.3). Decisions made since the last interview and why these had been made were then discussed. The monitoring process used by the case farmers since the last visit and its role in decision making was also investigated. Any evaluations made during this period were identified along with the factors that had initiated these, the process used and the outcome of the process. Finally, their plans for the remainder of the study period, the process they undertook to formulate these and the planning horizons used were explored. The reasons behind particular actions were elicited. Similarly, where the plan differed from what a case farmer implemented, reasons were sought to explain the deviation. The interviews normally required one to two hours to complete, and the actual length was mainly a function of the number of decisions the case farmers had made over a period.

The final interview for each year was completed after the case farmers' had dried off their herds in late autumn. A follow-up interview was only undertaken if the case farmer identified an area that had been misinterpreted in the resultant interview summary. An attempt was made during the first year to investigate the case farmers' summer-autumn management processes during the winter months. However, this was not successful because they could not recall the level of detail required. The research time was therefore limited to the period when the management decisions of interest were being made.

The data collection process was repeated in years two and three. The main between-year difference was that the detail collected in year one, such as on the planning process, planning horizons, reasons for particular actions and so-on, did not need to be repeated, only confirmed. The major focus was on changes in management relative to year one and the reasons for these. Some areas overlooked in year one were identified. This again, appeared to be a problem of discovering tacit knowledge, and the case farmers not knowing what they did at an almost subconscious or pre-attentive level (Gladwin and Butler, 1984). Such omissions were not common, and in most cases were identified during a field visit when a chance remark initiated questions on an area not previously discussed.

In year three, an adjustment to the data collection protocol was made and a simple diary system (Volume II, Appendix I) was used between interviews. The case farmers were asked to record information about the farm state, the decisions they made between interviews, their monitoring and evaluation processes and any other relevant information about such decisions. This simplified the interview process because the farmers could remember more clearly the decisions they had written down. Eisenhardt (1989) mentioned that one of the benefits of the case study method was that the data collection protocol could be changed during the study. She noted however, that this is not a license to be unsystematic and that the protocol should only be changed if it will lead to better theory. Interviews were also used after the within-case analysis to confirm the case reports for each year and to collect further information identified as missing and relevant during the data analysis phase.

To obtain a clear picture of farmers' decision-making, rapport must be developed (Doorman, 1990). The longitudinal case study allows longer term contact with farmers and this facilitates the development of rapport (Maxwell, 1986), although there is a balance where too much or too little rapport can create problems in terms of data collection (Seidman, 1998). The objective is to develop neutral rapport where the interviewee feels comfortable telling the interviewer anything without expecting either a positive or negative reaction. Rapport was developed with the case farmers through taking time to explain the project in the early stages, ensuring their comments were respected, maintaining confidentiality and continuing contact outside the study period (Seidman, 1998).

4.4.3 Data analysis

Yin (1989) considered that data analysis is one of the least well developed aspects of case study research since there are few standardised procedures for the analysis of case study data. The analytical techniques that are used tend to be those adopted from qualitative research (Miles and Huberman, 1984; Tesch, 1990; Dey, 1993; Kelle and Laurie, 1995). Data analysis can be separated into within- and cross-case analysis (Yin, 1984, 1989, 1993; Eisenhardt, 1989).

4.4.3.1 Within-case analysis

Within-case analysis is the heart of the process of theory building from cases (Eisenhardt, 1989). However, despite its importance, it is one of the least well documented parts of the case study approach (Miles and Huberman, 1984; Eisenhardt, 1989; Dey, 1993). This has in part, been attributed to the constraints placed on reporting procedures in journals that provide limited space for description of data analysis procedures (Eisenhardt, 1989; Dey, 1993). Another major problem faced by researchers who use the case study approach is the large volume of data that they must analyse (Eisenhardt, 1989; Chetty, 1996). For example, in this study some 30 interview transcripts each comprising 15 - 20 pages of text were analysed. The within-case data analysis process used in this study was a modified version of the qualitative data analysis procedure advocated by Dey (1993). He separated analysis into an iterative process of describing, classifying and connecting where several cycles may be completed before the analysis is finished. The following sections describe the within-case analysis process providing an overview of the first iteration for the first transcript and then the subsequent analyses.

4.4.3.2 Description

Description is the process where the data in a transcript is summarised to provide a thorough and comprehensive account of the phenomenon of interest, a "*thick description*" (Geertz, 1973; Denzin, 1978; Dey, 1993), and the context in which it occurred (Patton, 1990; Dey, 1993). The transcript of interview one for case study one was summarised (Dey, 1993) under the headings farm state (context), planning and control. Within these major headings, concepts and sub-processes were then separated out under important sub-headings. Diagrams were used to elaborate important points or sub-processes identified in the data (Strauss and Corbin, 1990; Dey, 1993). Examples of these included decision rules, time lines, process and causal models, and matrices. The latter were used for classifying the components of the monitoring process. The summary was also used to identify potential categories and important relationships (logical, process and causal) in the data. It also played an important role in maintaining the holism of the data (Chetty, 1996; Kvale, 1996). Because the qualitative data analysis process advocated by Dey (1993) is iterative, several versions of a transcript summary may be written. For example, some eight versions of the first summary for case study one were written. The number of iterations undertaken for later interview transcripts declined (to around three per interview transcript) because few new categories and relationships were identified.

4.4.3.3 Classification

Classification is the process by which data in the transcript is classified into well defined categories, sub-categories and supra-categories (Dey, 1993). Classification is important for the development of a conceptual framework that makes the actions of the subject intelligible and facilitates comparison (Glaser and Strauss, 1967; Strauss and Corbin, 1990; Dey, 1993; Maykut and Morehouse, 1994). A computer software program called NUDIST (Non-numerical Unstructured Data Indexing Searching and Theorising) (Richards and Richards, 1994) was used to classify or code the data. It allows the coding of on-line documents such as interview transcripts and field notes, and off-line documents such as company reports. The strengths of the program are that data can be quickly coded, nodes are easily modified in terms of names, definitions and position in the tree structure, evidence stored in each node along with supporting memos can be readily accessed and printed, and powerful search tools assist the identification of further evidence for the existence of categories or relationships.

NVivo (Richards, 1999) a related program which has all of these capabilities as well was used part way through the analysis. It has the additional options of allowing the researcher to develop models from the concepts in the tree structure. As with the categories, text units that demonstrate linkages or relationships between categories can be stored in a node representing the linkage. These linkages can also be named and defined. The transcripts from interview one were entered into the NUDIST program. The data was analysed and text units were placed in nodes that were named and defined. The nodes were then arranged in a tree structure or hierarchy based on logic.

A form of comparative analysis (Glaser and Strauss, 1967; Miles and Huberman, 1984, 1994; Straus and Corbin, 1990; Dey, 1993) where the text was broken up into "*units of meaning*" (Maykut and Morehouse, 1994) was used to classify the data. A unit of meaning was compared to other text units that had been grouped under a category, and the category's definition, to identify whether it was similar or different from the category (Dey, 1993; Maykut and Morehouse, 1994). Central to this process is the category definition (Dey, 1993). In this study, the extant theory provided the majority of the categories because the process the case farmers used could be described using a predominance of existing concepts. The process of writing a summary identified a number of categories as did the classification process (Dey, 1993). A limited number of new categories were identified, and these related mainly to the control process.

Categories must be grounded conceptually and empirically. That is, they must relate to the wider theoretical context of the study, and the empirical data (Dey, 1993). Sub-categories were developed where theoretically important distinctions were identified between the data within a category (Strauss and Corban, 1990). Similarly, categories were combined into a supra-category if it provided a useful theoretical concept (Strauss and Corbin, 1990; Dey, 1993). The structure of the category hierarchy was determined by logic (Dey, 1993; Araujo, 1995; Richards and Richards, 1995). The classification process is dialectical and involves iterations between the data and the category name, definition and location in the category hierarchy (Dey, 1993). As the data was analysed, categories were redefined, renamed, repositioned in the tree structure, merged, and/or separated out into sub-categories.

4.4.3.4 Connection

The final step in the qualitative data analysis process is connection (Dey, 1993) or axial coding (Glaser and Strauss, 1967; Strauss and Corbin, 1990). During connection, relationships between categories in the data are identified and defined. In effect, the classification process has broken down the data, and axial coding puts it back together in a new way. These may be explanatory, causal relationships or chronological relationships that depict a process (Dey, 1993). The data collection protocol made it relatively simple to identify the relationships between categories and develop a model of the tactical management process used by the case farmers. The majority of connections were relatively explicit in the data. These included the sequence in which planning, implementation and control occurred, the schedule of planned and actual events and the reasons for these events, the change in conditions that brought about the implementation of a contingency plan and how these were monitored. These connections were identified in the data through linking words or conjunctions (Dey, 1993) such as "and then", "because", "therefore", “as a result", "and after that", "as a consequence" and so on. Some processes such as decision rules were more difficult to identify in the data (Strauss and Corbin, 1990) because they involved several relationships, some of which were inferred from the context.

The relationships identified during the connection phase of the research were initially specified in memos (Strauss and Corban, 1990; Dey, 1993; Richards and Richards, 1994), but the author found it more efficient to write these directly into the next iteration of the transcript summary. Often these were recorded as diagrams (Miles and Huberman, 1984, 1994; Strauss and Corbin, 1990) that provided a concise overview of emerging relationships, which was useful for further analysis (Strauss and Corbin, 1990). Tables, time lines, matrices, flow diagrams, decision rules and decision trees were also used to assist in the analysis (Miles and Huberman, 1984, 1994).

4.4.3.5 Subsequent analysis

After the first iteration through the phases description, classification and connection, a second summary was written drawing on the previous summary, the transcript, and the category hierarchy. This second summary was much more detailed than the first because the in-depth analysis had identified a lot more information than was obtained during the first summary. The structure of the category hierarchy was used to structure the summary. The writing of the second summary also raised questions about the category hierarchy. Following the writing of the second summary, the data was re-analysed in terms of categories and connections and then a further summary was written. Several iterations of the process were undertaken before the author was comfortable with the analysis.

The process was then repeated for the other five interviews undertaken with case study one in year one of the investigation. It was much less time consuming than for the first interview because the majority of categories and relationships had been identified and defined and the analysis process was mainly about matching the data to existing categories. The final node structure contained over 400 categories.

Once the individual interview summaries were completed, these were combined into a case report for year one. The process of writing the summary identified further refinements that could be made to the category hierarchy and connections. In some instances, this resulted in a reinterpretation of the data and changes to the category hierarchy and summary. Tables and diagrams were used where possible to illustrate the findings as suggested by Miles and Huberman (1984, 1994). This helped identify areas that required further analysis or clarification. The case report, raw data and category hierarchy were then provided to the author's supervisors for peer assessment in order to avoid problems with the mis-interpretation of data. Areas of contention were discussed and changes made where necessary before a final case report was written up for year one (Volume II, Appendix XX). Within-case analysis normally involves a detailed report on each case that is often pure description, but is essential for gaining insight into the phenomenon of interest (Eisenhardt, 1989). The above process was then repeated for years two and three for case study one. Case reports were written up for years two and three (Volume II, Appendices XX - XXII). The same within-case analysis process was also carried out for case study two and case reports written (Volume II, Appendices XXIII – XXV).

The aim of within-case analysis is for the researcher to become intimately familiar with each case and for the researcher to identify the individual patterns within each case prior to beginning the cross-case analysis (Eisenhardt, 1989). The case reports written for this study (Volume II, Appendices XX - XXV) used a combination of methods to present an overview of the data. The majority of the case report was in written form and summarised under important headings. Tables, matrices and diagrams were used to show some of the more complex areas, or to summarise key points (Miles and Huberman, 1984, 1994).

4.4.3.6 Within-case, cross-year analysis

Little mention is made of within-case, cross-year analysis in the literature. The main focus of the cross-year analysis was to identify between-year differences in the case farmers' tactical management and the reasons for these differences. Tables, diagrams and matrices (Miles and Huberman, 1984, 1994) were used to assist with the cross-year analysis. The cross-year analysis also resulted in further refinement to the results because it forced the researcher to look at the data in new ways. A case report for each case study for the three years was written. The structure of the report followed that of the previous case reports, except that a more abstract report was written with examples, and much of the detailed results were placed in the appendices as tables and matrices (see Chapters 5 & 6).

4.4.3.7 Cross-case analysis

Once the within-case analysis is completed, cross-case analysis is used to determine why different cases produced similar or different results (Yin, 1989; Eisenhardt, 1989). In this study, categories that were important components of the tactical management process formed the basis for the cross-case comparison (Eisenhardt, 1989). Because only two cases were investigated, selected paired and group comparisons were not possible (Eisenhardt, 1989). Similarly, the majority of data was in the form of interview transcripts and there was insufficient secondary data to analyse the data by source (Eisenhardt, 1989). As with the within-case analysis the primary method of cross-case analysis was the use of tabular displays or matrices (Miles and Huberman, 1984, 1994) similar to those used by Chetty (1996) and Crawford (1996). The tabular displays allowed the differences and similarities between the cases for important theoretical areas to be quickly identified. Diagrams of the processes used by the cases were also compared to identify similarities and differences.

In cross-case analysis, Yin (1984) advocated a replication strategy where a theoretical framework is used to study a case in depth and then successive cases are investigated to determine whether the pattern found matches that in previous cases. Alternatively, cases may be selected on theoretical grounds to exhibit a different pattern (Yin, 1984; Vaughan, 1992; Miles and Huberman, 1994). In this study, the cases were identical in relation to most theoretically important characteristics, the only exceptions being in relation to the case farmers' values, and level of production system intensification, with the latter only occurring through the period of the study. These differences, as reported by Vaughan

(1992) were not evident when the cases were selected, but were identified as the cases were investigated. The case farmers' production systems were very similar at the start of the study, but diverged over the three years because of differences in their attitudes towards intensification. Because the cases were (theoretically) almost identical, this limited the use of case-ordered effect matrices (Miles and Huberman, 1994). The focus of the cross-case analysis was to confirm that the case farmers used similar tactical management processes, and identify those areas where they were different. This was achieved primarily by comparing time ordered displays, often in the form of time ordered matrices, taxonomies, process and decision models (Miles and Huberman, 1994). The results of the cross-case analysis were written as a cross-case report (Chapter 7).

4.4.3.8 Comparison to the literature

Once the general model of the tactical management process had been developed, it was compared to the existing literature (Eisenhardt, 1989). Similarities and differences were identified and where differences occurred, reasons for these differences were sought, and the theory modified or extended. Eisenhardt (1989) stressed the importance of examining literature that contradicts the study's results. This was achieved to a reasonable degree by comparing the general model developed from the study with both the normative and descriptive literature. Comparison of case study results to the literature is particularly critical for this type of research because it is based on a limited number of cases (Eisenhardt, 1989) and is therefore generalisable to propositions (Yin, 1989). Linking the results of case study research to the literature enhances its internal validity and generalisability and also increases the theoretical level of the research (Eisenhardt, 1989).

4.5 Quality of case study research

In theory-building research using case studies, Eisenhardt (1989) considered that the ultimate criteria for assessing the quality of the study is whether or not the researcher has generated *good theory*. She stated that good theory is parsimonious, testable and logically coherent. Several empirical criteria also need to be assessed in relation to the quality of case study research (Eisenhardt, 1989). These include the strength of the method, the evidence used to ground the theory, and the quality of new insights provided by the theory. In social science, four logical tests are used to assess the quality of a given piece of research (Kidder, 1981; Yin, 1989). These are the traditional tests of reliability and validity where the test of validity is further subdivided into the tests of construct, internal and external validity. The following section describes the methods used in this study to ensure the quality of the research.

Reliability is defined as the extent to which a research procedure produces the same results when repeated by another researcher or the same researcher at another point in time (Kirk and Miller, 1986, p. 19; Yin, 1989, p. 40; Dey, 1993, p. 250). The goal of reliability is to minimise the errors and bias in a study (Hammersley and Atkinson, 1983; Yin, 1989). In contrast to quantitative research, in qualitative research, where the researcher is the "instrument", no procedures exist for formally assessing reliability (Guba and Lincoln, 1981; Goodwin and Goodwin, 1996). Individual researchers have different personalities, epistemological and ontological assumptions, theoretical knowledge and experience.

Due to the nature of qualitative data and the problems of context, qualitative researchers often consider two aspects of reliability, internal and external reliability (Goetz and LeCompte, 1984; Goodwin and Goodwin, 1996). Internal reliability is best defined as the degree to which independent researchers, given a set of previously generated constructs, would match them with the data in the same way as the original researcher (Goetz and LeCompte, 1984, p. 217). Table 4.2 summarises the research tactics advocated by qualitative researchers (Merton, 1968; Guba and Lincoln, 1981; Goetz and LeCompte, 1984; Lincoln and Guba, 1985; Kirk and Miller, 1986; Bryman, 1988; Yin, 1989; Maykut and Morehouse, 1994; Goodwin and Goodwin, 1996) for minimising the threats to internal reliability and those adopted in this study.

Table 4.2. Tactics used by qualitative researchers to minimise the threats to internal reliability.

Tactics	Used in the study
1. Provide low inference descriptors (raw data)	Yes[3]
2. Develop a detailed database	Yes
3. Provide an explicit description of the data collection and analysis procedures	Yes
4. Mechanically record the data (camera, tape recorder, video)	Yes
5. Multiple researchers	No
6. Pre-testing	Yes
7. Peer review	Yes
8. Provide explicit definition of constructs	Yes
9. Triangulation	Yes
10. Overlap methods	No

[3] The author will provide the raw data upon request.

The raw data is provided for perusal (upon request) along with a detailed database of the coding. A detailed description of the data collection and analysis procedure is provided in this chapter. Interview data was recorded on tape to enhance reliability. The data collection protocol was pre-tested during a pilot study and peer review was used. Explicit construct definitions are provided and some triangulation between field data and interview data was undertaken but overlap methods were not used.

In contrast to internal reliability, external reliability is defined as the degree to which independent researchers would discover the same phenomena or generate the same constructs in the same or similar settings (Goetz and LeCompte, 1984). Goetz and LeCompte (1984, pp. 214 - 217) identified five threats to the external reliability of ethnographic research which are also applicable to other forms of qualitative research. These five threats relate to the researchers failure to define or specify explicitly the following areas: the social role of the researcher, characteristics of informants, social context, definitions of constructs and premises, and the methods of data collection and analysis. Some of these threats are more important in ethnography because the social role of the researcher and other individuals in the study can be an important determinant of what is discovered. These threats are mainly minimised by the researcher providing detailed documentation of the five areas (Goetz and LeCompte, 1984; Yin, 1989; Dey, 1993). The author's role in the research was documented, as were the characteristics of the case farmers. The relationship between the author and the case farmers was professional and based on mutual respect. The constructs, and data collection and analysis procedures were also well documented.

Scientific methods can be reliable, but not produce valid results (Silverman, 1994). Therefore, validity is an important criteria by which the quality of a piece of research is judged. Hammersley (1991, p. 57) defined validity as the extent to which an account accurately represents the social phenomena to which it refers. The test of validity is subdivided into the tests of construct validity, internal validity and external validity (Kidder, 1981). *Construct* and *face* validity are important in qualitative research because during theory building, researchers are more likely to develop new concepts, and the definition of concepts is an arbitrary process with few guidelines (Kirk and Miller, 1986). Face validity is defined as the fit between a researcher's observations and their concepts (Dey, 1993). To demonstrate face validity, criteria by which the data was categorised and how the links between concepts were identified was made explicit, and the scope of the findings were discussed (Dey, 1993). However, although typical instances of the concepts were identified, no extreme or negative instances were found (Dey, 1993).

In contrast to face validity, construct validity is defined as the degree to which measures used by a researcher can be shown to correspond to the abstract construct under investigation (Kidder, 1981; Smith and Glass, 1987, p. 4; Yin, 1989). The construct as defined by the researcher must match previously established and authoritative definitions of the concept from the literature (Dey, 1993). Table 4.3 summarises the tactics advocated in the literature (Kidder, 1981; Yin, 1989; Dey, 1993) for the control of threats to construct validity. All of these methods were used to varying degrees in the study. Multiple sources of evidence were used (interviews, field work, documents), but the primary source was the interview transcripts. Multiple instances of the constructs were demonstrated in the data and the software programs NUDIST and NVivo were useful for documenting the chain of evidence. The case farmers reviewed all of the draft interview summaries and annual case reports and the author drew the majority of the constructs used in this study from the literature.

Table 4.3. Tactics used in qualitative research to minimise the threats to construct validity.

Tactic	Used in the study
1. Use multiple sources of evidence	Yes
2. Demonstrate there are multiple instances of the construct	Yes
3. Establish chain of evidence	Yes
4. Have key informants review draft case study reports	Yes
5. Use constructs from the literature	Yes

Two other types of validity, internal and external, must be assessed when evaluating the quality of a piece of research. In the case of qualitative research, internal validity relates to the question of whether the researcher sees what they think they see (Goodwin and Goodwin, 1996). That is, whether the conceptual categories understood to have mutual meaning between the participants and the researcher are actually shared (Goetz and LeCompte, 1984). Qualitative researchers (Guba and Lincoln, 1981; Goetz and LeCompte, 1984; Lincoln and Guba, 1985; Bryman, 1988; Denzin, 1989; Eisenhardt, 1989; Yin, 1989; 1993; Eisenhart and Howe, 1992; Vaughn, 1992; Maykut and Morehouse, 1994; Silverman, 1994; Goodwin and Goodwin, 1996; Chetty, 1996) have developed a wide range of tactics to minimise the threats to internal validity and these are summarised in Table 4.4. Changes in the observer were controlled primarily through introspection, discussions with the case farmers and peer review. Fieldwork was also used to verify the authors interpretation of the interview data.

Problems with observer bias were controlled through a range of methods (Table 4.4). The theoretical tools of the author were specified in the two literature review chapters and the normative-descriptive cleavage provided a useful contrast. Prolonged exposure in the subjects' natural setting was important in ensuring limited bias. The author spent some 60 - 80 hours with each case farmer on their farms over the three years. Respondent validation of transcript summaries, self-monitoring, and peer debriefing were important in limiting bias. Other techniques such as multiple sources of corroborative evidence and data triangulation were used.

Table 4.4. Important threats to internal validity of qualitative research and the tactics by which such threats are minimised.

Threat	Tactic	Used in the study
1. Changes in the observer	Use of field notes	Yes
	Introspection	Yes
	Discussion with informants	Yes
	Peer review	Yes
2. Observer bias or misinterpretation	Acknowledge theoretical tools at the outset	Yes
	Monitor possible bias	Yes
	Prolonged exposure	Yes
	Natural settings	Yes
	Archival benchmarking	No
	Respondent validation of case summaries	Yes
	Use of insiders and outsiders	No
	Peer debriefing	Yes
	Multiple sources of corroborative evidence	Yes
	Use of negative cases	No
	Comparing evidence to confirm or refute rival hypotheses	No
	Perform pattem matching	Yes
	Perform time series analysis	Yes
	Triangulation	
	- data[4]	Yes
	- investigator[5]	No
	- methodological	No
	- theoretical[6]	Yes
3. Reactive effects	Comparison to existing documented cases	Yes
	Record reactive effects on the subjects	Yes
	Interview subjects on the reactive effects	No

Pattern matching and time series analysis was used to identify relationships (Table 4.4). The author also found that recent work of a similar nature had been undertaken by French researchers (Chapter 3), and this provided documented cases against which the results could be compared. Archival bench-marking was not used because of resource

[4] Synonymous with the use of multiple sources of corroborative evidence
[5] Synonymous with multiple researchers
[6] Synonymous with comparing evidence to confirm or refute rival hypotheses.

requirements. Similarly, insiders and outsiders were not used to minimise bias because of the nature of the research. This approach tends to be used in research involving groups where people inside and outside of the group that are not part of the study, but have a knowledge of the area of interest, can be used to check for bias. The research design (literal replication) precluded the use of negative cases, and multiple researchers and methods were not used in this study and nor were rival hypotheses tested.

Reactive effects were noted, and normally recorded in the interview transcripts. The case farmers were not interviewed about reactive effects explicitly. In most cases, the reactive effects occurred where the case farmers collected data about the state of their farms at particular times because the author had asked them about this. This information was not collected as part of the case farmers' normal management process. An alternative form of this problem was where the case farmers would collect information ahead of schedule because of the timing of the next interview. These instances were identified through the interview process and the problem was discussed with each farmer. Care was taken in the analysis to identify these instances.

The final criteria by which a piece of research is judged, external validity, refers to the question of generalisability (Denzin, 1978) that is, to what populations, settings and measurement variables can the effect be generalised (Kidder, 1981; Denzin, 1989; Yin, 1989; Eisenhart and Howe, 1992). External validity is achieved by establishing the domain or locations in space and time to which the results of a study can by generalised (Yin, 1989). Table 4.5 shows the threats to external validity and the tactics used by qualitative researchers to minimise these threats (Denzin, 1978; Guba and Lincoln, 1981; Goetz and LeCompte, 1984; Yin, 1989). General threats to external validity were minimised by providing a detailed description of the cases and context, using purposeful sampling (deviant case sampling) and through the use of replication logic (two similar cases). Care was taken to select the cases to avoid selection effects. None of the case farmers had been the subject of prior research, but one had had research trials on his property. Effort was taken to explicitly define constructs and any disparities between the definitions of constructs used in the study and those in the literature were reported. Goetz and LeCompte (1984) identified four specific threats (*selection, setting, history,* and *construct* effects) to the external validity of qualitative research. These threats were minimised through careful case selection, avoiding individuals studied by other researchers, describing historical conditions, explicitly defining constructs and reporting disparaties in construct definitions between the study and the literature.

Table 4.5. Tactics used by qualitative researchers to minimise the threats to external validity.

Threat	Tactic	Used in this study
General Threats	Provide a detailed description of the case and the context to demonstrate *typicality* or *atypicality*	Yes
	Use theoretical or purposive sampling	Yes
	With a single-case study, use rival theories	NA[7]
	With a multiple-case study, use replication logic	Yes
Specific Threats		
Selection effects	Careful case selection	Yes
Setting or observer effects	Obtain observations from different perspectives (e.g. participant/non-participant)	NA[7]
Historical effects	Avoid individuals studied by other researchers	Yes
	Describe historical conditions	Yes
Construct effects	Explicitly define constructs	Yes
	Report disparities between definitions of constructs used in the study and those reported in the literature	Yes

4.6 Summary

To investigate the tactical management processes used by expert dairy farmers over the summer-autumn, a longitudinal case study research strategy was chosen. This enabled in-depth investigation of the complex processes of tactical farm management through time. A theory building or theory elaboration case study approach was adopted for this study because the author wanted to develop a fresh perspective on the predominantly prescriptive farm management literature in relation to tactical management.

An embedded multiple-case study design, although more resource demanding, was chosen because the author wished to compare the tactical management processes of

[7] Not applicable.

expert farmers, a form of replication logic. The unit of analysis was the decisions made by the case farmers over the summer-autumn rather than the cases themselves (i.e. an embedded rather than holistic study). The cases were studied over a three-year time frame, and each year was treated as a separate case to identify between–year variations in tactical management.

The method used in this study could be separated into four phases: design, single case data collection and analysis, within-case-cross year analysis and cross-case analysis. During the design phase, a review of the literature was undertaken and from this a data collection protocol developed. This was tested and refined using a pilot study. The case farmers were then selected. The primary criteria being that they had to be recognised experts in the tactical management of a seasonal supply dairy farm over the summer-autumn and capable of articulating that expertise. Two case farmers were selected and these were investigated over three years. In effect, this was equivalent to the study of six cases.

Data was collected through semi-structured interviews, field observations and relevant documents. The qualitative data analysis process advocated by Dey (1993) was used to analyse the data and the computer programmes NUDIST and NVivo were used to facilitate this process. Case reports for each case farmer for each of the three years of the study were developed from the analysis. A within-case cross-year analysis was undertaken to identify between-year differences in the case farmers' tactical management processes. The results of these analyses was summarised in two final case reports (Chapters 5 & 6). A cross-year case analysis was then undertaken (Chapter 7) and the results of this, a general model of the tactical management process, was compared with the literature (Chapter 8). A range of tactics were used by the author to ensure the reliability and validity of the study. The results of the first within-case, cross-year analysis are reported in the following chapter.

CHAPTER 5 CROSS-YEAR CASE REPORT FOR FARMER A

5.1 Introduction

Central to case study research is the report, which describes the context surrounding the case, and the theoretically important results that have emerged from its investigation. This chapter begins with a description of the case study, Farmer A, his farm and farming system. Important findings from the three-year study of the tactical management processes used by Farmer A to manage herd production over the summer-autumn are then presented. First, important characteristics of each year are described to provide the relevant context for the results. Second, an overview of the tactical management processes is provided. Finally, the components of this process are described under the sub-headings, planning and control. Particular emphasis is placed on comparing the similarities and differences in tactical management across the three years.

5.2 Case description

At the time of the initial case study Farmer A was a 50/50 sharemilker[1] with thirteen years dairy farming experience, including six years as a manager and the last four years as a 50/50 sharemilker. He had three years secondary education and was a qualified diesel mechanic. He was in his late thirties and married with three young children. His goals were to pay off current debt and accumulate assets to either move up to a larger herd of over 300 cows or purchase a farm. The herd was owned outright and there was a small mortgage on an 8.0 ha runoff[2].

The case farm is located in the Ohakea district of the Manawatu region in the lower half of the North Island of New Zealand. The climate is temperate with 918 mm annual rainfall, a minimum mean daily air temperature of 8.4°C in July and a maximum mean daily air temperature of 17.6°C in February (NZMS, 1980). At that time, the farm area was 74.0 ha

[1] A 50/50 sharemilker owns the herd and farms it on another farmer's land. The income from milk is shared 50/50. Returns from stock sales are retained by the sharemilker. The farmer pays for the cost of maintaining the land and buildings. The cost of bought-in feed and grazing is shared 50/50 between the farm owner and sharemilker.

[2] Block of land used by New Zealand dairy farmers to run dry stock.

(72.0 ha effective for grazing) comprising a 48.0 ha milking area and 24.0 ha runoff. The runoff was important because the young stock and dry cows graze on these blocks over the summer-autumn. It was also used to generate much of the silage and hay used by Farmer A.

The soil type on the farm is Ohakea silt loam, a pallic soil (Hewitt, 1992) and part of the farm has an underlying ironstone pan. Some two thirds of the farm was tile drained. A third of the farm was mole drained in 1991. However, drainage needed further improvement. The farm is also near a military air base and runoff from the airfield during heavy rain can cause flooding. Olsen P levels of between 21 – 25 indicated a moderate level of soil fertility. The pastures on the farm were predominantly ryegrass and white clover. Approximately 2.0 - 3.0 ha was regrassed each year after a summer brassica crop.

The milking area was subdivided by both conventional and electric fences into thirty paddocks. The runoff had 10 paddocks. The farm was long and thin in shape, but well raced. Water was supplied from a bore to one to two troughs in every paddock. The water supply was adequate, but high in iron. The herd was milked through a 12-aside herring-bone shed, taking 1.5 hours per milking. Aside from a four bedroom house, the only other buildings on the farm were a five bay implement shed and three hay barns (3000 bale capacity). Farm machinery was adequate for most operations, but contractors were employed for weed spraying, hay baling, silage making and fertiliser spreading. Farmer A did the majority of the farm work and his wife helped out with milking, calf rearing and general farm work.

During year one of the study, 146 Friesian cows were peak milked[3] on 48.0 ha at a stocking rate of 3.0 cows per hectare. The herd produced 48,720 kg milksolids[4] (MS) at 334 kg MS/cow or 1015 kg MS/ha. Data from the dairy company for year one shows that the average[5] supplier peak milked 157 cows on 71.0 ha at a stocking rate of 2.2 cows per hectare. The total production for the "average" supplier was 47,854 kg MS at 298 kg MS/cow or 674 kg MS/ha. In year two, the effective area was increased to 52.0 ha and an extra four cows were peak milked at a slightly lower stocking rate of 2.9 cows/ha. Total production was 45,474 kg MS, or 303 kg MS/cow and 875 kg MS/ha. In that year, the average dairy company supplier peak milked 172 cows on 75.0 ha at a stocking rate of

[3] Peak milked - the number of lactating cows on the farm when milk production peaks in the spring.
[4] This includes an estimate for milk fed to calves.
[5] Data for the Ohakea district could not be separated out by the dairy company.

2.3 cows/ha. Total production was 48,825 kg MS or 273 kg MS/cow and 651 kg MS/ha. In the final year of the study, Farmer A peak milked 174 cows on the 63.0 ha at a stocking rate of 2.8 cows/ha. Production was 46,922 kg MS or 270 kg MS/cow and 745 kg MS/ha. The average dairy company supplier peak milked 194 cows on 73.1 ha at a stocking rate of 2.6 cows/ha. Total milk production was 56,314 kg MS or 290 kg MS/cow and 740 kg MS/ha.

5.3 Description of the three years

Important data describing the state of the farm at the start of the summer in each of the three years, and monthly pasture growth rates from that point in time until the end of the month in which the herd was dried off are shown in Table 5.1. In year one, at the start of the planning period, the farm was in a better state than normal in terms of average pasture cover, cow condition and milk production. The level of supplements (hay and silage) on hand at the start of the period was also better than normal, but the forage crop yield was considered about average. Climatic conditions were cooler and wetter than average throughout the summer and as a result, growing conditions were better than normal until early April, after which it turned cool and dry. Consequently, pasture growth rates were above average from January to early April and below average in late April (Table 5.1). The pattern of pasture growth is reflected in the monthly data on average pasture cover, pre- and post-grazing residuals, cow intakes, milk production, cow numbers and average herd condition during year one (Volume II, Appendix II). Pasture growth rates were such, that Farmer A decided not to feed the bulk (11,000 kg DM) of grass silage over summer-autumn, and retained it instead for the winter, early spring.

In the second year, the milking area was increased by 4.0 ha and an additional 4 cows were peak milked (Table 5.1). The effective area in pasture was 3.0 ha greater than the previous year, once the additional area in forage crop was deducted. At Christmas, the farm was carrying 10 more cows than the previous year and the feed position was slightly better. The farm had a higher level of pasture cover and the herd was in better condition than the previous year. Milk production per cow was the same as the previous season and silage reserves were similar. An additional 1.0 ha of forage crop had been planted. However, the final yield was not quite as good as the previous year and 912 fewer bales of hay were in storage.

Table 5.1. The resources on-hand at the start of the summer-autumn period, and the monthly pasture growth rates for the three years of the study.

Resources at 25/12/xx	**Year 1**	**Year 2**	**Year 3**
Average pasture cover (Kg DM/ha)[6]	1700	1800	1650
Pasture quality	Good	Good	Poor
Cow condition	4.5 (+)	4.8 (+)	4.8
Milk production (kg MS/cow/day)	1.39	1.39	1.22
Milking cow numbers	140	150	174
Effective area (ha)	48.0	52.0	63.0
Stocking rate (cows/ha)	2.92	2.89	2.76
Stocking rate (cows/pasture ha)	3.04	3.06	2.97
Forage crop area (ha)	2.0	3.0	4.5
Estimated yield (kg DM/ha)	11,000	9,000	4500
Silage (bales) (250 kg DM/b)	100	103	25
Hay (bales) (15 kg DM/b)	2400	1488	2592
Pasture growth rates (kg DM/ha/day)			
25/12 - 31/12	28	39	28
January	28	35	17
February	24	8	13
March	33	19	28
April	23	25	41
May	NA	NA	25
Total (kg DM/ha) for period 25/12 – 31/4	**3421**	**2851**	**3157**
Supplements fed[7](kg DM)	23,000	31,250	32,500
Supplement fed per cow[8] (kg DM/cow)	243/164[9]	208	187
Planned winter supplements (kg DM)	72,000	58,160	63,340

January was cool and wet, as in the previous year, but the pasture growth rate was greater. Conditions started to turn dry at the end of January and February was very dry with much lower pasture growth rates than in year one. March was cooler than normal, and rainfall was about average, but because the farm was so dry at the start of the month, pasture growth was limited through most of March and much less than recorded in year one. During April, pasture growth rates were about average and slightly higher than in year one. Overall, the farm grew 17% less pasture per hectare over the summer-autumn than in year one (Table 5.1) due to the drier conditions. Some 36% more supplement was fed over the summer than in year one. However, if the 11,000 kg DM of silage had been fed over the summer of year one, instead of being retained for winter, the supplement situation would have been little different between years (Table 5.1). The impact of climate

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[6] During summer, the figures given for average pasture cover are estimates because Farmer A was not formally monitoring this information.

[7] This is an estimate of the supplements fed to the herd over the summer-autumn. Allowance must be made for wastage.

[8] This is based on the number of cows on-hand at the start of the summer.

[9] If the 11,000 kg DM/ha of silage that was meant to have been fed over the summer had been fed, the herd would have received 243 kg DM/cow. However, when this feed was diverted for use in the following spring, the actual amount fed declined to 164 kg DM/cow.

between year one and year two on farm production parameters is summarised in Volume II, Appendix II.

In year three, the milking area was further increased from 52 to 63 ha effective. Cow numbers were increased to 174 cows, 24 more than in year two, and run at a slightly lower stocking rate (Table 5.1). The farm state at the start of summer reflected spring climatic conditions. In late November, two thirds of the farm was flooded and to maintain milk production, the silage paddocks were grazed by the milking herd. After the flood, conditions changed from very wet to hot and dry, and in response, paddocks were not topped[10]. At the start of summer, pasture quality was a lot poorer than in normal years because of the combination of silage not being made and the deferral of topping.

The flood limited silage making to 25 bales, and 93% of the hay was bought-in. Crop establishment was also severely inhibited and, by mid January, the yield was less than 20% of that normally expected at that time of year. The final per hectare yield of the forage crop was less than half that of the other two years (Table 5.1). At Christmas, average pasture cover, and milk production were below the previous two years, although cow condition was the same as in year two, and higher than in year one. Farmer A noted that this was the worst feed position he had experienced in dairying.

Conditions through January were drier than either of the two previous years with an average pasture growth rate of 17 kg DM/ha/day. Conditions remained very dry through until mid February and then around the 22 - 24th February, 40 mm of rain fell and pasture growth rates improved. The pasture growth rate over February was 13 kg DM/ha/day greater than in year two, but much lower than in the wet summer of year one. During March, good rain fell through the first half of the month. As a result, the pasture growth rate increased, and averaged 28 kg DM/ha/day. During April, ideal growing conditions occurred and pasture growth rates averaged 41 kg DM/ha/day. This was 78% and 64% more than in year one and year two, respectively. This allowed milking to continue into May. Slightly more supplement was fed over the summer-autumn than in year two (+ 4%), but considerably more than in year one (+ 41%), when silage was carried forward into winter. On a per cow basis, 164, 208 and 187 kg DM/cow of supplements was fed over summer-autumn in years one, two and three, respectively. Interestingly, despite the very dry conditions at the start of the summer, on a per hectare basis, the farm only grew 8% less pasture than the wet summer of year one. In contrast, 10% less milk was

[10] Seed head and low quality pasture are cut with a mower after the herd has grazed a paddock.

produced on an annual basis (see Volume II, Appendix II for more detail on the farm state during the three years of the study).

The study period therefore covered three contrasting years (Table 5.1). The first could be classified as a "wet summer" with above average pasture growth rates through the summer, and slightly below average conditions in April. The second year had above average pasture growth rates through January, then very dry conditions in February and early March, followed by an average April. In contrast, dry conditions occurred in December in the final year, and pasture growth rates were below average for both January and February. However, the rains came in late February, ensuring pasture growth rates through March were above average, and in April, ideal growing conditions occurred and pasture growth rates were 64% above average. This demonstrates the level of uncertainty that confronts pastoral dairy farmers in New Zealand and is the reason why expert tactical and operational management is critical to achieving sustained high performance.

5.4 The tactical management processes used by Farmer A

The tactical management processes used by Farmer A can be described within the classical cyclical process of planning, implementation and control. First, a plan is developed that consists of an overall goal, a sequence of events or activities, associated targets, and a set of contingency plans or options. Implementation of the plan was controlled by monitoring a wide range of indicators or measures. These were compared to the targets, and if there was a significant deviation, a control response was introduced. This involved primarily the selection of a suitable contingency plan to minimise the impact of the deviation. Other control responses involved changing targets, or refining the monitoring system. Farmer A continued to implement the plan until the monitoring process identified a deviation that warranted a response. Monitored data and targets were not just used to implement control responses, they were also used to determine when to implement the activities previously specified in the plan. Predefined initiation and termination dates were used to trigger a new planning process. The following section describes first, the planning process, and second, the control process used by Farmer A over the three years of the study. Due to the wealth of data, examples are only given to illustrate important aspects of management practice. Further information describing the tactical management process used by Farmer A is provided in supporting appendices

(Volume II, Appendices II - X) and the annual case reports (Volume II, Appendices XX - XXII).

5.5 Planning

5.5.1 The planning horizon

One of the first steps in Farmer A's planning process, was the determination of the planning horizon. Two primary planning horizons were used for tactical management over the summer-autumn period. The first planning period was from Christmas until mid March; the second from then until calving. On April 1st, a formal planning process was initiated to quantify the qualitative plan formulated in mid March. These planning horizons were consistent over the three years. However, if the autumn rains occurred before mid March, the formal planning process would be initiated earlier. The activation date for the first planning period related to a change in seasonal conditions. Prior to Christmas, pasture growth tends to exceed "herd" (including some replacements) feed demand, and the focus of management was on the control of pasture quality. By Christmas, silage paddocks, harvested in November, had regrown and been incorporated back into the grazing rotation. Post-Christmas, as conditions become hotter and drier, herd feed demand tends to exceed pasture growth, and the focus of management shifted to ensuring an adequate feed supply. Normally 60 - 65% of total milk production was achieved prior to Christmas on the case farm.

The termination date for the first planning period in mid March was seasonally related. Normally around this date (10 - 20th March), the autumn rains arrive. Conditions prior to this are dry and warm, and following rains a rapid increase in pasture growth rates, the "*autumn flush*" normally occurs. A range of tactics were used to take advantage of this "pulse" of pasture growth in order to prepare the farm for the next calving.

On April 1st, Farmer A changed from an informal to a formal planning mode and quantified the autumn plan through to calving. A critical event, drying off, normally occurred around mid to late April. Therefore, planning could not be delayed any later than April 1st. Drying off, in effect halved feed demand, and when timed in combination with the autumn flush can be used to rapidly increase farm feed reserves in the form of average pasture cover. Drying off was also used to prevent further loss of cow condition in the herd. This decision was therefore critical for preparing the farm for the coming lactation. It dictated the condition of the herd and how much feed was taken into the winter. These parameters in turn influenced the feed on-hand and condition of the herd at calving: both important determinants of milk production and reproductive performance over the spring. The drying off decision was also irrevocable and if made too early, income from further milk production in the current season was foregone. The second planning horizon was terminated at calving. This was a critical obligatory event on a dairy farm. Prior to this, Farmer A was managing a non-lactating herd to ensure that it was in good body condition, with sufficient feed supplies ahead for calving. From the start of calving, both dry and lactating cows were managed. The aim was to ensure the freshly lactating herd was fully fed until pasture growth exceeded feed demand in late spring.

The formal planning process was also initiated in order to assess the impact of the autumn rains. By April 1st, the timing and quantity of autumn rain, and its impact on pasture growth rates was known. There was little point planning for the next spring, Farmer A claimed, "*until there was feed to work with*" and, therefore, formal planning was delayed for as long as possible to quantify the impact of the autumn rains. The final reason for delaying formal planning till April was that prior to the autumn rains, the sward characteristics of summer pastures were such that it was difficult to accurately measure pasture cover. In contrast, autumn swards could be measured reasonably accurately and the data was therefore able to be used with more confidence in formal feed budgeting. Using formal planning when conditions were highly variable was not favoured. Informal planning was considered to be adequate under these conditions.

Alternative tactical planning horizons were used in two instances. First was in year one, when a formal feed budget was completed for the period early March to calving to determine whether silage should be fed post the post-forage crop. Silage was not incorporated into the summer plan in years two and three, and therefore Farmer A did not repeat this process. The second instance was in the extremely dry year three, when the planning horizon was shortened to mid March because he expected that the herd might have to be dried off at this point. However, when conditions improved, the next plan was not developed until April 1st.

Shorter-term planning horizons were used by Farmer A within the two tactical plans. These related to specific events and were each around one to four weeks duration. The periods can be separated into: pasture feeding pre-forage crop (25/12/xx - 31/1/xx), forage crop feeding (1/2/xx - 15/3/xx)[11], pasture feeding post-forage crop (16/3/xx - initiation of drying off), and the drying off process itself. The sequence and timing of these events varied across the three years and was dependent on the conditions at the time. At the one to four weeks planning level, Farmer A used an approach similar to a rolling plan. He was normally thinking ahead two to four weeks and considering alternative courses of action should conditions differ from expectations ('the norm'). In effect, contingency plans were being selected for key decision points so that, should conditions differ from expectations, he was mentally prepared to implement an appropriate contingency plan. Farmer A also thought in time frames that related to the grazing rotation length for the herd.

Although two distinct tactical planning horizons were identified, Farmer A was clearly thinking across a number of different planning horizons simultaneously. Thus, at Christmas, he was planning in relation to: (i) the next calving, (ii) drying off, (iii) to mid March, the start of the autumn, (iv) the 24 - 30 days until the next grazing round, (v) a month out to the start of the forage crop, and then in shorter time frames such as (vi) over the next week, and (vii) the next day's operations.

5.5.2 Planning process

Farmer A primarily used an informal qualitative planning process over the summer, and then changed to a formal quantitative planning process incorporating a feed budget around April 1st. This point was chosen because it was normally two weeks after the autumn rains arrived and allowed Farmer A to observe how the autumn was developing (dry, normal, or wet). As the critical decision, drying off, tended to occur two to four weeks after the formal plan was developed, this provided Farmer A with a more accurate assessment of the drying off date, than if he had undertaken the planning exercise at mid March. The following sections describe the informal and formal planning processes used by Farmer A.

5.5.2.1 Informal planning process

Farmer A had a "typical" summer plan developed over time and based on experience. It contained a set of heuristics that determined the components of the plan. These

[11] In year one, silage was fed after the forage crop and this constituted another short-term planning period.

heuristics could be classified as sequencing, activation and termination, input type and level, arbitration and target setting rules (see Section 5.5.3 on the plan for more detail). This "typical" plan was implemented each year unless some factor(s) caused Farmer A to modify it. As such, there was no "planning" process unless the "typical" plan had to be modified. Planning over the summer, in relation to this study, was the process of modifying a pre-existing plan. The "typical" plan was modified for four reasons. First, if a strategic decision had been made that impacted on the plan. For example, in year three, Farmer A delayed culling by three weeks in order to obtain objective data through herd testing because he had made a strategic decision to increase herd size.

Farmer A also modified his plan in response to learning during the previous planning cycle, an example of historical control. In year two Farmer A learnt that he could not predict the likelihood of a "wet" summer and that the use of a higher milk production target in combination with this inaccurate forecast increased the risk of not having the herd in a milking state upon the arrival of the autumn rains. As such, this option was removed from his planning repertoire after year two. The third factor related to atypical tactical decisions made in the previous planning period. In year three, a tactical decision was made in the preceding spring to plant an additional paddock of forage crop because limited silage had been harvested over the spring. This changed the "*typical*" summer plan which normally contained only two paddocks of forage crop.

The fourth factor that determined if the "typical" plan was modified was the state of the farm (herd, pasture, supplement, forage crop) at the start of the summer. Farmer A assessed the state of the farm in relation to average pasture cover, pasture growth, cow condition, milk production, reproductive state, silage on-hand, likely forage crop yield (weeks of grazing), the number of cows (stocking rate), and cow intake. This information was then used to develop a rough mental feed budget to assess whether the "typical" plan was feasible. The summer was classified as "typical" if the "typical" plan proved to be feasible. This occurred when the farm was in a normal or better than normal state. Farmer A also distinguished between a "typical" and "wet" summer during year two of the study. The summer was classified as "wet" when the farm state was exceptional and the rough mental feed budget suggested there was feed surplus to requirements for the "typical" plan. Farmer A also used a prediction of cow intakes from post-grazing residuals to consider how well the herd would be fed in three to four weeks time based on the grazing rotation and likely pasture growth rates. He also compared the situation to the previous year. This information was also used to assess if the typical plan was feasible and to classify the situation as "dry", "typical" or "wet".

The summer was classified as "dry" if the "typical" plan proved infeasible because the farm was in a poor state at the start of summer. A poor, or below average feed position was normally due to poor growing conditions through late spring, and given that summer is usually the driest period of the year, it was sensible to predict that the poor feed position was likely to deteriorate further through January and February. Farmer A classified year one as "typical", year two as "wet" and year three as "dry". The classification process was in effect a simple mental feed budget where a rough estimate of the feed supply (supplements, pasture growth) was compared to feed demand and a decision made as to whether the herd could be fed as planned in the "typical" plan, or whether this plan had to be modified because of insufficient feed (a "dry" summer), or too much feed (a "wet" summer).

Farm state at the start of summer did not just relate to the feed situation. In year two, after a wet spring, Farmer A identified a number of cows that were not in-calf due to nutritional stress. To ensure these animals were in-calf for the next season, he modified his typical plan by delaying the removal of the bull by two weeks. This also meant pregnancy testing had to be shifted two weeks later.

If the summer was classified as typical, the "typical" plan, or a version that had been modified due to strategic decisions and learning, was adopted and implemented. If, instead, the summer was classified as "wet", as in the case of year two, then the main change was in relation to an increase in the milk production targets in the plan (Table 5.2). Changing the milk production target selection heuristic impacted on input levels and the activation and termination dates for various activities. For example, if a higher milk production target was used in the plan, cow intakes were increased and the forage crop was grazed earlier and at a faster rate than normal. As such, a simple change to the milk production target selection heuristic had quite major impacts on Farmer A's management.

In contrast, if the summer was classified as "dry", as in year three, then the "typical" plan was modified to ensure as many cows as possible made it through the summer to take advantage of the autumn rains. A much more complex set of modifications was undertaken in the dry summer of year three. Milk production targets were reduced to 0.87 kg MS/cow/day. This also meant other targets and input levels had to be reduced, while sequencing, activation and termination dates for activities were also changed (Table 5.2). Changes in the type of inputs used in the plan were also identified. For example, ultrasound was used for pregnancy diagnosis instead of the traditional method because it allowed Farmer A to cull empty cows a month earlier than normal. The plan modification process was iterative. Farmer A would postulate a change or changes to the "typical" plan and then test the feasibility of the change(s) using mental simulation. If it was feasible, the modified plan was implemented. If it proved infeasible, further modifications were made and tested until a suitable plan was developed.

Table 5.2. Examples of modifications to plan heuristics for a "typical", "dry" and "wet" summer.

Rule type	Examples
Target setting rules	
Typical summer	IF conditions at the start of summer are typical, THEN use a milk production target of 1.04 kg MS/cow/day.
Dry summer	IF conditions at the start of summer are dry, THEN reduce the milk production target to 0.87 kg MS/cow/day.
Wet summer	IF conditions at the start of summer are above average, AND indicate a wet summer, THEN increase the milk production targets by 0.09 kg MS/cow/day.
Sequencing rules	
Typical and wet summers	IF conditions at the start of summer are typical or above average, THEN plan to feed silage after the forage crop has been grazed.
Dry summer	IF conditions at the start of summer are dry, AND forage crop yields are poor, AND silage that is normally used in the spring is available, AND the amount of silage available is low, THEN plan to feed silage with the forage crop and buy in good quality hay to supplement the silage.
Activation rules	
Typical summer	IF milk production ≤ 1.13 kg MS/cow/day, AND the forage crop is ungrazed, THEN graze the forage crop.
Dry summer	IF milk production ≤ 0.87 kg MS/cow/day, AND the forage crop is ungrazed, AND the rotation length = minimum, THEN graze the forage crop.
Wet summer	IF milk production ≤ 1.22 kg MS/cow/day, AND the forage crop is ungrazed, THEN graze the forage crop.
Termination (and activation) rules	
Typical summer and wet summer	No corresponding rules
Dry summer	IF analysis of pre- and post-grazing residuals shows that the herd can be consistently fed 11.0 kg DM/cow/day, AND the herd is on once-a-day milking, AND the month is February or March, THEN stop milking the herd once-a-day and put the herd on twice-a-day milking.
Input type and level rules	
Typical summer	IF milk production ≤ 1.13 kg MS/cow/day, AND the forage crop is ungrazed, THEN graze the forage crop and feed the herd sufficient crop to maintain milk production at 1.04 kg MS/cow/day.
Dry summer	IF milk production ≤ 0.87 kg MS/cow/day, AND the forage crop is ungrazed, THEN graze the forage crop and feed the herd sufficient forage crop to maintain milk production at 0.87 kg MS/cow/day.
Wet summer	IF milk production ≤ 1.22 kg MS/cow/day, AND the forage crop is ungrazed, THEN graze the forage crop and feed the herd sufficient crop to maintain milk production at 1.13 kg MS/cow/day.

The plan modification process varied in complexity. It normally involved changes to one or more of the sequencing, activation and termination, input type and level, and target selection heuristics. At its simplest, a new input or management practice just replaced the existing input or practice in the plan without any further modification. For example, Farmer A substituted a new variety of forage crop for an existing variety in the plan without changing the timing, sequencing, or other planning heuristics. At a slightly more complex level, 1.0 hectares of forage crop was substituted for silage in year two and heuristics for the activation and termination of silage feeding were applied to the feeding of the second forage crop. At a more complex level, the planning heuristics could be modified. Other changes, particularly the modification of the "typical" plan for a "dry" or "wet" summer required Farmer A to replace the activities in the plan with contingency plans designed primarily to modify feed demand or feed supply. The above results show that although the planning process is based on a "typical" plan or template, the template is changing from year to year in response to the conditions, prior strategic and tactical decisions and farmer learning.

5.5.2.2 Formal planning process

By mid March, the summer plan terminated and was replaced by the autumn plan. The timing of this change-over was season-dependent because the autumn rains normally occurred between 10th – 20th March. Farmer A delayed the adoption of a formal planning process until April 1st[12], so that he could observe the effects of the autumn rains on feed supply. A formal planning process using a feed budget was then undertaken. The reasons for this change were discussed in Section 5.5.1.

A formal feed budget form, originally developed by the dairy extension service was used to plan from April 1st until calving[13]. It was used to estimate the drying off date for the herd which would ensure targets for farm pasture cover and herd condition at calving were met. Heuristics or decision rules were still used to specify the sequence of events within the plan. Targets or terminating conditions at planned start of calving for average pasture cover and average herd condition were specified. The situation at April 1st was assessed and data collected on the number of cows on hand, current milk production and cow intakes, the average pasture cover and pasture growth rates, and the amount of

[12] In year one, Farmer A also used this approach in early March to determine whether he needed to feed silage after the forage crop. This process was not repeated in subsequent years because Farmer A made a strategic decision to use all his silage in the early spring.

[13] Planned start of calving was July 15th in year one and July 20th in years two and three.

supplements on-hand. Key events that occurred during the planning period were specified, including the return of replacement in-calf heifers, the timing and amount of supplements fed, and calving date. Heuristics were used to determine the sequence of these events. Pasture growth rates and a pattern of feed demand for the herd were specified on the basis of previous experience. Average monthly pasture growth rates for the winter were used even though the introduction of on-off grazing had improved pasture growth rates in recent years. The conservative figures provided Farmer A with some flexibility. In year three, the budgeted average pasture growth rate for April was increased by 5 kg DM/ha/day because after the prolonged dry spell, and with the recent good rains, it was believed that better than average production would occur. This proved to be true as actual pasture growth rates in April were 11 kg DM/ha/day above average.

The feed budget form had monthly time steps, except for April where shorter time intervals were required to calculate the drying off date. During the three years, limited analysis of alternative management actions was undertaken. Rather, heuristics were relied on to generate the body of the plan, and the feed budget was primarily used to estimate the one variable not determined by the decision rules, the drying off date. As with the summer planning process, heuristics were used to select most of the targets in the autumn plan, however, the most important targets from a management perspective, average pasture cover levels, were derived from the feed budget.

Only one example of an analysis of alternatives during autumn planning was identified during the study. In year one, three options were identified for extending the lactation: grazing off, bought-in hay, and urea. Only urea was analysed using a partial budget framework: the two other options were screened out before any formal analysis was undertaken. Grazing was not considered further because of a bad experience with this option. Bought-in hay was discarded because it was a maintenance feed and therefore not suitable for increasing cow condition over winter. Partial budget analysis showed it was profitable to use urea to extend the lactation. Despite this, it was not incorporated into the plan, partly because the weather became cold and average pasture cover had declined, and partly because Farmer A had no experience with nitrogen and was concerned about the risk associated with the response rate over the autumn. The farm owner who had to pay half the cost, also influenced the decision because he did not believe that autumn nitrogen was profitable.

In year two, no partial budget was derived, but average pasture cover at drying off, with and without urea, was calculated for a range of drying off dates. The results were formulated into a matrix and on the basis of this analysis, urea was incorporated into the autumn plan. In year three, urea was incorporated directly into the plan without any analysis. By this stage, Farmer A was quite comfortable applying 3.0 tonnes of urea to pastures to extend the lactation.

Prior to the study, Farmer A and the farm owner had had no experience in using urea in the autumn. They also both had a philosophy of maintaining a low input system. At that time New Zealand dairy farmers were beginning to move away from low input, high stocking rate, moderate per cow performance systems towards higher input, higher per cow performance systems. The pasture growth response from nitrogen in year two highlighted its benefits and in year three, it became a normal part of the autumn plan. Thus, Farmer A's attitude, and that of the farm owner, changed with respect to the use of urea.

The other formal analysis was undertaken in year one when, in early March, Farmer A developed a feed budget to assess whether he could milk through the late summer and into autumn without having to use the summer silage. The analysis was prompted by wet, cold springs in the previous two years. Silage would instead be reserved for the spring because Farmer A believed climatic conditions had changed. Further, the wet summer of year one had reduced the need to use silage over the late summer, early autumn. The feed budget was used to test this belief quantitatively. The criteria for the decision to defer silage use was whether the herd could be milked through until mid April or later and still meet the terminating conditions at planned start of calving. The feed budget showed these conditions could be met, and the silage feeding plan was changed. While this was a revision of the summer plan, it involved an extension of the planning horizon through until calving to estimate the likely consequences of the decision.

The feed budget was not updated in years one and two with new information on average pasture cover obtained through the monitoring process. Actual average pasture cover was simply compared to the target for that period, minimising the need for plan revision. However, in year three, a very rapid and unexpected decline in average pasture cover in early May prompted the development of a new feed plan. Thus, when conditions fell outside Farmer A's "comfort zone" as determined by pasture cover targets, a new planning exercise was initiated to reassess the feed position.

5.5.2.3 Rolling planning

A process of informal rolling planning was also used during both the summer and autumn. The next event, or couple of events in the plan were considered, and contingency plans identified for use if pasture growth rates were less than expected. This provided preparation for changes in farming conditions. At no point was a plan considered "final". Climatic conditions were expected to deviate from the norm, and adjustments to accommodate these were anticipated. The planning process generated a schedule of events, and a set of targets critical for controlling the implementation of the plan. Although the control aspect of planning was emphasised by Farmer A, no formal revision or analysis of contingency plans was made during the summer, or autumn planning processes. These appeared to be stored in memory with revisions being made according to the conditions and time of year. For example, Farmer A might consider what options he would implement in early January if conditions became dry and milk production fell below target prior to when his forage crop was ready to graze in late January. A contingency plan suitable to the conditions was then activated when a deviation from the plan occurred. Farmer A's plans for the three years of the study are discussed in the following sections.

5.5.3 The plan

Farmer A had a plan for a "typical" summer that had been developed over time and based on experience. Central to the plan was a set of five heuristic types that determined several important components of the plan (Volume II, Appendix III). Heuristics determined the sequence of events or operations within the plan. Some events were obligatory, for example, sow the new grass after the forage crop is grazed, or pregnancy test the herd six weeks after the bull is removed. The sequence of other activities appeared to be based on a concept of marginality. The grazing of the forage crop for example, was delayed and other resources (average pasture cover and cow condition) used to ensure it reached optimum yield. The herd was dried off after all other options had been exhausted to ensure the summer-autumn feed was efficiently converted to milk.

The heuristics also determined when an event or activity was activated or terminated. Some events were activated or terminated by benchmark dates. For example, the new grass had to be sown by mid March and this determined the termination date for forage crop grazing and the activation date for new grass sowing. The activation and termination dates of other activities were dependent on the timing of preceding events. The start of mating for example, determined when the bull would be removed, and this in turn determined the date of pregnancy testing. In other cases, the timing of events was not rigidly set by dates, but rather by when specific conditions occurred. For example, the forage crop was to be fed when milk production fell to 13 litres/cow/day (1.13 kg MS/cow/day), although Farmer A stated that this normally occurred around early February. This provided some flexibility within the plan and made it more responsive to the actual feed conditions that occurred after the preparation of the first period (summer) plan.

The third type of heuristic used by Farmer A specified the type and level of input that should be used for some period during the plan. For example, when supplement was fed, the amount had to be sufficient to maintain milk production at, or above 12 litres/cow/day (1.04 kg MS/cow/day). Again, a precise amount of supplement was not specified, rather the heuristic provided the flexibility to manipulate the pasture to supplement ratio to suit feed conditions and milk yield.

The fourth type of heuristic used in the planning process was one that specified the targets used to control the implementation of the plan. These heuristics adjusted the targets to suit the type of summer Farmer A expected. For example, in a "dry" summer, Farmer A used lower milk production targets than in a "typical" or "wet" summer. Reducing milk production targets reduced the level of cow intake required, and allowed the use of cow body condition reserves to buffer the feed supply. This increased the likelihood of cows making it through to the autumn rains still in milk. Combinations of inputs were often used, such as in year three when silage, hay, forage crop and pasture were fed together. Few examples of the final type of heuristic, arbitration rules, were identified. These heuristics set priorities between the younger cows (rising three year olds) and the rest of the herd.

The plans developed by Farmer A can be separated into four components: the goals (and values) that drove the process, a predictive schedule of events, and the targets and associated contingency plans used to manage implementation. These components are discussed in the following sections.

5.5.3.1 Goals and values

There was no evidence of a process for goal formulation in relation to tactical management. The goals for the summer-autumn had been formulated previously and were the same in each of the three years. Farmer A's autumn goal was "*to optimise milk production from the available feed resource without jeopardising next season's* *production*". The optimisation of milk production over the autumn was constrained by the need to achieve certain minimum terminating conditions or targets at the next planned start of calving. These terminating targets contributed strongly to the determination of the herd drying off date. Conditions at calving were known by the farmer to have a much greater influence on production (and hence profitability) than feeding decisions made throughout the summer-autumn, and thus dominated decision-making.

The goal for summer was to "*optimise milk production from the available feed resource and ensure the maximum number of cows were in a lactating state at the start of the autumn*". This goal was subservient to the autumn goal. Accordingly, a range of targets were set to prevent actions taken during the summer adversely affecting next season's production. For example, cow condition and milk production targets "protected" herd body condition, whilst rotation length and milk production targets "protected" pasture from over-grazing (see Section 5.5.3.3).

Importantly, precise and quantifiable milk production targets were not set for the summer-autumn tactical management, although some were set for budgeting purposes. Milk production was known to be very dependent on the climatic conditions over the summer-autumn and these could neither be predicted with certainty nor controlled. Setting precise production goals was therefore not seen by Farmer A to have value.

Values played a limited role in tactical management over the summer-autumn period. Their main influence was on option selection. Farmer A's "*low input*" philosophy limited the use of bought-in feed. However, these values changed over the course of the study period. Prior to year one, the use of urea, maize silage, bought-in hay, and grazing off, were not considered to be viable ways of extending the lactation. They would only be reconsidered under extreme climatic conditions. However, as explained earlier, the practice of urea use in the autumn did change over the three years. Also by the third year a decision had been made to buy-in rather than make hay and silage if conditions were dry in order to improve pasture regrowth.

5.5.3.2 The predictive schedule of events

The schedule of events[14] specified in each plan for the three years are summarised in Table 5.3. In a typical year, the plan was to cull any cows unsuitable for carrying over the

[14] The schedule of events comprises those for the period of the study (Christmas - drying off). This schedule of events covers the summer period and the early part of the autumn plan. Events beyond drying off are not incorporated, although this would include the return of the in-calf rising two year heifers to the milking area, the feeding of supplements over the winter and the grazing rotation of the herd over winter.

summer at the start of the planning period and then graze the herd on a 25 - 30 day rotation until the forage crop was ready for grazing in late January-early February. The bulls were removed from the herd on the 26th January. The herd was introduced to the forage crop when milk production fell to 13 litres/cow/day (1.13 kg MS/cow/day) and fed sufficient to maintain milk production at 12 litres/cow/day (1.04 kg MS/cow/day). The herd was herd tested mid February and then pregnancy tested in late March to identify empty cows. Once the forage crop was grazed in late February, early March, the herd was fed silage at a level that maintained milk production at 12 litres/cow/day. While on supplements, the herd was maintained on a 25 - 30 day rotation, and when the silage was completed, the herd remained on this round until drying off. Thin younger cows were placed on once-a-day milking when their condition fell to 3.5 condition score units, and if condition continued to fall, they were dried off. This was expected to occur in late summer and through into the autumn. The new grass was sown in mid March and then Farmer A estimated a feed budget on April 1st. Cull cows were sold at or near drying off, and then when average pasture cover and cow condition targets were met around the 15th April, the herd was dried off. At that point, the rotation length was doubled to about a 60 day rotation.

Table 5.3. Farmer A's plan[15] for the summer-autumn for the three years of the study.

Year 1	Year 2	Year 3
Cull cows unsuitable for carrying through the summer at, or shortly after Christmas.	Cull cows unsuitable for carrying through the summer at, or shortly after Christmas.	Delay culling until the next herd test.
		Herd test on January 11th.
		Dry off up to 20 low producing and/ or high somatic cell count cows and either cull or place on the runoff.
Carry 140 cows through the summer-autumn.	Carry 144 cows through the summer-autumn.	Carry 150 - 160 cows through the summer autumn.
Maintain a 25 - 30 day rotation.	Maintain a 25 - 30 day rotation.	Maintain a 24 day rotation.
Remove the bull on the 26th January.		Remove the bull on the 26th January.
		Place younger cows on once-a-day milking if condition score falls to 3.5 condition score units.
		Dry off younger cows if condition score continues to fall and they are on once-a-day milking.

[15] This is Farmer A's plan as at 25/12/xx. In the last row, the drying off date estimated through the feed budget undertaken in early April is given.

Table 5.3 (continued)

Year 1	Year 2	Year 3
Feed the crop in late January/early February when milk production falls to 13 litres/cow/day (1.13 kg MS/cow/day). Feed one third of the herd's diet and maintain production at 12 -13 litres/cow/day (1.04 kg MS/cow/day). Feed the crop for 2 - 3 weeks.	Feed the first forage crop in late January, early February when milk production falls to 14 litres/cow/day (1.22 kg MS/cow/day). Feed the first forage crop for 3 weeks and maintain milk production at 13 litres/cow/day (1.13 kg MS/cow/day).	Put the herd of on once-a-day milking and feed the forage crop in late January, early February when milk production falls to 10 litres/cow/day (0.87 kg MS/cow/day). Feed the forage crop along with a bale of hay and a bale of silage until early to mid March and maintain milk production at 10 litres/cow/day (0.87 kg MS/cow/day).
Herd test mid February.	Remove the bull on the 9th February.	Pregnancy test early February with ultrasound.
Place younger cows on once-a-day milking if condition score falls to 3.5 condition score units.	Place younger cows on once-a-day milking if condition score falls to 3.5 condition score units.	Cull empty cows.
Dry off younger cows if condition score continues to fall and they are on once-a-day milking.	Dry off younger cows if condition score continues to fall and they are on once-a-day milking.	
Pregnancy test the herd in early March.	Herd test mid-late March.	Put the herd on twice-a-day milking if conditions improve in March.
Feed silage (12,500 kg DM) after the crop to maintain milk production at 12 -13 litres/cow/day (1.04 kg MS/cow/day).	Feed the second forage crop three weeks after the first and maintain milk production at 13 litres/cow/day (1.13 kg MS/cow/ day).	
Maintain a 25 - 30 day rotation post-silage.	Maintain a 25 - 30 day rotation post-forage crop.	Maintain a 24 day rotation post-forage crop.
Sow the new grass mid March.	Sow the first paddock of new grass mid March.	Sow new grass late March.
	Pregnancy test the herd in late March.	
Sell the cull cows at or near drying off.	Sell the cull cows at or near drying off.	Sell remaining cull cows at or near drying off.
	Sow the second paddock of new grass mid April.	
Dry off the herd when the autumn rains arrive around mid April and increase the rotation length to 60 days. The feed budget estimated the herd could be milked until the end of April provided average pasture cover remained above 1400 kg DM/ha.	Dry off the herd when the autumn rains arrive around mid April and increase the rotation length to 60 days. The feed budget estimated the herd could be milked until the end of April provided average pasture cover remained above 1325 kg DM/ha.	Dry off the herd and increase the rotation length to 60 days. The feed budget estimated the herd could be milked until May 1st provided average pasture cover remained above 1580 kg DM/ha.

Heuristics were used to determine both the sequence and timing of events as described in Section 5.5.3. The other interesting point was that milk production targets were the primary driver of input use, especially feed. Milk production was used as an indirect measure of intake, and during summer it was used in place of a formal feed budget to set herd feed intake targets. The logic behind this approach is shown in Figure 5.2 (Section 5.6.1).

The "schedule of events" included dates and associated decision rules that specified the particular conditions under which these events would be implemented. This meant an inherent flexibility was built into the plan. For example, the forage crop was grazed when milk production fell to 13 litres/cow/day (1.13 kg MS/cow/day), a function of feed supply. Similarly, the date on which the thin younger cows were put on once-a-day milking depended on when their condition fell to 3.5 condition score units, again a function of feed supply. Silage feeding occurred after the forage crop was finished, and at the point milk production fell below 12 litres/cow/day (1.04 kg MS/cow/day), again a function of feed supply. The inclusion of decision rules within the plan rather than just dates, increased the plan's responsiveness to changing conditions, and better integrated the planning and control functions.

Several reasons were identified for differences between plans across the three years. Some were attributed to strategic decisions made earlier in the year, some were a result of historical control while others were responses to "*atypical*" decisions made prior to, and conditions at the start of the summer planning period. The strategic decision not to feed silage in the autumn, but to retain it for the early spring was the major difference between year's one and two. An extra 1.0 ha of forage crop was planned to substitute the role of summer pasture silage (see Section 5.5.2.1). The second major difference between the two years occurred because Farmer A inferred that another wet summer was likely on the basis of conditions at the start of summer and a belief that a climate shift had occurred. Milk production targets for forage crop feeding were accordingly increased by 0.09 kg MS/cow/day. The other difference between the plan in year one and year two was due to conditions prior to the first planning period. The spring had been cold and wet, and the herd had not been fed as well as planned. Consequently, herd submission and conception rates were below target. The bull was therefore left with the herd for an additional two weeks to mate late cycling cows, delaying pregnancy testing by two weeks.

The major differences between plans in years one and three were due first to strategic decisions (i.e., spring silage use and increased cow numbers for the year three calving), and second, to the impact of conditions prior to, and at the start of the summer planning period. Pre-January culling was delayed until a herd test could be undertaken to obtain more objective data for strategic selection decisions. Most changes to the year three plan however, were in response to the very poor feed position prior to Christmas. Several important changes to the plan were made: reduce the milk production and average herd condition score targets, feed silage and hay with the forage crop, pregnancy test a month earlier using ultrasound, cull empty cows once identified rather than at, or near, drying off, place the herd on once-a-day milking, and return the herd to twice-a-day milking if conditions improved. All of these changes to the "typical" plan were designed to maximise the number of days in milk and get cows through to when the autumn rains could be expected.

5.5.3.3 The targets

A set of targets and associated contingency plans for control purposes were available. The targets can be separated into two types, "terminating" which are those that act at the end of each planning period (Table 5.4), and intermediate, which are those that are used to control the implementation of the plan through time (Table 5.5). The terminating targets acted as planning constraints. They are designed to ensure that conditions are set up for optimal system performance in the next planning period. For example, the terminating conditions for the autumn plan were that the average pasture cover must be at least 2200 kg DM/ha and the herd at condition score 4.5 at the planned start of calving (Table 5.4). Based on experience, an average pasture cover target of less than 2200 kg DM/ha would result in the herd being underfed during early lactation. Besides lower milk production, cow condition and reproductive performance could also be negatively impacted on. On the other hand, if average pasture cover exceeded the target, then many of the paddocks would be at a pasture cover of over 3500 kg DM/ha during late winter. Regrowth from these paddocks would be poor and during the second round post-calving and insufficient feed would be grown to meet herd feed demand. These parameters meant Farmer A also set a maximum average pasture cover target of 2300 kg DM/ha for the winter period (Table 5.5).

Table 5.4. Terminating targets used by Farmer A for the two planning periods across the three years of the study[16].

Terminating conditions	Year 1	Year 2	Year 3
Mid March			
Lactating cow numbers	maximise	maximise	maximise
Average herd condition	4.5	4.5	4.0
Planned start of calving			
Average pasture cover	2200	2200	2300
Average herd condition	4.5	4.5	4.5

The "intermediate" milk production targets (Table 5.5) played an important role over the summer in determining the timing and amount of forage crop (and silage in year one) fed,

[16] Farmer A's reason for each of these targets is described in detail in the case reports in Volume II, Appendices XX - XXII.

while the individual cow condition score targets determined when to place the thin, younger cows on once-a-day milking. Similarly, the average pasture cover targets generated from the feed budget played an important role in determining the drying off date. The intermediate targets contributed to the goals for optimising system performance.

Table 5.5. ***Intermediate targets specified in the plan that are used in the control process[17].***

Targets	Year 1	Year 2	Year 3
Summer			
Milk production			
Pre-forage crop .			
(litres/cow/day)	> 13.0	> 14.0	> 10.0
(kg MS/cow/day)	> 1.13	> 1.22	> 0.87
Forage crop.			
Introduction			
(litres/cow/day)	13.0	14.0	10.0
(kg MS/cow/day)	1.13	1.22	0.87
Maintenance			
(litres/cow/day)	≥ 12.0	≥ 13.0	≥ 10.0
(kg MS/cow/day)	≥ 1.04	≥ 1.13	≥ 0.87
Silage			
(litres/cow/day)	≥ 12.0	NA[18]	NA[19]
(kg MS/cow/day)	≥ 1.04	NA	NA
Rotation length (days)	25 – 30	25 - 30	24 - 30
Cow intakes (kg DM/cow/day)	12.0	13.0	10.0
Post grazing residuals[20] (kg DM/ha)	≥ 1200	≥ 1200	≥ 1200
Individual cow condition (condition score units)	≥ 3.5	≥ 3.5	≥ 3.5
Average herd condition (condition score units)	≥ 4.5	≥ 4.5	≥4.0
Average pasture cover (kg DM/ha)	1400[21]	NA	NA
Benchmark dates			
Removal of bull	26th January	9th February[22]	26th January
Pregnancy testing	Early March	Mid-late March[23]	Early February[24]
Initiation of forage crop grazing	Late January/early February	Late January/early February	Late January/early February
Completion of forage crop	≤ February 28th	≤ February 28th[25] ≤ mid March[26]	≤ mid March
New grass sowing	Mid March	Mid March Mid April[27]	Late March

[17] Farmer A's reason for each of these targets is described in detail in the case reports in Volume II, Appendices XX - XXII.
[18] Silage was not in the original plan for year two.
[19] The plan in Year 3 was to feed silage with the forage crop.
[20] Ideal target, but not strictly adhered to. In dry years, this target is relaxed.
[21] This target was set for April 1st .
[22] Bull removed late in order to mate some late cycling cows.
[23] Later removal of the bull meant the pregnancy diagnosis had to be delayed.
[24] Ultrasound pregnancy diagnosis was used in that year, and could be undertaken a month earlier than the traditional method.
[25] First forage crop.
[26] Second forage crop.
[27] Date for sowing the paddock that had grown the second forage crop.

Table 5.5 (continued)

Targets	Year 1	Year 2	Year 3
Autumn			
Rotation length (days)	25 - 30	25 - 30	24 - 30
Individual cow condition (condition score units)	≥3.5	≥ 3.5	≥3.5
Average herd condition (condition score units)	≥4.5	≥4.5	≥4.5
Average pasture cover[28] (kg DM/ha)	1400	1325	1540
Rainfall (mm)	≥ 25	≥ 25	≥ 25
Milk production (litres/cow/day)	NA	≥ 12.0[29] ≥ 10.0[30]	NA
(MS/cow/day)	NA	≥ 1.04 ≥ 0.87	NA

The importance of targets in decision-making differed between the two planning periods. During summer, milk production targets played the predominant role, rather than average pasture cover, which could not, in Farmer A's opinion, be measured reliably over the summer. During autumn, however, average pasture cover and herd condition played the predominant role. By then objective measurement of pasture was more accurate, allowing the use of formal feed budgeting. Autumn pasture cover was an important predictor of pasture cover at calving - a terminating target. At the start of summer, the average condition of the herd tended to be at a reasonable level (≥ 4.5 condition score units) and gradually declined as autumn approached. Because of the limited time to improve herd condition before calving, the terminating target of 4.5 condition score units became a dominant factor in decision-making.

Benchmark dates were used to control implementation. Some dates such as bull removal, the sowing of new grass and grazing the forage crop were as discussed previously. Other targets were non-negotiable across years, irrespective of conditions on the farm while others were adjusted to suit the conditions. Over the three years, the targets for individual cow condition score, average herd condition score at drying off and calving, and significant rainfall events remained unchanged (Tables 5.4 & 5.5). Other targets changed, for example, in year two, cow intake and milk production targets were increased to take advantage of an expected "wet" summer, and in year three, the "dry" year, the milk production, cow intake, and condition score targets were reduced to

[28] These are the final average pasture cover targets set by Farmer A. Some were revised from those first set after the autumn feed budget was completed around April 1st.

[29] Used to determine when to put the herd onto once-a-day milking. If milk production fell below this level, it indicated the herd was losing condition.

[30] Farmer A used this second, and lower milk production target, to indicate that the herd was losing condition while on once-a-day milking.

maintain the herd in a lactating state until the autumn rains. Thus, cow condition became a form of "feed supplement" to a much greater degree than in previous years. In year three, the average pasture cover target at calving was increased because Farmer A had less silage on-hand than normal.

An interesting proviso was attached to some of the summer targets such as for milk production and cow intake. Because there was insufficient control over the system during the summer to set rigid targets, these were provisional and dependent on feed supply. For this reason, the season's milk production targets were for financial budgeting purposes rather than tactical production management.

5.5.3.4 Contingency plans

The contingency plans considered by Farmer A during the three year study can be classified in terms of their impact on feed supply or demand (Table 5.6). Only some of these were implemented. However, although options can be classified in this way, some had other purposes. For example, placing thin cows on once-a-day milking or drying them off did reduce feed demand, but also protected cow condition. The sale of fewer culls than planned in year three, increased feed demand, but also allowed herd size to be increased for the following season (the primary motive).

Table 5.6. The contingency plans considered by Farmer A during the three years of the study.

Category	Contingency Plans
Increase feed supply	Feed the forage crop early[a] Increase forage crop break Increase the level of forage crop fed Feed silage early[a] Increase the level of silage fed Reduce rotation length Apply nitrogenous fertiliser Apply additional nitrogenous fertiliser Use winter, early spring silage over the summer-autumn and replace later Feed 100% hay to dry cows on the milking area
Decrease feed supply	Increase rotation length Delay grazing of forage crop[a] Retain silage for the spring Provide part of the milking area to the young stock
Increase feed demand	Increase milk production targets in order to increase cow intakes Increase cow intakes by maintaining current rotation length Increase cow intakes Delay placing thin cows on once-a-day milking Delay placing herd on once-a-day milking Sell less culls than planned Dry off less cows than planned Retain dry cows on milking area Return dry cows from the runoff to the milking area Extend the lactation

Table 5.6 (continued)

Category	Contingency Plans
Decrease feed demand	Reduce milk production targets in order to reduce cow intakes Sell culls early[a] Feed cull cows on waste ground until sold Place thin cows on once-a-day milking Dry off thin cows and place on runoff Do not place the herd back onto twice-a-day milking Place dry cows currently run on the milking area onto the runoff Place the herd on once-a-day milking Dry off the herd early

[a] Contingency plans considered by Farmer A, but not implemented.

The contingency plans can also be classified by their impact on the plan (Table 5.7). Several (8) changed the timing of events, while a few (2) changed the sequence of events. A few changed the type of input or event (3) or the sequence of events (2). More (7) were used to change the timing of events. However, by far the most common contingency plan was to change the quantity of input provided or used (18). Many of the contingency plans had mirror images. For example, reducing or extending the rotation had opposite effects on cow intake.

Table 5.7. The contingency plans used or considered by Farmer A during the three years of the study.

Category	Contingency Plans
Changes activation or termination date (Timing of events)	Feed the forage crop early[a] Delay grazing of forage crop[a] Feed silage early[a] Sell culls early[a] Delay placing thin cows on once-a-day milking Delay placing herd on once-a-day milking Extend the lactation Dry off the herd early
Changes sequence of events	Retain silage for the spring Use winter, early spring silage over the summer-autumn and replace later
Changes quantity of input provided or used	Increase forage crop break by increasing the milk production target Increase the level of forage crop fed Increase the level of silage fed Increase rotation length Reduce rotation length Increase cow intakes by maintaining current rotation length Provide part of the milking area to the young stock Increase milk production targets in order to increase cow intakes Reduce milk production targets in order to reduce cow intakes Increase cow intakes Sell less culls than planned Dry off less cows than planned Dry off thin cows and place on runoff Retain dry cows on milking area Return dry cows from the runoff to the milking area Place dry cows currently run on the milking area onto the runoff Place thin cows on once-a-day milking Do not place the herd back onto twice-a-day milking Place the herd on once-a-day milking Apply additional nitrogenous fertiliser
Changes type of input or activity provided or used	Apply nitrogenous fertiliser Feed 100% hay to dry cows on the milking area Feed cull cows on waste ground until sold

[a] Contingency plans considered by Farmer A, but not implemented.

5.6 The control process

The control process used by Farmer A is summarised in Figure 5.1. First, important performance indicators were monitored. Some of this data was recorded and stored, but much of it was retained in Farmer A's memory. Data was processed and analysed to varying degrees and then compared to targets. If the targets were not met or exceeded, then the implementation of the plan continued to be monitored. However, if the performance indicator equaled or exceeded the target, this identified a decision point, a point in time when a decision had to be made.

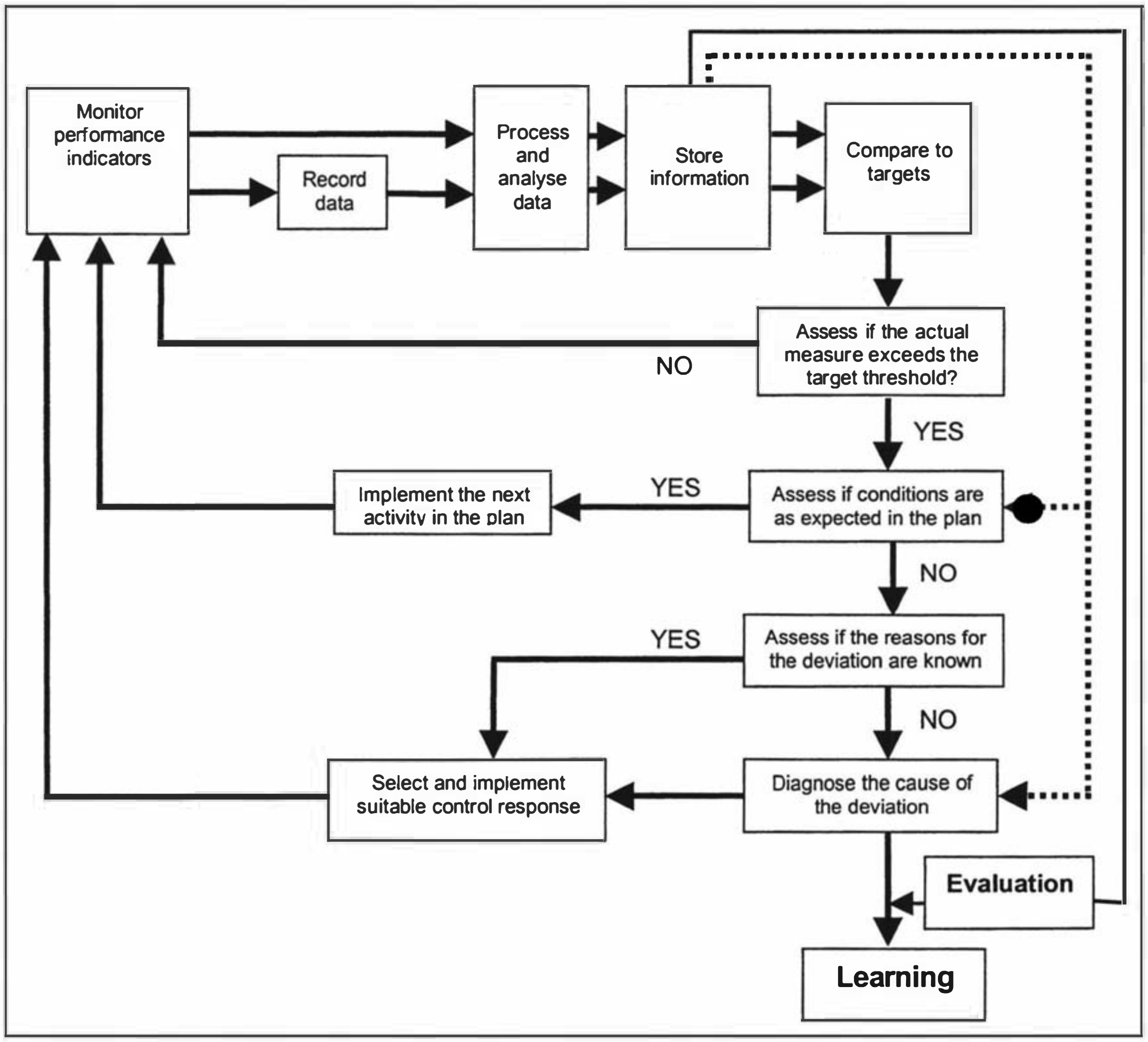

Figure 5.1. The control process used by Farmer A.

One of three responses was possible. If the conditions at the time were as expected, the next activity in the plan was implemented. If however, conditions varied from those expected, and the reason for this deviation was known, a suitable control response was selected to minimise its impact. However, if the reason for the deviation was unknown, its cause was diagnosed, and a suitable control response selected. Control responses used by Farmer A included the selection of contingency plans, the adjustment of targets, the development of new plans, and the modification of the monitoring system. Information stored mentally and in other storage facilities (farm diary, folders) was accessed for evaluation purposes, although there were few instances where Farmer A undertook evaluation. However, when it, or diagnosis was undertaken, learning was an important by-product of the process. The following section describes the control process used by Farmer A in more detail.

5.6.1 Monitoring

The monitoring process used by Farmer A was relatively complex (Volume II, Appendix IV). Some 28 factors were monitored over the summer-autumn, and these can be classified into two high level categories, "*internal*" and "*external*" factors (Table 5.8). All the internal factors could be classified under the sub-category "*production*". "*Financial*" information was not overtly used in the control of the tactical management of the production system. "*Production*" factors can be further sub-divided into two sub-categories: "*feed*" and "*livestock*" factors. These factors dominated the control process. The external factors can be separated into "*climatic*" and "*market*" factors. Climatic information was used to validate other measures and to predict pasture growth rates over a two to four week period. However, weather forecasts were only used for short-term decisions (two to three days) such as hay making, as they were considered to be too unpredictable to be useful for tactical management. Market factors can be separated into output prices (stock and milk) and input prices. The only input price information monitored by Farmer A was urea and this information was used for planning purposes.

The methods used to monitor the factors shown in Table 5.8 can be further classified into two categories: objective or subjective. An objective method requires the use of some form of measuring device. A subjective method relies on one or more of the five senses and these can be further separated into either a quantitative and qualitative category. A quantitative method is one in which some form of quantitative scale is used to measure a factor. For example, pasture or condition scoring. In contrast, a qualitative method does not need a quantitative scale. Most monitoring was subjective in nature. Only milk production, aspects of milk quality, average pasture cover, pasture growth rates, pre- and post-grazing residuals and cow intake were monitored objectively.

***Table 5.8. Classification of the methods used by Farmer A to monitor the farm over the summer-autumn.*[31]**

Factor	**Early summer**		**Late summer & early autumn**		**Autumn**	
	Method	**Classification**	**Method**	**Classification**	**Method**	**Classification**
Internal Factors						
Production factors						
Feed Factors						
Average pasture cover	Visual assessment	Subjective, qualitative	Falling plate meter Visual assessment	Objective Subjective, qualitative	Falling plate meter Visual assessment	Objective Subjective, qualitative
Pasture growth rates	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Falling plate meter Visual assessment	Objective Subjective, qualitative
Pre- and post-grazing residuals	Pasture scoring Visual assessment	Subjective, quantitative Subjective, qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective, qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective, qualitative
Pasture quality	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Crop yield	Visual assessment	Subjective, qualitative				
Crop quality	Visual assessment	Subjective, qualitative				
Silage yield	NA	NA	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Silage quality	NA	NA	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Rotation length	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Livestock factors						
Cow numbers	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Milk yield	Company docket	Objective	Company docket	Objective	Company docket	Objective
Individual cow milk yield	Milking time	Subjective, qualitative	Milking time	Subjective, qualitative	Milking time	Subjective, qualitative
Milk quality of herd	Laboratory test at factory	Objective	Laboratory test at factory	Objective	Laboratory test at factory	Objective
Production index	Herd test	Objective	Herd test	Objective	Herd test	Objective
Individual cow somatic cell count	Herd test	Objective	Herd test	Objective	Herd test	Objective
Average herd condition	Condition scoring	Subjective, qualitative	Condition scoring	Subjective, qualitative	Condition scoring	Subjective, quantitative
Individual cow condition	Condition scoring	Subjective, quantitative	Condition scoring	Subjective, quantitative	Condition scoring	Subjective, quantitative
Cow intakes	Pasture scoring Visual assessment	Subjective, quantitative Subjective, qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective, qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective qualitative
Reproductive status	Visual assessment of behaviour	Subjective, qualitative	Pregnancy testing Visual assessment of behaviour	Subjective, qualitative Subjective, qualitative		

[31] Where more than one method is used for monitoring a particular factor, the more important method from a decision making perspective is placed first.

Table 5.8 (continued)

Factor	Early summer		Late summer & early autumn		Autumn	
	Method	Classification	Method	Classification	Method	Classification
External factors						
Climatic factors						
Rainfall	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Temperature	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative
Wind run	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative
Cloud cover	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Weather forecast	Weather reports and maps	Subjective, qualitative	Weather reports and maps	Subjective, qualitative	Weather reports and maps	Subjective, qualitative
Market factors						
Output price						
Cull cow schedule	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative
In-calf cow store price	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative
Milk price	Dairy company newsletter	Subjective, quantitative	Dairy company newsletter	Subjective, quantitative	Dairy company newsletter	Subjective, quantitative
Input prices						
Urea price	NA	NA	Stock agent	Subjective, quantitative	NA	NA

Farmer A also measured a large number of factors indirectly through proxy measures (Volume II, Appendix IV). His detailed knowledge of the cause-effect relationships within his farming system made this possible (Figure 5.2). Milk production (litres/cow/day), for example, was used to indirectly monitor cow intake, cow condition, average pasture cover and pasture growth rates. Milk production is influenced by the dry matter intake of the herd. Therefore, if milk production is declining, then its likely, so too is cow intake. The decline in cow intake is due to a decline in pre-and post-grazing residuals. Pre- and post-grazing residuals in any particular paddock are a function of pasture growth since the previous grazing. A decline in milk production therefore also suggests pasture growth rates may be declining. Pre- and post-grazing residuals tend to reflect the average pasture cover on the farm, and if these are declining, then so too is average pasture cover. Similarly, Farmer A also knew that when milk production fell below a certain point, normally 12 - 13 litres/cow/day, the herd began to lose condition, and the rate of condition loss was proportional to the rate of decline in milk production. He also knew that changes in some factors along the causal chain were more quickly identified than others. For example, the measurement of a change in average pasture cover or average pasture growth rates using a falling plate meter required a minimum monitoring interval of five days while the visual identification of a change in herd condition could take up to a week to recognise.

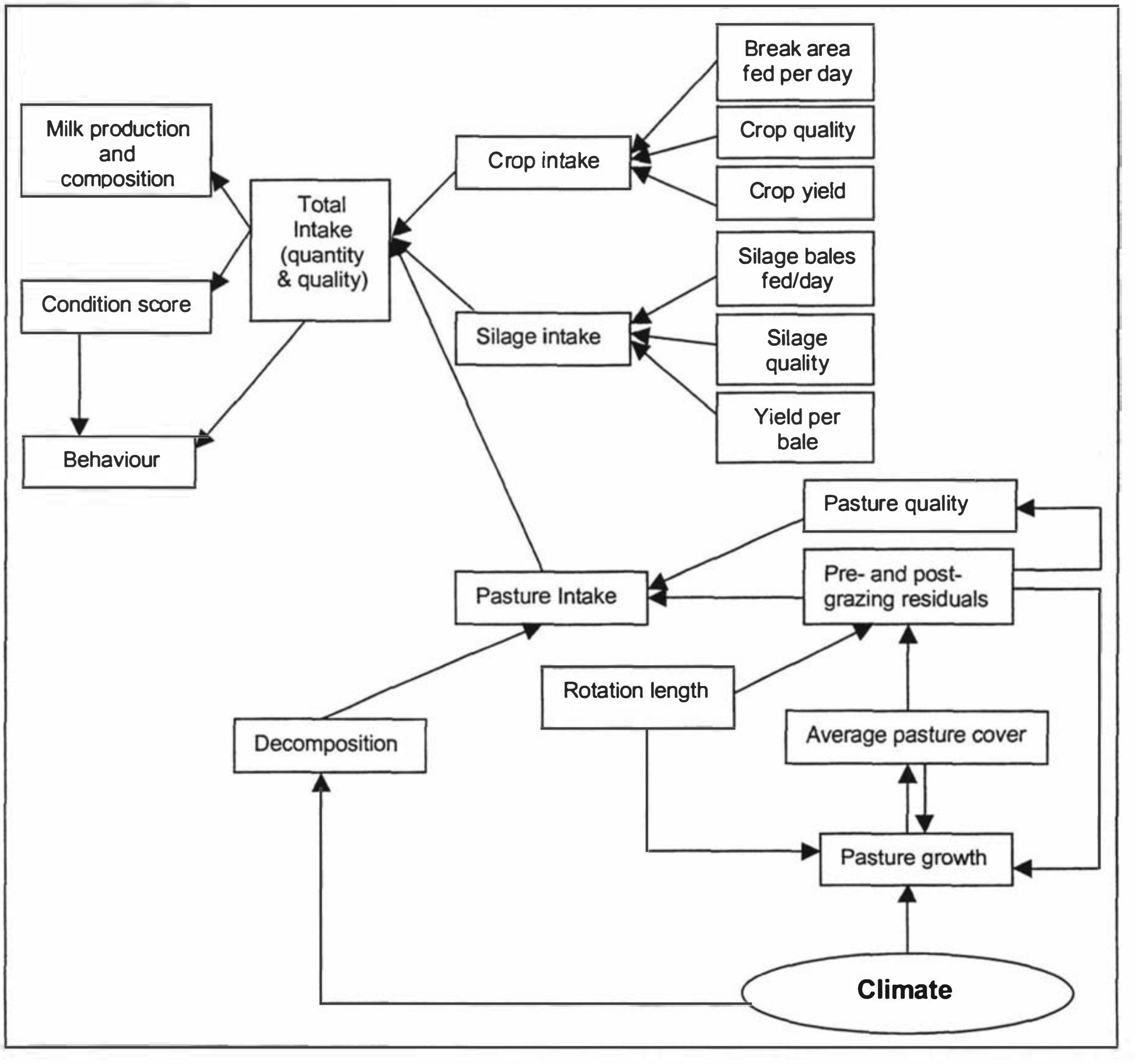

Figure 5.2. Causal relationships used in Farmer A's monitoring system.

Indirect measures were important in managing production. For example, rather than using a falling plate meter, that was costly in terms of time, and had low accuracy due to summer sward conditions, milk production was used as an indirect measure of pasture cover. This measure was sufficiently accurate for the farmer to direct operational management decisions.

The roles played by monitoring information included: determination of decision points, triangulation, determination of control responses, diagnosis and evaluation, prediction of short-term feed position, and planning. Determining the decision points, that is the point at which a performance indicator equals or exceeds a target, was the most important of these roles. At the decision point, a choice between continuing the current plan, or a control response is required. If the latter type of decision was made, then the indicator took on a "*problem recognition*" role. Table 5.9 summarises the factors monitored by Farmer A over the summer-autumn to identify decision points. All these can be classified as lead indicators and were used for concurrent control.

Table 5.9. The role of key indicators in the decision point recognition phase of the control process over the summer-autumn period.

Key Indicators	Indicator Type (Lead/lag)	Role in decision point recognition
Early Summer		
Average milk production (l/cow/day)	Lead	Determines when to feed the forage crop. Determines how much forage crop to feed. Determines when to change grazing rotation.
Pre- and post-grazing residual, cow intakes and climatic data	Lead	Indicates when intakes are about to fall below target and the likelihood that intakes will be below target at the next grazing of a paddock in 25 -30 days. May determine when to reduce stocking rate, or reduce milk production target.
Forage crop state and yield	Lead	Determines when to initiate silage feeding.
Forage crop maturity (and milk production)	Lead	May determine initiation of grazing of forage crop.
Date	Lead	Determines when forage crop is finished.
Rainfall Average milk production	Lead	Determines when to feed additional supplements and change grazing rotation. Also when to remove herd from the forage crop.
Individual cow condition	Lead	Determines which cows to put on once-a-day or dry off.
Production index Milking time Somatic cell count Bulling behaviour	Lead	Used to identify potential cull cows.
Weather forecast	Lead	Used to predict weather for hay making.
Late Summer & Early Autumn		
Average milk production (l/cow/day)	Lead	Determines when to feed the silage. Determines how much silage to feed.
Date	Lead	Determines new grass sowing.
Average herd condition	Lead	Determines whether the herd goes on once-a-day milking.
Rainfall Average milk production	Lead Lead	Determines when to feed additional silage and change grazing rotation.
Pre- and post-grazing residual, cow intakes and climatic data	Lead	Indicates when intakes are about to fall below target and the likelihood that intakes will be below target at the next grazing of a paddock in 25 - 30 days. Initiates silage feeding. Indicates when the herd should return to twice-a-day milking.
Silage state	Lead	Initiate use of spring silage in a dry year.
Individual cow condition	Lead	Determines which cows to put on once-a-day or dry off.
Production index Milking time Somatic cell count Bulling behaviour Pregnancy test	Lead	Used to identify potential cull cows and make culling decisions.
Autumn		
Average pasture cover (actual and predicted)	Lead	Determines drying off date, intake levels, culling date.
Pasture growth	Lead	Determines drying off date.
Pre- and post-grazing residual, cow intakes and climatic data	Lead	Indicates when intakes are about to fall below target and the likelihood that intakes will be below target at the next grazing of a paddock in 25 - 30 days. May determine when to reduce stocking rate. Indicates drying off is imminent. Indicates whether herd should return to twice-a-day milking.
Average herd condition	Lead	Determines drying off date.
Individual cow condition	Lead	Determine which cows to put on once-a-day or dry off.
Pasture quality (clumpiness of post-grazing residual)	Lead	Determines when to bring dry cows onto the milking area to control pasture quality.

In a normal year, the primary indicator for decision point recognition for the summer and early autumn was milk production. This was because it was objective, accurate, and available on a daily basis. In contrast, pasture cover measurement by falling plate meter was believed to be up to 40% out due to sward conditions. Cow condition was difficult to measure accurately, and was less timely than milk yield for identifying changes in the feed situation on the farm. However, as described in Section 5.5.1 from April 1st onwards, average pasture cover, pasture growth and cow condition became primary measures for decision point recognition.

Virtually identical measures for decision point recognition were used across the three years. There were only three exceptions. In year one, a formal feed budget was completed in early March to assess the impact of a strategic decision to use silage in the spring rather than the autumn. Farmer A then used objective average pasture cover information for decision making. In year three, a very dry summer, ultrasound was used instead of the traditional pregnancy diagnosis method to allow the identification (and sale) of cull cows three to four weeks earlier than normal. In the same year, pasture quality, reflected in the "clumpiness" of the post-grazing residual, became a problem during the autumn and this influenced decision making.

Acceptable accuracy is important in decision point and problem recognition. Many of the factors monitored by Farmer A were used to triangulate the measures used for decision point recognition. Triangulation was facilitated through an intimate knowledge of the farming system (Figure 5.2). Farmer A could (i) predict effects further along the causal chain, and (ii) use effects that occur later in the chain to confirm changes in antecedent factors. Three methods (early warning, short-term predictor, and confirmatory measures) were used to achieve triangulation. Subjective and qualitative measures gave an early warning of a change in a factor, for example, visual assessment of pasture cover change (without scoring). Second, an indirect measure of the factor of interest, such as cow intake for cow condition, was used as a "*short-term predictor*". "*Confirmatory*" measures, for example milk production per cow per day and changes in cow condition confirmed the veracity of Farmer A's monitoring of cow intake and pre-and post-grazing residual measures, respectively. Objective measurement had a central role in validating situations because of the predominance of subjective measures. It was important that the latter were "calibrated" against an objective measure to ensure acceptable accuracy. Milk production during summer, and both milk production and average pasture cover during the autumn, were used for this purpose. Triangulation every two to five days between milk production, pre- and post-grazing residuals and cow intake was pivotal to the farmer's measurement system.

The monitored information was also used for control response selection once a decision point was recognised. In this case, situation specific information was used in conjunction with heuristics to determine whether to continue to implement the existing plan, and if this was not the case, then to select which control response to implement. Volume II, Appendix V shows the range of information used for control response selection (see also Section 5.6.4.1).

Few external sources of information were monitored for tactical production management. Those that were used could be classified as market factors and included the cull cow schedule, in-calf cow store price and milk price. The milk price influenced the consideration of external feed options such as urea, while the relative value of cows sold for meat versus store influenced when (and where) in-calf culls were sold.

Farmer A undertook limited diagnosis and evaluation and few lagging indicators, used for historical control, were identified during the study. Milk production was an important lagging indicator. As described earlier, it was used to determine Farmer A's accuracy in subjectively assessing the system. Milk production therefore acted as the primary lead and lag indicator for management decision-making.

Monitoring results were also used to make short-term (two to four week) predictions of the future feed situation on the farm. More than 25 mm of rain indicated a rapid increase in pasture growth rates about two weeks later. The post-grazing residual of the paddock the herd had just left, plus estimated growth, gave the pre-grazing pasture cover at the next grazing in 25 - 30 days. Cow intake was then estimated and compared to the required target (Volume II, Appendix VI). These methods provided Farmer A with a quick and simple method of forecasting and up to a month's forewarning of potential feed deficits. Control responses could then be made well in advance of the problem. The entire process was repeated every two to five days.

Finally, information collected during the summer was used for formal feed planning around April 1st. Information on the state of the herd (milk production and average condition score), pastures (average pasture cover and pasture growth rates), supplements (forage crop, silage, hay), and the prevailing weather conditions, was all used to develop a feed budget through to calving.

5.6.1.1 Activation, termination and frequency of monitoring

Central to an efficient monitoring system are rules that determine when to activate and terminate the monitoring of a factor and the monitoring interval. Decision rules were used to determined when particular factors had to be monitored, and in some cases the frequency of monitoring (Volume II, Appendix VII). The simplest means by which the monitoring was initiated was through the occurrence of an event (e.g. pregnancy testing, herd testing, forage crop feeding). Once the event was completed, the monitoring of the respective factor was terminated. Benchmark dates also initiated the monitoring process. For example, average pasture cover was objectively monitored soon after mid March when sward characteristics allowed the pasture to be measured with acceptable accuracy.

The activation or termination of monitoring was primarily initiated when the factor of interest, or some indirect measure of the factor, passed a threshold. For example, the condition of the younger cows was not consciously monitored until the average condition of the herd fell below 4.5 condition score units. Milk production data provided an indirect measure of the condition of the younger cows in the herd. When milk production fell below 12 litres/cow/day (1.04 kg MS/cow/day), this indicated the younger cows were losing condition and their condition was then consciously monitored.

The majority of the measures used by Farmer A were monitored on a daily basis (Volume II, Appendix IV). Other than irregular measures such as herd and pregnancy testing, the other measures were monitored at two to 13 day intervals. Pre- and post-grazing residuals and cow intakes were monitored at two to five day intervals, and average pasture cover and pasture growth rates were monitored at five to 13 day intervals. Daily measures were mainly monitored as Farmer A went about his normal farming duties and few monitoring activities required additional effort. These included herd testing, pregnancy diagnosis, and the monitoring of pre- and post-grazing residuals, cow intake, average pasture cover and pasture growth rates. A 10 day monitoring interval was normally used for average pasture cover and pasture growth rates because division by ten made mathematical calculations simple when estimating pasture growth rates. Farmer A also believed that this monitoring interval was appropriate at that time of the year because conditions changed so rapidly. Average pasture cover and pasture growth rates were not monitored at intervals less than five days because this created problems with errors.

The frequency with which some factors were monitored changed. Rate of change influenced some of these decisions. For example, milk production per cow per day was not estimated from daily milk dockets until total volume changed significantly. Similarly, the frequency with which average pasture cover was monitored was also influenced by the rate of change in that factor and its absolute value. In years where conditions were good and average pasture cover was improving, the monitoring interval was extended. However, where conditions were deteriorating rapidly, the monitoring frequency was reduced. The imminence of a critical decision also influenced the frequency of monitoring. In year one, Farmer A reduced the monitoring interval to his minimum of five days as the drying off date approached.

The activation, termination and monitoring interval decision rules had been developed through time as Farmer A learnt what factors needed to be monitored at particular points in time (and under particular conditions) to ensure his goals were met. He admitted that during his early days in farming he had monitored every thing that was possible to monitor, but over time, had learned what was important. These rules minimised the effort Farmer A had to put into monitoring.

The monitoring system used by Farmer A was timely, effective and low cost in terms of time and capital. The majority of the factors were monitored on a daily basis and the longest monitoring interval used during the study was 13 days. The short monitoring interval and triangulation process ensured suitable and timely information for decision making. The majority of factors were also monitored while Farmer A went about his normal farm activities, minimising the time cost. Where possible, decision rules were used to activate, terminate and adjust the frequency of monitoring to further reduce the monitoring effort. The effort required for the most time-costly process, objective measurement of average pasture cover, was also minimised by Farmer A visually pre-selecting only four representative samples from each paddock. The capital cost of monitoring was also low because the only instrument Farmer A had to purchase for monitoring purposes, a falling plate meter, was made from waste material on the farm.

5.6.2 Recording and data processing

Farmer A used a very simple recording system: milk production data provided by the company (ten daily) was stored in a folder along with herd and pregnancy test results. The bulk of the collected information was stored in either a large farm diary or mentally. In the diary, information about key events (sale of culls, date crop fed, drying off), pasture cover and pasture growth rate data, and mating information was recorded. This formed an historical record of the season and could be referred back to for diagnostic or evaluation purposes, or to check what had been done in previous seasons. As with the recording, limited processing was undertaken by Farmer A on the data collected. Means were calculated for milk production per cow and average pasture cover. Pasture growth rates and cow intake (both current and predicted) were also estimated. Likely pasture growth rates were predicted for the next three to four weeks and cow intake at the end of this period was calculated to provide an indication of the likely feed position on the farm.

5.6.3 The environment

To understand the control responses used by Farmer A, it is important to understand the environment in which he operates. The focus of this study was production management of a dairy herd over the summer-autumn. The primary source of risk facing Farmer A in relation to production was variation in climate, which in turn dictated pasture growth rates, the primary feed source[32]. Variation in pasture growth leads to variation in feed supply that in turn causes variation in milk production. During the three years of the study, milk production ranged from 270 kg MS/cow and 745 kg MS/ha to 334 kg MS/cow and 1015 kg MS/ha. Managing variation in pasture growth dominated decision-making in relation to production management. Risk associated with pests and disease was rated low because preventative procedures could be used to control these, including two debilitating animal health problems, bloat and facial eczema.

During the summer-autumn, other sources of risk (market, human, social and legal, technological, inter-firm competition, and financial) were rated as low and had minimal influence on Farmer A's production decisions. Market risk was low because by early summer the price for milk was known with reasonable certainty once the dairy company had updated their final price forecast for the season. The nature of the product (milk) and the fact that it was sold to a cooperative meant that Farmer A made few marketing decisions that would impact on production. He could however, make marketing decisions in relation to the sale of cull cows, the other source of output price risk. Stock prices can vary considerably during the summer-autumn, but cull cow sales over this period only make up a small proportion of total income (< 10%). In relation to empty cows, production decisions over-rode any concern about market risk and their value. As such, these animals were sold to the works in response to the feed situation on the farm, and not on the basis of their price in the market. However, this situation was reversed for in-calf cull cows. These animals were worth up to twice the works price if sold to other dairy farmers

[32] Pasture supplied between 80 – 90% of the feed consumed by the milking herd over the summer-autumn period during the three years of the study.

who were building up herd numbers[33]. These animals were retained on either the milking area or runoff for sale at the end of the milking season. The additional monetary gain by selling these cows later offset the extra feed cost associated with carrying them an extra two to three months.

Input price risk was low because of the short time frame and the relatively low rate of inflation (< 3%) occurring at the time (Burtt, 2000). An exception to this was the price for bought-in feeds which is dependent on supply and demand, a function of the summer-autumn weather (dry, normal, wet). However, Farmer A did not normally buy in feed over this period.

Human risk was rated as low because Farmer A did not employ labour. His owner/operator status meant his greatest risk was from injury or disability. During the three years, there were no recorded instances of legal and social, or technological sources of risk influencing Farmer A's decision making in relation to production management. Because he was a member of a nation-wide cooperative dairy industry, no competition existed between dairy farmers in terms of milk sales. There was some competition between farmers in relation to the sale of cull cows, but this had no influence on Farmer A's decision-making in relation to production management. Farmer A also had limited debt, access to over-draft facilities, good cost control, and a regular cash flow from milk sales. Interest rate effects were minimal. As such, financial risk did not influence Farmer A's production management decisions over the summer-autumn.

5.6.4 Control responses

Preliminary control responses were used by Farmer A over the summer-autumn in relation to animal health[34] and forage crops and silage were fed during periods when pasture growth rates were most variable. By far the most common type of control was concurrent control. No examples of "elimination of disturbances" control responses were identified. However, examples of historical control were observed, the number of which was dependent on the amount of learning that occurred in any one year.

The types of control responses used by Farmer A for both concurrent and historical control over the three years are shown in Table 5.10. Four of the five possible concurrent

[33] During the study period, the dairy industry was in an expansion phase and demand for in-calf cows was such, that in-calf culls could fetch up to twice their works value in the store (live sales) market.
[34] Preventative animal health remedies were used for bloat and facial eczema control.

control responses (see Section 2.4.1, Chapter 2) were used. He developed a new plan in the summer of year one, when above average feed condition allowed him to remove his silage from the summer plan and transfer it to the autumn plan. This was undertaken because he believed there had been a change in climatic patterns. However, he did not change goals in response to a deviation from the plan. He did however adjust implementation, modify plans, and adjust the monitoring system. Only one instance of implementation adjustment was identified over the three years. This was in year three, when he learnt that the bulbs of a new variety of turnips had to be left for two to three days after the initial grazing before they were soft enough for the herd to eat.

Table 5.10. The nature of the concurrent control responses used by Farmer A across the three years of the study.

Type of response	Year 1	Year 2	Year 3
Concurrent control			
Adjust implementation	No	No	Yes
Modify plan			
Change planning horizon	No	No	No
Introduce contingency plan	Yes	Yes	Yes
Develop & introduce new contingency plan	Yes[35]	No	Yes[36]
Introduce opportunity	No	No	No
Remove activity or input	Yes	No	No
Change targets	Yes	Yes	Yes
Develop a new plan	Yes	No	No
Adjust monitoring system			
Recalibrate monitoring system[37]	Yes	No	No[39]
Introduce new monitoring method	No	No[38]	No
Change goals	No	No	No
Historical control			
Implement new forms of preliminary control	Yes	No	No
Implement new forms of elimination of disturbances control responses	No	No	No
Refine the existing plan			
Introduce new input or activity	No	No	No
Remove input or activity	Yes	No	No
Change targets	Yes	Yes	No
Implement new forms of concurrent control			
Introduce new contingency plan	Yes[40]	No	Yes
Remove contingency plan	No	Yes[41]	No
Modify monitoring system			
Recalibrate monitoring system	No	No	No
Introduce recalibration rules[42]	Yes	No	No
Introduce new monitoring method	No	No	No
Change goals	No	No	No

35 Associated with the introduction of a higher milk production target.

36 Introduced a contingency plan to feed the herd above target intake because the dry matter at that time of year was not maintaining cow condition as would be expected under normal conditions. Rather than recalibrate the monitoring system, the herd was fed to a higher level.

37 Includes introducing new rules of thumb for assessing silage and forage crop yield.

38 A new monitoring method (ultrasound pregnancy diagnoses) was introduced in year two. However, its selection occurred during the planning, not the control process.

39 Rather than recalibrate pasture dry matter, Farmer A increased cow intake targets to ensure cow condition was maintained.

40 Associated with the introduction of new milk production targets.

41 Associated with the removal of the rule to use higher milk production targets during a wet summer.

42 For pasture, silage and forage crop yield estimation.

Plan modification was the most common form of concurrent control (Table 5.10). Four of the six methods of plan modification were used: introducing contingency plans, developing and implementing new contingency plans, removing activities or inputs, and changing targets. Farmer A did not change the planning horizon, or introduce opportunities. The most common form of plan modification was through the implementation of contingency plans (see Section 5.5.3.4). Some instances of new contingency plan development were identified and these tended to occur under extreme conditions.

Only one instance of input removal was identified: deferring silage from the summer-autumn to the spring in year one. This control response was partly concurrent and partly historic. Only one instance of monitoring system adjustment was recorded. In year one, the pasture scoring system was recalibrated because the sward structure was different for the wetter than normal summer conditions.

Farmer A used four of the six forms of historical control over the three years of the study (Table 5.10). New forms of "elimination of disturbances" control response was not used, nor were goals changed for the summer-autumn. In year one, a new form of preliminary control, the transfer of summer silage to the spring to cope with a perceived increase in the variability of pasture growth as a result of perceived climate change was introduced. Existing plans were refined either through the removal of an input or activity or by changing targets. New forms of concurrent control were introduced and the monitoring system was modified in several ways.

The introduction of a new input or activity was not used to modify plans. In year two, after learning in the previous year that the herd could produce at a higher level over the summer if feed conditions were above average, Farmer A increased the milk production targets for the summer plan because another wet summer was anticipated. This historical control response was reversed when in year two, he learnt that wet summers could not be reliably predicted and that higher milk production targets increased the risk of not milking the herd through to the autumn rains.

Some examples of Farmer A implementing new forms of concurrent control were identified. In year one, he learnt that under good growing conditions, he could take advantage of the additional feed by increasing the milk production target and changing the associated contingency plans. These contingency plans were then included in his repertoire. Pasture scoring was recalibrated in year one because of the unusual growing conditions during the wet summer. This knowledge provided him with a recalibration rule that could be used under such atypical conditions. This was the only modification made to the monitoring system.

5.6.4.1 Control response selection

The process for choosing a control response can best be represented by a set of decision rules (Figure 5.3). The decision rules took the form of an "IF" statement that specifies the conditions that indicate a decision point has been reached, then normally several "AND" statements that specify important characteristics that define the problem situation, followed by a "THEN" statement which specifies the response that should be instigated (Volume II, Appendix VIII). The problem situation characteristics played two important roles. First, they determined if the current plan was continued or a control response required. Second, if a control response was required, they determined the exact nature of that response. In other words, the problem situation characteristics were matched to a problem solution.

IF milk production is ≤ 13.0 litres/cow/day	) Identifies decision point
AND rainfall ≥ 25 mm, **AND the crop is ungrazed,** **AND the rotation length = 25 days,**	)) Determines nature of response)
THEN feed sufficient forage crop to maintain production at 1.04 kg MS/cow/day.	) Specifies response)

Figure 5.3. The structure of a control response selection process rule.

However, not all control responses were selected in this manner. A form of *ex-ante* evaluation of decisions was also used to determine whether a control response was required. Two instances of this approach were recorded over the three years and these both involved appraising whether the next option in the current plan should be implemented. A mental simulation of both the current option and the preferred alternative was undertaken. The predicted outcomes were compared in relation to their possible impact on milk production and the state of the herd and farm at the end of the planning period. The best course of action was then selected. In year two, for example, the impact of using spring silage was assessed in terms of the likely impact on milk production and cow condition over the summer. This evaluation suggested the silage should be fed during the summer.

Four factors were found to influence the type and number of contingency plans used in any one year. These were: the type of resources available (a function of strategic decision making), the state of the farm at the start of the summer (quantity of resource available), the nature of the summer and autumn, and the type of summer plan implemented by Farmer A ("wet", "dry", "typical"). Resource availability had a limited effect on the choice of contingency plans. However, in year one, the strategic decision to use autumn silage in the spring limited the summer-autumn contingency for silage.

The state of the farm at the start of the summer in combination with the climatic conditions over the summer-autumn also dictated the type and number of contingency plans used by Farmer A (Table 5.11). A greater number of contingency plans were used when the farm was in a poor state at the start of summer as opposed to a good state. Similarly, more contingencies were used during a dry summer than a wet summer. In part, this was because in a wet summer, the main response was to increase the milk production, and associated cow intake, targets. In contrast, in a dry summer, a range of contingencies was introduced to either increase feed supply or reduce feed demand. Similarly, if conditions alternated between dry and wet during the summer-autumn, a greater number of contingency plans were introduced (Table 5.11). For example, in year three, the summer was dry and contingency plans were introduced to increase feed supply and reduce feed demand. In contrast, pasture growth rates in the autumn were considerably above average and contingency plans then had to be put in place to increase feed demand by the herd and ensure pasture quality did not deteriorate (i.e. essentially a shorter grazing rotation).

The "plan" (“dry”, “typical” or “wet”) chosen by Farmer A to meet the conditions expected over the summer also influenced the type and number of contingency plans used. If a plan was modified for expected conditions, certain activities and targets in the “typical” plan were replaced with what would normally be contingency plans. As such, if the prediction was correct, fewer contingency plans had to be implemented compared to the situation where the plan had not been modified. However, if the prediction was wrong, as was the case in year two when a “wet” summer was predicted, additional contingencies had to be implemented to reverse the “inappropriate” changes to the modified plan.

Table 5.11. A cross-year comparison of the contingency plans used by Farmer A[43].

	Year 1	Year 2	Year 3
Feed position at start of summer	**Good**	**Good**	**Poor**
Type of season			
Summer	**Wet**	**Dry**	**Very dry**
Autumn	**Typical**	**Dry**	**Good**
Summer plan used	**Typical**	**Wet**	**Dry**
Category			
Feed deficit responses			
Increase feed supply	Reduce rotation length	Reduce rotation length Use winter, early spring silage over the summer-autumn and replace later Provide part of the milking area to the young stock[44]	Feed 100% hay to dry cows on the milking area Apply additional nitrogenous fertiliser
Decrease feed demand	Feed cull cows on waste ground until sold	Reduce cow intakes by reducing the milk production target Dry off thin cows earlier than planned	Reduce cow intakes by further reducing the milk production target[45] Feed cull cows on waste ground until sold Do not place the herd back onto twice-a-day milking Place dry cows currently run on the milking area onto the runoff Retain dry cows on the milking area[46]
Feed surplus responses			
Decrease feed supply	Retain autumn silage for the spring		
Increase feed demand	Increase cow intakes by increasing the milk production target Extend the lactation[47]	Increase cow intakes by increasing the milk production target	Increase cow intakes Delay placing herd on once-a-day milking Delay drying off thin cows Return dry cows from the runoff to the milking area Extend the lactation[48]

[43] These include contingency plans that increase or reduce targets.

[44] This option was used to increase feed supply on the land the replacement stock were run on. It was used because the feed deficit on this block was greater than that on the milking area and the young stock had priority over the older stock.

[45] Farmer A had reduced the milk production target to 10 litres/cow/day or 0.87 kg MS/cow/day in the summer plan. As a contingency to reduce cow intakes further, he reduced this target to 7.5 litres/cow/day or 0.70 kg MS/cow/day in February.

[46] Used to reduce feed demand on the runoff where feed was short. Farmer A had originally planned to run 30 dry cows on the runoff, but the dry conditions prevented this.

[47] The feed budget in early April estimated a drying off date of 30th April. This is 15 days later than the typical date of mid April.

[48] The feed budget undertaken on March 28th set a date of May 1st. The herd was actually dried off on May 20th.

5.6.5 Evaluation

Two types of evaluation were used by Farmer A, diagnosis and *ex-post* evaluation. Diagnosis was only used when an outcome differed significantly from Farmer A's expectations (Volume II, Appendix IX). His "holistic" monitoring system[49] and knowledge of cause and effect relationships in the production system meant expectations for a range of outcomes (daily milk production, empty rate etc.) had been developed. Thus, while an outcome might be different from the plan, this was explainable and no diagnosis was thought to be necessary. Diagnosis did occur when conditions were outside Farmer A's experience, and/or the monitoring system provided inaccurate information (Volume II, Appendix IX). In the former situation, insufficient knowledge was available to accurately develop an expectation. For the latter case, and this often occurred under extreme conditions, expectations were based on inaccurate information. For example, in the summer of year one and January of year two when pasture growth rates were extremely high, Farmer A underestimated pasture cover because sward characteristics were abnormal. As such, his expectations for milk production (litres/cow/day) were wrong because these had been based on inaccurate information about feed supply. Similarly, in year three, his expectations in relation to the number of cows mated to artificial insemination were found to be wrong once pregnancy test results were obtained from the veterinarian. Cold, wet conditions in the previous spring had placed the herd under nutritional stress and some of the cows that had not conceived demonstrated "silent heats" as opposed to normal behaviour. Farmer A had failed to identify these "silent heats" and believed the cows were in-calf.

The diagnostic process used by Farmer A was identified. If an outcome differed significantly from an expectation, knowledge of cause and effect relationships was used to develop a set of hypotheses about possible causes. If this knowledge was inadequate his peers or a local expert such as a veterinarian, were consulted before a set of hypotheses about possible causes was developed. The most likely hypothesis was then selected from the set and a means by which it could be tested devised. Data was then retrieved from either memory or the farm recording system to test the hypothesis. If it was confirmed, the process was complete, but if refuted, the process was repeated with the next most likely hypothesis.

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[49] Farmer A's use of post-grazing residuals to estimate cow intakes in 25 - 30 days time provides an even longer-term predictor of an approaching feed problem than his other indicators and allowed the development of accurate expectations.

Diagnosis was not the only form of evaluation undertaken by Farmer A (Volume II, Appendix IX). *Ex-post* evaluation was undertaken after a decision or set of decisions had been implemented and the outcome was known. Evaluation was undertaken at the end of a planning period, after a new input or management practice had been implemented, when a poor outcome was identified, or when a normal decision about which he was not confident had been implemented. Ignoring on-going evaluations, some 70% of the evaluations involved a new management practice and/or atypical climatic conditions (Volume II, Appendix IX). The purpose of the *ex-post* evaluation was to evaluate the decision (or decisions) to confirm that it was a "good" decision, or that it needed to be changed. The ultimate aim of the evaluation was to improve Farmer A's management.

The *ex-post* evaluations were either those undertaken on an on-going and regular basis or carried out irregularly. The former were used to ensure the accuracy and timeliness of the monitoring systems and that the plan was implemented correctly (Volume II, Appendix IX) while the latter were used to evaluate specific management decisions. Four forms of *ex-post* evaluation were used (Volume II, Appendix IX). The first method was to compare the outcome of a decision with a norm. In these instances, a new input or management practice had been used and the evaluation was used to determine if it performed as well as, or better than the current practice. For example, when a new forage crop was introduced, its performance was compared to the variety usually planted. The purpose of the evaluation was to decide whether to retain the new input or practice, or discard it. The criterion for retention was that it performed as well as, or better than the norm.

The second method of *ex-post* evaluation was to compare the outcome to the standards specified in the plan. The purpose of the evaluation was to determine if the decision of interest had allowed Farmer A to meet the standards set in the plan. For example, to assess whether drying off had occurred at the right date, the check was whether average pasture cover and cow condition targets (standards) for drying off had been met. If they had, this confirmed that the decision was correct. However, if the standards had not been met, then it identified an area for improvement. The third method of evaluation was to compare the outcome with Farmer A's expectations. The criterion for evaluating a decision was whether or not expectations had been met. If it did, then it was retained in Farmer A's repertoire of decisions, but if it did not, it was discarded.

The fourth method was to compare the actual outcome to a mental simulation of the likely outcome if the decision (or decisions) of interest had not been implemented or an alternative had been adopted. The criterion used to assess the decision was whether the actual outcome was better than that anticipated for an alternative decision. If the criterion was met and if the decision was a new practice, it was retained in Farmer A's repertoire, and if it was not met, it was discarded. If the decision was not a new management practice, and the criterion was met, this confirmed the efficacy of the decision. If the criterion was not met, then this identified an area for improvement.

A range of factors initiated the evaluation process (Volume II, Appendix IX). In some instances, it was because the outcome deviated from some standard or norm; in others, there were extreme, or rapid changes in conditions, and in some instances the evaluation took place after the outcome of the decision was known. Most evaluations occurred when there were extreme climatic conditions, a rapid change in conditions, or a new management practice had been introduced. The evaluations did not always occur immediately after one of the above conditions had occurred. Sometimes an area of interest might be reflected on for several months before a conclusion was reached. Some evaluations that were undertaken after the summer-autumn were therefore probably not recorded during the study.

The evaluations undertaken by Farmer A can be classified into five main categories: planning, implementation, control, overall management of a planning period and systems performance (Volume II, Appendix IX). Planning decisions can be separated into those associated with input use, management practices, choice of targets and planning assumptions. Interestingly, over the three years, no evidence was found that Farmer A evaluated his planning assumptions. Limited evaluation of plan implementation was undertaken. He did however undertake an on-going evaluation of his allocation of silage, forage crop break size and area in pasture to ensure the herd was fed to the level specified in the plan.

Control can be separated into two areas of evaluation, control decisions and the monitoring system. Control decision evaluation can be further classified into two sub-categories: contingency plan selection and target choice. Contingency plan selection can be separated into three areas, input use, management practices, and target choice. Only one instance of management practice evaluation was recorded during the three-year study. No instances of input selection or target choice evaluation were recorded. The monitoring system was evaluated in terms of accuracy, timeliness, and the accuracy of short-term predictions based on monitored data. System performance was only evaluated in two areas: reproductive performance and forage crop yield failure. Similarly, overall management of only one period, autumn of year one, was evaluated.

The planning and control decisions evaluated by Farmer A are classified by type and level in Table 5.12. The majority (71%) of the decisions evaluated were associated with planning rather than control. Interestingly also, almost a third of the decisions evaluated were strategic in nature. Therefore, although the focus of this study was at the tactical level, information generated from the tactical management process was used to evaluate various aspects of strategy. The relatively limited number of evaluations undertaken by Farmer A reflected the relative stability of his farming system over the period of the study. Few new inputs or farming practices were introduced, although it is possible that these might not have all been recorded (e.g., because they took place outside the study timeframe). On the other hand, this may be a result of inadequate evaluation and therefore active exploration of new ways to increase performance.

Table 5.12. Classification of planning and control decisions evaluated by Farmer A.

Decision	Decision type	Decision level
Use of inputs		
Use of a leafier variety of forage crop	Planning	Strategic
Management practices		
Planting an additional paddock of forage crop	Planning	Tactical
The use of ultrasound to identify empty cows early	Planning	Tactical
The decision to go onto once-a-day milking	Planning	Tactical
The decision to dry off the herd at a specific date	Control	Tactical
Choice of targets		
Decision to increase the milk production target	Planning	Tactical
Decision to increase the milk production target	Control	Tactical

5.6.6 Learning

Learning was one of the products of the evaluation process (Volume II, Appendix X). In some cases the learning occurred during the diagnosis or evaluation processes, and at other times, learning was delayed until reflection had occurred. Some learning related to events outside of the summer-autumn period, demonstrating the reflective and sometimes lagged nature of the learning process. Several instances of learning that occurred prior to the initiation of the study were also identified (Volume II, Appendix X), and these included: identification of relevant monitoring factors, specification of a suitable milk production target, the impact of post-grazing residuals on milk yield, management of cows at low body condition score and the impact of on-off grazing on winter pasture growth rates. Not surprisingly, learning tended to occur when either a new management practice or input was used, and/or in an extreme season where conditions were outside those previously experienced by Farmer A.

Learning occurred in relation to four primary areas: the environment, the production system, the management system and values (Volume II, Appendix X). In many instances, learning related to the interaction between two or more of these areas. For example, the effect of late harvesting of supplements (a management practice) on pasture regrowth (production system) in a dry year (environment). The learning classified under the environment related to the biophysical environment, and in particular, climate. Despite Farmer A's experience, numerous instances were recorded over the three years where climatic conditions were different to any previously encountered. This illustrates the magnitude of climatic variation faced by the farmer. No instances of learning in relation to the socio-economic environment were recorded.

Three aspects related to production were learned (Volume II, Appendix X). These were how the system responded to: climatic extremes, new management inputs or practices, and the interactions between these two factors. Learning related mainly to livestock and forage, and the interaction between these sub-systems. The area of learning in relation to forage was primarily aspects of performance such as yield, growth rate, quality and utilisation, and the determinants of these. Areas of learning in relation to the herd were primarily performance related (milk production, reproductive performance), and the drivers of this (intake and body condition). Few instances of learning related to soils were recorded and these related to the use of urea to increase pasture growth rates.

The most complex learning related to the management system and the impact of new management inputs or practices on productivity. Management system learning could be usefully separated into strategic and tactical management processes (Volume II, Appendix X). Under each of these levels, the management process can be separated into planning, implementation and control. Areas of learning related to planning encompassed forecasting, activity rules for input use and management practices, target selection, contingency plan specification and planning assumptions. Learning in relation to implementation included input use and management practices. Control was separated into monitoring (method, accuracy, timeliness and usefulness) and contingency plan selection (input use, management practice and choice of targets).

The final area of learning was in relation to Farmer A's values. At the start of the study period, Farmer A had a "self-sufficiency" or "low input" philosophy. The preference was to make all supplements on the property and only used nitrogen as an option of last resort. His learning challenged this thinking (Volume II, Appendix X) and in years two and three, nitrogen was incorporated directly into the autumn-winter plan. Similarly, in year three, hay was bought-in so as not to reduce pasture regrowth during the expected “dry” summer.

The outcome from the learning process depended on the learning event (Volume II, Appendix X). In some cases, the information simply added to the farmer's general understanding of the production system and environment. However, in other cases it resulted in a change in practice or the values (or philosophy) underpinning the management system.

The very dry third year showed that the farmer had also learnt to trust his tactical management procedures and not to panic. The validity of the procedural rules for extremely dry conditions was established. Farmer A also learnt about "shifts" in the climate. Three consecutive cold, wet springs prior to year two had been experienced, and this led to changes in management (Volume II, Appendix X). Similarly, after experiencing two consecutive wet summers, Farmer A decided that the conditions at the start of year two indicated a continuation of this trend and the higher milk production target, found to be effective during the previous wet summer, was adopted. However, conditions turned dry very quickly and Farmer A "unlearned" this lesson, deciding to return to the previous milk production target. These examples demonstrate the difficulties farmers face when trying to distinguish between short-term aberrations and longer-term trends. It also shows the "power" of experience in influencing farmer behaviour. Although Farmer A had been classified as an expert, mistakes were still made. However, the important point is that the mistake was quickly identified and rectified. The way in which tactical management is undertaken suggests that the context or situation in which the learning takes place is important. Both plan and control response selection are dependent on the context in which the decision is made. Therefore, a link must be made between the conditions associated with the learning and the learning outcome.

5.7 Conclusion

In this chapter, the tactical management process used by Farmer A has been described and between-year differences identified and discussed. The tactical management process used by Farmer A was a cyclic process as proposed in the normative literature. Both formal and informal planning processes were used and heuristics played an important role in planning. Farmer A monitored multiple factors and through his intimate knowledge of the production system he had developed a simple low cost (time and capital) monitoring system. An important component of the tactical management process was evaluation. This facilitated learning and was used to improve Farmer A's management. In the following chapter, the tactical management process used by the second case farmer is reported.

CHAPTER 6 CROSS-YEAR CASE REPORT FOR FARMER B

6.1 Introduction

This chapter begins with a description of the case study, Farmer B, his farm and farming system and therefore follows the same format as the preceding case report. Between-year differences in management processes are highlighted. Because replication logic was used to select supposedly identical cases, where a process used by Farmer B is the same as that used by Farmer A, to prevent duplication, the reader will be referred back to the relevant description in Chapter Five.

6.2 Case description

At the time of the initial case study Farmer B was a 50/50 sharemilker[1] with thirteen years dairy farming experience which included six years as a manager and the last four years as a 50/50 sharemilker. He had four years secondary education and obtained a diploma in agriculture from the local university. He was in his early thirties and married with three young children. His goals were to pay off current debt and accumulate assets to move up to a larger herd of over 500 cows. Farmer B owned the herd and described his debt load as reasonably high[2].

The case farm is located in the Kairanga district of the Manawatu region in the lower half of the North Island of New Zealand. The climate is temperate with 988 mm annual rainfall, a minimum mean daily air temperature of 8.0°C in July and a maximum mean daily air temperature of 17.6°C in February (NZMS, 1980). At that time the farm area was 97.5 hectares comprising 94.0 effective hectares for milking with the young stock grazed off-farm. The farm had been converted from an arable farm over several years as land in cash crops was regrassed. Farmer B had farmed the land since 1985 when the milking

[1] A 50/50 sharemilker owns the herd and farms it on another farmer's land. The income from milk is shared 50/50. Returns from stock sales are retained by the sharemilker. The farmer pays for the cost of maintaining the land and building. The cost of bought-in feed and grazing is shared 50/50 between the farm owner and sharemilker.

[2] Equity would be around 60% given the market value of the herd at the time.

area had only been 37 ha. Thus, although Farmer B knew the farm well, much of the area had only recently been regrassed out of cash crops. Although the farm was well set up in terms of subdivision, races, water supply and milking plant, the pastures and drainage still required further development. Drainage was particularly important because of the nature of the soil type, a Kairanga silt loam, a gley recent soil (Hewitt, 1992). Some 60.0 ha of the farm was tile and mole drained some 15 years ago and requires remoling. The other third of the farm had little drainage and this was considered a major limitation. The farm was also prone to flooding from a nearby river during periods of high rainfall. The farm had Olsen P levels of between 21 – 37 indicating a moderate to high level of soil fertility. The pastures on the farm were predominantly ryegrass and white clover. Approximately 5.0 – 8.0 ha was regrassed each year after a summer forage crop.

The milking area was subdivided by both conventional and electric fences into 32 paddocks. The farm is rectangular in shape and well raced. Water was supplied from an artesian bore with two troughs in every paddock. The herd was milked through a 29-aside herring-bone shed. This took a maximum of two hours per milking during the season. There were three houses on the farm, one occupied by the owner, one rental, and one used by Farmer B. Aside from the house, the only other buildings on the farm were two hay sheds, an implement shed and workshop. Farm machinery was adequate for most operations, but contractors were employed for hay and silage making, fertiliser spreading and cultivation work. Farmer B employed a farm worker and his wife helped out with calf rearing and general farm work.

During year one, 330 Friesian-Jersey cross cows were peak milked on 94.0 ha at a stocking rate of 3.51 cows per hectare. The herd produced 96,726 kg milksolids[3] (MS) at 322 kg MS/cow or 1029 kg MS/ha (Table 6.2). Data from the dairy company for that year shows that the average[4] supplier peak milked 157 cows on 71.0 ha at a stocking rate of 2.2 cows per hectare. The total production for the "average" supplier was 47,854 kg MS at 298 kg MS/cow or 674 kg MS/ha. In year two, the effective area was increased to 104.0 ha and an extra 30 cows were peak milked at a slightly lower stocking rate of 3.17 cows/ha. Total production was 82,056 kg MS, or 249 kg MS/cow and 789 kg MS/ha. In that year, the average dairy company supplier peak milked 172 cows on 75.0 ha at a stocking rate of 2.29 cows/ha. Total production was 48,825 kg MS or 273 kg MS/cow and

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[3] This includes an estimate for milk fed to calves.
[4] Data for the Ohakea district could not be separated out by the dairy company.

651 kg MS/ha. In the final year of the study, Farmer B peak milked the same number of cows on the same area. Production was 107,640 kg MS or 326 kg MS/cow and 1035 kg MS/ha. The average dairy company supplier was peak milking 194 cows on 73.1 ha at a stocking rate of 2.55 cows/ha. Total milk production was 56,314 kg MS or 290 kg MS/cow and 740 kg MS/ha.

6.3 Description of the three years

In general, the climatic conditions experienced by Farmer B were similar to those experienced by Farmer A as their farms were only 20 km apart. In year one, at the start of the planning period, the farm was in a good position in terms of the feed position, cow condition and milk production (Table 6.1). Pasture growth rates were above average from January to April and below average in May. The pattern of pasture growth is reflected in the monthly data on average pasture cover, pre- and post-grazing residuals, cow intakes, milk production, cow numbers and average herd condition during year one (Volume II, Appendix XI).

In the second year, the milking area was increased by 10.0 ha and an extra 30 cows were peak milked (Table 6.1). However, 84 replacement heifer calves were grazed at home rather than run on a grazier's property. The effective area in pasture was 8.0 ha greater than the previous year, once the additional area in forage crop was deducted. The farm had experienced a very cold wet spring, and the condition of the herd had fallen to 3.8 condition score units at mating. The farm had received 200 mm of rain in December compared to 70 mm in the previous year. These conditions, particularly as the drainage on the farm was sub-standard, limited pasture growth rates and influenced the state of the farm and the herd at January 1st. As a result, the farm was carrying 3 less cows than the previous year and in a much poorer feed position at the start of the summer. Average pasture cover was 300 kg DM/ha lower and the herd was in poorer condition than the previous year. Similarly, milk production per cow was 21% below the previous season and there was 63% less silage on-hand. Farmer B had also planted 2.0 ha less forage crop, although the per hectare yield was similar to the previous year. The farmer had no maize silage and 1040 less bales of hay on-hand. However, 8.0 ha of maize had been planted for maize silage.

Table 6.1. The resources on-hand at the start of the summer-autumn period, and the monthly pasture growth rates for the three years of the study.

Resources at 1/1/xx	Year 1	Year 2	Year 3
Average pasture cover (kg DM/ha)[5]	2000	1700	2000
Pasture quality	Good	Good	Good
Cow condition	4.75	4.1	4.75
Milk production (kg MS/cow/day)	1.31	1.04	1.31 - 1.36
Milking cow numbers	323	320	327
Effective area (ha)	94.0	104.0	104.0
Stocking rate (cows/ha)	3.4	3.1	3.1
Stocking rate (cows/pasture ha)	3.6	3.3	3.4
Calf numbers	0	84	0
Forage crop area (ha)	5.2	3.2	8.0
Estimated yield (kg DM/ha)	10,500	10,000	7,500
Maize silage crop (ha)	0	4.0	0
Grass silage (wet tonnes)	120	75	500
Maize silage (wet tonnes)	300[6]	0	350[7]
Hay (bales) (15 kg DM/b)	2250	1210	0
Bought-in feed			
Summer urea (tonnes)	0	4.0	0
Maize silage (wet tonnes)	0	420	8.0 ha
Greenfeed maize (wet tonnes)	0	125	0
Cut pasture (kg DM)	0	10,000	0
Pasture growth rates (kg DM/ha/day)			
January	44	24	25
February	32	25	8
March	37	24	45
April	44	30	62
May	18	25	25
Total (kg DM/ha) for period 1/1 – 31/5	**5285**	**3863**	**5029**
Supplements fed[8] (kg DM)	120,600	122,050[9]	285,000
Supplement fed per cow[10] (kg DM/cow)	373	381	872
Planned winter/early spring supplements (kg DM)	158,550	225,580	NA[11]

Pasture growth rates through January, February, and March were considerably lower than those recorded in year one. During April, pasture growth rates were about average, but much lower than in year one when the farm had a much higher average pasture cover. However, during May, pasture growth rates were 39% higher than in year one. Overall, the farm grew 27% less pasture per hectare over the summer-autumn than in year one (Table 6.1) and this reflected the drier conditions. A similar amount of supplement was fed over the year two summer as in year one. The difference in conditions between years one

[5] During summer, the figures given for average pasture cover are estimates because Farmer B was not formally monitoring this information.
[6] Only 100 wet tonnes is available for the summer-autumn.
[7] Only 250 wet tonnes of maize silage was available for the summer-autumn.
[8] This is an estimate of the supplements fed to the herd over the summer-autumn. Allowance must be made for wastage.
[9] Includes an estimate for increased pasture growth in response to the urea application.
[10] This is based on the number of cows on-hand at the start of the summer.
[11] Farmer B moved to a new farm during the winter of year three.

and two of the study is reflected in the monthly data on average pasture cover, pre- and post-grazing residuals, cow intakes, milk production, cow numbers and average herd condition (Volume II, Appendix XI).

In year three, the milking area and cow numbers peak milked remained the same as in year two (Table 6.1). During November, heavy rain had caused flooding, and then the farm had had five weeks of hot, dry conditions over December with 5mm of rain falling. This reduced regrowth ahead of the herd, limited the amount of hay and silage that could be cut off the milking area, and inhibited forage crop establishment. Conditions were so dry at mid December, that Farmer B began feeding silage to the herd on the 20th December. Cow numbers at January 1st were slightly higher than in year two, but the replacement heifer calves were not grazed on the milking area. The farm was in a much better position than in year two, and very similar to year one in terms of average pasture cover, cow condition and per cow milk production (Table 6.1). However, unlike year one, conditions had been dry for five weeks and pasture growth was limited. In contrast, the farm had considerably more grass and maize silage on-hand than the previous two years (Table 6.1). However, at January 1st, there was no hay on-hand, and although there was a larger area in forage crop, Farmer B estimated that the final yield would only be 15 - 20% of average. The forage crop yield improved to 75% of average, and the data suggest that Farmer B fed over twice the level of supplement per cow in year three as compared to the two previous years. Therefore at January 1st, Farmer B was in a good feed position in terms of supplements and average pasture cover, but pasture growth rates were low due to the dry conditions.

Through January pasture growth rates were similar to year two, but 43% down on year one (Table 6.1). Pasture growth rates however, were only 8.0 kg DM/ha/day through February, lower even than those recorded in year two, and only 25% of those recorded in year one. Pasture growth rates increased to 45 kg DM/ha/day in March, almost twice that recorded in year two, and 22% above those of year one. During April, growing conditions were ideal and pasture growth rates averaged 62 kg DM/ha/day. This was 41% and 107% higher than years one and two respectively. Pasture growth rates declined through May, and were the same as year two, but higher than year one.

Despite the very dry conditions at the start of the summer in year three, the farm only grew 5% less grass per hectare than the wet summer of year one. In contrast, it produced 30% more than year two. The difference in conditions between year three and the previous two years of the study is reflected in the monthly data on average pasture cover, pre- and post-grazing residuals, cow intakes, milk production, cow numbers and average herd condition (Volume II, Appendix XI).

The study period therefore covered three contrasting years (Table 6.1). The first could be classified as a "wet summer" with above average pasture growth rates from January to April and then below average growth rates in May. The second year could be classified as a dry summer with below average pasture growth rates through January to April, with above average pasture growth rates in May. In contrast, dry conditions occurred in December in the final year, and pasture growth rates were below average for both January and February. However, the rains came in late February, ensuring pasture growth rates were exceptional through March and April, and slightly above average through May. The supplement situation was similar in years one and two, but in year three, the farm had over twice that level of supplement on-hand for use over the summer-autumn.

6.4 The tactical management processes used by Farmer B

The tactical management processes used by Farmer B was essentially the same as that used by Farmer A (as described in Section 5.4). The following section describes the important components of this process. First, the planning process, and second, the control process used by Farmer B over the three years of the study are described. Due to the wealth of data, examples only are given to illustrate important aspects of management practice. Further information describing the tactical management process used by Farmer B is provided in the supporting appendices (Appendices XI - XIX) and annual case reports (Volume II, Appendices XXIII - XXV).

6.5 Planning

6.5.1 The planning horizon

One of the first steps in Farmer B's planning process, was the determination of the planning horizon. Two primary planning horizons were used for tactical management over the summer-autumn period. The first was from January 1st until mid March; the second was from mid March until the point in the spring at which pasture growth equalled feed demand, commonly referred to as "balance date". Balance date was on September 30th. A formal feed budget was developed at the start of the second planning period. The activation date for the first planning period related to a change in seasonal conditions. Prior to January 1st, pasture growth tends to exceed “herd” (including some replacements) feed demand, and the focus of management was on the control of pasture quality. By January 1st, silage paddocks, harvested in November, had regrown and been incorporated back into the grazing rotation. Post-January 1st, as conditions become hotter and drier, herd feed demand tends to exceed pasture growth, and the focus of management shifted to ensure an adequate feed supply. Farmer B saw this as the period of the year when he fed the herd silage and forage crop.

The termination date for the first planning period and the activation date for the second planning period was partly season related and partly critical event related. Normally around this date (typical date = mid to late March), the autumn rains arrive. Conditions prior to this are dry and warm, and as a result of the rains, there is normally a rapid increase in pasture growth rates which farmers refer to as the "*autumn flush*". Farmer B identified maize silage feeding and drying off with this second planning horizon. He stressed that at mid March, the focus shifted from the current to next season. A critical event, drying off, normally occurred in May. In effect feed demand is halved, allowing average pasture cover to rapidly increase. Drying off was also used to prevent further loss of cow condition in the herd. This decision was therefore critical for setting up the farm for the coming season, and in particular, another critical event, calving. The drying off decision was also irrevocable and if it was made too early, income from further milk production in the current season was foregone.

The termination point of the second planning horizon was balance date. This was the point at which pasture growth equals feed demand in the spring. After this point, pasture growth exceeded feed demand and the focus of management was the control of pasture quality. Prior to this point, feed demand exceeded pasture growth, and Farmer B used pasture cover, supplements and cow body condition to make up the feed deficit and ensure the herd was fully fed. To ensure this, average pasture cover was not allowed to fall below a certain minimum level. Farmer B specified this level for balance date which in turn sets the minimum level for average pasture cover on-hand at calving. Calving was a critical event because the level of feed on-hand and condition of the herd at this point determined milk production in early lactation and subsequent reproductive performance. The tactical planning horizons were changed in response to the conditions and a strategic decision. In year three, the summer planning horizon was brought forward to December 20th because conditions were extremely dry and Farmer B had over four times his normal quantity of grass silage on-hand. In the same year, the start of the initiation of formal feed budgeting was delayed until early April because the feed situation on the farm was above average. Similarly, in the same year, the autumn planning horizon was terminated at June 1st rather than September 30th because Farmer B had made a strategic decision to change farms on this date.

Farmer B sometimes thought in terms of shorter-term planning horizons in much the same way as Farmer A (see Section 5.5.1). For example, in early January in year two, his main focus was to ensure he did not graze the forage crop until the end of January. This planning horizon encompassed two events, the maintenance of the herd on a purely pasture diet, followed by a period of three weeks in which the herd was supplemented with grass silage. The selection of this planning horizon was goal-driven. To optimise the use of the forage crop, its grazing had to be delayed until the end of January. Given the poor feed position at the start of January, the plan was tailored to achieve this. Farmer B was also planning out to the end of February, the point to which he wanted his forage crop to last. The reason for this was that if he could use the crop to ensure the maximum number of cows were in a lactating state at this point, he had a greater chance of taking advantage of the autumn rains. Similarly, in early March, Farmer B was planning through to early April. His concern at that point was that if pasture growth rates did not improve and/or he could not generate additional feed through some other means, he might have to dry off the herd in early April.

Although two distinct tactical planning horizons were identified, Farmer B was clearly thinking across a number of different planning horizons simultaneously. Thus, at January 1st, he was planning in relation to: (i) balance date, (ii) the next calving, (iii) drying off, (iv) to mid March, the start of the autumn, (v) the 24 - 30 days until the next grazing round, (vi) goal-driven, event-based short-term planning horizons, that encompassed one or more events of between one week and two months duration and then in shorter time frames such as (vii) over the next week, and (viii) the next day's operations.

6.5.2 Planning process

Across the three years, Farmer B used a primarily qualitative planning process with some quantitative aspects over the summer, and then changed to a formal quantitative planning process incorporating a feed budget, that also included some qualitative planning processes. The formal planning process was undertaken around mid March, a point in time when the autumn rains normally arrived. The following sections describe the informal and formal planning processes used by Farmer B.

6.5.2.1 Informal planning process

Farmer B had a "typical" summer plan developed over time and based on experience. The plan contained a set of heuristics identical to those used by Farmer A which determined the components of the plan (see Section 5.5.2.1). This “typical” plan was implemented each year unless some factor or factors caused Farmer B to modify it. The typical plan was modified for four reasons. First, if a strategic decision had been made that impacted on the plan, then the plan had to be modified. For example, in year one, Farmer B introduced maize silage and a new forage crop, Japanese millet into the plan. He also modified his plan in response to learning during the previous planning cycle, an example of historical control. For example, in year two having learnt that the Japanese millet was not as good as his traditional forage crops, Farmer B replaced it with a more traditional crop, Emerald rape. The plan was also modified in response to atypical tactical decisions made in the preceding planning period. For example, in year two Farmer B decided to use the 100 tonnes of maize silage he had in reserve during the preceding wet spring. He had originally planned to feed this in the autumn. As such it was not available, and had to be removed from the plan.

The fourth factor that determined if the “typical” plan was modified was the state of the farm at the start of the summer. Farmer B assessed the state of the farm in relation to average pasture cover, pasture growth, cow condition, milk production, reproductive state of the herd, silage on-hand, likely forage crop yield (weeks of grazing), the number of cows (stocking rate), cow intake and feed demand (kg DM/ha/day). This information was used to undertake a mental feed budget where Farmer B estimated the feed demand (kg DM/ha/day) of the herd, compared it to the likely pasture growth over January- February, and then considered how well the grass silage and forage crop would make up any feed deficit. Farmer B also used a prediction of cow intakes from post-grazing residuals to consider how well the herd would be fed in three to four weeks time based on the grazing rotation and likely pasture growth rates. He also compared the situation to the previous year. This information was also used to assess if the typical plan was feasible and to classify the situation as "dry" or "typical", where typical included both a normal and above average feed position.

If the feed situation was classified as "typical", then the "typical" or modified version of the "typical" plan was implemented. However if the situation was classified as "dry" then several changes were introduced into the plan (see Table 6.3). For example, in year two, to cope with a "dry" year, Farmer B introduced heuristics that changed the milk production target and the sequence of silage and forage crop feeding, brought forward the date at which thin and cull cows would be removed from the milking area, and extended the use of the forage crop (see examples in Table 6.2). These changes were designed to ensure as many cows as possible would be in milk when the autumn rains arrived. Farmer B had had to feed out his autumn maize silage in the previous cold, wet spring. This meant this option had to be removed from the plan. An iterative process, similar to that described for Farmer A was used by Farmer B to modify the typical plan.

Modifications to the "typical" plan in year three, another "dry" year, were quite different (Table 6.2). This was because Farmer B had made a strategic decision to dramatically increase the amount of summer-autumn supplement he used[12]. Changes to the "typical" plan included: initiating the summer plan 11 days earlier, changing the sequence, timing (December 20th to March 1st) and amount of grass silage fed, delaying the date at which the forage crop was grazed, bringing forward the date at which the thin younger cows were removed from the milking area and increasing the amount and period over which the maize silage was fed.

The plan modification process varied in complexity, usually involving changes to one or more of the sequencing, activation and termination, input type and level, and target selection heuristics. At its simplest, a new input or management practice replaced the existing input or practice in the plan with minor modifications. For example, Farmer B twice substituted new varieties of forage crop, which did not change any of the heuristics except that in the case of Japanese millet, heuristics had to be devised for a second grazing. At a slightly more complex level, Farmer A inserted new inputs into the plan such as maize silage. New heuristics had to be developed for such options, but in the case of the maize silage, the heuristic was a derivation of the ones used for an analogous supplement, grass silage. Other changes were of a similar nature.

[12] It was more than double the amount fed per cow used in the previous two years (see Table 6.1).

Table 6.2. Examples of modifications to plan heuristics for a "typical", and "dry" summer.

Rule type	Examples
Target setting rules	
Typical summer	IF conditions at the start of summer are typical or above average, THEN use a milk production target of 1.04 kg MS/cow/day.
Dry summer	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN reduce the milk production target to 0.87 kg MS/cow/day until the forage crop is ready to graze in late January.
Sequencing rules	
Typical summers	IF conditions at the start of summer are typical or above average, THEN plan to feed silage after the forage crop has been grazed.
Dry summer	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN maintain the herd on their current rotation length allowing milk production to fall below target and begin feeding the silage at the point when it can be used to feed the herd to target until the end of January. Feed the forage crop after the silage.
Activation rules	
Typical summer	IF milk production ≤ 1.13 kg MS/cow/day, AND the forage crop is ungrazed, THEN graze the forage crop.
Dry summer	IF the grass silage has been fed, AND it is a dry year, AND it is late January, THEN feed the forage crop at such a rate that milk production is held at 1.04 kg MS/cow/day.
Termination (and activation) rules	
Typical summer	No corresponding rules
Dry summer	IF it is a dry year, AND a forage crop is available, AND the grass silage has been used, AND the level of other supplement on the farm is limited, THEN ensure the forage crop lasts for the month of January and dry off cows to ensure milk production is held around 1.04 kg MS/cow/day.
Input type and level rules	
Typical summer	IF date ≥ January 1st, AND the forage crop is ungrazed, AND milk production > 1.13 kg MS/cow/day, THEN maintain the rotation length at 21 - 22 days.
Dry summer	IF average pasture cover and expected pasture growth rates are insufficient to maintain the herd at target milk production until the end of January, AND grass silage is available, AND grass silage is insufficient to fully feed the herd until the end of January, AND no other supplements are available, THEN reduce the milk production target to 0.87 kg MS/cow/day for the period when the herd is grazing solely pasture and draw on cow condition as an alternative supplement.

An important response in a "dry" summer was to reduce the milk production target. This had quite major implications, changing cow intakes, and the timing and rate of input (pasture, supplement and cow body condition) use heuristics. Similarly, sequencing heuristics were changed, such as in years two and three when silage was fed before the forage crop rather than after it to increase yield.

One instance was recorded where Farmer B used a more formal approach to modify the summer plan. This was in year three where December had been extremely dry, but Farmer B had over four times his normal amount of grass silage on-hand as a result of his high input strategy. Rather than use his heuristics to modify the plan and then use mental simulation to test its feasibility, Farmer B had to adopt a more quantitative approach. Using estimates of feed demand and feed supply he devised a new plan over a period of several days. Although the plan was not documented, the planning process was more formal and required much greater effort than in previous years. This suggests that where changes to a plan are extreme, farmers cannot simply modify their existing heuristics, but must undertake a more quantitative analysis to determine how the change will be incorporated into their plan.

6.5.2.2 Formal planning process

Farmer B initiated a formal planning process and used a planning aid (feed budget) around mid March at the termination of the summer plan. The timing of this change-over was season-dependent because the autumn rains normally occurred around this date. The change in planning approach related to the need to accurately assess the farm feed position prior to drying off the herd (a critical event) and because sward characteristics had changed enabling more reliable pasture measurement. Because of the importance of the drying off decision, Farmer B believed that a formal planning process should be used to assess the most appropriate date. In year three, Farmer B delayed the development of a formal plan until early April because feed conditions were above average in late March and he was in the process of changing farms.

A formal feed budget form, originally developed by the dairy extension service was used to plan from April 1st until balance date at the end of September. The planning aid was used to estimate the drying off date for the herd which would ensure calving targets for farm pasture cover and herd condition and balance date targets for average pasture cover were met. Heuristics or decision rules were still used to specify the sequence of events within the plan. Terminating conditions at balance date and targets at planned start of calving for average pasture cover and average herd condition were specified. The situation at mid March was assessed and data collected on the number of cows on hand, current milk production and cow intakes, the average pasture cover and pasture growth rates, and the amount of supplements on-hand. Key events that occurred during the planning period were specified, including the return of replacement in-calf heifers, grazing off dates for part of the herd, the timing and amount of supplements fed, and calving date. Heuristics were used to determine the sequence of these events. Pasture growth rates and a pattern of feed demand for the herd was specified. Farmer B had obtained pasture growth rate data from the local university and his local farm consultant. He validated these against his monitored data over time. Average monthly pasture growth rates were used and there was no evidence that Farmer B adjusted these in response to specific conditions at the start of the planning period.

The feed budget form had monthly time intervals, except for May where shorter time intervals were required to calculate the drying off date. During the three years, limited analysis of alternative management actions was undertaken. Rather, Farmer B, like A, relied on his heuristics to generate the body of the plan, with the feed budget used to estimate the drying off date and derive associated average pasture cover targets

During the planning phase, only one example of Farmer B undertaking an analysis of alternatives was identified during the study. In year one, he revised his mid March feed budget in early April and analysed two scenarios. The first scenario was to implement the plan set out in mid March of culling cows in early April and then drying off two mobs of thin younger cows, the first in early April and the second in late April. The second scenario was to milk the entire herd through until drying off and then cull. The latter scenario allowed Farmer B to dry off the herd earlier. However, the trade-off was that the thin younger cows could lose too much condition, which might be difficult to put back on, and as the schedule price tends to decline through the autumn, culling later would reduce returns from the cull cows. As such, Farmer B decided to continue to implement his mid March plan. Importantly, Farmer B reported that he had used partial budgets to analyse changes to his plan (e.g. the use of winter grazing) in previous years. He also stated that once this analysis had been completed there was little need to repeat it unless prices or input costs changed significantly.

In year two, Farmer B analysed the ability of his autumn plan to cope with variation in spring pasture growth rates. The region had been experiencing a sequence of cold, wet springs and Farmer B had set aside a reserve of maize silage as insurance against subsequent poor spring conditions. He used his feed budget to assess the degree of variation in pasture growth rates this reserve could buffer through the spring. His analysis suggested that it could cope with a 30% decline in pasture growth rates similar to that experienced in the year one spring. This was the only form of risk analysis undertaken by Farmer B over the three years.

The number of times and the means by which Farmer B formally revised his initial feed budget varied across the three years. In year one, Farmer B revised his feed budget in early April and again in early May just prior to drying off. These feed budgets were different from the first in that Farmer B employed a consultant to input his plan into a spreadsheet-based computer program that had weekly time intervals. The shorter time periods were more useful for control purposes, but the analysis was essentially the same as that undertaken in mid March. Because Farmer B did not have the software for the detailed feed budget, he could not revise the feed budget in between the consultant's visits. Instead he used a graph of weekly average pasture cover levels to estimate the plan's progress. The date of the second revision was designed so that the drying off date could be estimated near to the time that it was expected to occur. In year two, Farmer B only revised the plan once on April 27th, and he used the gross feed budget rather than the detailed spreadsheet. He stated that he did not bother undertaking a detailed feed budget because the feed position was so good over the autumn. It was not until June 8th, post-drying off, that he completed a detailed feed budget with his consultant. In year three, Farmer B did not formally revise his plan over the autumn. Again, the feed position was good, and Farmer B had a large quantity of maize silage on-hand.

6.5.2.3 Rolling planning

Although there was no formal revision of the summer plan, Farmer B, like A (see Section 5.5.2.3), did use a process similar to rolling planning. This reflected Farmer B's attitude towards planning, in that at no point did he think his plan was inflexible. He stated that his plan consisted of "*possible options*" that may change depending on conditions. He recognised that his ability to forecast future conditions was limited, and that as a result, he had to build flexibility into his plan. He stated that although he may plan to dry off cows during the summer, he could not predict how many cows this would actually be. Similarly, although he aimed to maintain milk production at or above 1.04 kg MS/cow/day, he knew that in extremely dry conditions, this target would not be met. Although the control aspect of planning was emphasised by Farmer B, he did not revise or analyse his contingency plans during the summer, or autumn planning processes. These appeared to be stored in memory and as the plan was implemented, certain contingency plans were revised according to the conditions and time of year. For example, Farmer B might consider what options he would implement in early January if conditions became dry and milk production fell below target prior to when his forage crop was ready to graze in late January. A contingency plan suitable to the conditions was then activated when a deviation from the plan occurred. Farmer B's plans for the three years of the study are discussed in the following sections.

6.5.3 The plan

As with Farmer A, Farmer B had a "*typical*" plan developed over time and based on experience. Heuristics (Volume II, Appendix XII) were also central to Farmer B's plan. The plans developed by Farmer B can be separated into four components: the goals (and values) that drove the process, a predictive schedule of events, and the targets and associated contingency plans used to manage implementation. These components are discussed in the following sections.

6.5.3.1 Goals and values

There was no evidence of a process for goal formulation in relation to summer management. The goals for the summer had been formulated previously and were the same in each of the three years. Farmer B's goal for the summer period was to efficiently produce milk from the feed resource and ensure as many lactating cows as possible were on-hand at the start of the autumn. The summer goal was subservient to the autumn goal which was to optimise autumn milk production while ensuring early spring milk production was optimised, and that the herd was in good condition for mating. Autumn milk production was constrained by the need to achieve certain minimum terminating conditions or targets at balance date (average pasture cover and condition). These were designed to optimise systems performance over the early part of the next lactation. Farmer B believed that conditions at balance date and calving had a much greater influence on production (and hence profitability) than feeding decisions made throughout the summer-autumn. The terminating conditions in turn set the conditions at planned start of calving for cow condition and average pasture cover. The targets at planned start of calving in turn dictated the levels for these at drying off and in effect constrained autumn milk production. These terminating conditions, in effect, determined how long into the autumn Farmer B could milk his herd.

Farmer B did reformulate his autumn goals in relation to the terminating average pasture cover target for balance date and his pasture cover and cow condition targets for calving. These were increased in years two and three to improve herd nutrition in early lactation and milk production and reproductive performance (see Section 6.5.3.3). The goal for the autumn plan remained the same, but the increase in target levels had implications in terms of drying off date (it shifted earlier) and feeding levels in early lactation (improved).

To ensure the summer-autumn goals were met, Farmer B used a range of targets (see Section 6.5.3.3). These in-effect could be viewed as lower level goals in a goal hierarchy and underneath these goals were the tasks Farmer B undertook to meet the targets and hence higher level goals. A range of targets were set to prevent actions taken during the summer adversely affecting next season's production. For example, cow condition and milk production targets "protected" the herd body condition, whilst rotation length and milk production targets "protected" the pasture from over-grazing.

An aberration occurred in year three when Farmer B terminated his sharemilking agreement, and the need to leave the farm with an average pasture cover of 2000 kg DM/ha on June 1st dictated his autumn planning. Similarly, in year two, Farmer B decided to retain his replacement heifer calves on the milking area. His goal over the summer-autumn for this stock class was to produce well grown replacement stock. To ensure this goal was met he measured their actual performance against monthly liveweight targets.

Importantly, precise and quantifiable monthly milk production targets were not set for the summer-autumn. Some were set for budgeting purposes, but these played no role in monthly tactical production management. Farmer B knew that milk production was very dependent on the climatic conditions over the summer-autumn and these could neither be predicted with any accuracy, or be controlled. Setting precise production goals was therefore not seen to have value.

Values played a limited role in tactical management over the summer-autumn period. Their main influence was on option selection. Farmer B was an opportunity seeker and actively sought out opportunities to buy in feed at a suitable price. This expanded the feed options he had open to him outside those encompassed by the farm boundary. He actively sought out options in years one and two. However, in year three when he had over twice the supplement level on the farm as in previous years external feed sources were not sought.

6.5.3.2 The predictive schedule of events

The schedule of events[13] specified in the "typical" plan and each plan for the three years of the study are summarised in Table 6.3. In year one, Farmer B made two strategic changes to his typical plan. First, an alternative forage crop that could be regrazed was introduced. Prior to this, forage crops were only grazed once over February. Second, maize silage was introduced as an autumn supplement. In the past, no autumn supplement had been used. Therefore, prior to year one, the typical plan (Table 6.3) had been to graze the herd on a 21 - 22 day rotation until the forage crop was ready in late January, early February. The herd was introduced to the forage crop when milk production fell to 1.13 kg MS/cow/day and fed sufficient to maintain milk production at 1.04 kg MS/cow/day. While on the forage crop, the rotation length was extended out to 35 - 42 days. The bulls were removed from the herd in early February. The cows were herd tested in late February. Once the forage crop was grazed in late February, early March, the herd was fed silage at a level that maintained milk production at 1.04 kg MS/cow/day. While on supplements, the herd was maintained on a 35 - 42 day rotation, and when the silage was completed, the herd remained on this round until drying off. The new grass was sown in mid March. The herd was pregnancy tested in late March and then herd tested in early April. The cull cows were identified and sold after herd testing. Thin younger cows were dried off when their condition fell to 3.5 condition score units. The rotation length was extended further as stocking rate was reduced. When average pasture cover and cow condition targets were met around the late April, early May, the herd was dried off. At that point, the rotation length was doubled to about a 100 days.

Farmer B, like Farmer A, used heuristics to determine both the sequence and timing of events. Milk production was used as an indirect measure of intake during the summer in place of a formal feed budget to set herd feed intake targets. The logic behind this approach is shown in Figure 6.2 (see Section 6.6.1). The "schedule of events" included dates and associated decision rules that specified the particular conditions under which these events would be implemented. This meant an inherent flexibility was built into the plan in much the same way as described for Farmer A (see Section 5.5.3.2).

[13] The schedule of events comprises those for the period of the study (Christmas - drying off). This schedule of events covers the summer period and the early part of the plan developed at April 1st. Events beyond drying off are not incorporated, although this would include the return of the in-calf rising two year heifers to the milking area, the feeding of supplements over the winter and the grazing rotation of the herd over winter.

Table 6.3. Farmer B's plan[14] for the summer-autumn for the three years of the study.

Typical year	Year 1	Year 2	Year 3
		Set stock the calves across the entire farm over the summer-autumn.	
Maintain the herd on a 21 - 22 day rotation until late January or milk production falls to 1.13 kg MS/cow/day	Maintain the herd on a 21 - 22 day rotation until late January or milk production falls to 1.13 kg MS/cow/day	Maintain the herd on a 23 - 24 day rotation feeding solely pasture until three weeks before the end of the month. During this period, allow milk production to 0.87 kg MS/cow/day.	Maintain the herd on a 23 -24 day rotation and feed them 3 - 4 kg DM/cow/day of grass silage whilst maintaining milk production at, or above 1.04 kg MS/cow/day from the 20th December until early March.
		Feed grass silage before the forage crop. Feed grass silage at the point when it can be used to feed the herd to target until the end of January. While feeding silage and the forage crop, maintain the herd on a 23 - 24 day rotation unless the feed situation improves.	
When milk production falls to 1.13 kg MS/cow/day in early February, feed the forage crop for 3 weeks and maintain milk production at or above 1.04 kg MS/cow/day	When milk production falls to 1.13 kg MS/cow/day in early February, feed the forage crop for 3 weeks and maintain milk production at or above 1.04 kg MS/cow/day	Feed the forage crop at the end of January after the grass silage at a level that maintains milk production at 1.04 kg MS/cow/day. In a dry year make the forage crop last until the end of February, and reduce cow numbers if necessary to maintain milk production at 1.04 kg MS/cow/day.	
Remove the bull in early February	Remove the bull in early February	Remove the bull in early February.	Remove the bull in early February.
Herd test on the 20th February	Herd test on the 20th February	Herd test 20th February	Herd test 20th February
		Dry off thin cows if there is insufficient feed to maintain milk production at 1.04 kg MS/cow/day.	Dry off the thin cows if cow condition declines below target.
When the forage crop is finished, feed grass silage for four weeks and use the grass silage to extend the rotation out to 35 - 42 days while holding milk production at 1.04 kg MS/cow/day.	When the forage crop is finished, feed grass silage for four weeks and use the grass silage to extend the rotation out to 35 - 42 days while holding milk production at 1.04 kg MS/cow/day.	Complete the grazing of the forage crop by the end of February.	Feed the forage crop for one week in early March. Maintain milk production at, or above 1.04 kg MS/cow/day.
	Regraze the forage crop for a week in late February and then continue to feed the grass silage. A third grazing may be obtained from the forage crop in March.	Maintain the herd on a 23 - 24 day rotation after the forage crop unless the feed situation improves.	Maintain the herd on a 23 -24 day rotation after the forage crop and feed maize silage to maintain or increase cow condition.
Sow the new grass by mid March.	Sow the new grass by mid March.	Sow the new grass by mid March.	Sow the new grass by mid March.

[14] This is Farmer B's plan as at 1/1/xx. In the last row, the drying off date estimated through the feed budget undertaken in early autumn is given.

Table 6.3 (continued)

Typical year	Year 1	Year 2	Year 3
Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.	Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.	Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.	Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.
Undertake a herd test in early April.	Undertake a herd test in early April.		Undertake a herd test in early April.
Sell cull cows in early April after pregnancy diagnosis.	Sell cull cows in early April after pregnancy diagnosis.	Sell cull cows in early April after pregnancy diagnosis.	Sell cull cows in mid April after pregnancy diagnosis and herd testing.
Dry off the thin induction and rising three year old cows in early April.	Dry off the thin induction and rising three year old cows in early April.		
Extend the rotation as the cull and dry cows are removed from the milking platform	Extend the rotation as the cull and dry cows are removed from the milking platform		
	Feed 100 tonnes of maize silage through April.	Harvest paddock of maize and ensile in mid April.	
	Production will decline to 0.87 kg MS/cow/day in the last month of lactation and the herd will hold condition on the maize silage		
Dry off the herd in late April, early May	Dry off the herd in late May The feed budget estimated the herd could be milked until May 20th provided average pasture cover remained above 2100 kg DM/ha.	Dry off the herd. Date is unknown, but is very dependent on pasture growth over the summer-autumn and the acquisition of other feed sources. The feed budget estimated the herd could be milked until June 10th provided average pasture cover remained above 1800 kg DM/ha.	Dry off the herd in May. The feed budget estimated the herd could be milked until May 10th provided average pasture cover remained above 2300 kg DM/ha.

Several reasons were identified for differences between plans across the three years. Some were attributed to strategic decisions made earlier in the year, while others were responses to prior learning or to conditions prior to, and at the start of the summer planning period. The major differences between the typical plan and year one were a result of strategic decisions to replace the traditional forage crop with Japanese millet that provided two rather than one grazings, and the introduction of maize silage.

In year two, the plan was different from year one because of (i) learning, (ii) strategic decisions, and (iii) differences in the state of the farm at the start of summer (Table 6.3). Japanese millet was replaced by a previous forage crop, Emerald rape, because Farmer B had learnt that the Japanese millet did not perform as well as his traditional forage crop. Similarly, the replacement heifer calves were also to be grazed at home because they had not performed on the grazier's property used in the previous year. This meant that the forage crop in year two would not be regrazed. Farmer B also made a strategic decision to plant 4.0 hectares of maize for maize silage for the following year. This was to be harvested in mid April.

The other major changes to the plan in year two were in response to the poor state of the farm at the start of summer. Average pasture cover was 300 kg DM/ha below the previous year, and there was 37.5% less area in forage crop, 60% less silage on-hand and no maize silage for the autumn. To further compound the situation, conditions had turned hot and dry. On the basis of these conditions, Farmer B believed the summer would be "dry" and his plan reflected his response to these conditions (Table 6.3). The previous wet spring had also forced Farmer B to use 100 tonnes of maize silage he had in reserve. This was planned for use in the autumn.

In year three, the changes to the plan were also in response to strategic decisions in relation to the type and quantity of supplements and the dry conditions at, and leading up to, the start of the summer planning period (Table 6.3). Although the farm was dry and the forage crop poor, there was over four times the normal amount of grass silage and 150 additional tonnes of maize silage on-hand. This allowed Farmer B to modify his "typical" plan and use the supplement to counter the dry conditions. The resultant plan utilised the strategic changes whilst minimising the impact of the dry conditions.

6.5.3.3 The targets

The targets used by Farmer B can be separated into terminating (Table 6.4) and intermediate targets (Table 6.5) as for Farmer A (see Section 5.5.3.3). The terminating targets for the autumn plan were that the average pasture cover must be 1700 - 1800 kg DM/ha at balance date (Table 6.4). This was selected on the basis of experience because Farmer B knew that if it was significantly under this level, the herd would be underfed during early lactation. This would lead to problems in relation to milk production, cow condition and reproductive performance. He also knew that if he had a higher average pasture cover than this at balance date, it would result in pasture quality problems.

Farmer B also set a maximum average pasture cover target of 2300 kg DM/ha for the winter period (Table 6.5). If average pasture cover exceeded this target, then many of the paddocks would be at a pasture cover of over 3500 kg DM/ha at calving. Regrowth from these paddocks would be poor during the second round post-calving, and insufficient feed would be grown to meet demand. Farmer B did not have terminating condition score targets in his plan. During summer, he used his heuristic for drying off thin cows to ensure the herd was in reasonable condition at the start of autumn. Rather than use a terminating target at balance date, he specified a target condition score at calving for the autumn plan (Table 6.5).

Table 6.4. Terminating targets used by Farmer B for the two planning periods across the three years of the study[15].

Terminating conditions	Year 1	Year 2	Year 3
Mid March			
Lactating cow numbers	maximise	maximise	maximise
Balance date			
Average pasture cover	1700	1800	NA[16]

The "intermediate" milk production targets played an important role over the summer in determining the timing and amount of forage crop (and silage in year one) fed, while the individual cow condition score targets determined when to place the thin, younger cows on once-a-day milking (Table 6.5). Similarly, the average pasture cover targets generated from the feed budget played an important role in determining the drying off date to ensure the terminating targets were met.

Table 6.5. Intermediate targets specified in the plan that are used in the control process[17].

Targets	Year 1	Year 2	Year 3
Summer			
Milk production			
Pre-supplement[18]			
kg MS/cow/day	> 1.13	≥ 0.96	NA
Forage crop.			
Introduction			
kg MS/cow/day	1.13	NA	NA
Maintenance			
kg MS/cow/day	≥ 1.04	≥ 1.04 ≥ 0.96[19]	≥ 1.04
Grass silage			
kg MS/cow/day	≥ 1.04	≥ 1.04	≥ 1.04
Rotation length (days)			
Pre-forage crop	21 - 22	23 - 24	23 – 24
Forage crop	21 - 22	23 - 24	23 – 24
Grass silage	35 – 42	23 - 24	23 – 24

15 Farmer B's reason for each of these targets is described in detail in the case reports in Volume II Appendices XXIII – XXV.

16 In year three, Farmer B terminated his sharemilking contract and moved to another farm. As such, his terminating conditions for the autumn plan were 2000 kg DM/ha at June 1st, the date he had to leave the farm.

17 Farmer B's reason for each of these targets is described in detail in the case reports in Volume II, Appendices XXIII – XXV.

18 The supplement may be silage or the forage crop.

19 Milk production target reduced when conditions deteriorated.

Table 6.5 (continued)

Targets	**Year 1**	**Year 2**	**Year 3**
Summer			
Cow intakes			
kg DM/cow/day	≥12.0	≥11.0[20] ≥12.0	≥12.0 ≥15.0[21]
Individual cow condition			
Condition score units			
February	≥ 3.50	≥ 3.50	≥ 3.50
March	≥ 3.50	≥ 3.50	≥ 3.50
Average herd condition			
Condition score units	No target	No target	No target
Average pasture cover	No target	No target	No target
Post grazing residuals (kg DM/ha)			
Minimum[22]	≥ 1400	≥ 1400	≥ 1400
Maximum	NA	NA	≤ 1700
Significant rainfall (mm)	NA	NA	≥ 50
Benchmark dates			
Removal of bull	Early February	Early February	Early February
Pregnancy testing	Late March	Late March	Late March
Initiation of grass silage feeding	NA	January 10th	20th December
Initiation of forage crop grazing	Late January/early February	Late January/early February	March 1st
Completion of forage crop	≤ February 28th	≤ February 28th	March 7th
New grass sowing	March 15th	March 15th	March 15th
Autumn			
Rotation length (days)			
Pre-culling	35 - 42	23 - 24	23 - 24
Post culling & destocking	60	50	23 - 24
Drying off	100	100	100
Thin cows condition score			
Early April	≥ 3.50	≥ 3.50	≥ 3.50
Late April	≥ 3.75	≥ 3.75	≥ 3.75
Early May	≥ 4.00	≥ 4.00	≥ 4.00
Average herd condition			
Calving	4.75[23]	4.75	5.00
Average pasture cover (kg DM/ha)			
Drying off	2000	1800	2300
June 1st[24]	NA	NA	2000
Winter maximum	2300	2300	NA[25]
Planned start of calving	2000	2100	NA
Balance date	1700	1800	NA
Milk production			
kg MS/cow/day	≥ 1.04	≥ 1.04	≥ 1.04
Benchmark dates			
Date herd must be grazed off	NA	June 1st	May 31st

[20] The intake target was reduced to link in with the reduction in milk production target through January.

[21] From mid March until drying off, Farmer B aimed to feed the herd 15.0 kg DM/cow/day to hold cow condition. He had to feed this level of intake because with the "lush" pasture, the herd was losing condition, even when fed 13 - 14 kg DM/cow/day.

[22] Ideal target, but not strictly adhered to. In dry years, this target is relaxed.

[23] The target condition score for the herd at planned start of calving was 4.5 condition score units. When Farmer B found he had a high empty rate, he decided to increase this target to 4.75 condition score units to enhance reproductive performance next season.

[24] Farmer B shifted to a new farm at the end of year three, and part of his agreement when leaving the property on June 1st was to ensure the farm had an average pasture cover of 2000 kg DM/ha. As such, average pasture cover targets at planned start of calving and balance date were not relevant to the autumn plan in year three.

[25] Farmer B left the farm on June 1st for another sharemilking position.

The importance of targets in decision-making differed during the two planning periods. In summer, milk production targets played the predominant role when average pasture cover could not be measured reliably. During autumn, however, average pasture cover played the predominant role. By then objective measurement of pasture was more accurate allowing the use of formal feed budgeting. Autumn pasture cover was an important predictor of average pasture cover at balance date - a terminating target. Individual cow condition score targets were also important over the autumn to ensure the herd did not get too thin and calved at the correct condition score. Farmer B also increased these targets through the autumn to allow for the reduction in available time to improve cow condition.

Benchmark dates were also used to control implementation. These were designed to optimise systems performance and determined by previous events, or the planning procedure. In years two and three some benchmark dates were determined by contractual obligations. For example, in year two, the herd was dried off by June 1st to utilise contracted grazing. Other targets were non-negotiable across years, irrespective of conditions on the farm at the point of planning, while others were adjusted for strategic purposes or to suit the conditions (Tables 6.4 & 6.5). Individual cow condition score and post-grazing residual targets did not change during the three years of the study. Several targets were changed in response to strategic decisions to improve per cow performance. In year one, the condition score target for calving was increased by 0.25 condition score units to improve the reproductive performance of the herd. In year two, the average pasture cover target for both balance data and calving was increased by 100 kg DM/ha in order to improve per cow performance over the early spring. Finally, in year three, the condition score target for calving was increased by another 0.25 condition score units to enhance milk production in early lactation and subsequent reproductive performance.

Targets were also changed in response to conditions. For example, in year two milk production targets pre-forage crop and during forage crop grazing were reduced in response to dry summer conditions (Table 6.5). In year three, the maximum date by which the forage crop had to be grazed was extended in order to delay its grazing and increase final yield. An interesting proviso was attached to some of the summer targets such as for milk production and cow intake. Because there was insufficient control over the system during the summer to set rigid targets, these targets were provisional and dependent on feed supply. For this reason, the season's milk production targets were for financial budgeting purposes rather than tactical production management.

6.5.3.4 Contingency plans

The contingency plans considered by Farmer B during the three years of the study are summarised in Table 6.6 in terms of their impact on feed supply or feed demand. Only some of these were implemented. However, although options can be classified in this way, and did have the specified effect on feed supply or feed demand, some options were also designed or used for other purposes. For example, drying off thin cows did reduce feed demand, but it also protected cow condition. Similarly, delaying the sale of culls in year two increased feed demand, but the primary purpose of this action was to retain these animals so that they could be sold at a higher price.

Table 6.6. The contingency plans considered by Farmer B during the three years of the study.

Category	Contingency Plans
Increase feed supply	Feed silage before the forage crop[b] Graze the forage crop earlier than planned[26] Increase pasture silage ration Extend feeding period for pasture silage Reduce rotation length Apply urea Purchase and feed greenfeed maize Increase maize silage ration Purchase standing maize for maize silage Purchase and feed standing pasture Use winter grazing to extend the lactation[b]
Decrease feed supply	Harvest forage crop as silage Reduce forage crop ration Extend rotation length Reduce pasture silage ration Reduce the maize silage ration
Increase feed demand	Increase milk production target in order to increase cow intakes while on the forage crop Increase cow intakes Delay sale of cull cows Delay drying off of thin cows Extend lactation length
Decrease feed demand	Graze off young stock Reduce milk production target and associated cow intakes Dry off the thin cows earlier than planned Sell cull cows earlier than planned Dry off the herd earlier than planned

[b] This option was mentioned by Farmer B, but not used.

The contingency plans can also be classified by their impact on the plan (Table 6.7). Several (7) changed the timing of events. In contrast, only one contingency plan changed the sequence of events. In contrast, a reasonable number of contingencies were used in each of the other three areas to change: the type of input or activity (7), timing of events (8) in the plan, and the quantity of input provided or used (9). Many of the contingency

[26] Grazed for crop maturity reasons rather then issues related to feed supply or feed demand.

plans had mirror images. For example, drying off the herd earlier or later than planned had opposite effects on feed demand.

Table 6.7. The contingency plans used or considered by Farmer B during the three years of the study.

Category	Contingency Plans
Changes activation or termination date (Timing of events)	Graze the forage crop earlier than planned Extend feeding period for pasture silage Sell cull cows earlier than planned Delay sale of cull cows Delay drying off of thin cows Dry off the thin cows earlier than planned Dry off the herd earlier than planned
Changes sequence of events	Feed silage before the forage crop[39]
Changes quantity of input provided or used	Increase milk production target in order to increase cow intakes while on the forage crop Reduce milk production target and associated cow intakes Increase cow intakes Reduce forage crop ration Increase pasture silage ration Reduce pasture silage ration Increase maize silage ration Reduce the maize silage ration Extend rotation length Reduce rotation length
Changes type of input or activity provided or used	Harvest forage crop as silage[b] Apply urea Purchase and feed greenfeed maize Purchase standing maize for maize silage Purchase and feed standing pasture Use winter grazing to extend the lactation[b] Graze off young stock

[b] This option was mentioned by Farmer B, but not used.

6.6 The control process

The control process used by Farmer B is essentially the same as that used by Farmer A (see Section 5.6). However, there was one important difference. Farmer B did not just use internal resources to cope with deviations from the plan, he actively sought out resources, external to the farming system, and implemented these into the plan if they were suitable (Figure 6.1). If the targets were not met or exceeded, Farmer B determined if a suitable opportunity has been identified from his monitoring of the external environment. If it had not, then he continued to monitor the implementation of the plan. However, if a suitable opportunity had been identified, the plan was modified and the opportunity implemented. If the performance indicator equalled or exceeded the target, a decision point was identified. This was a point in time when a decision had to be made.

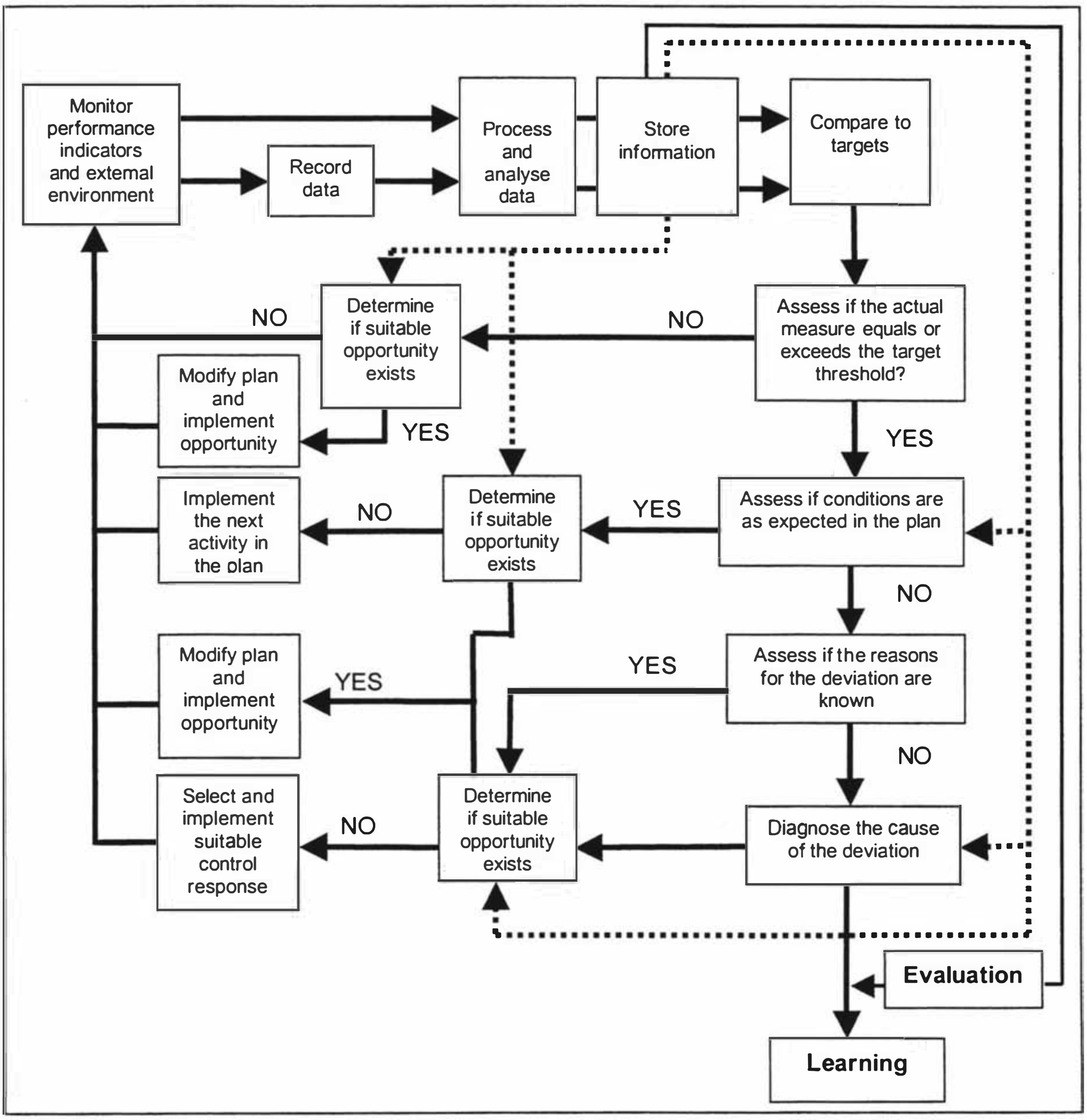

Figure 6.1. The control process used by Farmer B.

One of several responses was possible. If the conditions at the time were as expected, Farmer B then determined if there were any opportunities available. Farmer B identified opportunities through monitoring the external environment for suitable external feed sources. If no suitable external feed sources were identified, then the next activity in the plan was implemented. In contrast, if an opportunity existed, then it was incorporated into the plan and implemented. If conditions varied from those expected in the plan, and the reason for the deviation was unknown, its cause was diagnosed. Once the cause was established, or if it was already known, then Farmer B determined if there were any opportunities available. If there was, then the plan was modified and the opportunity or opportunities implemented. If no suitable opportunities were available, Farmer B selected a suitable control response and implemented it. Stored information was accessed to evaluate particular decisions.

There were few instances where Farmer B undertook either diagnosis or evaluation. However, an important by-product of this process was learning. Control responses implemented by Farmer B included the integration of opportunities, the selection of contingency plans, the adjustment of targets, the development of new plans, and the modification of the monitoring system. The following section describes the control process used by Farmer B in more detail.

6.6.1 Monitoring

The monitoring process (Volume II, Appendix XIII) used by Farmer B is relatively complex. Some 41 factors were monitored over the summer-autumn (Table 6.8). These factors can be classified under the same classification schema as used for Farmer A (Section 5.6.1). All of the internal factors monitored by Farmer B can be classified under the category "*production*". Financial information was not used in the control of the tactical management of the production system. "*Feed*" and "*livestock*" factors played the dominant role in the control process. Climatic information, an external factor, was used to validate other measures and to predict pasture growth rates over a two to four week period. However, weather forecasts were only used for short-term decisions (two to three days) such as haymaking. This was because they were considered too unpredictable to be useful for tactical management decisions. Farmer B actively monitored market information about the input prices of potential external feed sources, which he might incorporate into his system.

The measurement methods used by Farmer B were further classified as objective or subjective and if subjective, either quantitative or qualitative (Table 6.8). The majority of the methods used by Farmer B were subjective in nature. Objective measures were used for milk production, aspects of milk quality, average pasture cover and pasture growth rates. Cow and calf liveweight were also measured in year two. Farmer B also measured a large number of factors indirectly through proxy measures (Volume II, Appendix XIII). His detailed knowledge of the cause-effect relationships within his farming system, like that reported for Farmer A (see Section 5.6.1), made this possible (Figure 6.2). For example, milk production (litres/cow/day) was used to indirectly monitor cow intakes, cow condition, average pasture cover and pasture growth rates.

Table 6.8. Classification of the methods used by Farmer B to monitor the farm over the summer-autumn.

Factor	Summer		Autumn	
	Method	Classification	Method	Classification
Internal Factors				
Production factors				
Feed Factors				
Average pasture cover[27]	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective, qualitative	Falling plate meter Pasture scoring Visual assessment	Objective Subjective, quantitative Subjective, qualitative
Pasture growth rates[27]	Falling plate meter Visual assessment	Objective Subjective, qualitative	Falling plate meter Visual assessment	Objective Subjective, qualitative
Pre- and post-grazing residuals	Pasture scoring Visual assessment Falling plate meter	Subjective, quantitative Subjective, qualitative Objective	Pasture scoring Visual assessment Falling plate meter	Subjective, quantitative Subjective, qualitative Objective
Pasture quality	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Forage crop yield	Yield score	Subjective, quantitative	Yield score[28]	Subjective, quantitative
Forage crop quality	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Pasture silage yield	Yield score	Subjective, quantitative	Yield score	Subjective, quantitative
Pasture silage quality	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Maize silage yield	NA	NA	Yield score	Subjective, quantitative
Maize silage quality[29]	NA	NA	Visual assessment	Subjective, qualitative
Maize crop yield[30]	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Maize crop maturity	NA	NA	Visual assessment	Subjective, qualitative
Greenfeed maize yield[31]	NA	NA	Yield score	Subjective, quantitative
Cut pasture[32]	NA	NA	Pasture scoring	Subjective, quantitative
Rotation length	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Livestock factors				
Cow numbers	Visual assessment	Subjective, quantitative	Visual assessment	Subjective, quantitative
Milk yield	Company docket	Objective	Company docket	Objective
Individual cow milk yield	Herd test	Objective	Herd test	Objective
Milk quality of herd	Laboratory test at factory	Objective	Laboratory test at factory	Objective
Production index	Herd test	Objective	Herd test	Objective
Individual cow somatic cell count	Herd test	Objective	Herd test	Objective
Average herd condition	Visual assessment	Subjective, qualitative	Condition scoring	Subjective, quantitative
Individual cow condition	Visual assessment	Subjective, qualitative	Condition scoring	Subjective, quantitative
Cow liveweight[33]	Electronic scales	Objective	Electronic scales	Objective
Calf liveweight[34]	Electronic scales	Objective	NA	NA
Cow intakes	Pasture scoring Visual assessment Falling plate meter	Subjective, quantitative Subjective, qualitative Objective	Pasture scoring Visual assessment Falling plate meter	Subjective, quantitative Subjective qualitative Objective

27 The falling plate meter was only used over the summer in year one.
28 This was a greenfeed maize crop that farmer B purchased off a neighbour in year two.
29 Only used in years two and three.
30 The maize crop was only grown in year two on the milking area.
31 Only used in year two when a greenfeed maize crop was purchased.
32 In year two Farmer B purchased standing pasture off a neighbour, harvested it and carted it to the herd.
33 Only used in year two.
34 Only used in the summer of year two.

Table 6.8 (continued)

Factor	**Summer**		**Autumn**	
	Method	**Classification**	**Method**	**Classification**
Per hectare feed demand (kg DM/ha/day)[35]	Pasture scoring Falling plate meter	Subjective, quantitative Objective	Pasture scoring Falling plate meter	Subjective, quantitative Objective
Reproductive status	Visual assessment of behaviour	Subjective, qualitative	Pregnancy test	Subjective, qualitative
External Factors				
Climatic factors				
Rainfall	Rain gauge	Objective	Rain gauge	Objective
Weather forecast	Weather map	Objective	Weather map	Objective
Temperature	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative
Wind run	Tactile and visual assessment	Subjective, qualitative	Tactile and visual assessment	Subjective, qualitative
Cloud cover	Visual assessment	Subjective, qualitative	Visual assessment	Subjective, qualitative
Market factors				
Output prices				
Cull cow schedule	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative
In-calf cow store price	Newspaper & stock agent	Subjective, quantitative	Newspaper & stock agent	Subjective, quantitative
Milk price	Dairy company newsletter	Subjective, quantitative	Dairy company newsletter	Subjective, quantitative
Input prices				
External feed sources				
Urea	Newspaper, local farmers	Subjective, quantitative	Newspaper, local farmers	Subjective, quantitative
Grazing	Newspaper, local farmers	Subjective, quantitative	Newspaper, local farmers	Subjective, quantitative
Maize for silage	Newspaper, local farmers	Subjective, quantitative	Newspaper, local farmers	Subjective, quantitative
Greenfeed maize	Newspaper, local farmers	Subjective, quantitative	Newspaper, local farmers	Subjective, quantitative
Cut pasture	Newspaper, local farmers	Subjective, quantitative	Newspaper, local farmers	Subjective, quantitative

Indirect measures were important in managing production. For example, rather than using a falling plate meter, that was costly in terms of time, and had low accuracy due to summer sward conditions, milk production was used as an indirect measure of pasture cover. This measure was sufficiently accurate to direct operational management decisions. In contrast, in the summer of year one, average pasture cover data, measured using a falling plate meter, took two to three hours to collect and collate, was inaccurate and only monitored every fortnight. This information was not used in decision making in that year.

[35] This figure was calculated by multiplying cow intake by stocking rate.

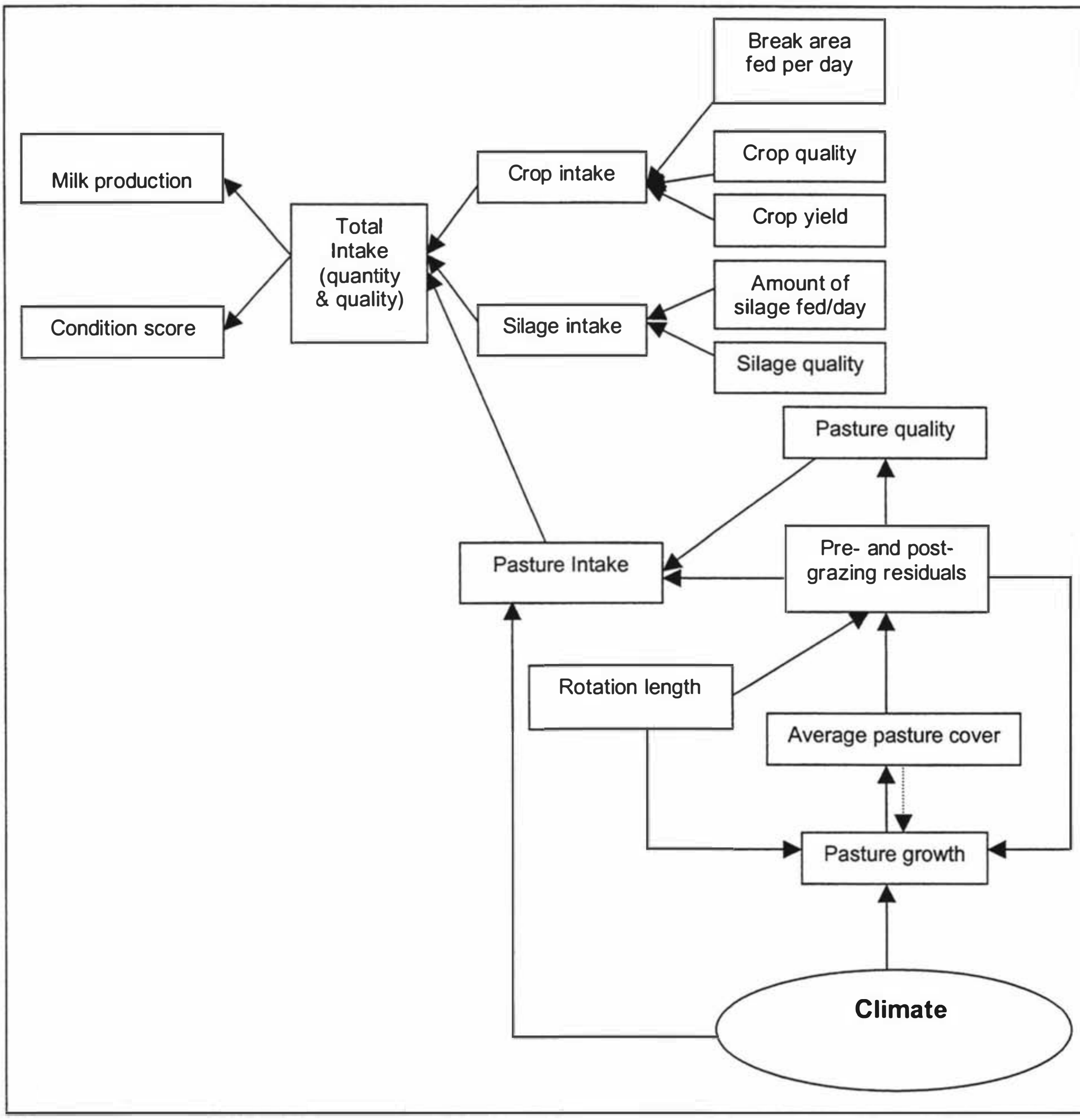

Figure 6.2. Causal relationships used in the Farmer B's monitoring system.

Several roles were played by the information monitored during the control process. These included: determination of decision points, triangulation, determination of control responses, diagnosis and evaluation, prediction of short-term feed position, and planning. These roles were the same as those defined in Chapter 5 (see Section 5.6.1). One exception was that Farmer B also used external market indicators to identify opportunities. As such, the indicators he used played both problem and opportunity recognition roles. Table 6.9 summarises the factors monitored by Farmer B through the summer-autumn to identify decision points. All these can be classified as leading indicators and were used for concurrent control.

Table 6.9. The role of key indicators in the decision point recognition phase of the control process over the summer-autumn period.

Key Indicators	Indicator Type (Lead/Lag)	Role in decision point recognition
Early Summer		
Average milk production (MS/cow/day)	Lead	Determines when to feed the forage crop or silage. Determines how much forage crop or silage to feed.
Pre- and post-grazing residual, cow intakes, feed demand (kg DM/ha/day), pasture growth rates and climatic data	Lead	Used to predict future pasture growth rates over the next two weeks and the supplements that are likely to be required. Indicates when milk production and intakes are about to fall below target and therefore the need to feed supplements or the amount of supplement. Also used to determine when to extend rotation length, change milk production targets, and reduce stocking rate.
Forage crop maturity	Lead	May determine initiation of grazing of forage crop.
Forage crop yield	Lead	Used to assess area required to feed the herd to target.
Production index Somatic cell count Bulling behaviour	Lead	Used to identify potential culls.
Weather forecast	Lead	Used to predict weather for hay making.
External feed sources	Lead	Used to identify external feed sources that can be introduced into the system.
Late Summer		
Date and/or the quantity of forage crop on-hand	Lead	Indicates when to feed grass silage
Forage crop yield and quality[36]	Lead	Indicates when to regraze the forage crop and terminate silage feeding.
Average milk production (MS/cow/day)	Lead	Determines how much forage crop and silage to feed.
Pre- and post-grazing residual, cow intakes, feed demand (kg/DM/ha/day), pasture growth rates, climatic data	Leading	Predicts likely feed position in 2 – 4 weeks. Indicates when milk production and intakes are about to fall below target and therefore the need to feed supplements or the amount of supplement. Also used to determine when to extend the rotation length, and reduce stocking rate.
Rotation length[37] (and grass silage feeding)	Lead	Determine when to extend rotation length.
Individual cow condition	Lead	Determines which cows to dry off.
Production index Somatic cell count Bulling behaviour Pregnancy status	Lead	Used to identify potential cull cows.
External feed sources	Lead	Used to identify extemal feed sources that can be introduced into the system.
Rainfall	Lead	Determines application date for autumn urea. Also determined when the silage ration had to be doubled.
Autumn		
The quantity of grass silage on-hand	Lead	Indicates when to feed the maize silage.
Average milk production (MS/cow/day)	Lead	Determines how much silage (maize or grass) to feed.
Pre- and post-grazing residual, cow intakes, feed demand (kg DM/ha/day) pasture growth rates, climatic data	Lead	Predicts likely feed position in 2 – 4 weeks. Indicates when milk production and intakes are about to fall below target and therefore the need to feed supplements or the amount of supplement. Also used to determine when to extend rotation length.
Date	Lead	Determines when to sell culls. Determined drying off date[38].
Individual cow condition	Lead	Determine which cows to dry off.
Average pasture cover (actual and predicted)	Lead	Determines drying off date.
External feed sources	Lead	Used to identify extemal feed sources that can be introduced into the system.
Culling	Lead	Determines when to extend the rotation length[37].
Pasture quality (post-grazing residual > 1700 kg DM/ha)	Lead	Determines termination date for maize silage feeding, extension of rotation length.

[36] Only used in year one when Farmer B used a forage crop he could regraze.
[37] This was only used in year one.
[38] In year two, a grazing contract in part determined when the herd had to be dry.

As reported in Chapter Five, in a normal year, the primary indicator used for decision point recognition over the summer was milk production. From mid March onwards however, average pasture cover, and pasture growth became the primary measures for decision point recognition. Average herd condition was not used in decision making, rather, individual cow condition data in combination with specific decision rules were used to dry off thin cows and protect the condition of the herd. Average pasture cover and herd condition were critical factors in ensuring the targets for planned start of calving were met. In contrast, milk production was treated as a variable that was adjusted to ensure these were met.

Few between-year differences were identified (Table 6.8). The majority of these were attributed to unusual circumstances (e.g. weighing the cows because of very poor body condition after a poor spring), or changes in input use (e.g. retaining young stock on the milking area, purchasing bought-in feeds, growing maize silage on the milking area). The other instance was where Farmer B used a falling plate meter over the summer of year one, but not in later years. He did this because the farm had been going through a period of rapid development and he wanted to confirm that his subjective assessment of sward conditions over the summer was accurate. The formal monitoring in combination with his milk production measures gave him confidence in his subjective measures and after year one, he did not use the falling plate meter over summer.

Acceptable accuracy is important in decision point and problem recognition. Many of the factors monitored by Farmer B were used to triangulate the measures he used for decision point recognition. Triangulation was facilitated through an intimate knowledge of the farming system (Figure 6.2). The process used by Farmer B was similar to that reported for Farmer A in Chapter 5 (see Section 5.6.1).

The monitored information was also used for control response selection once a decision point was recognised. In this case, situation specific information was used in conjunction with heuristics to determine whether to continue to implement the existing plan, and if this was not the case, then to select which control response to implement. Volume II, Appendix XIV shows the range of information used for control response selection (see Section 6.6.4.1). Several external sources of information were monitored for tactical production management. Those that were used could be classified as market factors and included market prices (cull cow schedule, in-calf cow store price, milk price), and input prices (external feed sources). The relative value of cows sold for meat versus store influenced whether, when and where Farmer B sold his in-calf culls, and if external feed source were identified for a reasonable price, these options were purchased and used.

Farmer B undertook limited diagnosis and evaluation and few lagging indicators, used for historical control, were identified during the study. One of the few examples was empty rate, which was a ratio of the number of empty cows divided by the number of cows mated. This information was used to evaluate the Farmer B's reproductive management and on the basis of this, refine the subsequent season's reproductive management providing a form of historical control. The other important lagging indicator was milk production, to ensure the accuracy of the monitoring system.

Monitoring results were also used to make short-term (two to four week) predictions of the future feed situation on the farm in much the same way as reported for Farmer A (see Section 5.6.1). Information from the monitoring process was also used to estimate the likely intake of the herd 25 - 30 days into the future (Volume II, Appendix XV). This process was also the same as reported for Farmer A (see Section 5.6.1). Farmer B repeated this forecasting process whenever there was a change in cow intakes and post-grazing residuals. Information collected during the summer was also used for the second planning period, commencing around mid March. He used information about the state of the herd, pasture, supplements and prevailing weather conditions to develop a feed budget through to balance date.

6.6.1.1 Activation, termination and frequency of monitoring

Farmer B had decision rules that determined when particular factors had to be monitored, and in some cases the frequency of monitoring (Volume II, Appendix XVI). In the simplest case, the occurrence of an event (e.g. pregnancy or herd testing, forage crop feeding) initiated the monitoring of a factor. The forage crop, for example, was actively monitored just prior to the point at which it was grazed. Conversely, the completion of an activity could terminate the monitoring of a factor (e.g. herd testing, forage crop and silage feeding, milking). Benchmark dates sometimes triggered the activation of the monitoring process. For example, objective pasture monitoring was normally initiated around mid March. Individual cow condition score monitoring was initiated in year three on the basis of date, change in condition score and the number of thin cows that had been dried off. Farmer B stated that because it was March 1st, the average condition score of the herd had fallen to 4.25 condition score units, and he had not dried off any thin cows by that stage, he thought it best to begin monitoring individual cow condition.

Changes in the factor of interest played the most important role in the timing of the monitoring process. This occurred when a factor, or some indicator of the factor, exceeded a threshold. For example, the condition of the herd was not consciously monitored if its condition was equal to, or greater than 4.5 condition score units and the thin younger cows had been dried off. If however, it fell below this level, formal monitoring would be activated. If it returned above this level monitoring would be terminated. Alternatively, daily milk production was used as an indicator of cow condition, and if it fell below 1.04 kg MS/cow/day, it indicated the younger cows in the herd were losing condition and the monitoring process was activated. It was not just the absolute value of a factor that initiated the monitoring process, it was also its rate of change. If milk production, for example, declined at a rate equal to, or greater than 0.061 kg MS/cow/day in year two, this indicated the herd was losing condition and monitoring of the condition of the younger cows was initiated. Similarly, in year three, when the farm was in a good feed position in early autumn and average pasture cover was increasing, Farmer B did not activate objective pasture monitoring until April 6th.

The final factor that activated a monitoring activity was a planning need. In year two, and three, Farmer B only monitored average pasture cover when this information was required for planning, or plan revision purposes (Volume II, Appendix XVI). It was not used for concurrent control purposes. This occurred in years when the feed situation on the farm was good and improving. As such, Farmer B reduced his monitoring input and relied on his subjective measures of average pasture cover.

The majority of the measures were monitored on a daily basis (Volume II, Appendix XIII). Other than one-off measures such as herd and pregnancy testing, the other measures were monitored at two to 14 day intervals. For example, pre- and post-grazing residuals and cow intakes were monitored at two to seven day intervals depending on the rate of change in the factor. Average pasture cover and pasture growth rates were monitored at 14 day intervals in year one. Daily measures were monitored as Farmer B went about his normal farming duties. Few monitoring activities required additional effort and these included herd testing, pregnancy diagnosis, and the monitoring of pre- and post-grazing residuals, cow intake, average pasture cover and pasture growth rates.

Farmer B did change the frequency with which he monitored some factors. Rate of change influenced some of these. For example, cow intake was not calculated unless there was a significant change in pre- and post-grazing residuals, or milk production. The frequency at which average pasture cover was monitored was also influenced by the rate of change in that factor and its absolute value. In years where conditions were good and average pasture cover was improving, the monitoring interval was extended. For example, in year one, average pasture cover was monitored at fortnightly intervals, but in years two and three when the farm was in a good feed position, it was only monitored twice and once respectively over the autumn. The intensity of monitoring was also increased if a problem was detected. In year three, when pasture growth was exceptional, Farmer B did not believe that his estimates of cow intake were being reflected in the herd's level of milk production. He therefore increased the frequency of monitoring in an attempt to better calibrate his estimates of pre- and post-grazing residuals and cow intake.

The monitoring system used by Farmer B was timely, effective and low cost in terms of time, but not capital. The majority of the factors were monitored on a daily basis and the longest monitoring interval used during the study was 14 days. The short monitoring interval and triangulation process provided suitable and timely information for decision making. The majority of factors were also monitored while Farmer B went about his normal farm activities, minimising the time cost. Where possible, Farmer B used decision rules to activate, terminate and adjust the frequency of monitoring to further reduce the monitoring effort. Farmer B had several thousand dollars invested in his monitoring system. He had purchased a commercial falling plate meter, a set of electronic scales, and used a computer and associated software to record and process some of his information.

6.6.2 Recording and data processing

Farmer B used a range of data recording techniques. The simplest was to remember information. A farm diary was used to record key events (sale of culls, date crop fed, drying off), pasture cover and pasture growth rate data, mating information and rainfall data. It acted as a historical record of the season and could be referred back to for diagnostic or evaluation purposes, or to check what had been done in previous seasons. Milk production data provided by the company was stored in a folder. A computer program, "Dairyman" was used to record herd records (milk production and reproductive performance) along with pasture cover and pasture growth rate data. The herd records could be retrieved and analysed to identify potential culls and to rank individual cows. Limited processing was undertaken on the collected data. Farmer B calculated means to estimate milksolids production per cow, average pasture cover, and pasture growth rates.

Cow intakes, and per hectare feed demand were also calculated. A spreadsheet was used to calculate average pasture cover and pasture growth rates. Likely pasture growth rates were estimated for the next 3 – 4 weeks and cow intake and per hectare feed demand was calculated at the end of this period to provide an indication of the likely feed position on the farm.

6.6.3 The environment

To understand the control responses used by Farmer B, it is important to understand the environment in which he operates. The focus of this study was production management of a dairy herd over the summer-autumn. The primary source of risk facing Farmer B in relation to production was variation in climate, which in turn dictated pasture growth rates, the primary feed source[39]. Variation in pasture growth leads to variation in feed supply that in turn causes variation in milk production. During the three years of the study, milk production ranged from 249 kg MS/cow and 789 kg MS/ha to 326 kg MS/cow and 1035 kg MS/ha. Managing variation in pasture growth dominated decision-making in relation to production management. Interestingly, the percentage of feed supplied by pasture over the summer-autumn declined from 80% to 63% over the three years of the study as Farmer B increased his use of inputs. This reduced his exposure to climatic risk. Risk associated with pests and disease was rated low because preventative procedures were used to control these including two debilitating animal health problems, bloat and facial eczema.

During the summer-autumn, other sources of risk (market, human, social and legal, technological, inter-firm competition, and financial) were rated as low and did not influence the production decisions made by Farmer B. Market risk was rated low for the same reasons given for Farmer A (see Section 5.6.3). It only influenced Farmer B's decision making in year two when he sold his in-calf cull cows prior to drying off because the value of such animals had been declining rapidly in response to excess supply.

Input price risk was low because of the short time frame and the relatively low rate of inflation (< 3%) occurring at the time (Burtt, 2000). An exception to this was the price for bought-in feeds, which is dependent on supply and demand, a function of the summer-

[39] Pasture supplied between 63 – 80 % of the feed consumed by the milking herd over the summer-autumn period during the three years of the study.

autumn weather (dry, normal, wet). This had some impact, but Farmer B would, where possible, contract the purchase of bought-in feed and grazing to minimise this risk. If feed had not been contracted, the decision to purchase was a function of price relative to the returns that could be generated from such feed. If the cost was too high relative to the returns, then it was not purchased.

Farmer B rated human risk low. He did employ labour, but noted that there was limited scope for labour seriously affecting production at this time of year because his monitoring system would identify problems in this area promptly. This was confirmed by the data where only one minor instance was recorded of labour adversely affecting production. This problem was identified and rectified within a few days. Because of his owner/operator status, his greatest risk was from injury or disability. During the three years, there were no recorded instances of legal and social, technological or inter-firm competition sources of risk influencing Farmer B's decision making in relation to production management. As with Farmer A, there was limited inter-firm competition risk. One difference was that competition existed for external feed sources because Farmer B purchased these options. However, he reduced this risk by using contracts where possible. He also developed good relationships with his neighbours who often provided these external feed sources.

Farmer B had access to over-draft facilities, good cost control, and a regular cash flow from milk sales. Because of the short-term nature of the time frame at the tactical level, variation in interest rates were minimal. Although Farmer B stated that his cash flow or short-term liquidity could influence his production decisions, there was no evidence that financial risk influenced production management during the study.

6.6.4 Control responses

Preliminary control responses were used by Farmer B in relation to animal health[40] and forage crops and silage were fed during periods when pasture growth was most variable. By far the most common type of control was concurrent control. No examples of "elimination of disturbances" control responses were identified. However, some examples of historical control were identified, the number of which was dependent on the amount of learning that occurred in any one year. The types of control responses used by Farmer B for both concurrent and historical control over the three years are shown in Table 6.10. Two of the five possible concurrent control responses were not used by Farmer B. He did not adjust his monitoring system, or change his goals in response to a deviation from the plan. He did however adjust implementation, and modify his plans. Only two instances of implementation adjustment were identified over the three years. In year two, Farmer B's worker misinterpreted his instructions and implemented the plan incorrectly. Farmer B identified this mistake and corrected it. In year three, Farmer B changed the way he fed out maize silage, but this impacted negatively on production, so he changed back to his original method. In year one, Farmer B also changed his autumn plan because he had 20% empty cows, a result of an extremely wet spring. As such he decided to milk 15 cows through the winter on a neighbour's farm to ensure he had sufficient numbers for the next spring. He also had to cull more cows than predicted and purchase in-calf cows during the winter.

Plan modification was the most common form of concurrent control (Table 6.10). Six methods of plan modification were used: changing planning horizon, introducing both contingency plans and opportunities, developing and implementing new contingency plans, removing an input or activity and changing targets. In year three, Farmer B changed the summer planning horizon because conditions were extremely dry in December. The most common form of plan modification was through the implementation of existing contingency plans. In each of the three years, Farmer B developed and implemented several new contingency plans. These new contingency plans were associated with new inputs, or extreme climatic conditions. For example, in year one, he learnt that if the Japanese millet crop grew more quickly than normal, it had to be grazed earlier otherwise utilisation declined.

In contrast to contingency plans, new opportunities were only introduced into the plan occasionally and this tended to occur under extreme conditions. For example, in year two, when the farm was in a poor feed position, several opportunities in the form of external feed sources were introduced. Only one instance of an activity or input being removed from the plan was recorded and this was in year two when the Farmer B decided to remove his replacement heifer calves from the milking area and graze them off. Targets were adjusted occasionally and again, this was in response to extreme conditions. For example, in year one he increased his milk production and associated cow intake targets to take advantage of above average summer pasture growth rates.

[40] Preventative animal health remedies were used for bloat and facial eczema control.

Similarly, in year three he increased his cow intake targets because under the exceptional growing conditions, his monitoring system was over-estimating average pasture cover. Rather than recalibrate, Farmer B just increased his cow intake targets to maintain herd condition.

Table 6.10. The nature of the concurrent control responses used by Farmer B across the three years of the study.

Type of response	Year 1	Year 2	Year 3
Concurrent control			
Adjust implementation	No	Yes	Yes
Modify plan			
Change planning horizon	No	No	Yes
Introduce existing contingency plan	Yes	Yes	Yes
Develop & introduce new contingency plan	Yes	Yes	Yes
Introduce opportunity	No	Yes	No
Remove activity or input	No	Yes	No
Change targets	Yes	Yes	No
Develop a new plan	Yes	No	No
Adjust monitoring system			
Recalibrate monitoring system	No	No	No[42]
Introduce new monitoring method	No	No[41]	No
Change goals	No	No	No
Historical control			
Implement new forms of preliminary control	Yes	Yes	No
Implement new forms of elimination of disturbances control responses	No	No	No
Refine the existing plan			
Introduce new input or activity	Yes[43]	No	No
Remove input or activity	No	Yes[44]	No
Change targets	Yes	Yes	Yes
Implement new forms of concurrent control			
Introduce new contingency plan	Yes	Yes	Yes
Remove existing contingency plan	No	No	No
Modify monitoring system			
Recalibrate monitoring system	No	No	No
Introduce new calibration rules[45]	No	No	Yes
Introduce new monitoring method	No	No	No
Change goals	No	No	No

Farmer B used four of the six forms of historical control over the three years (Table 6.10). New forms of "elimination of disturbances" control response was not used, nor were goals changed. In year one, maize silage was introduced into the autumn plan, a preliminary control response. In year two a reserve of maize silage was set aside to cope with a perceived increase in climatic variability as a result of a perceived change in climate.

[41] A new monitoring method was introduced in year two, electronic weighing of cows, but this was in response to a deviation from the plan in the spring.

[42] Although Farmer B realised that his calibration for pasture yield was wrong under the abnormal conditions in year three, he did not recalibrate his pasture measurement methods. Instead, he increased the cow intake target to ensure the herd were fed sufficient dry matter to maintain condition.

[43] Grazing calves on the milking area, and maintaining a reserve of maize silage for early spring.

[44] Grazing calves on the milking area.

[45] Includes recalibration rules for pasture, silage and forage crop estimation.

Although a new form of preliminary control was not introduced in year three, Farmer B dramatically increased the level of pasture silage on-hand at the start of summer. This quantity allowed him to cope with a much higher level of production risk. Existing plans were refined through the introduction or removal of inputs, or the modification of targets. New forms of concurrent control were implemented and the monitoring system was modified. Inputs were added and removed from the plan over the three years. For example, maize silage, Emerald rape, and grazing calves on the milking area, were new inputs introduced by Farmer B as historical control responses. Conversely, other inputs, such as Japanese millet, were removed from the plan as an historical control response.

Farmer B made several changes to his targets to improve per cow performance after a series of wet, cold springs. In year one, he increased the condition score target for calving by 0.25 condition score units because he thought it would improve the reproductive performance of the herd. In year two, he increased the average pasture cover target for both balance data and calving by 100 kg DM/ha in order to improve per cow performance over the early spring. Finally, in year three, he increased the condition score target for calving another 0.25 condition score units to enhance milk production in early lactation and subsequent reproductive performance. Farmer B also changed his grazing rotation length targets because he believed he could improve pasture growth rates by retaining the herd on a fixed round and allowing the post-grazing residuals to increase as opposed to extending the rotation and keeping the post-grazing residuals at a fixed level.

The second area of historical control used by Farmer B was in relation to the implementation of new forms of concurrent control. As previously mentioned, he developed several new contingency plans. These were effective and therefore introduced into his repertoire of contingency plans. The final form of historical control was in relation to Farmer B's monitoring system. In year three he learnt some new rules of thumb for calibrating silage and his new forage crops. These rules were incorporated into his monitoring system. He also learnt that his pasture dry matter calibration was not suitable under extremely high pasture growth rates over autumn, tending to over-estimate average pasture cover.

6.6.4.1 Control response selection

The process used by Farmer B to select an appropriate control response was the same heuristic-based approach (Volume II, Appendix XVII) as used by Farmer A (see Section 5.6.4.1). However, not all control responses were selected in this manner. Occasionally, a form of *ex-ante* evaluation of decisions was used to determine whether a control response was required. Three instances of this approach were recorded over the three years. This process was used for three different purposes. These were (i) to decide between several alternatives (e.g. apply urea, buy greenfeed maize, buy maize and ensile it and feed it out) and the planned option; (ii) to decide whether to implement the planned option (applying urea) or not because conditions had changed; and (iii) to decide whether to change the timing of a planned option (feed maize silage earlier). If several alternatives were involved, then Farmer B used a screening process to reduce the number of options to one. This was then compared to the planned option. In this case, three external feed sources were compared across three criteria (cost, risk and immediacy of response). The same process was used in all cases to compare the alternative to the planned option. A simulation of the alternative versus the planned option was compared. In two instances, this was a mental simulation, and in one, a feed budget was used because Farmer B was undertaking a plan revision. The best option was then chosen. The criteria for selection varied. In one instance (purchase of greenfeed maize), profitability was used and this was calculated using a partial budget format. However, in relation to the timing of maize silage use, impact on system performance (pasture and milk production), and condition score was used, while in the case of the use of urea, the criteria was the achievement of average pasture cover targets.

Farmer B had used formal partial budgeting techniques in the past to analyse alternatives. He also reported that often such analyses were undertaken at discussion groups. As such, the results of these analyses could be used for future decision making provided costs and prices did not change significantly.

The most common form of control response was the contingency plan[46] (Table 6.11). Four factors were found to influence the type and number of contingency plans used in any one year: the type of resources available, the state of the farm at the start of the summer (quantity of resource available), the nature of the summer and autumn, and the type of summer plan ("dry", "typical") adopted. Resource availability had limited effect on the choice of contingency plans (except for maize silage use and heifer calf grazing in year two). When the farm was in a good state at the start of summer and experienced a wet summer and a good autumn, few contingency plans (4) were used (see Table 6.11 for detail).

[46]The process of adjusting targets and introducing external opportunities were included as types of contingency.

Table 6.11. A cross-year comparison of the contingency plans used by Farmer B[47].

	Year 1	Year 2	Year 3
Feed position at start of summer	**Good**	**Poor**	**Very good**
Type of year **Summer** **Autumn**	**Wet** **Good**	**Dry** **Dry**	**Very dry** **Exceptional**
Summer plan used	**Typical**	**Dry**	**Dry**
Category			
Feed deficit responses			
Increase feed supply	Increase pasture silage ration[48]	Apply urea Purchase and feed greenfeed maize Purchase standing maize for maize silage Purchase and feed standing pasture	Increase pasture silage ration Graze the forage crop earlier than planned Extend feeding period for pasture silage Increase maize silage ration Reduce rotation length
Decrease feed demand	Dry off the herd earlier than planned[49]	Graze off young stock Reduce milk production target and associated cow intakes Dry off thin cows earlier than planned Dry off the herd earlier than planned[50]	Sell cull cows earlier than planned
Feed surplus responses			
Decrease feed supply		Reduce forage crop ration[51]	Reduce pasture silage ration Extend rotation length Reduce the maize silage ration
Increase feed demand	Increase milk production target in order to increase cow intakes while on the forage crop[52] Delay drying off thin rising three year cows[53]		Increase cow intakes Delay drying off of thin rising three year cows Extend the lactation

47 These include contingency plans that increase or reduce targets.

48 Introduced because cold, windy conditions increased cow maintenance requirements.

49 Conditions turned cool in May and the herd had to be dried off a week before the autumn feed budgets original prediction.

50 The herd was dried off 14 days earlier than planned in the feed budget (as opposed to the plan developed at the start of January) because Farmer B had to send them away to grazing at the end of May.

51 This is actually a feed deficit response because Farmer B wanted to extend the use of the forage crop into March to ensure as many cows as possible were still in a milking state by mid March.

52 This was used to take advantage of the good growing conditions over February.

53 These were expected to be dried off in early April, but were still in good condition at that point, so were milked until late April.

Year two provided a useful contrast to year one where the farm was in a poor state at the start of summer, and then experienced dry conditions throughout the summer-autumn. In this instance, eight options were used to increase feed supply or reduce feed demand to cope with the dry conditions (Table 6.11). In contrast, only two such options were used in year one. Conversely, only one option was used to reduce feed supply or increase feed demand in year two, as opposed to two in year one. However, this option was only used to reduce feed supply to ensure the forage crop lasted through into March. It was not used to utilise surplus feed. Therefore in year two, Farmer B effectively used nine contingency plans designed to respond to feed deficit conditions, and no contingency plans to cope with feed surplus conditions. In year two, Farmer B actively sought out four external feed sources to minimise the impact of the dry conditions and poor farm state at the start of summer (Table 6.11). These options were not used in either of the other two years, primarily because overall feed conditions (at the start and during) were much better.

Year three provided an interesting contrast to the other two years. At the start of summer, the farm was in the best state of any of the three years. However, the summer was much drier than the dry year in year two, and this was followed by autumn pasture growth rates which were much higher than those experienced in year one, a good autumn. As such, a combination of options was used to cope with both feed deficit and feed surplus conditions. The extreme conditions in year three meant that more contingencies were used than in either of the other two years. Less feed deficit responses were used than in year two even though summer pasture growth rates were much lower than in year two. This was because there was a much greater quantity of summer supplement available in year three than year two. Therefore, less options were required to cope with the feed deficit conditions. Pasture growth rates in year three increased to exceptional levels over autumn, whereas they were below average in year two. This meant that in year three options had to be implemented that increased feed demand or reduced feed supply (Table 6.11). Interestingly, several of the options classified under "increase feed supply" were initiated because the forage crop yield was four times that expected. Thus, the options to graze the forage crop early, and extend silage feeding were in response to an increase, not a decrease in feed supply. The nature of the "plan" ("dry" or "typical") chosen by Farmer B to meet the conditions he expected over the summer also influenced the type and number of contingency plans used, as described in Section 5.6.4.1, except Farmer B did not classify the summer as "wet".

6.6.4.2 Opportunity selection

Farmer B used an opportunity recognition and selection process to improve his ability to cope with the extreme conditions (Figure 6.3). The external environment was monitored mainly through the newspaper and a network of local farmers. Information collected about external feed sources included feed type, quality, price, and locality. The feed type and quality had to be suitable for milking cows during the summer-autumn. The information feed price and feed quality information was processed and analysed. The analysis converted the price for the feed source to a common unit, usually cents per kilogram of dry matter. Farmer B knew the conversion rate for feeds of various quality to milk and therefore the maximum price he could pay to make an economic return on an external feed source. Locality or proximity of feed sources to the farm was also important in terms of reducing costs. For example, forage crops on the adjoining boundary were sought out as were feed sources that could be cut and carried a short distance. The feed cost and other information was compared to the pre-set criteria. If it matched, Farmer B then decided whether he wanted to take advantage of the opportunity. In most cases this was a simple decision once the opportunity had met the criteria and the feed situation was such that it could be used. However, in one instance, three opportunities were screened on the basis of several criteria (cost, risk, immediacy of effect) until the most suitable option was identified. This was then compared to the internal option on the basis of impact on profitability (cost and returns) using a partial budget framework. If Farmer B decided to take advantage of an opportunity, it was purchased, the current plan modified and the opportunity implemented.

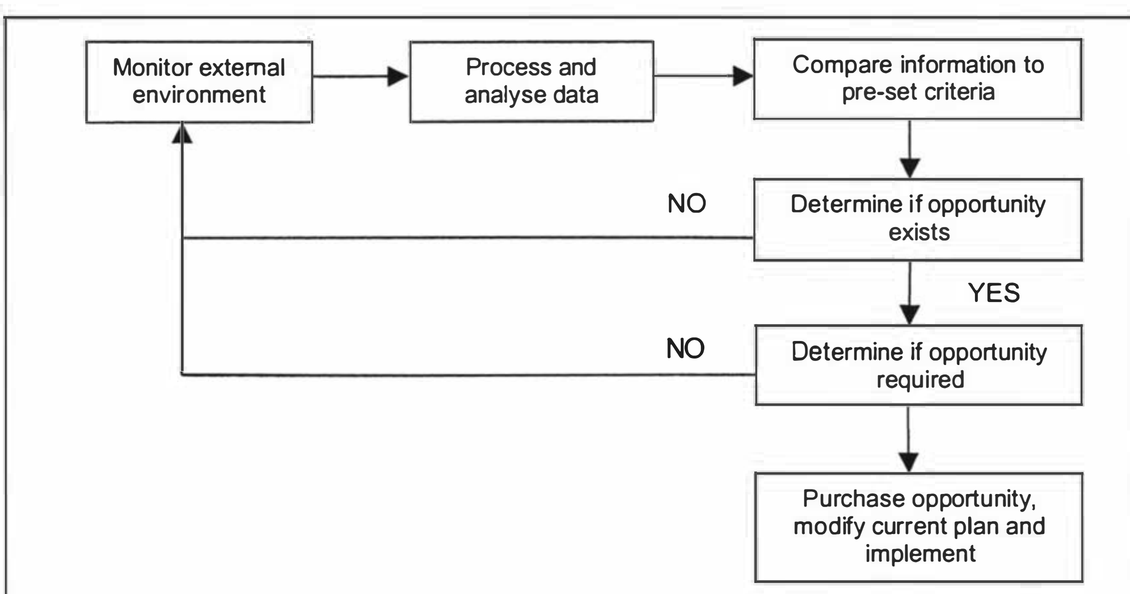

Figure 6.3. The opportunity recognition and selection process.

The process shown in Figure 6.3 was used by Farmer B during the study period. However, he did point out that prior to this, partial budgets had been used to assess the value of such feed sources. These analyses then provided the criteria for decision making and were reassessed if the price for feeds or milk price changed appreciably. He also reported that such analyses were often undertaken at farmer discussion group meetings and these also provided criteria, particularly the maximum amount one could pay for a given feed to obtain an economic return from it. As such, these two factors limited the amount of formal analysis Farmer B undertook during the three years of the study.

6.6.5 Evaluation

Two types of evaluation were undertaken by Farmer B, diagnosis and *ex-post* evaluation. Farmer B undertook diagnosis (Volume II, Appendix XVIII) in much the same way as Farmer A (see Section 5.6.5). It was used when one of four conditions occurred or some combination of them. First, conditions were outside those previously experienced by Farmer B; second, a new management practice was used, third, the monitoring system provided inaccurate information (often due to unusual conditions), and finally, employed labour implemented the plan incorrectly (Volume II, Appendix XVIII). In the first and second situations, Farmer B had insufficient knowledge to accurately develop an expectation. In the latter, his expectations were incorrect because the actions of his farm worker were not as he had expected. Similarly, if the monitoring system was inaccurate, and this often occurred under unusual conditions, then the expectations were based on incorrect information. Examples of these scenarios included, in year one, where the monitoring system failed to identify that the herd had a 20% empty rate. In year three, milk production declined below target because the silage yield was over-estimated. This occurred because a new method of storage had been used and the bulk density of the silage was lower than under the old storage system. Milk production fell below target in April of year one because the farm worker misinterpreted instructions about what area to allocate the herd.

A second form of evaluation, *ex-post* evaluation, was undertaken by Farmer B over the period of the study (Volume II, Appendix XVIII). This was undertaken after a decision or set of decisions had been implemented and the outcome was known. It was used in one of four situations: at the end of a planning period, after a new input or management practice had been implemented, when a poor outcome was identified, or when a normal decision about which he was not confident had been implemented. Ignoring on-going evaluations, some 80% of the evaluations were associated with a new management practice and/or the occurrence of climatic conditions outside those previously experienced by Farmer B (Volume II, Appendix XVIII). The purpose of the *ex-post* evaluation was to evaluate the decision (or decisions) to confirm that it was a good decision, or that it needed to be changed. The ultimate aim of the evaluation was to improve Farmer B's management.

The *ex-post* evaluations could be classified into two main types, those undertaken on an on-going and regular basis and those carried out on an irregular basis (Volume II, Appendix XVIII). Four methods of *ex-post* evaluation were used (Volume II, Appendix XVIII) by Farmer B. These were the same types as described for Farmer A in Section 5.6.5.

The same range of factors initiated the evaluation process (Volume II, Appendix XVIII) as described in Section 5.6.5. Similarly, the evaluations undertaken by Farmer B were classified into the same five main categories: planning, implementation, control, overall management of a planning period and systems performance (Volume II, Appendix XVIII) as described in Section 5.6.5. All of the planning evaluations undertaken by Farmer B related to the use of inputs. This was because many of the changes he made to his farming system over the three years of the study were in relation to input use rather than management practices. Pasture growth rate assumptions were the only planning assumption evaluated. Limited evaluations were completed in relation to targets or implementation. Evaluation of the allocation of silage, forage crop break size and area in pasture was ongoing and used to ensure feeding levels matched the plan.

Control can be separated into two areas of evaluation, control decisions and the monitoring system. Control decisions can be further classified into two sub-categories, contingency plan selection and target choice. Contingency plan selection can be separated into two areas, input use and management practices. Several evaluations of contingency plan selection were undertaken and most of these related to input use, reflecting the changes in input use that occurred over the three years of the study. No instances of target choice evaluation were recorded. The monitoring system was evaluated in terms of accuracy, timeliness, and the accuracy of short-term predictions based on monitored data. Several areas of systems performance were evaluated including reproductive performance, forage crop yield failure, short-term declines in pasture growth and milk production, the rate of liveweight gain in his young stock, and general farm performance. Two areas of overall management evaluation were identified.

Evaluation in year one encompassed the summer plan and in year two the control of the summer plan.

The planning and control decisions evaluated by Farmer B are classified by type and level in Table 6.12. Slightly over half (59%) of the evaluated decisions related to planning as opposed to control. The other interesting point was that almost half (47%) of the evaluated decisions were strategic in nature. Therefore, although the focus of this study was at the tactical level, information generated from the tactical management process was used to evaluate aspects of strategy. The majority of the evaluated decisions were input use decisions (82%) as opposed to management practice (12%) or target choice (6%) decisions. This reflects Farmer B's shift to a higher input system over the three years of the study (e.g. introduction of maize silage, growing of maize, increase in silage use, use of greenfeed maize and cut pasture) and the introduction of new forage crops (Japanese millet, Barkant turnips).

Table 6.12. Classification of planning and control decisions evaluated by Farmer B.

Decision	Decision type	Decision level
Use of inputs		
The use of maize silage	Planning	Strategic
The use of Japanese millet	Planning	Strategic
Grazing the calves off-farm	Planning	Strategic
Grazing the calves on the milking area	Planning	Strategic
Level of supplement on-hand in the previous spring	Planning	Strategic
New forage crop variety	Planning	Strategic
Practice of using cow condition as a supplement over summer	Planning	Strategic
Delay grazing forage crop until March 1st and sow new grass later than normal	Planning	Tactical
The planned activation date for feeding Japanese millet	Planning	Tactical
Quantity of supplement made in the spring	Control	Tactical
Grazing the calves off the milking area on higher quality land	Control	Tactical
Use of urea in March	Control	Tactical
The use of cut pasture	Control	Tactical
Doubling silage ration after significant rainfall	Control	Tactical
Management practices		
Sale of cull cows at planned date	Control	Tactical
Drying off thin cows as planned	Control	Tactical
Choice of targets		
Choice of condition score target at calving	Planning	Strategic

6.6.6 Learning

Learning was one of the products of the evaluation process (Volume II, Appendix XIX). In some cases the learning occurred during the diagnosis or evaluation processes, and at other times, learning was delayed until reflection had occurred. Some learning related to events outside of the summer-autumn period, demonstrating the reflective and sometimes lagged nature of the learning process. No examples of learning prior to the initiation of the study were identified. Not surprisingly, learning tended to occur when either a new practice or input was used, and/or in an extreme season where conditions were outside those previously experienced by Farmer B.

The learning undertaken by Farmer B (Volume II, Appendix XIX) could be classified into the same categories as described in Chapter Five (Section 5.6.6) with three exceptions. Farmer B did not undertake any learning in relation to his values or the planning sub-process of forecasting. He did however, leam about his young stock because they did not perform to expectations on the grazier's property in year one and were subsequently grazed on the milking area in year two.

The outcome from the learning process depended on the learning areas (Volume II, Appendix XIX). In some cases, the information just added to the Farmer B's general understanding of the production system and environment. However, in other cases it resulted in a change in the Farmer B's management system. This may have been a change in planned input use at the strategic level, or the addition of a new contingency plan at the tactical level. Some examples of Farmer B "unlearning" were found. This occurred when a new input (Japanese millet) or management practice was used (method of feeding maize silage) which did not perform to expectations. In each of these cases, the new input or management practice was discarded. The way in which tactical management is undertaken suggests that the context or situation in which the learning takes place is important. Both plan and control response selection is dependent upon the context in which the decision is made. Therefore a link must be made between the conditions associated with the learning and the learning outcome.

6.7 Conclusion

In this chapter the tactical management process used by Farmer B is described and cross-year differences identified and discussed. The process used by Farmer B was a cyclic process as proposed in the normative literature. Both formal and informal planning processes were used and heuristics played an important role in planning. Farmer B monitored multiple factors and through his intimate knowledge of the production system he had developed a simple monitoring system that required limited time input. Importantly, Farmer B actively searched for external opportunities to increase system variety and better allow him to manage production risk. An important component of the tactical management process was evaluation. This facilitated learning and was used to improve Farmer B's management. The following chapter presents the results of a cross-case analysis of the tactical management processes used by Farmers A and B.

CHAPTER 7 CROSS-CASE ANALYSIS

7.1 Introduction

Cross-case analysis is central to any multiple-case study research. Once the within-case analysis is completed, cross-case analysis is used to identify patterns that occur across the cases investigated during the study (Eisenhardt, 1989). The cases used in this study were selected using replication logic (Yin, 1984). That is, they were selected on the expectation that they would exhibit the same theoretically important characteristics. As such, one would expect to find the same phenomena to be exhibited in each case. In this chapter the results from the two case studies (Chapters 5 & 6) are compared and contrasted in relation to the theory and concepts of tactical farm management (Eisenhardt, 1989; Chetty, 1996). First, the overall tactical management process used by both case farmers is compared. Second, components of the respective processes are compared and contrasted under the headings of "planning" and "control". Reasons for differences between cases are explained by drawing on the context of decision-making on each farm.

7.2 The tactical management process

The tactical management processes used by the two case farmers across the three years were virtually identical. At the start of a planning period, a plan was developed. The plan was then implemented and the control process used to determine when to implement the next activity in the plan, or where conditions deviated from the plan, introduce a control response. The latter, can be considered as control decisions, and the ratio of control to implementation decisions is a function of the degree to which conditions deviated from those predicted in the plan. The only real difference between the two case farmers was that Farmer B also introduced opportunities, in the form of external feed sources, into the plan, another form of control. This entire process was repeated for the next planning period. Predefined initiation and termination dates were used to trigger a new planning process, although these dates could be changed under extreme climatic conditions, or because of a change in strategy (see Section 7.3.1). As such, the tactical management process can be viewed as comprising a major planning decision, followed by a cyclic process of "minor" implementation and control decisions until the plan is implemented (Figure 7.1), after which a new planning decision is initiated.

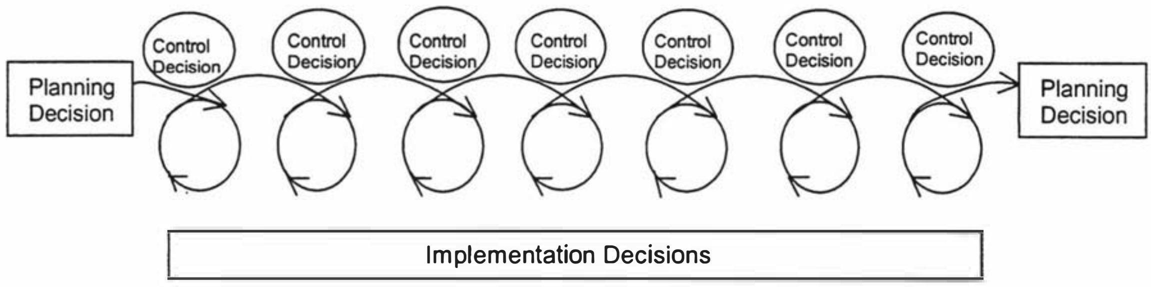

Figure 7.1. Representation from a decision-making perspective of the tactical management process used by the case farmers.

7.3 Planning

The case farmers used a similar planning process. Important aspects of this identified through the study included the determination of the planning horizon, the process itself, and the product of the process, the plan. The following sections compare and contrast these aspects of planning in relation to the two case farmers.

7.3.1 Planning horizon

Similar planning horizons were used by the two case farmers over the summer-autumn period. The summer planning horizon for Farmer A was from the 25th December until mid March, while for Farmer B it was from January 1st until mid March. The second planning horizon for Farmer A was from mid March until calving, while that of Farmer B went from mid March until balance date, the point when pasture growth equals animal feed demand in the spring. The activation date for a new planning period was determined by a change in seasonal conditions and/or the occurrence of a "critical" event or decision. Informal planning was used by both farmers over the summer. Farmer B switched to formal planning for the autumn earlier than Farmer A (mid March vs April 1st) primarily because the latter first wanted to assess the impact of the autumn rains on pasture growth.

The planning horizons (pre-summer (late spring), summer, post-summer (autumn)), for these farmers are a function of the physiological state of the sward and the balance between pasture growth and feed demand. These in turn dictated the management focus or goals for the period. A critical decision, drying off, also influenced the termination date for the summer planning period. The main difference between the two case farmers was the termination date for the second planning horizon. Farmer A chose a critical event, calving, as the termination date for his planning horizon, whereas Farmer B chose a point when seasonal conditions changed, that is, the point when pasture growth first exceeded animal feed demand in the spring. Farmer A did not plan through until balance date because he considered the level of uncertainty post-calving required a separate planning period. Not only are conditions much more variable in the spring than the winter, there are several groups of animals (heifers, mixed age cows, lactating and dry cows) to consider. An informal planning process for the period from calving to balance date was adopted. However, the terminating conditions at calving for the autumn plan were designed to ensure key targets in terms of average pasture cover and cow condition were met at balance date. Therefore, in effect, Farmer A was undertaking the same process as Farmer B, but in two planning steps rather than one. In contrast, Farmer B had completed a Diploma of Agriculture at the local university where he had been taught to formally plan through until balance date. He did however, view calving as a critical event within this planning horizon. These tactical planning horizons were not rigidly fixed. Two factors changed planning horizons: abnormal conditions and strategic decisions.

The case farmers thought across a number of different planning horizons simultaneously. These ranged from daily operational plans through to two tactical planning periods (e.g. January 1^{st} to balance date). The most common shorter-term planning horizon was event-based (e.g. silage or forage crop feeding), encompassing a period of 1 to 4 weeks. In several instances, however, events were combined in relation to the achievement of a specific goal and this “amalgam” was considered to be a “planning horizon”. Concurrently, likely farm pasture cover and resultant cow intakes were predicted for when the herd returned to the paddock just grazed. This horizon depended on the rotation length at the time, but tended to be between three to five weeks over most of the summer-autumn.

7.3.2 Planning process

During the summer period the planning process was primarily qualitative with some quantitative aspects. This changed to a formal process, using feed budgeting, in the autumn. The only difference between the two farmers was when formal planning was initiated; two weeks after the start of the autumn period for Farmer A versus at the start of the period for Farmer B. Farmer A's later start was in order to identify the nature of the autumn, and thus a more accurate assessment of the drying off date. By early April, the type of autumn for pasture growth could be determined. Farmer B's earlier start meant the first plan was a broad guide to the likely drying off date, usually in May.

7.3.2.1 Informal planning process

The informal planning process used by the case farmers is represented in Figure 7.2. They had developed a "typical" summer plan over time. This was implemented each year unless some factor or factors caused it to be modified. Plan modification was undertaken by the case farmers for four reasons. First, if a strategic decision had been made that impacted on the plan (Figure 7.2). Second, through learning during the previous planning cycle, an example of historical control, the case farmers might identify some improvement to the "typical" plan, and modify it accordingly. Third, if a tactical decision made in the preceding planning period required a change in some aspect of the plan. Fourth, if the state of the farm at the start of the summer was "atypical".

The case farmers assessed the state of the farm in relation to four areas: pasture (average pasture cover, pasture growth), supplements (silage on-hand), forage crop (likely yield) and the herd (milk production, condition score, reproductive state, stocking rate or numbers and intake and feed demand). This information was then used to simulate outcomes for the summer planning period under likely pasture growth rates. A mental feed budget was used to assess the feasibility of the "typical" or modified "typical" plan (Figure 7.2). If the plan appeared feasible, the summer was classified as "typical" and the plan was implemented. However, if the "typical" plan was found to be infeasible (as a result of "atypical" conditions), the summer was classified as "dry" and the case farmers postulated changes to the "typical" or modified "typical" plan that would best meet their summer goals. The adjusted plan was tested using simulation (mental feed budget). If the adjusted plan proved feasible, it was then implemented (Figure 7.2). However, if the adjusted plan again proved infeasible, further changes were postulated and the revised plan was re-tested. Feed was not the only farm state factor that influenced the plan. The reproductive state of the herd could cause the case farmers to modify their "typical" plans. For example, Farmer A delayed the date the bull was removed by two weeks because herd reproductive performance was below average.

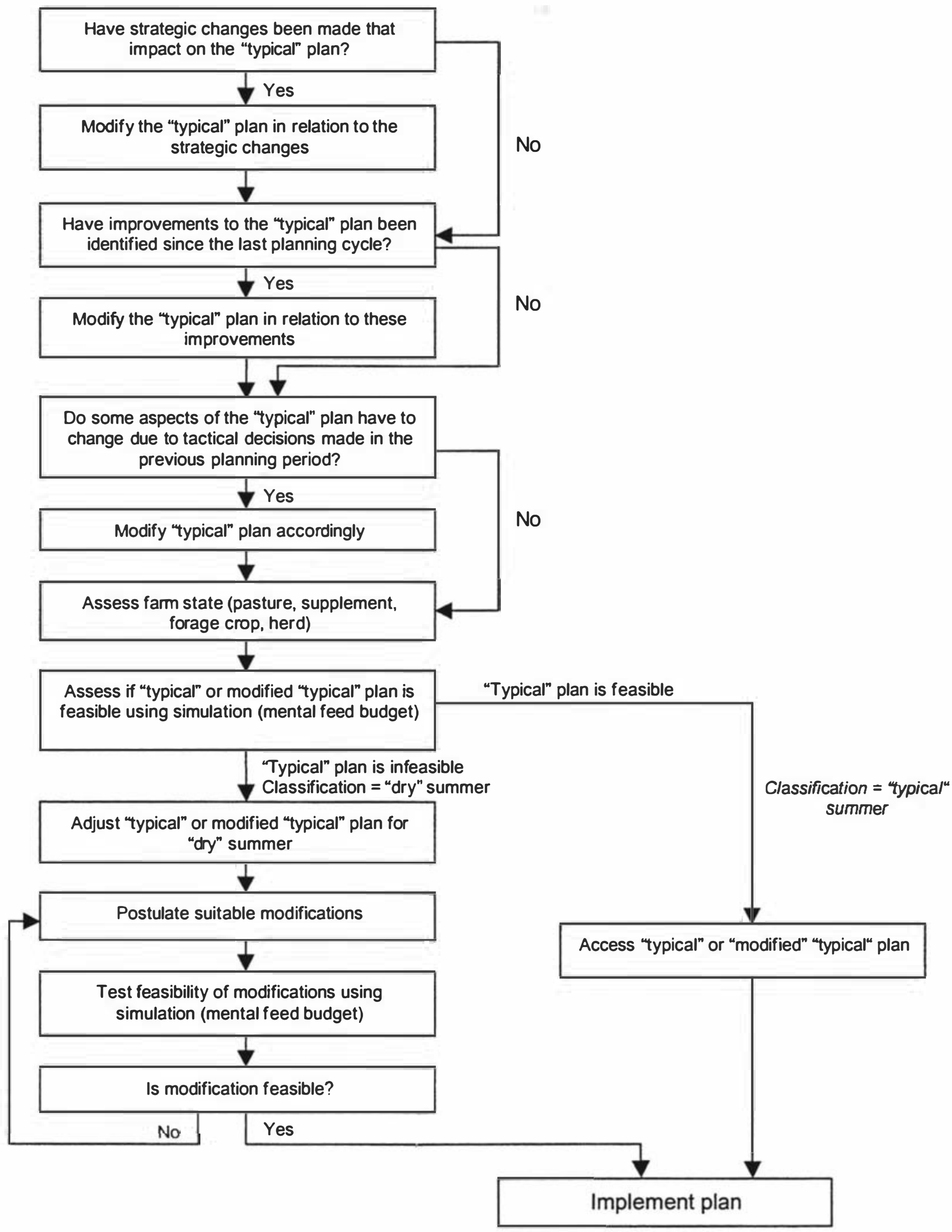

Figure 7.2. The planning process used by the case farmers over the summer.

This was an iterative process, and the number of iterations was a function of the magnitude of the feed problem and/or other modifications to the plan (strategic, tactical or learning decisions). A feasible plan could be developed on the day it was considered, or the process could require a number of iterations over several days. The changes made to the case farmers' "typical" plans involved: changing heuristics that determined the sequencing and timing (activation and termination) of events, input levels, types, and priorities (arbitration heuristics), and important targets.

The summer was classified as "typical" if the farm was in a normal or better than normal state. However, in year two Farmer A used the simulation process (and a belief that the summer would be "wet") to identify that the "typical" plan was too "conservative". He then used the plan adjustment process to develop a plan for a "wet" summer. The summer turned dry and he subsequently removed this "adjustment" from his planning repertoire. Failure to correctly predict a "wet" summer (a difficult task even for a weather forecaster) therefore caused him to adopt a more conservative stance.

The degree to which heuristics were modified from those in the "typical" plan varied. At the simplest level, a new milk production target, input or management practice replaced those currently in the plan without any further modification. At a more complex level, the planning heuristics were modified. Again, this varied in complexity. For example, when Farmer A changed from using traditional pregnancy diagnoses to ultrasound, he only had to shift the date of the practice four weeks earlier. A slightly more complex process was when Farmer B replaced a brassica crop with millet. He had to incorporate heuristics for the regrazing of the millet, because the brassica crop was only grazed once. Other changes, particularly the modification of the "typical" plan for a "dry" summer required the case farmers to replace the activities in the plan with contingency plans designed primarily to reduce feed demand or increase feed supply.

In some situations, the changes to the plan were such that the case farmers could not simply modify their existing planning heuristics and check the feasibility of the change using simulation. Rather, a more prolonged process spread over several days was undertaken, with a greater level of quantitative analysis. When Farmer B dramatically increased the amount of grass silage in his summer plan, he spent several days mentally quantifying alternative options in terms of feed supply and feed demand, before deriving a summer plan. Prior to this, his planning effort for the summer had been relatively minor. This suggests that where changes to the plan were complex, the case farmers had to revert to a higher level of formality. Evidence from the autumn period showed that where quantitative analysis had been used to analyse a new option (Farmer A with urea) and that option had been successfully implemented, it was incorporated into the plan as a heuristic and the analysis was not repeated in subsequent years. In contrast, options that were found to be ineffective were removed from the plan. For example, Japanese millet in

Farmer B's plan, and the use of higher milk production targets in a "wet" summer by Farmer A. In summary, while the planning process was based on a "typical" plan or template, the template changed from year to year in response to the conditions at the start of summer, previously made strategic and tactical decisions, and farmer learning.

7.3.2.2 Formal planning process

In autumn, both case farmers used a feed budget to aid planning. The local extension service had developed a simple form to guide farmers through the steps needed to estimate their herd drying off date. The changeover from an informal to formal planning process occurred primarily in response to the proximity of a critical decision, drying off. Around that time the sward characteristics changed and average pasture cover, could be measured more accurately and therefore this information could be used for planning. Neither farmer saw benefit from using more formal planning over the summer. Rather, additional time costs would be incurred for planning and the associated objective monitoring of pasture. The case farmers also mentioned that the level of uncertainty was much lower over the autumn-winter than the summer period.

The first step in feed budgeting was to assess the situation. Objective data was collected on the average pasture cover on the farm along with information about: the level of supplement on-hand, cow numbers, the condition of the herd, level of milk production and areas in pasture and new grass. The terminating conditions in terms of average pasture cover and cow condition were specified for the plan, and these along with a maximum average pasture cover target, acted as constraints. Cow intakes were derived, by experience, from the production profile for the planning period. Average pasture growth rates were then specified for each month of the plan. Farmer A based his estimates on experience, and Farmer B had obtained his from outside experts but had validated them through his monitoring system over time. Once the patterns of feed demand and feed supply were quantified, the drying off date that would allow them to achieve their terminating targets was calculated. As such, the planning process was relatively simple. The feed budget had monthly time steps except for the month in which drying off was expected to occur. Here shorter time periods were used so that the case farmers could determine the exact date for drying off. The output from the feed budget was the expected drying off date, a summary of the timing of events, type and level of inputs used, and the monthly pattern of average pasture cover over the period of the plan. The latter was graphed through time and the line of the graph used for control purposes.

In most instances, average pasture growth rates were used. In one instance, Farmer A increased his average pasture growth rates by 5 kg DM/ha/day for the first month of the plan because of favourable conditions for growth. The farmers were not confident in forecasting pasture growth rates other than those based on means because short-term weather conditions were considered to be too uncertain. The same view applied to the use of medium- to long-term weather forecasts.

Farmer A's autumn plan was not routinely revised prior to drying off. In contrast, Farmer B usually revised his plan one to two times before drying off. Farmer A's behaviour could be attributed to the proximity of planning to his nominal drying off date, a period of two to three weeks. Average pasture cover targets were however, monitored to guide decisions, and in year three, their rapid decline did prompt a review. Farmer B reviewed his feed budget twice in year one, once in year two, and never in year three. This purely reflected how the farm's feed situation was developed up to drying off.

A consultant was used by Farmer B nearer the drying off date to develop a revised plan on a spreadsheet program with weekly time intervals. Farmer B did not have this software and he found the weekly time intervals were useful for control purposes. The consultant's role was to enter Farmer B's plan into the spreadsheet and calculate the drying off date. While the more detailed spreadsheet feed budget had some advantages in terms of control (weekly versus monthly time periods), the graph produced from the less detailed feed budget could be used to the same effect. The consultant's charges were about $NZ300 per visit.

Although a formal, quantitative planning process was adopted by both case farmers, there was limited evidence that they analysed alternative courses of action in this way. In year one, Farmer A used a partial budget to investigate the profitability of using urea to extend the lactation. Prior to this he had screened out other options such as grazing off and bought-in hay. He had had a bad experience with grazing, and therefore did not view this as an option he would investigate further. He saw bought-in hay as a maintenance feed and therefore not suitable for increasing cow condition over the winter. Urea was found to be profitable, but conditions for a pasture response at the time were not suitable, and it was not incorporated into the plan. In year two, Farmer A did not revise his partial budget for urea, but used the feed budget to estimate the average pasture cover required for three drying off dates with and without urea. In year three, after using urea in the previous year, he incorporated it straight into the plan without any analysis.

The only formal analysis of alternative options by Farmer B occurred in year one when in early April, he analysed the effect of milking his empty and thin cows through until drying off. He compared the two scenarios, but decided against the change because of its effect on the condition of the younger cows, and the value of his empty cull cows, for a minimal increase in milk production. This analysis was not documented, and no estimate of the impact of the change on profitability was calculated. Farmer B mentioned that although he did not use partial budgets during the study period, he had used them in the past for analysing alternative options in the plan (e.g. winter grazing). He also stated that once the analysis was completed, it did not need to be repeated in future years unless prices or costs changed significantly. Farmer B also had to change his autumn plan in year one because he had a 20% empty rate, an effect of the previous cold, wet spring. No formal analysis was undertaken. Instead, the case farmer decided to milk the best of his empty cows through the winter on a neighbouring farm, sell less culls on production, and buy in additional cows mid-winter to make up herd numbers. These changes were then entered into the revised feed budget in early April.

No formal account of risk was taken in the planning processes used by the case farmers. They did not use probabilities; rather most of their planning was based around means or a "typical" summer. Limited forecasting was used, and even where they predicted a dry year, this "prediction" was based on the current state of the farm (low average pasture cover, pasture growth rates, milk production, cow condition, supplement level, and poor forage crops), as opposed to some means of forecasting climatic conditions. One exception was where Farmer A used above average pasture growth rates for April because conditions were exceptional at the start of the month. Farmer B did make an assessment of the ability of his reserve stack of maize silage to cope with a reduction in spring pasture growth rates. Farmer A used conservative pasture growth rates in the autumn plan, which provided him with additional flexibility.

The main means by which the case farmers coped with risk in relation to planning was in the nature of their plan. It was designed to cope with uncertainty. For example, many of the heuristics for determining when an event occurred were condition rather than date dependent. The time at which the forage crop, for example, was fed, was determined by the point at which milk production fell to 13 litres/cow/day or 1.13 kg MS/cow/day. The case farmers stressed that the plan's outcome was dependent on the climatic conditions that occurred over the summer-autumn. Although they both had precise milk production targets for financial budgeting purposes, these played no role in the case farmers' tactical feed management. The case farmers knew that they did not have the degree of control over their systems to precisely achieve production goals. The plans also contained targets and contingency plans that were critical for control in an uncertain environment. The following sections describe important aspects of the case farmers' plans.

7.3.2.3 Rolling planning

Given the limited number of formal plan revisions, neither case farmer could be viewed as a user of the formal process of rolling planning. However, they did use an informal process that was similar in nature. The next event (or couple of events) in their plan was considered, and contingency plans identified for use should pasture growth rates be less than expected. This process was used in conjunction with information provided from the case farmers' prediction of the feed situation on the farm over two to three weeks based on their grazing rotation and pre- and post-grazing residuals. Given the latter was updated every two to seven days, this minimised the risk that the case farmers would encounter farming conditions for which they were not prepared.

7.3.3 The plan

The structure of the plans used by the case farmers were essentially the same (Figure 7.3). Plans comprised a primary goal for the planning period, a predictive schedule of events, a set of targets and associated contingency plans for control purposes, and a set of decision rules that determined whether to implement the plan, or one of the contingency plans. The latter will be discussed later under control, because it was during the control phase that these decision rules were applied.

The plan comprised a set of heuristics that determined the important components of the plan. These heuristics or rules could be classified as sequencing, activation and termination, input type and level, arbitration, and target setting rules. Sequencing rules determined the order of events. Activation and termination rules determined when to initiate and terminate an activity (or event). Some rules were based on benchmark dates, for example, the date at which the new grass had to be sown. Others were dependent on the timing of previous events, for example, the date of pregnancy testing depended upon when the bull was removed. Alternatively, activation and termination dates were condition-dependent and triggered when thresholds, representing specific farm state variables, were crossed. For example, the forage crop was grazed when milk production fell below 1.13

kg MS/cow/day. Condition-dependent rules made the plan more flexible and responsive to changing circumstances.

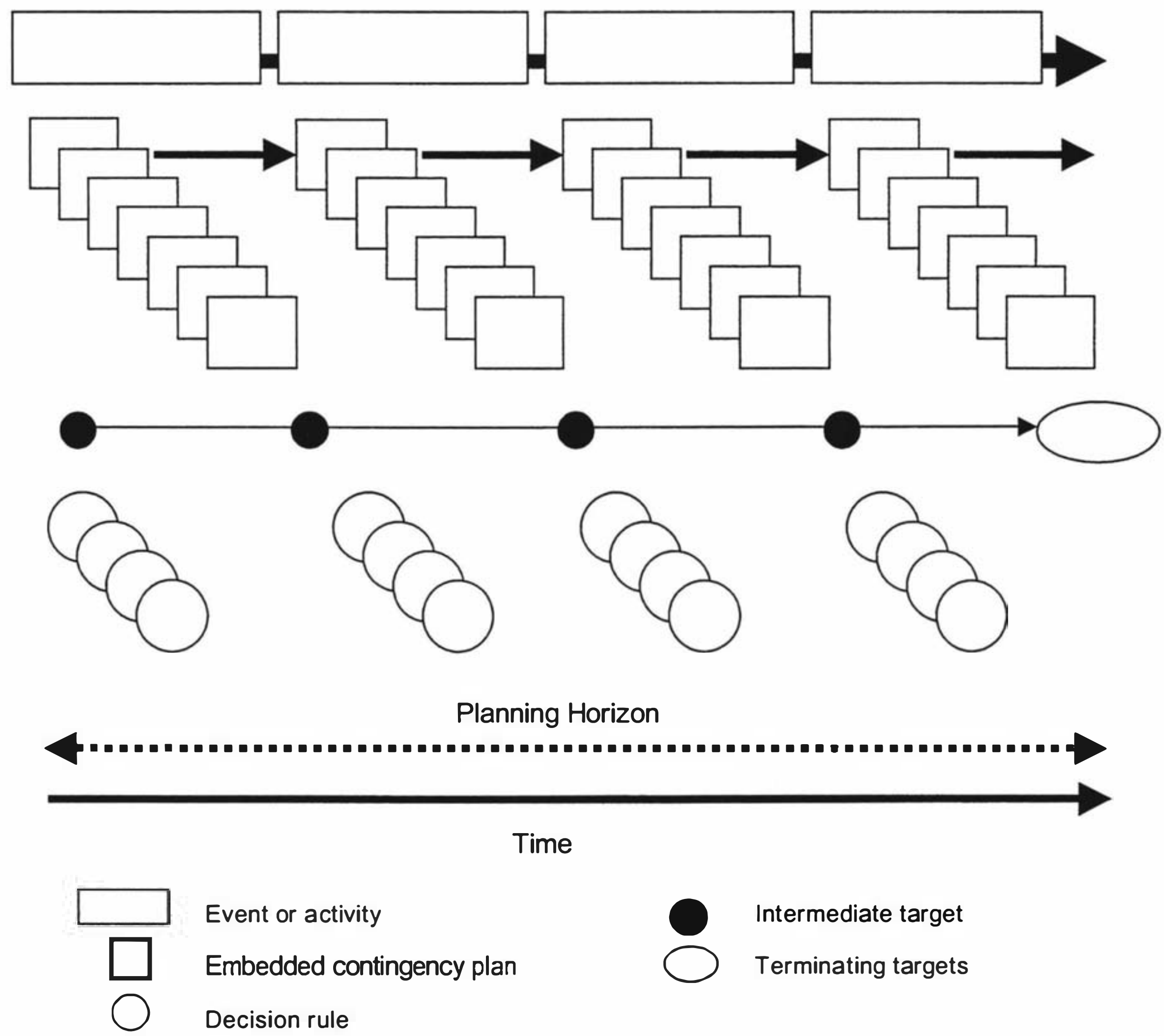

Figure 7.3. A diagrammatic representation of a case farmer's plan.

"Input level and type" rules determined the type of input and the level at which it was specified in the plan. In most instances, the case farmers used milk production targets to specify the amount of input. This provided some flexibility in relation to manipulating the ratio of pasture to supplement fed because over much of the summer these inputs were combined. Arbitration rules, although rarely identified, were used to determine resource use priority between stock classes, or age groups. Target setting rules, specified the level at which particular targets were set for different "types" of summers. The majority of planning rules and their rationale for use by the case farmers were very similar. The reasons for the rules were based primarily on a concept equivalent to marginality, although the case farmers did not use this term. Therefore in most cases the rules that determined the sequence, timing, level and type of input used by the case farmers were in place because they assisted in optimising system performance. Some rules were obligatory, for example, the sequence or timing of some events was a function of the timing of prior events.

7.3.3.1 Goals and values

Goals for the summer-autumn period were essentially the same for the two case farmers. No evidence was found of a goal formulation process prior to or during planning; they had been formulated at some point in the past. The summer goal was aimed at optimising summer milk production from the available feed resource whilst ensuring as many lactating cows as possible made it through to the autumn period. The summer goal was subservient to the autumn goal. Variation in the two case farmer's autumn goals, was a function of their respective planning horizons. Effectively, they both wanted to optimise autumn milk production from the available feed resources without jeopardising next season's production. To ensure next season's production was not jeopardised, they had to ensure that the herd was in good condition with sufficient feed on-hand at calving. Farmer A specified particular terminating conditions at calving to ensure this, while Farmer B specified such conditions for the later balance date. Sub-goals for the summer-autumn goals could be represented in a goal hierarchy. For example, targets for milk production and condition score determined those for cow intake, which in turn determined sward condition (pre- and post-grazing residuals, average pasture cover) and supplement use goals.

Values played a limited role in the summer-autumn management. They did influence the options the case farmers used in their planing or control decisions. The owners' values could limit the options available to the case farmers because of their “sharemilking” position. Farmer A had a "low input" philosophy and tended to avoid the use of “too much” supplement or bought-in feed. However, this attitude changed over the study period as he began to use nitrogen and at increasing levels. In contrast, Farmer B used a higher level of supplement, and actively sought out feed sources off-farm that might be used to further extend the lactation over the summer-autumn. He also significantly increased the level of supplement fed to the herd over the summer-autumn during the period of the study. Farming practice shifted away from per hectare production to focus on increased per cow production and the use of greater input levels to achieve this. The changes identified on these two fanns reflected the broader changes occurring in the dairy farming community at that time.

7.3.3.2 The predictive schedule of events

Both case farmers had a "typical" plan that acted as a template for planning purposes. It was modified to accommodate variation in farm state, strategic decisions, and improvements identified during the previous planning cycle. The case farmers' predictive schedules for their "typical" plans (Table 7.1) were almost identical. Since the case farmers were in the same region, only 20 kilometers apart and experienced very similar climatic conditions, this was perhaps not surprising. Small differences in the planned dates for reproductive management activities (removal of bull, pregnancy diagnosis) resulted from differences in calving date. Farmer A planned to place his thin cows on once-a-day milking when their condition fell to 3.5 condition score units and then dry them off if they continued to lose condition. In contrast, Farmer B dried them off directly. This difference reflected Farmer A's belief that the younger cows' future ability to compete with their older counterparts was a function of the length (days) of their first lactation. Farmer A also planned to place the younger cows on once-a-day milking and dry them off much earlier then Farmer B. This reflected the higher level of pasture production and supplement use on Farmer B's property over the summer-autumn, which reduced the level of within-herd competition. Farmer B also planned to dry off a few weeks later than Farmer A did, and this again reflected the higher pasture production and supplement use on his property.

Farmer A planned to maintain a “fixed” rotation length over the summer-autumn, while Farmer B intended to extend it when feeding supplements and after reducing stocking rate in early April. Farmer A’s position reflected his belief that this management would enhance pasture regrowth. Farmer B changed to a fixed rotation during year's two and three for the same reason. Farmer A also planned to sell his empty cows later than Farmer B because he believed they converted feed into milk more efficiently than pregnant cows. In contrast, Farmer B sold his empty cows earlier to obtain a higher price and used the resultant feed to increase milk production from the remainder of the herd. Farmer B also stated that he had to sell his culls early because of his high stocking rate.

Table 7.1. The predictive schedules used by the case farmers in their "typical" plan.

Farmer A	Farmer B
Cull cows unsuitable for carrying through the summer at, or shortly after Christmas[1].	
Maintain a 25 - 30 day rotation until late January or milk production falls to 1.13 kg MS/cow/day.	Maintain the herd on a 21 - 22 day rotation until late January or milk production falls to 1.13 kg MS/cow/day.
Remove the bull on the 26th January.	
Feed the forage crop in early February when milk production falls to 13 litres/cow/day (1.13 kg MS/cow/day). Feed the forage crop for 2 - 3 weeks and provide one third of the herd's diet, maintaining production at 12 -13 litres/cow/day (1.04 kg MS/cow/day).	Feed the forage crop in early February when milk production falls to 13 litres/cow/day (1.13 kg MS/cow/day). Feed the forage crop for 3 weeks and maintain milk production at or above 1.04 kg MS/cow/day.
	Remove the bull in early February.
Herd test mid February.	Herd test on the 20th February.
Place younger cows on once-a-day milking if condition score falls to 3.5 condition score units.	
Dry off younger cows if condition score continues to fall and they are on once-a-day milking.	
Feed silage after the forage crop to maintain milk production at 12 -13 litres/cow/day (1.04 kg MS/cow/day) for about 3 weeks.	Feed silage after the forage crop to maintain milk production at 12 -13 litres/cow/day (1.04 kg MS/cow/day) for about 4 weeks. Use the grass silage to extend the rotation out to 35 - 42 days while holding milk production at 1.04 kg MS/cow/day.
Pregnancy test the herd in early March.	
Sow the new grass mid March.	Sow the new grass by mid March.
	Pregnancy test the herd 6 - 8 weeks after the bull is removed in late March.
Maintain a 25 - 30 day rotation post-silage.	
	Undertake a herd test in early April.
	Sell cull cows in early April after herd testing and pregnancy diagnosis.
	Dry off the thin induction and rising three-year-old cows in early April.
	Extend the rotation as the cull and dry cows are removed from the milking platform.
Sell the cull cows at or near drying off.	
Dry off the herd around mid to late April.	Dry off the herd in late April, early May.

The case farmers' plans diverged over the three years due primarily to strategic decisions. Farmer B's strategy changed from a relatively low to a higher input system. By year three, he had tripled the amount of summer-autumn supplement fed prior to the study. In contrast, the amount of supplement fed per cow over this period by Farmer A declined by 23%[2]. In the New Zealand dairy industry over this period there was a swing towards higher per cow production and greater use of supplements to achieve this. These results demonstrate how Farmer B adopted this approach, while Farmer A remained with the more traditional low input systems used by New Zealand dairy farmers prior to the 1990's. The only other difference between the case farmers' plans in relation to strategic

[1] Farmer B culled his herd prior to the start of summer.
[2] This is based on the supplement Farmer B planned to feed in year one. He changed the plan partway through and diverted some 11,000 kg DM of grass silage for use in the spring.

decisions was Farmer B's decision to retain the replacement heifer calves on the milking area in year two because of problems with his grazier.

Other differences between the plans resulted from the farm state at the start of the summer. For example, in year three, although both farms were "dry", Farmer A had minimal supplements while Farmer B had over twice the normal amount on-hand. As a result, Farmer A planned to use a range of extreme options (e.g. go onto once-a-day milking), to ensure the maximum number of lactating cows made it through to the autumn rains. In contrast, because of the level of supplement on-hand, Farmer B did not need to use these options. In year two, Farmer A believed there had been a climatic shift to "wet" summers and as a result, the milk production target was increased as described earlier.

7.3.3.3 The targets

Targets were the third component of the case farmers' plans. Both used targets in two main ways: first, to trigger the implementation of the activities specified in the plan, and second, to identify when the implementation deviated from the plan. In the latter case, the case farmers then selected a suitable control response to minimise the impact of the deviation. Two types of targets were used in tactical management: terminating and intermediate. Terminating targets were those specified at the end of a planning period (Table 7.2). These acted as constraints to the plan and ensured the system was in a state for optimum performance, *ceteris paribus*, in the next planning period.

Table 7.2. Terminating targets used by the case farmers for the two planning periods across the three years of the study.

Terminating targets	Farmer A	Farmer B
Summer Plan		
Mid March		
Lactating cow numbers	maximise	maximise
Average herd condition (condition score units)	4.5	NA
Autumn Plan		
Calving		
Average pasture cover (kg DM/ha)	2200	NA
Average herd condition (condition score units)	4.5	NA
Balance date		
Average pasture cover (condition score units)	NA	1700-1800[3]

[3] The average pasture cover target was increased from 1700 to 1800 kg DM/ha in year two.

The intermediate targets, applied between the start and end of the planning horizon (Table 7.3). These targets had three roles. First, they were used to control the implementation of the plan. Second, they were used to ensure the terminating targets were met; and third, they were used to optimise system performance. The targets that primarily controlled the implementation of the plan changed from one planning period to the next. During summer, milk production was the primary target, while average pasture cover took over this role in the autumn plan. This change occurred because, unlike for the autumn period, average pasture cover could not be measured accurately over the summer due to sward characteristics. The intermediate targets can be separated into three types: benchmark dates, milestones, and thresholds. Benchmark dates specified the date at which a certain activity or event must be implemented at or by. In contrast, milestones projected steps on the way to a final terminating target, for example, intermediate average pasture cover targets. A threshold target, if exceeded, caused the activation of an activity or event.

Table 7.3. A comparison of the intermediate targets used by the case farmers in their summer and autumn plans.

Targets	Used by both case farmers	Level	Level
Summer		**Farmer A**	**Farmer B**
Milk production[4] (kg MS/cow/day)			
Pre-forage crop	Yes	> 1.13	> 1.13
Forage crop			
Introduction	Yes	1.13	1.13
Maintenance	Yes	≥ 1.04	≥ 1.04
Silage	Yes	≥ 1.04	≥ 1.04
Rotation length (days)	Yes	25 - 30	23 - 24[5]
Cow intakes (kg DM/cow/day)	Yes	12.0	12.0
Post-grazing residuals (kg DM/ha)	Yes	1200	1400
Individual cow condition (condition score units)	Yes	≥ 3.5	≥ 3.5
Rainfall (mm)	No	≥ 25	NA
Benchmark dates			
Removal of bull	Yes	26th January	Early February
Pregnancy testing	Yes	Early March	Late March[6]
Initiation of forage crop grazing	Yes	Late January/early February	Late January/early February
Completion of forage crop	Yes	≤ February 28th	≤ February 28th
New grass sowing	Yes	Mid March	Mid March

[4] Farmer A expressed his milk production targets in units of litres/cow/day, but these are converted to milksolids/cow/day for comparison purposes.
[5] In year one Farmer B extended the rotation length through the summer-autumn, but then changed to a fixed rotation length in years two and three.
[6] Is part of the autumn plan.

Table 7.3 (continued)

Targets	Used by both case farmers	Level	Level
Autumn		**Farmer A**	**Farmer B**
Rotation length (days)	Yes	25 - 30	23 - 24
Individual cow condition (condition score units)			
Late March	Yes	≥3.50	≥ 3.50
Early April	Yes	≥3.50	≥ 3.50
Late April	Yes	≥3.50	≥ 3.75
Early May	Yes	≥3.50	≥ 4.00
Average herd condition (condition score units)			
Drying off	No	≥4.5	NA
Calving	Yes	≥ 4.5[7]	≥ 4.5-5.0[8]
Average pasture cover[9] (kg DM/ha)			
Drying off[10]	Yes	Variable	Variable
Winter maximum	Yes	2300	2300
Calving	Yes	2200[11]	2000-2100[12]
Rainfall (mm)	No	≥ 25	NA
Benchmark dates			
Date herd must be grazed off	No	NA	Variable[13]

Several methods were used to derive the targets. The simplest method was the determination of benchmark dates on the basis of previous events: mating date set the benchmark dates for when the bull was removed and pregnancy testing could commence. Similarly, the activation and termination dates for forage crop grazing were determined by the benchmark date for new grass sowing. The derivation of other targets, such as average pasture cover levels, was based on the case farmers' experience and knowledge of their system's cause and effect relationships and production goals. The terminating targets were used to derive many of the intermediate targets. For example, intermediate condition score targets were designed to ensure the target average herd condition score at calving was met

The majority of the targets used by the case farmers were identical. The main difference was in relation to the terminating targets because they applied to different planning horizons. Another difference occurred because the case farmers used different targets for the same purpose. That is, Farmer A used average herd condition score targets, while Farmer B used individual cow condition score targets to manage the condition of the herd.

[7] Terminating target for Farmer A.
[8] Farmer B increased this target from 4.50 condition score units in year one to 4.75 condition score units in year two and to 5.00 condition score units in year three.
[9] These are the final average pasture cover targets set by Farmer A. Some were revised from those first set after the autumn feed budget was completed around April 1st.
[10] The actual level of pasture cover depends on the resources the case farmers have available in that year.
[11] Terminating target for Farmer A.
[12] The average pasture cover target was increased from 2000 to 2100 kg DM/ha in year two.
[13] Dependent on the situation.

Only Farmer A used a rainfall target. This was because Farmer B had a higher stocking rate and better soil type than Farmer A. As such, less dead matter built up in the sward and significant rainfall events tended to have less effect on cow intakes on Farm B than Farm A.

Between-farmer differences in target levels (Tables 7.2 and 7.3) can be attributed to differences in production goals, strategic decisions in terms of stocking rate, calving date and supplement use, and the farm resource-base. The case farmers changed some of their targets over the duration of the study while others remained unchanged. As previously stated, Farmer B increased his targets for condition score at calving and average pasture cover at calving and balance date to improve per cow performance (production goal). Similarly, Farmer A changed his targets in response to the strategic decision to synchronise heifer mating and replace autumn silage with additional forage crop.

Conditions, or the farm state, at the start of the planning period, also influenced the case farmers' selection of targets. For example, in a dry year, both case farmers reduced their milk production and associated cow intake and condition score targets, relaxed their "ideal" post-grazing residual targets, and also changed benchmark dates. The purpose of these adjustments was to maximise the number of cows still in milk by the autumn. Targets were also adjusted if conditions changed sufficiently during the implementation of the plan. This provided further flexibility to their plans. However, the terminating targets for the autumn plan, were non-negotiable because they were critical for ensuring the best chance for optimum production in the next season (Table 7.2).

The final reason for which the case farmers changed their targets was in response to learning. Experience or knowledge gained in the previous season to increase herd productivity could be reflected in increased target levels. Equally these could be dropped if the change did not succeed.

7.3.3.4 The contingency plans

The contingency plans considered by the case farmers during the three years are summarised in Table 7.4. One useful way of classifying these is by their impact on feed supply or feed demand. The case farmers expected pasture growth, the primary source of feed, to exceed or fall below their expectations during the summer-autumn period. Their response to such variation was to adjust feed supply or feed demand. In a feed deficit situation, they would either increase feed supply or reduce feed demand (Table 7.4). The converse applied in a feed surplus situation (Table 7.4). A weakness of the classification schema is that some contingency plans were not implemented primarily to influence feed supply or feed demand. For example, cow intake was often increased to sustain or regain body condition in late autumn rather than increase feed demand *per se*.

Table 7.4. Comparison of the contingency plans used or mentioned by the case farmers over the three years of the study.

Category	Farmer A	Farmer B	Match
Feed deficit situation			
Increase feed supply		Feed silage before the forage crop[14]	No
	Graze the forage crop earlier than planned[14]	Graze the forage crop earlier than planned	Yes
	Increase forage crop break by increasing the milk production target		No
	Increase the level of forage crop fed		No
	Feed silage early[14]		No
	Increase pasture silage ration	Increase pasture silage ration	Yes
		Extend feeding period for pasture silage	No
	Reduce rotation length	Reduce rotation length	Yes
	Apply nitrogenous fertiliser	Apply nitrogenous fertiliser	Yes
	Apply additional nitrogenous fertiliser		No
	Use winter, early spring silage over the summer-autumn and replace later		No
	Feed 100% hay to dry cows on the milking area		No
		Increase maize silage ration	No
		Purchase and feed greenfeed maize	No
		Purchase standing maize for maize silage	No
		Purchase and feed standing pasture	No
		Use winter grazing to extend the lactation[14]	No
Decrease feed demand		Graze off young stock	No
	Reduce milk production target and associated cow intakes	Reduce milk production target and associated cow intakes	Yes
		Dry off the thin cows earlier than planned	No
	Sell cull cows earlier than planned[14]	Sell cull cows earlier than planned	Yes
	Feed cull cows on waste ground until sold		No
	Place thin cows on once-a-day milking		No
	Dry off thin cows and place on runoff		No
	Do not place the herd back onto twice-a-day milking		No
	Place dry cows currently run on the milking area onto the runoff		No
	Place the herd on once-a-day milking		No
	Dry off the herd earlier than planned	Dry off the herd earlier than planned	Yes

[14] This option was mentioned by the case farmers but not used.

Table 7.4 (continued)

Category	Farmer A	Farmer B	Match
Feed surplus situation			
Decrease feed supply	Extend rotation length	Extend rotation length	Yes
		Harvest forage crop as silage[14]	No
	Delay grazing of forage crop[14]		No
		Reduce forage crop ration	No
	Retain silage for the spring		No
		Reduce pasture silage ration	No
	Provide part of the milking area to the young stock		No
		Reduce the maize silage ration	No
Increase feed demand	Increase milk production target in order to increase cow intakes	Increase milk production target in order to increase cow intakes	Yes
	Increase cow intakes	Increase cow intakes	Yes
	Increase cow intakes by maintaining current rotation length		No
	Delay placing thin cows on once-a-day milking		No
		Delay drying off of thin cows	No
	Dry off less thin cows than planned		No
	Sell less culls than planned		No
		Delay sale of cull cows	No
	Retain dry cows on milking area		No
	Return dry cows from the runoff to the milking area		No
	Delay placing herd on once-a-day milking		No
	Extend the lactation	Extend the lactation	Yes

An alternative, and more abstract, method of classifying the case farmers' contingency plans is to consider the effect it has on the plan. Four types of changes were identified: the activation or termination dates for events or activities, the sequence of events, the quantity of inputs used, and the type of inputs used (Table 7.5). Few contingency plans were used that changed the sequence of events. The same number of contingency plans were used by the farmers to change the activation and termination dates of events (Figure 7.5). However, Farmer A used twice the number of contingency plans that changed the quantity of input provided or used, as Farmer B. This was reversed for the contingency plans that changed the type of inputs.

Five factors were identified which explained the between-farmer differences in the number and type of contingency plan used: physical conditions, accuracy of the plan, variety of inputs and activities, external sourcing of inputs, and quantity of inputs. Although the case farms were in the same region, they experienced some differences in climatic conditions and this influenced their choice of contingency plans. The accuracy of plans also influenced the number and type of contingency plans used. For example, if a case farmer thought the summer would be dry and adjusted the plan to cope with this and the prediction proved correct, then fewer contingency plans would need to be implemented. The variety of inputs and activities in a plan influenced the range of contingency plans.

Table 7.5. Classification of the contingency plans used by the case farmers on the basis of impact on the plan.

Category	Farmer A	Farmer B
Changes sequence of events	Retain silage for the spring Use winter, early spring silage over the summer-autumn and replace later	Feed silage before the forage crop[14]
Changes activation or termination date	Graze the forage crop earlier than planned Delay grazing of forage crop Feed silage early Sell cull cows earlier than planned Delay placing thin cows on once-a-day milking Delay placing herd on once-a-day milking Extend the lactation Dry off the herd earlier than planned	Graze the forage crop earlier than planned Extend feeding period for pasture silage Sell cull cows earlier than planned Delay sale of cull cows Delay drying off of thin cows Dry off the thin cows earlier than planned Extend lactation Dry off the herd earlier than planned
Changes quantity of input provided or used	Increase cow intakes by increasing milk production targets Reduce cow intakes by reducing the milk production target Increase cow intakes Increase cow intakes by maintaining current rotation length Increase forage crop ration Increase pasture silage ration Increase rotation length Reduce rotation length Sell less culls than planned Dry off less cows than planned Dry off thin cows and place on runoff Retain dry cows on milking area Return dry cows from the runoff to the milking area Place dry cows currently run on the milking area onto the runoff Provide part of the milking area to the young stock Place thin cows on once-a-day milking Do not place the herd back onto twice-a-day milking Place the herd on once-a-day milking Apply additional nitrogenous fertiliser	Increase cow intakes by increasing milk production targets Reduce cow intakes by reducing the milk production target Increase cow intakes Reduce forage crop ration Increase pasture silage ration Reduce pasture silage ration Increase rotation length Reduce rotation length Increase maize silage ration Reduce the maize silage ration
Changes type of input or activity provided or used	Feed 100% hay to dry cows on the milking area Feed cull cows on waste ground until sold Apply nitrogenous fertiliser	Harvest forage crop as silage[14] Apply nitrogenous fertiliser Purchase and feed greenfeed maize Purchase standing maize for maize silage Purchase and feed standing pasture Use winter grazing to extend the lactation[14] Graze off young stock

Differences occurred because, for example, Farmer B used maize silage and Farmer A did not, or Farmer A had access to an adjacent runoff and Farmer B did not. External sourcing of inputs explained several differences in contingency plan use. Farmer B sourced external feed sources to cope with feed deficits, but Farmer A did not. The quantity of input used by the case farmers also influenced contingency plan use. For example, in the dry summer of year three, Farmer A had access to 187 kg DM/cow of supplement, while Farmer B had 872 kg DM/cow available. This meant the dry conditions created limited problems for Farmer B, but Farmer A had to implement some extreme options such as once-a-day milking, and reducing milk production targets to ensure the herd was still milking in late March.

Many of the contingency plans have mirror images, e.g. increase maize silage ration, reduce maize silage ration, retain silage for the spring, use spring silage over summer, graze the forage crop earlier than planned, delay the grazing of the forage crop. The set of contingency plans is not complete and this is demonstrated by the omission of many of the mirror images.

7.4 The control process

The case farmers used a virtually identical control process (Figure 7.4) with the exception that Farmer A did not search for and implement opportunities while Farmer B did. Important performance indicators were monitored as the first step in the control process. Once collected some of the data was formally recorded. Data was then processed, analysed, stored, and then compared to targets. Monitoring continued if targets were not met or exceeded. However, if targets were met or exceeded either the next step in the plan was implemented, or if conditions were different from those predicted, a suitable control response was selected and implemented. If the reason for conditions being different from those predicted was unknown, diagnosis was undertaken before a suitable control response was selected. Farmer B also monitored the external environment for opportunities (external feed sources) and those that were suitable were incorporated into the plan and implemented.

The control process shown in Figure 7.4 primarily relates to the implementation of the plan. A meta-level control process was also used in relation to the tactical management process to evaluate a decision (or series of decisions). The decision was implemented and the outcome of the decision monitored. The outcome was then compared to the expected outcome (a norm, standard, expectation) and evaluated. Diagnosis was used when the case farmers did not know the reasons for an outcome deviating from their expectation. The evaluation process was normally initiated for one of three reasons: (i) an outcome differed from their expectation, normally a result of extreme conditions; (ii) a new management practice or input had been implemented; and (iii) a decision (or decisions) they were not confident of had been implemented.

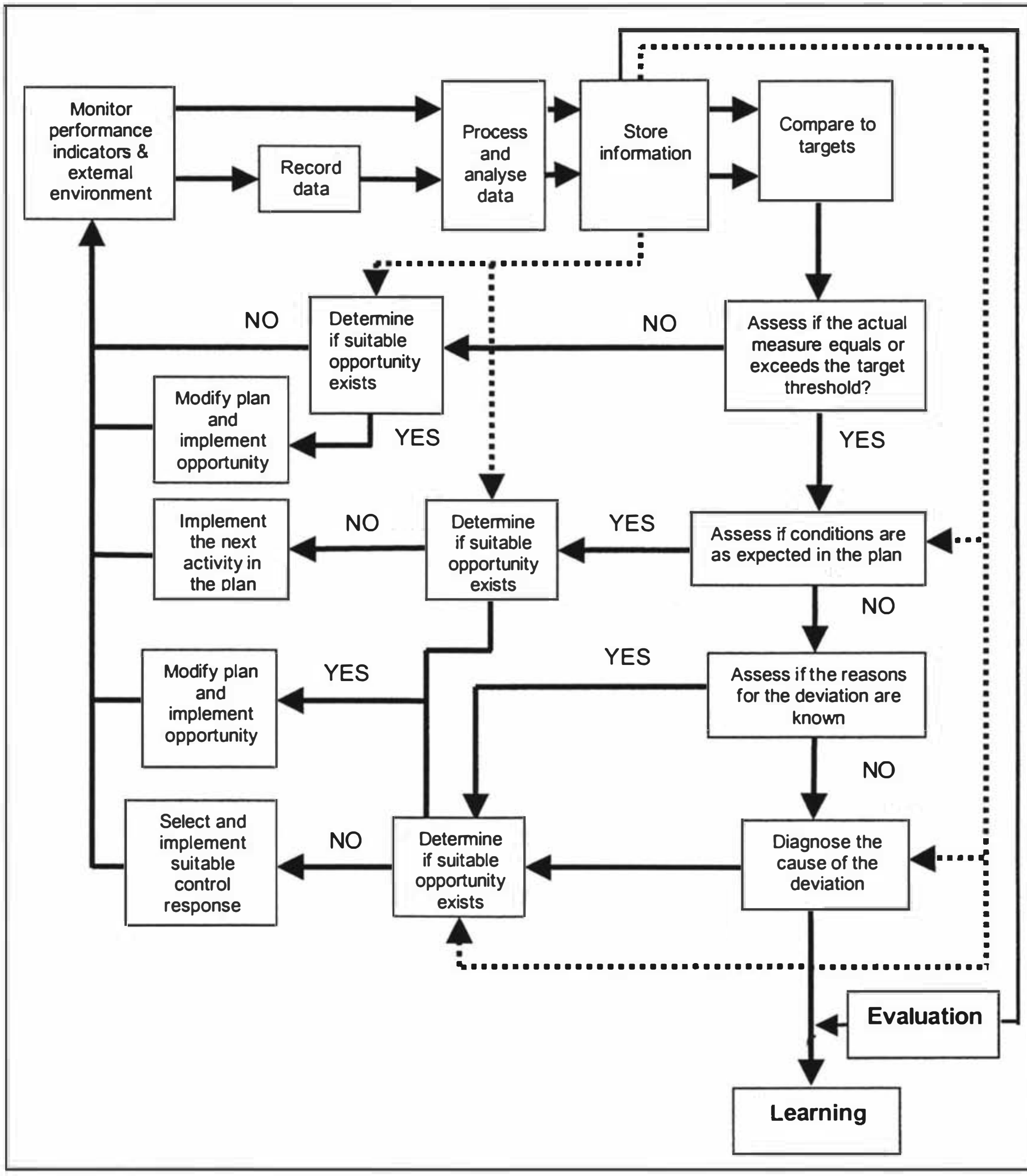

Figure 7.4. The control process used by the case farmers.

The outcome of the evaluation process was learning in relation to the environment, and both their production and management systems. With respect to the management system, five outcomes were possible. First, the efficacy of a new management practice was confirmed and it was retained as part of the case farmers' repertoire. Second, a new management practice was found to be ineffective and discarded. Third, the appropriateness of a decision was confirmed, or fourth, refuted. Fifth, an improvement to a new or existing management practice was postulated from what was learnt during the evaluation process. Although critical to the development of an effective management system, only a limited number of examples of the evaluation process were identified during the study. This may be because the case farmers are experts. The following sections describe the control process in more detail.

7.4.1 Monitoring

Some 28 of the total 41 factors monitored by the case farmers in relation to the tactical management of their milking herd were common. Farmer B monitored 13 factors not monitored by Farmer A. Monitoring factors can be classified under two categories, "production" and "market". Under production two sub-categories were identified: "*feed*" and "*livestock*". Nine of the feed factors were common to both case farmers. However, Farmer A did not monitor six of the feed factors monitored by Farmer B. All of these related to feed inputs used by Farmer B but not by Farmer A. Farmer B also monitored three livestock factors not monitored by Farmer A. Two of these factors, calf and cow liveweight were only monitored once under unusual conditions. The third livestock factor monitored by Farmer B was feed demand per hectare. Farmer A did not use this measure, but rather used a combination of cow intake and pre- and post-grazing residuals to achieve the same end.

In relation to the external environment, both case farmers monitored the same climatic factors. They also monitored the same market information in relation to output prices. However, there was an important difference in the input costs they monitored. Farmer B was developing a high input system and actively sought out external feed sources. In contrast, Farmer A ran a low input system, and the only external feed source information he sought was in relation to urea.

There was little between-year variation in the factors monitored. The majority of these differences were in response to changes in the resources used on the milking area. This was either in response to a strategic change in input use (e.g. the introduction of maize silage), or a tactical decision to purchase an external feed source (e.g. greenfeed maize). Some factors were monitored because of unusual situations. For example, the monitoring of calf and cow liveweight in year two by Farmer B.

The monitoring methods used by the case farmers could be categorised as either objective or subjective. Most were subjective and informal in nature. Only milk production, aspects of milk quality, average pasture cover, pasture growth rates, pre- and post-grazing residuals and cow intake were monitored objectively. Several subjective but quantitative methods were used and these comprised some form of pasture, feed or condition scoring. Monitoring methods for the 28 factors were almost identical. The exceptions were either because of a recent change in the farm situation, or because the case farmers were substituting one method of measurement for another. For example, Farmer B objectively monitored his average pasture cover through the summer to obtain some base-line objective information because the farm had been undergoing a rapid process of development. Substitution of measurement method occurred either due to farmer preference or because of specific conditions in a particular year. For example, Farmer A preferred to use milk volume (litres/cow/day) to monitor milk production whereas Farmer B preferred to use milksolids (MS/cow/day).

A large number of factors were measured indirectly by the case farmers through proxy measures. Their detailed knowledge of the cause-effect relationships within the farming system enabled this. Their mental models of their production systems were virtually identical (Figures 5.2 and 6.2). They also knew that changes in some factors along the causal chain could be identified more quickly than others. Indirect measures enabled the farmers to select the most suitable, accurate and efficient methods for monitoring production. Indirect measures were very similar, the only identified difference being that Farmer A used cow behaviour to indirectly indicate both changes in cow intake and cow condition, and Farmer B did not.

Information played several roles during the control process. These included: determination of decision points, triangulation, determination of control responses, diagnosis and evaluation, prediction of short-term feed position, and planning. Determining the decision points, that is, the point at which a performance indicator equaled or exceeded a target was the most important of these roles. Both case farmers used the monitored information in this capacity to determine when to implement either (i) the next step in the plan, or (ii) a control response. In the latter case, the indicator took on a "problem recognition" role. Only internal information was used for these two processes. One important difference was identified in this area. Farmer B collected external information to identify opportunities in terms of bought-in feed, whereas Farmer A did not, as explained earlier. Information, in this case, took on an opportunity recognition role.

The factors used through the summer-autumn to determine decision recognition points are shown in Table 7.6. All of these indicators can be classified as leading indicators and were used for concurrent control. Seventeen of the 32 indicators listed in Table 7.6 were not common between the case farmers. Seven of these related to Farmer B's high input production system and the use of external feed sources. Several other differences also related to differences in the case farmers' farming systems. Farmer A consistently used rainfall to determine changes in supplement feeding and rotation length. However, Farmer B only used rainfall to adjust supplement feeding once in the three years. He believed that his farm's soil quality factors and higher stocking rate meant dead matter did not build up in the sward and therefore, rainfall did not reduce cow intake as it did on Farmer A's property. Rainfall information was however, used by Farmer B to determine when to apply urea in year two. Similarly, because of his high stocking rate, Farmer B culled by date, whereas Farmer A used average pasture cover to trigger this decision. Farmer B also used indicators (sale of culls) to initiate the extension of the rotation in year one, but this management practice was not used in subsequent years.

Table 7.6. A comparison of the indicators used by the case farmers for decision point recognition.

Key Indicators	Used by Farmer A	Used by Farmer B	Role in decision point recognition
Early Summer			
Average milk production (l/cow/day)	Yes Yes Yes	Yes Yes No	Determines when to feed the forage crop or silage. Determines how much forage crop or silage to feed. Determines when to change grazing rotation.
Pre- and post-grazing residual, cow intakes and climatic data[15]	Yes	Yes	Used to determine when to extend rotation length. Used to indicate whether or not supplements need to be fed and on a daily basis, how much. Indicates when intakes are about to fall below target and the likelihood that intakes will be below target at the next grazing of a paddock in 3 - 5 weeks. May determine when to reduce stocking rate or milk production target.
Forage crop state and yield	Yes	Yes	Determines when to initiate silage feeding.
Forage crop maturity and date (and milk production)	Yes	Yes	May determine initiation of grazing of forage crop.
Rainfall & Average milk production	Yes	No	Determines when to feed additional supplements, change grazing rotation, and remove herd from forage crop (utilisation).
Individual cow condition	Yes	Yes[16]	Determines which cows to put on once-a-day or dry off.
Production index Milking time Somatic cell count Bulling behaviour	Yes	Yes[17]	Used to identify potential cull cows.
Weather forecast	Yes	Yes	Used to predict weather for hay making.
External feed sources	No	Yes	Used to identify external feed sources that can be introduced into the system.

[15] Farmer B also used estimates of pasture growth and feed demand (kg DM/ha/day) for these decisions.
[16] Farmer B, unlike Farmer A does not place his thin cows on once-a-day milking.
[17] Milking time was not used by Farmer B.

Table 7.6 (continued)

Key Indicators	Used by Farmer A	Used by Farmer B	Role in decision point recognition
Late Summer & Early Autumn			
Average milk production (l/cow/day)	Yes	Yes	Determines when to feed the silage. Determines how much silage to feed.
Date and/or quantity of forage crop on-hand.	Yes	Yes	Determines when to feed silage after the forage crop.
Date	Yes	Yes	Determines new grass sowing.
Average herd condition[18]	Yes	No	Determines whether the herd goes on once-a-day milking.
Rainfall & Average milk production	Yes	No[19]	Determines when to feed additional silage and change grazing rotation.
Rainfall	No	Yes	Determines when to apply urea.
Pre- and post-grazing residual, cow intakes and climatic data[15]	Yes	Yes	Used to determine when to extend rotation length. Used to indicate whether or not supplements need to be fed and on a daily basis, how much. Indicates when intakes are about to fall below target and the likelihood that intakes will be below target at the next grazing of a paddock in 3 - 5 weeks. May determine when to reduce stocking rate or initiate silage feeding.[20].
Individual cow condition	Yes	Yes	Determines which cows to put on once-a-day or dry off.
Production index Milking time Somatic cell count Bulling behaviour Pregnancy test	Yes	Yes	Used to identify potential cull cows, and make culling decisions.
External feed sources	No	Yes	Used to identify external feed sources that can be introduced into the system.
Autumn			
Average pasture cover (actual and predicted)	Yes	Yes	Determines drying off date.
Average pasture cover	Yes	No	Determine sale date for culls.
Pasture growth	Yes	No	Determines drying off date.
Post-grazing residual, cow intakes and climatic data[15]	Yes	Yes	Indicates when intakes are about to fall below target and the likelihood that intakes will be below target at the next grazing of a paddock in 3 – 5 weeks. May determine when to reduce stocking rate. Indicates drying off is imminent[21].
Average herd condition	Yes	No	Determines drying off date.
Individual cow condition	Yes	Yes	Determine which cows to put on once-a-day or dry off.
Date	No	Yes	Determine sale date for culls. Partly determined drying off date in year two[22].
The quantity of grass silage on-hand	No	Yes	Indicates when to feed the autumn supplement.
The quantity of autumn supplement on-hand[23]	No	Yes	Used in the assessment of the drying off date.
Maturity of the maize crop[24]	No	Yes	Determines when to harvest the maize crop.
External feed sources	No	Yes	Used to identify external feed sources that can be introduced into the system.
Pasture quality	Yes	Yes	Determines initiation of decisions to maintain pasture quality (increase intake, reduce supplements, extent rotation length, increase stocking rate).
Culling	No	Yes	Determines when to extend the rotation length[25].

18 Only used by Farmer A in year three when conditions were extremely dry.
19 Only used once under extreme conditions to double the silage ration.
20 Farmer A also used it to determine when to return the herd to twice-a-day milking.
21 Also used for supplement feeding decisions by Farmer B.
22 A large proportion of the herd were contracted to be grazed off by a set date.
23 This varied across the years and included cut pasture, maize silage and greenfeed maize. To simplify the table, these have all been placed under the category autumn supplement.
24 A maize crop was only grown on the milking area in year two.
25 Only used in year one.

A third reason for between-farm differences in indicators (3) was that different indicators were used for the same purpose. For example, Farmer A used average herd condition, while Farmer B used individual cow condition, as indicators to control the herd condition score. Similarly, Farmer A used average pasture cover, average herd condition and pasture growth rates to make the drying off decision, whereas Farmer B only used average pasture cover. Few between-year differences in the use of decision point recognition indicators were identified. These tended to occur where there was a change in inputs (maize silage, maize crop, greenfeed maize) or activities (e.g. placing the herd on once-a-day milking).

For both case farmers, the importance of the various decision point recognition indicators changed over the summer-autumn. In a normal year, the primary indicator used for this purpose over the summer was milk production. This was an objective, accurate and daily measure. During autumn, from mid March to early April onwards, average pasture cover became the primary decision point recognition indicator. A change in sward conditions at this time allowed more accurate estimates of average pasture cover and pasture growth to be made than during the summer. A formal feed budget could then be used for planning purposes. Farmer A also used average herd condition and pasture growth rates as important decision point recognition indicators. However, Farmer B did not use pasture growth rates and relied on his individual cow condition rather than average herd condition indicators to protect the condition of the herd. Average pasture cover and average herd condition were critical factors in ensuring the case farmers' targets for planned start of calving were met. In contrast, milk production was treated as a variable that could be adjusted to ensure these targets were met.

An important aspect in the determination of the decision point and problem recognition was ensuring that the factor was measured with sufficient accuracy. Many of the factors monitored by the case farmers were used to triangulate the measures used for decision point recognition. Triangulation was facilitated through their knowledge of cause and effect relationships within the system. They could (i) predict effects further along the causal chain, and (ii), use effects that occurred later in the chain to confirm changes in antecedent factors. The case farmers used three methods (early warning, short-term predictor, and confirmatory measures) to triangulate the monitoring measures. First, direct, subjective and qualitative measures were used to identify a change in a factor before it was monitored more formally[26], a form of "*early warning*". For example, a change

[26] This was either an objective, or a subjective quantitative method.

in average pasture cover could be assessed visually before it was monitored using the falling plate meter. Second, the case farmers would monitor an indirect measure of the factor of interest and then use their knowledge of cause and effect relationships to predict the value at the next monitoring: a "*short-term predictor*". For example, the measurement of intake was used to predict subsequent milk production and cow condition.

Thirdly, decision point recognition indicators were triangulated through the use of other "*confirmatory*" measures. For example, milk production per cow per day and changes in cow condition were used to confirm the veracity of cow intake and pre-and post-grazing residual measures. The triangulation process ensured reliable information was used for decision point recognition. It also tested the validity of the case farmers' monitoring systems and production system models. Central to this process was the role of objective measurement. Because the case farmers used so many subjective measures, it was important that these were calibrated to ensure acceptable accuracy. Milk production over the summer, and milk production and average pasture cover over the autumn, were used to calibrate subjective measures.

The information the case farmers monitored was also used for control response selection once a decision point was recognised. Here, situation specific information was used in conjunction with heuristics to determine whether to continue to implement the existing plan, or implement an alternative control response. This will be discussed in more detail in Section 7.4.5.

Monitoring information was used for diagnosis and evaluation. Few lagging indicators, used for historical control, were identified during the study. One example, the empty rate, (the ratio of the number of empty cows divided by the number of cows mated) was used to evaluate reproductive management. This knowledge was then used to refine the subsequent season's reproductive management. The other important lagging indicator was milk production which, as explained earlier, was used in a triangulation role for pasture, crop and silage yields. Yield estimates were then adjusted as required.

Pasture growth rate data in combination with climatic data was used to predict pasture growth rates two to four weeks in advance. Farmer B, unlike Farmer A, also monitored feed demand (kg DM/ha/day) and used this information in combination with pasture growth rate forecasts to predict the likely future feed position of the farm. Both case farmers used information about the current climatic conditions and pasture growth rates, and post-grazing residuals to estimate the likely intake of the herd three to five weeks into the future. These methods provided the case farmers with quick and simple means of forecasting their feed position and provided up to a month's forewarning of any potential feed deficits. Thus, plans could be reviewed and possible control responses considered well in advance of a potential problem. Finally, monitoring information was used for planning. Information was collected just prior to the start of a planning period on the farm feed situation and state of the livestock.

7.4.2 Activation, termination and frequency of monitoring

Both case farmers limited the effort expended on monitoring by using decision rules to activate, terminate and change the frequency of monitoring. The activation (and termination) of the monitoring of a given factor was initiated by both case farmers due to one of five reasons: the occurrence of (i) an event, or (ii), a benchmark date, (iii) the value for the factor exceeded a threshold, (iv), an indirect measure of the factor exceeded a threshold, and (v) information was needed for planning. The point at which a threshold was reached was dependent on the state of the farm. In years when the farm was in a poor state, thresholds were exceeded at an earlier date than in good years. Similarly, if the dates at which events occurred changed between years, the associated activation and termination dates would change. The timing of events and farm state explained most of the between-farmer differences in activation and termination dates. Some information was also monitored for planning purposes, such as average pasture cover for feed budgeting in early autumn.

Farmer B also used the rate of change in the factor, or an indirect measure of it, to activate or terminate the monitoring process, a process not used by Farmer A. For example, a decline in milk production at a rate equal to or greater than 0.061 kg MS/cow/day indicated the younger cows in the herd were losing condition and monitoring was initiated. Similarly, as in year three, when in mid March average pasture cover was high and increasing, objective pasture monitoring was delayed until April 6th.

The frequency with which factors were monitored was almost identical for the two case farmers. Most factors were monitored on a daily basis as they went about their routine farm work. A slightly longer monitoring interval was used for pre- and post-grazing residuals and cow intake because they did not change very rapidly. Farmer A normally used a two to five day interval, but like Farmer B, this was dependent on the rate of change in these factors. The objective measurement of average pasture cover and pasture growth rate was normally monitored at 10-day intervals by Farmer A and 14-day intervals by Farmer B. Farmer A believed that a 10-day interval was appropriate given the rate of change in pasture growth rates at this time of year. He also believed that a monitoring interval of no less than five days should be used to avoid error problems related to measurement. In contrast, Farmer B used a standard monitoring interval of 14 days. Some factors were only monitored once or at intervals of around two months (pregnancy and herd testing).

The case farmers adjusted the frequency with which some factors were monitored. Both case farmers only monitored milk production, pre- and post-grazing residuals and cow intake when they changed significantly. Farmer A also adjusted the monitoring interval for the objective measurement of average pasture cover and pasture growth rate in response to the rate of change in these factors and the approach of a critical decision such as drying off. When feed conditions were good, he would use a longer monitoring interval (up to 13 days), but if conditions were deteriorating rapidly, or the drying off decision was imminent, then the monitoring interval was reduced to five days. In contrast, Farmer B either objectively monitored average pasture cover and pasture growth rates at 14 day intervals as in year one, or as a result of excessive workload (year two), or, if feed conditions were good, and improving, (year three), he would cease monitoring altogether until such information was required for plan revision. In the latter two cases, Farmer B used his subjective and indirect measures of average pasture cover and pasture growth rate to control the implementation of the plan.

The case farmers' monitoring systems were low cost in terms of time. Most factors were monitored as the farmers went about their daily farming routines. The use of activation, termination and monitoring frequency decision rules further reduced the time cost associated with monitoring. The most time-costly monitoring process was the objective measurement of average pasture cover and pasture growth rate which required two to three hours to complete. Given that most factors were monitored on a daily basis and a triangulation process was used, the case farmers had a timely and sufficiently accurate monitoring system. There was a large difference in the capital costs associated with the case farmers' monitoring systems. Farmer A had minimal capital tied up in monitoring with the only measuring device being hand-made from waste material. In contrast, Farmer B had several thousand dollars invested in a falling plate meter, electronic scales, a computer and associated software.

7.4.3 Recording and data analysis

The case farmers used similar data recording and analysis techniques. Much of the information the case farmers collected was stored mentally. The farm diary acted as the other primary storage facility including information about key events, dates, pasture cover and pasture growth rates, mating and rainfall data. It provided an historical record of the season, could be referred back to for diagnostic or evaluation purposes, or to check what had been done in previous seasons. Milk production data provided by the company was stored in folders. Farmer B used the software program "*Dairyman*" to store herd records (reproductive performance, milk production, animal health). This information could be retrieved and analysed to identify potential culls and to rank individual cows. He also used a spreadsheet to store pasture cover and pasture growth rate records.

Limited data analysis was undertaken by the case farmers. Most data was not analysed in any way, being subjective in nature. However, both case farmers calculated simple means for average pasture cover, average pasture growth rates, milk production per cow, and intake per cow. They also predicted pasture growth rates over the next three to four weeks on the basis of current pasture growth rates and climatic conditions to calculate cow intake, or indicate the likely future feed position on the farm. Farmer B also calculated per hectare feed demand for the same purpose. These calculations were either undertaken mentally or with the aid of a calculator. Farmer B used a spreadsheet program to calculate average pasture cover and average pasture growth rates. Both farmers used the same recording and analysis techniques over the three years. The main difference between farms was Farmer B's use of a computer and Farmer A's reliance on a farm diary and a set of folders.

7.4.4 The environment

The major herd management risk over the summer-autumn was variation in climate, which in turn dictated pasture growth rates, the primary feed source. The level of variation in pasture growth rates over the period of the study for the two case farms is shown in Table 7.7. Variation in feed supply in turn causes variation in milk production. During the three years of the study, milk production ranged from 270 kg MS/cow and 745 kg MS/ha to 334 kg MS/cow and 1015 kg MS/ha on Farm A and from 249 kg MS/cow and 789 kg MS/ha to 326 kg MS/cow and 1035 kg MS/ha on Farm B. Pasture provided some 80 – 90% of the Farmer A's feed over the summer-autumn. However, the proportion of feed supplied by pasture on Farm B declined from 80% in year one to 63% in year three as Farmer B changed from a low to a high input system. As such, by year three, Farmer B's exposure to risk from variable pasture growth rates had declined relative to Farmer A. This is demonstrated by the ease with which Farmer B managed through the dry summer of year three relative to Farmer A. Despite this, climate remained the primary source of risk over the summer-autumn for both farmers. Risk from pests and diseases was rated as low by both farmers because preventative procedures were used to control these including the two most debilitating animal health problems at that time of year, bloat and facial eczema.

Table 7.7. A comparison of the variability in pasture growth rates (kg DM/ha/day) on the case farms over the three years of the study.

	Farmer A				Farmer B			
	Year 1	Year 2	Year 3	Mean	Year 1	Year 2	Year 3	Mean
January	28	35	17	26.7	44	24	25	31.0
February	24	8	13	15.0	32	25	8	21.7
March	33	19	28	26.7	37	24	45	35.3
April	23	25	41	29.7	44	30	62	45.3
Total (kg DM/ha)	3253	2648	2989	2963	4727	3088	4254	4023

During the summer-autumn, other sources of risk (market, human, social and legal, technological, inter-firm competition, and financial) had little or no influence the production decisions made by the case farmers (Table 7.8). Market risk was low because by early summer, the season's milk price was known with reasonable certainty because the dairy company update their final price forecasts in February. The farmers made few marketing decisions that would impact on milk production. However, marketing decisions could be made in relation to the sale of cull cows, the other source of output price risk. Such prices can vary considerably during the summer-autumn, but cull cow sales over this period only make up a small proportion of total income (< 10%). In most instances, production decisions over-rode any concern about market risk in relation to cull cow sales. In year two however, Farmer B sold some in-calf cull cows earlier than planned because the market was declining due to over-supply.

Input price risk was low because of the short (five month) time frame and the relatively low rate of inflation (< 3%) occurring at the time (Burtt, 2000). An exception to this was the price of bought-in feeds. This was dependent on supply and demand, which in turn was a function of the nature of the summer-autumn (dry, normal, wet). Farmer A did not buy-in feed, but Farmer B did. However, where possible, Farmer B contracted the purchase of bought-in feed. If the cost of non-contracted feed was too high during the summer-autumn, it was not purchased. Overall, market risk was low for both farmers with Farmer B having slightly higher exposure because of his use of bought-in feed.

Table 7.8. Subjective classification of the risks facing the case farmers over the summer-autumn period.

Risk source	Farmer A	Farmer B
Production	High	High
Climate	High	High
Pests and disease	Low	Low
Market	Low	Low
Output prices	Low	Low
Input prices	Low	Low
Human	Low	Low
Technological	Low	Low
Social and legal	Low	Low
Competitors	Low	Low
Financial	Low	Low

Both farmers rated human risk as low for the summer-autumn. Farmer A had slightly lower exposure to human risk because he did not employ labour, whereas Farmer B did. However Farmer B believed that with his intensive monitoring system, poor decision-making by his labour unit would have a minimal impact on summer-autumn production. Because of their owner/operator status, the case farmers' greatest risk was from personal injury or disability. During the three years, there were no recorded instances of legal and social, technological or inter-firm competition sources of risk influencing the case farmers' decision-making in relation to production management.

Financial risk was also classified as low because both case farmers had reasonable equity (≥ 60%), access to over-draft facilities, and achieved high levels of production with good cost control. Quarterly variation in interest rates was minimal. Farmer B had lower equity than Farmer A and did mention that his cash flow situation might influence production decisions over the summer-autumn. Liquidity was not found to influence production decisions.

7.4.5 Control responses

The types of control responses used by the case farmers are shown in Table 7.9. Both case farmers used preliminary control responses to prevent animal health problems and forage crops and silage were fed when pasture growth was most variable. Concurrent control was by far the most common type of control response. Neither case farmer used elimination of disturbances control responses. However, some examples of historical control were identified, the number of which was dependent on the amount of learning that occurred in any one year.

Table 7.9. A comparison of the control responses used by the case farmers.

Control Response	Farmer A	Farmer B
Preliminary	Yes	Yes
Concurrent	Yes	Yes
Elimination of disturbances	No	No
Historical	Yes	Yes

The range of concurrent control responses used by the case farmers is shown in Table 7.10. Both case farmers adjusted implementation as a control response. Their primary concurrent control response however, was to modify the current plan. Four common plan modification methods were used for concurrent control: introduction of an existing contingency plan; the development and implementation of a new contingency plan; removal of an activity or input, and changing targets. The main method of plan modification was through existing contingency plans. Changing targets was used by both case farmers in each of the three years, and when applied, had a significant impact on the farming system. Farmer B used two plan modification methods not adopted by Farmer A: changing the planning horizon and introducing opportunities into the plan. However, these methods were only rarely used.

Neither case farmer changed their goals in response to a deviation from the original plan. However, both case farmers changed their plans in year one. Farmer A changed his summer plan because of above average feed conditions and a belief that a change in climate had occurred. Farmer B changed his autumn plan in year one because 20% of his herd was found to be empty and he milked 15 of these cows on a neighbour's farm over winter to ensure sufficient numbers for the spring. He also changed the number of cows he culled on production and had to purchase in-calf cows over the winter. Farmer A did adjust his monitoring system and recalibrated his pasture yield estimation during a period of unusual summer growing conditions. However, Farmer B did not adjust his monitoring system. Although no examples of the case farmers introducing a new monitoring method as a concurrent control response over the summer-autumn were identified, Farmer B began weighing the herd when their condition fell to 3.8 condition score units in the poor spring of year one.

Table 7.10. A comparison of the nature of the concurrent control responses used by the case farmers.

Type of response	Farmer A	Role	Farmer B	Role
Concurrent control				
Adjust implementation	Yes	Minor	Yes	Minor
Modify plan				
Change planning horizon	No	None	Yes	Minor
Introduce existing contingency plan	Yes	Major	Yes	Major
Develop & introduce new contingency plan	Yes	Minor	Yes	Minor
Introduce opportunity	No	None	Yes	Minor
Remove activity or input	Yes	Minor	Yes	Minor
Change targets	Yes	Moderate	Yes	Minor
Develop a new plan	Yes	Minor	Yes	Minor
Change goals	No	None	No	None
Adjust monitoring system				
Recalibrate monitoring system	Yes	Minor	No	None
Introduce new monitoring method	No	None	No	None
Historical control				
Implement new forms of preliminary control	Yes	Minor	Yes	Minor
Implement new forms of elimination of disturbances control responses	No	None	No	None
Refine existing plan				
Introduce new input or activity	No	None	Yes	Minor
Remove input or activity	Yes	Minor	Yes	Minor
Change targets	Yes	Minor	Yes	Minor
Implement new forms of concurrent control				
Introduce new contingency plan	Yes	Minor	Yes	Minor
Remove existing contingency plan	Yes	Minor	No	None
Modify monitoring system				
Recalibrate monitoring system	No	None	No	None
Introduce new calibration rules[27]	Yes	Minor	Yes	Minor
Introduce new monitoring method	No	None	No	None
Change goals	No	None	No	None

The other form of control used by the case farmers was historical control (Table 7.10). Four of the six forms of historical control were used over the three years of the study. They did not implement new forms of "elimination of disturbances" control responses, and nor did they change their goals for the summer-autumn. They did however, implement new forms of preliminary control, refine existing plans, implement new forms of concurrent control and modify their monitoring systems. In relation to refining an existing plan, three control responses were identified: introducing a new input or activity, removing a new input or activity, and changing targets. Both case farmers used the latter two responses, but only Farmer B introduced new inputs or activities. In relation to forms of concurrent control, the case farmers could either introduce a new contingency plan or remove an existing one. Farmer A did both but Farmer B only introduced new contingency plans, he did not remove any. The case farmers made few modifications to their monitoring system over the three years. They did not recalibrate their monitoring system, and nor did they introduce new methods as a result of deviations from the plan in the previous decision-

[27] Includes recalibration rules for pasture, silage and forage crop estimation.

making cycle. They did however introduce new calibration rules for unusual situations or new crops and supplements[28].

7.4.5.1 Control response selection

The process used by both case farmers for choosing a control response can best be represented by a set of decision rules (Figure 7.5). These took the form of an "IF" statement that specifies the conditions that indicate a decision point; then normally several "AND" statements that specify important characteristics of the farm state that define the problem situation; followed by a "THEN" statement which specifies the control response that should be instigated if those conditions exist. The problem situation characteristics played two important roles. First, they determined if the current plan was continued or if a control response was required. Second, if a control response was required, they determined the exact nature of that response. In other words, the problem situation characteristics were matched to a problem solution.

IF indicator equals or exceeds target,	) Identifies decision point
AND farm state for factor A = X,	)
AND farm state for factor B = Y,	) Determines nature of response
AND farm state for factor n = Z	)
THEN control response = Ω	) Specifies the response

Figure 7.5. Control response selection process.

However, not all contingency plans were selected using the process shown in Figure 7.5. In a few instances[29], a form of *ex-ante* evaluation was used by the case farmers to determine what contingency plan to implement. This process was initiated when feed conditions deviated from expectations. In each instance, the current plan was compared against one or more alternatives. However, in only one of the five recorded instances, was more than one alternative considered. In this instance, Farmer B screened the alternatives until only one option remained. The case farmers simulated the two options (current plan versus alternative) for the conditions they expected to encounter over the next period. The simulated outcomes were compared, and the decision with the best forecasted outcome chosen. In one instance, Farmer B used a planning aid (feed budget) rather than a mental simulation to analyse the impact of modifying the plan. This analysis

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[28] In one case it was the way of making the silage that changed the calibration. Silage made in a pit has a higher density than that made on the surface and covered.

[29] This process was only recorded twice for Farmer A and three times for Farmer B.

was undertaken at the point when the feed budget was normally revised, and as such, it was a relatively simple process to compare the two decisions[30].

Non-financial criteria were used in all but one instance to decide between an alternative and the current plan (Table 7.11). In this instance the case farmer used, what was in effect, a partial budget, to estimate the net financial advantage. Although not used for contingency plan selection during the study, both case farmers mentioned using formal partial budgets in the past to analyse alternatives. Similarly, they reported that such analyses were undertaken at their local discussion group meetings. These formal analyses provided guidelines for future decision-making (provided costs and prices did not change significantly) and reduced the need to undertake additional formal analyses.

Table 7.11. The criteria used by the case farmers to decide between an alternative and the current plan.

Analysis	Criteria
Farmer A	
Feed spring silage over summer versus retain silage for the spring as planned.	The herd is in a lactating state when the autumn rains arrive.
Reduce the milk production target versus maintain the milk production target as planned.	The herd is in a lactating state when the autumn rains arrive.
Farmer B	
Feed bought-in greenfeed maize or dry off additional cows as planned.	Net financial advantage.
Feed maize silage early versus feed maize silage at the planned date.	Effect on milk production, condition score, intake, pre- and post-grazing residuals, pasture growth.
Not apply nitrogen in early spring versus apply nitrogen in the early spring as planned.	Spring average pasture cover targets are met.

The most common form of control response was the modification of the plan through the implementation of a contingency plan. The case farmers considered some 48 contingency plans[31] over the three years, of which 43 were implemented. Only 11 of the 43 options were common to both (Table 7.4). However, some options were variations of another. For example, delaying the use of an option (e.g. culling) had a similar impact to using less of the same option (culling fewer cows). Several factors were identified which accounted for differences in the contingency plans used over the three years. These included: farmer attitude (or values) and strategic choices that determined the resources and activities in the plan, the nature of the summer ("dry", "typical", "wet") plan, the state of the farm at the start of the planning period, and the conditions over the planning period.

[30] In this case, the comparison was between applying nitrogen and not applying it.
[31] In this instance, adjusting targets and introducing external opportunities are included as types of contingency plans.

As would be expected, interaction between these factors determined the actual choice of contingency plans.

Strategic choices that determined the resources and activities in the plan directly influenced the contingency plans used by the case farmers. Their attitude towards intensification, which in turn dictated many of the contingencies that could be used, explained most of the between-farm differences. As such, Farmer A's plan did not encompass the use of higher cost feeds such as maize silage, and grazing[32], and nor did it include the level of supplementation used by Farmer B. In a dry year, without these inputs, Farmer A had to rely on other contingency plans such as placing the herd on once-a-day milking. Farmer attitude towards intensification also influenced the use of external feed sources. As such, only Farmer B actively sought to procure external feed sources to better cope with dry climatic conditions (Table 7.4).

Differences in strategic decisions not related to intensification also explained cross-case differences in contingency plan use. For example, Farmer A had made a strategic decision to buy a runoff adjacent to the property for raising replacement stock, while Farmer B instead purchased grazing[33]. This provided Farmer A with contingencies not available to Farmer B. It also meant that when Farmer B made a strategic decision to graze his replacement stock on the milking area in year two, contingency plans relating to this stock class were related to the milking area (i.e. they became a potential competitor with the milking herd).

The nature of the case farmers' summer plan ("dry", "typical", "wet") influenced the type and number of contingency plans used (Figure 7.12). The match between planned and actual conditions determined the number of contingency plans used. Plans were modified to cope with likely future conditions ("dry", "wet"), often incorporating what, in a typical year, were contingencies, as events or activities in the plan. In situations where the summer conditions were correctly predicted, fewer contingency plans were used.

[32] One exception to this rule was that Farmer A began using urea during the study period.
[33] Farmer B leased a runoff in year three, but it was some distance from his milking area.

Table 7.12. A comparison of the contingency plans used by the case farmers to minimise the impact of feed deficit and feed surplus situations over the three years.

	Year 1		Year 2		Year 3	
	Farmer A	**Farmer B**	**Farmer A**	**Farmer B**	**Farmer A**	**Farmer B**
Type of year						
Summer Autumn	Wet Typical	Wet Good	Dry Dry	Dry Dry	Very dry Good	Very dry Exceptional
Position at start of summer	Good	Good	Good	Poor	Poor	Very good
Summer plan used	Typical	Typical	Wet	Dry	Dry	Dry
Category						
Feed deficit responses						
Increase feed supply	Reduce rotation length	Increase pasture silage ration[34]	Reduce rotation length Use winter, early spring silage over the summer-autumn and replace later Provide part of the milking area to the young stock[35]	Apply urea Purchase and feed greenfeed maize Purchase standing maize for maize silage Purchase and feed standing pasture	Feed 100% hay to dry cows on the milking area Apply additional nitrogenous fertiliser	Reduce rotation length Graze the forage crop earlier than planned Increase pasture silage ration Extend feeding period for pasture silage Increase maize silage ration
Number	1	1	3	4	2	5
Decrease feed demand	Feed cull cows on waste ground until sold	Dry off the herd earlier than planned[36]	Reduce cow intakes by reducing the milk production target Dry off thin cows earlier than planned	Graze off young stock Reduce milk production target and associated cow intakes Dry off thin cows earlier than planned Reduce forage crop ration[37] Dry off the herd earlier than planned[38]	Reduce cow intakes by further reducing the milk production target[39] Feed cull cows on waste ground until sold Do not place the herd back onto twice-a-day milking Place dry cows currently run on the milking area onto the runoff Retain dry cows on the milking area[40]	Sell cull cows earlier than planned
Number	1	1	2	5	5	1
Sub-total	2	2	5	9	7	6

[34] Introduced because cold, windy conditions increased cow maintenance requirements.
[35] This option was used to increase feed supply on the replacement stock's area. It was used because the feed deficit on this block was greater than that on the milking area and the young stock had priority over older stock.
[36] Conditions turned cool in May and the herd had to be dried off a week before the target date predicted in the feed budget.
[37] This is actually a feed deficit response because Farmer B wanted to extend the use of the forage crop into March to ensure as many cows as possible were still in a milking state by mid March.
[38] The herd was dried off 14 days earlier than planned in the feed budget (as opposed to the plan developed at the start of January) because the case farmer had to send them away to grazing at the end of May.
[39] Farmer A had reduced the milk production target to 10 litres/cow/day or 0.87 kg MS/cow/day in the summer plan. As a contingency to reduce cow intakes further, he reduced this target to 7.5 litres/cow/day or 0.70 kg MS/cow/day in February.
[40] Used to reduce feed demand on the runoff where feed was short. Farmer A had originally planned to run 30 dry cows on the runoff, but the dry conditions prevented this.

Table 7.12 (continued)

	Year 1		Year 2		Year 3	
	Farmer A	**Farmer B**	**Farmer A**	**Farmer B**	**Farmer A**	**Farmer B**
Feed surplus responses						
Reduce feed supply	Retain autumn silage for the spring					Reduce pasture silage ration Extend rotation length Reduce the maize silage ration
Number	1	0	0	0	0	3
Increase feed demand	Increase cow intakes by increasing the milk production target Extend the lactation[41]	Increase cow intakes by increasing the milk production target[42] Delay drying off thin cows[43]	Increase cow intakes by increasing the milk production target		Increase cow intakes Delay placing herd on once-a-day milking Delay drying off thin cows Return dry cows from the runoff to the milking area Extend the lactation	Increase cow intakes Delay drying off of thin cows Extend the lactation
Number	2	2	1	0	5	3
Sub-total	3	2	1	1	5	6
Grand Total	5	4	6	9	12	12

The final and most important factor that determined differences between the case farmers' use of contingency plans was the state of the farm at the start of, and the conditions during, the planning period. This is best demonstrated using Table 7.12 which shows the farmers' contingency plans used for manipulating feed supply and demand across the three years. Year one is similar for both case farmers in that the farm state was good at the start of summer, they both used a "typical" plan and both experienced a wet summer, although conditions on Farm B were better over the autumn than Farm A. Options to counter feed surplus conditions, therefore had a relatively minor impact on the plan. The main contingency plan used by both farmers was to increase cow intake to achieve the increased milk production target. The "typical" plan was demonstrated to be robust under good conditions, that is, few contingency plans were required. Importantly however, growing conditions never reached the point where pasture quality became a problem.

Year two demonstrates the effect of farm state on contingency plan use. Farm B was in a poor state while Farm A was in a good state at the start of the summer. Summer-autumn was dry and Farmer B used nine contingency plans relative to Farmer A's five, to cope

[41] The feed budget in early April estimated a drying off date of 30th April. This was 15 days later than the typical date of mid April.
[42] This was used to take advantage of the good growing conditions over February.
[43] These were expected to be dried off in early April, but were still in good condition at that point, so were milked until late April.

with the feed deficit conditions. Year three, in which both farms experienced a very dry summer followed by good to exceptional autumn conditions, provided another interesting contrast in tactical management. The majority of options used by Farmer A were designed to reduce feed demand because he had a small quantity of supplement on-hand. In contrast, most of those used by Farmer B were designed to increase feed supply because he had a large quantity of supplement available.

The switch in seasonal conditions from a very dry summer to an extremely good autumn explains the greater variety and number of contingency plans used in year three. Having introduced options to cope with a feed deficit, the case farmers then had to introduce options to cope with feed surplus conditions (Table 7.12). Fewer contingency plans were required to manage a wet versus dry summer. This was because a summer "surplus" feed situation could be managed simply by increasing milk production targets (Table 7.12). A greater range of options had to be implemented to manage a dry year. As would be expected, the more extreme the conditions and the worse the farm state, the greater the use of contingency plans by management.

7.4.5.2 Target selection

One type of contingency plan resulted in a change in the intermediate milk production targets used by the case farmers. This relatively simple change had a significant impact on the farming system since the case farmers had also to change the cow intake and post-grazing residual targets. As a result, the herd consumed feed at a faster or slower rate, therefore changing the rate and timing at which resources were used. Targets were also changed as an historical control response designed to improve system performance. Several such changes were made by each case farmer over the three years of the study. Farmer B increased his targets for cow condition at calving and average pasture cover for calving and balance date to improve both per cow milk production and reproductive performance. Farmer A introduced higher milk production targets for a wet summer, and then decided after his experience in year two that the risk associated with such targets was too great.

7.4.5.3 Opportunity selection

An important difference in the nature of the contingency plans used by the two case farmers was identified. In a year when feed supply was most limiting, Farmer B actively sought out and utilised "opportunistic" contingency plans, an approach not adopted by Farmer A. Farmer B actively searched for external sources of feed that could be procured to improve system performance and reduce climatic risk. Farmer B therefore had more options to cope with variety in the environment. He only actively sought off-farm feed sources if conditions for pasture growth and/or the level of supplement on-hand was below average.

To identify an opportunity (external feed source), Farmer B collected information about feed type, quality, price, and locality (Figure 7.6). This information was processed and analysed, and the price for the feed source converted to a common unit, usually cents per kilogram of dry matter. The calculated feed cost and other information was compared to pre-set criteria. If it matched, Farmer B then decided whether he wanted to take advantage of the opportunity. In most cases this was a simple decision to proceed. However, in one instance, three opportunities were compared and the unsuitable options screened out. The remaining option was then compared with another internal alternative on the basis of profitability. An opportunity could be adopted at any one of the following points: (i) during the implementation of an activity, (ii) at the next decision point where it replaced the next planned activity, or (iii) if a problem was identified, it then replaced a control response.

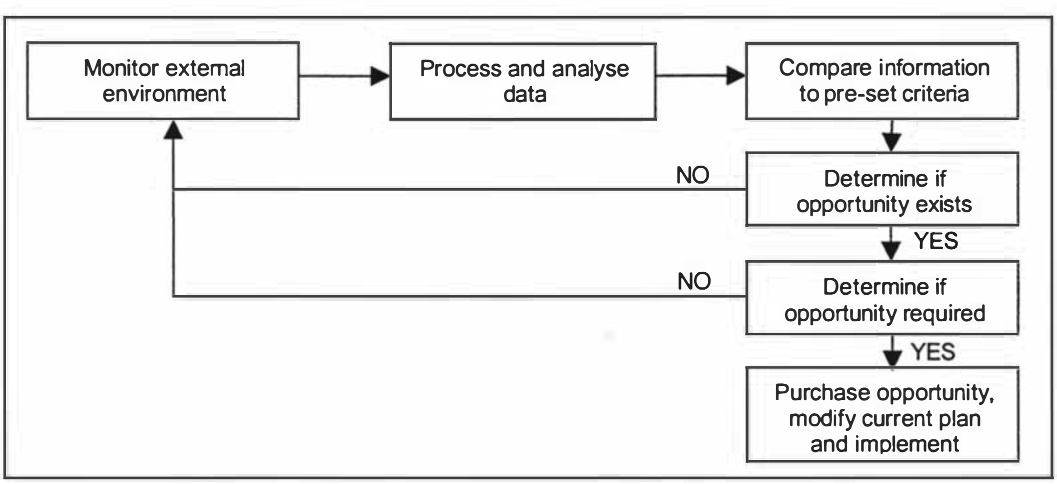


Figure 7.6. The opportunity recognition and selection process.

7.4.6 Evaluation

Two forms of evaluation were used by the case farmers, diagnosis and *ex-post* evaluation. Diagnosis was used rarely when an outcome differed significantly from the case farmers' expectations (Table 7.13). These expectations were developed from monitored information and the case farmers' detailed knowledge of cause and effect relationships within the production system. An outcome might deviate from the plan, but because the case farmers expected this, no diagnosis was undertaken. Thus, limited diagnosis was undertaken by the farmers during the study and only when one of four conditions, or some combination of them, occurred. First, conditions were unusual or extreme; second, a new management practice was used; third, the monitoring system provided inaccurate information (often due to unusual conditions); and finally, in the case of Farmer B[44], his labour unit implemented a plan incorrectly. In the first and second situations, the case farmers had insufficient knowledge to accurately develop an expectation. Similarly, if their monitoring systems were inaccurate, and this occurred under unusual conditions, they had poor information upon which to base their expectations. In the fourth instance, Farmer B's expectations were incorrect because the actions of his farm worker had not turned out as he had expected.

Table 7.13. The evaluations carried out by the case farmers.

Category and instance	Farmer A	Farmer B
Planning		
Planning Decisions		
Use of inputs		
The timing of feeding Japanese millet		*Ex-post* evaluation
The use of maize silage		*Ex-post* evaluation
Grazing the calves off-farm		*Ex-post* evaluation
Grazing the calves on the milking area		*Ex-post* evaluation
Level of supplement on-hand in the previous spring		*Ex-post* evaluation
New forage crop variety	*Ex-post* evaluation	*Ex-post* evaluation
Practice of using cow condition as a supplement over summer		*Ex-post* evaluation
Delay grazing forage crop until March 1st and sow new grass later than normal		*Ex-post* evaluation
Planting an additional paddock of forage crop	*Ex-post* evaluation	
Management practices		
The use of ultrasound to identify empty cows early	*Ex-post* evaluation	
The decision to go onto once-a-day milking	*Ex-post* evaluation	
Choice of targets		
Choice of condition score target at calving		Diagnosis
Decision to increase milk production target	*Ex-post* evaluation	

[44] Farmer A did not employ labour.

Table 7.13 (continued)

Category and instance	Farmer A	Farmer B
Planning assumptions		
Feed input decisions		
Validity of pasture growth rate assumptions[45]		*Ex-post* evaluation
Implementation		
The level of supplement feeding and forage crop & grazing area allocation[45]	*Ex-post* evaluation	*Ex-post* evaluation
Allocation of grazing area		Diagnosis
Method of feeding maize silage		*Ex-post* evaluation
Control		
Control decisions		
Contingency plan selection		
Use of inputs		
Quantity of supplement made in the spring		*Ex-post* evaluation
Grazing the calves off the milking area on higher quality land		*Ex-post* evaluation
Use of urea in March		*Ex-post* evaluation
The use of cut pasture		*Ex-post* evaluation
Doubling silage ration after significant rainfall		*Ex-post* evaluation
Management practices		
Sale of cull cows at planned date		*Ex-post* evaluation
Drying off thin cows as planned		*Ex-post* evaluation
The decision to dry off the herd at a specific date	*Ex-post* evaluation	
Choice of targets		
Decision to increase milk production target	*Ex-post* evaluation	
Monitoring system		
Accuracy of monitoring		
Calibration of various measures[45]	*Ex-post* evaluation	*Ex-post* evaluation
Accuracy of silage yield estimates		Diagnosis
Pasture scoring	Diagnosis	
Forage crop yield and break size estimate	*Ex-post* evaluation	
Number of empty cows	Diagnosis	
Number of cows mated to the bull	Diagnosis	
The use of ultrasound to identify empty cows early	*Ex-post* evaluation	
Timeliness of monitoring		
Date cow liveweight monitoring was initiated in the spring		*Ex-post* evaluation
Initiation date of objective pasture measurement	*Ex-post* evaluation	
Monitoring interval of objective pasture measurement	*Ex-post* evaluation	
Accuracy of predictions		
Comparison of short-term predictions with actual pasture growth rates[45]	*Ex-post* evaluation	*Ex-post* evaluation
Overall management of a period		
Summer plan	*Ex-post* evaluation	*Ex-post* evaluation
Summer control	*Ex-post* evaluation	*Ex-post* evaluation
Systems performance		
Livestock		
Reproductive performance	Diagnosis (2)	Diagnosis
Milk production		Diagnosis (4)
Liveweight of replacement stock		*Ex-post* evaluation
Forage		
Pasture growth rates		Diagnosis
Forage crop yield	Diagnosis	*Ex-post* evaluation
General farm productivity		Diagnosis

Both case farmers used the same diagnostic process. A set of hypotheses were developed about possible causes of deviations. If their system models were inadequate for this process, both consulted their peers or a local expert (veterinarian, consultant,

[45] On-going evaluation.

stock and station agent, contractor, university academic) and then using this additional information, developed a set of hypotheses about possible causes. Farmer B tended to use a greater range of experts than Farmer A. The most likely hypothesis was selected and tested using data retrieved from memory or the farm recording system. If the test proved negative, the process was repeated with the next most likely hypothesis until the cause was eventually identified.

Evaluations were also undertaken by both farmers on a regular on-going basis (Table 7.13). These were used to ensure the validity of: planning assumptions, the accuracy and timeliness of monitoring, and correct implementation of plans. In contrast, irregular *ex-post* evaluations (Table 7.13) were used by the case farmers to judge the efficacy of a decision (or set of decisions) after it had been implemented and the outcome was known. *Ex-post* evaluation was undertaken in four contexts: at the end of a planning period, after a new input or management practice had been implemented, when a poor outcome was identified, or when a "normal" decision had been implemented about which the farmers were not confident. As such, four factors caused the case farmers to initiate an *ex-post* evaluation: (i) an outcome deviated from some standard or norm; (ii) there were extreme, or rapid changes in conditions; (iii) a new input or management practice had been implemented, or (iv) the outcome of a decision of interest became known (Table 7.14). In some instances, the case farmers evaluated a decision soon after the outcome was known, however, in others, they reflected on a decision over a period of several months. The processes for *ex-post* evaluation were described in Section 5.6.6. At least 70% of the evaluations involved a new management practice and/or extreme climatic conditions. The purpose of the *ex-post* evaluation was to evaluate the decision (or decisions) to either confirm that it was a good decision, or that it needed to be changed. The ultimate aim of the evaluation was therefore to improve management.

Table 7.14. The four types of *ex-post* evaluation used by the case farmers.

Method of *ex-post* evaluation	Criteria	Purpose of evaluation
Compare outcome to norm	Outcome ≥ norm	Evaluate new input or management practice
Compare outcome to standard	Outcome ≥ standard	Evaluate decision designed to ensure standard met
Compare outcome to expectation	Outcome ≥ expectation	Evaluate decision designed to meet specific expectations
Compare outcome to mental simulation of alternative decision(s)	Outcome ≥ simulated outcome	Evaluate if the decision was correct

The evaluations undertaken by the case farmers during the study can be classified into five main categories: planning, implementation, control, overall management of a planning period and system performance (Table 7.15). These can be further subdivided into subcategories, as defined in Section 5.6.6. Farmer B undertook 64% more evaluations than Farmer A (Table 7.15). When classified by type, Farmer B undertook 67% more diagnoses and 63% more *ex-post* evaluations than Farmer A. If analysed over the five main evaluation areas, Farmer B completed twice as many evaluations under planning and implementation as Farmer A and three times the number of system's performance evaluations. However, they completed the same number of evaluations in terms of overall management and control decisions. Farmer B's change to a higher input system explained the differences between farmers in the number of planning evaluations: eight of his ten evaluations related to input use decisions. In contrast, Farmer A only evaluated two input use decisions over the three years of the study.

Table 7.15. The evaluations carried out by the case farmers.

Category and instance	Farmer A			Farmer B		
	Diagnosis	*Ex-post* evaluation	Total evaluations	Diagnosis	*Ex-post* evaluation	Total evaluations
Planning Decisions	0	5	5	1	10	10
Use of inputs		2	2	0	9	9
Management practices		2	2	0	0	0
Choice of targets		1	1	1	0	1
Planning assumptions		0	0	0	1	1
Implementation	0	1	1	1	2	3
Control decisions	3	7	11	1	10	11
Contingency plan selection	0	2	2	0	7	7
Use of inputs	0	0	0	0	5	5
Management practices	0	1	1	0	2	2
Choice of targets	0	1	1	0	0	0
Monitoring system	3	6	9	1	3	4
Accuracy of monitoring	3	3	6	1	1	2
Timeliness of monitoring	0	2	2	0	1	1
Accuracy of predictions	0	1	1	0	1	1
Overall management	0	2	2	0	2	2
Systems performance	3	0	3	7	2	9
Livestock	2	0	2	5	1	6
Forage	1	0	1	1	1	2
General farm productivity	0	0	0	1	0	1
Totals	6	16	22	10	26	36

Although there was little difference in the total number of control decisions evaluated by the case farmers (Table 7.15), the sub-categories show some interesting differences. The majority of Farmer B's evaluations (64%) related to contingency plan selection whereas the majority (82%) of Farmer A's evaluations were to do with the monitoring system. Farmer B's data again reflects the shift to a higher input system with 71% of the contingency plans evaluated being related to input use. In contrast, Farmer A placed more emphasis on evaluating the accuracy of his monitoring system (6 vs 2 evaluations). This difference came through when both case farmers had poor reproductive performance after a cold, wet spring. Farmer A diagnosed both the cause of the problem and why his monitoring system had not identified the problem. In contrast, Farmer B was only interested in the cause of the problem. Farmer B also undertook three times as many system's performance evaluations as Farmer A. The majority of these were situations where milk production or pasture growth rates varied from expectations.

Analysis of the planning and control decisions evaluated by the case farmers showed that a reasonable proportion (14% – 50%) of these could be classified under strategic planning (Table 7.16), particularly on the use of inputs. One exception was where Farmer B evaluated condition score targets for calving. He also evaluated four times as many strategic planning decisions as Farmer A. This again related to the greater number of changes that Farmer B made to his farming system over the three years of the study. He also evaluated almost twice as many tactical decisions as Farmer A. However, most of this difference was in relation to tactical control decisions as opposed to tactical planning decisions and again in relation to input use. Farmer B introduced a range of new inputs as opportunistic control decisions over the three years. In contrast, Farmer A did not introduce new inputs through opportunistic control decisions.

Table 7.16. A comparison of the types of planning and control decisions evaluated by the case farmers.

Decision Type	Farmer A	Farmer B
Strategic	**1**	**8**
Planning	**1**	**8**
Input use	1	7
Management practice	0	0
Target choice	0	1
Control	**-**	**-**
Tactical	**6**	**9**
Planning	**4**	**2**
Input use	1	2
Management practice	2	0
Target choice	1	0
Control	**2**	**7**
Input use	0	5
Management practice	1	2
Target choice	1	0
Total	**7**	**17**

7.4.7 Learning

Learning was one of the products of the evaluation process. In some cases the learning occurred during the evaluation process, and at other times, learning was delayed as the case farmers reflected on an aspect of their management over time. This made it difficult to compare learning that occurred over the summer-autumn because the instances of learning recorded during the study included those associated with the previous period, the spring. Learning tended to occur when a new practice or input was used, and/or in an extreme season where conditions were outside those previously experienced by the case farmers (Table 7.17). These factors accounted for both the between-year and cross-case differences in learning. Forty six percent more learning experiences were recorded for Farmer B compared to Farmer A (Table 7.17). The major reason for this difference is that Farmer B introduced almost three times as many new inputs as Farmer A (Table 7.17).

Table 7.17. The factors that initiated farmer learning.

Primary Initiator	Farmer A				Farmer B			
Year	**1**	**2**	**3**	**Total**	**1**	**2**	**3**	**Total**
Extreme conditions	3	0	4	7	1	3	4	8
New Input	1	0	2	3	4	3	1	8
New Practice	1	1	1	3	0	1	2	3
Total	5	1	7	13	5	7	7	19

The learning undertaken by the case farmers improved their knowledge in relation to three primary areas: the environment, the production system, and the management system (Table 7.18). Farmer A's learning also resulted in a change in his values. Learning mostly related to the interaction between two or more of the primary areas (Table 7.18). Limited learning occurred in relation to the environment (15 – 18%) or values (0 – 5%). The bulk of the learning was in relation to the farmers' production (30 – 33%) and management systems (38 – 48%).

The learning classified under "environment" related solely to the biophysical environment, and in particular, climate. The case farmers learnt about the variety or variation in the environment. No instances of learning in relation to the socio-economic environment were recorded. Of particular interest, was the number of instances (Farmer A = 7, Farmer B = 11) where climatic conditions were found to be outside those previously encountered by the case farmers, despite their experience. This demonstrates why climate was considered to be the major source of production risk.

Table 7.18. A comparison of the instances of learning by category, undertaken by the case farmers during the study period.

Area of Learning	Farmer A					Farmer B				
Year	1	2	3	Total	%	1	2	3	Total	%
Total areas of learning	17	5	18	40	100	13	24	22	72	100
Environment	3	1	3	7	18	2	5	4	11	15
Biophysical	3	1	3	7	18	2	5	4	11	15
Climate	3	1	3	7	18	2	5	4	11	15
Production System	5	0	7	12	30	5	11	8	24	33
Livestock	2	0	1	3	8	1	3	1	5	7
Herd	2	0	1	3	8	1	1	1	3	4
Young stock	0	0	0	0	0	0	2	0	2	3
Forage	3	0	5	8	20	4	6	7	17	24
Pasture	3	0	2	5	13	1	4	3	8	11
Supplements	0	0	3	3	8	3	2	4	9	13
Soils	0	0	1	1	3	0	2	0	2	3
Management System	9	4	6	19	48	7	8	12	27	38
Planning	6	3	3	12	30	4	5	3	12	17
Forecasting	0	1	0	1	3	0	0	0	0	0
Activity rules	1	0	3	4	10	2	3	1	6	8
Target selection	2	1	0	3	8	0	0	2	2	3
Contingency plan specification	2	0	0	2	5	0	2	0	2	3
Planning assumptions	1	1	0	2	5	2	0	0	2	3
Implementation	0	0	1	1	3	0	0	1	1	1
Control	3	1	2	6	15	3	3	8	14	19
Monitoring	1	0	2	3	8	1	1	5	7	10
Contingency plan selection rules	2	1	0	3	8	2	2	3	7	10
Values	0	0	2	2	5	0	0	0	0	0

The case farmers learnt three things in relation to their production systems. These were in relation to how it responded to: extreme climatic conditions (Production system – environment interaction), and new management inputs or practices (Production system – management system interaction), and a combination of extreme climatic conditions and new management inputs or practices (Production system – environment - management system interaction). The production system learning related to three main areas, soils (3%), livestock (7 – 8%), and forage (20 – 24%), with the latter being the primary area of learning (Table 7.18). Often, learning was about the interaction between the forage and livestock sub-systems.

The most complex area of learning was that associated with the management system. Here learning related to how new management inputs or practices impacted on the production system (Management system – production system interaction), and how the production system responded to management inputs or practices (new or existing) under extreme climatic conditions (Management system – environment – production system interactions). The outcome of the learning was a change in the case farmers' management processes. This ranged from changes to the planning process (forecasting, activity rules[46], target selection, contingency plan specification, planning assumptions) to changes in the implementation and control processes. Learning in relation to control could be separated into monitoring and contingency plan selection rules. Monitoring included the areas of method, accuracy, timeliness and usefulness. Contingency plan selection rules included decisions to do with input use, management practices and target selection.

The number of instances of learning in relation to planning and implementation was the same for both farmers (Table 7.18). The main difference occurred in relation to control. Over twice as many instance of learning in relation to control were recorded for Farmer B as Farmer A. This difference could be assigned equally between learning in relation to monitoring and contingency plan selection rules. The majority of these experiences related to the introduction of new inputs that required new contingency plan selection rules or calibration rules for yield measurement.

The outcome from the learning process depended on the learning areas (Volume II, Appendices X & XIX). In some cases, the information just added to the case farmers' general understanding of the production system and environment. However, in other cases it resulted in a change in their management system. Three types of learning in relation to the management system were identified. First, learning could confirm the efficacy of a new management practice or input, and it was retained. Second, the effectiveness of a management practice or input (new or old) could be found wanting and it was changed to improve managerial performance. Third, the effectiveness of a new management practice could be found wanting, and because no means of improvement could be identified, it was discarded.

[46] Rules that determined the placement of an input or management practice in the plan.

Instances of learning in relation to the management system covered the continuum of management levels from operational through to strategic (Table 7.19). Few instance of learning at the operational level were recorded for either case farmer. As expected, learning in relation to tactical management was dominant for both case farmers. However, the most interesting finding was that the tactical management process played an important role in learning about and refining both case farmers' strategies. This was particularly important for Farmer B (37% of all learning instances) who undertook a major change in strategy over the period of the study. In contrast, only 23% of all learning instances could be classified as strategic for Farmer A, whose system was relatively stable over the study period.

Table 7.19. Management system learning by level: the percentage of instances (Appendices X & XIX) at each level within the management hierarchy.

Decision level	Farmer A	Farmer B
Strategic	14	37
Tactical	78	58
Operational	8	5

The learning processes used by the case farmers are represented in Figures 7.7 and 7.8. The first process (Figure 7.7) was used when a new management practice was introduced. Some factor caused the case farmers to postulate a management change. This was due to extreme conditions, outside information, previous experience, their management and production system knowledge, or some combination of these factors. The management change was implemented and then the outcome of the change monitored. This was compared to the case farmer's expectation of the likely outcome of the change. If the outcome was the same as, or similar to the expectation, then the postulate was confirmed and the new management practice was retained. If the expectation was not met, then the case farmer determined the reason for the deviation. In some instances these were known because the reasons for the deviation were identified by the monitoring system. If the reason for the deviation was not known, then a diagnosis was undertaken. If the new practice did not perform as expected, the case farmers then determined if it could be refined to enhance performance. If it could be improved, then the improved version was implemented when conditions were appropriate and the cycle repeated. However, if it could not be refined, then it was discarded. Learning occurred in each of the above instances.

A similar process was used when learning occurred in relation to an existing management practice (Figure 7.8). In this case, an existing management practice was implemented and because of extreme conditions, the outcome was significantly different from the case farmers' expectations. The reasons for the deviation were either identified through the case farmers' monitoring systems, or if they were not, diagnoses was undertaken. The case farmers then determined if a new management practice could be postulated from what they had learned. In some cases it could not and the primary outcome of the learning was information about the variation in the environment and how their production system responded to such variation. However, in many of the instances, the case farmers postulated a management change that would improve their capacity to cope with such conditions in the future. The future could have been the next year, or in several cases it was immediately after the learning had occurred because the extreme conditions were still present. The management change was implemented at the point in time when the appropriate conditions were identified and tested, as shown in Figure 7.7, for a new management practice. Therefore, under extreme conditions learning pertains first to how the production system responds to extreme conditions under the current management practices. A second loop of learning occurs if the case farmers can postulate a change to their current management practices to cope with such conditions, and then test this through another cycle.

The evaluation and learning processes used by the case farmers demonstrate how they adapted their management system to environmental conditions and integrated new inputs and management practices into it. The integrated knowledge of the environment, production and management systems was used to enhance the farmer's tactical management.

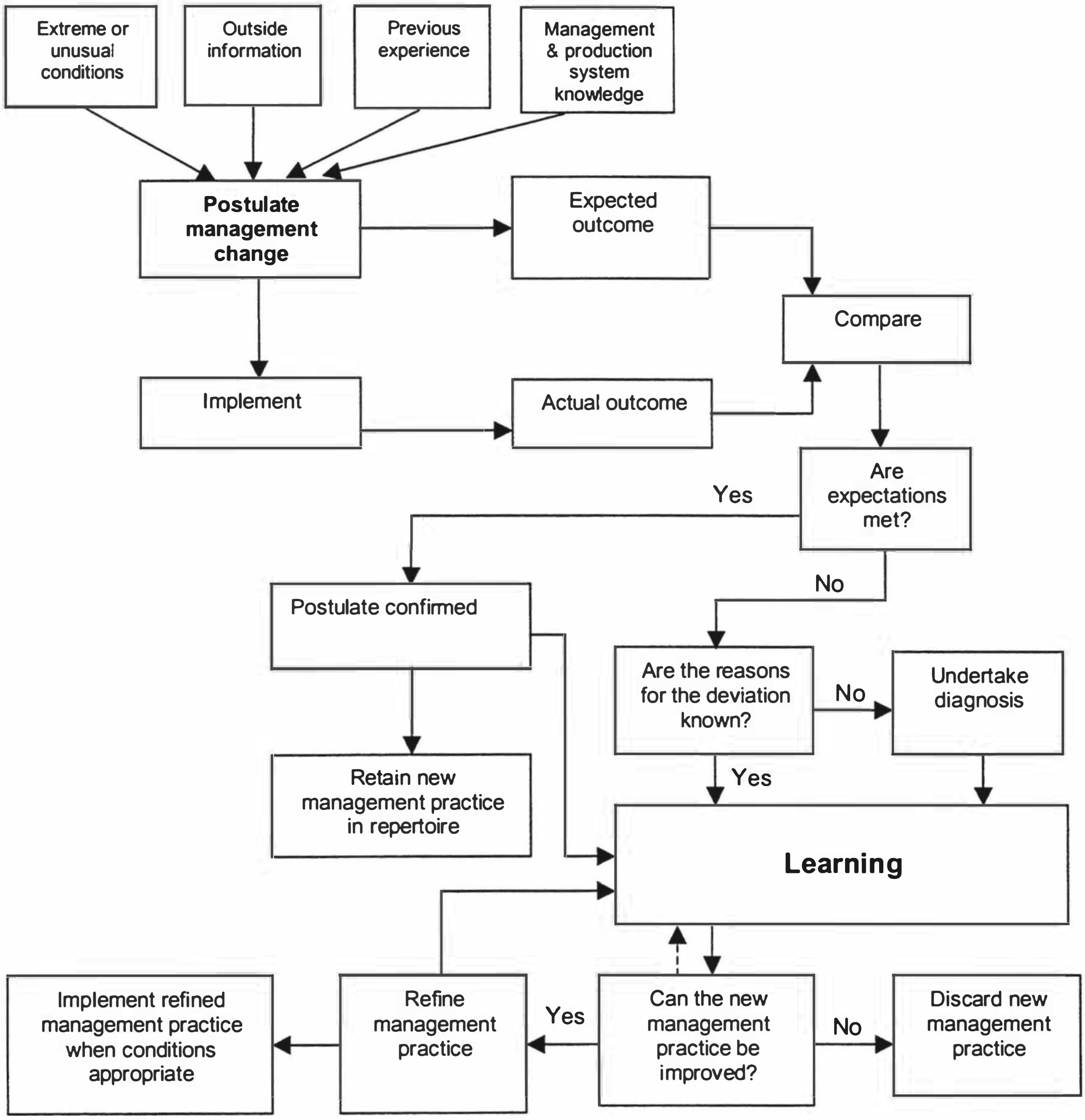
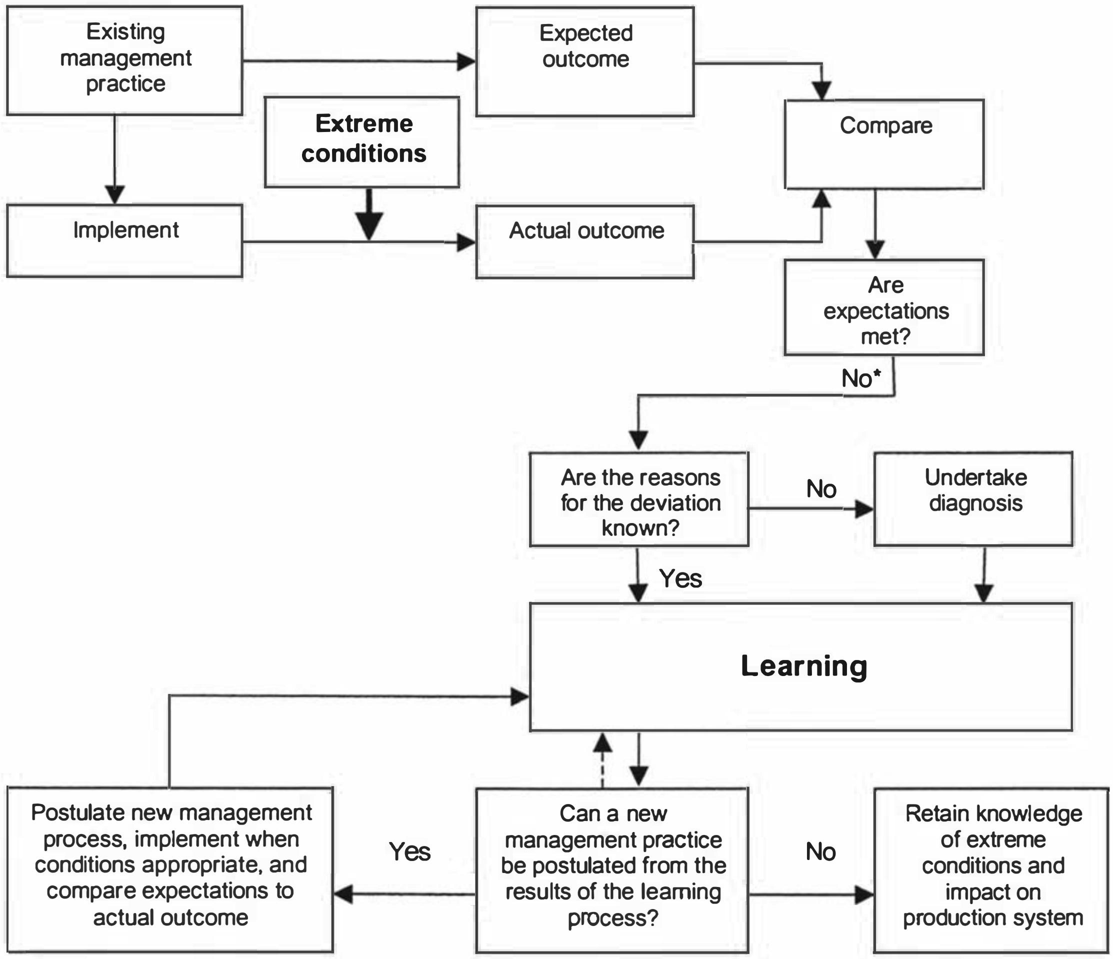


Figure 7.7. The learning process used by the case farmers when introducing a new management practice.



*This process is only used where extreme conditions result in an unexpected outcome. As such, there is no "yes" option for this process.

Figure 7.8. The learning process used by the case farmers when extreme conditions caused unexpected outcomes.

7.5 Conclusion

In this chapter the similarities and differences between the tactical management processes used by the case farmers was discussed. These were found to be essentially the same with some minor differences. These differences related primarily to a change in Farmer B's production strategy. This suggests that a generic model could be developed to explain the components of production management over the summer-autumn period on a seasonal supply dairy farm. In the next chapter, a general model of the tactical management process developed from this cross-case analysis is compared to the literature.

CHAPTER 8 COMPARISON OF THE RESULTS WITH THE LITERATURE

8.1 Introduction

In this chapter, the tactical management process used by the case farmers is compared with the literature in relation to planning and control. Initially a theoretical classification of the cases is made. The product of the case farmers' planning process, the plan and its components: goals, predictive schedule of events, targets and contingency plans are compared with other reported research. Aspects of the control process compared with the literature include the monitoring process, data storage and processing, decision point recognition, control response selection, evaluation and learning.

8.2 Classification of the cases

The theoretically important characteristics of the cases (Table 8.1) provide the context in which the results can be interpreted and compared with other studies (Orum *et al.,* 1991; Ragin, 1992a; Vaughan, 1992; Walton, 1992). In relation to decision-making, the cases are examples of decisions at the tactical level (Gorry and Morton, 1971; Boehlje and Eidman, 1984; Dryden, 1997; Parker *et al.*, 1997). They are predominantly structured decisions (Gorry and Scott Morton, 1971; Dryden, 1997), and encompass planning, implementation, and associated control decisions (Thornton, 1962; Boehlje and Eidman, 1984). Production management is the field of decision-making (Boehlje and Eidman, 1984), and the decision makers can be classified as "experts" (Dreyfus, 1997).

The case farms are single enterprise, semi-intensive pastoral-based dairy farms operated by one to two full time labour units. Market, human, technological, social and legal and financial risk was low for the case farmers (Gabriel and Baker, 1980; Sonka and Patrick, 1984; Martin, 1996). However, production risk was high, primarily due to climatic variability and management of this dominated decision-making. Competition (Emery and Trist, 1965; Wright, 1985) between dairy farm businesses was low because they are members of a cooperative with a single international marketing agency, the New Zealand Dairy Board.

Table 8.1. Theoretically important characteristics of the case study.

Characteristic	Case study Classification
Decision-making	
Management level	Tactical
Structuredness	Structured
Decision type	Planning and associated control decisions
Field	Production management
Type of decision maker	Expert
Farm characteristics	
Production system	Pastoral-based dairy farming
Intensity of production	Semi-intensive
Number of enterprises	Single enterprise
Full time labour units per farm	1 - 2
Environment (Risk)	
Production	High
Market	Low
Human	Low
Technological	Low
Social and legal	Low
Financial	Low
Competition in environment	Low

8.3 Tactical management process

The tactical management process used by the case farmers can be represented as a cyclical process of planning, implementation and control, in much the same manner as proposed by Barnard and Nix, (1973), Boehlje and Eidman, (1984) and others (see Section 2.3). While the process was found to be cyclic, planning decisions were made irregularly (Figure 8.1). The ratio of implementation to control decisions was a function of the level of uncertainty in the environment. This model is more useful than the decision-making model (Hardaker *et al.*, 1970; Castle *et al.*, 1972; Osburn and Schneeberger, 1978; Kay, 1981; Boehlje and Eidman, 1984) which fails to capture the importance of management control. Although some authors (e.g. Kay and Edwards, 1994; Ohlmer *et al.*, 1998) have included a control aspect in their models of decision-making; this, with the exception of Makeham and Malcolm (1993), tends to be a minor component. The model reported here for the case farmers is similar to those reported in the descriptive tactical management literature (Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). In essence farmers have a plan, implement it and then use control decisions or "*regulations*"

(Aubry *et al.*, 1998) to manage deviations from the plan due to uncertainty in the environment.

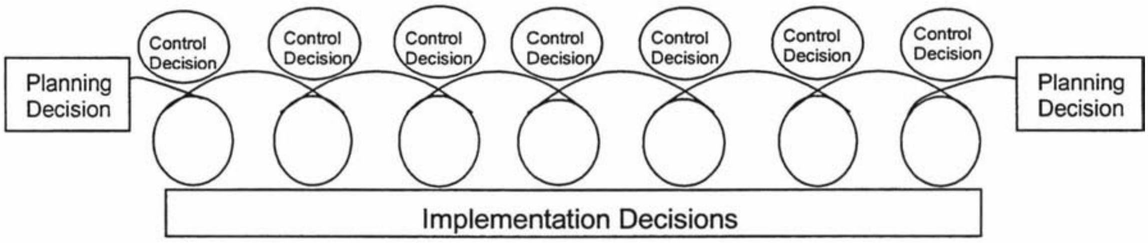


Figure 8.1. Representation of the tactical management process used by the case farmers from a decision-making perspective.

As proposed by Simon (1960) and Gorry and Morton (1971), the tactical decisions made by the case farmers were predominantly "structured" in nature. It was only under extreme conditions or where a new input or management practice was used that the case farmers used less structured decision-making processes. In these instances, rather than automatically draw on their heuristics to select a plan or control response, the case farmers either undertook a less "structured" planning process, or in the case of control decisions, diagnostic and/or evaluation processes were used that lead to learning and the introduction of a new control response. As such, these less structured decisions required more rigorous diagnosis, search, design, screen and choice sub-processes as proposed by Mintzberg *et al.* (1976), than the more structured decisions the case farmers normally made. These "unstructured" decisions were analogous to Scoullar's (1975) problem-solving process that he proposed managers would use in novel situations, where a knowledge, rather than a performance gap existed. This is discussed further in Sections 8.4.2.1, 8.6.4, and 8.6.9.

8.4 Planning horizon

Little useful information is provided in the prescriptive literature on how to determine the planning horizon for a particular plan (Section 2.3.2.1). Decisions are interdependent, because earlier decisions nearly always have consequences for later decisions and this interdependence extends out to infinity, therefore, in theory, the planning horizon could be viewed as being infinite (Reisch, 1971; Kennedy, 1974; Hanf and Schiefer, 1983). Other than suggesting that tactical plans should have shorter planning horizons than strategic plans (Wright, 1985), the literature suggests that decisions on the planning horizon be left to the manager's judgement (Reisch, 1971; Hanf and Schiefer, 1983; Wright, 1985). Hanf and Schiefer (1983) also highlighted the trade-off that occurs between reducing uncertainty and lessening the manager's appreciation of longer-term consequences as the planning horizon is shortened.

Both the criteria used for setting their planning horizons, and the means by which the problem of interdependency and consequences was overcome, were identified for the case farmers. The planning horizon primarily reflected seasonal changes in the physiological state of the pastures, the balance between pasture growth and herd feed demand and the goals associated with these changes. Similar results were reported by Mathieu (1989) who found that on a French pastoral farm in the Jura mountains, the year could be separated into three phases on the basis of relative pasture growth rates, which are a function of the physiological status of the sward and the climate. Other descriptive studies (Gladwin, 1979; Cerf *et al.*, 1993; Siddiq and Kundu, 1993) have reported the importance of climate to the annual calendar of operations adopted by farmers, but they have not discussed this in relation to planning horizons. Farmer A also used a critical event, calving, to reduce the length of his mid-year planning horizon and simplify the planning process. Proximity to a critical event, drying off, also influenced the case farmers' choice of the summer plan termination date. Mathieu (1989) also mentioned the importance of critical events, but in relation to system performance, rather than planning horizon determination.

Because the case farmers' planning horizons were primarily a function of seasonal changes in the feed balance, each period had different goals and associated tasks for achieving these goals. Similarly, Cerf *et al.* (1993) reported that farmers separated the year into different periods according to the tasks required for production. For the case farmers, extreme climatic conditions (dry spring, early autumn rains) that shifted the change-point precipitated modifications to their planning horizons. A strategic decision such as changing farms could also prompt a change in planning horizon.

The case farmers had developed a simple means of overcoming the problem of interdependency and consequences (Reisch, 1971; Kennedy, 1974; Hanf and Schiefer, 1983). Within the plan, they set terminating targets which specified the farm's state at the end of each planning horizon. These terminating targets were designed to ensure optimum system performance, *ceteris paribus*, in the next planning period. The targets were selected on the basis of the case farmer's knowledge of cause and effect relationships in system performance and ensured short-term gains were not obtained in the current planning period at the expense of longer-term production. The literature does not comment on terminating targets or their role in relation to the problem of interdependency and consequences.

Rather than undertake a full planning process at regular intervals, the case farmers developed a plan at the start of each planning period, and then used the control process to cope with uncertainty. This achieved the same outcome as the rolling planning process (Kennedy, 1974; Hanf and Schiefer, 1983), but reduced the input required by the farmers. Plans were revised, but on an irregular basis in response to strategic decisions, extreme conditions, or the imminence of a critical decision (drying off).

The case farmers were also thinking across a number of different planning horizons simultaneously, reflecting the hierarchical nature of the planning process (Anthony, 1965; Gorry and Scott Morton, 1971; Barnard and Nix, 1979; Dalton, 1982; Buckett, 1988; Parker *et al.,* 1997). This ranged from daily operational plans through to periods that encompassed two tactical planning periods (e.g. January 1st to balance date). The most common shorter-term planning horizon was event-based and encompassed a period of one to four weeks. However, in several instances events were combined in relation to the achievement of a specific goal and this "amalgam" was considered to be a "planning horizon". This suggests that planning horizons may also be a function of a hierarchical goal structure, the goals being tailored to specific condition/event-dependent periods. Although several authors (Gasson, 1973; Petit, 1977; Dalton, 1982; Olsson, 1988; Trip *et al.,* 1996; Ohlmer *et al.,* 1997) mention the hierarchical nature of goals, this is not related to a manager's planning horizons. At the event level, the process was similar to a rolling plan (Kennedy, 1974; Hanf and Schiefer, 1983). The case farmers were normally thinking ahead two to four weeks and considering both the planned, and alternative, courses of action should conditions differ from their expectations. In effect, they were pre-selecting contingency plans for key decision points so that, should conditions differ from their expectations, they were mentally prepared to implement an appropriate contingency plan.

8.4.1 Interdependence of planning and control and hierarchies of plans

Previous authors' (Kennedy, 1974; Jolly, 1983; Wright, 1985; Parker, 1999) criticism of the discipline's focus on planning to the detriment of control is well supported by the case study findings. The case farmers spent limited time on planning, rather relying on control to cope with uncertainty in the environment. These findings support the views of Wright

(1985) and Kaine (1993) that where uncertainty is high, greater emphasis will be placed on control relative to planning. The interdependence of planning and control (Anthony, 1965) was demonstrated by the study. Important components of the case farmers' plans were essential for control: these were their targets (or standards) and associated contingency plans and decision rules.

As proposed in the normative literature (Anthony, 1965; Bamard and Nix, 1973; Dalton. 1982; Wright, 1985; Buckett, 1988; Renborg, 1988; Martin *et al.*, 1990; Attenaty and Soler, 1991; Harling, 1992; Hemidy, 1996; Parker *et al.*, 1997), the plans of the case farmers could be placed in a hierarchy where goals of higher level plans constrained the activities of lower level plans. This was demonstrated by the impact strategic decisions had on the case farmers' "typical" tactical plans (see Section 8.4.2.1). Plans ranging from long-term (five to 10 years) in relation to farm purchase, to annual financial plans, tactical plans of 2.5 to 6.5 months duration, event based plans of one to four weeks, and daily plans were used. The case farmers thought about plans at multiple levels of the planning hierarchy simultaneously.

8.4.2 The planning process

The case farmers altemated between "informal[1] and qualitative" and "formal and quantitative" approaches to planning. In contrast, the literature has tended to identify farmers as using one approach or the other. The work of Gladwin (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984) and that of the French (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) suggested that farmers used an informal qualitative heuristic-based planning approach. Other studies (Jacobsen, 1993; Ohlmer *et al.*, 1998; Catley *et al.*, 2000) also found that the majority of farmers used an informal qualitative approach and that few developed formal written plans. Similarly, survey research (Lockhart, 1988; Parker *et al.*, 1993; Nuthall, 1996; Nuthall and Bishop-Hurley, 1999) has tended to report on the use, or non-use of formal quantitative planning approaches by farmers but has not explored the transition from one approach to the other. The other interesting point was that although budgeting is widely recognised in the discipline as an important planning aid for resource allocation (Bamard and Nix, 1979; Harsh *et al.*, 1981; Calkin and Di Pietre, 1983; Osbum and Schneeberger,

[1] In this context, an informal planning approach is not documented, whereas a formal planning approach will generate a written plan.

1983; Kay and Edwards, 1994), to the point that Boehlje and Eidman (1984) referred to it as a "fundamental planning tool", it was only used for part of the year by the case farmers.

The case farmers' transition from an informal qualitative approach to a formal quantitative approach was initiated by two main factors. The first, and main reason, was that drying off, a critical event and an important determinant of next season's productivity, occurred around the date formal planning was initiated. Second, average pasture cover, a measure of the primary feed resource, could not be accurately measured because of sward characteristics until around mid March. It was a key variable in the planning exercise and formal planning was considered pointless until it could be assessed more accurately. During summer, no additional benefit was perceived to be realised from formal planning, particularly given the high level of uncertainty over this period relative to what they currently did. Rather, the additional planning and pasture measurement would incur additional time costs.

Farmer A reverted back to an informal planning approach post-calving. Increased uncertainty and complexity were cited as reasons for this. In contrast, Farmer B incorporated the post-calving period into his formal plan. He had been trained at university to formally plan through this period whereas Farmer A had not. The influence of previous training (learning) on planning mode is not discussed in the farm management literature. The case farmers' adoption of an informal planning mode during summer, and post-calving for Farmer A, supports Wright's (1985) contention that farmers would expend less effort on planning under conditions of greater uncertainty. This is contrary to Ohlmer *et al.*'s (1998) findings that farmers expend more planning effort when the plan is complex. The literature is silent on the influence of the accuracy of a measurement system on the choice of planning approach. The case results, and the importance of the drying off decision, however, do support Wright's (1985) argument that the perceived net benefits from planning determine the effort farmers put into this process.

8.4.2.1 Informal planning process

A predominantly informal, qualitative, heuristic-based planning process was used by the case farmers at the start of summer, similar to that described in several other studies (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). However, some important differences were identified (Figure 8.2). The "typical" plan was modified in response to prior learning, a form of historical control, previously made strategic and tactical decisions and the state of the farm at the start of summer. Although implicit in the hierarchical nature of plans (Anthony, 1965; Wright, 1985) no mention is made of the influence of strategic decisions on farmers' "typical" plans in the farm management literature, but learning is mentioned by Chibnik (1981) and Aubry *et al.* (1998). Similarly, there is no reference to the influence of tactical decisions made in the previous planning period on the structure of the "typical" plan.

The results showed that the state of the farm at the start of the summer period had a major influence on the nature of the case farmers' summer plans (Figure 8.2). At the start of the summer, the state of the farm was quantified in terms of the pasture, supplement, forage crop and herd resources. This information was then used to develop a mental feed budget for the summer period to test whether the "typical" plan was feasible. If the plan was feasible, the "typical" plan or a modified version of it was implemented. This process was largely sub-conscious. If, however, the simulation suggested the "typical" plan was not feasible, then the case farmers undertook a more conscious planning process. In this situation, the case farmers proposed some changes to the plan in relation to their planning heuristics (sequence and timing of events, level and type of input, target selection) so that their summer goals would be met. A simulation was then run to test the efficacy of the changes. If the adjusted plan proved feasible, it was implemented: if not, further changes were investigated. Sometimes this iterative process was completed over several days. The time taken was dependent on the nature of the farm state and the severity of the changes required to achieve the summer goals. This problem was compounded if a major change to the typical plan had already been made due to strategic or historical control reasons. A more formal quantitative approach was used in such situations.

Although several studies (Gladwin and Butler, 1984; Gladwin *et al.,* 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.,* 1996) mention that farmers use "typical" plans, only Aubry *et al.* (1998) reported that such plans are modified through the activation of alternative solutions when specific circumstances are encountered. The results suggest the case farmers had broadly defined a set of conditions within which the "typical" plan was robust, but if conditions fell outside this range, as determined by mental simulation, the plan was modified. Importantly, no other studies mention the role of quantitative information and mental simulation in relation to heuristic-based planning.

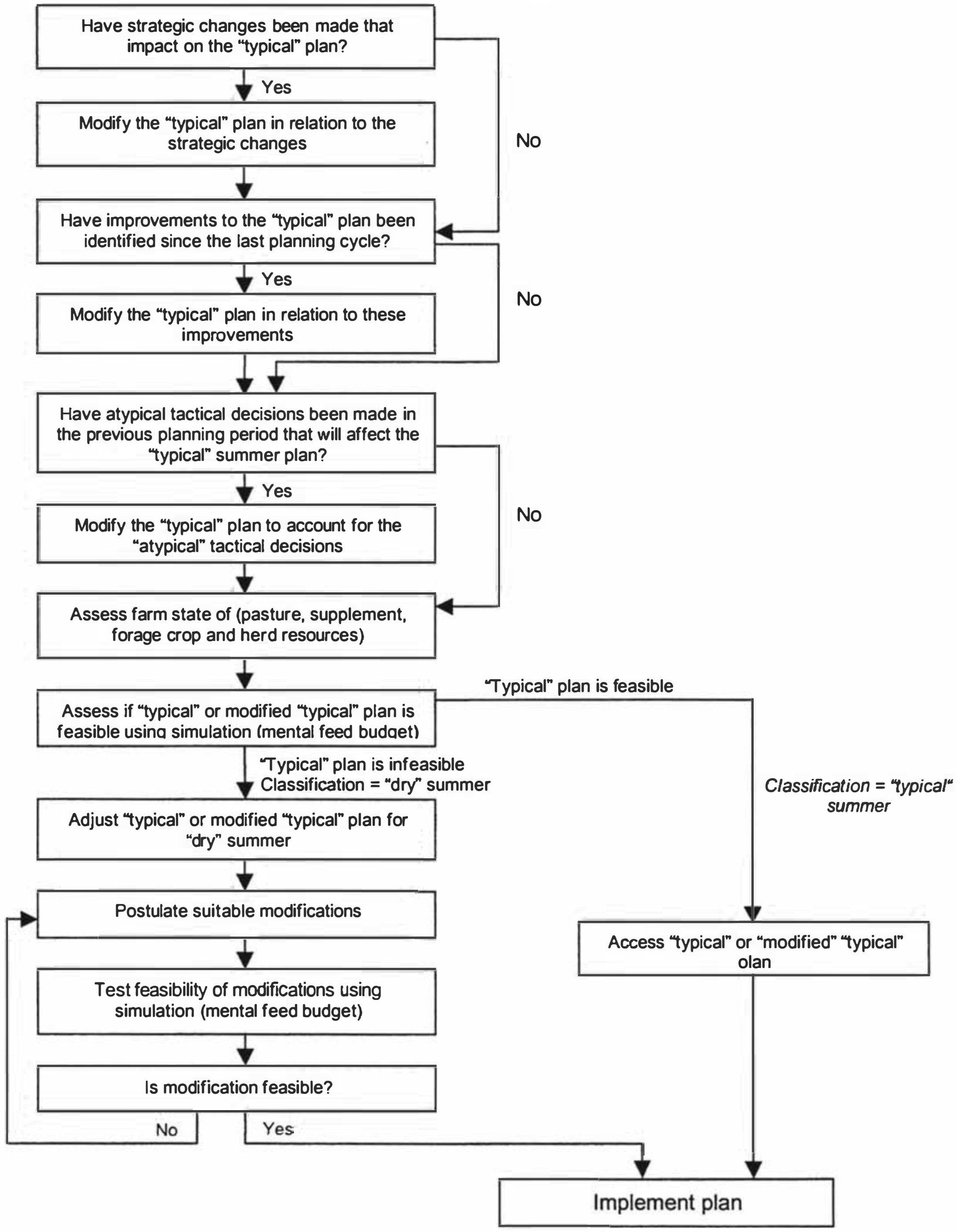


Figure 8.2. The planning process used by the case farmers over the summer.

The case farmers' planning process for a "typical" year was largely sub-conscious or "pre-attentive" (Gladwin and Butler, 1984) and as such avoided the cognitive effort and stress involved in more formal planning (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984). This finding supports the views of Simon (1960), Gorry and Morton (1971) and Koontz and Weihrich (1988), that effort declines as decisions become more structured, and that this structuredness eventuates from the repetitive nature of the decisions, a factor more likely to occur at the tactical and operational than the strategic level of decision-making. Even at the strategic level, Ohlmer *et al.* (1998) reported that farmers preferred quick and simple, rather than elaborate planning procedures.

An important contrast to the above work however, was that the case farmers, as proposed by Schank and Ableson (1977), followed predefined plans except when unexpected events forced them out of "plan mode" and into "decision mode" to choose between alternative plans. Several studies (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) found that farmers also act in this way, but these findings were in relation to control, rather than planning.

In some cases, a modification made as a result of a strategic decision was relatively simple and easily incorporated into the plan through adaptation of the existing planning heuristics. The substitution[2] or introduction[3] of alternative, but relatively isomorphic supplements to improve summer feeding levels for the herd was an example of this. Although at a different planning level, this concurs with the findings of Gladwin *et al.* (1984) who found that farmers were more likely to adopt new crops that had similar planning heuristics to those already grown than those that had quite different planning heuristics. Planning heuristics could be adapted to the analogue crop relatively simply. In contrast, changes that could not be easily incorporated into the existing planning heuristics were analysed quantitatively by the case farmers. Evidence provided by Farmer A suggested that over time, such changes, if successfully implemented, were incorporated as a planning heuristic, therefore removing the need for analysis in subsequent plans. While little has been reported in the literature on these effects, some authors (Simon, 1960; Gorry and Morton, 1970; Koontz and Weihrich, 1988) have suggested that with repetitive, tactical decisions, such as those undertaken by the case farmers, the decision-making process becomes routinised over time. Interestingly, unlike Chibnik (1981), Ohlmer *et al.* (1998) or Catley *et al.* (2000), no evidence was found that the case farmers tested the changes incrementally before introducing them in full.

The informal planning process depicted in Figure 8.2 is useful for demonstrating the distinction between "*structured*" and "*unstructured*" decisions. In a year where conditions are "typical", no previous strategic changes or "atypical" tactical decisions have been

[2] For example, the substitution of silage with an additional area of the forage crop that is currently grown.
[3] The introduction of maize silage, an analogue of grass silage, into the autumn plan.

made, and no instances of historical control are to be introduced, then the planning decision is "*structured*" and the "typical" plan is selected and implemented. However, where one or more of the above factors occur, the decision making process becomes less "*structured*". In such instances, the case farmers used a process that is akin to the more rigorous search, design, screen and choice sub-processes reported by Mintzberg *et al.* (1976) for "unstructured" decisions.

8.4.2.2 Formal planning process

The case farmers changed from an informal qualitative to a formal quantitative planning approach in autumn. In the literature, however, farmers have been classified as either using or not using formal quantitative planning approaches rather than both (Lockhart, 1988; Parker *et al.,* 1993; Nuthall, 1996; Ohlmer *et al.,* 1998; Nuthall and Bishop-Hurley, 1999). A relatively simple planning aid, a feed budget, provided assistance to the planning process. It assisted with the derivation of "typical" cow intakes, and the conversion of supplements to dry matter equivalents, and provided the template for estimating drying off date and the average pasture cover targets for control purposes. However, the feed budget provided the case farmers with no guidance about the sequence or timing of events, other than drying off date; neither did it help with decisions in relation to the type, level or combination of inputs to use with the exception of cow intakes. It did not help the case farmers identify alternative options, and nor did it assist in the development of contingency plans. Finally, it did not provide guidance on the selection of suitable terminating conditions for the plan. This supports Reich's (1971) view that the "pre-decisions" made before the mechanical process of computation, are much more important than the latter in relation to planning. It also highlights why Wright (1985) distinguished the cognitive process a manager undertakes when developing a plan from the use of planning aids. The effective use of planning aids depends upon the user's knowledge of the planning process, and their production system. Someone with limited knowledge and experience of pastoral systems, that is, a novice, would struggle to use a simple feed budget effectively.

Both case farmers believed the feed budget enhanced a manager's planning process and resultant plan (see Attonaty and Soler, 1991). Given the importance of the planning period, the low capital and time cost (up to one hour) and usefulness of the planning aid, the low adoption rate of formal feed budgeting by New Zealand pastoral farmers (Nuthall, 1992; Parker *et al.*, 1993; Nuthall, 1996; Nuthall and Bishop-Hurley, 1999) is surprising. This is especially so, given Wright's (1985) belief that planning effort is proportional to the perceived net benefit from planning. However, there is another cost associated with formal feed planning, and that is the need for a two to three hour pasture walk every five to 14 days for control purposes. This increases the "costs" compared to the visual assessment practiced by the case farmers over the summer. Survey data supports their preference, with the most important reason given for non-adoption being the time requirements of formal feed planning and monitoring (Nuthall and Bishop-Hurley, 1999). It must also be remembered that the case farmers are "*experts*" and this may allow them to undertake management activities that are not possible for other less "*expert*" farmers.

The simplicity of the feed budget used by the case farmers ensured isomorphism with reality, because they dictated the inputs, relationships and constraints. This supports Petit's (1977) view that the effectiveness of a planning aid is dependent on its match with reality. Unlike more complex models, there is no "black box" where relationships are opaque to the user, a problem identified by Cox (1996). The simplicity of the feed budget and its reliance on the decision maker also overcomes the problems associated with planning aids identified by Wright (1985): invalid representation of reality, inconsistency with decision maker objectives, misinterpretation of output, and failure to incorporate all relevant data. However, the dependence on user knowledge is a weakness for inexperienced farmers and this may suggest why less "*expert*" farmers do not adopt feed budgeting. The case farmers, as advocated by Kelly and Malcolm (1999), separated economic analysis from their "*technical*" model. Overall, the results support the view of Kaine (1993), Cox (1996) and Parker (1999) that farmers do not necessarily need more advanced planning aids to make effective decisions.

Both case farmers used planning aids for tactical decision-making. In contrast, Jacobsen (1993) and Catley *et al.* (2000)[4] reported that farmers in their studies did not use planning aids. Similarly, Ohlmer *et al.* (1998) found few farmers used planning aids for strategic decisions. This contrast may be because techniques for tactical planning are less complex conceptually (e.g. simple budgeting) than those used for strategic planning (e.g. discounting techniques and SWOT analysis). Catley *et al.* (2000), for example, reported that cutflower growers found strategic planning difficult. Other authors (Wright, 1985; Attonaty and Soler, 1991; Kaine, 1993) have argued that the adoption of normative planning aids by farmers for strategic decision-making is irrational in an uncertain environment. Wright (1985) believed that planning aids were more suited to tactical management where the level of uncertainty is less than for longer strategic planning

[4] Catley *et al.* (2000) studied cut flower growers. To simplify the text, these will be referred to as "farmers" unless otherwise stated.

periods. Survey results support this view (Nuthall, 1992; Parker *et al.*, 1993) and have indicated that between 30 - 40% of New Zealand dairy farmers use planning aids for tactical feed management. No equivalent survey data was available on farmers' use of strategic planning aids.

The planning process used by the case farmers can also be compared to the general normative planning models (e.g. Barnard and Nix, 1979; Kay, 1981; Dalton, 1982; Boehlje and Eidman, 1984; Kay and Edwards, 1994). The majority of models initiate the planning process with the determination or clarification of goals. In this case, the goals used by the case farmers were predetermined, a function of the repetitive nature of the tactical planning process. Unlike other authors, Wright (1985) proposed that the next step in the planning process was "situation assessment" where the manager assessed the environment and identified important changes and trends to determine whether it was worthwhile undertaking a new planning exercise. The case farmers did this to a limited degree and they provided examples of the initiation or delay in planning due to changes in climatic conditions. However, for the most part, they initiated planning at the same time each year. Again, this difference can be attributed to the tactical focus of this study compared to Wright's (1985), which was at the strategic level. At the strategic level, new planning exercises are likely to be initiated in response to changes in the environment at irregular and unpredictable intervals. In contrast, the results from this study suggest that tactical plans are likely to be developed at the same time each year, with some minor variance occurring in response to extreme conditions.

Few examples of forecasting, perceived as an important component of the normative planning process (Dalton, 1982; Boehlje and Eidman, 1984; Buckett, 1988), were identified during the study. At the start of the summer, the case farmers made some assessment of its nature (i.e., dry, normal, wet) and associated likely pasture growth rates, based primarily on the state of the farm at the time and the assumption that conditions tend to become drier. Weather forecasts were considered to be too inaccurate to predict pasture growth rates. Similarly, during the autumn, when feed budgeting, average rather than predicted pasture growth rates were used by the farmers. There was one exception to this: in year three, Farmer A predicted higher pasture growth rates for April, on the basis of climatic conditions at the end of March and his knowledge of climate-farm-system interaction. As reported in other studies (Quin, 1978; Gladwin, 1989; Ohlmer *et al.*, 1998), the case farmers did not use probabilities in planning. Variation in pasture growth rates was managed through control of deviations from the plan rather than complex planning models. This supports Wright's (1985) view that under conditions of high uncertainty, control may be relatively more important than planning.

After forecasting, the next step in formal planning models is normally the establishment of the conditions and constraints within which the firm will operate (Boehlje and Eidman, 1984). During both summer and autumn planning exercises, the case farmers undertook this exercise, although it was done in more detail during the latter. The constraints included those imposed by the farm's resources. Terminating conditions for the end of the planning period, and several intermediate targets such as pasture cover levels, cow condition and milk production were also viewed as constraints. These factors were designed to optimise system performance during the planning period, and ensure that the farm's state at the end of the period would enable performance to be optimised during the ensuing period. In this sense, they are similar to the husbandry constraints, defined by Barnard and Nix (1979), for long-term farm productivity.

Most planning models include processes that involve the identification, analysis and selection of alternatives (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Buckett, 1988; Giles and Renborg, 1990; Kay and Edwards, 1994). The case farmers rarely formally analysed alternative courses of action as part of the formal feed budgeting process. Rather, their "typical" plan, or a modified version of it, was used and the only analysis was the estimation of the likely drying off date. Alternatives that were analysed were components of the plan (e.g. the introduction of urea) rather than entirely different plans. The reason for the paucity of analysis appeared to be a function of the level of the plan in the planning hierarchy and the role of heuristics in plan development. The majority of decisions about the management practices, and type and amount of inputs were made at the strategic level prior to the tactical plan's development. For example, Farmer B's decisions to grow a new type of forage crop, or introduce maize silage into the autumn plan, were made prior to the summer-autumn period. Analysis was therefore only required if the case farmer decided to investigate: the addition of a new, or removal of an existing activity (input or management practice), or a different level of input. Alternatively, weather conditions forced the case farmers to change the sequence or timing of events, the rate of input use or the type of input.

Only four examples of the case farmers formally analysing alternative courses of action during a planning exercise were recorded. In three of these, a specific alternative (or option) was compared with the "status quo". No other options were considered or screened in contrast to the findings of Gladwin (1976, 1979ab, 1980, 1983, 1989) and

Ohlmer *et al.* (1998). A feed budget was used to simulate the plan "with" and "without" the option. The impact on cow condition and milk production was mentally assessed because the feed budget did not provide this output. The number of criteria used to determine the best option were less than that reported by Catley *et al.* (2000) and included factors such as average pasture cover, cow condition, milk production and risk of the cull cow price falling. The case farmers selected between options using non-financial criteria, thereby foregoing the need to undertake a full financial analysis. This appeared to be a simpler process than Gladwin's (1976, 1979ab, 1980, 1983, 1989) elimination by aspect.

One instance of a more complex, analytical process was identified: exploration of options to extend the lactation. Three options were screened using aspects such as risk and practicality until only one option was left. A formal partial budget was then used to quantify the value of using this option. At this point, profitability was the criteria for the adoption of the option since infeasible options had been screened out. Some aspects of this process were similar to that reported by Gladwin (1976, 1979ab, 1980, 1983, 1989) and Ohlmer *et al.* (1998) such as the initial screening of options. However, in this instance a formal partial budget was used to decide between options rather than a heuristics-based process as reported by Gladwin (1976, 1979ab, 1980, 1983, 1989). These results also support Jacobsen's (1993) findings that farmers use economic principles such as marginality when making decisions.

Following option selection, the next step in the formal planning models is the development of the plan (Boehlje and Eidman, 1984). Little is written about this aspect in the normative literature although Reisch (1971) and Wright (1985) identified this as an important area needing further development. This study suggests that this step is critical to the success of the planning exercise. Plan development by the case farmers involved decisions about the sequencing and timing of events, the type, level and combination of inputs used, priority of resource use and target selection. These important cognitive aspects (Wright, 1985) of the planning process were the same as those identified by Aubry *et al.* (1998) with the exception of target selection.

Only the case farmers' autumn plans were documented and this information was used for control purposes. Therefore, they did not follow the advice of Boehlje and Eidman (1984) and document their summer plan. Similarly, Jacobsen (1993), Aubry *et al.* (1998) and Ohlmer *et al.* (1998) reported that farmers rarely document their plans, and Ohlmer *et al.* (1998) found that farmers preferred mental to written plans because they were more easily updated. Ohlmer *et al.* (1998) also reported that farmers only tended to document complex financial plans. Establishment of standards of performance is another aspect of formal planning (Boehlje and Eidman, 1984). The standards (or targets) used in the summer plan were pre-defined and based on experience. They were designed to maintain the production system in a state that optimised performance over both the short- and long-term. In effect, they constrained the values of important production parameters within certain bounds designed to keep system performance on track. Target selection heuristics were used to determine the level of some key targets over both the summer and autumn periods if conditions were "atypical", to optimise systems performance under more extreme conditions. While this process was not found in the literature in relation to planning, Boehlje and Eidman (1984) identify this as a control response. Although some of the targets used in the autumn plan were derived from heuristics, (e.g. milk production, cow intakes, cow condition, terminating average pasture cover levels), the formal feed budget was used to derive intermediate average pasture cover targets.

The case farmers had a good understanding of the likely range of conditions they could expect. Contingency plans were "stored" mentally as could be expected given the tactical nature of the plans and the expertise of the case farmers. Other studies (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.,* 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.,* 1996; Aubry *et al.*, 1998) have also reported that farmers have pre-defined contingency plans which are activated when conditions deviate from the plan as proposed by Boehlje and Eidman (1984).

The case farmers used the final step in the formal planning process, the modification of plans in the light of control results (Barnard and Nix, 1973; Boehlje and Eidman, 1984), during both the summer and autumn to cope with uncertainty. Several authors (Reisch, 1971; Kennedy, 1974; Hanf and Schiefer, 1983; Jolly, 1983; Boehlje and Eidman, 1984; Wright, 1985) have argued that control and plan revision is important because of the dynamic nature of the planning process. This view is supported by the results from this and other similar studies (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998).

The case farmers did not formally analyse or account for risk in their planning procedures. For example, as reported by others (Quin, 1978; Gladwin, 1989; Ohlmer *et al.*, 1998), they did not use probabilities to assess the level of risk associated with alternative plans. Farmer A used conservative pasture growth rates to provide some flexibility, and both case farmers retained silage (maize or grass) in reserve to cope with extreme conditions. Risk was mainly managed through the farmers' control process. A wide choice of options (see Table 7.4) provided them with the flexibility to cope with deviations from the plan. The outcome from the planning process, the plan, is discussed next.

8.5 The plan

The "typical" or "modified typical" plan used by the case farmers comprised a set of heuristics that determined the activities, their sequence and timing, the type and level of inputs and the intermediate targets in the plan. In effect, they reflected the cognitive processes the case farmers had to undertake to develop their "typical" plan over time. Wright (1985) believed that these cognitive processes are central to planning. The heuristics used for planning by the case farmers could be classified into the categories identified by Aubry *et al.* (1998) of: sequencing, activation and termination or time range, arbitration and mode establishment decision rules. The sequencing rules could be further subdivided into obligatory and non-obligatory heuristics. Similarly, the mode of establishment decision rules could be separated into type, level and combination of input determining heuristics. Limited evidence of grouping rules (Aubry *et al.*, 1998) was found in the study other than grouping cows on the basis of age. Unlike cropping (e.g. Aubry *et al.*, 1998), and the more diverse alpine pastoral livestock farms (e.g. Fleury *et al.*, 1996), the case farmers tended to treat their paddocks as homogenous entities over the summer-autumn. Target selection heuristics, not identified by Aubry *et al.* (1998) were used to select intermediate targets for control purposes under "atypical" summer conditions.

The case farmers' knowledge of cause and effect relationships within the production system and the short- and long-term consequences of their actions formed the basis for developing planning heuristics. This corresponds with Papy's (1994) view that interaction occurs between a farmer's knowledge model and their plan (action model) and that this interaction is two way. That is, not only is the plan a product of the farmer's knowledge model, but conversely, the planning (and control) process contributes to the development of the knowledge model. Mathieu (1989) also reported the importance of farmers understanding grass physiology and the consequences of different actions on system performance. The planning heuristics were also a function of the case farmers' knowledge of the local climatic patterns. Several authors (Gladwin, 1979; Cerf *et al.*, 1993; Siddiq and Kundu, 1993; Fleury *et al.*, 1996) have reported on the influence a farmer's knowledge of climatic patterns has on their plans.

The planning heuristics used by the case farmers appeared to be based on the concept of marginality. Similar results were reported by Jacobsen (1993). As with Aubry *et al.* (1998), the priority of resource use within the case farmers' plans was based on the criteria of "impact on final yield". However, the case farmers were considering the effect not only in terms of impact on the current, but also next season's milk yield, where next season's yield had priority. A farmer's concern for longer-term productivity was also reported by Buxton and Stafford Smith (1996). Gross margins did not play a role in determining the priority of resource use as reported by Aubry *et al.* (1998) probably because in this study, only a single (rather than multiple) enterprise was involved.

The planning heuristics identified in this and the study by Aubry *et al.* (1998) make explicit the important planning decisions a farmer must make. These include:

1. What activities should be included in the plan?
2. How should the activities be sequenced?
3. When should an activity be activated and terminated?
4. What inputs, or combination of inputs should be used?
5. What level of inputs should be used?
6. How should resource use be prioritised?
7. What targets should be set to control the implementation of the plan?

Making these cognitive processes associated with planning explicit, enables farmers to reflect on the structure of their own plan and to compare this with those of others. It also provides researchers with a basis for understanding and comparing farmers' plans, as illustrated by the focus of the French work (Mathieu, 1989; Cerf *et al.,* 1993; Fleury *et al.,* 1996; Aubry *et al.,* 1998).

The plans used by the case farmers contained five important components: the goals for the planning period, a predictive schedule of events, a set of targets for controlling the implementation of the plan, a rich set of contingency plans that could be implemented if a deviation from the plan occurred, and a set of decision rules that were used in conjunction with the targets to implement the plan, or if a deviation occurred, implement a suitable contingency plan (Figure 8.3).

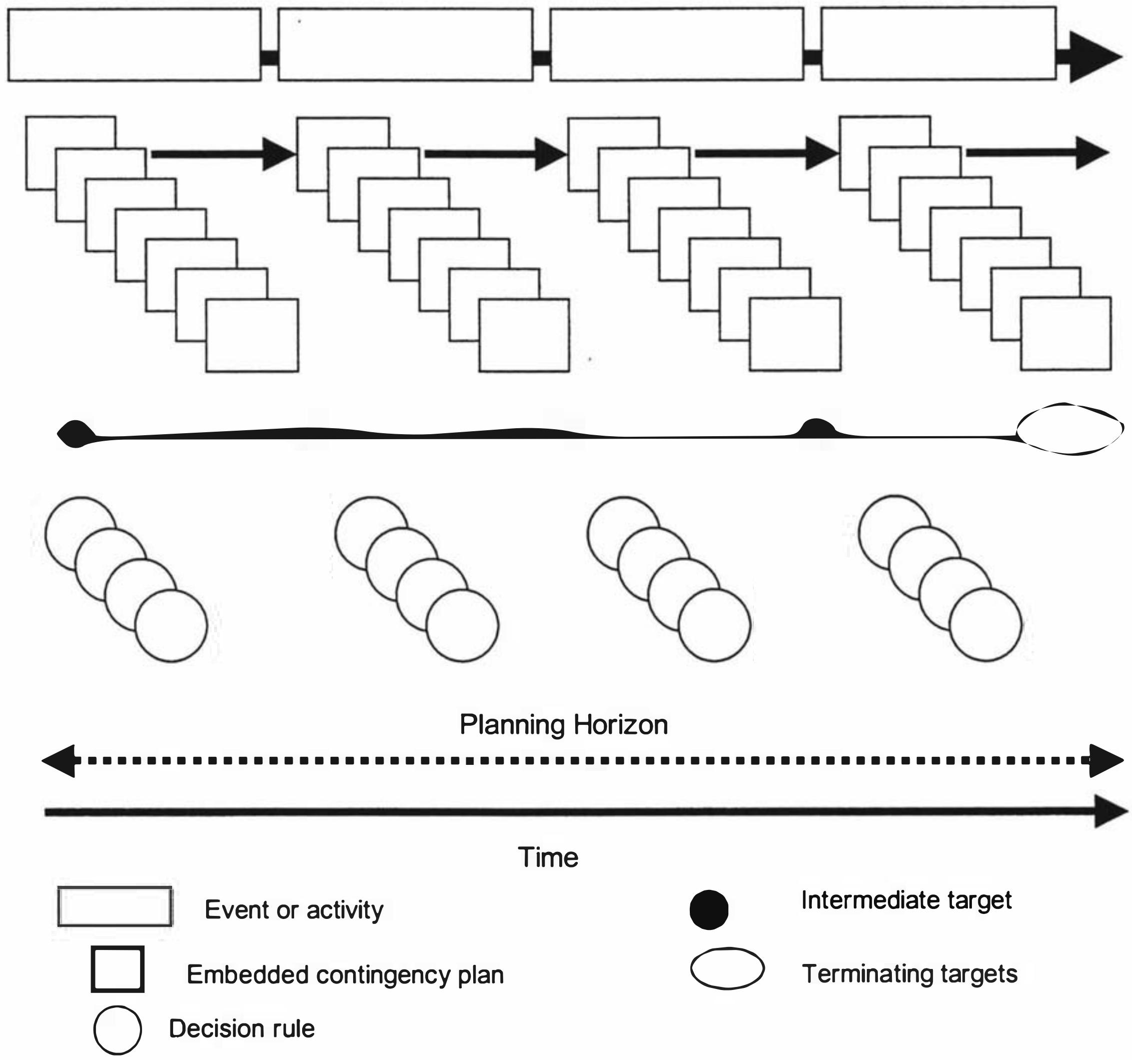


Figure 8.3. A diagrammatic representation of a case farmer's plan.

This structure (Figure 8.3) is identical to those reported from several other studies (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) although the terminology is different in several instances. The French (Sebillotte, 1993; Papy, 1994) referred to the plan as a "cognitive action model". Sebillotte (1993) described this as a representation of "*the mental image a farmer has of the actions required to attain certain objectives*". Gladwin (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984) referred to the plan as a "predefined plan" or "script". Both identified goals, a predictive schedule of events, and an associated set of intermediate targets as important components of farmers' tactical plans. Neither made reference to contingency plans. Gladwin (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984) called these "embedded sub-plans" and found that farmers used decision rules to determine whether to implement the plan, or one of the "embedded sub-plans". In contrast, the French (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) coined the term "regulations" which incorporates both the decision rules and the contingency plans. These differences in terminology are not surprising given that Gladwin's work was undertaken from an anthropological perspective, while that of the French was undertaken from a systems perspective.

Implicit within the literature is the components one would expect in a plan. For example, Boehlje and Eidman (1984) discuss the process of planning and mention the need to clarify goals, set out procedures, define targets and develop contingency plans. However, the nature of what exactly a plan should comprise is not discussed and this is one of the criticisms raised by Reisch (1971) and Wright (1985) of the planning literature in farm management. In the following sections, the components of the case farmers' plans are discussed and compared with the literature. The section on the decision rules used to select between the plan and possible contingency plans, however, is left until the discussion on control, since these are primarily control decisions.

8.5.1 Goals and values

Goal formulation, as proposed by several authors (Buckett, 1988; Giles and Renborg, 1988; Olsson, 1988; Trip *et al.*, 1996) was found to be separate from, but an important driver of, the management process (Ohlmer *et al.,* 1998; Catley *et al.,* 2000). The case farmers' tactical goals were predefined and formulated at an earlier point in time. This is not surprising given the repetitive nature of tactical management (Gorry and Morton, 1971). Their tactical goals however, changed through time; as one goal was achieved, they moved to the next. These findings support the views of Neilson (1961), Gasson (1973) and Boehlje and Eidman (1984). The case farmer also had multiple goals in line with other studies (Gasson, 1973; Smith and Capstick, 1976; Gillmor, 1986; Fairweather and Keating, 1994). These could be represented as means and ends (Gasson, 1973; Trip *et al.*, 1996; Ohlmer *et al.*, 1997), or in a hierarchy of goals, targets and tasks similar to those proposed by Petit (1977) and Dalton (1982). The goals and targets could also be represented as a hierarchy that moved from the higher level goals of the period, to production goals, which in turn dictated animal requirement goals, which then determined forage state objectives (pre- and post-grazing residuals, average pasture cover) in much the same way as proposed by Mathieu (1989). As with the farmers in Mathieu's (1989) study, the case farmers used the intermediate targets (milk production, condition score, average pasture cover) to determine when "regulatory" decisions had to be made. Therefore, a combination of decision rules and targets (intermediate and terminating) ensured congruence between goals and minimised conflict of purpose.

Like other pastoral-based agriculturalists (Landais and Deffontaines, 1989), the case farmers were continually faced with decisions about whether livestock should consume forage "now", or "later". Decisions were constrained by concern for the longer-term productivity of their system as reported by Buxton and Stafford Smith (1996). Thus, although there were conflicts between decision options during the summer-autumn, e.g. whether to use feed to maximise current milk production, or conserve it for next season's production, the case farmers always placed longer-term productivity ahead of short-term gains. Terminating targets at the end of a planning horizon were designed to ensure this occurred. Similarly, some of the intermediate targets and decision rules were aimed at protecting resources such as capital stock (cow condition) and pastures (new grass, post-grazing residuals and average pasture cover). The case farmers did not mention objectives for each field [paddock], as reported by Cerf *et al.* (1993), Fleury *et al.* (1996) and Aubry *et al.* (1998). This may be because the fields on New Zealand dairy farms are treated as being relatively homogeneous over the summer-autumn.

The case farmers' tactical goals over the summer-autumn were similar in nature to the strategic goals reported by Ohlmer *et al.* (1998). They reported that farmers tended to express goals in qualitative (direction of change) as opposed to quantitative terms. This is in contrast to Kay and Edwards (1994) who recommended that goals should be written, specific, measurable and specified for a precise time period. The case farmers specified the time period, but did not cover the other aspects suggested by Kay and Edwards (1994). Although the case farmers wanted to optimise milk production over the summer-autumn, they did not quantify this goal for production management purposes because conditions were perceived by them to be too variable for such goals to be precise[5]. Similarly, Wright (1985) and Kaine (1993) found that farmers facing high risk situations had broad imprecise objectives. While the case farmers had annual milk production goals specified in their financial budgets, these played no part in their tactical feed management due to the level of uncertainty they faced. In contrast, they had very specific and quantifiable targets including milk production per cow per day for operational and tactical management.

[5] They did quantify this goal for financial management purposes, but did not expect to achieve it with any degree of precision.

As reported in other descriptive studies (e.g. Ohlmer *et al.*, 1998), personal values appeared to play a limited role in tactical management. Like Gasson (1973), it was found that values influenced a farmer's choice among available modes of operation, in this case the level and type of inputs used. Fleury *et al.* (1996) considered that to understand farmer's tactical management, one had to appreciate higher level issues such as the degree of intensification they were willing to undertake.

8.5.2 The predictive planning schedule

As reported in other studies (Gladwin and Murtaugh, 1980; Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998), the case farmers had a "typical" plan that contained a predictive planning schedule of the events or activities to be undertaken to achieve targets. Five factors influenced the nature of the case farmers' predictive planning schedule and these accounted for between-year and across-farmer differences: values, strategic decisions, learning, prior tactical decisions and the state of the farm at the start of the planning period (Figure 8.4). Values influenced the farmers' strategic choices, which in turn influenced the structure of the predictive planning schedule. Other authors have reported the influence of values (Gasson, 1973) and attitudes towards intensification (Fleury *et al.,* 1996) on farmers' plans. Over the three year period, the case farmers' predictive planning schedules diverged considerably, primarily as a result of strategic decisions made by Farmer B to increase inputs over the summer-autumn. In contrast, Farmer A was prevented from pursuing this approach by his "low input" philosophy. Through learning (Aubry *et al.,* 1998), new or improved management practices were identified, some of which were introduced into the case farmers' predictive planning schedules. Prior tactical decisions also influenced the predictive planning decision. Although implicit in the management process, this has not been reported in the literature. The state of the farm at the start of the summer could precipitate changes to the "typical" plan. Little is understood about what influences between-year and across-farm differences in predictive planning schedules.

The case farmers' predictive planning schedule had inherent flexibility. Although some summer and autumn activities were date specific (e.g. pregnancy testing, sowing new grass), the timing of most was specified by condition-dependent heuristics. The latter reduced the need for plan revision in response to changing conditions, i.e. if conditions were below average, the heuristic triggered the next event in the plan earlier. Similar results have been found in other descriptive studies (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998).

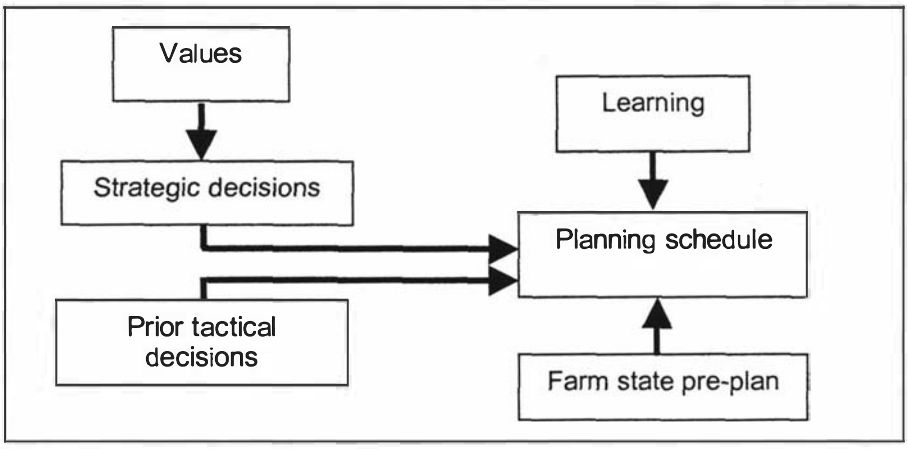


Figure 8.4. Factors that influence a farmer's predictive planning schedule.

8.5.3 Targets

The third component of the case farmers' plans was their targets (or standards) (Figure 8.5). These were used in two main ways, first to trigger the implementation of the activities specified in the plan, and second, to identify when the outcome deviated from the plan. In the latter case, suitable contingency plans were adopted to minimise the impact of the deviation. This is the same as the role attributed to targets in the normative (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994; Parker, 1999) and descriptive literature (Mathieu, 1989; Fleury *et al.*, 1996; Aubry *et al.*, 1998) although the former tend to only mention their role in relation to deviations from the plan. The case farmers used a broad range of targets, some 19 were common. In the literature the focus tends to be on the indicators that are measured rather than the standards against which they are compared. As such, inferences must often be drawn on the basis of comments made about indicators. For example, Cerf *et al.* (1993) concluded that arable farmers needed a large set of indicators for management. It can be inferred from this that a large set of associated targets is required. Landais and Deffontaines (1989) also reported that shepherds in the southern French Alps used a large and diverse number of indicators, but made no mention of corresponding targets.

A novel typology of target types was developed from the case studies (Figure 8.5). Two main types of targets were used in tactical management: terminating and intermediate. The former were specified at the end of a planning period and acted as "sustainability" constraints in much the same way as Barnard and Nix (1973) described for "husbandry" constraints. In contrast, intermediate targets were applied between the start and end of the planning horizon. Mathieu (1989), Fleury *et al.* (1996), and Aubry *et al.* (1998)

identified these as intermediate objectives. They can be separated into three types: benchmark dates, milestones, and thresholds (Figure 8.5). Benchmark dates specify the date at which a certain activity or event must be implemented. Milestones, on the other hand, are projected steps on the way to a final terminating target, for example, intermediate average pasture cover targets. Threshold targets, if exceeded, trigger an activity or event. Aubry *et al.* (1998) mentioned that farmers used dates and “states of progress of work” to activate events within the plan or contingency plans, but did not place these in a typology. Mathieu (1989) separated intermediate objectives into production, animal requirement, and forage state targets. She also described "regulations" to adjust regrowth speed, and regrowth duration, but did not mention targets or objectives for these factors. Intermediate targets were identified for production, animal requirements, forage state, climatic events and regrowth duration (rotation length). These had associated benchmark date targets. Some of these can be viewed as sub-categories of the "milestone" and "threshold" categories.

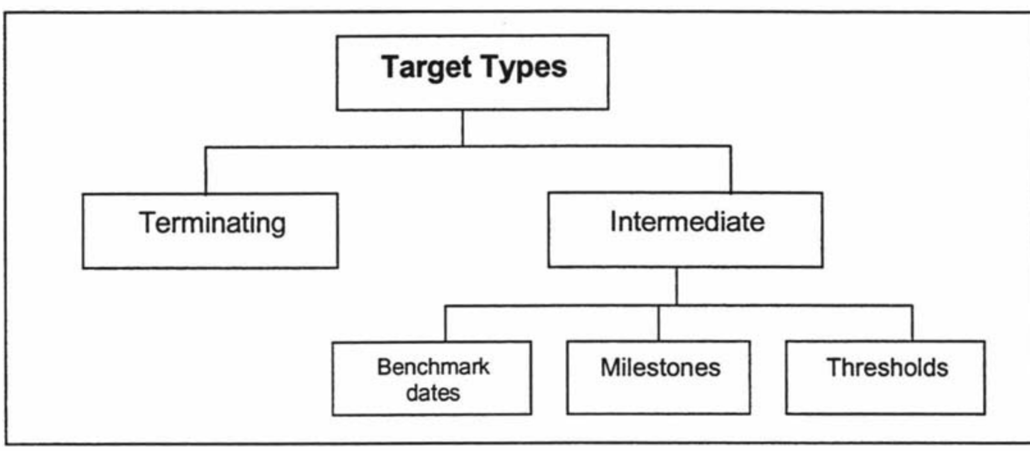


Figure 8.5. A typology of target types.

Intermediate targets had three roles: controlling the implementation of the plan, ensuring the terminating targets were met, and optimising system performance. Except for the first, little mention is made of other roles in the literature, although the third role is often implied (e.g. Parker, 1999). Targets changed from one planning period to the next. Thus, milk production was the primary target for summer, while average pasture cover took over this role in the autumn plan.

Little has been written on how farmers derive targets (Osburn and Schneeberger, 1983; Boehlje and Eidman, 1984). The case farmers’ targets were based on previous experience and their knowledge of farm system dynamics. Osburn and Schneeberger

(1983) recommended obtaining targets from farms that operate under similar conditions. Both case farmers belonged to a local district discussion group and interaction with this may have provided input into their target formulation. Farmer B compared his farm to similar farms in the district when evaluating performance. Budgets have been advocated as another source of targets (Osburn and Schneeberger, 1983; Boehlje and Eidman, 1984), and both case farmers used feed budgeting to derive intermediate average pasture cover targets.

Biological growth charts and lactation curves, and goals are alternative sources of information on targets (Boehlje and Eidman, 1984). A biological growth chart was used in one instance when Farmer B brought replacement heifers back onto the milking area in year two[6]. Actual liveweights were compared with targets from a growth chart. Surprisingly, given the overriding importance of farm milksolids yield, lactation curves were not used to derive milk production targets although the farmers did have milksolid yield targets for various stages of the summer-autumn period for financial management purposes.

Goals combined with the case farmers' tacit knowledge played an important role in target derivation. Targets were linked: thus, those associated with termination influenced intermediate targets. In turn, intake and post-grazing residual targets were also logically derived from the intermediate milk production targets as reported by Mathieu (1989). For example, if Farmer B wanted the herd to produce 1.04 kg MS/cow/day, he knew that to do this, they had to consume 12.0 kg DM/cow/day, and that to do this, they needed to leave behind a post-grazing residual of 1400 kg DM/ha. The cascade of targets provides most clues on where management intervention should occur. Most of the targets used by the case farmers were identical. Goals, planning horizons, knowledge and local experience contributed to the few variances. Some targets changed during the study in response to changes in production goals, strategic decisions, environmental conditions, learning or some combination of these.

A change to one target, for example milk production, precipitated changes to related targets (e.g. feed levels). Many of the targets were flexible. They could be adjusted to suit the conditions, as recorded also by Fleury *et al.* (1996). Adjustment of targets is viewed as a normal control response in the normative literature (Boehlje and Eidman,

[6] These were normally kept off the milking area and were not expected to become part of the study.

1984). However, some targets were non-negotiable within a season. These were the terminating conditions for the autumn plan including the targets set for calving or balance date (pasture cover, and/or cow condition score). They were non-negotiable because they were critical for ensuring optimum production in the next planning period.

8.5.4 Contingency plans

Boehlje and Eidman (1984), in one of the few comments on contingency plans in the normative literature, recommended farmers prepare a set of contingency plans for different forecasted scenarios. In contrast, the case farmers' contingency plans were developed through time from experience. A wide range of options to cope with different conditions was available. Two feed situations over the summer-autumn were confronted: a deficit or surplus. Two "types" of responses were available for each of these "situations" (Figure 8.6) and these were mirror images of each other. Thus, in a feed deficit situation, the case farmers could implement contingency plans that would increase feed supply, reduce feed demand, or produce a combination of these responses. These control responses were used in the manner proposed by Makeham and Malcolm (1993), to minimise the impact of adverse situations and exploit favourable circumstances. Mathieu (1989) classified contingency plans on the basis of their impact on either grazing duration or rate of pasture regrowth. This is useful from an agronomic perspective, but does not identify the management "problem" facing a farmer.

Contingency plans were either sourced from existing resources (e.g. cow condition, stored feeds), or externally (e.g. nitrogenous fertiliser, grazing, maize silage, greenfeed maize). The latter increased the farmers' "system" variety to cope with uncertainty (Dalton, 1982). The typology in Figure 8.6 is useful when comparing different pastoral-based systems, and it could be applied to other tactical management fields such as cash flow management, water budgeting and labour management. However, at a more abstract level, the typology shown in Figure 8.7 may provide a more useful framework in relation to tactical management. It defines the impact a contingency plan can have on the plan when implemented, rather than its impact on the problem situation. The categories in this typology are similar to those identified by Aubry *et al.* (1998) for planning heuristics.

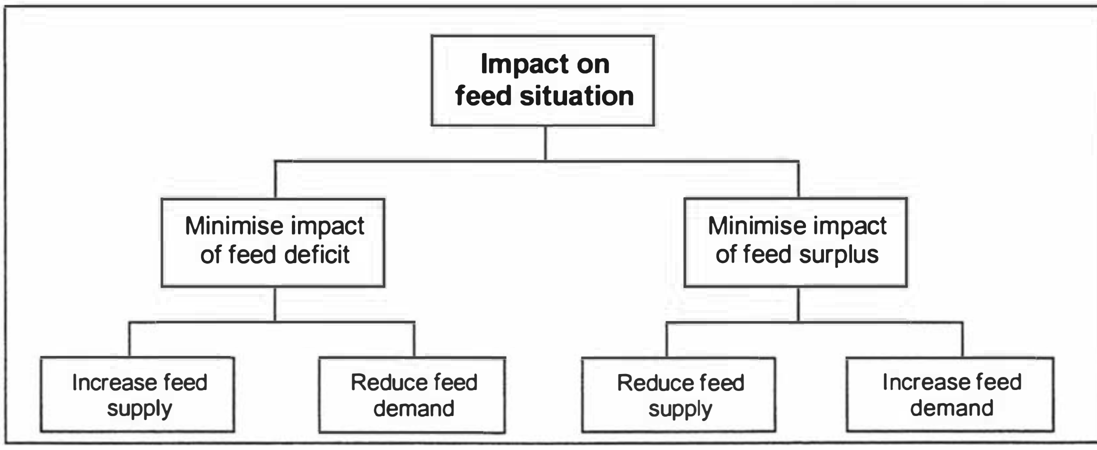


Figure 8.6. Typology of contingency plans used by the case farmers.

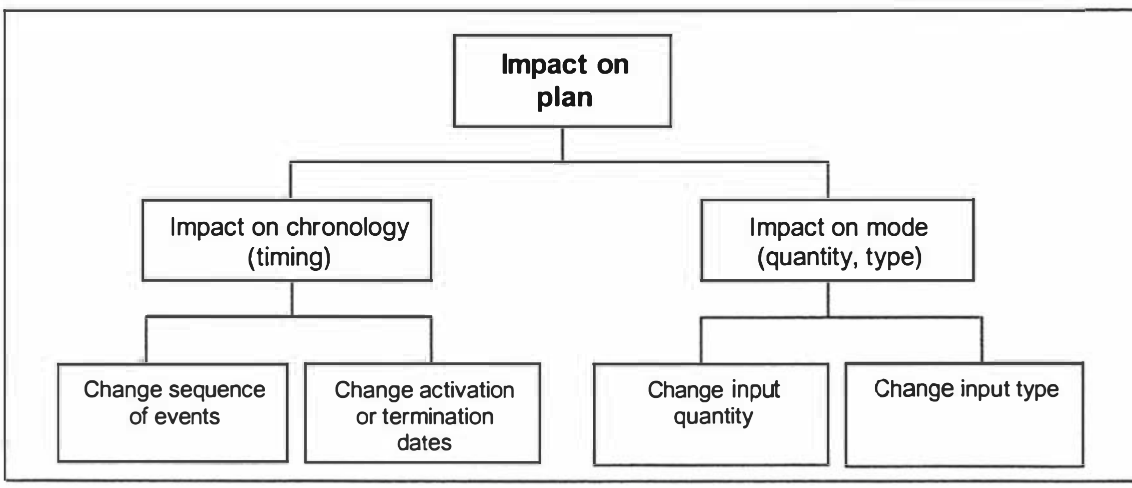


Figure 8.7. An alternative typology for the contingency plans used by the case farmers.

8.6 The control process

The control process used by the case farmers (Figure 8.8) was consistent with other studies of tactical management (Gladwin and Butler, 1984; Gladwin *et al.*, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). These studies have also shown that farmers monitor a range of indicators and compare these to intermediate objectives or targets in their plans. When an indicator reaches a threshold value, a decision point is identified. Decision rules are then used to determine what action to take. This may be to continue the implementation of the plan, or it may be to modify the plan in some way. At each decision point in the plan, farmers had a set of sub- or contingency plans. Decision rules were used to select the contingency plan that would best minimise the impact of any deviation from the plan.

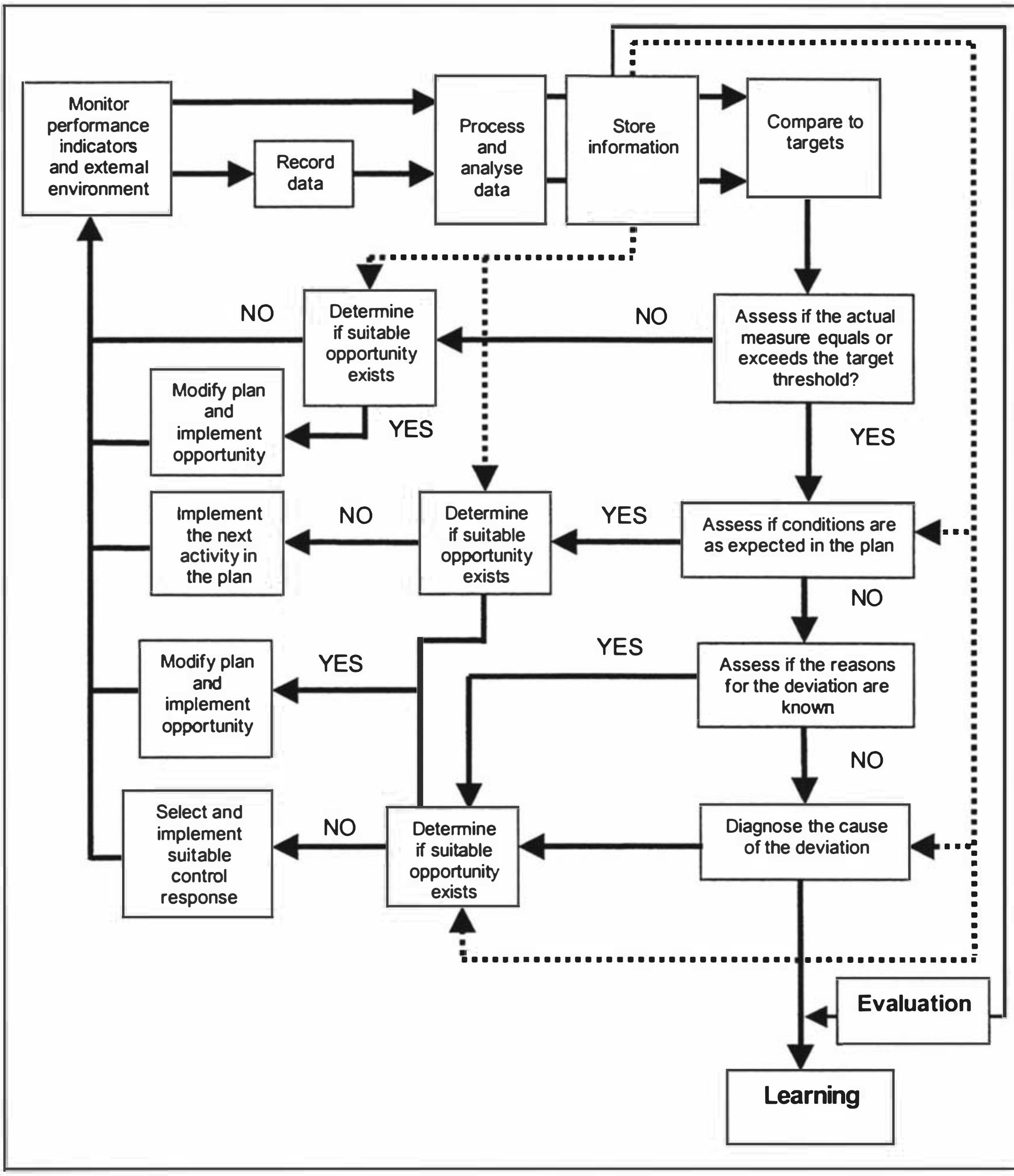


Figure 8.8. The control process used by the case farmers.

Some differences between earlier studies and the current study were identified. These differences reflect the background of the researchers since neither of the earlier research groups had a background in mainstream farm management. For example, Gladwin

(Gladwin and Butler, 1984; Gladwin *et al.*, 1984) is an economic anthropologist, and the French researchers (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998) have approached their research from a systems perspective. As such, they do not use certain concepts, which are basic to mainstream farm management. For example, they do not mention the term control, and nor have they separated control into the monitoring and evaluation functions. Similarly, they make no mention of opportunity finding, recording, data processing, data analysis or information storage. Also, few references are made to farmer learning in these studies. Aubry *et al.* (1998) mentioned that farmer learning accounted for some of the between-year variation in farmers' plans, but they did not incorporate this aspect into their model of tactical management. Similarly, Papy (1994) stated that interaction occurred between a farmer's action model (tactical management process) and his knowledge model of the production system. However, this was not elaborated on.

The control process used by the case farmers (Figure 8.8) was also similar to that advocated in the normative literature (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994; Parker, 1999). A minor distinction is that the establishment of standards is incorporated into the "control" process (Boehlje and Eidman, 1984) whereas the results from this study suggest standards or targets are established during planning. However, this is a case of semantics because Boehlje and Eidman (1984) also advocated that standards be set during the planning process. The recording and storage of monitored information is assumed in most models of control (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994), although Dalton (1982) viewed it as a separate function of management. Most data collected by the case farmers was not recorded. This is not surprising given the quantity of information and the subjective, qualitative nature of much of it. Limited analysis was undertaken on the data and where this did occur it comprised mainly the calculation of means or ratios as proposed by Barnard and Nix (1973). Information, stored in memory or in some documented form, was later used for other management functions such as contingency plan selection, diagnoses, evaluation and planning as proposed by Boehlje and Eidman (1984).

Mauldon (1973) stated that control encompasses the decision of whether or not to depart from the current plan. This was a key part of the case farmers' control process and as with the normative model, they compared the monitored information to their targets (or standards). If the performance indicators were below (or above[7]) the targets, then the case farmers continued to monitor the implementation of the plan, much in the same way as proposed in the normative literature. However, when one of the performance indicators matched or exceeded a target, a decision point was reached to either continue to implement the plan or adopt a contingency. For both options, secondary indicators were used for option selection. Relative to the normative literature (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994; Parker, 1999), which focuses on identifying deviations and the need for management control, the case farmers put additional input into the use of targets to control implementation.

The case farmers used a diagnostic process to identify the reasons for a deviation from the plan, and an evaluation process to assess the efficacy of a management decision (Figure 8.8). An important distinction in this model is that two processes, diagnosis and evaluation, were identified. In the normative literature, these two processes are encompassed under a general term, "*evaluation*", (Barnard and Nix, 1973; Mauldon, 1973; Boehlje and Eidman, 1984; Parker, 1999). The results also support the views of Johnson (1954), Mauldon (1973), Makeham and Malcolm (1993) and Parker (1999) that learning is an important outcome of the evaluation process (Figure 8.8). Once the cause of a deviation from the plan was identified, the case farmers implemented an appropriate control response (Figure 8.8). This was again consistent with the normative literature (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994; Parker, 1999).

Farmer B used monitoring to actively seek out opportunities to expand options and improve farm profitability. Farmer A, on the other hand, relied solely on the resources set out in his plan at the start of a planning period. Normative models of the control process do not incorporate an opportunity recognition step (Bamard and Nix, 1973; Mauldon, 1973; Boehlje and Eidman, 1984). The focus tends to be internal and on ensuring performance matches that predicted in the plan. Interestingly, several authors (Lee and Chastain, 1960; Nielson, 1961; Suter, 1963) in the early 1960's recognised the difference between problem and opportunity recognition. While this distinction was not incorporated into control process models, Boehlje and Eidman (1984) made it in their decision-making model. Similarly, in a recent study of decision-making, Catley *et al*. (2000) distinguished between problem detection and "prospecting", where prospecting is equivalent to opportunity finding. The components of the control process are discussed in more detail in the following sections.

[7] This depends on the nature of the target.

8.6.1 Monitoring

The case farmer's monitoring process comprised: the factors that were monitored, the method of monitoring, the roles the monitored information played, the means by which, and reasons why monitoring frequency changed, and dealing with errors. These aspects are discussed in more detail in the ensuing sections.

8.6.1.1 The factors that are monitored

The case farmers monitored a large number of factors (28 – 41) over the summer-autumn. Only one other study (Landais and Deffontaines, 1989) reported a similar breadth of monitoring. The factors monitored by the case farmers were both internal (those which the case farmers have control over) and external (those outside their control), (Figure 8.9). The internal factors monitored all related to "production". Finance and labour were not found to be important in relation to tactical production management for these cases. The external factors monitored by the case farmers comprised climatic and market factors.

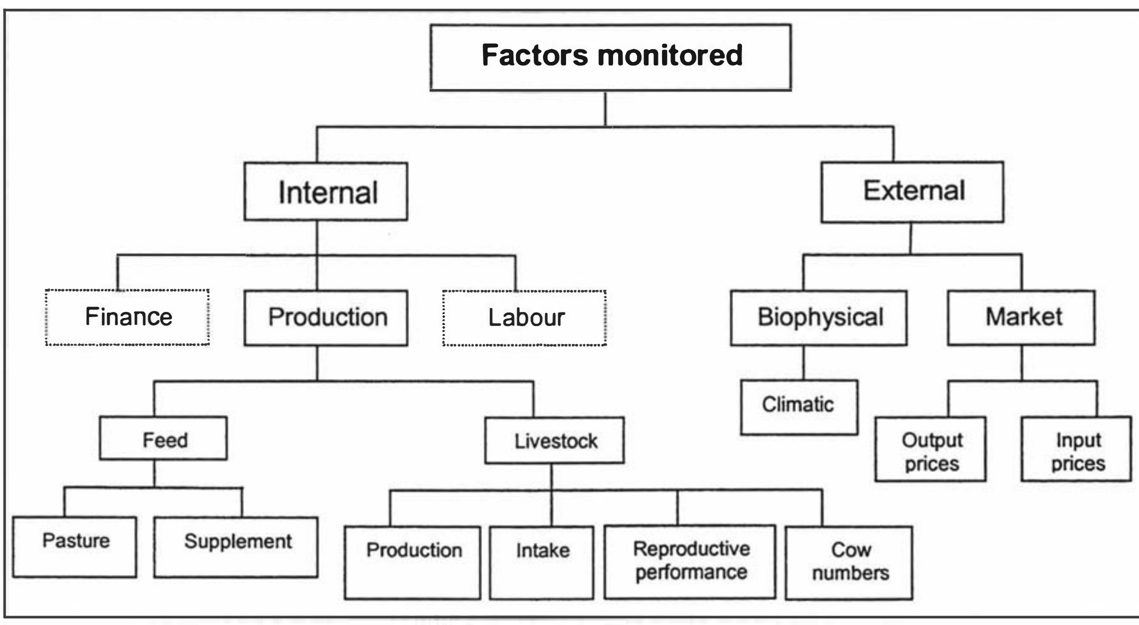


Figure 8.9. A typology of the factors monitored by the case farmers[8].

The case farmers' approach aligns with Kennedy (1974) and Boehlje and Eidman (1984) who suggested a systems approach for identifying factors to monitor and separating these on the basis of whether variables were endogenous or exogenous. Examples of a

[8] The categories in boxes with a dotted margin are categories not identified during this study, but postulated as part of a broader typology.

typology of the factors monitored by farmers for tactical management purposes have not been reported in the literature. Harsh *et al.* (1981) did however distinguish between on and off-farm sources of information. The internal factors monitored by the case farmers were all classified under production. However, one could expect that if the focus had been financial or labour management, these categories would have been identified. Boehlje and Eidman (1984) recommended identifying areas of control on the basis of enterprises or activities. They separated these into production, servicing and marketing enterprises but did not separate internal and external factors. As such, climate would be incorporated under production. The work of Emery and Trist (1965) also suggests that where there is competition between agricultural businesses, managers will monitor the activities of their competitors. In this study, the farmers were members of a cooperative industry with no direct competition for milk supply and payment was the average price per kilogram milksolids supplied with no seasonal premia or differentials.

Three reasons for differences in the factors the case farmers monitored were identified: input use or activities, unusual or extreme conditions, and farmer values ("low" versus "high" input philosophy). Between-year differences in the factors monitored by the case farmers were attributed to changes in inputs or activities, or unusual conditions.

The indicators of tactical management can also be classified into a typology that comprises market and production indicators (Figures 8.10, 8.11, 8.12, 8.13, 8.14). Few studies, with the exception of Landais and Defontaines (1989), have reported on the range of indicators used for tactical management and none provide a typology of indicators, although Mathieu (1989) reported that the farmers used indicators that measured the physical state of the livestock and forage, a similar cleavage to that identified in this study.

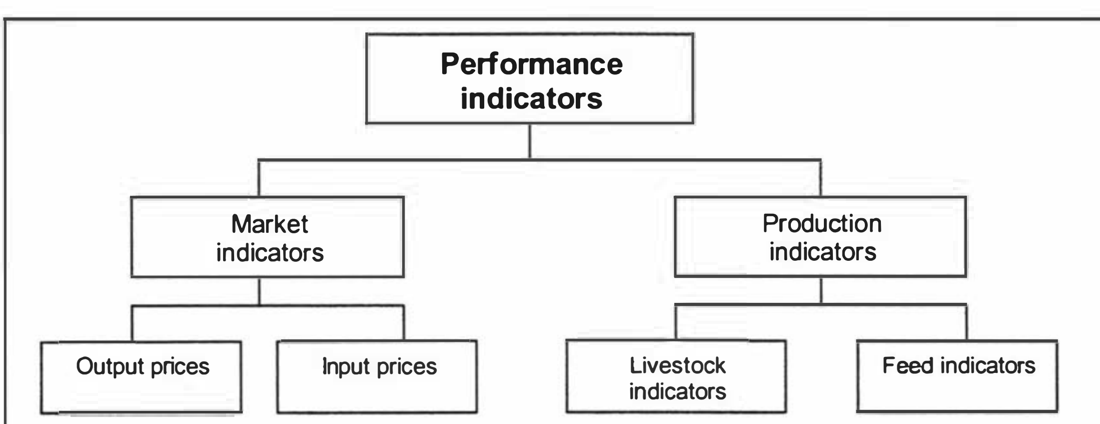


Figure 8.10. A typology of the performance indicators used by the case farmers.

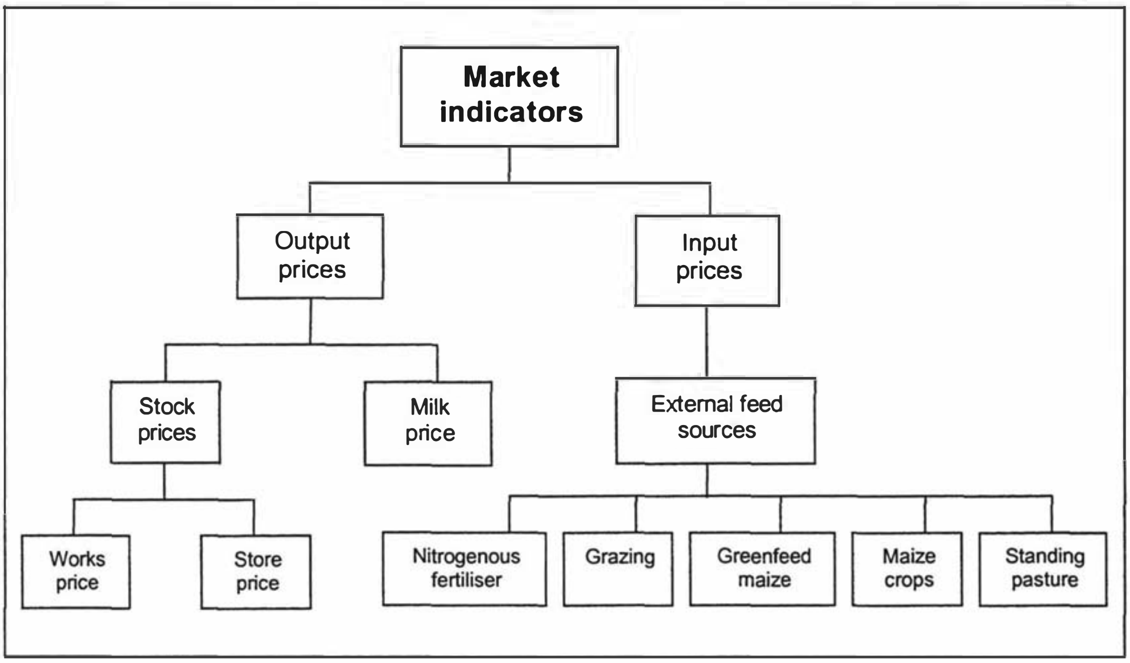


Figure 8.11. A typology of the market indicators used by the case farmers.

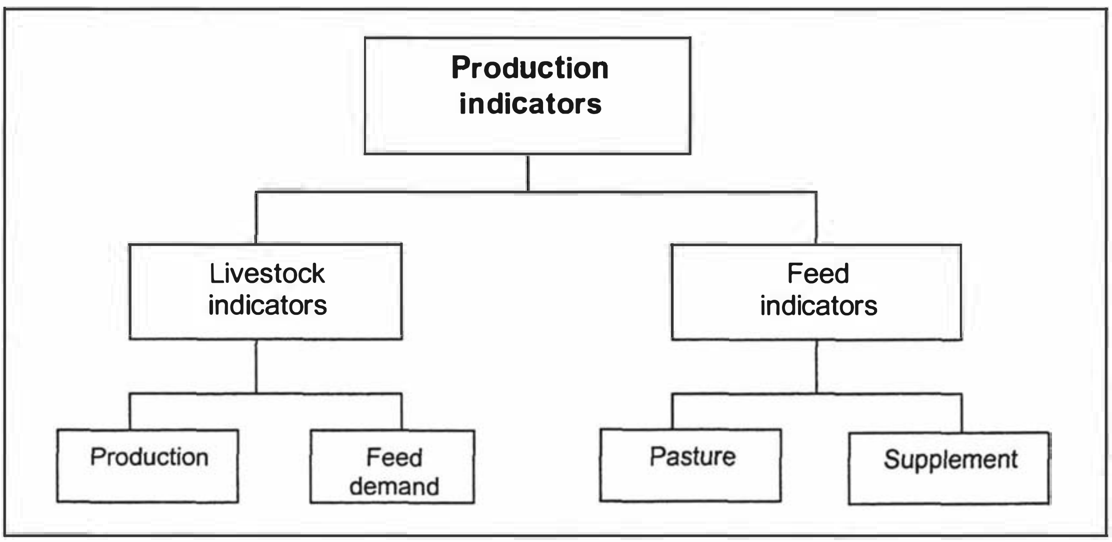


Figure 8.12. A typology of the production indicators used by the case farmers.

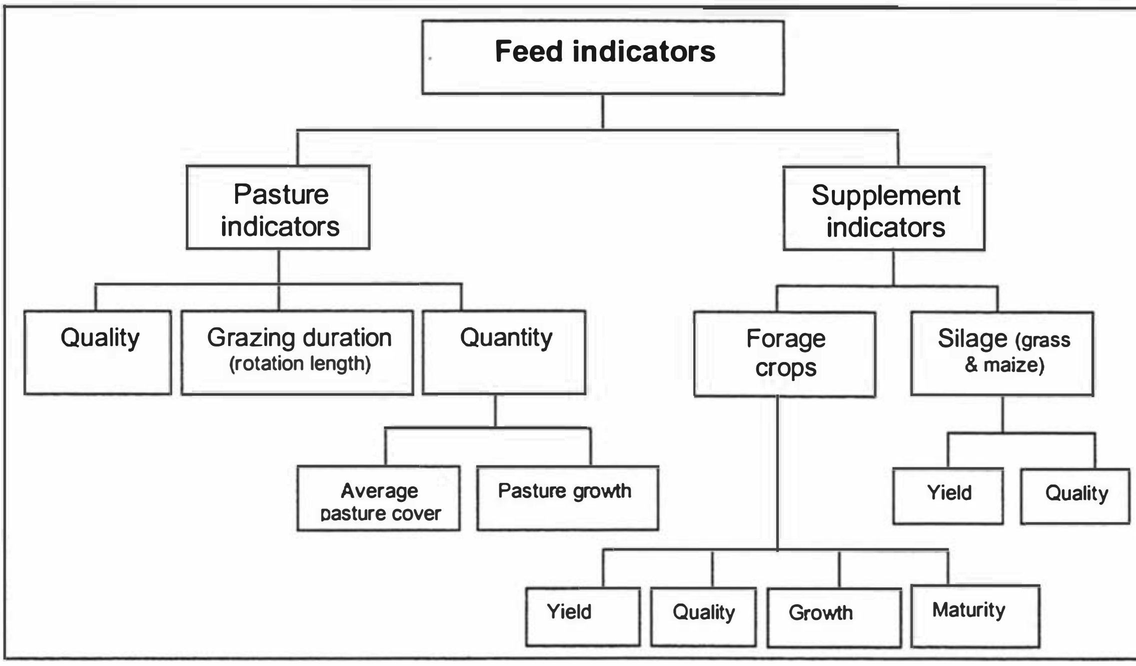


Figure 8.13. A typology of the feed indicators used by the case farmers.

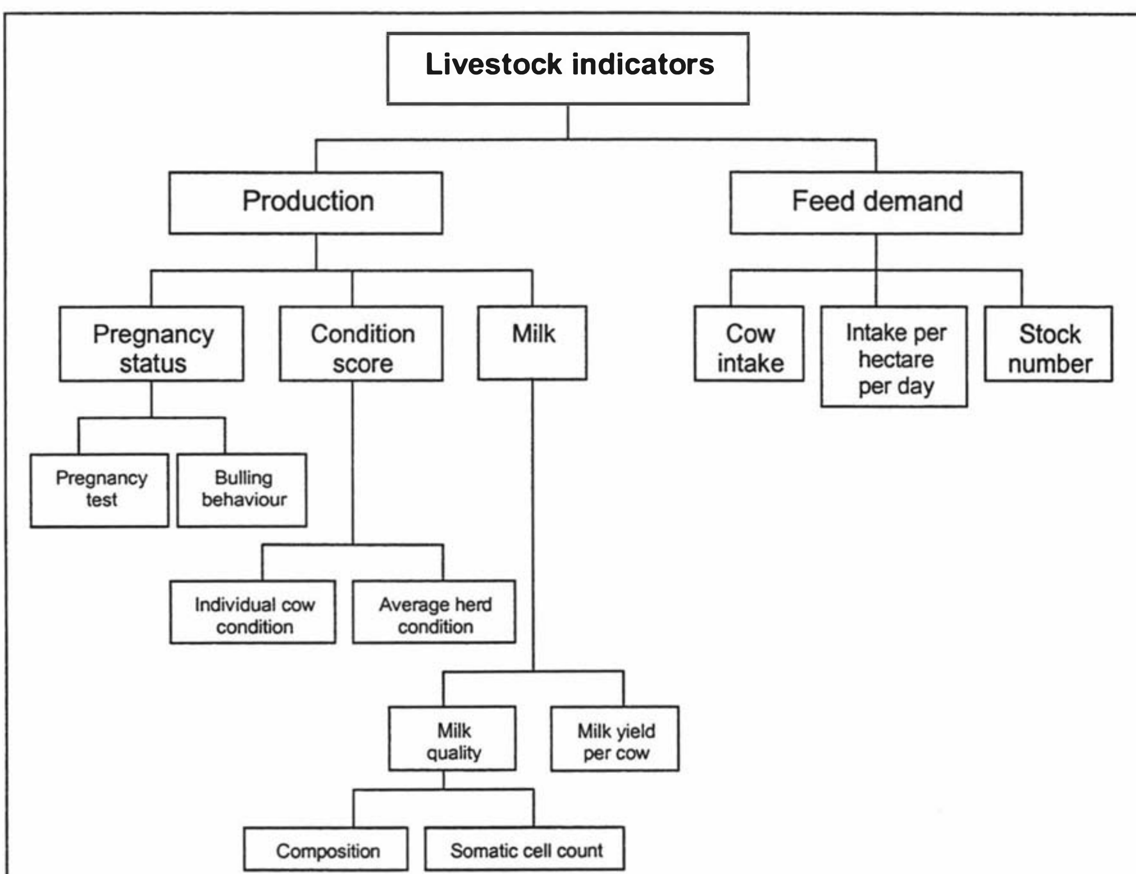


Figure 8.14. A typology of the livestock indicators used by the case farmers.

Little is written about the nature of the indicators, or the monitoring process used by farmers in the descriptive literature. For example, Cerf *et al.* (1993) only mentioned three indicators, and Fleury *et al.* (1996), Aubry *et al.* (1998) and Catley *et al.* (2000) provided even less information on the nature of the indicators used by farmers in their studies. Similarly, little information on the nature of the indicators used by farmers was provided by Ohlmer *et al.* (1998) in a study of strategic decision-making. It appears that more is written about the development of simple and effective indicators that scientists can use to monitor the management practices of farmers than about the indicators used by farmers (Mathieu and de Vaubernier, 1988; Gilbert and Mathieu, 1989; Havet and Lafon, 1992).

Between-farm differences in the use of performance indicators were attributed to differences in input use, activities, or the use of alternative indicators for the same purpose. The main causes of between-year differences in performance indicator use were changes in input use or activities. These were a result of previous strategic or tactical decisions. No information was found in the literature on the reasons for between-farm and between-year differences in performance indicator use.

8.6.1.2 Monitoring methods

The monitoring methods used by the case farmers can be classified into a typology (Figure 8.15). The objective, subjective distinction was made by Parker (1999). However, he did not separate subjective methods into further sub-categories. The results from this study found that these could be separated into quantitative and qualitative methods. A subjective, quantitative method, was one where a quantitative value was placed on a subjective assessment of a factor, such as pasture, condition and yield scoring. The converse applied to subjective qualitative measures such as the visual assessment of pasture on-hand or cow body condition.

Indirect measures were also important in the case farmers' monitoring systems and these were sometimes used in preference to a direct measure (e.g. use of milk production to measure pasture cover over summer). The effective use of these indirect measures required an in-depth understanding of the cause and effect relationships within the production system.

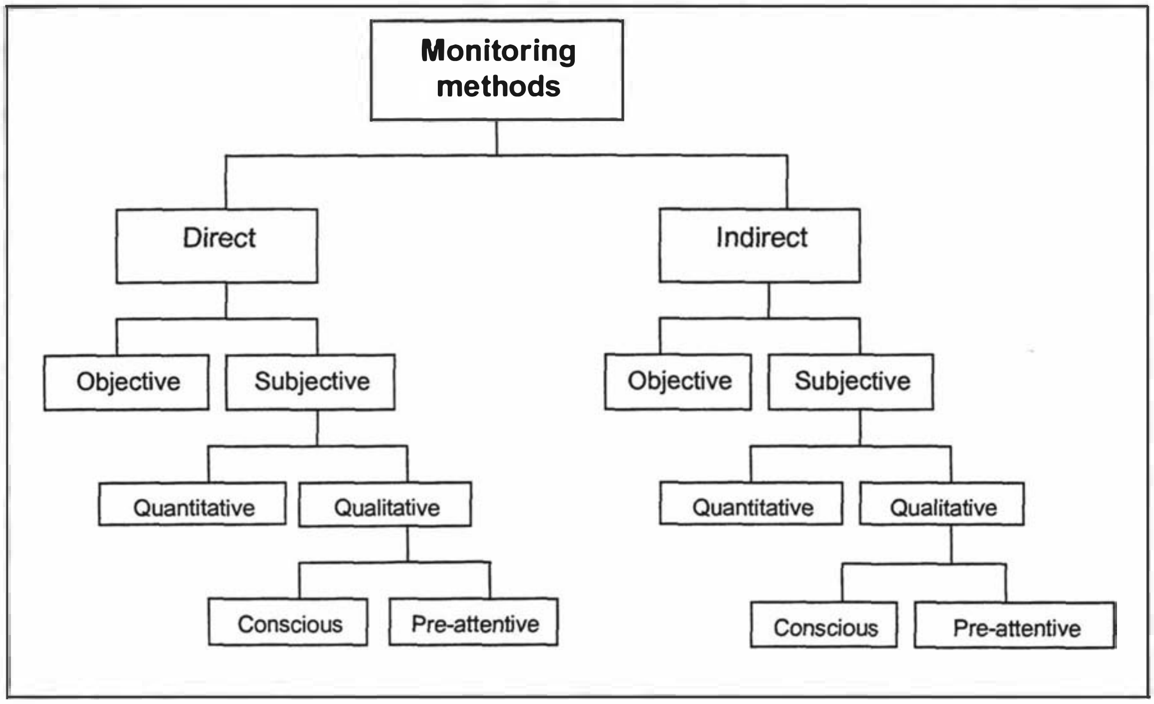


Figure 8.15. A typology of the monitoring methods used by the case farmers.

Subjective, qualitative methods can be separated into two sub-categories, conscious and pre-attentive (Figure 8.15). The former applied where the case farmers consciously made a visual assessment of a factor of interest. The latter applied where a factor was monitored sub-consciously. The state of the factor (e.g. cow condition) was not registered consciously by the case farmers unless they were either asked about it (by the author), or it crossed some threshold.

Most measures used by the farmers were subjective. They were considered to be timely, rapid, and required no capital outlay. They also had acceptable accuracy because they were calibrated against accurate objective measures. Parker (1999) argued that farmers were more likely to adopt subjective indicators, provided their accuracy was established through calibration to standards, because they were convenient and faster to measure. He also suggested that a proportion of farmers replaced objective measures with subjective measures once they had learned the association between relevant indicators. Thus, farmers learn visual "cues" that are associated with system performance. These then replace the objective measures. Another advantage of subjective measures was that they provide multivariate information whereas the information provided by objective measures tends to be univariate (Paine, 1997). The case farmers did not mention this: they primarily used univariate objective indicators for problem recognition.

Few between-farm or between-year differences in monitoring methods were identified. These occurred because base-line data was unavailable[9], or because the case farmers substituted one form of measurement for another. This substitution could be attributed to farmer preference, or between-year condition-induced changes in monitoring method. The literature is silent on these matters.

8.6.1.3 The role of information from the monitoring process

Monitored information played several important roles in relation to the case farmers' tactical management (Figure 8.16). These were: planning, decision point recognition, triangulation, early warning prediction, control response selection, and learning (diagnosis and evaluation).

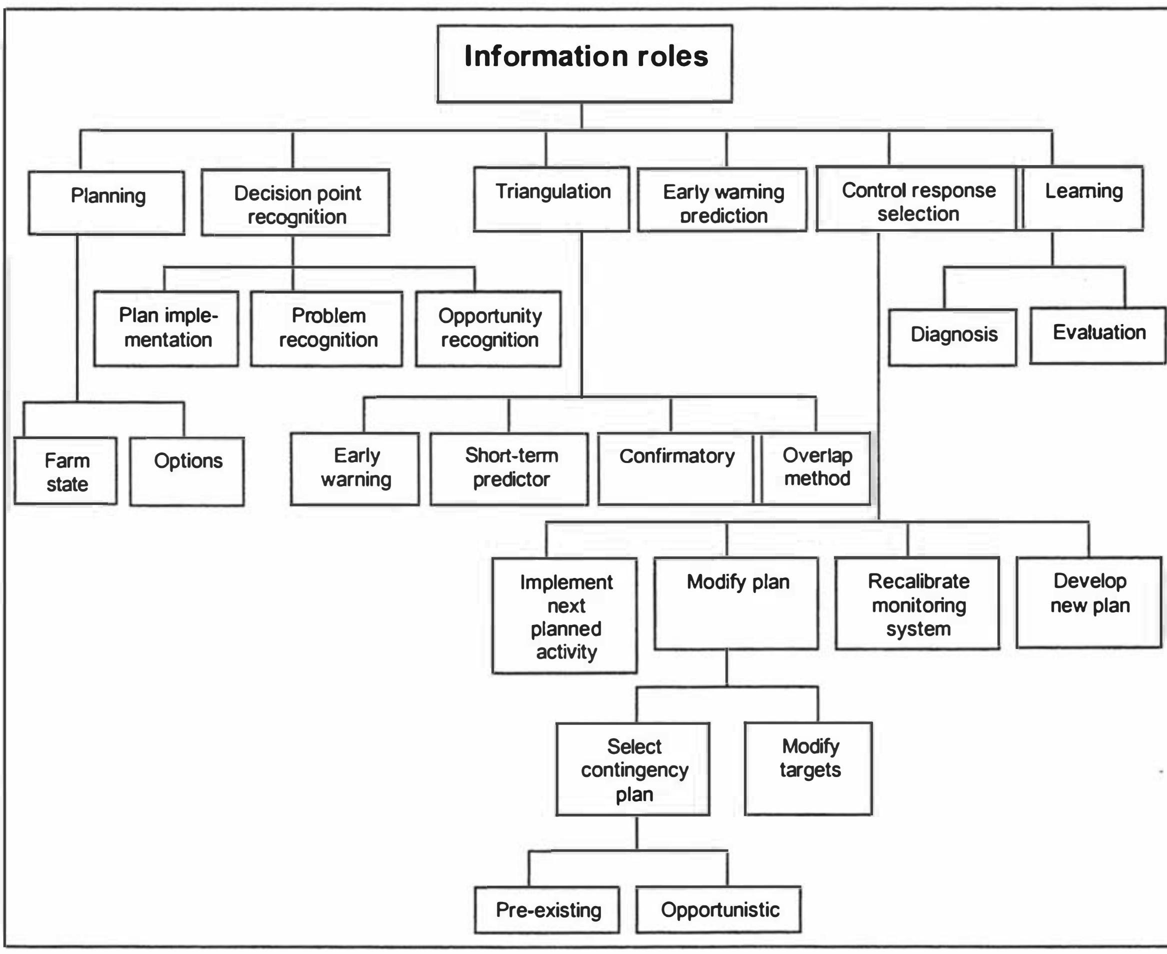


Figure 8.16. A typology of the roles monitored information played in the tactical management process used by the case farmers.

[9] Rapid conversion of dairy farm from arable property.

Few authors have taken a broad view of the role of information in the management process. A recent exception has been Ohlmer *et al.*'s (1998) study of strategic decision-making. The role monitored information plays in problem recognition is highlighted in both the normative (Barnard and Nix, 1973; Kay, 1981, Boehlje and Eidman, 1984, Kay and Edwards, 1994, Parker, 1999) and descriptive literature (Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998; Ohlmer *et al.*, 1997). The normative decision-making literature in the 1950's and 1960's identified information gathering as an important step preceding option generation, analysis and selection (Bradford and Johnson, 1953; Johnson and Haver, 1953; Johnson, 1954; Lee and Chastain, 1960; Johnson *et al.*, 1961; Nielson, 1961; Suter, 1963) and this has been supported by recent descriptive studies (Cerf *et al.*, 1993; Ohlmer *et al.*, 1998). Ohlmer *et al.* (1998) also found that problem detection induced farmers to search for options, and that the intensity of the search was a function of the importance of the problem. One of the case farmers exhibited this behaviour in year two of the study when the farm was in a serious feed deficit situation.

Prior to the start of each planning period, the case farmers used their monitoring systems to collect information about the farm state for planning purposes. In the normative literature (Boehlje and Eidman, 1984, Kay, 1981, Kay and Edwards, 1994, Parker, 1999), this is viewed as part of the planning process. By separating out the various roles of the information, the use of a monitoring system by farmers for both planning and control is made explicit. In the normative decision-making literature, information collection is an important step in the identification and analysis of options. Ohlmer *et al.*'s (1998) descriptive study of strategic decision-making supported this view. This process is equivalent to the option generation and analysis phase of the planning process but is different from that used in the normal tactical monitoring system and it may be more useful to think of this sub-process as part of planning rather than monitoring. Alternatively, this process might be considered part of a strategic monitoring system that is being used to identify new options and technologies for use in planning.

The use of monitoring information for decision point recognition may be for one of three purposes (Figure 8.10): to recognise when to implement the next activity in the plan, to recognise that there is a significant deviation from the plan (problem recognition), or to recognise an opportunity. All these roles have been reported previously. The majority of the indicators used for decision point recognition could be classified as lead indicators as defined by Parker (1999) after Kaplan and Norton (1996abc): that is, they indicate progress towards the achievement of the plan. The case farmers used few lag indicators, but this is not surprising given the tactical level of the case study and the role of concurrent control.

The third role played by the monitored information was triangulation where it was used to ensure the veracity of the monitoring system (Figure 8.16). This prevented reliance on a single measure that may have been incorrect, a problem identified by Osburn and Schneeberger (1983). It also allowed subjective measures to be calibrated correctly against objective measures such as milk production or average pasture cover. The system they operated, a dairy farm, allowed subjective measures to be calibrated on a daily basis against milk production, an option not available to farmers of sheep and cattle, or arable farms where production is measured less often or only at the point of sale.

Few authors have commented on the role of triangulation or the processes farmers use to achieve this. Four methods of triangulation were used by the case farmers (Figure 8.16). First, a less formal method was used to indicate the likely change in a factor before it was monitored more formally. This information played an "*early warning*" role, providing an indication of a change in a factor before it was formally monitored. Both qualitative and quantitative subjective measures were used as early warning indicators.

The second method of triangulation was where indirect measures were used to predict likely changes in the value of a factor of interest before it was monitored. For example, the use of milk production to indicate a change in average pasture cover and cow condition. This information provided a "*short-term prediction*" of the value of another variable. Knowledge of cause and effect relationships was used to make these short-term predictions. The third method of triangulation was achieved through the use of confirmatory measures. For example, a reduction in cow condition was used to confirm that average pasture cover and cow intake had declined.

The final method of triangulation, overlap method triangulation, used alternative methods to measure the same factor (Figure 8.17). Numerous aspects of farm system performance were monitored using two or more of the following factors: objective, subjective quantitative and subjective qualitative methods. The other important point is that the monitoring interval increased as the measurement process became more formal. For example, average pasture cover was monitored on a daily basis using visual assessment, a subjective qualitative method. It was also monitored at two to seven day intervals using pasture scoring, a subjective quantitative method. Finally, it was measured at 10 - 14 day intervals with a falling plate meter, an objective method. The use of alternative methods and different monitoring intervals provide a powerful triangulation process.

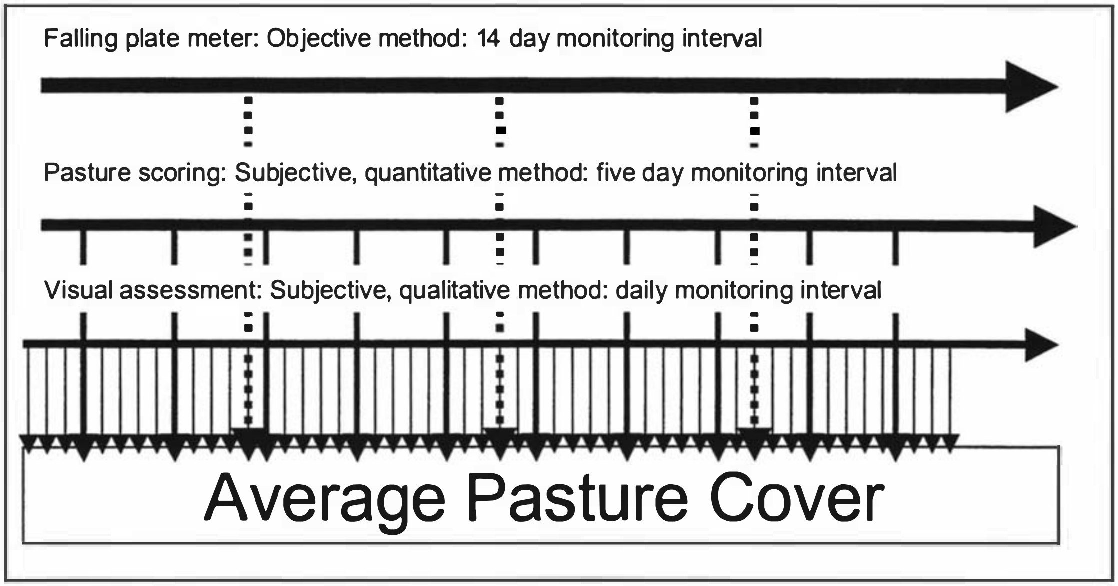


Figure 8.17. The overlap method triangulation process used by the case farmers.

Central to the triangulation process was the objective measurement of average pasture cover and more particularly, milk production. No other studies have reported on the role played by objective measures in maintaining the veracity of farmers' monitoring systems. However, these results support Blackie's (1971) and Parker's (1999) view that farmers would prefer subjective monitoring methods because they are faster and more convenient, provided they were calibrated against some standards to ensure accuracy. Paine (1997) also mentioned the holistic nature of farmers' monitoring systems, but this was in relation to the non-unitary nature of the information. The triangulation processes used by the case farmers provides another facet of the "*holism*" of farmers' monitoring systems. In effect the case farmers have created a monitoring "*network*" that ensures information is timely, accurate and inexpensive. This "*network*" has been created through a detailed knowledge of their production systems, confirming the views of Kennedy (1974) and Wright (1985) that the development of an effective control system is dependent on a farmer having a detailed understanding of his or her system.

The fourth role (Figure 8.16) played by the case farmers' monitored information was a form of early warning prediction (Figure 8.18). Harsh *et al.* (1981) also discussed the role of information in making predictions to identify problems in advance. A combination of climatic, pasture growth, pre- and post-grazing residual, cow intake, rotation length and supplement information was used, to predict the likely feed situation on the farm in two to four weeks time. This provided (every two to seven days) an early warning on likely feed problems up to a month in advance (Figure 8.18). Time to consider possible courses of action or contingency plans was therefore generated: a critical aspect for coping with climatic uncertainty. The early warning system of monitoring was undertaken mentally as the case farmers shifted their herds between paddocks.

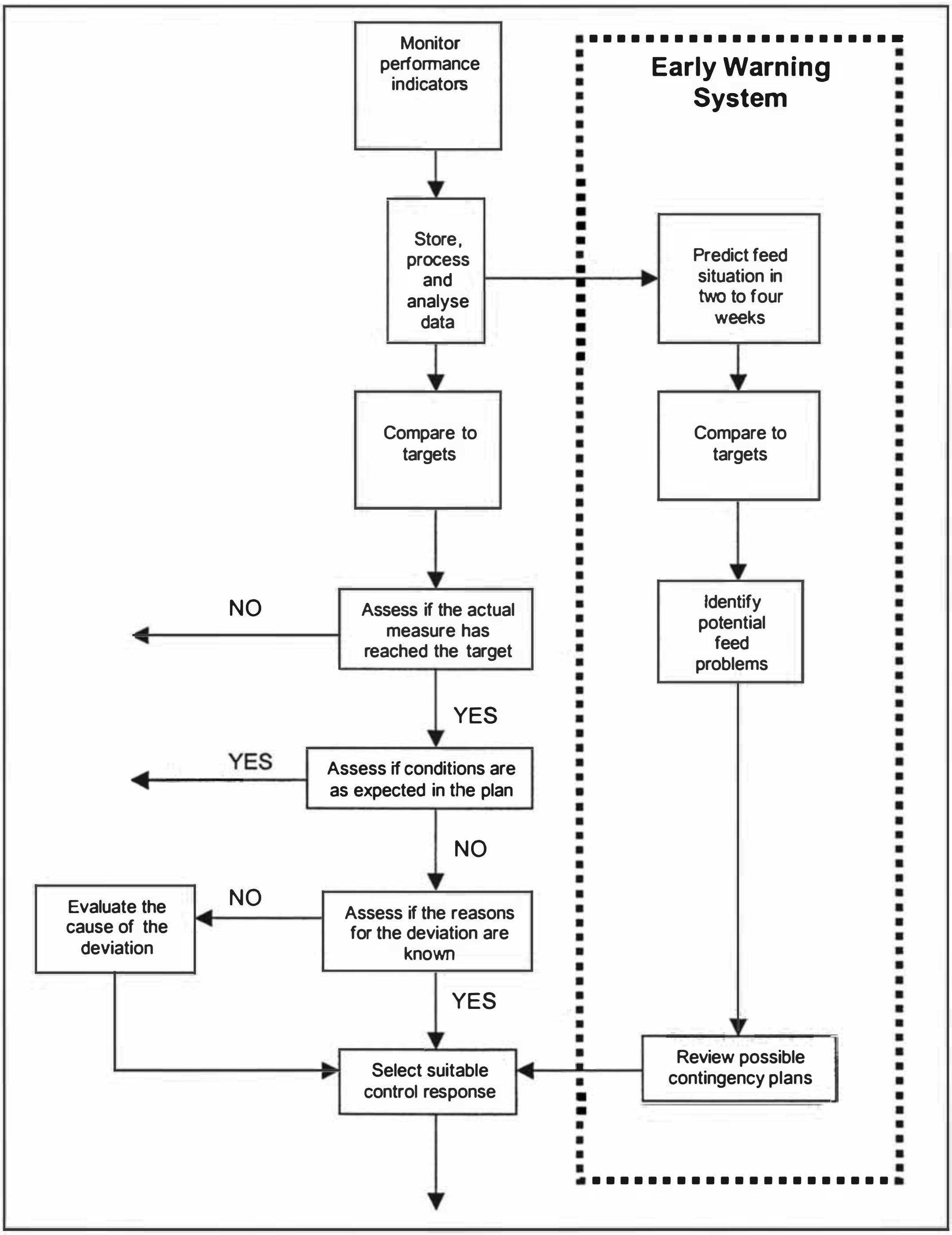


Figure 8.18. The role of the early warning system in contingency plan selection.

Information was also used for control response selection (Figure 8.16). Once a decision point had been identified through a primary indicator, secondary indicators were used to determine whether to implement the next activity in the plan, or a control response. If it was the latter, the secondary indicators in conjunction with heuristics were then used to select the most appropriate control response. Boehlje and Eidman (1984) mentioned the role of heuristics in the selection of control responses, but not the role of monitored information. The descriptive literature, in contrast, has reported similar results (Gladwin and Butler, 1984; Cerf *et al.,* 1993) to those found in this study.

Finally, monitoring information was used for learning (Figure 8.16). Diagnosis was used where the cause of a deviation from the plan was unknown, whereas evaluation was used to assess the outcome of some aspect of the management process. Evaluation is recognised as an important function in the management process (Barnard and Nix, 1973; Mauldon, 1973; Boehlje and Eidman, 1984; Parker, 1999), but only Harsh *et al.* (1981) explicitly discussed the role of diagnostic information in identifying the cause of a problem, and identifying opportunities for improvement in farm performance.

8.6.1.4 Activation, termination and frequency of monitoring

The case farmers had developed heuristics to determine the activation, termination and frequency of monitoring. Most factors were monitored at a sub-conscious or "pre-attentive level" on a daily basis as they went about their normal farm operations. Decision rules activated (and terminated) more formal monitoring that required some form of objective or subjective, quantitative measurement. In effect, the decision rules minimised the monitoring effort and ensured that only those factors relevant to decision-making were monitored.

Gladwin and Murtaugh (1980, p. 118) in relation to a study of planning, stated that "... *experts use conscious attention judiciously, at the most difficult moments of their performance, while pre-attentive processes handle routine behaviour*". The data from this study supports their conclusions, but in relation to the monitoring process. Four factors were found to activate (or terminate) the conscious monitoring of a factor as suggested in Figure 8.19. Threshold values that activated (or terminated) monitoring of a factor were either direct, or indirect measures of the factor. A threshold was either an absolute value, or a "rate of change" in the factor.

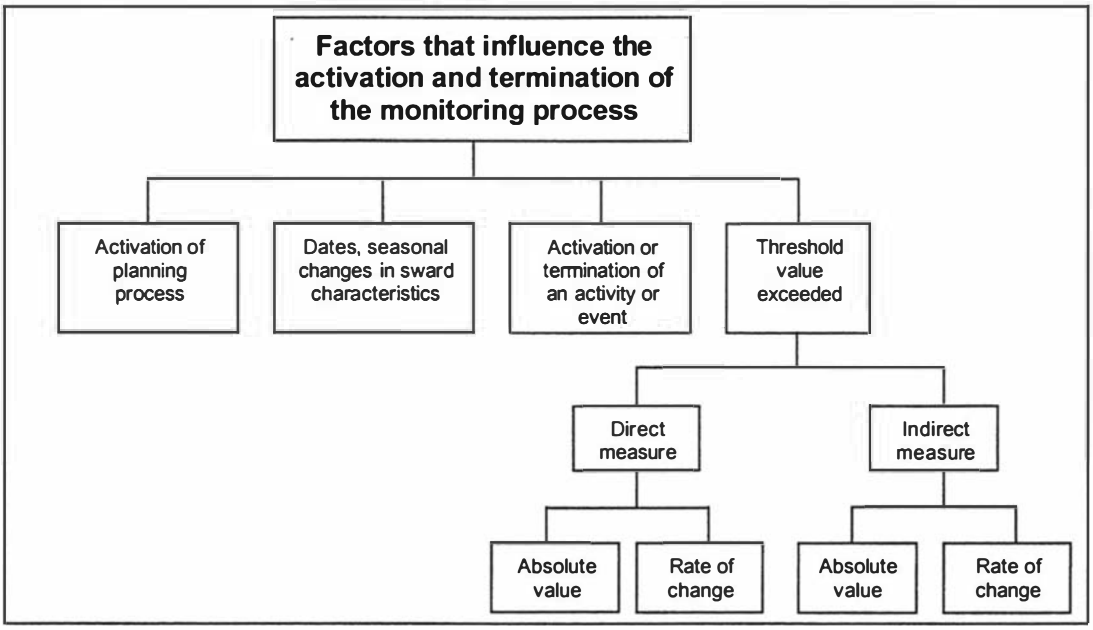


Figure 8.19. Factors that influence the activation and termination of the monitoring process.

The case farmers monitored most factors on a daily basis using subjective, qualitative methods. Other factors (e.g. herd and pregnancy testing) were monitored infrequently (one to three times) over the summer-autumn. Intermediate monitoring intervals (two to fourteen days) were used for the more formal methods (subjective, quantitative or objective). However, the actual monitoring interval was not rigidly set, but was influenced by several factors (Figure 8.20). Generally, the less stable the factor, the shorter the monitoring interval. This is logical and coincides with Kennedy's (1974) view that a shorter monitoring interval should be used for less stable systems.

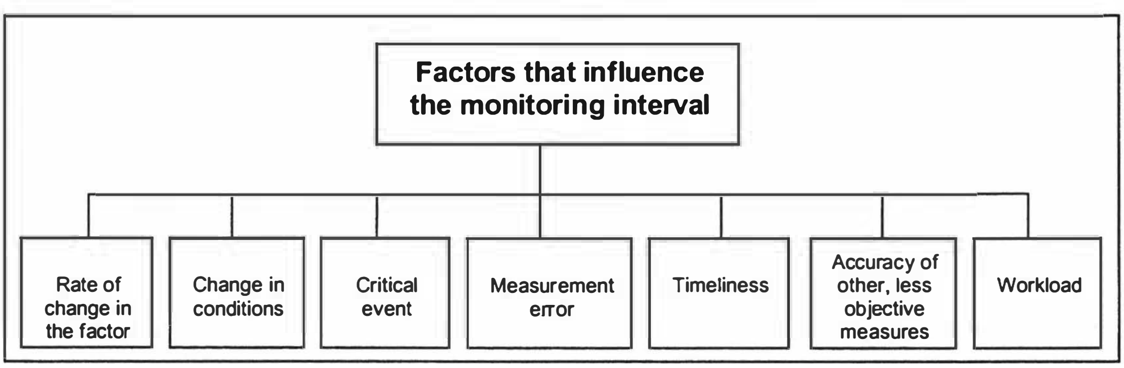


Figure 8.20. Factors that influence the monitoring interval.

The imminence of a critical event also influenced the monitoring interval. Other authors (Mathieu, 1989; Fleury *et al.*, 1996) have stressed the importance of critical events in relation to control. Fleury *et al.* (1996) suggested it was important to maintain flexibility to cope with variation during these critical periods, but did not mention whether monitoring frequency should be changed leading up to such events.

Measurement error, a factor identified by Kennedy (1974), only influenced the monitoring interval of two factors: the objective measurement of average pasture cover and pasture growth rates. Farmer A stated that measurement error limited the monitoring interval to a minimum of five days. It was not important for other measures because they were mostly subjective. The only other important objective measure was milk production, a measure for which accuracy was not influenced by monitoring interval. Timeliness, for decision-making, influenced the monitoring interval used by Farmer A in relation to the objective measurement of average pasture cover. He believed that the monitoring interval should not be much greater than 10 days over the autumn due to the rate of change in pasture cover at that time of year. In contrast, Farmer B used a standard 14 day interval through the autumn. Farmer A's comments support Kennedy's (1974) view that as system stability declines, the monitoring interval should be reduced.

The final two factors that influenced the monitoring interval were the accuracy of alternative measurement methods and workload. In years two and three, Farmer B ceased[10] objective pasture measurement over the autumn because he had a high workload and was comfortable that subjective pasture scoring was sufficiently accurate for management purposes. This seems entirely logical but the impact of workload or the accuracy of other measures on monitoring interval was not identified in other descriptive studies of farm management.

Few guidelines are provided in the literature on how best to determine the monitoring interval. The general guideline is that the monitoring interval should be such that it allows effective intervention if required (Boehlje and Eidman, 1984; Buckett, 1988). Lockhorst *et al.* (1996) stressed that the older the information, the less useful it is for management purposes. Conversely, Kennedy (1974) argued that the shorter the monitoring interval, the more accurate the information system required (he defined accuracy as "the degree of match between predicted and actual outcome"). However, the downside of more frequent monitoring is higher costs and measurement errors (Kennedy, 1974). Therefore, the monitoring interval should only be reduced if the benefits from this action outweigh the costs.

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[10] It was only undertaken for planning, not for control purposes.

As already mentioned, Kennedy (1974) argued that the more unstable the system, the greater the need for intervention. Between-year pasture growth rate data (Chapters 5 & 6) demonstrate how unstable the case farmers' dairy production systems are. It is therefore not surprising that they use very short monitoring intervals for most factors. The triangulation process (Section 8.6.1.2) limited the number of time consuming objective monitoring methods the case farmers had to use. Decision rules were also used to minimise monitoring input. These practices allowed the case farmers to monitor their systems at minimal cost while maximising the timeliness of the information.

8.6.1.5 Sources of error in the monitoring system

Environmental error (Parker, 1999) was a major source of error for the monitoring system used by the case farmers. Few instances of imprecise plan implementation (Parker, 1999) were recorded, as would be expected with "expert" farmers. Instrument error (Parker, 1999) was considered important by the case farmers. They did not use a falling plate meter for decision-making during summer because it was believed to be too inaccurate. Overall, they used few instruments and these comprised the falling plate meter and the electronic measurement of milk volume along with laboratory measurements at the dairy factory for milk composition. The milk production data was viewed as precise and this was used to calibrate all other measures.

8.6.1.6 Formal versus informal monitoring systems

The case farmers used a combination of both formal and informal monitoring systems as defined by Blackie (1971) and Parker (1999). The results of the study have also provided some insight into why farmers do not adopt formal monitoring systems (Lockhart, 1988; Nuthall, 1992, 1996; Parker *et al.*, 1993; Nuthall and Bishop-Hurley, 1999). It may also explain why, in one study (Nuthall and Bishop-Hurley, 1999), 60% of respondents stated that they thought feed budgeting was unnecessary. The informal monitoring systems used by the case farmers over the summer demonstrated that such systems could be timely, accurate and low cost in terms of both time and capital provided the user has the expertise to operate them effectively. Parker (1999) proposed that one of the reasons why farmers did not adopt formal monitoring systems was because visual assessment proved adequate for achieving their production goals. Time and resource constraints were also mentioned in two studies as important reasons why farmers do not adopt feed budgeting (Nuthall, 1992; Nuthall and Bishop-Hurley, 1999). The results also support Boehlje and Eidman's (1984) view that farmers should only change from informal to formal monitoring systems if the benefits outweigh the costs.

8.6.2 Recording, data processing and analysis

The case farmers did record (Barnard and Nix, 1973; Kay, 1981; Dalton, 1982; Boehlje and Eidman, 1984; Kay and Edwards, 1994) a proportion of the data they collected through their monitoring process. However, much of it was simply stored mentally, supporting the view of Hardaker and Anderson (1981) that production management can be undertaken without formal recording. The other main form of data storage was the farm diary. Data was also stored in folders, and Farmer B used a computer to store pasture and herd records. Catley *et al.* (2000) similarly reported that the recording systems used by cutflower growers ranged from memory through to sophisticated computer programmes. The stored data could be used in one of three ways by the case farmers: (i) analysed immediately for problem recognition, (ii) accessed at a later date for diagnostic or evaluation purposes, or (iii) used the following year to compare seasons. Boehlje and Eidman (1984) also claimed that some information is stored until required for decision-making at a later date.

Three primary types of data was processed (Boehlje and Eidman, 1984) by the case farmers: subjective visual images, subjective scores and objective measures. Each required a different form of processing, with the subjective visual images requiring the least complex processing. Means were estimated from subjective scores and calculated from objective measures. Boehlje and Eidman (1984) proposed that once data was collected and stored it would be analysed and simple means and ratios calculated for control purposes. In most instances the case farmers calculated simple means. However, they also used climatic and pasture growth rate data to predict future pasture growth rates and cow intakes, in order to provide an early warning of potential feed problems. This is a relatively sophisticated form of analysis not mentioned in the farm management literature.

8.6.3 Decision point recognition

The most important role played by the information collected through the case farmers' monitoring system was to determine decision points during the implementation of the plan. These results support the findings of Gladwin and Butler (1984) who reported that the first decision point used by a decision-maker is whether or not to implement the plan. The next decision point occurs at any point in the plan where more than one sub-plan can be embedded and a choice has to be made. This is similar to the definition used in this study of a decision point: "any point in the implementation phase where the case farmers must decide between the implementation of: (i) the next activity in current plan, (ii) a control response, or (iii) an opportunity". As such, there were three types of decision point recognition processes (Figure 8.21): implementation point recognition, problem recognition, and opportunity recognition. Although not explicitly stated, Gladwin and Butler (1984) recognised the difference between implementation point recognition and problem recognition. Similarly, the French research (Mathieu, 1989; Fleury *et al.*, 1996, Aubry *et al.*, 1998) into tactical management recognised that at the decision point, farmers must chose between "*regulations*", one of which is the planned activity or event for the next decision period. In contrast to this, the normative literature on the management process (Barnard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994; Parker, 1999) focuses on problem recognition, and except for Mauldon (1973), implementation point recognition is implied.

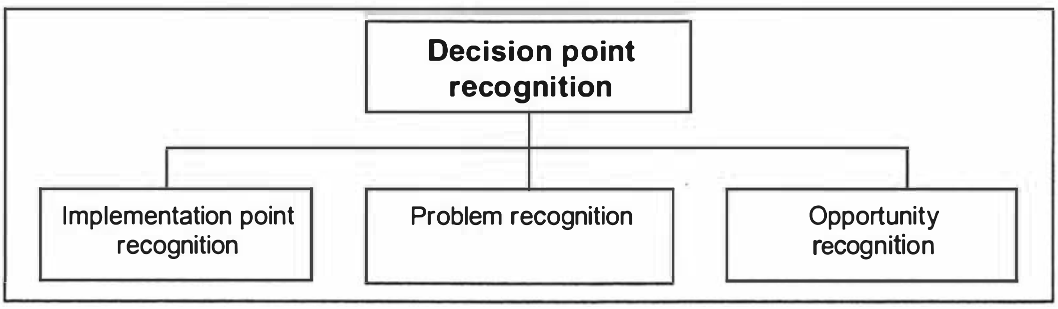


Figure 8.21. A typology of decision point recognition processes.

When a primary indicator met or exceeded a target, it was the secondary, not primary, indicators that were used by the case farmers to identify a problem. A problem existed if the secondary indicators showed that conditions at the time differed from those predicted in the plan. This is subtly different from the process prescribed in the normative literature (Bamard and Nix, 1973; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994; Parker, 1999) where a problem is identified when actual performance deviates significantly from performance standards. In the former, it is the conditions at the time a target is met or exceeded that determine if a problem exists, whereas in the latter, it is the degree of deviation from the target that identified a problem. Similar results were reported by Gladwin and Butler (1984), who found that a farmer's choice between implementing the plan or introducing a contingency plan was dependent on the conditions at the time of the decision.

A third decision point recognition process, opportunity recognition (Figure 8.21) was used by one of the case farmers[11]. Although this distinction is made in the decision-making

[11] This second process was only relevant to Farmer B. Farmer A did not actively search for opportunities that could be used for control purposes.

literature (Lee and Chastain, 1960; Neilson, 1961; Suter, 1963; Boehlje and Eidman, 1984), it was not reported in the management process literature. The major difference between opportunity and problem recognition is that the former is detected through an externally-focused monitoring system, while the latter relies on an internally-focused monitoring system. This is similar to the internal, external cleavage in strategic farm management (Martin *et al.*, 1990; Parker *et al.*, 1997). Opportunities also over-ride the normal plan or control responses. Between-farm differences in the decision point recognition process related to farmer values. Farmer B, with his high input philosophy actively sought out opportunities while Farmer A, because of his "low input" philosophy, did not. Once a decision point had been identified, and it was determined the plan had to be modified, the case farmers had to deduce the cause of the problem and select between alternative control responses, or decide to implement an opportunity. Interestingly, diagnosis was only used occasionally by the case farmers.

8.6.4 Diagnosis

Diagnosis was undertaken in situations where the actual outcome differed significantly from the case farmers' expected outcome. Although several authors (Mauldon, 1973; Barnard and Nix, 1979; Boehlje and Eidman, 1984) in the normative management process literature mention the need to identify the reasons for a deviation from the plan, few explicitly refer to this process as diagnosis. Diagnosis is more commonly recognised in decision-making models, but is normally termed *problem detection* or *definition* (Lee and Chastain, 1960; Johnson *et al.*, 1961; Neilson, 1961; Brannen, 1961; Osburn and Schneeberger, 1978; Kay, 1981; Boehlje and Eidman, 1984; Kay and Edwards, 1994). In one of the few descriptive studies, albeit on strategic decision-making, Ohlmer *et al.* (1998), reported that farmers undertook problem detection. However, little detail was provided about the nature of the farmers' problem detection processes in this publication.

The process the case farmers used to determine when to undertake a diagnosis is shown in Figure 8.22. A plan was developed which contained "planned" milestones and associated outcomes. The plan was then implemented and the "actual" milestones and associated outcomes (a function of the environment and case farmers' implementation and control processes) were monitored. Monitored information on the state of the farming system and the environment were used, along with the case farmers' system models, to predict "expected" milestones and associated outcomes. These expectations were updated as new information became available. Deviations from the plan were identified when the measured milestones or outcomes differed significantly from those predicted in the plan. If no deviation was identified, then the implementation of the plan continued. However, if a significant deviation was identified, the case farmers then determined whether the deviation was significantly different from their expectations. If it was not, then a suitable control response was selected. However, if it was, then this deviation, not the deviation from the plan, initiated the diagnostic process.

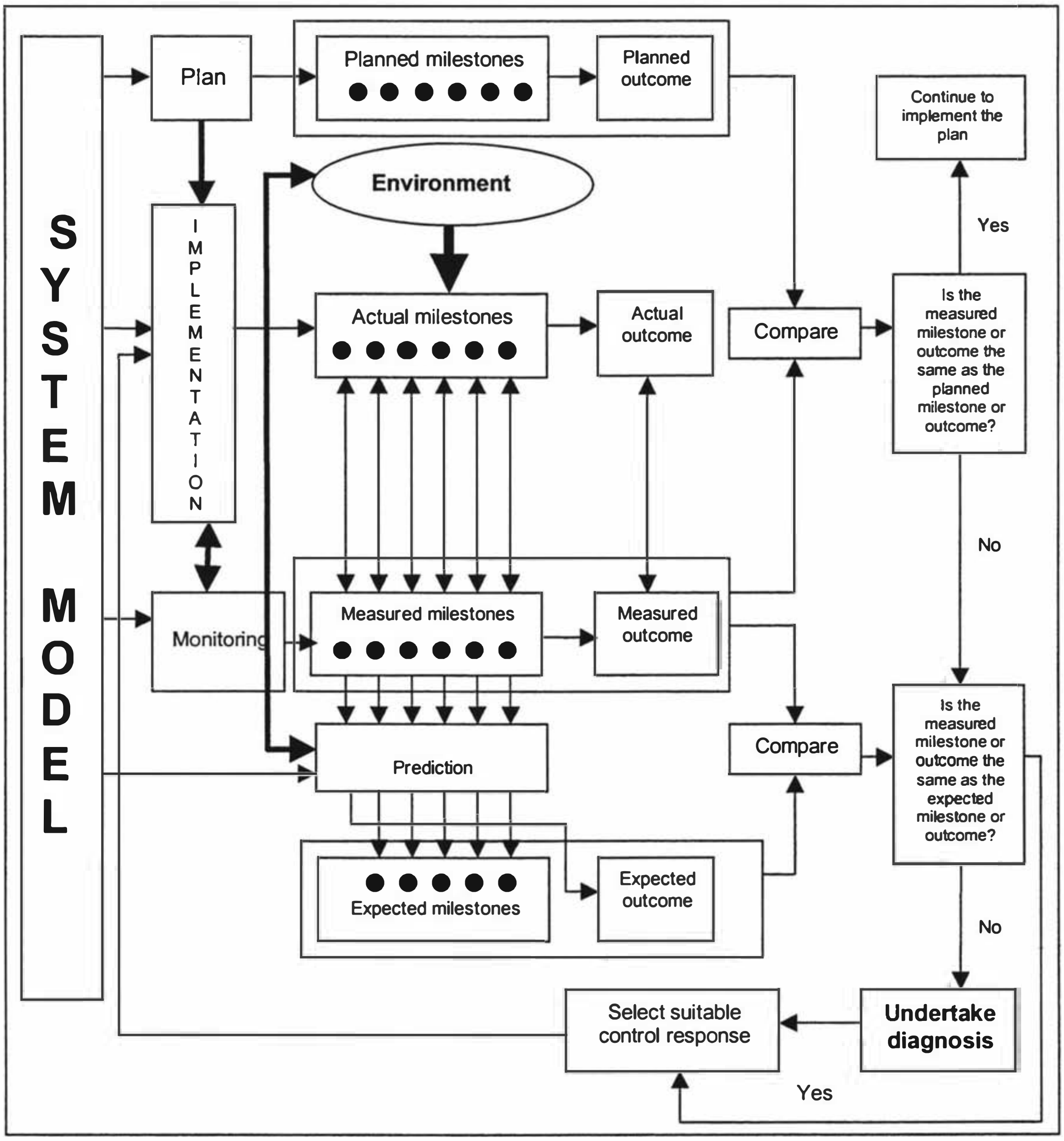


Figure 8.22. The process used by the case farmers to determine when to undertake a diagnosis.

Mauldon (1973) and Barnard and Nix (1979) discuss the need to identify the cause of a deviation between actual and planned performance. However, no mention is made of the role of expectations in this process. This is an important finding because it is only when an expectation is not met, rather than a planned level of performance, which determines when diagnosis is undertaken. This explains why the case farmers undertook limited diagnosis during the study despite experiencing considerable climatic variation. The process of using system models to predict expectations from information collected through the monitoring system meant that the case farmers knew the outcome (or next milestone) and the reason why it had deviated from the plan before it occurred. As such, there was no need for diagnosis. However, where the case farmers' expectations were not met, diagnosis was promptly undertaken to identify the cause of the inaccurate prediction. Ohlmer *et al.* (1998) also reported that farmers either knew the cause of a deviation from the plan or if they did not, diagnosis was undertaken. No mention was made of diagnoses in earlier studies of farmers' tactical management (e.g. Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998).

Several reasons were identified as to why the case farmers' failed to predict a milestone or outcome. The first was that their system models were not well enough developed to accurately predict outcomes under certain conditions. This occurred where environmental conditions were outside the case farmers' experience, or new inputs or management practices were used. A second reason was that the monitoring system was providing inaccurate information upon which predictions were based. This often occurred under unusual environmental conditions and again reflected a limitation in the case farmers' system models. The final reason was that the plan was not implemented as expected. This occurred when someone other than the case farmer implemented the plan incorrectly.

Because diagnosis was found to be about expectations not being met rather than planned outcomes, the reasons for a deviation as mentioned above are quite different from those proposed to account for a deviation from the plan. For example, Barnard and Nix (1973) identified four reasons why the actual outcome might deviate from the plan. These were that the underlying assumptions in the plan were wrong, the targets were not achievable, or changes in either the socio-economic or biophysical environment had occurred. These are problems to do with planning or changes in the environment. In this study, the reasons for a deviation from expectations were due to problems associated with system knowledge, accuracy of the monitoring system, and implementation. The planning problems mentioned by Barnard and Nix (1973) could be considered a sub-set of problems to do with system knowledge.

The above results support Scoullar's (1975) view that managers perform two types of decision-making processes, those for routine decisions and those for novel decisions. This is similar to Simon's (1960) programmed and unprogrammed decisions and Gorry and Morton's (1971) structured and unstructured decisions. Scoullar (1975) believed that a problem, as opposed to a routine decision, was a gap between actual and desired knowledge, not between actual and desired performance. For the case farmers, this is the nature of the problems they diagnosed. It is the knowledge, not the performance gap, that they are interested in closing when they initiate diagnosis.

The diagnostic process used by the case farmers is shown in Figure 8.23. If an outcome differed significantly from expectations, then the case farmers drew on their system knowledge to hypothesise possible causes. If their system models were inadequate for this process, they consulted with their peers or a local expert and then developed their hypotheses. The most likely true hypothesis was then selected and the means by which it could be tested devised. Data was retrieved from either the case farmers' memory or their recording system to test the hypothesis. If it was confirmed, the process was complete, but if it was refuted, the process was repeated with the next most likely hypothesis. Descriptive studies that report the use of diagnoses by farmers (e.g. Ohlmer *et al.*, 1998) provide no information about the process applied. Similarly, in the normative literature, Lee and Chastain (1960) describe a three-step model that comprises: recognise alternative problem definitions, analyse alternative problem definitions, and define the problem. However, they provide little insight into how each step is undertaken.

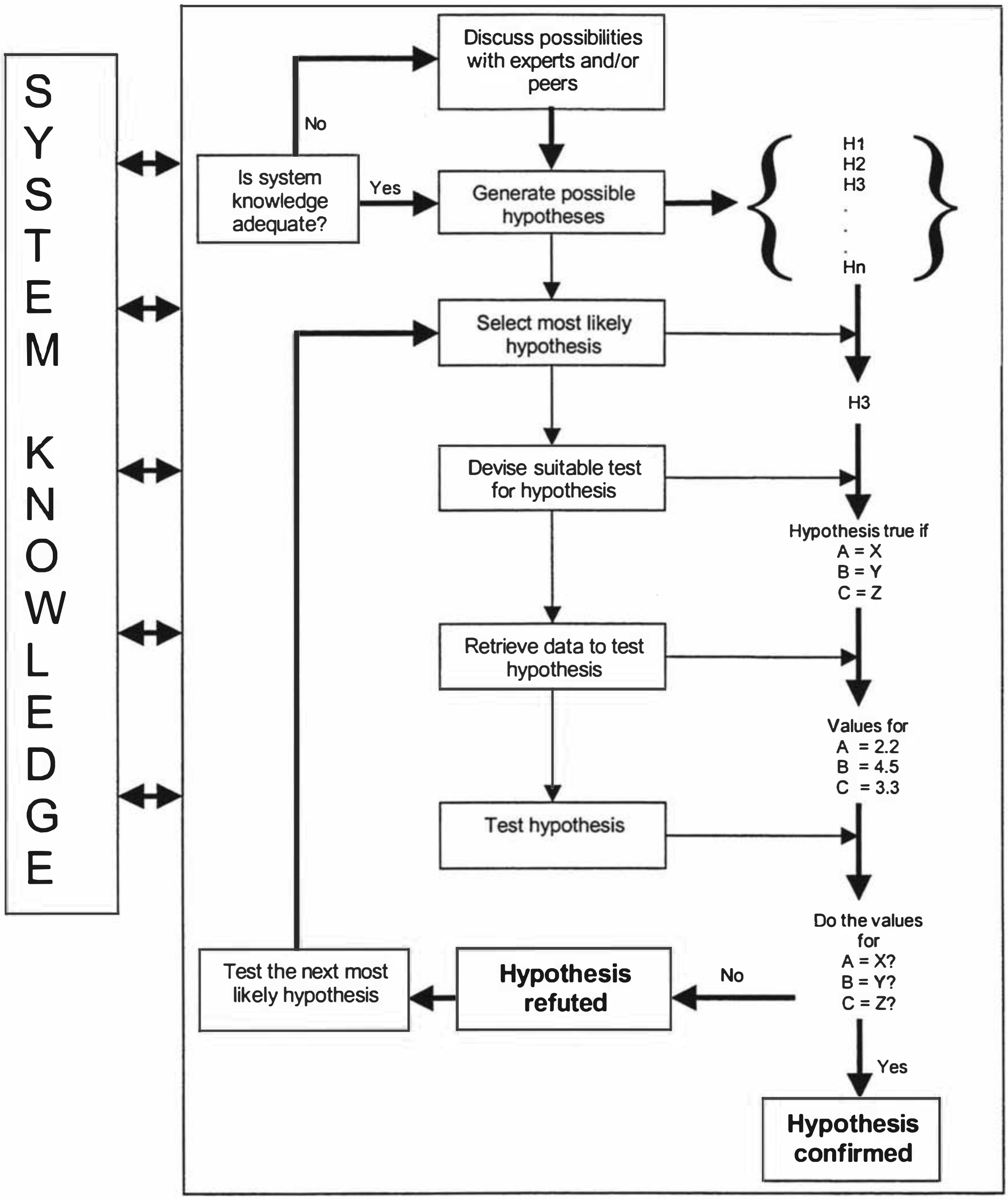


Figure 8.23. The diagnostic process used by the case farmers.

In contrast to Lee and Chastain (1960), Scoullar (1975) provided a more detailed diagnostic process involving seven steps (Figure 8.24). This process identified the cognitive abilities a farmer needs to diagnose a problem. However, there does not appear to be a clear linkage between the preceding six steps and the critical step, step 7 (Figure 8.24). Like Lee and Chastain's (1960) model, Scoullar's (1975) model is relatively "opaque". There are some similarities between this model and the model in Figure 8.23.

For example, both models rely on system models, and emphasise the importance of understanding system relationships in the diagnostic process. However, Scoullar's (1975) model does not make explicit how the steps are actually used for diagnosis. Similarly, although the model derived from this study (Figure 8.23) makes explicit how system knowledge can be used in problem diagnosis, it does not make explicit how this is done. For example, how are hypotheses and their associated tests generated? This level of detail was outside the scope of the study.

1. Recognising a 'model' under which the problem will be studied
2. Recognising all important variables within the 'model'
3. Knowledge of methods needed to investigate the variables within the 'model'
4. Knowledge of principles and generalisations.
5. Comprehension of accumulated facts
6. Recognising the interrelationships between variables
7. Recognising the causes of the problem

Figure 8.24. The diagnostic process (Source: Scoullar, 1975).

Other diagnostic models found in the farm management literature consist of hierarchical decision tree structures (Barnard and Nix, 1979; Dalton, 1982; Osburn and Schneeberger, 1983; Buckett, 1988; Kay and Edwards, 1994) that break farm performance down into its various sub-components for diagnostic purposes. This may be a useful way of representing the sub-process for "selecting the most likely hypothesis" in Figure 8.23.

8.6.5 Evaluation

Ex-post evaluation was used by the case farmers after a new input or management practice had been implemented, or at the end of a planning period. The purpose of the *ex-post* evaluation was to evaluate a decision post-implementation, or the overall management of a planning period. It was also undertaken on an on-going basis to ensure both the planning assumptions and mental models of the production system were valid, and that the implementation and monitoring system were effective. Few authors (Calkin and DiPietre, 1983, Parker, 1999) in the normative management process literature mention *ex-post* evaluation. Parker (1999) stated that it was part of the control process and important for learning and Calkin and Di Pietre (1983) proposed that it be used to review the effectiveness of the components of the management process. Similarly, many of the normative decision-making models (Hardaker *et al.*, 1970; Castle *et al.*, 1972; Harsh *et al.*, 1981; Osbum and Schneeberger, 1983; Boehlje and Eidman, 1984; Makeham and Malcolm, 1993; Kay and Edwards, 1994) proposed that evaluation was used to improve the decision-making process and as a means of learning from experience. Nielson (1961) also hypothesised that better managers would evaluate the outcomes of their decisions and develop mental feedback systems to improve their managerial processes. The results of this study support the normative view and Nielson's (1961) hypothesis in particular. Evaluation appears to be a form of meta-control that uses information generated from the management process to learn about and improve it.

Few descriptive studies mention evaluation. One exception, Ohlmer *et al.* (1998), in a study of strategic decision-making, reported that only one of the 18 farmers used *ex-post* evaluation to improve farm performance. The reason given for this was that the majority of the decisions were strategic and non-repetitive in nature. Therefore, *ex-post* evaluation provided no benefit to the farmers, and instead, they used concurrent control to influence the outcome of the decision. Given, however, the repetitive nature of tactical decisions, the case farmers undertook a large number of *ex-post* evaluations relative to the farmers in Ohlmer *et al.*'s (1998) study since they were assessing the effectiveness of a decision or set of decisions on the basis of its outcome post-implementation[12].

Three methods of *ex-post* evaluation were identified from the case study: norm-base, standards-based and mental simulation-based methods (Figure 8.25). No typology of evaluation methods was found in the literature. A norm-based method was used when an input or management practice was substituted for another. The outcome was then compared to the norm that would have been expected if the normal input or management practice had been used. The standards-based[13] method was used where a decision had been implemented to specifically achieve a standard or set of standards. The decision was then assessed on the basis of whether the standards were achieved. Mental simulation-based evaluations could be further subdivided into ex-ante (expectation-based) and *ex-post* mental simulation-based methods. In the first instance, expectations of the likely outcome from alternative decisions were developed prior to the decision. The actual outcome was then compared to the predicted expectation, post-decision. In the second instance, the likely outcome of not making the decision (or making a different one) was

[12] In one instance, ex-ante evaluation, the outcome is simulated prior to the decision being made.
[13] Standards are also used in the on-going evaluations used to ensure the accuracy and timeliness of the monitoring system and the correct implementation of the plan. These on-going evaluations are considered separate to the four methods discussed here.

simulated for the conditions after the outcome was known, and the actual outcome compared against the simulated outcome for the alternative decision.

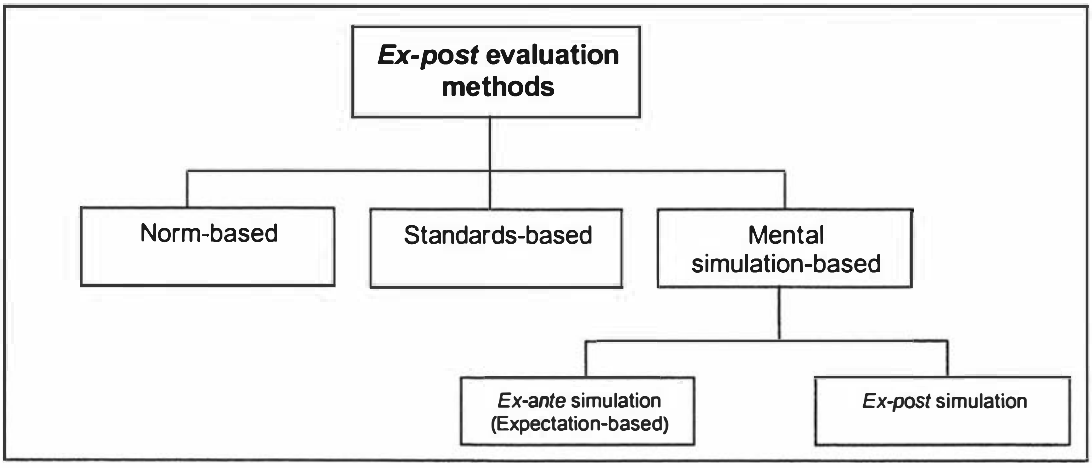


Figure 8.25. A typology of *ex-post* evaluation types.

There is little information on the evaluation process in either the normative or descriptive literature. One exception, Osburn and Schneeberger (1983) provided a series of questions that one would ask if evaluating a decision (Figure 8.26). The majority of these questions reflect the process used by the case farmers for *ex-post* evaluation. The case farmers did consider the impact a decision would have before they made it. They also compared the actual outcome to their expectations, and they did make allowances for conditions different from those expected prior to implementation. During evaluation they also identified why the outcome had been different from their expectations. They also incorporated information they had learnt through evaluation into their system knowledge for later use in decision-making.

1. What did I think would happen when I made the decision?
2. Did the outcome approximate or approach my expectation?
3. Were my expectations consistent with the realities of the situation?
4. If not, what factors might explain the difference between predicted and actual outcome?
5. Were these factors included in my analysis?
6. Are they sufficiently important to include next time?
7. Am I satisfied or is a new activity called for?

Figure 8.26. Important evaluation questions (Source: Osburn and Schneeberger, 1983).

Evaluations undertaken by the case farmers generally occurred during an extreme season, a period of rapid change, or where a new input or different management practice had been introduced. These factors explained the between-farmer and between-year differences in the number and types of evaluations undertaken during the study. In some cases the case farmers reflected on the area of interest for several months before a conclusion was reached. This corresponds to the literature on experiential learning (Kolb, 1974, 1984; Wilson and Morren, 1990). Both strategic and tactical decisions were evaluated as a result of information provided by the tactical monitoring system. Kaplan and Norton (1992, 1993, 1996abc) also indicated that operational measures play an important role in evaluating the strategy of the business.

A novel typology of the areas of evaluation is shown in Figure 8.27. This provides a framework for considering the areas within which farmers might undertake evaluation and a means to focus future research on how farmers learn about various aspects of their farm business.

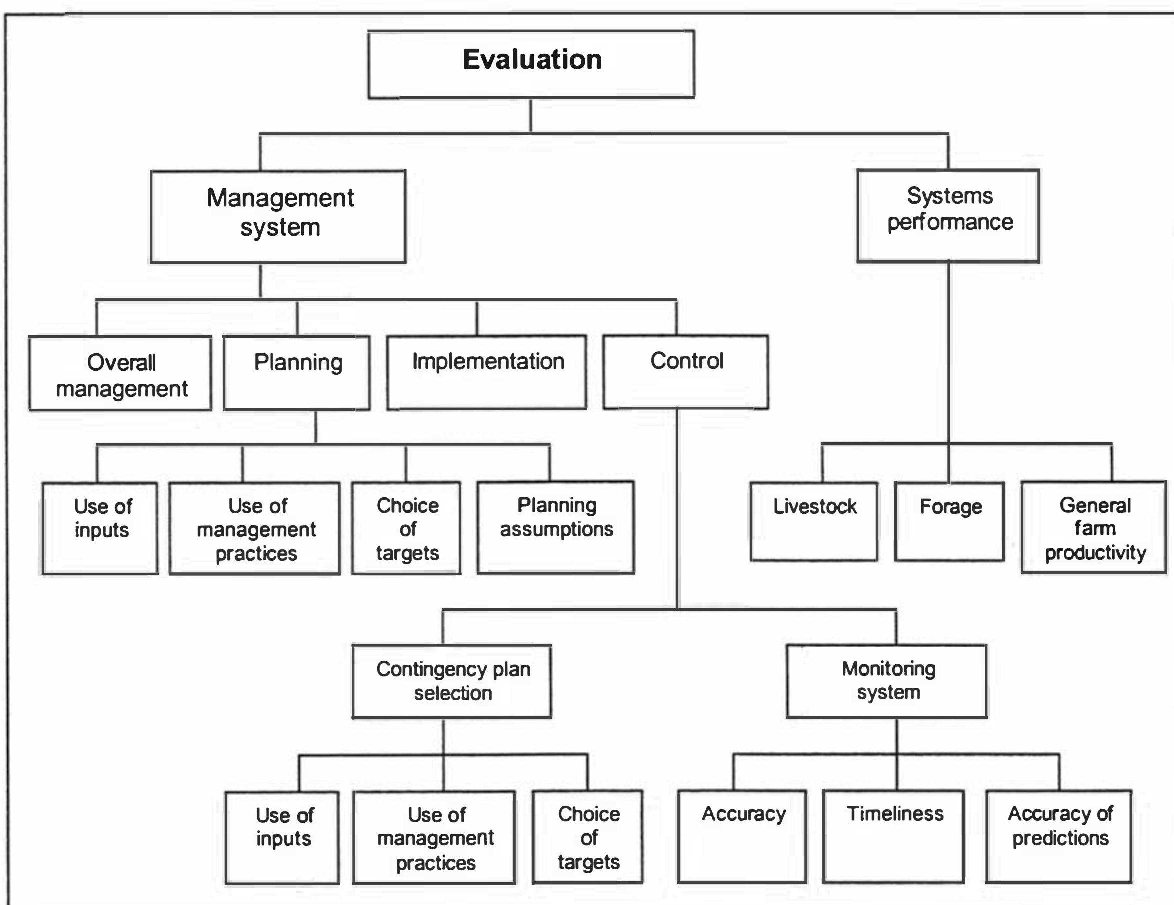


Figure 8.27. A typology of the areas of evaluation undertaken by the case farmers.

8.6.6 Limits to control and the environment

The inherent uncertainty within a manager's environment is an important determinant of the limits to control (Ashby, 1956). Therefore any study of farmers' management practices should provide some description of the nature of the environment in which they operate. Analysis of the environment confronting the case farmers during this study suggested that a modified version (Figure 8.28) of the classification schema used in the risk management literature (Sonka and Patrick, 1984) is more useful for classifying the environment than that proposed by Wright (1985). This taxonomy was modified to incorporate one further risk source identified by Emery and Trist (1965), competition from other firms (in this case, other dairy farmers). The sources of risk faced by the case farmers were virtually identical (see Section 8.2). Production risk dominated other sources of risk over the summer-autumn period. The supply of their main source of feed, pasture, was climate-driven, and the farmers felt they had limited ability to "control" this. Wright (1985) and Mathieu (1989) both identified climate as a major source of variation on farms. Although the case farmers set precise production objectives for budgeting purposes, they did not expect to achieve these objectives due to climatic conditions. This is in line with the views of Wright (1985) and Kaine (1993) that where managers have insufficient system variety to offset the variety in the environment, they will set broad, imprecise objectives.

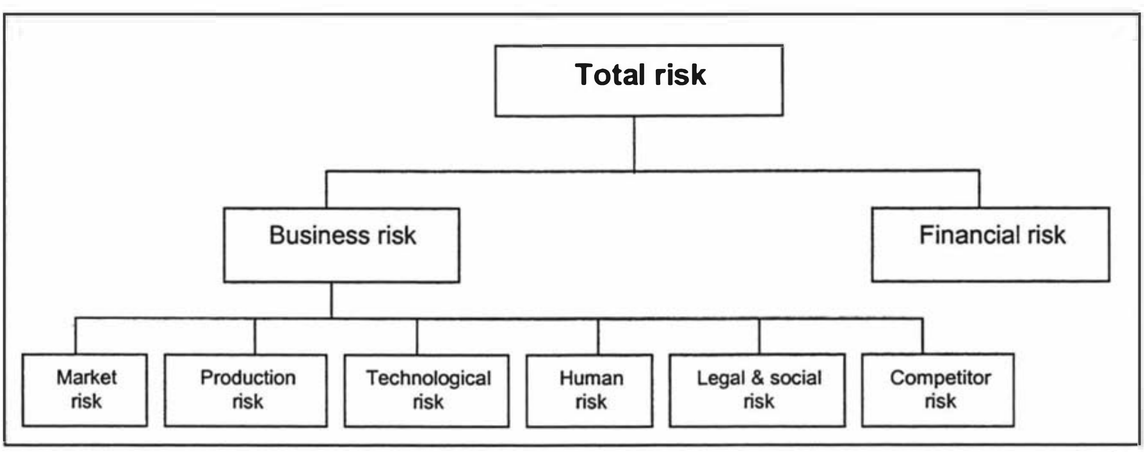


Figure 8.28. Sources of risk faced by the case farmers (Adapted from Sonka & Patrick, 1984).

Dalton (1982) argued that to cope with variety in the environment, managers must either reduce it or develop management procedures that have equal and opposite variety. The case farmers did not attempt to reduce variety within the environment. Rather, they used management procedures to increase the variety within their systems. Four approaches to mitigating risk were identified: sourcing feed off-farm, increasing stored feed, growing forage crops and improving management through refinement of management processes (Kennedy, 1974; Wright, 1985).

Kennedy (1974) stated that an important question for management was the degree to which systems variety is developed for control purposes before the marginal cost of this variety outweighs the benefits. Farmer B used a concept similar to marginality when determining whether to incorporate an extemal feed source into his system and evaluate the minimum response he would require from his maize silage reserve to cover its cost. However, there was no evidence that the case farmers formally (or otherwise) analysed the variety within their systems as proposed by Kennedy (1974).

8.6.7 Control responses

Deviations from the case farmers' plans would be accounted for by:

1. The underlying assumptions in the farmers' plans were incorrect.
2. Targets in the plan were not achievable.
3. Changes in the biophysical environment had occurred.
4. The monitoring system was inaccurate.
5. The plan was implemented incorrectly.

Three of these reasons (1 – 3) were also proposed by Bamard and Nix (1973). They also identified changes in the socio-economic environment as a reason for deviations from the plan. However, this aspect did not influence the case farmers' plans and this is in part a reflection of the production management focus of the study. The results could have been quite different if the research focus had been finance or marketing.

The primary cause of deviations from the plan was the weather. This uncertainty contributed to incorrect planning assumptions (e.g. a "wet" vs normal summer), unachievable targets (e.g. the use of higher than normal milk production targets by Farmer A in year two) and inaccuracies in monitoring (e.g. under-estimation of pasture cover by Farmer A during the wet summer of year one). Incorrect implementation of a plan (by Farmer B's farm worker) was only recorded once during the study. Reasons for deviations from farmers' plans in descriptive studies of tactical management (Mathieu, 1989; Fleury *et al.*, 1996; Aubry *et al.*, 1998), have also been attributed to climatic variation.

During the summer-autumn, the case farmers were dealing primarily with short-term aberrations. However, they had detected what they thought was a longer-term change in climatic conditions on the basis of repetition of phenomenon. Two seasons of wet, cold springs and summers had been experienced and upon this basis both case farmers' changed their spring, and Farmer A his summer, management. These responses suggest they found it difficult to differentiate between short-term aberrations and longer-term changes, considered by Wright (1985) to be an important aspect of control.

The case farmers used three of the four types of control responses defined in the literature (Mauldon, 1973; Dalton, 1982; Boehlje and Eidman, 1984) to cope with the variation in the environment. These were preliminary, concurrent and historical control. They did not use an "elimination of disturbances" control response. However, these results are a function of case selection because some New Zealand dairy farms use irrigation of pastures for this purpose. Concurrent control was the predominant type of control used by the case farmers as would be expected for tactical management. Preliminary control was used to prevent the occurrence of animal health problems such as bloat and facial eczema and forage crops and silage were fed during periods when pasture growth rates were most variable. Historical control was used as Mauldon (1973) proposed, after learning had taken place.

The evidence suggested that each type of control required a different form of systems analysis (Dalton, 1982). A concurrent control response was initiated when an indicator equaled a target, but conditions differed from those expected in the plan. The farm state or conditions at the time were then used to select a suitable control response. In contrast, an historical control response was developed when an outcome deviated from a target or expectation. The reason for the deviation from the plan was diagnosed, and a suitable and improved control response was developed for the next decision-making cycle. The latter is a much more complex cognitive process (learning) and uses a different form of problem recognition and control response determination. These decisions are more akin to "unstructured" decisions (Simon, 1960; Gorry and Morton, 1971; Mintzberg *et al*., 1976).

A typology of the concurrent responses used (and not used) by the case farmers is shown in Figure 8.29. Interestingly, only Boehlje and Eidman (1984) have developed this area in the farm management literature. For concurrent control which they (1984, p. 676) defined as those control responses which enable adjustments to be made during events, they identified three response types. These were changes in the timing, level and method of using inputs. In essence, these represent a form of contingency plan. Although these were the primary control responses used by the case farmers, a much broader range of concurrent control responses were identified as described by Figure 8.29.

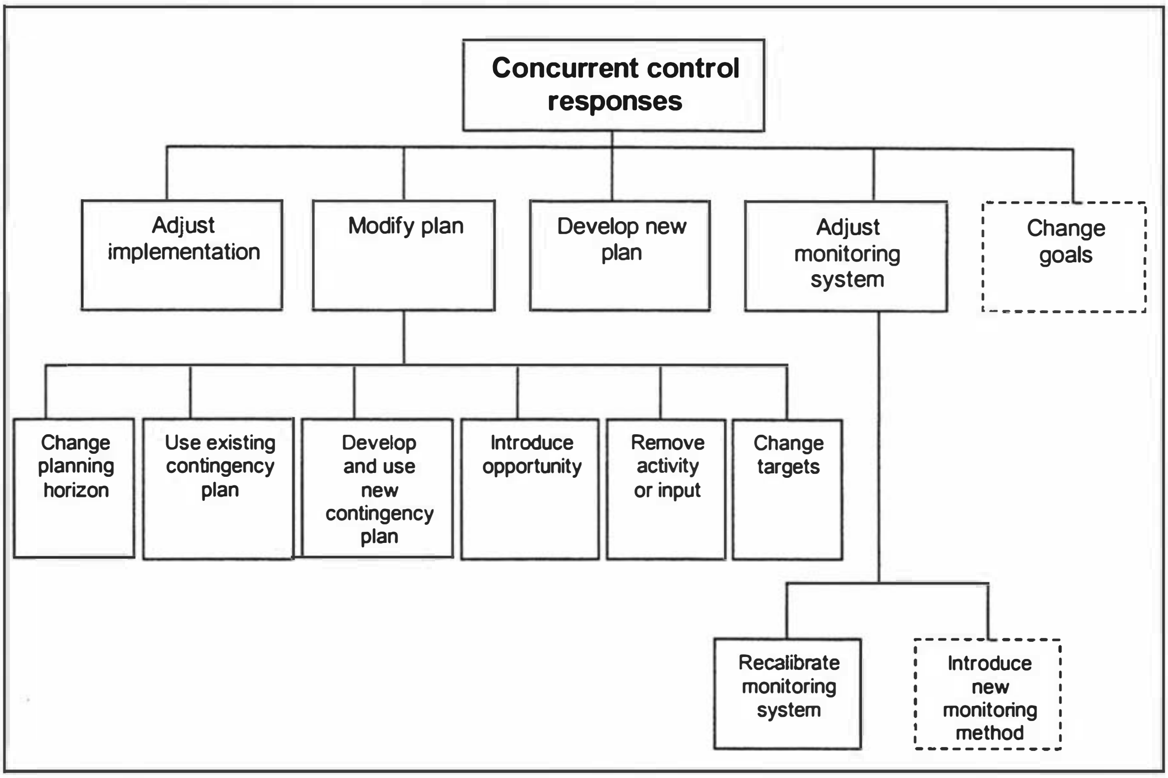


Figure 8.29. A typology of concurrent control responses[14].

Adjustment of implementation (Boehlje and Eidman, 1984) was rarely used by the case farmers (Figure 8.29). The most common form of concurrent control was plan modification. Six methods of plan modification were identified (Figure 8.29), although all except the use of existing contingency plans and changing targets were rarely used. Modification of the monitoring system, viewed as a form of historical control by Boehlje and Eidman (1984) was used concurrently to ensure the accuracy of the case farmers' monitoring system.

Kennedy (1974) argued that feedback or concurrent control systems should be used in situations where the costs of errors in forecasts and estimates are high and the cost of monitoring and associated interventions is relatively cheap. Farmer A had minimal capital invested in his monitoring system, but Farmer B, due to his use of computerised systems, has several thousand dollars invested. Nevertheless, Farmer B's capital cost was minor in comparison to the total income generated by the property. Interestingly, Kennedy

[14] The categories with the dotted outline were not observed during the study; but are included for completeness.

(1974) also argued that the greater the need for system's variety, the more complex and costly the control system. The control systems used by the case farmers were relatively complex, however, they have developed relatively low cost control systems. Understanding how these work could be an effective way to lower costs.

A typology of the historical control responses used by the case farmers is presented in Figure 8.30. This is similar to, but more detailed than the historical control responses proposed by Boehlje and Eidman (1984, p. 676) (e.g. refine the plan in terms of preliminary controls, refine the plan itself, or the standards used in the plan, modify the monitoring system, and modify concurrent control procedures). Two control responses are included in the typology for completeness, but were not used by the case farmers: the implementation of new forms of "elimination of disturbances" control response, and changing goals.

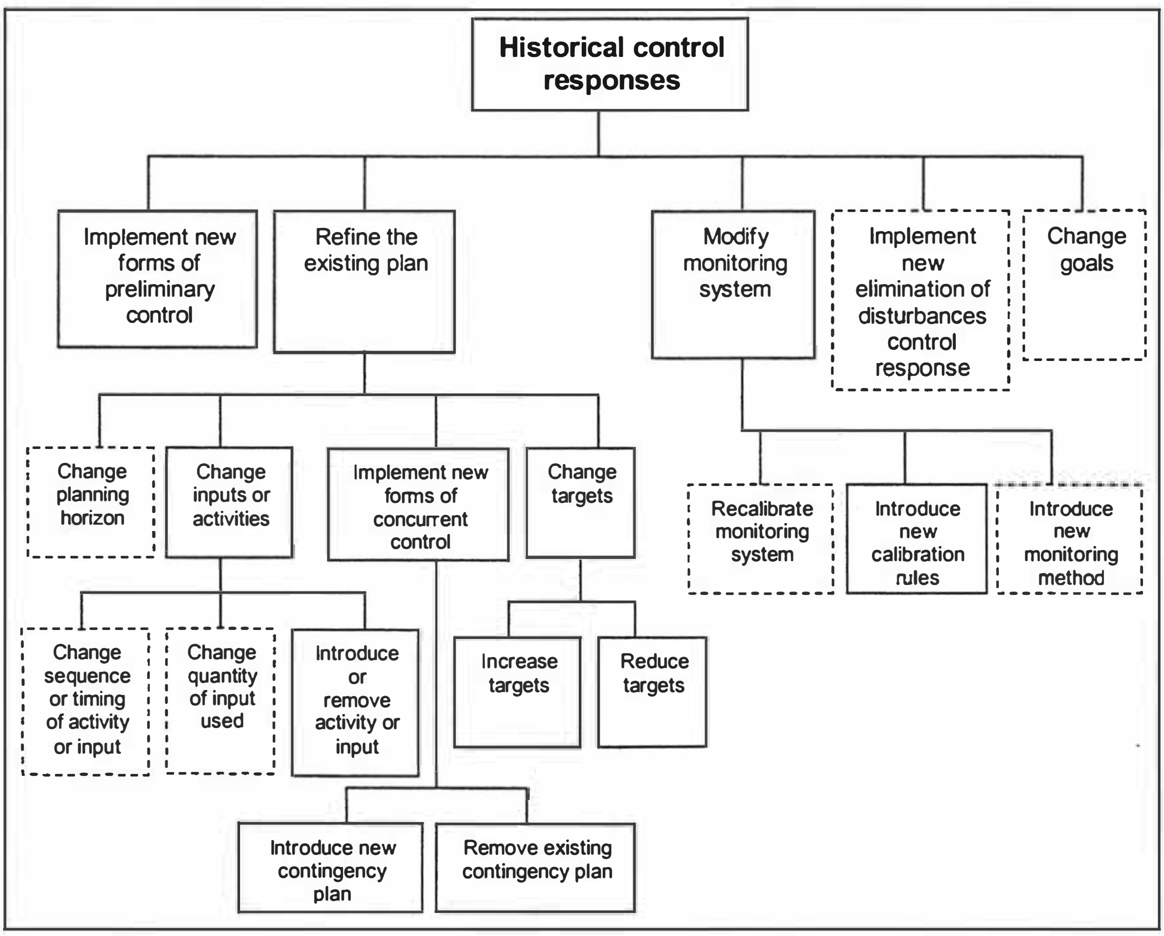


Figure 8.30. A typology of historical control responses[14].

The control responses used by the case farmers can also be considered from a risk management perspective (Jolly, 1983). The majority of the risk management responses used by the case farmers could be classified as those that controlled risk impacts and maintained short-run flexibility. Martin and McLeay (1998) reported that over 70% of the pastoral farmers in their survey used short-run flexibility to manage risk. Similarly, maintaining flexibility was ranked third or fourth by livestock farmers as a production risk response in earlier studies (Boggess *et al.*, 1985; Patrick *et al.*, 1985; Wilson, *et al.,* 1993; Martin, 1994, 1996). The other control response used by the case farmers was the maintenance of feed reserves for the early spring. This risk response was ranked between first equal and third by livestock farmers as a production management response in earlier studies (Boggess *et al.*, 1985; Patrick *et al.*, 1985; Wilson, *et al.,* 1993; Martin, 1994, 1996). It would be, as also suggested by Jolly (1983), beneficial to farmers if the management process and risk management literature were combined.

8.6.8 Plan implementation and contingency plan selection

As proposed by Boehlje and Eidman (1984), the final step in the control process was the specification of the control response. Decision rules were used by the farmers to determine what action should be taken once a decision point was recognised (Figure 8.31). The first line of the decision rule consisted of an "IF" statement that specified the conditions under which a decision point was recognised. This was then followed by a series of "AND", and/or "OR", statements that specified important characteristics of the farm state relevant to the problem situation at that point in time. These characteristics played two important roles. First, they determined if the next step in the current plan should be implemented or if a control response was required. Second, if a control response was required, they determined the exact nature of that response. The last component of the decision rule was a "THEN" statement that specified the nature of the response.

IF indicator equals or exceeds target,	) Identifies decision point
AND farm state for factor A = X,	)
AND farm state for factor B = Y,	) Determines nature of response
OR farm state for factor n = Z,	)
THEN control response = Ω	) Specifies the response

Figure 8.31. The control response selection process.

The control response selection process is similar to that reported in several tactical management studies (Gladwin and Butler, 1984; Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998). These studies reported that at each decision point, farmers had a set of sub-plans (or "regulations") and used heuristics to select the most appropriate sub-plan for the conditions at the time. None of the studies broke the heuristics down into the components for identifying and determining the nature of the response as shown in Figure 8.31. However, Gladwin and Butler (1984) reported that each sub-plan contained a set of "*entry conditions*", and that a farmer will almost automatically chose the sub-plan that passes the "*entry conditions*" that exist at the decision point. In effect, the "AND" and "OR" statements are the equivalent of Gladwin and Butler's (1984) "entry conditions". Mathieu (1989) and Cerf *et al.* (1993) also found that the farm state determined a farmers' option selection. The process is also similar to situation assessment (Klein, 1993; Lipshitz, 1993; Endsley, 1997) where expert decision makers sub-consciously characterise the problem situation on the basis of a particular set of state variables, and then pattern match the classified system state to a specific problem solution.

The process of specifying entry conditions allowed the case farmers to make fine distinctions between situations and therefore to tailor control options to the conditions. This may explain why Buxton and Stafford Smith (1996) believed that it was inappropriate to generalise across farms in relation to tactical adjustments because they are situation and location specific.

Not all contingency plans were selected using the process shown in Figure 8.31. In a few instances, the case farmers used a form of *ex-ante* evaluation to determine which contingency plan to implement. In contrast to the previous almost sub-conscious approach, this was a more conscious form of option evaluation similar to that reported by Ohlmer *et al.* (1996, 1998). It was initiated when feed conditions deviated from the case farmers' expectations. As with the farmers in other studies (Ohlmer *et al.*, 1996, 1998), once a problem had been identified, the case farmers initiated a search for suitable options. Both case farmers accessed their memory for suitable options, but only Farmer B made an external search. At the tactical level, Farmer B knew that feed was likely to become a limiting factor over the summer-autumn and that the identification of external feed options was an important risk management strategy. In contrast, the farmers in the other studies (Ohlmer *et al.*, 1996, 1998) were involved primarily with strategic decisions many of which involved the deregulation of their agricultural markets. As such, these decisions were not repetitive, and the "problems" confronting the farmers were relatively unique.

Where a case farmer considered several alternatives, something rarely recorded during the study, these were screened out using specific criteria until only one was left. This screening process was similar to that reported by Gladwin (1976, 1979ab, 1980, 1983, 1989) and Ohlmer *et al.* (1998). However, the process reported by Gladwin (1976, 1979ab, 1980, 1983, 1989) was used to select the option to be implemented, whereas the case farmers and those in Ohlmer *et al.*'s (1998) study then compared the screened option to the option in the current plan. Ohlmer *et al.* (1996, 1998) also reported that once an option had been identified for further in-depth analysis, further information was collected about it. This did not happen in this study, because unlike the farmers in Ohlmer *et al.*'s (1996, 1998) study, who were making unique strategic decisions, the case farmers in this study were making repetitive tactical decisions where they either already knew the information or had previously collected it during their normal monitoring process.

Once a suitable option was identified, the case farmers then used simulation (mental feed budget) to compare the outcome of implementing the option or continuing to implement the current plan. Like the farmers in Ohlmer *et al.*'s (1998) study, only one option was considered in-depth. The outcomes were compared, and the decision with the best outcome chosen. As with Ohlmer *et al.* (1998) few instances were recorded where the case farmers used planning aids to analyse options.

The criteria used by the case farmers to select between the options was dependent on the decision. In some instances, profitability was the criterion, while in others, factors such as cost, productivity and impact on important drivers of productivity such as average pasture cover, pasture growth rates and cow condition were used. Impact on productivity (yield) was also reported by Cerf *et al.* (1993) to be an important criterion for deciding between options. Gross margins, another important criterion identified by Cerf *et al.* (1993) for deciding between options was not used by the case farmers. This was because they operated a single, rather than multiple enterprises

Factors that influenced the between-year and across-farmer selection of contingency plans were also identified (Figure 8.32). The farmer's attitude towards intensification influenced strategic decisions about the type of inputs used in the plan. This influenced the nature of the plan, which in turn dictated the contingency plans open to the farmer. Gasson (1973) mentioned that values influence the modes adopted by farmers to meet their goals and Fleury *et al.* (1996) noted that to understand a farmer's tactical management, one had to understand the level of intensification they were aiming at.

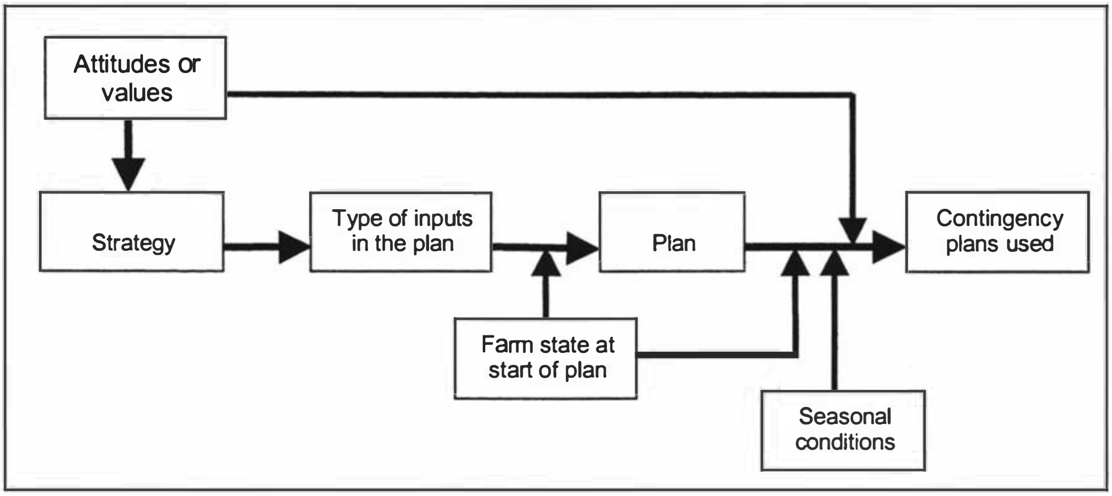


Figure 8.32. Factors that impact on a farmer's choice of contingency plans.

8.6.8.1 Target selection

The case farmers also used the process described in Figure 8.31 to change intermediate targets in response to variation in climatic conditions. The targets they changed primarily related to milk production and/or cow intake. The changes were made either to take advantage of surplus feed, or reduce feed demand when feed supply was limiting. Boehlje and Eidman (1984) proposed that farmers would change targets as a control response because they were inappropriate. However, the control response used by the case farmers was instigated to change feed demand, not because the standards were inappropriate. As such, target selection can be considered another form of contingency plan. Ohlmer *et al.* (1998) also reported that where poor conditions could not be compensated for, farmers adjusted their performance aspirations downwards.

8.6.8.2 Opportunity selection

One of the case farmers used an opportunity recognition and selection process to improve his ability to cope with the atypical conditions (Figure 8.33). The external environment was monitored and the information processed, analysed and compared to pre-set criteria. If it matched, the case farmer then decided whether he wanted to take advantage of the opportunity. In most instances this was a simple decision once the opportunity had met the criteria and the feed situation was such that it could be used. However, in one instance, three opportunities were compared, screened on the basis of several criteria until the most suitable option was identified. This was then compared to an internal option using a partial budget framework. The external feed source proved the preferable option on the basis of profitability. If the case farmer decided to take advantage of an opportunity, it was purchased, the current plan was modified and it was implemented.

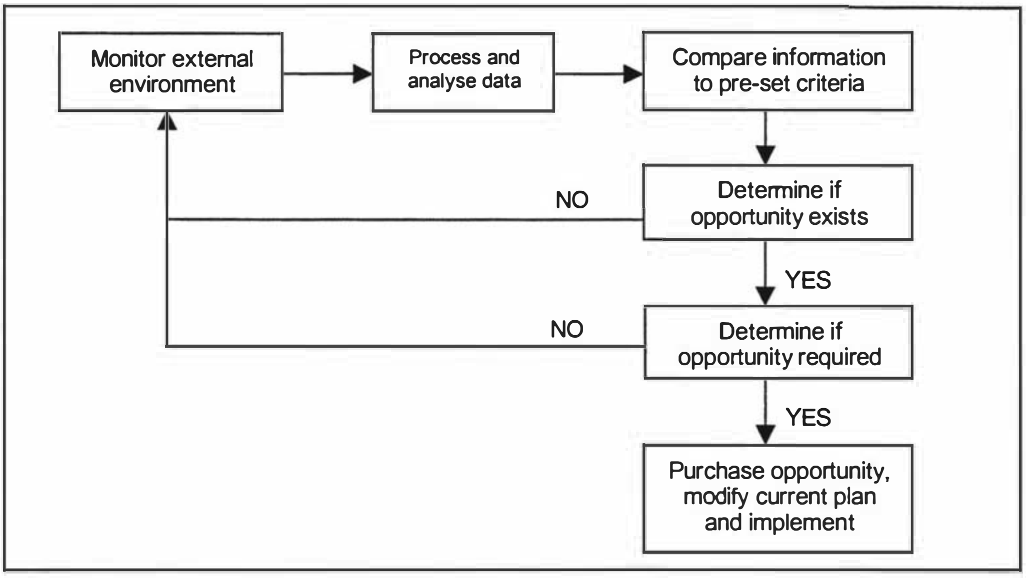


Figure 8.33. The opportunity recognition and selection process.

The results of this study show that the problem and opportunity recognition processes use quite different information. The former is identified by monitoring the internal system and comparing the outcome to targets or standards, whereas the latter is identified by monitoring the external environment and comparing the information from the search with pre-set criteria. If the preset criteria are met, the decision-maker must then decide whether to implement the opportunity. This may require a comparison with other opportunities and/or the next option in the plan. Although opportunities are mentioned by several authors (Lee and Chastain, 1960; Neilson, 1961; Suter, 1963; Boehlje and Eidman, 1984) in the normative literature, no process of opportunity recognition and selection are provided except in relation to SWOT analysis in strategic management (e.g. Parker *et al.,* 1997). Lee and Chastain (1960) and Nielson (1961) distinguished between problem and opportunity recognition, but this was not taken further in subsequent literature. Catley *et al.* (2000), in the descriptive literature, referred to opportunity finding as "prospecting", but provided no description of the process.

8.6.8.3 Changing plans and goals

A more significant control response is the changing of a plan after it has been implemented. This control response is advocated in the normative literature (Barnard and Nix, 1973; Boehlje and Eidman, 1984; Parker, 1999), particularly where there is some longer-term change in the planning environment. Catley *et al.* (2000) reported that this was the major strategic control response used by cutflower growers in response to declining flower prices. A problem in this study was deciding what constituted a change in plan relative to the modification of a plan. With few exceptions, the changes the case farmers made to their plans were primarily modifications. In one instance, the plan was changed because the reproductive performance of Farmer B's herd was much poorer than expected. In other instances, the case farmers believed there had been a shift in climatic patterns and changed their plans to cope with this perceived shift.

Wright (1985) argued that an important aspect of control is to distinguish between short-term aberrations and longer-term changes in the environment. Similarly, Ohlmer *et al.* (1998) in a study of farmers' strategic decision-making made a distinction between diagnosing random and non-random deviations from the plan. They found that where the latter was diagnosed, farmers developed a new plan. However, neither Wright (1985) nor Ohlmer *et al.* (1998) provided any insight into how the distinction is made between a short-term aberration and a longer-term change in the environment. The case farmers in this study used repetition of experience to identify if a fundamental shift in climate had occurred. After experiencing three cold, wet springs, the case farmers changed their plans for that period. This was not a very robust method as Farmer A found when he changed his summer plan after experiencing two wet summers and what he thought was a third, only to find that conditions turned dry.

The case farmers also adjust their "typical" plans at the start of the planning period in response to the farm state at the time, or due to historical control[15]. Aubry *et al.* (1996) found that farmers changed their plans in response to learning (historical control), but made no mention of changes in response to conditions at the start of the planning period. Interestingly, despite some extreme years, the case farmers did not change their primary goals for the summer-autumn period. They did however change their targets (both intermediate and terminating). Although changing goals is a recognised control response (Boehlje and Eidman, 1984; Parker, 1999), this was not mentioned in the descriptive literature.

8.6.9 Learning

An important outcome of the case farmers' evaluation process was learning. Planning (Mauldon, 1973), planning aids (Petit, 1977; Wright, 1985; Attonaty and Soler, 1990; Cox,

[15] Historical control responses included changes in response to a perceived shift in climatic patterns.

1996), the control process (Johnson, 1954) and indicators (Shadbolt, 1997) all played *a* role in their learning. Four important areas of learning were identified: the environment, the production system, the management system and values (Figure 8.34). The categories are intended to represent discrete areas of learning, in fact, most of the learning by the farmers involved the interactions between two or more of the higher level categories. The context within which the learning occurred was critical because many of the planning and control heuristics were situation specific. The importance of the situation in decision making has been stressed by several authors (Gladwin and Butler, 1984; Mathieu, 1989; Cerf *et al.,* 1993; Klein, 1993; Lipshitz, 1993; Endsley, 1997).

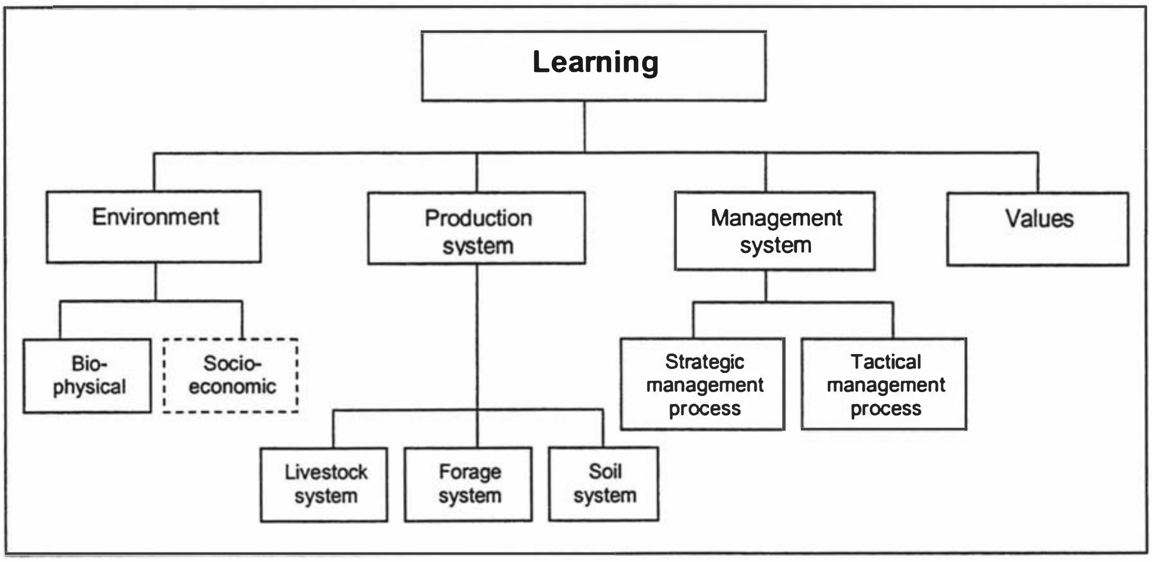


Figure 8.34. A typology of the areas of learning undertaken by the case farmers[14].

Learning with respect to the tactical management process could be separated into the sub-categories planning, implementation and control (Figure 8.35). Areas of learning with respect to planning related to forecasting, activity rules[16], target selection, contingency plan specification and planning assumptions. Learning in relation to control could be separated into contingency plan selection and monitoring. Contingency plan selection included decision to do with input use, management practices and the choice of targets. Monitoring included the areas of method, usefulness, accuracy, timeliness and accuracy of predictions. No evidence was found of other typologies for learning in relation to the management process, in the literature.

[16] Rules that determined the placement of an input or management practice in the plan.

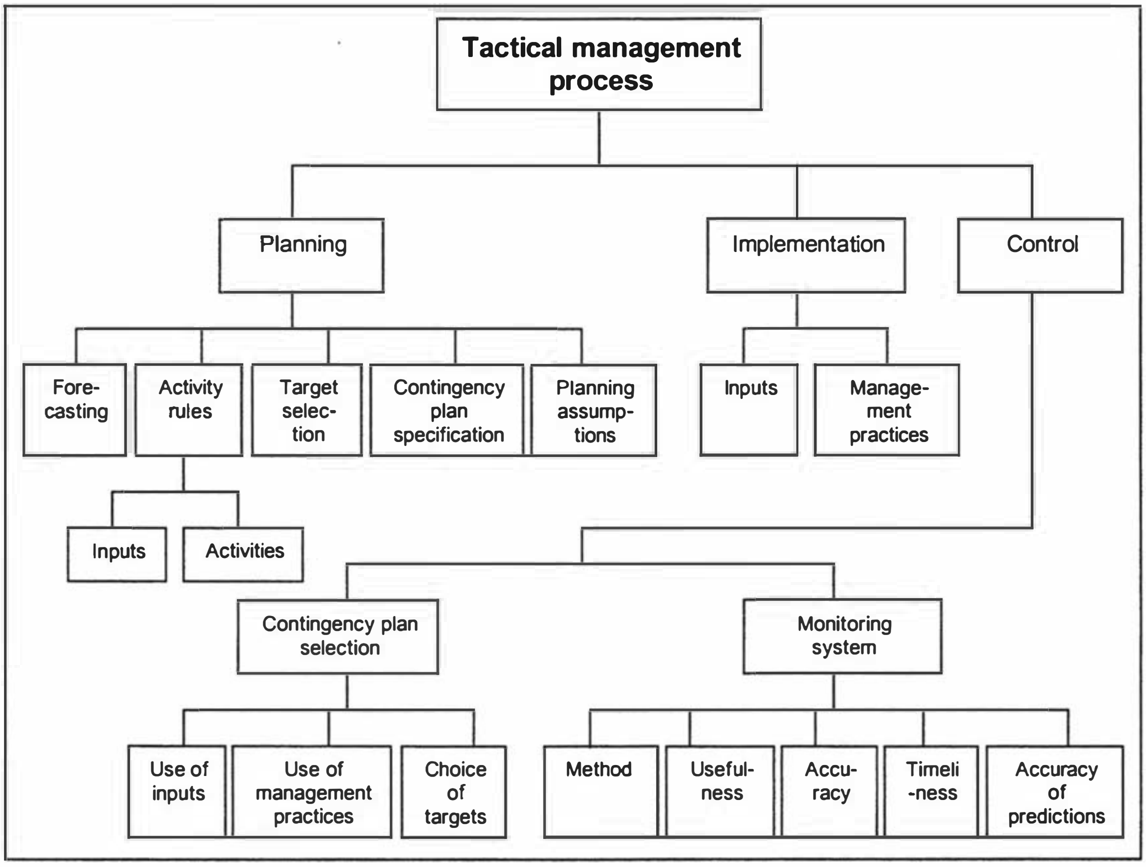


Figure 8.35. A typology of the areas of learning in relation to tactical management undertaken by the case farmers.

A new management practice, or climatic extremes were the most obvious promoters of learning. In some cases, learning simply added to the case farmers' general understanding of the production system and environment. In other cases it resulted in a change to their management practices. Three learning outcomes were identified in relation to the management practice. First, learning could confirm the efficacy of a new management practice and it was retained. Second, the effectiveness of a management practice (new or old) could be found wanting and it was changed to improve managerial performance. Third, the effectiveness of a new management practice could be found wanting, but because no means of improvement could be identified, it was discarded. Petit (1977) used the term "model validation" to describe the process where new knowledge is created by correcting old mistakes. However, he did not mention knowledge creation in relation to new management practices.

Instances of learning in relation to the management system covered the continuum of management levels from operational through to strategic. The tactical management process played an important role in learning about and refining strategy. Around one third of the lessons learnt in relation to the case farmers' management systems could be classified as strategic in nature. This supports Kaplan and Norton's (1992, 1993, 1996abc) view that managers should identify important cause and effect relationships between business strategy and operational measures.

Two learning processes were identified during the study (Figures 8.36 and 8.37). The first process (Figure 8.36) was used when a new management practice was introduced. Some factor caused the case farmers to postulate a management change. This was due to extreme conditions, outside information, previous experience, their management and production system knowledge or some combination of these factors. The management change was implemented and then the outcome of the change monitored and compared to the case farmers' expectations of the likely outcome of the change. These were compared and if the outcome was the same as, or similar to the case farmers' expectations, this confirmed their postulate and the new management practice was retained. If expectations were not met, the cause of the deviation was determined. In some instances, these were known because the reasons for the deviation were identified through the monitoring system. If the reason for the deviation was not known, then diagnosis was undertaken. Learning accrued from each of the three outcomes, i.e. if the expectations were met, if they were not met, but the reasons for the deviation were determined pre-outcome, and if the deviations were not met and diagnoses had to be undertaken to determine the cause. If the new practice did not perform as expected, the case farmers then determined if it could be refined to enhance performance. If it could, it was implemented when conditions were appropriate and the cycle repeated. However, if it could not be refined, then it was discarded.

A similar process was used where learning occurred in relation to an existing practice (Figure 8.37). In this case, an existing management practice was implemented and because of extreme conditions (outside the farmer's previous experience), the outcome was significantly different from the case farmers' expectations. The reason for the deviation may have been identified through the monitoring system, but if it was not, diagnoses was undertaken. The case farmers then determined if a new management practice could be postulated from what they had learned. In some cases it could not, and the primary outcome of the learning was information about the variation in the environment and how their production system responds to such variation. However, in many of the cases, the case farmers postulated a management change that improved their capacity to cope with such conditions in the future. The learning was either applied in the next production cycle or immediately after it had occurred in the current production cycle because extreme conditions were still present. The management change was implemented at the appropriate time and conditions and tested as shown in Figure 8.36 for a new management practice. Therefore, under extreme conditions learning pertains first to how the production system responds to extreme conditions under current management practices.

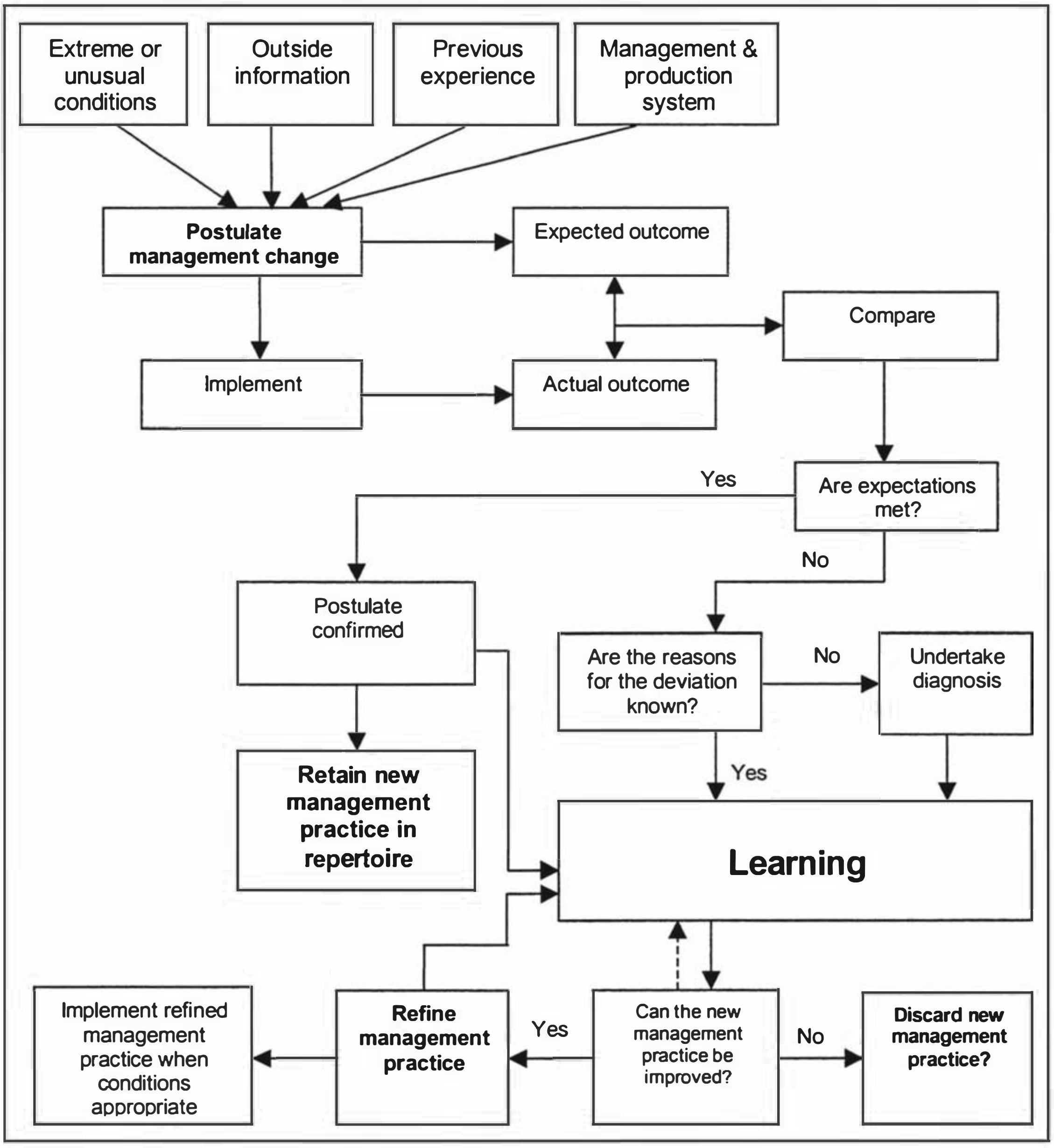
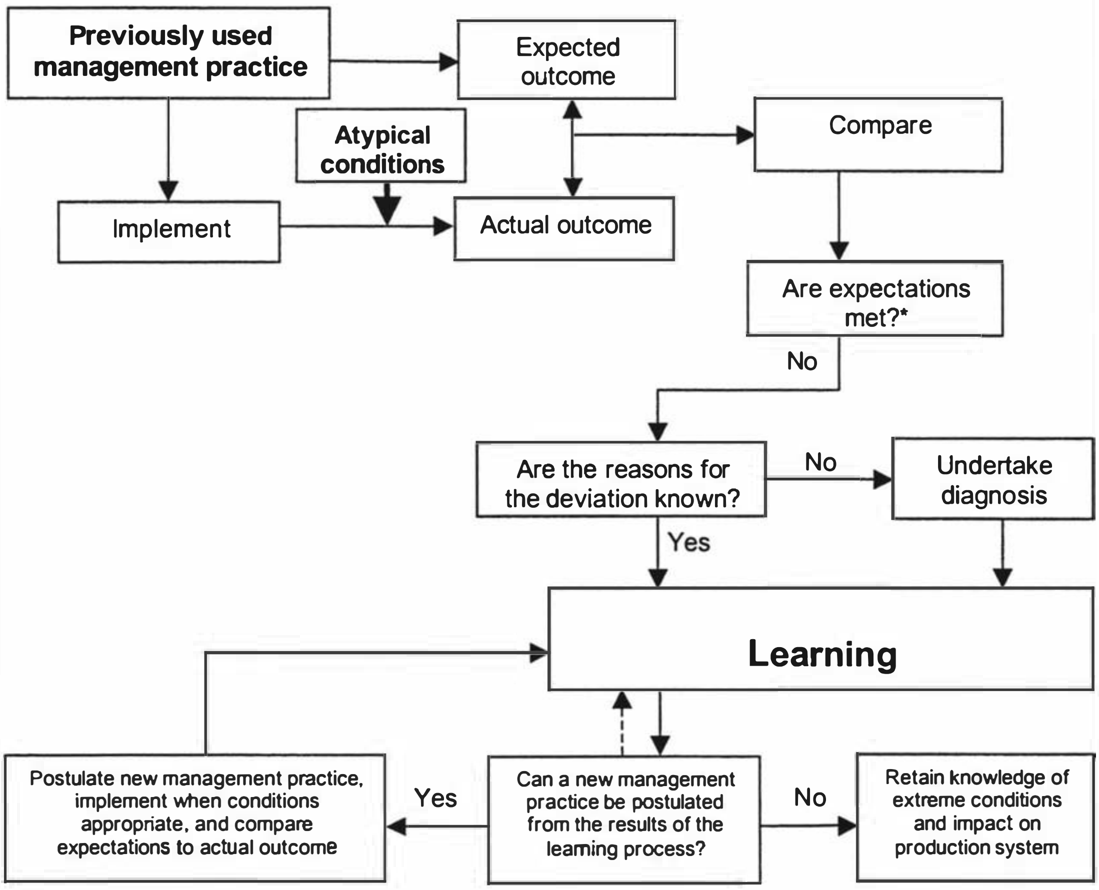


Figure 8.36. The learning process used by the case farmers when introducing a new management practice.

A second loop of learning occurs if the case farmers can postulate a change to their current management practices to cope with such conditions, and then test this through another cycle. No examples of learning processes in relation to the tactical management process were found in the literature.

Petit (1977) argued that a decision maker should assess three criteria (logical consistency, consistency with experience, and workability) to determine a model's validity. Consistency with experience appeared to be the primary criterion used by the case farmers to assess the validity of their mental models.



* Expectations are not met under the definition of "extreme conditions" in this instance.

Figure 8.37. The learning process used by the case farmers when extreme conditions cause unexpected outcomes.

The results of this study support the views of Papy (1994) that learning occurs through the interaction of a farmer's knowledge model of the production system and his or her action model (management system). Petit (1977) believed that a farmer's mental models are revised as they adapt to changes in the environment. However, changes in management practices also caused the farmers to revise their mental models. The management process is analogous to the action learning cycle proposed by Kolb (1974, 1984) where a learner will plan an action, implement it, monitor the outcome and compare it to his or her predicted outcome and then reflect on the outcome (Wilson and Morren, 1990; Bumside and Chamala, 1994). Through reflection comes learning. This cycle is similar to the management process of planning, implementation, monitoring and evaluation. It is therefore not surprising that the management process is conducive to learning, as proposed by several authors (Johnson, 1954; Mauldon, 1973; Chibnik, 1981; Burnside and Chamala, 1994; Parker, 1999). Petit (1977) stressed that invalidation of a farmer's mental models leads to the correction of a decision maker's errors and is an essential step in the learning process, a point that is highlighted in the learning models (Figures 8.36 and 8.37). The results of the study also support the views of Attonaty and Soler (1991) and Murray-Prior (1998), that learning is an important aspect of management that helps managers cope with uncertainty and changing conditions. Several examples were identified where the case farmers reassessed their decision rules in response to changes in the environment. This also supports Murray-Prior's (1998) criticism of the static nature of Gladwin's (1976) hierarchical decision tree models and Petit's (1977) view that knowledge should be viewed as a process, not a state, because it is not likely to be valid once and for all. At a higher level, the results support the view that the control process over time enhances a farmer's control over their system through learning (Johnson, 1954; Mauldon, 1973).

The learning processes (Figures 8.36 and 8.37) were used to close a knowledge, as opposed to a performance gap (Scoullar, 1975). These processes have many of the attributes of an "unstructured" decision as reported by Mintzberg *et al.* (1976). For example, more rigorous diagnostic, and design[17] sub-processes are used than for a normal "structured" decision. The learning process was also critical for ensuring the farmers could continually improve their acquired "tools" and apply them creatively to solve problems and exploit opportunities as proposed by Cameron (1993).

The study also identified that a bad experience could overly influence farmer behaviour to the point that it limited the use of potentially profitable options. For instance, Farmer A would not use winter grazing on this basis, despite it being considered a profitable option for extending the lactation. This demonstrates a negative aspect to experiential learning and suggests that in the case of a bad experience, emotion clouds the farmer's objective reasoning. Effective learning requires the manager to overcome such "emotional" bias. The author could find no reference to this "emotional" bias in the farm management literature.

[17] Design is analogous to the process of postulating a new management practice.

8.7 Summary and conclusion

In this chapter, a theoretical classification of the cases was made and the tactical management process used by the farmers was compared to the literature. The importance of distinguishing between "*structured*" and "*unstructured*" decisions at the tactical level was highlighted. Factors that determined the case farmers' choice of planning horizon were identified, as were the means they used to overcome the problems of interdependency and consequences. The use of both formal and informal planning processes for tactical management, something not previously described in the literature, was reported. A model of the informal planning process was developed that demonstrated how the case farmers modified their "*typical*" or predefined plans in response to prior learning, previously made strategic and "*atypical*" tactical decisions, and the farm state at the start of the planning period. New typologies in relation to targets (standards) and contingency plans were developed. Important findings were identified in relation to control. A more refined model of the control process was developed. Models for the important control sub-processes, monitoring, opportunity selection, diagnosis, evaluation and learning were developed or further refined. Similarly, typologies for monitoring, evaluation and learning were developed or extended. In the next chapter the conclusions and implications from the study are discussed. The methodology is evaluated, and future areas of research leading from this study are outlined.

CHAPTER 9 CONCLUSIONS

9.1 Introduction

The New Zealand dairy industry provides some 20% of the county's export receipts. An important competitive advantage for this industry is the ability of its farmers to produce relatively low cost milk from pasture. However, despite its importance, little was known about the management processes used by New Zealand dairy farmers to convert pasture into milk. Summer-autumn is a critical period on a New Zealand dairy farm where tactical management decisions made during this period influence not only productivity in the current, but also the subsequent season. Pasture growth rates, the primary source of feed, are also at their most variable during this period. A study of the management practices used by high performing dairy farmers over the summer-autumn period could identify practices that could be adopted by "*less expert*" farmers to improve the productivity of their farms. Such research would enhance the New Zealand dairy industry's international competitiveness. An assumption central to this thesis was that an in-depth understanding of the tactical management processes used by farmers could only be obtained through the use of a longitudinal research method. Therefore, the overall aim of this thesis was to develop a theory, through an in-depth, longitudinal research method, to explain the tactical management processes used by high performing or "expert" pastoral-based dairy farmers over the summer-autumn. This was achieved by addressing the following objectives:

1. To describe how high performing pastoral-based dairy farmers tactically manage their farms through the summer-autumn period.

2. To explain why high performing dairy farmers tactically manage their farms in the way they do during the summer-autumn period.

3. To compare the results of the study to the literature.

4. To develop theory to explain how high performing dairy farmers tactically manage their farms through the summer-autumn period.

In this chapter, the conclusions from the study are outlined and implications from the research for dairy farmers, extension agencies and the discipline are discussed. The research methodology is evaluated and areas for future research are identified.

9.2 Research conclusions

The results of the study support the author's view that a management process framework, as opposed to either a decision-making or problem-solving framework is best suited to the investigation of the management practices of farmers. This is because the cyclic and repetitive nature of management and management control, is less well accounted for in the latter process models. As such, management can be thought of as a cyclic process involving irregular planning decisions followed by regular, repetitive and less major implementation and control decisions.

The interdependence of planning and control was strongly affirmed. Under conditions of high uncertainty, dairy farmers placed greater effort on control than planning. To facilitate control, plans incorporated targets, contingency plans and contingency plan selection rules. Decision rules, monitoring and learning processes played an important role in coping with a changing and unpredictable environment as proposed by Attonaty and Soler (1991). The study also identified that goal formulation was separate from, but an important driver of, the tactical management process.

As expected, the majority of decisions undertaken by the farmers were of a structured nature. Instances of unstructured decisions were identified and these were in situations where, as proposed by Scoullar (1975), a knowledge gap existed. Such unstructured decisions required the used of diagnostic, evaluation and learning processes. However, as postulated by Simon (1960) and Gorry and Morton (1971), structured decision-making dominated at the tactical level and unstructured decisions were only made when the farmers confronted situations outside their normal experience.

An important contribution from this study is that several important management sub-processes (e.g. opportunity finding, diagnosis, contingency plan selection, evaluation and learning) have been made more explicit. As such, this should alleviate many of Cary's (1980) criticisms of the simplistic nature of the management models applied to farming.

Important contributions in relation to tactical planning were made through the study. The factors that influence a farmer's choice of planning horizon and the role of terminating targets in overcoming the problems of interdependency and consequences were identified. By building on previous empirical work, a model of the planning process used by farmers at the tactical level was developed. It was found that although farmers draw on a "typical" plan each year, the planning process is more complex than previous research suggested. Strategic decisions, learning (or historical control), atypical tactical decisions made in the previous planning period and the state of the farm at the start of the planning period, in combination with heuristics and mental simulation, influence the development of a tactical plan in any one year. Although the role of heuristics in planning has been previously reported, no mention was made of the role of mental simulation. Further, the "typical" plans of farmers may change quite dramatically over a relatively short time frame in response to learning and changes in strategy.

The farmers were found to alternate between informal heuristic-based and formal quantitative planning processes, something not previously reported. The latter relied on the application of planning aids (feed budgets) at the tactical level. The structure of the farmers' plans was found to be the same as reported in the French work (Mathieu, 1989; Cerf *et al.*, 1993; Fleury *et al.*, 1996; Aubry *et al.*, 1998), however, new typologies for targets and contingency plans were developed. An important new plan heuristic (target selection) was added to the taxonomy of heuristics developed by Aubry *et al.* (1998).

The greatest contribution from this study has been made in the area of control. The control process was refined to make explicit the difference between plan implementation and control selection sub-processes. The control process also now incorporates an opportunity finding process, with separate diagnostic and evaluation processes that lead to learning. The complex and holistic nature of the monitoring process used by the farmers has been described. The farmers used their intimate knowledge of the production system to develop low cost, timely and accurate monitoring systems. Typologies have been developed for the monitored factors, methods of monitoring and role of monitored information. Important new findings were made in relation to the role of indirect measures, the importance of triangulation in measurement validation (accuracy), the role of decision rules in reducing monitoring effort and the role of a predictive process in ensuring that the farmers were prepared for changes in the environment. Factors that influenced the timing and frequency of monitoring were also identified.

Typologies of concurrent and historical control responses were developed to extend the earlier work in this area (Mauldon, 1973; Dalton, 1982; Boehlje and Eidman, 1984). The control response selection process used by the farmers was formalised and an opportunity selection process developed. The study highlighted the finesse of the control response selection process and the number of factors a farmer might consider when selecting a response.

The diagnostic sub-process within the control process was described; this was based on expectations, not outcomes. Expectations were used to identify knowledge, as opposed to performance gaps and as such were critical for stimulating learning. The evaluation process was described and typologies of evaluation areas and methods identified. Learning process models were developed along with a typology of learning areas. Importantly, farmers were found to learn in three key areas: the environment, the production system and the management system. Knowledge of the production system and its interaction with the environment was critical to the development of an effective management system. The tactical management process, analogous to the action learning cycle of planning, action, observation and reflection, was central to learning. The tactical management process also performed an important role in evaluating strategic decisions.

9.3 Implications of the findings

The findings from this study have implications for dairy farmers, extension agents and the discipline of farm management. For dairy farmers, the study provides a model of the tactical management process against which they can compare their own management practices and reflect on areas for improvement. The importance of a detailed knowledge of the production system and environment were identified as critical for effective tactical management in the field of production. As such this area is important for farmer education. The model identifies important areas of a farmer's production management which should be evaluated. For example, in relation to planning, they could consider their choice of a "typical" plan, the heuristics underlying the plan in terms of sequencing, timing, input and target selection rules, the contingency plans they have to cope with variation, and their choice of intermediate and terminating targets. Similarly, under control, they could consider the effectiveness of their monitoring system, the means by which they select control responses and identify opportunities. The management process has an important role in relation to learning and therefore is central to improving farmers' management skills and productivity.

The research findings have implications for extension. The tactical management model should prove useful for extension organisations interested in benchmarking (Zaire, 1994; Finnigan, 1996; Ferris and Malcolm, 1999) best practice in relation to pastoral management, whether in dairying or sheep and cattle or deer farming. It should help identify differences between the management practices of highly productive and less productive farmers in a much more useful way than comparative analyses of financial and production records. The study also makes explicit the areas of learning extension agents should consider when helping farmers improve their productivity. The linkage between production system knowledge and the use of such knowledge in the development of effective management systems provides some insight into how to adapt extension programs to enhance farmers' management skills. The experiential learning process derived from this study should be explored by extension agents to help them develop more explicit learning processes for farmers.

The study demonstrated why farmers might not adopt the formal planning and monitoring systems advocated by extension agents. Such information may provide the basis for the development of more farmer-friendly systems. However, care must be taken with the interpretation of these results because the farmers in this study were "*experts*". Some researchers have also advocated the development of expert systems to assist farmers in their management (Nuthall, 1989; Todd *et al.*, 1993; Bishop-Hurley and Nuthall, 1994). The results of the study suggest that such systems may not be as generalisable as previously hoped for because of the situation-specific nature of the decisions rules used in the management sub-processes such as control response selection (Stafford Smith and Forran, 1992). The results also demonstrate that dairy farmers have the capacity to quickly change their production and management systems. Consequently, tactical management expert systems might quickly become redundant unless they were continually updated.

This study has implications for farm management as a discipline. It has demonstrated the benefits of adopting an in-depth longitudinal approach for the study of management. Until more farm management researchers take up this approach, the discipline's theory on farm management is going to remain "*under-exposed*" (Rougoor *et al.*, 1998). A more standardised approach to management research would be beneficial to progressing the discipline. Rather than investigating the management practices of farmers through three lenses (the management, decision-making and problem-solving processes), it would be more sensible to use the approach most suited to the phenomenon of "management". The management process approach provides the best "lens" through which to view management, given its cyclic and on-going nature.

The use of a case study approach raised the issue of what is a case and what are the best means by which cases in farm management studies should be classified. Some basic characteristics were identified in this study that should be considered for case selection in any farm management case study. This builds on the classification schemas proposed by Boehlje and Eidman (1984) and Dryden (1997) and incorporates their ideas of management fields (production, market, finance, labour), decision levels (strategic, tactical, operational), and structuredness (structured, unstructured). Added to this are the categories, enterprise numbers (single or multiple) and level of risk in the environment (production, finance, market, human, technological, social and legal, inter-firm competition).

A distinguishing feature between farm and business management is the need for farm managers to understand the production system. In contrast business management can be viewed as a generic process that can be applied to a wide range of business types. This study reinforces the view that to be an expert production manager, one must have a detailed understanding of the production system. It is this comprehensive knowledge which is used to develop the heuristics behind effective planning and control procedures.

Learning in production management occurs in relation to the environment, the production and management systems and the interaction between these three components. This should be borne in mind when developing farm management curriculum. Gatton College in Queensland, Australia has proposed a farm management curriculum that contains modules in environment and management systems followed by a module that integrates these two areas (Cameron, 1993). However, no mention was made of a production systems module. The results from this study suggest that modules in production systems along with finance, human resource management and marketing are required to develop well-rounded farm management professionals. They also support Cameron's (1993) view that learning in these areas is best fostered by experiential-based case studies.

9.4 Evaluation of the methodology

The case study approach allowed the tactical management processes used by the case farmers to be investigated in-depth and provided a method of developing rich theory. The longitudinal nature of the case study proved suitable for investigating a dynamic management process, particularly as much of the knowledge used by the case farmers for management was tacit. The cross-year approach was useful for identifying between-year differences in management. The tacit nature of farmer knowledge also meant some aspects of management not identified in year one of the study were picked up in years two or three. The longitudinal nature enhanced rapport between the interviewer and farmers which in turn improved the flow of information during interviews. The trade-off in undertaking a three-year as opposed to a single-year case study was a significant reduction in the number of case farmers.

Many of the descriptive studies on management include limited information about the research method. A detailed description of how a longitudinal case study-based method can be used to investigate the management practices of farmers is provided by this study.

Eisenhardt (1989) recommended that a case study comprise between four and ten cases. This study was equivalent to six cases (2 cases by three years). Having completed this investigation, the author believes that a distinction should be made between case studies that investigate a small number of explanatory variables and those that investigate complex processes. The latter require the analysis of a large amount of data and a large number of categories and linkages between categories. For example, in this study some 600 pages of transcripts were analysed and over 400 categories were identified. It is axiomatic that for in-depth process studies, fewer cases should be selected than for studies focussed on several easily measured explanatory variables.

An important aspect of this study was the focus on case definition, of what the cases were "a case of". This is important in terms of developing generalisations to theory and for comparing across studies. This aspect had been poorly developed in the descriptive studies reviewed in the literature. The other aspect of case selection was the choice of a time period that crossed two planning horizons. This provided a richer insight into the planning processes (informal versus formal) used by the case farmers. These results suggest that in future management studies researchers should obtain a reasonable overview of the planning horizons and planning processes used by their case farmers before selecting the study period.

Although considerable effort was taken to define the cases in the case study, one important area that could have been taken further was the case farmers' personal attributes. More explicit information about their objectives, level of training, financial situation, attitudes to risk, locus of control, personality and management style would have enhanced this study. Similarly, it would have been useful to develop a goal hierarchy for each case farmer showing the linkages between their tactical management goals and their intermediate financial goals and longer-term goals. This would show how the case farmers believed their tactical management decisions over the summer-autumn impacted on their financial performance and what longer-term goals were driving their management.

Users of the case study method stress the importance of a thorough working knowledge of the relevant literature before undertaking the data collection and analysis phases. The author reiterates this, especially for researchers and post-graduate students with limited background in the discipline. A detailed literature review is critical before either case selection or data collection commences. In this type of research, because the researcher is the "*instrument*", it is essential that one is sensitised to the data otherwise theoretically important data can be overlooked, either during the interview or data analysis processes.

Semi-structured interviews proved an effective data collection method and for detailed management process research, tape transcription was essential. The use of diaries by the case farmers in year three of the study assisted them in recalling what they did. The author would recommend their use in future studies. Respondent verification of the interview summaries and case reports was critical as they identified areas where the data had been misinterpreted, particularly with respect to tacit knowledge. Misinterpretation of what the farmers "really meant" occurred despite the author's good knowledge of dairy farm and pastoral management suggesting verification is an essential component of the research process.

Field observations provided useful data in relation to the interviews, despite being made only once or twice a month. There were several instances where such observations identified important aspects of management, normally tacit knowledge, which had not been identified through the interviews. Field observations should therefore be integral to any study of tactical farm management. Quantitative field data was not collected during the study due to resource constraints, putting a heavy reliance on information provided by the case farmers. However, through the field observations the author was able to assess that the data provided by the case farmers was consistent with his own assessment of the farm state during the visits. In situations where non-expert farmers were the focus of a study, field measurements would be essential to validate farmer claims.

The qualitative data analysis process advocated by Dey (1993) proved suitable for analysing the data. Central to this process, particularly given the magnitude and complexity of the data, were the data analysis software programs NUDIST and NVivo. Without these programs, data analysis within the time frame of the study, would not have been possible. These programs were well suited to the development of category hierarchies but were less useful for the development of process models. A broader range of qualitative data analysis software has been developed since this study was initiated and the author would recommend other researchers to investigate their capabilities for both categorisation and process modeling before their acquisition.

Tight definitions of terms were critical to the qualitative data analysis process. Where these were ambiguous, either for those derived from the literature or developed by the author, problems occurred. However, the greatest challenge with this research approach was the time it took to analyse the data. This was a function of the magnitude of the data and complexity of the tactical management process. A major problem was determining when to initiate closure: intense reflection on the data could result in the identification of new categories or connections between categories. Thus, in this type of research, there are trade-offs to be made between time on analysis and premature closure. Development of a model of the process is an important step in speeding up the analyses of subsequent cases. This suggests that where there is a good body of theory from which to develop a framework, data analysis may be more straightforward. However, in areas where there is limited theory, additional time should be allowed for data analysis. Under such conditions, it would be prudent for fewer cases to be selected.

Tables and time-lines assisted cross-year and cross-case analysis as recommended by Miles and Huberman (1994) and this proved a powerful process for generating theory. Much of the abstraction of processes and identification of new typologies occurred during the cross-year and cross-case analyses. This suggests that if a greater number of theoretically diverse cases had been able to be selected, greater theoretical development is likely to have occurred.

The author used a range of techniques to minimise bias. Particularly important was the time spent with the case farmers, the recording and transcription of interviews, field observations and case farmer verification. However, some problems in obtaining a "true record" were identified. First, because of the time spent with the farmers and the development of rapport, it was difficult to maintain neutrality throughout the three years. The research process also had the potential to influence what the case farmers did. For example, early in the study, instances were recorded where the case farmers monitored information earlier than normal so that it was available at the next visit. These changes in routine were identified, discussed, and the problem rectified. A more difficult area to control was the impact of the author's questions on the case farmers' reflective and learning processes. These questions, particularly those about why they did something and the verification process, caused them to think more deeply about what they did than otherwise would have been the case. To reduce this problem, greater use of observation and less direct questioning techniques could be used. Routine verification is essential to minimise bias.

An important aspect of a longitudinal study such as this is the time commitment required from the case farmers. Each visit can require between two and four hours, the latter being required if field observations were undertaken. The case farmers were also required to read each of the interview summaries and annual case reports. This is a large voluntary commitment by any standards and it is important that this is understood at the start. It is also important to develop good rapport with the case farmers to ensure their commitment continues. A risk to this type of research is that the case farmers withdraw their commitment partway through the study.

9.5 Future research

From this study a range of future research areas have been identified in relation to dairy farmers, pastoral-based farmers, and management in general. In relation to the dairy industry and its focus on productivity (Boedeker, 2000), an important area for future research would be to follow the French research (Darre, 1989; Jeanine and Cristofini, 1989; Deffontaines, 1993; Papy 1994; Dore *et al.*, 1997) and develop production management typologies based on the model from this study, within and across regions. A holistic research approach that coupled on-farm management research with that from experimental and systems-based modeling research linked through an extension service would provide a powerful means of developing innovations for improving the productivity of the dairy industry.

Part of such a broad approach would be to investigate the management practices used by farmers in different situations. These "situations" would need to be identified as relevant to the industry and its focus on improving productivity. This is an important research area in itself. Examples might include different production systems or levels of intensification within and across regions. Other comparisons might be on the basis of risk factors. For example, the farms in this study had low financial risk and financial constraints had a limited impact on the farmers' production management. However, this may not be the situation for farmers who have a high debt load or those who operate small farms with marginal levels of profitability.

One finding from this study was that the case farmers relied primarily on heuristics for decision making and that financial analysis was rarely used. Implicit within these heuristics was the concept of marginality and the linkage between the heuristic and the overall financial performance of the business. However, the role of economics in the case farmers' decision making and the linkages between decisions and financial performance were not explored in any detail. Given economics is viewed as central to decision making in farm management, this is an important area for further research.

The subjects in this research were "experts". Important future research is required to identify differences between "*expert*" and other farmers (novice and "*less expert*" farmers). The model developed in this study could be used to postulate hypotheses about the differences between "*expert*" and "*non-expert*" farmers. If such information could be identified, this could help extension agents improve the productivity of less proficient farmers through the application of benchmarking principles (as opposed to comparative analysis (Ferris and Malcolm, 1999; Parker, 2000)) to transfer best practice.

Future research that leads directly from this study is the investigation of the management practices used by "*expert*" dairy farmers at other times of the year. Similarly, systems modeling could be used to investigate the efficacy of the tactical management practices used by "*expert*" farmers. The French have used this approach to identify further enhancements to farmer practice. Several new management sub-process models were developed as a result of the study (e.g. informal planning process, diagnosis, opportunity recognition and selection, evaluation and learning). Because of the breadth of this investigation, these sub-processes were not investigated in-depth. This is an area for future research.

The applicability of the tactical management model to other pastoral farming types (e.g. deer, sheep and cattle) could be investigated. The study highlighted three areas where New Zealand dairy farmers have a management advantage over sheep and cattle farmers. First, as demonstrated in this study, they manage predominantly single-enterprise farm businesses where a single stock class, the dairy herd[1], is the focus of management decision-making. As such, few arbitration heuristics were identified in this study. However, sheep and cattle farmers operate several enterprises, and within these, several stock classes, which complicate tactical management. Research that identified decision rules which could assist sheep and cattle farmers manage multiple enterprises and stock classes under conditions of uncertainty should prove beneficial to that industry.

The second management advantage of dairy farmers is their access to an objective production measure (milk) that is monitored on a daily basis. This was central to the case farmers' control systems. How other pastoral farmers control their systems without the benefit of such a measure is of special interest. Finally, at the tactical level, dairy farmers have limited market risk because they are provided with relatively accurate price forecasts for milk that are updated throughout the season. In contrast, unless fixed contracts are used, most sheep and cattle farmers face high market risk and buy and sell their produce on the spot market. They therefore must manage high levels of both market and production risk. Identification of how "*expert*" farmers manage this would provide considerable benefit to their industry.

The final area of future research is for farm management in general. The case classification framework (level, structuredness, field, environment (risk)) provides a useful template for guiding future research. An important research area in relation to management level is strategic management. However, despite its importance to the survival and growth of the farm business, with the exception of Ohlmer *et al.* (1998) little is known about the strategic management processes used by farmers. The use of long-term longitudinal studies such as used in this investigation could provide important insights into this area.

[1] Young stock tend to be grazed off.

Of interest are the differences between structured and unstructured decisions, particularly those that involve learning, which has been shown in this study to be the driver of innovation in terms of management. Research into this area could be expected to pay high dividends for a country that has a competitive advantage in dairy production.

This study focused on the field of production management. Corresponding studies of marketing, finance and human resource management could be carried out to identify whether the field of management moderates the processes applied. A multiple-case study investigating tactical management across the four fields of management has the potential to generate rich theory.

The work of Martin (1994, 1996; Martin and McLeay, 1998) has suggested that farmers develop risk management strategies in response to the degree of uncertainty in their operating environments. The results in this thesis support this view. Given the increasing uncertainty faced by farmers, case studies could be used to investigate the risk management strategies used by “expert” farmers across a range of operating environments. The aim of such research would be to classify the nature of the risk (production, market, human, social and legal, technological and inter-firm competition) faced by different farm types and then identify the risk management strategies that are most suitable for coping with such risk. Such a study could be expected to generate a powerful body of risk management theory.

The management processes used by the case farmers can be described by Kelly’s (1955) construct theory (man as a scientist). Future research could investigate whether Kelly’s (1955) work could form the theoretical basis for research into management processes, a suggestion that was previously made by Murray-Prior (1998).

The importance of goals and to a lesser extent, values in relation to the tactical management process was observed in this study. Despite their importance in the normative management literature, there remains limited empirical evidence on the topic of goal formulation or the role of values in this. This would appear to be an important area for future farm management research since those in business management (e.g. Covey, 1990) claim this to be a primary driver of personal performance.

This study was based primarily on the farm management literature. There have been some interesting developments in the areas of cognition, naturalistic decision-making, artificial intelligence, expertise, and organisational decision-making in other disciplines that could be incorporated into farm management. Future research needs to investigate the applicability of findings from these areas to the management processes used by farmers.

The final area for future research is in terms of methodology. The greatest problem with longitudinal studies is the magnitude of the data that must be analysed. The development of methods that can reduce the time required for data analysis would be beneficial. The refinement of current software programs so that they can better assist researchers classify data and develop process models would be beneficial. Problems also occur because of the tacit nature of management knowledge. Methods that could more reliably capture this "performance differentiating" information, such as the integration of diaries and field observations, could reduce the number of observations required to obtain an accurate picture of how farmers manage. Further, such methods would help to get to the heart of the on-going challenge for farm management: how to help farm managers become more expert in their management.

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