Agricultural software – A case study of feed and animal information systems in the New Zealand dairy industry

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Abstract

Every farmer utilises agricultural software, either directly or indirectly, as part of feed and animal information systems (IS) used for decision making and compliance on New Zealand (NZ) dairy farms. With continued development and availability of advanced information and communication technologies (ICT), more farmers are using software in their IS. This study investigates: how NZ dairy farmers use agricultural software in their feed and animal IS; the software attributes that influence the use and impact of these software; and, the drivers and inhibitors of software use and impact. A case study research approach was used to investigate these questions. Evidence was collected using semi-structured interviews with six NZ dairy farmers with farms of different scale and ownership structure, and with five commercial agricultural software providers. Results show that feed and animal IS are particularly useful for farmer decision making and compliance at the operational and tactical management levels, but also produce data and information critical for strategic management. The number of software products used and the degree of data and information collation in animal IS compared to feed IS are considerably different. Animal IS were streamlined, with data and information collected and collated together in a limited number of software with only one or two 'focal' software as the centrepiece of the IS. In contrast, feed IS were less streamlined, with data and information flowing into a number of different software. Six important software attributes that influence use and impact of software were identified by farmers and providers, with 'simplicity' and, 'integration with software and hardware', the most highly recognised attributes. The delivery of software with these attributes was achieved by providers in a number of instances, however, other software failed to fully meet farmer needs. Organisational and people drivers/inhibitors had a greater effect on software use and impact than technological drivers/inhibitors indicating that these IS dimensions should be the focus of future improvements.

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List of Abbreviations

Abbreviation	Meaning
DSS	Decision-support systems
ERP	Enterprise resource planning
GIS	Geographical information systems
ICT	Information and communication technologies
IoT	Internet of Things
IS	Information systems
MIS	Management information systems
MS	Milksolids
NAIT	National Animal Identification and Tracing
NZ	New Zealand
PA	Precision agriculture
SME	Small to medium sized enterprises

Key definitions

Information systems - A system that uses formal and informal components (and procedures) to provide farm management at all levels, in all functions, with appropriate information, based on data from both internal (inside the farm) and external (outside the farm) sources. IS enable timely and effective decision making for planning, implementing and controlling the farming activities.

Agricultural software (also called 'software') - Computer or smartphone based programs, or applications, that are used for the management of agricultural business. It includes both computer-based software packages and smartphone applications as core components of individual solutions, and will consider other ICT (precision agriculture and ICT infrastructure) as part of a farmer's information systems.

Chapter 1 Introduction

1.1 Context

The dairy industry is an integral part of NZ's economy. In the 2014-15 year, $13.2 billion of export revenue was earned, representing 29 per cent of the total NZ merchandise export value (DairyNZ, 2015). In that same year, 48,240 people were employed in the dairy industry (excluding owner-operators); 35,340 of these people worked on-farm managing the 5 million dairy cows which graze throughout the country, whilst another 12,900 people worked in processing (DairyNZ, 2015).

The industry not only provides financial returns, food and employment for New Zealanders, but also the world. This is underlined by the fact that NZ is the largest dairy exporter in the world (DairyNZ, 2015), and exports 95 per cent of all dairy produce overseas (Fonterra).

A distinguishing aspect of production in dairy farming, and other primary industries in NZ, is that most farming operations use pastoral farming systems (Holmes & Roche, 2007). These systems influence farm management, whereby the yearly operations are synchronised with the pasture growth curve (Martin, Zwart, Gardner, & Parker, 2005), and farmers attempt to balance animal feed demand with the pasture growth curve. Therefore, pasture is the main source of feed for dairy cattle on many dairy farms (Holmes & Roche, 2007).

In general, NZ farmers have a business-like approach to farm management. They practice "hard-nosed commercialism", thinking beyond the confines of their family farm, considering global markets, managing risks in an unprotected and uncertain environment (both climatic and market), and use resources to strategically sustain growth and future viability (Martin et al., 2005).

Success has not always come easily to farmers and change has always been a feature in farming and rural communities (Martin et al., 2005). The external environment has provided many challenges over the last 75 years such as: the Great Depression in the 1930s which had many farmers facing significant levels of debt; rapid expansion through the 1950s and 1960s to capture strong global demand for agricultural products; the removal of government subsidies in the mid-1980s; and industry growth over the last 20 years with the proportion of pastoral land being used for dairy farming growing (DairyNZ & LIC, 2015; Martin et al., 2005).

The most recent increase in popularity of dairy farming has been driven by high but volatile milk payments, measured as dollars ($) per kilogram of milksolids produced (DairyNZ & LIC, 2015). All of these challenges have been met, and the resulting industry has consolidated and grown with larger herd sizes and fewer herds, and improvements in farm management practices (DairyNZ & LIC, 2015; Martin et al., 2005).

Amongst other things, two challenges facing farmers today are compliance and the use of new ICT which present a relatively different set of hurdles to those experienced in the past (Hammond, 2015). As farming is becoming more data-rich (Cooke, Lineham, Saunders, & Ogle, 2013) a greater emphasis is being put on the technology component of the IS in place to firstly, meet compliance requirements, and secondly, to remain highly productive and profitable (Hammond, 2015). Recent commercial investment into ICT for NZ agriculture has been estimated at between $200 to $400 million for software applications, however user uptake of this software has not proportionately increased (McEwen, 2016), which shows that increases in supply of software has not been matched by increases in demand by agricultural users.

Information required from farmers for compliance purposes has been growing as agriculture's impact on the environment has been highlighted (Foote, Joy, & Death, 2015; HorizonResearch, 2014). Furthermore, product delivery (production methods and food safety) and documentation of quality information are increasingly required of farmers by processors (or other buyers) to meet their compliance and market requirements (Hammond, 2015; Sørensen et al., 2010).

A long-list of information is required to accommodate regulators, including government and industry bodies, and the public. These entities (or groups) put pressure on the agricultural industry to change production focus from quantity, to quality and sustainability (Fountas et al., 2015; Hammond, 2015; Sørensen et al., 2010). This includes specified guidelines for the use of agrochemicals and animal welfare requirements (Husemann & Novković, 2014); human resources, and health and safety regulation (DairyNZ, 2012; Hammond, 2015; Ministry of Business Innovation & Employment, 2014).

The information systems (IS) used by farmers have changed as result of increasing compliance information requirements, and also as a result of ICT adoption, which can contribute to improvements in decision making (Doye et al., 2000; Hammond, 2015; Tocker, Shadbolt, & Gardner, 2006). ICT adoption has been occurring throughout the history of farming in NZ, including early use of innovations such as whole-farm budgets in the 1930s and feed budgeting tools since the 1970/80s, which have altered how decision making processes are implemented (Martin et al., 2005).

Historically, the focus of IS in agriculture was obtaining information without the use of computerised technologies (Blackie & Dent, 1979; Boehljie & Eidman, 1984) using simple farm recording systems (Fountas et al., 2015). Today, this has shifted to include IS that utilise ICT. This change has been enabled, in part, by the availability of computerised and precision agriculture technologies (Allen & Wolfert, 2011; Bywater & Kelly, 2005; Sørensen et al., 2010; Yule & Eastwood, 2012).

Furthermore, developments such as “Big Data”, the “Internet of Things” (IoT) and “Cloud computing” are creating noise in traditional news-media, social media and academic literature. Behind developments are ICT innovations which are becoming integrated into every industry, including agriculture (Kaloxylos et al., 2013; Poppe, Wolfert, & Verdouw, 2015; Poppe, Wolfert, Verdouw, & Verwaart, 2013; Sørensen et al., 2010). For instance, improvements in ICT for data capture, such as drones capable of taking high-resolution photos and GPS tracking on a variety of devices, result in greater access to data in volume, variety, velocity, and data analytics (Davenport, 2014; Sonka, 2014).

Data is invaluable for businesses because it can be processed into explicit information to enhance decision making (Bywater & Kelly, 2005; Sonka, 2014). Businesses using new ICT to capture, process and/or analyse an increasing amount of previously untapped data can improve their decisions by providing further insights and/or elimination of uncertainties (risk) (Hilbert, 2016). However, for this value to be realised, data needs to be accurate and relevant to the users’ requirements (Hilbert, 2016; Kuhlmann & Brodersen, 2001). This relies heavily on the processing and interpretation of data, to turn it into “useful information” readily available for decision making purposes (Bywater & Kelly, 2005; Davenport, 2014).

Therefore, a key factor in successfully integrating new ICT into farming systems is understanding what farm users currently do on-farm (Fountas et al., 2015; McCown, 2002b), and more precisely what their current IS look like, what the shortcomings of ICT are and how they can be improved.

Previous empirical studies in NZ have investigated IS and ICT technology in NZ. For instance, the IS used by NZ dairy farmers were explored by Tocker et al. (2006); Gray, Walcroft, Shadbolt, and Turner (2014); Hammond (2015); and, Eastwood, Dela Rue, and Gray (2016). Specific ICT were identified in each report, however the focus of these studies was largely on "how" these IS work (Hammond, 2015; Tocker et al., 2006), or, "how" the farmers managed a specific facet of farm management like risk (Gray et al., 2014). Eastwood et al. (2016) used a 'network of practice approach' to investigate grazing decision-support system design, which included an investigation of farmers' use of ICT for grazing management. In other NZ work, Allen and Wolfert (2011) and Dooley, Hammond, Allen, and McLean (2012) looked more closely at specific "farm tools" (smartphone applications and computer software), and what function of farm management they supported. Beside Eastwood et al. (2016) who looked solely at grazing management, these known NZ-based empirical studies explored more broadly how agricultural software is being used as part of on-farm feed and animal IS. Of these studies, only Eastwood et al. (2016) explored software use from both a farmers and a software providers perspective.

Therefore, the aim of this study is to explore how agricultural software is "used" on-farm in order to understand what farmers are actually using (and how) and what the impact of this is, and to identify if mismatches exist between software provision and actual use on farm, as described by both farmers and software providers. Insights from this study will contribute to the successful integration and further development of technology for the betterment of NZ dairy farm systems.

1.2 Problem Statement

In light of continued investment and increasing availability of ICT for agriculture, and increasing demands for data and information for decision making and compliance from farmers (and others), this research investigates the on-farm use of agricultural software in feed and animal IS in the NZ dairy industry from both a farmer and software provider perspective. The dairy industry was selected as the focus for this research because this research was primarily funded by DairyNZ and the Ministry for Primary Industries, through the Centre of Excellence in Farm Business Management scholarship. Furthermore, the dairy industry is of interest to the primary researcher and is a significant NZ primary industry (DairyNZ, 2015).

1.3 Research Questions

The research questions for this study were:

How do New Zealand dairy farmers use agricultural software in feed and animal information systems; what software attributes influence the use and impact of these software; and, what are the drivers and inhibitors of software use and impact.

1.4 Research Objectives

1. Identify how and why feed and animal information systems are used by the farmers, and identify the impact of software on farm management.
2. Describe and examine software attributes that influence the use and impact of agricultural software used in feed and animal information systems from the perspective of farmers and software providers of the most common feed and animal software used by the farmers.
3. Describe and examine the drivers and inhibitors of software use and impact from the perspective of farmers and software providers of the most common feed and animal software used by the farmers.
4. Compare and contrast farmers' and software providers' perspectives on software attributes and, 'drivers and inhibitors' with respect to feed and animal information systems.

1.5 Thesis Outline

The thesis is structured in the following order: Chapter Two reviews the Literature focussing on farm management, IS and ICT in agriculture, and the impact of ICT in agriculture. Chapter Three is the Method section which details the research design with an explanation of why this method was chosen, and how it was implemented. Chapter Four presents the Results and Discussion. The Conclusion in Chapter Five discusses the implications of this study and provides an assessment of the method and suggestions for future research.

Chapter 2 Literature review

2.1 Introduction

In this review, literature from theoretical and empirical work that is important for understanding agricultural IS, and the use and impact of software in these systems, is presented. This includes literature on farm management and decision making; IS (in agriculture and including information and communication technology); attributes that influence software use and impact; drivers and inhibitors of ICT use and impact; and how to gauge the impact of software (or ICT) on agricultural IS.

2.1.1 Farm management and decision making

2.1.1.1 What is management

In a traditional business sense, management can be defined as the co-ordination and overseeing (by a manager) of activities of employees in an organisation (or business), so that their activities can be completed efficiently and effectively (Robbins, Bergman, Stagg, & Coulter, 2012). Simply, efficiency is generating the most output from the least amount of input, whilst effectiveness is the "doing the right things" (activities/jobs/tasks) to help a business achieve its goals (Robbins et al., 2012).

These management basics can be applied to farm management, however often farm management literature has specific terms for similar ideas. A number of issues relevant to farming present challenges that differ from a pure business setting. According to Gardner, Parker, Martin, and Zwart (2005) the farm management challenge is how to utilise farm resources efficiently and effectively whilst being responsive to dynamic and uncertain external environment that can constrain their resources.

This is not overly dissimilar to business literature, except there is a difference in the emphasis on the manager as the person in charge of the co-ordination and overseeing within a business and has more of a focus on farm resources (in farm management) rather than the sole act of managing people (in business).

2.1.1.2 What is an organisation

An important idea in understanding management is the definition of an organisation, without this there would be no need for management. Organisations are considered arrangements of people, collectively to striving toward a "distinct purpose"; a goal or set of goals. The distinct purpose can only be achieved alongside a "deliberate structure" that allows the people to perform work that enables them to accomplish steps to meet goal/s (Robbins et al., 2012).

People

One person alone cannot be an organisation; it takes a number of people to achieve the work necessary to achieve the organisation purpose (Robbins et al., 2012). People involved in an organisation could include first-line service orientated employees, through to top business managers, or in an agricultural sense a farm manager and his/her family (Robbins et al., 2012). A major difference between the arrangement of people involved in a NZ agricultural business and a pure business organisation is that the majority of agribusinesses are considered small to medium sized enterprises (SMEs), and are often family farms which lack the number of people and formal relationships of larger businesses (Bywater & Shadbolt, 2005).

Distinct purpose

The distinct purpose of a business can be derived directly from a vision, or encompass other goals below this overarching vision (Robbins et al., 2012). In Martin and Shadbolt (2005b), an example vision for a dairy farming business was to "become large-scale, innovative, profitable producers of milk in NZ". This example identifies the purpose of the farm, with certain requirements (large-scale, innovative, in NZ), but does not limit where in NZ the farm can be located. The purpose provides insight into which aspects of a business are most important.

Deliberate structure

The structure of a business refers to how work relationships fit together (Robbins et al., 2012). This structure can be loosely defined and flexible whereby few people perform a number of jobs toward a common goal. Alternatively, this could be strictly defined with close accordance to rules, regulations, job descriptions and a definitive level of authority (Robbins et al., 2012). In traditional NZ farm businesses, these structures can often be informal relationships with no explicit roles, whereas more modern corporate farms may have strictly defined structures in place (Magnan, 2012). The reason for this informal structure is again, because most agribusinesses are SMEs. This brings with it a specific set of characteristics, including farmers having combined roles of director, manager and labour, and decisions being made more frequently with limited relevant information available. Furthermore, approximately 97 per cent of farms are family-owned which brings added complexity managing family, ownership, and business goals, membership and dynamics (Bywater & Shadbolt, 2005).

The people, distinct purpose and deliberate structure of an organisation determines what needs to be managed, and illustrates what efficiency and effectiveness look like for the specific business or farm.

2.1.2 Areas of management

2.1.2.1 Management levels

The organisational literature specifies that within each business there are management levels on which managers focus their efforts, depending on where they sit within the organisational structure. In a purely business context, these levels have been described as first-line, middle and top management (Robbins et al., 2012). Each level has progressively fewer managers, but the significance of management decision making grows. The managers near the head of an organisation are responsible for making organisation-wide strategic decisions, particularly with regard to establishment of high level goals and creating plans that affect the entire business. In contrast, the first-line managers could be more heavily involved in operational decisions to ensure products are being created and customers are being served (Robbins et al., 2012).

Agricultural literature looks more broadly at management, as often farm managers are involved at every level of the management of a farm business, including strategic, tactical, and operational management. Each level is distinctly different in terms of the outcome, focus, power and objective of decision making, see

Figure 1 below (Bywater & Shadbolt, 2005).

	Technical	*Management*	*Leadership*
Outcome	Excellence	Consistent results	Positive change
Focus	How (Hands) Do	What (Head) Organise	Why (Heart) Dream
Power	Expertise ***Operational***	Authority ***Tactical***	Influence ***Strategic***

Figure 1 The distinction between the levels of farm management (Peter Blyth, cited in Bywater & Shadbolt, 2005).

Strategic management involves making long term, infrequent decisions, that attempt to take a set of assumptions about the future, to craft plans to ensure future business success (Bywater & Shadbolt, 2005). This level of management is usually reliant on external factors with sources of information from outside the farm gate required (McLeod & Schell, 2001; Tocker et al., 2006).

The process of farming-related strategic management has been discussed in detail by Beijeman, Shadbolt, and Gray (2009). It was found that farm managers do not solely take the "classical schools" approach to strategic management presented by Nell and Napier (2005) in Martin and Shadbolt (2005b) (Figure 2).

Strategists can exhibit "strategic thinking" (a creative, synthetic, divergent, intuitive, and innovative thought process) to manage complex adaptive systems over time, capturing the emergent opportunities (Beijeman et al., 2009).

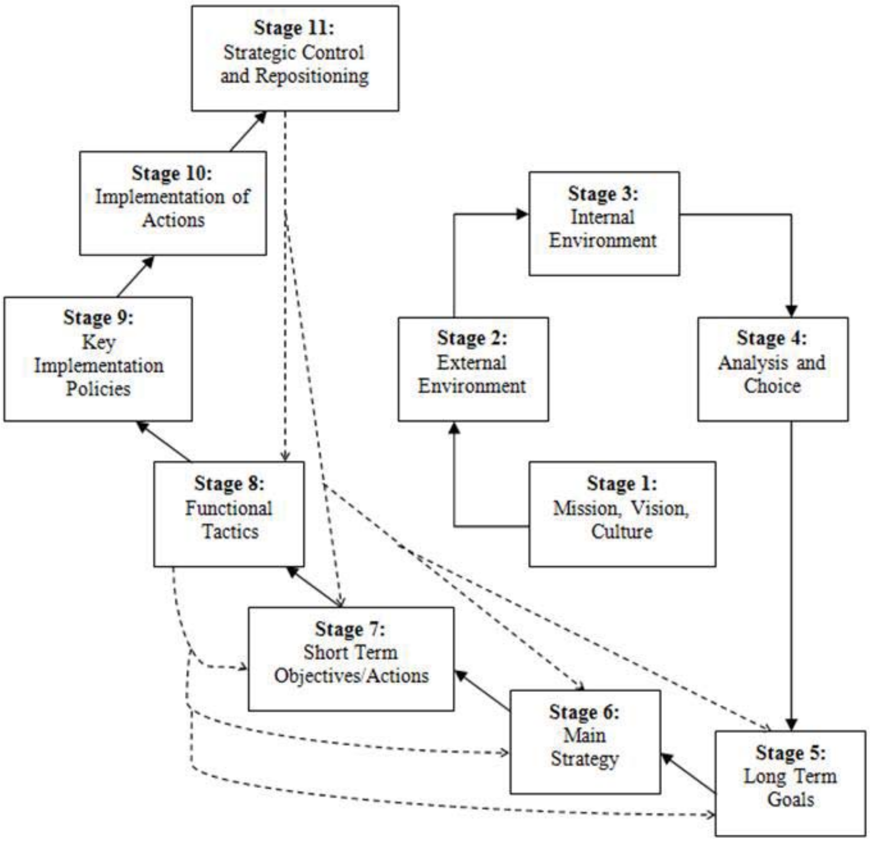


Figure 2 The strategic management process (Nell & Napier, 2005).

The types of strategies suggested by Mintzberg and Waters (1985) are shown in Figure 3 and demonstrate how strategy can be realised. A classical strategic planning approach (the deliberate strategy) to implementing an intended strategy can be taken, as strategic planners would do. Alternatively, management exhibiting more strategic thinking may act on emergent strategies, which influence the intended strategy causing it to become unrealised and the emergent strategy then becomes the realised strategy (Beijeman et al., 2009; Martin & Shadbolt, 2005b; Mintzberg & Waters, 1985).

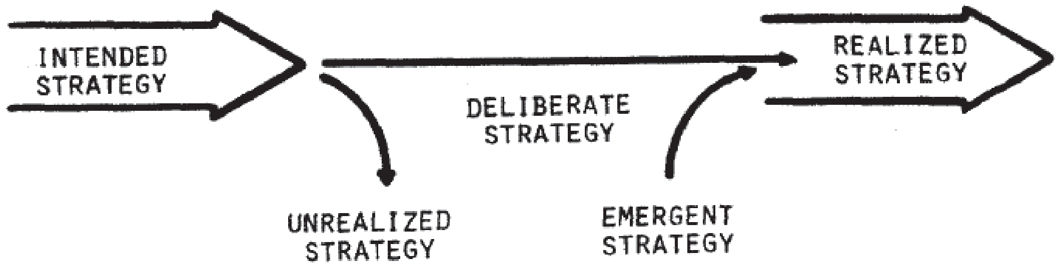


Figure 3 Types of strategy (Mintzberg & Waters, 1985).

Tactical management is different from strategic management in that it focuses on managing seasonal decision making of farm policies for efficient acquisition and allocation of resources (Bywater & Shadbolt, 2005). The tactical planning process depicted by Gray et al. (2003) (cited in, Gray, 2005b) is shown in Figure 4.

Tactical decisions tend to be associated with biological activity or business processes, but are usually confined to annual cycles (Bywater & Shadbolt, 2005). Information required for tactical management is usually a mix of internal technical information, and cost and price information, for the specified season (or planning horizon). It is more detailed and specific than the information used in strategic planning, although there is still a degree of uncertainty with regard to information representativeness (Bywater & Shadbolt, 2005). Planning aids such as cash flows, cash forecast, feed and labour budgets are often used for generating information to compare tactical plans (Gray, 2005b).

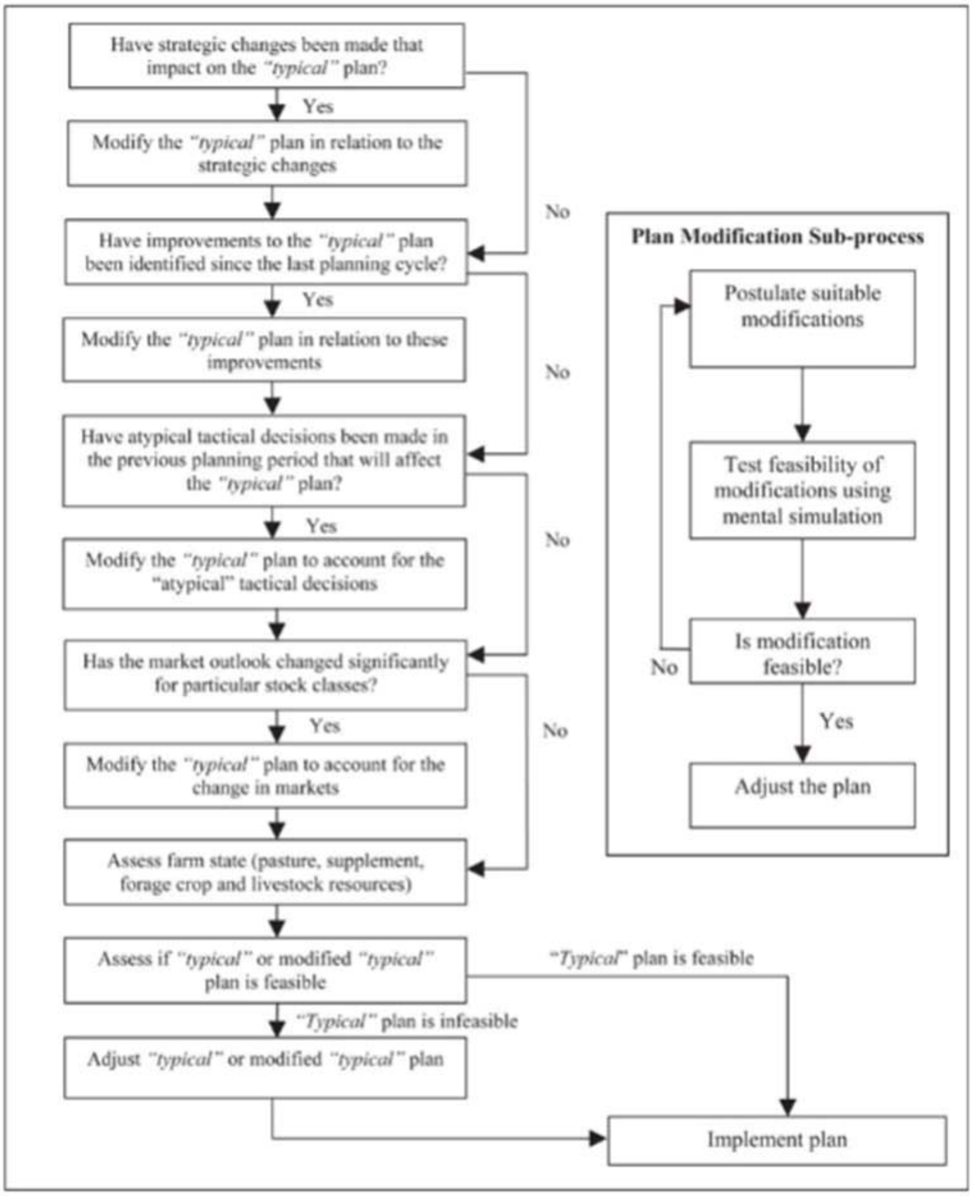


Figure 4 Tactical planning process (Gray et al., 2003, cited in Gray, 2005b).

Operational management is concerned with day to day tasks (Bywater & Shadbolt, 2005; Robbins et al., 2012). The time horizons are short and most of the information is generated within the farm business, is usually specific to the task/s and "known" with a degree of certainty (Bywater & Shadbolt, 2005). Processes involved in this level of management are structured. For instance, if "X" occurs then do "Y". The operating environment of a farm usually adds complexity and therefore variation away from the usual structured processes.

All levels of management can be "usefully viewed as an interdependent hierarchy of interconnected management processes", with strategy guiding tactics which then flow through to day to day operations (Gray, 2005b). These levels of management are illustrated by DairyNZ (the NZ dairy industry-good organisation), who developed the dairy industry standard roles (DISR) based on industry-agreed dairy farm roles (DairyNZ, 2014).

2.1.2.2 Management functions

Management functions, also called the "management process" (Gray, 2005a), occur at each level of management (Bywater & Shadbolt, 2005; Robbins et al., 2012). Robbins et al. (2012) identified that most management textbooks focussed on four basic management functions: planning, organising, leading and controlling. When performed efficiently and effectively these functions lead to achievement of the organisations purpose. These functions are not dissimilar to the planning, implementation and control functions that prescribe the activities a manager undertakes using the resources available for farm management (Boehljie & Eidman, 1984; Gray, 2005a).

Planning provides the pathway to accomplish recognised business objectives, through establishing strategies and planning activities to attain "planned" objectives. Implementation is the process of using resources and people to perform the plan, organising the workload to achieve the planned activities and supervising the process. Control involves measurement and monitoring of performance in order to correct (and/or manage) divergence from the expected implementation of the plan (Boehljie & Eidman, 1984). From the business literature perspective, implementation is represented by organising that is determining what needs to be done, how it will be done and who will be doing it, and leading by motivating, directing, and other actions involved with dealing with people (and resources) to accomplish the plan (Robbins et al., 2012).

2.1.2.3 Management fields or functional lines/structures

The last of the three main components (levels and functions) of management theory is functional lines/structure (in business) or fields (in farm management). Firstly in business, there are a large number of lines or structures that detail the formal arrangement of jobs within an organisation to accomplish the organisation goals effectively and efficiently (Robbins et al., 2012). This can be done in many ways, such as departmentalisation, cross-functional teams, centralisation and others (Robbins et al., 2012). Farm management takes a slightly different approach by focussing on "fields" of the whole farm system that need to be managed (Bywater & Shadbolt, 2005). Bywater and Shadbolt (2005) expanding on the fields presented in Boehljie and Eidman (1984). Bywater and Shadbolt (2005) incorporated human resources alongside production, marketing and finance and included social and environmental responsibility within these four fields (Figure 5).

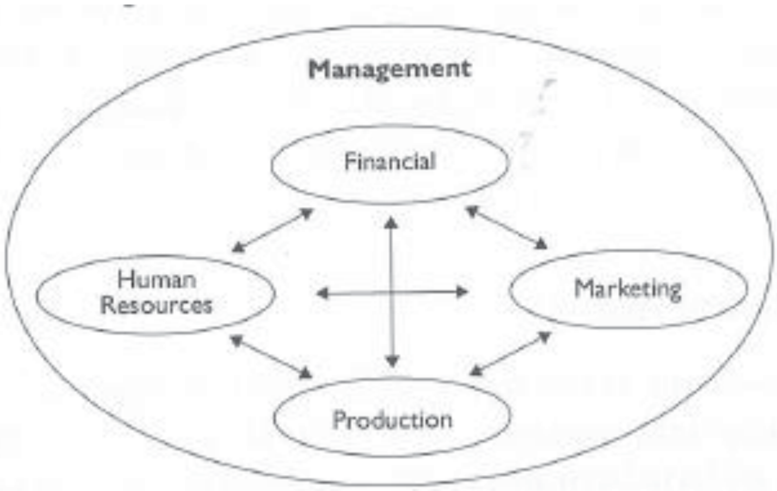


Figure 5 Fields of management. This depicts the fields of management, key aspects of a farming system that need to be managed (Bywater & Shadbolt, 2005).

These management fields are key areas of importance that must be adequately considered in planning, implementing and controlling at each level of management (strategic, tactical & operational). Farm business data is gathered and processed by farm IS into information considered along with externally provided information and knowledge in decision making (Boehljie & Eidman, 1984).

Boehljie and Eidman (1984) presented the cube diagram, in Figure 6, to describe how farm management decision making concerns management functions, management fields and the farm/business lifecycle (entry, growth and exit). The lifecycle element of the cube recognises that businesses generally move through three stages: entry or establishment, growth and survival, and exit or disinvestment. The stage that a business is in will influence all other aspects of the cube. For instance, during the growth stage, finance may be limited due to investment limitations, which will impact on planning, implementation and control (Boehljie & Eidman, 1984).

Since most agribusinesses in NZ are family-farms, lifecycles of individuals managing the business must also be considered. Over time, these individuals' personal skills and traits such as expertise, experience and motivation can be enhanced or diminished. Business lifecycle, and family individual lifecycles, often move in parallel with each other starting together as an investment and growing and consolidating, before the business is eventually sold or taken over by a new generation (Bywater & Shadbolt, 2005).

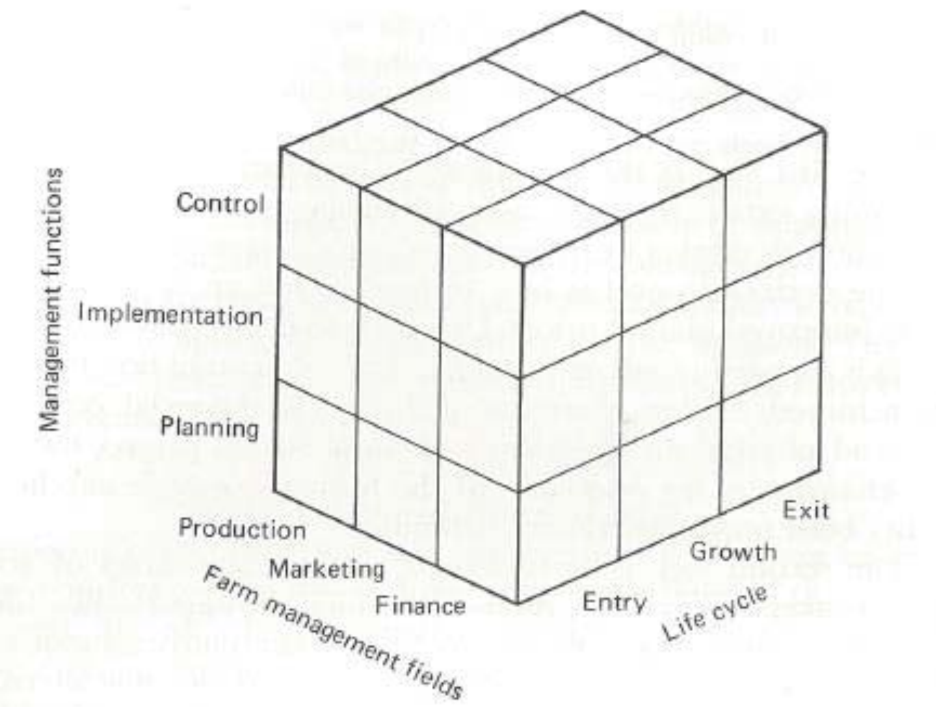


Figure 6 Farm management cube The cube signifies that decision making concerns the management functions, farm management fields and business lifecycle (Boehljie & Eidman, 1984).

Collectively management theory, and specifically farm management theory, provides context for consideration of how a farmer can successfully achieve his or her goals through effective and efficient management. This is a challenge that has seen the development of systems theory and the whole-farm systems approach to analyse what components of a farm influence goal/objective attainment.

2.1.3 Decision making and the management process

Farmers manage their operations using the "management process" or the functions of management – planning, implementation and control (Gray, 2001, 2005a). This process can be viewed as a series of decisions that occur throughout time. For instance, a farmer makes major planning decisions for a specified period of time (the planning horizon - usually a year for tactical decisions), followed by a series of implementation and control decisions (Gray, 2005a). This process is more easily visualized using the tactical management process diagram (Figure 7) (Gray, 2005a).

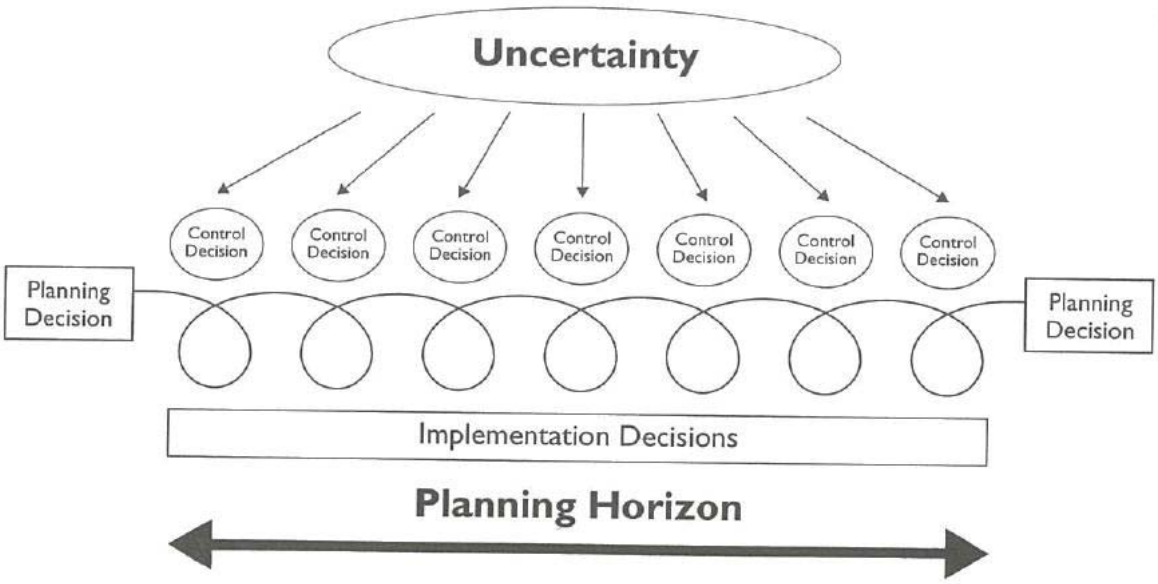


Figure 7 The tactical management process (Gray, 2005a).

Each function of management is interdependent; control cannot be happen without planning, and without implementation a plan will never be used and nor will it be controlled (Gray, 2005a). This supports the commonly touted adage, "if you can't measure it, you can't manage it", credited to the well-known management consultant, educator and author, Peter Drucker.

The planning horizon length will depend on the level of management functions being applied. Strategic management decisions will occur infrequently (once every 5-10 years), whereas tactical management decisions will occur through each year (usually alongside changes in the season or production cycle) and operational decisions occur on a day-to-day basis (Gray, 2005a).

2.2 Information systems introduction

This section provides normative theory on IS to establish an understanding on what these systems encompass.

2.2.1 What are information systems

Information systems can be defined as a "set of interrelated components that collect (or retrieve) data, process, store and distribute information to support decision making, coordinating, and control in an organisation" (Laudon & Laudon, 2015).

It is a system usually made up of people, data, activities, networks (data transfers & communication), and in many cases computers and other equipment. These IS can contain data and information on people, places and things within the internal and external environments (Bywater & Kelly, 2005).

Recent developments in IS used in business and agriculture have incorporated varying degrees of computing technology and software, however IS are not just computing technology and software (although the terms IS and ICT are often used synonymously (Valacich, Schneider, & Jessup, 2016)) (Lucey, 2005). They can be more formally based, involving computers, hardware and equipment, or informally based, relying on components such as discussions, telephone calls and meetings to obtain useful information (Fulweiler, 2001; Hammond, 2015; Lucey, 2005).

For example, one of the most effective informally-based IS in dairy farming is tail painting cows as a means of heat detection for animal breeding decision making. Data is collected from tail-painted animals standing to be mounted. Processing occurs through the paint being rubbed off and the farmer subsequently realises the animal is on heat. Information is distributed to attentive farmers who can combine this with their previous knowledge to make breeding decisions (Bywater & Kelly, 2005; Laudon & Laudon, 2013).

This IS introduction identifies some important terms such as: formally based IS, informally based IS, data, information and knowledge. There are clear differences between these terms which need explaining.

2.2.2 Informal IS

All farm managers utilise informal based IS, composed of components such as unplanned discussions with staff or neighbours, telephone calls, discussions with product or service providers, information gathered from reading newspapers and magazines, and past experiences (Boehljie & Eidman, 1984; Fulweiler, 2001; Hammond, 2015). IS in many businesses today are more dependent on formal computer technology, but an informal manual process or a combination of informal and formal is also effective (Fulweiler, 2001; Hammond, 2015).

2.2.3 Formal IS

Farmers also use formal based IS, particularly in areas of farm management that provide opportunities for high returns for their time and effort (including costs). These usually assist with the management of operations where a small deviation in the resulting implementation could result in a significant cost to the farm business (Boehljie & Eidman, 1984). Formal IS could include arranged formal meetings or documentation, written livestock and resource records, and computerised software and technologies (hardware and equipment) (Hammond, 2015; Jago, Eastwood, Kerrisk, & Yule, 2013; Lewis, 1998; Tocker et al., 2006; Yule & Eastwood, 2012). In practice, new technologies with Internet connectivity have increased the degree of sophistication of formal systems (Nikkilä, Seilonen, & Koskinen, 2010). However, many informally based IS cannot be replaced by more formal systems because it would be costly, complicated and foolish (Boehljie & Eidman, 1984).

2.2.4 Data

The distinction between raw data, information and knowledge helps to explain how IS work. Data is observable raw facts and figures gathered from events that occur in the real world in the internal business operations or from the external business environment (Bywater & Kelly, 2005; Laudon & Laudon, 2013). Data concerns and represents the present and past situation, rather than the future. In order to use data for decision making, coordinating, and control in a business, it must be processed into information and distributed (Bywater & Kelly, 2005). This processing incurs cost and accrues no value until the point of using the valued information (Lucey, 2005). An example of data is barcodes on packages of food. These describe specific product data, which once processed via an IS, can be used to develop useful information such as sales volume, product movements, and inventory levels (Laudon & Laudon, 2013).

2.2.5 Information

Information is data that has been collected, analysed, manipulated, interpreted and placed into a context to give it purpose. In this structure it can become "useful" for people using the information for decision making (Bywater & Kelly, 2005). The key difference between data and information therefore is usefulness, without this, information has no value, no matter how accurate or up-to-date it is (Lucey, 2005). The structure and purpose of information required an understanding of how a system functions and how data can be used to demonstrate current or past system performance. Information gathered should be used alongside the user's own knowledge of how to apply and use the information for decision making (Laudon & Laudon, 2013; Lucey, 2005). Too often, data is not successfully selected and processed into useful information; rather it exists as semi-processed data in an output which is sometimes called 'information overload' (Avison & Fitzgerald, 2003).

2.2.6 Knowledge

Buckingham et al. (1987) (cited in, Avison & Fitzgerald, 2003) defined information as 'explicit knowledge' which is information that is easily understood with nothing implied. People with knowledge know what the information presented means, the implications of information produced and how to use it effectively (Avison & Fitzgerald, 2003). In farm management, knowledge is developed through understanding, validation, and refinement of information gathered during the management process (involving historical control) and interaction with the farmers "knowledge system" and "areas of learning" (Figure 8) (Gray, 2005a).

Furthermore, in agriculture, because of complexity of the business, farmers often have to rely on "intuition", to make decisions in response to fast changing environments (Fountas, Wulfsohn, Blackmore, Jacobsen, & Pedersen, 2006). This decision making process is not easily understood or modelled, but can be recognised as a farmer's unique knowledge (experience and familiarity) with their farm, as well as site-specific experience (Fountas et al., 2006).

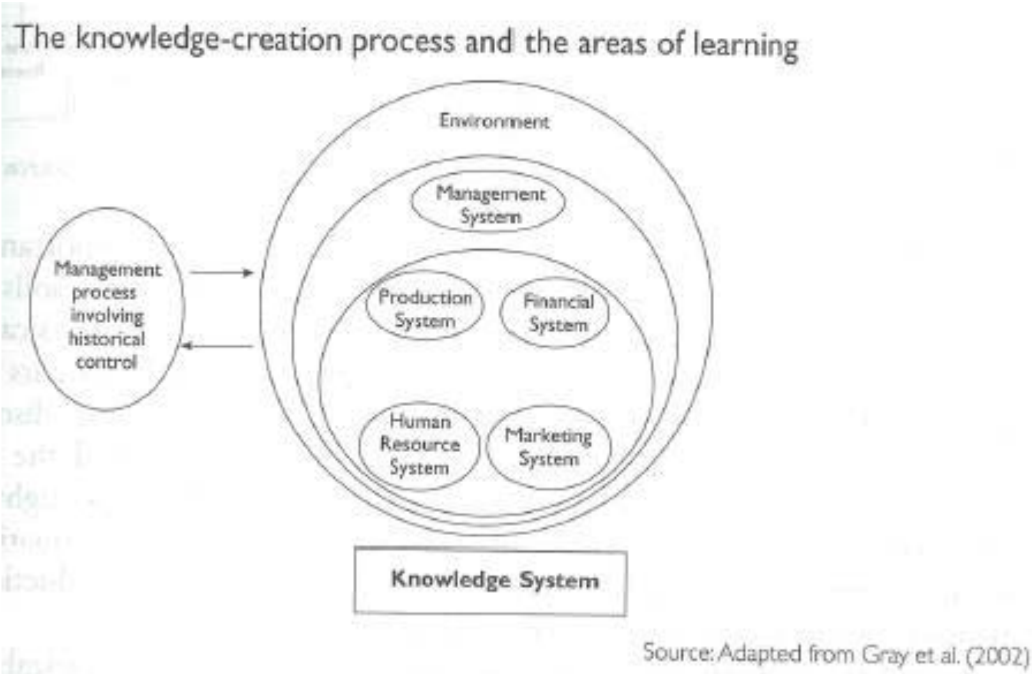


Figure 8 Knowledge-creation process and areas of learning, adapted from Gray et al. (2002) (Gray, 2005a).

2.2.7 How information systems turn data into information

Three core activities or elements in an IS turn data into information; these are input, processing, and output activities (Figure 9) (Laudon & Laudon, 2013). Input is the activity (or activities) that capture or collect raw data, processing transforms the input into a useful form, and outputs transfer the processed information to managers (or other relevant people) to use (Laudon & Laudon, 2013).

For example, the inputs of a farming system, which is made up of a range of sub-systems (production, finance, human resources and marketing) provide input data (such as daily production figures, expenditure receipt facts, hours worked, market prices) which can be processed into information outputs, such as information on farm profitability (Lucey, 2005). The relevancy of inputs and outputs will depend on the objectives and goal of the whole farm system, requirements of the end user of the information, and components of the system (formal or informal) used to gather and process data. Management planning and control processes therefore play an important part in defining the important inputs and outputs of an IS used in a farming system (Lucey, 2005).

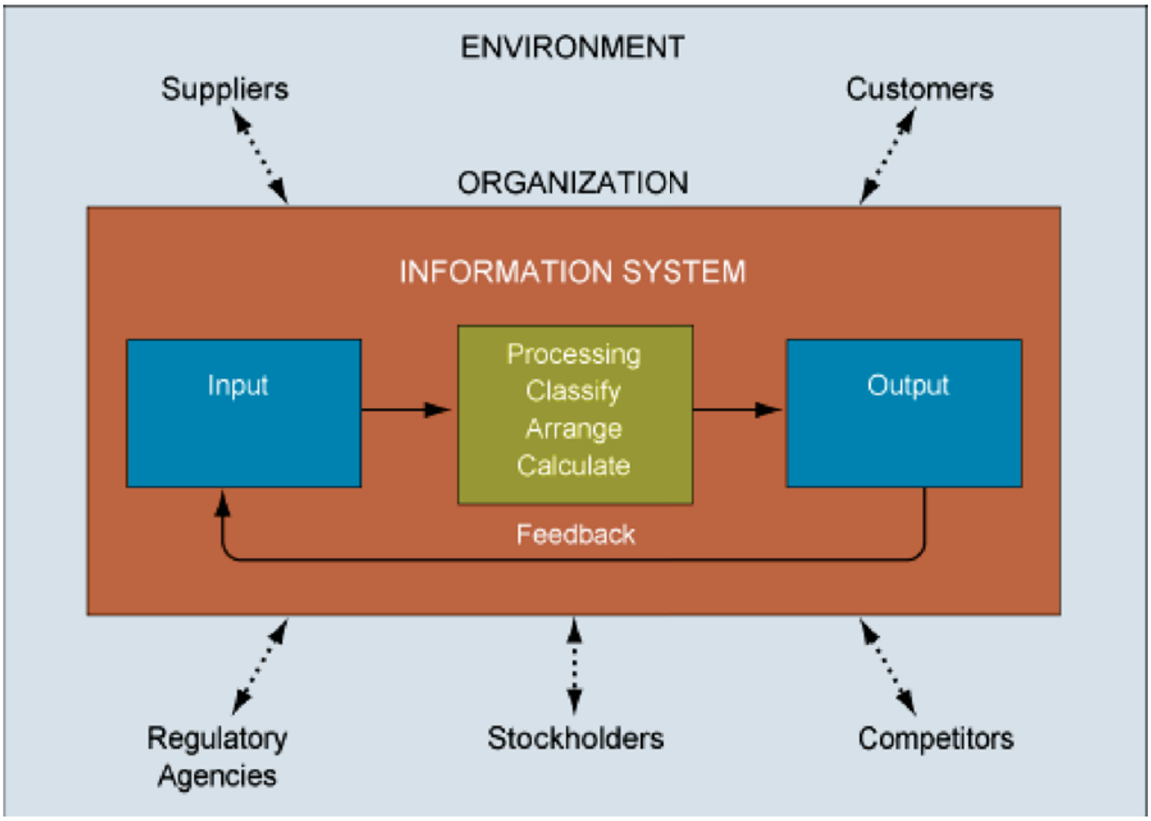


Figure 9 Functions of an information system (Laudon & Laudon, 2013).

The external and internal environment which a business operates in has a large influence on the input, processing, and output activities. Input data can be captured or taken from outside the business's physical walls and can include data and information requirements from regulatory agencies, suppliers, customers, competitors, and stockholders (Laudon & Laudon, 2013). In farming businesses, similar data and information needs exist but these are specific to farming related stakeholders such as staff in animals processing plants, agricultural technology providers and input suppliers (fertiliser and feed providers) which may require data and information from farms.

Typical processing activities used to turn data into useful information, include: data classification, coding, interpretation, storage/retrieval, comparison, calculation, summarisation, identification, monitoring and highlighting (Lucey, 2005). These activities can utilise limited (or no) computerised technology, or alternatively, they could use technology as the sole means of processing data (Laudon & Laudon, 2013). This process is "how" the data is transformed into something "useful". If data is not relevant to what the IS was created to provide, no amount of processing will correct the output (Lucey, 2005). That is, poor data in

= poor data out, good data in = good information out. Commonly known as “garbage in, garbage out”.

Typical outputs from a pure business sense could include information in the form of reports on performance, budgets, sales, productivity, forecasts, trends and decision support model outputs (e.g. simulation) (Lucey, 2005). The key to quality output is ensuring information is useful for the person/s receiving and using it (Bywater & Kelly, 2005).

IS require feedback from users and from other stakeholders of a business. This is a key activity that enhances the IS through review and alteration of the inputs and outputs for better management planning and control functions (Laudon & Laudon, 2013; Lucey, 2005; Martin & Shadbolt, 2005a) .

As previously mentioned, technology consisting mainly of computers (desktop, laptop, mobile, tablet) and accompanying software, are an integral part of IS. These provide the technical foundation, the tools and materials, of today’s IS. Computers and computer technology are not IS (*per se)* but a valuable means to formally collect, or process data into information.

2.2.8 Dimensions of information systems

There are three important dimensions of a modern business IS, these are: the organisation, the people, and the information technology, or, information and communication technologies (computers, data collection equipment and similar technology), (Figure 10) (Laudon & Laudon, 2013).

Organisation

Within an organisation**,** the structures, business processes, history, and culture all have an influence on IS. The structure, and in particular the way management levels are structured (strategic, tactical, operational management responsibilities), influence how data is collected, processed and used for decision making. Different business functions/fields require different data and information. For example, marketing may require campaign sales information, whereas human resources may require employee productivity information (Laudon & Laudon, 2013). A traditional family farm business in NZ, in which an owner-operator may be involved in every level of management, may require significantly less and different information compared to larger more corporate styled farms (Tocker et al., 2006).

Figure 10 Dimensions and relationship within a modern information system (Laudon & Laudon, 2013).

Business processes are related tasks and behaviours for accomplishing work. Some of these processes require very formal rules and others more informal. Formal rules are often ingrained in IS to perform a process automatically such as processes for billing customers automatically for provided goods or services (Laudon & Laudon, 2013). In this case, the system would have been developed using a system appropriate to easily identified quantitative problems. Informal rules are those which are not written but expected to be performed, such as returning missed calls (Morren Jr. & Wilson, 1990).

Organisations have history and culture which incorporates values, business assumptions, strategic intents, and business models. These factors have an influence on an organisation and need to be considered in the development or adoption of new components of IS in order to ensure the business continues to operate effectively and efficiently (Laudon & Laudon, 2013).

People

People are an essential part of an IS. They not only are the end user of output information, but can be heavily involved in data and processing, and also the building and maintenance of the systems (Laudon & Laudon, 2013). Some systems emphasise people especially those systems where human perception, behaviour and actions play a big part (Morren Jr. & Wilson, 1990). People therefore need to be skilled in using systems, understanding their role in systems, and skilled in using information for effective and efficient decision making (Laudon & Laudon, 2013).

Information and communication technology

According to Valacich et al. (2016), ICT includes hardware, software and telecommunications networks. Hardware refers to the physical equipment, such as a computer, tablet, phones, or printers; software refers to the programs which dictate what the hardware does; and telecommunications are networks groups of two (or more) computer systems linked together with communications equipment (Valacich et al., 2016).

ICT, and the people required to run and manage technology, are collectively known as a business's ICT infrastructure (Laudon & Laudon, 2013). Together, these components provide the necessary infrastructure "to support decision making, business processes and competitive strategy" (Valacich et al., 2016).

ICT is sometimes simply called Information Technology (IT), although IT may exclude telecommunications (voice) but include data networks (Zuppo, 2012). Both ICT and IT refer to technologies such as computer hardware (physical equipment), computer software (pre-programmed instructions), data management technology (software for data organisation on physical storage media) and networking and telecommunications technology (physical device and software) (Laudon & Laudon, 2013).

The technologies which constitute an organisation's ICT differ depending on the context and industry. The core definition of ICT does, however, revolve around the devices and infrastructures that facilitate the transfer of information through digital means (Zuppo, 2012). There is commonality amongst all ICT in that their role is as part of IS. IS use IT to collect, create and distribute useful data (Valacich et al., 2016).

ICT or IT has become pervasive in almost every society worldwide (Valacich et al., 2016). Given its prominence, change is a constant, as old technology become redundant and new technology continue to evolve (Laudon & Laudon, 2015; Valacich et al., 2016).

2.3 Information systems in agriculture

This section, firstly, defines and explores IS in agriculture according to literature. Secondly, empirical IS studies from NZ agricultural studies are described.

2.3.1 Information system in agriculture - Definition

In agricultural literature, IS have been called different terms that refer to the same, or similar, concepts. These include management information system (EuropeanCommission) (Boehljie & Eidman, 1984; Hammond, 2015; Sørensen et al., 2010; Verstegen, Huirne, Dijkhuizen, & Kleijnen, 1995), farm management information system (FMIS) (Fountas et al., 2015; Lewis, 1998; Nikkilä et al., 2010; Sørensen et al., 2010), and farm information system (FIS) (Doye et al., 2000). Other terms have been used to describe specific types of IS, which more recently have had a focus on the technology component of an IS. These include decision support systems (DSS) (Nikkilä et al., 2010; Sørensen et al., 2010) and geographical information systems (GIS) (Nikkilä et al., 2010; Zhang & Kovacs, 2012).

Starting with MIS, Verstegen et al. (1995) defined these IS specifically as electronic tools for data collection, processing and management used in decision making. This definition was derived from earlier theory by Boehljie and Eidman (1984) which indicated that MIS integrate computers and software requiring manual procedures, decision models and human time to provide information to support operations, management and decision making functions in a business.

Hammond (2015) used the term MIS to describe a system that incorporates formal and informal components (and procedures) to provide appropriate information for farm management at all levels and for all functions, using data from both internal and external sources. MIS enable farm managers to make timely and effective decisions for planning, implementing and controlling the farming activities.

Lewis (1998) noted that a FMIS exists when decision makers use information provided by a farm record system to assist their decision making; and Sørensen et al. (2010) defined FMIS as a planned system for collecting, processing, storing, and disseminating data in the form needed to carry out farm operations (and functions). Sørensen et al. (2010) also describes MIS as an integral part of the “overall management system” which forms part of an enterprise resource planning (ERP) and the overall IS. The following diagram (Figure 11) demonstrates how MIS works within farm systems according to Sørensen et al. (2010).

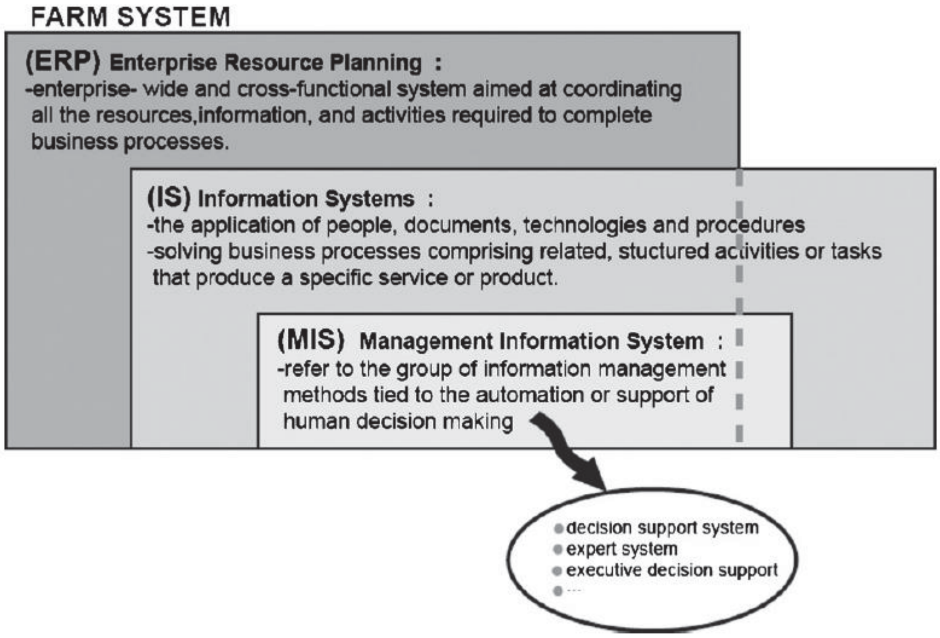


Figure 11 Concept of management information systems (Sørensen et al., 2010).

Fountas et al. (2015) explained that MIS in agriculture have evolved from simple farm recording systems to "large, comprehensive 'Farm Management Information Systems'" in order to accommodate communication and data transfer requirements, as well as meeting the requirements of a range of different stakeholders.

In contrast, Nikkilä et al. (2010) described FMIS solely as ICT software which runs on personal computers and is intended to provide standardised record keeping and financial planning functions, alongside a specialized function for agricultural users. This study also described DSS as types of IS that are used for a "very specific task", such as eco-management (ecology management) of a farm (Nikkilä et al., 2010). Fountas et al. (2015) summed up the literature on FMIS and DSS by stating that these systems are based on simulation models, or were targeted at optimisation models and methods.

It is evident from this IS literature that ICT is an important part of a modern day IS. However, just as important is the informal components of IS, particularly in agriculture. The definition of IS used in this research is "a system that uses formal and informal components (and procedures) to provide farm management at all levels, in all functions, with appropriate information, based on data from both internal and external sources. IS enable timely and effective decision making for planning, implementing and controlling the farming activities”.

This definition is adapted from Hammond (2015) who considers IS not only as ICTs, but includes informal components as an essential part of the system. Consequently, all software and ICT will be considered as part of an IS in this discussion and thesis.

2.3.2 Information systems in New Zealand agriculture - Empirical studies

Three NZ empirical studies applied IS theory to dairy farming. These studies include the identification of ICT, and the challenges and opportunities pertaining to dairy farming systems.

Firstly, Tocker et al. (2006), conducted qualitative case study research investigating the MIS used in two NZ dairy farms with different scale. Each case study farm was researched using semi-structured interviews, document analysis and observation. A farm manager from each farm was interviewed in order to understand their IS, with evidence then collated and analysed thematically before being compared to literature and the other farm.

It was found the role of each manager differed according to the scale of the farm. The “large farm” manager focussed more on the strategic and tactical levels of management, which included more information at the “summary” level of detail. In comparison, the “small farm” manager split his time evenly across all levels of management which included consideration of detailed information at the operational level.

The core activities of recording, analysing (processing) and presenting information were evident in both farms. Both farms had common ICT components for production and finance, with the larger farm also including ICT (formal components of IS) into their human resource system. Each farm also used formal components (precision agriculture hardware) of IS to collect physical information. Both farms did, however, identify challenges, especially regarding the management of human resources (specifically managing, attracting and retaining labour). The IS used in this field of management differed between the two farms.

Secondly, the study by Hammond (2015) looked at how and why dairy farmers use MIS by conducting case study research on two typical NZ dairy farms. Evidence was captured using a qualitative research approach, including semi-structured interviews and field observation with the owner-operator and the farm manager on farm; and the operations manager of the second farm. The interview utilised a number of models and documents to question each interviewee, including Figure 12 which shows an example of a framework for considering the activities or elements of MIS (Hammond, 2015).

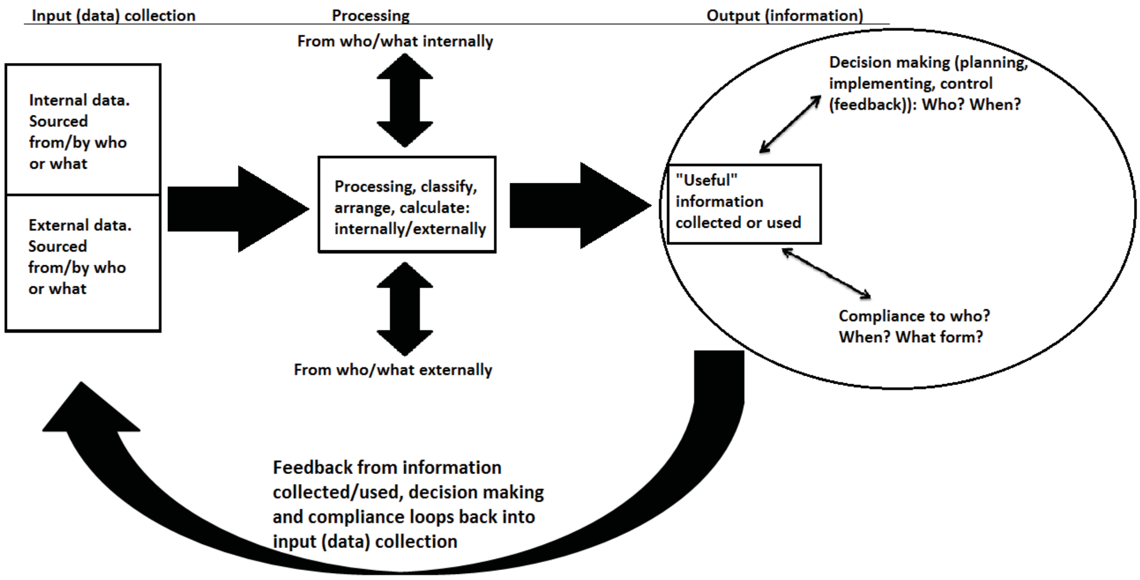


Figure 12 Example MIS, showing the activities and data/information flows (Hammond, 2015).

The results in Hammond (2015) were analysed using a thematic approach to describe the MIS for the production, finance, human resources and marketing fields of farm management, and sub-systems within these. It was found that MIS are very complex and specific to individual farms. However, they both involved a similar group of internal and external users/entities providing or collecting data or information, through to those eventually using information for decision making or compliance.

However, formal (ICT included) and informal components of the systems differed between case study farms which may be due partly to differences in operating structure, scale, staff experience (knowledge) and skillset. Compliance requirements, and staff skillset, understanding and training with regard to the use of both formal and informal components were identified as the most immediate areas challenging each case study's systems (Hammond, 2015).

Thirdly, and most recently, Eastwood et al. (2016) investigated the use of pasture measurement tools and DSS specifically for grazing management. They used a qualitative mixed-method approach to gather evidence from the "grazing DSS network of practice" – which included farmers (12), rural professionals (5), farm-system researchers (3) and technology developers (16), all of who were involved in dairy farmers' grazing management processes. The major results included identifying: the influence season has on grazing management processes; the influence that farm-ownership structure has on the use of grazing DSS; the drivers and inhibitors associated with farmer use, adoption and disadoption of grazing DSS which were identified according to four different user scenarios; and farmer and rural professional experience with using grazing DSS (Eastwood et al., 2016). Furthermore, they concluded this work by presenting a set of "desirable attributes of grazing DSS", and their thoughts on effective co-design of grazing DSS.

The influence that the 'season' has on grazing management and the use of DSS was derived from the "seasonal phases" which occur throughout the production year (Eastwood et al., 2016). These phases, including the pivotal point at the "balance date" (the point where feed supply meets feed demand). Farmers used critical success factors, tools (software included) and information to determine performance (the control measures) at pivotal points of the year (Eastwood et al., 2016). As the seasonal phases changed so did the critical success factors, tools and information used by farmers. The diagram in Figure 13 shows their representation of the annual grazing management cycle, which incorporates tools and information also identified in Hammond (2015).

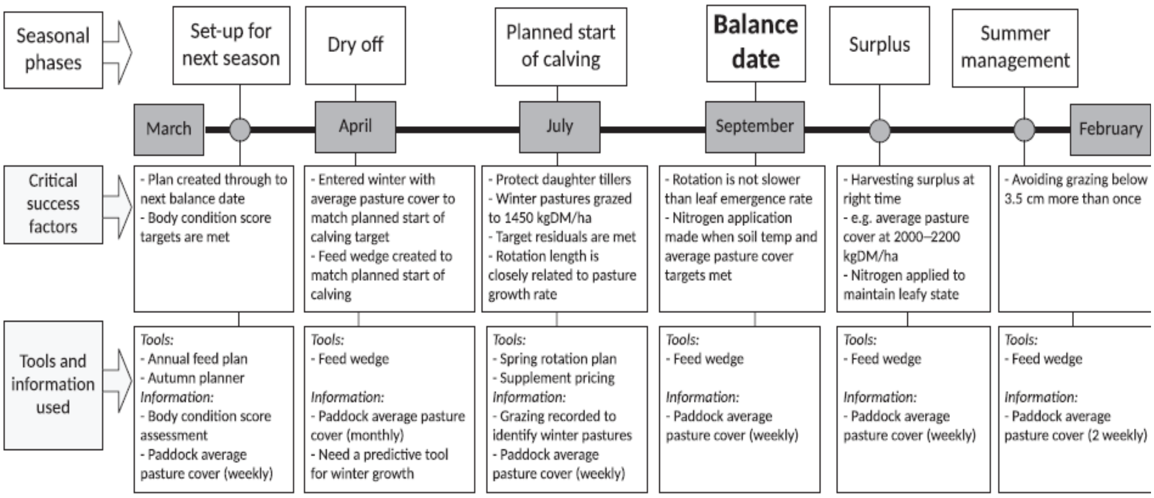


Figure 13 Example representation of the annual grazing management cycle, with seasonal phases, critical success factors and, tools and information used identified (Eastwood et al., 2016).

Like Hammond (2015) and Tocker et al. (2006), it was highlighted that farm-ownership structure differences have an influence on the IS in place on farm, which in this case were those specifically for grazing management (Eastwood et al., 2016). Larger, multi-farm business collected “farm-scale data”, used for company reporting and benchmarking (for tactical and strategic management); and “objective paddock-scale pasture data” due to a need for repeatability of processes across farms (with different managers and staff). In contrast, smaller multi-farm businesses and owner-operators were more focussed on systems for operational management, and used either used an “experienced-based” management approach, using good communication across the farm team or commercially available online grazing DSS (Eastwood et al., 2016).

It was also highlighted that the large multi-farm businesses were investing in their own in-house solutions (CRS Software Ltd) for benchmarking and reporting on grazing management, as a consequence of historic difficulties in transferring data between commercially provided software (Eastwood et al., 2016).

A number of desirable attributes of grazing DSS were identified. These were summarised by the diagram in Figure 14 which shows attributes and features of DSS, and links these to three different categorises of DSS – Basic, Intermediate and Advanced (Eastwood et al., 2016).

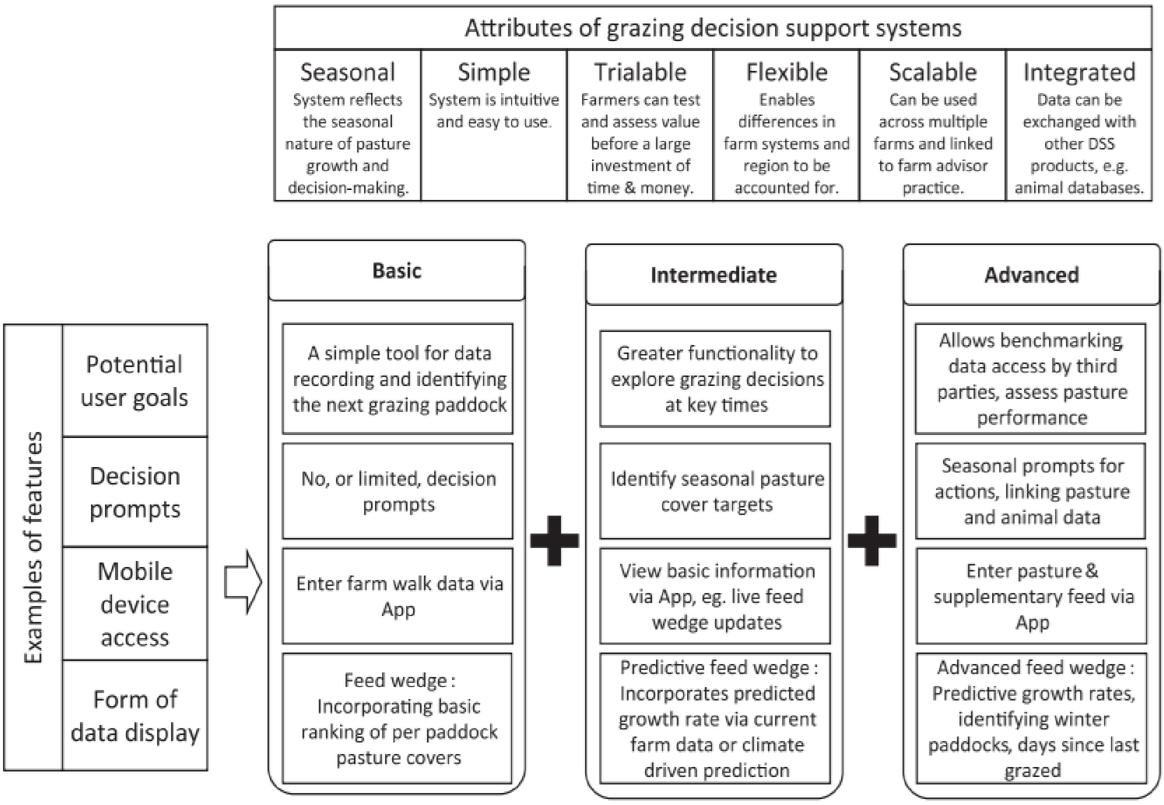


Figure 14 Potential attributes and features of grazing decision support systems for dairy farmers (Eastwood et al., 2016).

2.4 On-farm use of information and communication technology in information systems

This section firstly discusses specific use of ICT on-farm with a focus on NZ literature. Secondly, software attributes that influence the use and impact of software are presented and discussed. Finally, the drivers and inhibitors of ICT use and impact are presented and discussed.

2.4.1 Overview of ICT use by farmers in agriculture

"An adequate information supply together with land, labour, capital, and management is required for a successful agricultural business" (Alvarez & Nuthall, 2006). To assist with obtaining information (for management decision making), ICT is being used in all fields of farm management, within a range of IS, to help farm managers make decisions and meet compliance information requirements (Hammond, 2015).

The number of individual ICTs used on-farm is vast, including precision agriculture (hardware, sensors and machinery), agricultural software (for computers, tablets or smartphones) and other forms of ICT infrastructure (such as wireless routers and networking equipment), which are required to ensure data/information delivery, storage and security (and others).

Every piece of ICT can influence or impact on the farming system. Some ICT are used widely whereas others may not be, and often new technology is "overhyped and expectations can rapidly peak before crashing into the trough of disillusionment" (McEwen, 2016). Furthermore, some farmers prefer to use their minds for recording and processing farm data, including relying on informal components of IS such as observation. Decisions can then be made using intuition (Alvarez & Nuthall, 2006; Hammond, 2015).

Generally, the use (and impact) of ICT in any business is difficult to measure in totality. In agricultural systems this difficulty to measure the use and impact of ICT is exacerbated by biological systems that are broad, variable and unpredictable (Kuhlmann & Brodersen, 2001).

2.4.1.1 Precision agriculture (PA) use

Today it is often highlighted that farmers are using robotics, drones and sensor technologies as a means of on-farm data collection (Poppe et al., 2013; Sonka, 2014). These products all fall under the "precision agriculture" field (Jago et al., 2013), which entails the application of information technologies to measure and manage variability in land-based agricultural systems (Eastwood, 2008). Currently, ICT that falls under the category of precision agriculture is deemed state-of-the-art technology (Kaloxylos et al., 2013), created with the primary objective of increasing production, and reducing costs and environmental impacts (Cowan & Zinn, 2000).

In dairy farming, precision agriculture may be called "precision dairy" which is a subset of precision agriculture that focuses on dairy and "datafication" using ICT, particularly at the individual animal level (Eastwood, 2008; Jago et al., 2013). A commonly used precision agriculture technology used in Australasian (Australia and NZ) dairy farming is electronic identification (EID) for "precision management" of individual animals (Jago et al., 2013). This technology can come in the form of uniquely numbered livestock ear-tags which can be recognised via RFID readers to identify individual animals (Eastwood, Jago, Edwards, & Burke, 2015; Hammond, 2015). EID can also be used alongside GPS for "precision farming". Both technologies are forms of ICT used by farmers to gather data, process it and provide information for farm management (Jago et al., 2013).

In Hammond (2015), precision agriculture technologies were identified as being used in the production field of management, specifically for feed management and animal and milking management. These technologies included plate meter measuring equipment for capturing pasture covers; milk meters and supporting sensors (animal ear tags and tag-readers) for capturing individual cow milk-production data. These technologies are used for control purposes, to provide feedback for the farm managers planning functions (Hammond, 2015).

In-shed precision technologies were also used to implement decisions in real-time (Hammond, 2015). For instance, animal ear-tags and tag-readers integrated with in-shed software can alert farm staff when particular cows entered the milking shed. These alerts (or real-time information) could then be used to draft out animals ready for treatment or artificial insemination (Hammond, 2015). This kind of technology use is similar to other NZ dairy farmers, particularly those farmers with rotary dairy sheds, who use precision dairy equipment for similar purposes along with labour saving equipment such as auto drafting gates and automatic cup removers (Jago et al., 2013; Yule & Eastwood, 2012).

There is evidence that certain precision agriculture technologies are also being used outside the dairy-shed for management of pasture, nutrients (fertiliser & effluent), water (irrigation) and animal movements (Jago et al., 2013). These technologies provide additional data and information for farm decisions, although technology uptake and management decision making benefits are yet to be proven (Jago et al., 2013). However, even simple formal tools for production data capture, like rising plate meters for pasture measurement, are sometimes poorly adopted and used (Shannon, 2010, cited in Gray et al., 2014).

It is apparent that precision agriculture has some proven value as an ICT component of IS. However, despite the fact that precision agriculture tools have been around since the 1980's some existing systems provide limited functionality, are too complex or are expensive proprietary solutions which limit future usefulness (Kaloxylos et al., 2013). Factors influencing precision agriculture adoption and use in NZ have been identified and include: relating information to subsequent use in farm management; and a disjointed approach to precision agriculture development and support to farmers (Jago et al., 2013; Yule & Eastwood, 2012).

2.4.1.2 Agricultural software use

The use of computer technology in farm offices and homes is extensive in some countries, yet, the integration of such technologies is not as widespread in farm management practices (Alvarez & Nuthall, 2006). However, there is plenty of literature on the use and benefits of computer-based ICT in agriculture.

Agricultural software has often been called FMIS (Fountas et al., 2015; Kaloxylos et al., 2013; Nikkilä et al., 2010; Sørensen et al., 2010) and DSS (Bange, Deutscher, Larsen, Linsley, & Whiteside, 2004; Eastwood et al., 2016; Harwood, Al Said, Pearson, Houghton, & Hadley, 2010; Kuhlmann & Brodersen, 2001; McCown, 2002b) or decision support models (Bryant, López-Villalobos, Holmes, & Pryce, 2005; Bryant et al., 2010). Other researchers have used less generic terms to describe software that is used as part of IS of farmers, including "farm management tools" (Allen & Wolfert, 2011) and "farm tools" (including computer-based software and smartphone applications) (Dooley et al., 2012).

In the past, both agricultural ICT and PA technologies may have called "planning aids" or "external technologies" related to any of the steps within the planning process (Wright, 1985). These definitions include planning techniques such as budgeting, mathematical programming, simulation models, DSS, MIS and other various device used to monitor farm performance (Gray et al., 2014).

The definition of agricultural software used in this study is "computer or smartphone based programs, or applications, that are used for the management of agricultural business". This definition includes both computer-based software packages and smartphone applications as core components of individual solutions, and will consider other ICT (precision agriculture and ICT infrastructure) as part of a farmer's IS.

Computers and the Internet, amongst other forms or applications of ICT, provide the formal components of IS: to improve the capture of and access to data, improve processing and storage, and ease the management of information requirements (Sørensen et al., 2010; Valacich et al., 2016). In practice, IS's have increased in sophistication with the integration of ICT such as web-based and smartphone applications (Fountas et al., 2015) evolving from simple farm recordkeeping to large comprehensive FMIS used to communicate and manage a range of data, and to meet data and information requirements of different stakeholders (Fountas et al., 2015). Therefore, it is evident that the complexity of agricultural software varies from simple recordkeeping programs or smartphone apps, to highly complex FMIS.

Allen and Wolfert (2011) research compiled a comprehensive list of farm management tools used by farmers and rural professionals in Australasia. A list of 127 "tools" was identified. The results show that the tools were "disproportionately represented in the more established areas of farm management (stock, feed, financial), and under-represented in 'newer' areas of farm management (nutrient, labour)" (Allen & Wolfert, 2011). Furthermore, tools were classified as predominantly useful for operational management, rather than tactical and strategic management (Allen & Wolfert, 2011).

This study was expanded on further by Dooley et al. (2012) who classified 120 "farm tools" and 59 agricultural specific smartphone applications (apps) available to NZ farmers of which only 2 of tools were developed in NZ. These results reinforced the prominence in the development of "farm tools and apps" for agricultural production, particularly feed and stock management, and cropping. Furthermore, there was a greater proportion of strategic tools for planning functions, and more operational tools for control. Apps were focussed on operational and tactical planning purposes (Dooley et al., 2012).

The work from both Allen and Wolfert (2011) and Dooley et al. (2012) has been used to create an online database, called the "Toolbox" as part of a wider project. The Farm Business Management Toolbox is a website database available (agrione.ac.nz) to collate together and categorise "Farm tools (software, packages, apps)" available for use by farmers and consultants to aid decision making (AgriOne).

Financial tools research conducted by Gray et al. (2014) with three case study farmers found that one of three case study dairy farm managers used Cashmanager Rural, financial software for managing daily cash transactions and budgeting. All three managers identified and explained that daily cash transactions were limited on a dairy farm and therefore cash flow plans could be memorised, although errors did occur (Gray et al., 2014). All three farmers also used online financial banking systems (online banking and statements) for cash control purposes. None of the three farmers used DairyBase which is an online industry benchmarking program, nor Farmax, which is an operational and tactical planning and control software for NZ farmers (Gray et al., 2014)

Hammond (2015) found that both case study dairy farmers used a range of software for production, human resource and financial management of their dairy operations. In production, herd management software called MINDA is used to process and collate a range of herd information (animal health, breeding, movements and status). Milk production data is collected by "herd testing" which occur a 3-4 times per year to gather data on individual animal milk production and milk-quality. The major decisions that the collated herd information on cows related to were breeding and animal management, such as which cows to keep in the herd, and which to "cull" (Hammond, 2015).

Also in the production field of management, both farmers used Farmax, with analyses run and reports provided to them via their local private consultant. This software provided them with tactical plans for feed and animal management (Hammond, 2015). This result reinforces the fact that software has predominantly been created for traditional agricultural fields such as animal and feed management (Allen & Wolfert, 2011; Dooley et al., 2012); and also supports

Dooley et al. (2012) who state that Farmax can be effectively used to provide information for tactical decision making on dairy farms. Both farms in Hammond (2015) also used formal software for processing pasture data into useful information for decision making which supports Allen and Wolfert (2011) and Dooley et al. (2012).

For financial management, farmers interviewed by Hammond (2015) had used CashManager Rural for a long period of time, "Farm 1 since it was released in 1981 and Farm 2 since 1992" (Hammond, 2015). This supports Doye et al. (2000)'s finding that recording systems of farmers develop over time rather than being adopted or disposed of quickly.

Furthermore, because CashManager Rural was developed in NZ with training course available, both farmers received adequate training and support as the software developed over time. This indicating that longevity in training and support can alleviate the support and servicing problems identified by Yule and Eastwood (2012) and Jago et al. (2013) for precision agriculture technologies.

The software used by the farmers in Hammond (2015) were incorporated into a specific MIS and sub-system framework, categorised by the field of management. However, the data/information captured and processed within these software was considered (and used) holistically for a range of decisions across the different field of management. This finding supports that of Gray (2005a) and Fountas et al. (2006) which identified that farm management considers systems holistically for decision making.

Bryant et al. (2010) described and evaluated the Farmax Dairy Pro agricultural software, which is a pastoral grazing model of a dairy farm which was also one of the software's evaluated in Dooley et al. (2012) and Hammond (2015). This software was evaluated by Bryant et al. (2010) using two independent farmlet studies of spring-calving dairy cows in two different locations in NZ. It was found that Farmax could reliably predict mean annual yields (per cow and per hectare) for milk, fat, protein and milksolid (MS) concentration on both farmlets. Pasture cover was reliably predicted for one dataset, where validation was possible. The model also accurately predicted trajectory of yield, MS concentration and body condition score, however some variation was evident. The model can also be used to accurately predict changes in farm management practices that influence animal performance, pasture cover and total yields (Bryant et al., 2010).

In Bryant et al. (2010)'s review of other decision support models, they explained that models can incorporate knowledge of the farm, such as "potential pasture growth, calving patterns, cow genetic merit, supplementary feed made or purchased, typical nitrogen application rates, input prices and product returns" (Bryant et al., 2010). The models themselves ranged from detailed Microsoft Excel spreadsheets, through to Windows based software applications such as: UDDER which is a model for evaluating feeding and supplementation strategies in order to increase milk yield and farm gross margin (Hart, Larcombe, Sherlock, & Smith, 1998); and AUSFARM which is a model used to predict dairy production using pasture intake, milk yield, animal growth and liveweight change (Bryant et al., 2010); and others models (Bryant et al., 2005).

Evidence on the experience of farmers and rural professionals in the use of grazing DSS in Eastwood et al. (2016) showed that grazing DSS are not widespread in NZ, although most of their participants saw value in them for helping make management decisions. It was also suggested that while DSS are useful in providing data and decision rules, the high performers still require informal skills based on experience, intuition and acceptance of risk. Rural professionals used commercial software, including Farmax and UDDER, for providing strategy information for farmer clients, however these were not used absolutely. Many rural professional also had their own developed spreadsheets for specific functionality and reporting (Eastwood et al., 2016).

Additionally, the value proposition of commercially provided DSS was too equivocal to convince "non-users" of its value, and therefore improved DSS design is needed to address identified barriers that were highlighted (Eastwood et al., 2016). Businesses that were using DSS require skilled and motivated staff in order to capture quality data. This may require specific training of farm staff, especially for more sophisticated DSS (Eastwood et al., 2016).

DSS that incorporated smartphone apps was shown to aid farm staff in the collection of data, and also provided feedback information. Mobility was a highly desirable feature identified by interviewed farmers, which could also be further enhanced by greater integration of DSS with mobile platforms (Eastwood et al., 2016).

McEwen (2016) suggested there are three main categories of software application available for NZ farmers. These include financial applications, such as CashManager RURAL and

Figured/Xero, which can be used for cash management and meeting financial compliance requirement. As a category these financial tools are widely used. Other applications are data recording and geospatial applications, such as MINDA, AgHub, FarmIQ, Smartmaps, Land and Feed, and Agri360. The data recording applications focus on storage, processing and display of farm data. There are also modelling applications, such as OVERSEER, Farmax and UDDER, for forecasting and predicting outcomes relating to farm practices, given real world or hypothetical farm parameters (McEwen, 2016).

The adoption of ICT for financial management has been widely accepted by farm businesses (McEwen, 2016). Likewise, ICT for management of herd performance recording in the dairy industry has also become an important part of production IS (Hammond, 2015; McEwen, 2016). This is underlined by the success of LIC's MINDA application which is used for herd recording, which has over 90 per cent of market share (McEwen, 2016).

McEwen (2016) also explained that MINDA has helped to improve farm profitability through the analysis and benchmarking of collated individual cow data over her productive lifetime. This job would have been nigh on impossible in the past due to the amount of data generated by today's herds. The ultimate value in the use of MINDA is improved animal selection decisions, leading to higher genetic merit cows and milk production (McEwen, 2016).

In the area of compliance, research on software and models used to estimate nutrient loss from farmland has been of particular interest in recent times, especially regarding water quality concerns (Cichota & Snow, 2009; Monaghan et al., 2007; Shepherd, Wheeler, Selbie, Buckthought, & Freeman, 2013; Wheeler, Ledgard, & Monaghan, 2007). This is partly because of the impractically of routine direct measurement, and therefore simulation models are the best alternative to help address both economic and environmental concerns (Cichota & Snow, 2009; Shepherd et al., 2013).

Cichota and Snow (2009) presented an overview of models in use (or being developed) to estimate nitrogen and phosphorous losses from pastoral fields, demonstrating the wide range of alternative models (all with varying levels of detail and scale, and purpose). Many of these models have been tested and are supported by published work, however, others were not fully operational or lacked thorough evaluation (Cichota & Snow, 2009).

One of the farmers in Hammond (2015) used the OVERSEER nutrient budgeting model which was provided by their fertiliser company. Frustratingly for the farmer, this model often had to be changed to ensure the data was correct, which shows that this model was a challenge to get accuracy. OVERSEER is a topical of nutrient management models in NZ (Cichota & Snow, 2009; Shepherd et al., 2013; Wheeler et al., 2007). It is a decision support tool for farmers and consultants to develop nutrient plans. OVERSEER uses input data to produce nutrient budgets, define farm nutrient resources and flows, and helps identify current practices that may influence nutrient use. Generally, the software can be used to analyse alternative nutrient management strategies (Wheeler et al., 2007), although it is important to note that users must be familiar with model assumptions, and that the farm systems are thoroughly understood, otherwise created scenarios will be unrealistic (Wheeler et al., 2007).

It was summarised in Shepherd et al. (2013) that models like OVERSEER involve the simplification of complex biological processes, and therefore predictions will always be uncertain to some degree. However, given the impracticability of the alternative direct method of nutrient measurement, these models are important tools. Uncertainty therefore must be minimised through data calibration and/or validation, and the use of precise data inputs ("using industry-agreed protocol or input guidelines" (Shepherd et al., 2013). Having data interoperability between other software (and systems) is therefore a logical and desirable trait to have (Cooke et al., 2013; Fountas et al., 2015; Kaloxylos et al., 2013).

Hawkins (2016) explained that developing ICT in NZ can provide solutions for improvements in the environmental impact of farming, as well as increasing profitability. The business she works for (called Regen) provides services, including a smartphone application, to assist farmers in improving management of effluent, nitrogen and water. Using on-farm hardware and farm user's access to the Regen app on their smartphone enables Regen to provide daily recommendations and calculators to not only reduce environmental impact and improve profits, but also help farmers meet compliance reporting requirements by ensuring they have comprehensive records of effluent and water application (Hawkins, 2016).

"Technology is an enabler that will play a large role, but to have an impact on changed behaviours it has to connect to what farmers do every day" (Hawkins, 2016). This statement suggests that an understanding of the farm users is an essential aspect of providing technology and technology related services. There was, however, no mention of how and why farmers actually used this particular ICT and service, nor was there evidence of actual on-farm impact in this paper.

The larger scale, equity partnership dairy farm, in Hammond (2015) used a combination of hardware and software to monitor weather and manage water data for both production decision making (for farm resources) and compliance purposes (water use). They used hardware provided by Harvest Electronics to collect and collate information which can be accessed online on the Harvest website. It was explained that part of the reason for using such technology was to meet the “broad shareholder group” requirements, which required an “environmental twist” in farm practices so the farm could remain a leader in environmentally friendly farm practices (Hammond, 2015). Therefore it is evident that the goal of using various technologies may be because of a variety of visions for a farming business.

2.4.1.3 Overseas ICT use examples

McCown (2002a) conducted DSS research comparing 14 decision support products, collating the results into key characteristics and aggregated learnings from their use (McCown, 2002a). These DSS classifications were not too dissimilar from the classification of tools used in Dooley et al. (2012) but included only academic DSS. The difference between McCown (2002a) and Dooley et al. (2012) is that function of the DSS is largely targeted at what the tool can perform as described by Hearn and Bange (2002), rather than categorising tools according to what farm management functions they could be used (Dooley et al., 2012).

Fountas et al. (2015) collated a selection of 141 international commercial software packages (from 75 software providers) which they categorised into 11 different farm management functions (such as field operations management, best practice, finance, inventory and more). Cluster analysis was used to group “commercial FMIS”, and examine avenues for future development (Fountas et al., 2015). In their analysis they found academic FMIS which were more sophisticated FMIS, covering compliance and standard applications, as well as providing automatic data capture and interoperability between different software systems. Conversely, the commercial FMIS were targeted more at operational functions such as budgeting and recordkeeping, as well as functions for recording for traceability and quality assurance (Fountas et al., 2015).

Farm system work by Poppe et al. (2015) predicted that in the future apps will replace some of the functions currently done by farm management software, as well as providing new functionality. This is because apps will be far more easily built than desktop software, with future internet standardised software-components. Current farm management software will be broken up into one or more apps that will help farmers enter farm data manually, and if needed, will synchronise with other data exchanged by farmers and into apps that help farmers interpret data (Poppe et al., 2015).

2.4.2 Attributes that influence software use in agricultural information systems

It is readily known that often ICT solutions (agricultural software included) at times fail to meet the needs and desires of on-farm users (Eastwood et al., 2016; Fountas et al., 2015; Hammond, 2015; Kuhlmann & Brodersen, 2001; McCown, 2002a, 2002b). There are a number of reasons why ICT solutions in agriculture are, or are not, successfully used as part of on-farm IS. Amongst other things, issues can relate to the users and providers (the people), the agricultural system (the organisation), the ICT itself (the technology), or a combination of the three. These are the three dimensions which make up IS which form the boundaries of the system under analysis in this research. Additionally, there are also drivers and inhibitors that influence ICT use in agriculture which have been identified in Section 2.4.3.

The overall challenge in incorporating software into on-farm IS has been summarised and called the ‘problem of implementation’, by McCown (2002a). This research described and analysed problems, paradigms, and prospects of DSS in agriculture, and is supported by additional work (McCown, 2002b). Figure 15 demonstrates the problem (the ‘gap’) in the context of agriculture and agricultural DSS development (McCown, 2002a) which is identified as the gap is the discrepancy between “science-based best practice” and farm “management action” (McCown, 2002a).

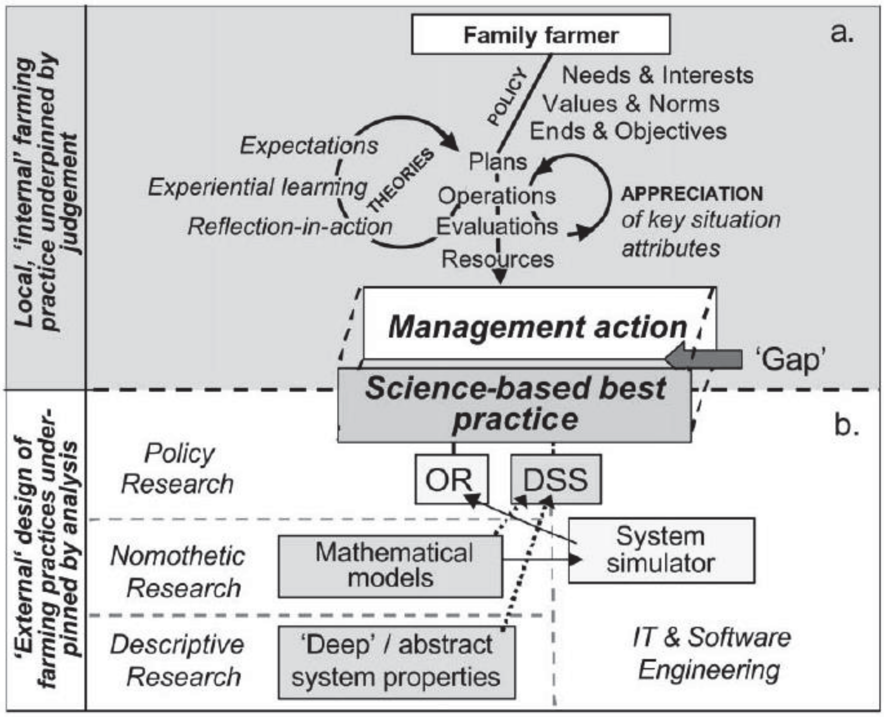


Figure 15 Internal (a) and external (b) processes for planning and decision making. OR = Organisational research, DSS = decision support system/s (McCown, 2002a).

McCown (2002a) suggests that a large component of the 'problem of implementation' from the standpoint of the farmer (shown in the internal part (a) in Figure 15) is that in being one's own boss (in the case of a traditional family farm), the use of DSS and other ICT is entirely voluntary, and therefore farm managers have "high degrees of freedom to choose (discretion) and power to act (agency)" (McCown, 2002a). Therefore, for DSS to be used, they must provide recognisable value as part of the farm manager's decision making processes, and satisfactory costs and risks (McCown, 2002a).

Furthermore, farm management as a "normal social practice" is conducted somewhat automatically by farm managers, with reactions (decision making) considered alongside current expectations and previous outcomes, provided that the environmental situation is within the normal range (for example, normal climatic conditions). The farm management system is honed as a consequence satisfactory results from previous work. Periodically, management processes will change as a result of business environment changes, including the opportunity to use new ICT such as DSS (McCown, 2002a). Changing technologies, amongst other things, do however bring with them other issues. Accordingly, the specific attributes of software and software provision that influence agricultural software use (by farm users) have been identified from the literature and summarised in Table 1. The attributes of software which influence software providers' (or developers') ability to provide software, have also been identified from the literature and summarised (Table 2).

The content from Table 1 and Table 2 highlights that there are a range of software attributes that influence agricultural software use[1]. The most highly reported attributes are - simplicity/complexity, value, and addressing the problem or need. These attributes are followed by ease of use or user friendliness, input and output requirements, and accuracy.

With respect to the simplicity/complexity attribute, this was used as catch-all term for describing a reason for software (or ICT) being used, or not used, because it was either relatively simple or overly complex, respectively. It was suggested that farmers want simplicity and reliability from their ICT because, more often than not, ICT that is overly-complex, difficult to use and error ridden is less likely to used (McEwen, 2016). It is likely that complex technology will have a large negative influence on adoption and use of technology by individuals, especially when training resources are also limited (Tarofder, Azam, & Jalal, 2017). It was also apparent that the terms "simplicity" and "complexity" are subjective and non-specific. Therefore, other attributes that influence simplicity or complexity have also been listed under simplicity/complexity in Table 1.

[1] Empirical and normative literature was not always clear in their isolation of attributes that influence agricultural use by farm users, or provision by developers, therefore, the author used his own judgement for the classification of the attributes.

Table 1 List of the main attributes that influence agricultural software use – Users' perspective.

Attributes	Hammond (2015)*	Kuhlmann and Brodersen (2001)**	McCown (2002a)*	McEwen (2016)**	Bryant et al. (2010) *	Fountas et al. (2015)*	Dooley et al. (2012) *	Gray et al. (2014) *	Alvarez and Nuthall (2006)*	Flett et al. (2004)*	Monaghan et al. (2007)**	de Olde et al. (2016)*	Eastwood, Dela Rue, and Gray (2016)*
Simplicity/complexity	x	x	x	x					x	x	x	x	x
Failure to address the problem or need of farmers.		x			x	x			x		x	x	x
Ease of use or user friendliness - including navigation, interface and language.	x			x		x				x			x
Data input and information output - including data entry requirements and information output issues.		x	x					x	x				
User preferences - such as a desire for software for operational control		x	x				x						x
Lack of integration between different software (and other ICT)						x			x				x
Fit with farm user work patterns (reliability, accessibility, up-to-date and on-time)		x		x				x	x				
Training (skills and knowledge of farm users)	x	x							x				
Accuracy - regarding uncertainty of quantitative input and outputs.				x	x	x					x	x	
Value of software - especially economic (costs versus benefits)				x		x			x	x	x	x	x

* Denotes empirical research

** Denotes normative research

Table 2 List of the main attributes that influence agricultural software provision - Providers perspective.

Attributes	Kuhlmann and Brodersen (2001)**	McCown (2002a)*	Kaloxylos et al. (2013)**	K. Poppe et al. (2015)**	Fountas et al. (2015)*	Sorensen et al. (2010)*	de Olde et al. (2016)*	Lynch and Gregor (2004)*	McCown (2002b)**
Obsolete or outdated software, or a decline in user requirements of software		x							
Imperfect knowledge of the relationship between inputs and outputs in biological systems (including time and space input variables)	x		x	x	x				x
Complexity of farm-user information systems						x			
Credibility of provider/s (including the method of software provision)	x	x							
Participation of user (farmers and intermediaries) in product development and the nature of this relationship		x							
Degree of influence of users involvements in product development								x	
Value (especially economic, costs versus benefits)							x	x	

* Denotes empirical research

** Denotes normative research

The second most highly reported attribute was 'addressing the problem or need'. It was explained that often software models are inadequate at addressing farmer's specific problems. This is especially relevant when considering the multi-disciplinary nature of farming, including production aspects such as soils, animals and plants (Bryant et al., 2010; Fountas et al., 2015; Kuhlmann & Brodersen, 2001). Even if a number of variables (or inputs) in agricultural software can be personalised for a farm, often it is time consuming and laborious to do this (Kuhlmann & Brodersen, 2001), which can result in imputation errors (Bryant et al., 2010).

Additionally, the desired outputs of ICT use by farmers may differ from what the software can actually accomplish (Kuhlmann & Brodersen, 2001). For example, a farmer may not only want to know what to do, but also when to do it. If software does not provide the desired outputs then it is less likely to be used, or alternatively, only certain aspects of the software will be used in practice.

With regard to value, this term generally referred to the relationship between the benefits and cost of using software. For instance, technology was deemed most useful by NZ dairy farmers if it contributes to improvements in production and profit (Flett et al., 2004). Therefore a key consideration of agricultural software development (by providers), and use (by farmers), is the profitability of using software (Flett et al., 2004) which extends from value attribute and is realised through improved decision making (Fountas et al., 2015). This value is, however, difficult to quantify (McCown, 2002b; Nuthall, 2004; van Asseldonk, Jalvingh, Huirne, & Dijkhuizen, 1999), especially when the benefit of using software also depends of the level of user's experience (Fountas et al., 2015).

For the providers (or developers) of agricultural software, there was less evidence in literature to explain attributes that influence the provision of agricultural software. The most highly reported attribute was "imperfect knowledge of the relationship between inputs and outputs in biological systems"(Kuhlmann & Brodersen, 2001). This attribute was not explicitly identified in empirical evidence from providers, but rather it was implied that this is a major attribute that influences what (and how) software (and other ICT, especially models) can be applied and used on-farm, or alternatively, used by intermediaries on behalf of farmers. This imperfect knowledge has an influence on the assumptions built into software which also influences software complexity (Kuhlmann & Brodersen, 2001; Shepherd et al., 2013).

Excessively complex models and/or over-simplifications of reality, limit the credibility of software, and this was the second most highly reported factor. Farmers (intermediaries and researchers) may not believe the outputs provided by these models/software. Any output from software will be considered alongside the users' own knowledge (experience or tacit knowledge) and intuition (Gray et al., 2014), which often leads users deduced that models are relevant for only average conditions and therefore not useful for them (Kuhlmann & Brodersen, 2001). These testaments were reinforced by McCown (2002a) who stated that gaining entry into farm management practice has been far more difficult than envisioned (this being the "problem of implementation"), and there seems to be no desire to develop more advanced "expert systems for decision support" (McCown, 2002a).

Value from the standpoint of the providers also is considered in terms of economics, but this does depend on the purpose of the software and the business model of the provider. For instance, LIC provides MINDA herd management software to it cooperative owners free of charge, but users incur the investment cost as members of the cooperative, as well as paying for associated running costs, like herd test data, processing and information shown on the MINDA software (Hammond, 2015). It is also indicated by Alvarez and Nuthall (2006) that software providers should consider alternative pricing models, instead of the traditional one price for all users. It was suggested that pricing should reflect the size of the farm business since their research showed that larger scale operations are more likely to use software. Therefore, pricing software on a per cow or per hectare basis could be appropriate (Alvarez & Nuthall, 2006).

The other attributes were listed in the table were only mentioned by individual authors, but are still worth considering in this study because limited work has been done in relation to investigating the perspective of providers of agricultural software.

2.4.3 Drivers and inhibitors of ICT use in agricultural information systems

Table 3 presents a summary of both drivers and/or inhibitors of ICT use in agricultural IS, taken from NZ research and research generated abroad. These drivers/inhibitors are presented to demonstrate the influence that global and industry-wide issues can have on the technologies available and used by farmers, and the technologies that can be created and provided by software providers. The drivers and inhibitors are closely associated with the attributes that influence software use presented previously.

Table 3 Drivers and inhibitors of ICT use for agriculture.

Driver/inhibitor	Explanation	Reference
Increasing compliance/regulatory requirements	Public and government attention on agriculture's economic viability and the impact it has on the environment (sustainability). This results in greater data and information requirements	(Cooke et al., 2013; Eastwood et al., 2016; Foote et al., 2015; Hammond, 2015; Hawkins, 2016; HorizonResearch, 2014; Husemann & Novković, 2014; McEwen, 2016; Sørensen et al., 2010)
Farmer preferences for using formal (including ICT) or informal methods of data and information collection	Farmers preferences in dealing with increasing managerial load (more data and information) by using informal IS components, rather than formal ICT	(Eastwood et al., 2016; Hammond, 2015; McCown, 2002b; Sørensen et al., 2010)
Farm scale and operating structure (and management support)	Increasingly large farms, which include multiple owners, are becoming more prevalent compared to traditional owner-operators in NZ. These farmers are more likely to use ICT with IS (Eastwood et al., 2016; Hammond, 2015; Poppe et al.,	(Eastwood et al., 2016; Hammond, 2015; Poppe et al., 2015; Tarofder et al., 2017; Tocker et al., 2006)

	2015; Tocker et al., 2006). This is especially so when management supports ICT use (Tarofder et al., 2017)	
Economic viability	ICT can be used to improve profitability of farming operations if used successfully (Flett et al., 2004; Hammond, 2015; Poppe et al., 2015), and/or if it has a relative advantage over alternative methods (Tarofder et al., 2017)	(Flett et al., 2004; Hammond, 2015; McEwen, 2016; Poppe et al., 2015; Tarofder et al., 2017)
Complex, unintegrated, agricultural IS, and increasing data and information generation or requirements	Complexity of agricultural IS and increasing data and information requirements makes it increasingly difficult for farmers to manage and collate fragmented data information together	(Allen & Wolfert, 2011; Cooke et al., 2013; Fountas et al., 2015; Hammond, 2015; Kaloxylos et al., 2013; Poppe et al., 2015; Sørensen et al., 2010)
Industry collaboration and/or competition	Collaboration between industry entities can enable further use of ICT, whilst greater competition reduces successful ICT use, but may encourage further supply of ICT technology	(Cooke et al., 2013; Fountas et al., 2015; Poppe et al., 2013; Tarofder et al., 2017)
Labour skillset and knowledge	Shortages in skilled labour able to make best use of ICT will reduce the successful use of this technology, and also discourage the further use of alternative technologies like precision	(Davenport, 2014; Eastwood et al., 2016; Fountas et al., 2015; Hammond, 2015; Jago et al., 2013; Poppe et al., 2013; Tarofder et al., 2017)

	agriculture (e.g. robotics). Conversely, younger, unskilled and inexperienced farmers can use ICT to improve decision making without years of experience, intuition and knowledge	
Improvements in ICT and ICT infrastructure	Improvements in the quality and quantity of ICT products available to be used at acceptable cost. For example, Big Data, the Cloud and the 'Internet of Things'. Furthermore, some farms and/or regions could become more or less competitive as basic ICT infrastructure, particularly quality Internet connectivity, limits adoption (Poppe et al., 2015). Rural Internet connectivity (access and speed) is an issue in NZ, with government initiatives in place to help alleviate this limitation (Ministry of Business Innovation & Employment, 2016)	(Fountas et al., 2015; Ministry of Business Innovation & Employment, 2016; Poppe et al., 2015; Poppe et al., 2013; Sonka, 2014)
Consumer preferences	Consumers' preference for healthy, safe and nutritious food products. These preferences are	(Fountas et al., 2015; Poppe et al., 2013)

	being traced back to the farm required ICT in this function	
Large numbers of farmers and providers of ICT, fuelled by continued investment in agriculture and ICT for agriculture	A large number of heterogeneous farmers and providers results in a wide range of ICT solutions, many of which will, or will not, work depending on the farm or provider (Kaloxylos et al., 2013; McEwen, 2016). Competitive pressure also encourages greater adoption and use of ICT in order to capture perceived competitive advantages (Tarofder et al., 2017)	(Kaloxylos et al., 2013; McEwen, 2016; Tarofder et al., 2017)
Seasonality	The change of seasons and consequently, the farming operation, necessitates a change in data and information requirements, and therefore a shift in ICT use (Eastwood et al., 2016).	(Eastwood et al., 2016)
Existing ICT business models	Existing ICT solutions (particularly farm software) have been developed as proprietary products or services with their functionality directly linked to cost. Historically, this may not have been a problem as less ICT products were available. Today, many proprietary offerings limit	(Fountas et al., 2015; Kaloxylos et al., 2013)

	integration between different systems, and because cost is linked to functionality it is difficult to upgrade functions whilst keeping their cost affordable	

Additional to the table above, the diagram below (Figure 16) presented by Eastwood et al. (2016), depicts a useful summary of factors (drivers and inhibitors) motivating future users of decision support systems. This highlights six key dimensions that can drive or inhibit farmer motivation to use DSS, including trialability, psychology around the use of precision farming tools, external forces, building knowledge, product features and the value of precision farming.

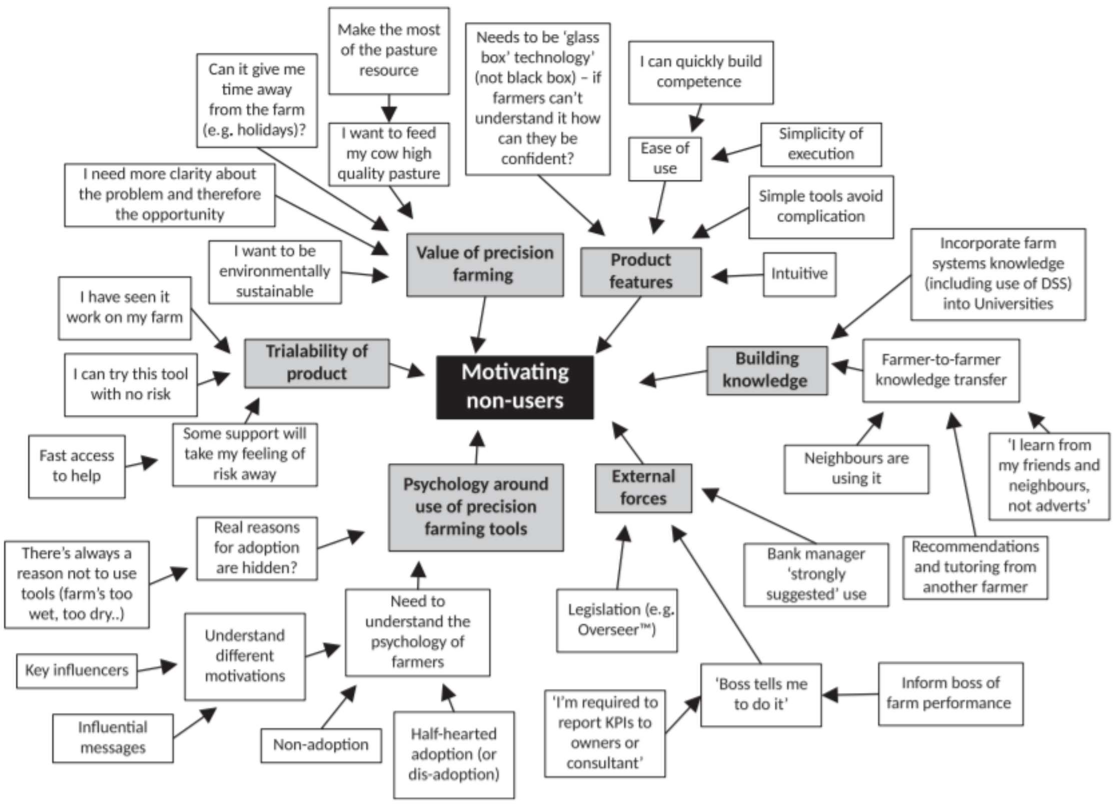


Figure 16 Factors motivating future users of grazing decision-support systems (Eastwood et al., 2016).

2.5 Gauging the impact of ICT on agricultural information systems

Attempts to determine the influence of ICT on businesses has been extensive but varying. Researchers have used a number of different terms for describing the influence, including: usefulness, ease of use, impact, relevance, use and others. Fewer studies have looked at how ICT is integrated into IS of agricultural entities as a whole.

In agriculture research, McCown (2002b) explained that attempts to critically reflect on individual experience of DSS (a type of ICT) use in order to make sense of it seem rare or rarely made public. This can partly be explained by a “lack of rewards for retrospective investment of scarce research attention” and also due to the fact that reflection on DSS experience is immensely challenging.

The following section describes empirical evidence and methods used in agricultural literature to show how the impact of ICT in agricultural entities has been studied.

2.5.1 Impact - Agricultural literature

In Flett et al. (2004) the Technology Acceptance Model (TAM) was applied to explain technology use in NZ dairy farming. This was applied in relation to four technologies – mineral supplements, new pasture species, soil testing and controlled intra-vaginal drug release (CIDRS).

The TAM model has two attitudinal components: perceived usefulness (Pundyk) and perceived ease of use (PEOU). Both are psychological constructs that influence technology acceptance usage behaviour, with PU having the greater effect (Brosnan, 1999).

To measure PU of technology five questions were asked of 985 respondents, including: “Is this technology important to your farming needs”; “Is this technology better than what it replaces”; “Is this technology able to increase your financial profits”; “Is this technology able to increase production for you”; and, “Is this technology able to save you time” (Flett et al., 2004; Sahin, 2006).

To measure PEOU of technology two questions were asked of the 985 respondents, including: “Is this technology easy for you to understand”; and, “Is this technology easy for you to use” (Flett et al., 2004; Sahin, 2006).

It was found that technology usefulness is primarily defined in economic terms for NZ dairy farmers, therefore if a technology contributes to improvements in production and profit it will be deemed useful. However, ease of use findings suggest that there is more to it than just economics, especially as newer technologies become more complex. It was also highlighted that additional research is needed to understand "what makes a product easy to use and learn", particularly regarding the motivations for technology adoption behaviour (Flett et al., 2004)

de Olde, Oudshoorn, Sørensen, Bokkers, and de Boer (2016) stated that although multiple studies have compared tools used for farm sustainability on a theoretical basis, little work has been done to compare tools in practice at the farm level. Their research was undertaken to gain insights in practical requirements, procedures and complexity involved in applying sustainability assessment tools (of which four tools were studied in-depth), as well as determining the perceived relevance of the tools, as expressed by farmers.

The comparison of tools was completed using a framework developed by Marchandet al. (2014), adapted from Binder et al. (2010), which includes normative, systemic and procedural aspects (Figure 17).

	Characteristic	Description
Normative aspects		
	Sustainability concept	The concept of sustainability adopted
	Goal setting	How goals were set for the sustainability assessments
	Scoring and aggregation method	The method for indicator assessment, weighing and aggregation
	Tool function	The function, or purpose, of the tool
Systemic aspects		
	Simplicity	Is simplicity of the system representation a goal of the tool
	Sufficiency (complexity)	Is sufficiency of the system representation a goal of the tool
	Indicator interaction	Is interaction between indicators addressed in the tool
Procedural aspects		
Preparatory phase		Preparation requirements
Phase of indicator selection		Possibility of indicator selection
Measurement phase (quantification of indicators)	Data correctness	The user's perception of the correctness of the data provided
	Data availability	The availability of the required data
	User-friendliness	The user's perception of the user-friendliness of the tool
	Compatibility	The extent to which the tool is compatible with existing data systems
Assessment phase (aggregation of indicators)	Transparency	Transparency of the tool's calculations, weighing and aggregation
Applicability of assessment results and follow up	Output accuracy	The user's perception of the accuracy; the proximity of the results to the true value
	Complexity	The complexity of the tool procedures, presentation and interpretation of the results
	Communication aid	Ability to use the tool as a communication aid to discuss sustainability
	Relevance (effectiveness)	The extent to which the tool is perceived by the users as relevant to use and implement

Figure 17 Framework to compare sustainability tools presented in (de Olde et al., 2016).

Normative and systemic aspects of each tool were determined by using peer-reviewed publications and manuals on the tools, whilst the data on procedural aspects were collected and compared for each tool used on five Danish farms. The experiences of the researchers who performed the assessment, and the experience of the farmers was collected through a questionnaire and provided the evidence to compare the procedural aspects of the tools (de Olde et al., 2016).

Using the method prescribed above, it was found that farmers preferred one tool (called RISE) over the other three because it was based on quantitative farm data and used a context specific approach with regional data. Other important factors of perceived relevance were: user-friendliness, complexity of the tool, language used and the value judgements (what is of value) of tool developers and the farm users. Alignment of value, embedded in tools, is essential for the acceptance of the tool output by users (the assessment tool findings), and therefore, the application of the findings to improve farm sustainability de Olde et al. (2016).

Research by Alvarez and Nuthall (2006) focussed on the adoption of computer based IS, including measures of software use and usefulness. An explorative qualitative model of adoption/rejection was developed and used to analyse the computer use of 39 dairy farmers in Canterbury (NZ) and 61 dairy farmers in Florida (Uruguay). Both mail and interview surveys were used to gather evidence. These surveys included measures of: software usefulness (ranked on a scale of 1-5), software "fit to the work environment" (ranked on a scale of 1-5), and whether software matched the current decision approach (ranked on a scale of 1-5).

The qualitative model used (Figure 18) considers a number of factors which contribute toward the three major reasons for adoption or rejection of software. These reasons were firstly, "knowledge gap", defined as the difference between knowledge of each farmer relative to the software developers' knowledge of what the software should do and look like. For example, a large knowledge gap would likely result in low use of software. Secondly, the "benefit perception" is the farmers' perception of the economic benefits and ease of management which would be derived from the adoption and use of software. Thirdly, the skills needed to manage the "information innovative" (CRS Software Ltd), which as a minimum, required a degree of computer operation ability.

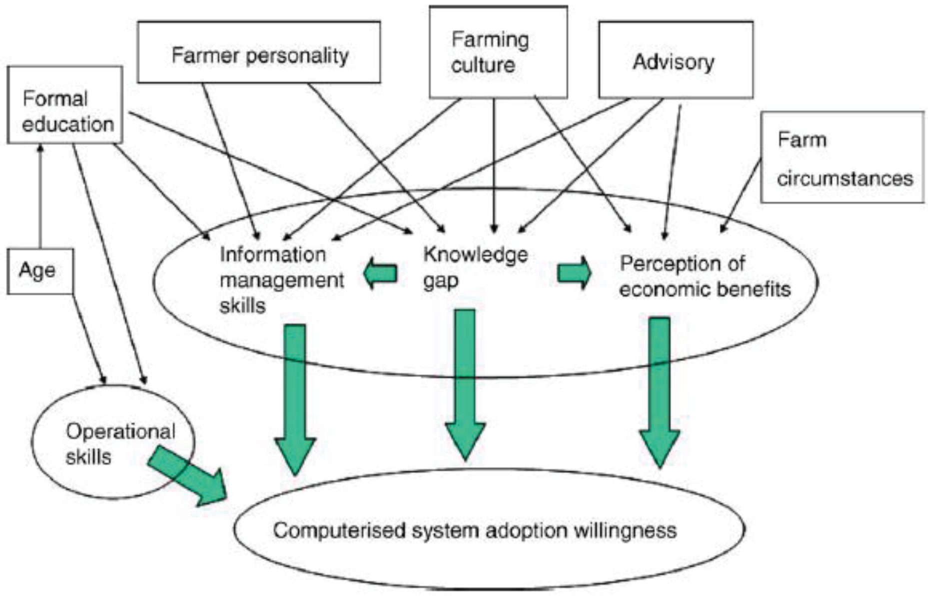


Figure 18 Computerised system adoption model (Alvarez & Nuthall, 2006).

The findings describe the attributes of a farm user that would be more or less likely to adopt and use software in their IS. The least likely users to adopt and use software can be described in brief as farmers with small farms, being 50 years or older, less formally educated, and with learning styles that are based on either concrete experience or active experimentation. The more likely adopters of software is the reverse of this. That is, large farms, and farmers younger than 50 years, more formally educated and with an abstract learning approach. The context of the individual farm's current level of IS development should also be considered as this will influence the ease of adoption (Alvarez & Nuthall, 2006).

The software usefulness results showed that both Canterbury and Florida farmers ranked software as "useful" (ranked 4.14 and 3.57 out of 5 respectively). This data was then analysed statistically and input into a model to measure "successfulness", which included scores for "fitting with the farmer's work environment", "matching with the farmer's decision system", and "software friendliness". It was found that the significance of the variables was poor, and therefore the models needed expanding and/or the scoring system was not accurate or expansive enough (Alvarez & Nuthall, 2006).

These finding have implications for understanding farmers use of ICT, which could benefit software developers or providers and extension organisations. As previously mentioned, this study suggested that software pricing should reflect the size of the farm business, such as being on a price per cow or per hectare (Alvarez & Nuthall, 2006).

Prior to the study in Alvarez and Nuthall (2006), Nuthall (2004) looked specifically at the interactions between farm profitability and the use of a farm computer. Quantitative methods were used to measure and analyse data from 23 Canterbury farms. It was found that, on average, profit tended to increase after purchasing a computer, however the wide variation of results, and other factors influencing the relationship between profit and computer use made any definite conclusions difficult (Nuthall, 2004). These findings are emphasised by a concluding comment stating that, "the concept that simply investing in, and using a computer and software will enhance profit would seem to be doubtful, at least in the NZ case" (Nuthall, 2004).

Lynch and Gregor (2004) looked at how participation in the development of DSS influenced system outcomes, including the view of the system in terms of usefulness and ease of use. This was a qualitative, interpretive study that examined the development process of 38 DSS in the Australian agricultural industry. The method used was a three phase process. Firstly, pilot testing was done to determine the appropriateness of phone interview. Secondly, 38 individuals were interviewed about DSS of which 90 per cent were either developers or managers of the systems, and thirdly, two selected DSS were discussed with 23 farm user interviewees. Supplementing the interview transcriptions were secondary publications and reports on various DSS found in the literature review process which enabled triangulation of data sources.

In short, it was found that "degree of user influence" in the design process was an important component influencing the outcome of the system as measured in terms of system impact. System impact was gauged by interviewing (via phone) the developers and managers of each DSS to determined how many units of each DSS had been sold or registered as a proportion of the market, and by also taking into account other subjective factors that influence impact. For example, one DSS called 'WheatMan' impacted a wide group of farmers through the provision of information from their system, even though many of these farmers were not registered users.

The impact of each DSS was categorised as “high”, “medium”, “low”, “not clear”, or “too early” (Lynch & Gregor, 2004). These categories were considered alongside the “degree of influence” that users had over the system design, which was also determined via the phone interview with the DSS developers. The outcome of these results can be seen in Figure 19. This table and the supplementary findings suggest that a higher degree of influence will result in a high impact assessment, and a low degree of influence will result in low impact assessment (Lynch & Gregor, 2004).

Level of Impact	*Degree of influence users had over system design*							
	Strong influence	*Moderate to strong influence*	*Moderate influence*	*Weak to moderate influence*	*Weak influence*	*No influence*	*NA or Not Clear*	*n*
High	AVOMAN	CottonLO-GIC	Feedmania		FeedLotto		PAM	9
		Rainman	Herbiguide PYCal				ProfitProbe	
Medium		GrazeOn Weed-Watch	DSFM Proplus	AusVit	Herdecon	CamDairy LambAlive	BreedCow &Dynama[t3-fna] LCDP	14
			WheatMan			NPDecide	Zack TakeAway[t3-fna]	
Low					Beefin PastureMas-ter	Applethining Chickbug	BreedBull (alias)	11
					Sheepo WaterSched WeedMaster	DairyMaster Littermac MilkCool		
Not clear						How often		2
						How wet		
Too early		DairyPro	HotCross					2
N	1	5	7	1	7	10	7	38

[a]NA – not applicable – systems that were originally developed for personal use by an extension officer.

Figure 19 Degree of influence of users versus Level of Impact (Lynch & Gregor, 2004).

The final aspect of this study looked specifically at two DSS – AVOMAN and WheatMan, comparing and contrasting the two systems which have different levels of impact and degree of influence. Rather than interviewing developers, the researchers talked to 23 farm users who had purchased either system, in order to gauge their views on what the system is used for to compare with documented information, and to determine how involved the farm users are/were in influencing the system development. The collated results of these discussions supported the idea that the degree of influence on development is a more important factor than just participation by farmers in the development of DSS. Which was as the case in AVOMAN, compared to WheatMan (Lynch & Gregor, 2004).

One of the key findings of Lynch and Gregor (2004)'s research was the revelation that "system success" is extremely difficult to gauge (Lynch & Gregor, 2004). Myers (1994) attempted to define IS success as "when an IS is perceived to be successful by the stakeholders and other observers". Given these findings (Lynch & Gregor, 2004; Myers, 1994), it can only be concluded that IS success is entirely subjective, as measured by the users of IS, and the same can be said about gauging the impact of software (or ICT).

2.6 Summary of literature

This literature review provides theoretical and empirical evidence on agricultural IS, and the use and impact of software in these systems. In particular, literature presented on: IS in agriculture, attributes that influence software use and impact, drivers and inhibitors of ICT use and impact, and gauging the impact of ICT on agricultural IS, was used to craft the methodology, especially the guiding interview questions, and applied during data collection. All literature was considered in the subsequent discussion section where results from this study are compared and contrasted against it.

Chapter 3 Method

3.1 Introduction

The purpose of this research is to determine how NZ dairy farmers use agricultural software in feed and animal IS; what are the software attributes that influence the use and the impact of this software; and, what are the drivers and inhibitors of software use, and the impact of this software. This chapter describes the research methods used to collect and analyse information to answer this question.

3.2 Selection of research strategy

There are two main types of research strategies: quantitative and qualitative (Bryman & Bell, 2011). Simply, quantitative research emphasizes the collection and analysis of numerical research data, whilst qualitative research emphasizes words in the collection and analysis of data. The core differences between these strategies can be seen in Table 4.

Table 4 Fundamental difference between quantitative and qualitative research (Bryman & Bell, 2011).

Fundamental differences between quantitative and qualitative research strategies		
	Quantitative	Qualitative
Principal orientation to the role of theory in relation to research	Deductive; testing of theory	Inductive; generation of theory
Epistemological orientation	Natural science model, in particular positivism	Interpretivism
Ontological orientation	Objectivism	Constructionism

Quantitative research uses a deductive approach which tests theories through research. It uses a natural science model, primarily positivism which is the philosophy that states that every claim can be justified scientifically, logically or mathematically, and views social reality as an external and objective reality (Bryman & Bell, 2011).

In contrast, qualitative research principally uses an inductive approach which means that emphasis is placed on the generation of theories through research, rather than testing theory.

This qualitative research strategy rejects scientific norms, practices and positivism, rather it emphasises the ways in which individuals interpret their social world (Bryman & Bell, 2011). Qualitative research takes the view that social reality is a constantly shifting emergent property of an individual's creation, rather than the external and objective reality view taken in quantitative research (Bryman & Bell, 2011). Given the characteristics of these strategies, a qualitative research approach was used in this study.

In each type of research strategy, there is an appropriate research method which is the framework for the collection and analysis of data used to create new knowledge (Bryman & Bell, 2011; Gillham, 2000). These research strategies include experimental, cross-sectional, longitudinal, case study or comparative designs. A combination of both quantitative and qualitative strategies could be employed, known as mixed method research, which can be used to provide more complete and comprehensive findings (Bryman & Bell, 2011).

According to Yin (2014), there are three conditions to consider in deciding what research method to use. These are: 1) the form (or type) of research question, 2) the extent of control a researcher has over the actual behavioural event and 3) the degree of focus on contemporary events. These conditions are demonstrated in Figure 20 which shows a range of research strategies (methods) and their research characteristics (Yin, 2014).

The basic categories of questions are: "who", "what", "where", "how", and "why". "How" is the explanatory question used in the research questions in this study, which can be examined using case study, archival analysis, historic data analysis or experimental research methods (Yin, 2014). The participants in this study were not expected to operate in a controlled environment or event since the focus of the research was primarily on how agricultural software is used as part of feed and animal IS, and what the software attributes and, drivers and inhibitors are that influence the use and impact of this software.

Table VI Research strategies versus characteristics

Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival analysis	How, why	No	Yes/No
History	How, why	No	No
Case study	How, why	No	Yes

Figure 20 Research strategy versus research characteristics (Yin, 2014).

By adhering to the criteria described in Figure 20 (uncontrolled research with a focus on contemporary events/issues), experiment, history and archival analysis were ruled out as being suitable methods. This left survey and case studies as the most suitable options of research method; both methods were utilised for evidence collection.

The survey research method usually comprises a cross-sectional design, whereby data is collected using questionnaire or by structured interview on more than one individual at a single point in time. Data is collected, either qualitatively or quantitatively, and can be used in connection with two or more variables to examine patterns and association between them (Bryman & Bell, 2011).

However, the survey method is useful for collecting descriptive “personal factual” and “factual” questions, usually via a questionnaire. This method was used, in brief, to collect information on each farm or agricultural software business in the case studies.

Case study methodology was used as the primary research method in this study to understand dairy farm feed and animal IS, how and why these are used; the software attributes of agricultural software in use; and, the drivers and inhibitors that influence software use and impact. This method enabled the collection of in-depth evidence, of both feed and animal case studies that could not be captured in-depth using a survey technique.

Basically, case study research entails a detailed and intensive analysis of a case study data which is particularly useful in understanding the complexity and nature of the case (Bryman & Bell, 2011). This method was selected in order to gather detailed evidence and "illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what results" (Yin, 2014).

Case studies can be descriptive, explanatory or exploratory. These three types of case study are used to classify the purpose of the case study method: descriptive case studies look to describe a phenomenon in its real world context; explanatory case studies look to explain how or why some conditions came to be; and, exploratory case studies look to provide insights which can be used to develop future research question or procedures (Yin, 2014).

In this research, exploratory case studies, with descriptive and explanatory questions, were used to understand how and why questions relating to feed and animal IS (with a focus on agricultural software) used by farmers; and also to explore how and why questions relating to agricultural software provided by software providers. The results can be used to identify future research questions.

3.3 Case selection

A classic case involves an individual, group, community, institution, event or entity (Yin, 2014). Case studies have been done on decisions, programs, processes such as entities systems and organisational change. These are examples of cases that are less easily defined in terms of the boundary of the case (the beginning and end points) (Yin, 2014). All of these cases may be used as a singular case (Yin, 2014). It is however preferred practice to include multiple cases in an investigation, for analysis of the evidence and replication of design, and/or contrasting between the cases (Gillham, 2000; Yin, 2014). In this study, multiple case studies were used to capture data-analysis and contrast benefits.

In selecting the case studies, the research questions specify that this study is focussed on "feed and animal IS" (the unit of analysis), as well as indicating that NZ dairy farmers (the farm users) and agricultural software providers have both participated in this study. The selected IS case studies are the feed IS and animal IS used by the six participating NZ dairy farmers. These IS were selected because feed and animal management are fundamental parts of NZ dairy production systems and, these two areas of the farm management production generate a large amount of farm data and information which is used for decision making at every level of management (Hammond, 2015).

Agricultural software is also provided and used prominently in both feed and animal areas of production, and therefore all farm users were able to speak about their experience with agricultural software used in their feed and animal IS. Agricultural software providers were able to speak about their software offerings.

3.4 Participants

The participants interviewed in this study represented two groups - 1) NZ dairy farmers who use agricultural software; and 2) agricultural software providers (or developers) who developed the feed or animal software used by some of the case study farmers.

3.4.1 Farm user participants

Evidence was gathered from six different dairy farming businesses. These farmers were initially selected from a list of farmers known to use agricultural software for the management of their farms. Farmers were found from suggestions made by DairyNZ and Massey University staff, or, from farmers know to the researchers.

A pre-selection checklist (Appendix 1.1) was used to determine whether farmers were suitable for this study. The three critical requirements were (in this order):

1. The farm uses agricultural software in their feed and animal IS.
2. Their farming business was sufficiently different to the other farm user participants, in terms of size (herd numbers), staff numbers, production system (systems 1-5) and ownership structure, as gauged by the primary researcher. This diversity enabled the research questions to be explored from a range of farming contexts.
3. Lastly, the relevant farm representative was interested, capable and willing to participate in the study.

All farm user interviewee/s were knowledgeable of each field of management, and involved, in varying degrees, at the different levels of farm management including: operational, tactical and strategic management. This knowledge of each farm management level gave the interviewee/s the ability to speak confidently about their IS, the agricultural software components, the software attributes, and, drivers and inhibitors that influence its use and impact.

3.4.2 Agricultural software providers

Five different agricultural software providers were interviewed after all farmer interviews had occurred. Farm user evidence was used to select the software providers approached for interviews.

If at least two of six farm users identified they used a software as part of either their feed or animal IS, then this software was shortlisted. A select number of shortlisted providers, including a mixture of both feed and animal software and software for operational/tactical and strategic, were then contacted by telephone to request an interview. The most highly identified feed and animal software was chosen first, and then the next highly identified software followed, and so on.

In total, seven interviews were conducted – two interviews with Provider 1 for animal software; one interview with Provider 1 for feed software; one interview with Provider 2 for animal software; one interview with Provider 3 for feed software; one interview with Provider 4 for feed software; and, one interview with Provider 5 who did not directly provide software for dairy farming, but understood agricultural software development e.g. a software developer.

3.5 Data collection

For all interviews, case study evidence was gathered from three sources: 1) a pre interview questionnaire; 2) a 90 minute in-depth semi-structured face-to-face interview (using interview guiding questions), and 30 minutes of direct observation of the relevant software used; and, 3) following the farm/office visit, a second, unstructured follow-up interview to confirm information took place via phone call lasting for 5-10 minutes (if required). These sources provided the opportunity for data triangulation by corroborating data to improve research construct validity and by viewing/sourcing evidence from a number of different data collection sources (Yin, 2014).

The pre interview questionnaire and interview guiding questions (both farmer and software provider questions) were honed iteratively after pilot testing with one farmer and one software provider, and from research supervisor feedback.

1) Pre interview

Each participant was contacted via telephone to introduce the researcher, the research proposal and invite the relevant farm user/s, or software provider, to be involved if they met the pre-selection requirement. Once a participant had informally agreed to participate in this study, a one page questionnaire (see Appendix 1.2.1 – farmers and Appendix 1.3.1 – software providers) was sent via email. Information requested included personal and basic farm/business information. This understanding of the business enabled preparation for the interview, and reduced the interview time by collecting this information in advance. The questionnaire also attached the research definition of IS and agricultural software, and an explanation of the research. The questionnaire data was collected from each participant before commencement of the interview, and once each participant had signed the formal consent sheet.

Also included in the initial email was information clarifying what participation in the research entailed. An attached written participant consent form was also sent to explain the interviewee/s rights and obligations, and this was clarified in person and signed off before the first interview commenced. The time and place for the first interview was also confirmed in writing and the details of the interview process were provided to the interviewee.

2) Interview

At each interview, the researcher firstly ensured the participation consent sheet had been signed, particularly the agreement to participate, the right to record the interview, and any queries were answered. The primary researcher then provided details of their background and the reasons why they were doing the study and briefly discussed the background of the interviewee/s. Once underway, the researcher worked through the in-depth semi-structured interview questions, and then when appropriate (and if accessible), the researcher and interviewee/s observed agricultural software in use (the field observation).

The in-depth semi-structured interview was conducted face-to-face conversation with a set of base questions for guidance (see Appendix 1.2.2 – farmers and Appendix 1.3.2 – software providers). Rather than following a rigid set of closed questions, the questions were open-ended allowing for a semi-structure interview to capture the depth of evidence required for qualitative research (Yin, 2014). The questions were specific in relation to IS and agricultural software use, honed from themes identified in the literature review. This type of interview allowed for a large degree of leeway in participant response (Bryman & Bell, 2011). Furthermore, with the permission of the participants, the interview was recorded using an audio recorder, and supporting notes were also hand-written. This enabled accuracy during the data analysis (Yin, 2014).

The purpose of the field observation was to build on what each participant said during the interview process. This provided specific evidence through observation of study participants in their working environment. Visual observations of participants showing software in use helped to build on and expand evidence sourced in the interview (Gillham, 2000). Observations were noted and verbal feedback was recorded via audio recorder (Yin, 2014).

3) Post interview and follow up

The initial findings were transcribed verbatim from the recordings and written up and used as a reference to further discuss and clarify evidence in the second interview via telephone. Software provider transcriptions were also verified before being written up into results which was to done to verify accuracy of results and to ensure providers were willing for evidence to be published in a thesis.

3.6 Data analysis

Qualitative data analysis techniques were applied in this research in order convert the from raw data (evidence) to meaningful and useful content related to the research questions. The process used is same as that depicted in Yin (2015) (Figure 21). The first step in this process was to transcribe audio-recorded data into written transcriptions for each interview. These transcriptions were used as the 'database' of compiled raw data for the data analysis. Throughout the transcription write-ups, themes were highlighted and noted according to theory presented in literature and also any emerging ideas. Identification of themes was conducted in order to disassemble and interpret the data (Yin, 2015).

Once each transcription was completed, the formal process of description and classification of data began. Initial themes were identified from the questions and structure in the interview guiding questions which were developed to address the research questions. As more data was analysed, the initial themes were reviewed and other theme emerged. A combination of both Microsoft Word and Microsoft Excel were used to code and classify data according to them during the analysis process. Once the primary researcher was satisfied with the themes and considered data was fully captured within these, comparisons to literature and between both cases and groups in this study could be made (feed and animal IS; and, farmers and software providers) (Yin, 2015).

The qualitative data analysis process was applied to the three major sections of this study: the description of IS; the software attributes that influence use and impact; and, the drivers and inhibitors of software use and impact.

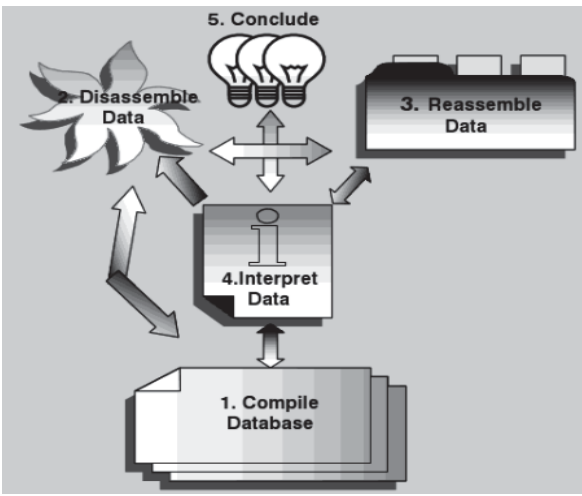


Figure 21 Five phases of analysis and their interactions (Yin, 2015).

3.7 Ethical considerations

This research involved in-depth data collection from six dairy farms, and five software providers. Ethical considerations were required for a number of reasons including: 1) to protect participants from any harm; 2) to get informed consent; to protect the participants (and their business's) privacy; 3) to eliminate the occurrence of participant deception (Bryman & Bell, 2011). Any data collected (evidence) and subsequent written reporting about the participants and their farming or business operations was made with these ethical considerations in mind.

Actions to ensure transparency of the research process included: 1) Application for a low-risk research notification to the Massey University Human Ethics committee; 2) Provision of formal documentation detailing research information, which was given to each participant prior to their agreement to participate; 3) Formal written consent was received from all participants prior to any data collection, which clearly identified each participants rights and obligations, and their agreement to participate; 4) Pseudonyms were used for every participant in reporting in order to preserve their anonymity and that of their farms or business.

The low-risk research notification email confirmation from the Massey University Human Ethics Committee was received, and can be supplied to interested parties upon request. The research information sheet and the formal consent form, for both farmers and software providers, are attached in Appendix 1.4 – farmers, and Appendix 1.5 – software providers.

3.8 Summary

Case study research was chosen as the appropriate method because it enabled the capture of detailed and comprehensive data which helps to understand how New Zealand dairy farmers use agricultural software in feed and animal information systems; what are the software attributes that influence the use and impact of the software; and, what are the drivers and inhibitors of software use and impact. Two case studies, with multiple groups of interviewees (6 farmers and 5 software providers), were conducted to enable comparison to be made.

Both sets of interviews were semi-structured and were supported by field observation and follow-up unstructured interviews. Qualitative data analysis techniques were applied to produce findings on the three main sections (the IS, the software attributes, and the drivers and inhibitors). Ethical considerations were kept at the forefront on this study and a multifaceted approach was used to protect and inform participants.

Chapter 4 Results

4.1 Introduction

The results section starts with a description of farmers interviewed in this study, and identification of the feed and animal IS case studies as described by these farmers. Following this, farmer results are presented on the following sections: ‘software attributes that influence the use and impact of feed and/or animal software’, ‘desirable software improvements categorised by attribute’, ‘drivers and inhibitors of software use and impact’, and ‘the impact of feed and animal software use’. After the farmer results, software provider results are presented using the same sections (excluding the desirable software improvements section, which was a farmer only section).

4.2 Description of the farmers

Six dairy farming businesses were investigated in this research, representing a range of sizes (herd numbers and effective hectares), staff numbers and roles, production systems (systems 1-5) and ownership structures. All of these businesses were operating solely as dairy farms. See Table 5 for an overview of these farming operations.

By investigating a diverse range of dairy farming businesses, this research is able to compare and contrast a range of similar and different feed and animal IS.

Table 5 Farmer interviewee overview.

Farm name	Ownership structure and role	Herd size (average)	Effective hectares (ha) on the milking platform	Production system	Staff numbers and roles
Farmer 1 (or Farm 1)	50:50 sharemilking. *Interviewees* - sharemilkers – husband and wife	320	90	System 3	2.5 full-time; 1x Farm Manager; 1x 2IC; and, 1x part-time administration
Farmer 2 (or Farm 2)	50:50 sharemilking. *Interviewees* - sharemilkers – husband and wife	425	160	System 3	2.5 full-time – 1x Farm manager; 1x 2IC; and, 1x part-time/calf rearer

Farmer 3 (or Farm 3)	Equity partnership. 50:50 sharemilkers run the business. *Interviewee* – owning partner/farm manager	1300	550	System 3	~9-10 full-time; including, 1 x Farm Manager; 1x Assistant Manager; 2x Shed Managers; 1x Machinery Operator; 1x Calf Rearer; ~2x Farm Assistants; and, relief milkers
Farmer 4 (or Farm 4)	Owner-operators – husband and wife. *Interviewee* - Husband (farm manager)	370	151	System 3/4	3 full-time – 1x Farm Manager; 1x Herd Manager; 1x relief milker; and, 1x part-time/calf rearer
Farmer 5 (or Farm 5)	Family company. *Interviewee* – husband (operations manager)	530	220	System 2	4 full-time – 1x Operations manager; 1x Herd Manager; 1x Assistant Herd Manager; and, 1x Farm Assistant
Farmer 6 (or Farm 6)	Corporate farm – ‘Complex’ owned by the government. *Interviewees* – Business analyst and Farm Technician.	Range between 220-850 (across 8 farms)	1400 across 8 farms (farms range from 65-290ha)	System 3-4	30 full-time staff across 8 farms – including, 8x Farm managers; 1x Business Manager; 1x Business Analyst; 1x Farm Technician; and support staff. Also, casual/relief staff

In terms of software used by each farmer, every business was unique. The software used by these farmers included the following feed and animal software seen in Table 6. Further information on the farmers use and impact of software can be seen in Appendix 2.0.

Table 6 Farmer software use.

Farmer name	Animal management software used (including websites)	Feed management software used (including websites)	Farm modelling software (for both feed and animal management)
Farmer 1	• LIC's MINDApro (desktop software) • LIC's MINDA app (Calving, Mating and Look-Up features) • Fonterra's Farm Source website • Fonterra's Farmsource app • LIC's MINDA Weights (part of MINDA Live online software)	• LIC's MINDA Land and Feed (part of MINDA Live online software) • LIC's MINDA app (Pasture feature) • DairyNZ Spring Rotation Planner (online content) • Harvest Electronics website and Greater Wellington District Council website	N/A
Farmer 2	• LIC's MINDApro (desktop software) • LIC's MINDA app (Look up feature) • LIC's Datamate app (used by LIC A.I technician) • DairyNZ 'Bull Team Builder' online content • DairyNZ BCS app • Open Country website	• Own Microsoft Excel spreadsheets • FMG Rural Weather app	N/A
Farmer 3	• LIC's MINDApro (desktop software) • LIC's Protrack Vector (in-shed software) • LIC's MINDA app (Health feature) • LIC's Datamate app (used by LIC A.I technician) • Fonterra's Farm Source website • Fonterra's Farmsource app • Open Country website	• Own Microsoft Excel spreadsheets • FarmKeeper (desktop software) • Pasture Coach (desktop software) • Ag Hub - Paddock Diary (online software) • Sentek information (accessed online via smartphone) • Horizons Council website	N/A

		• Weather app	
Farmer 4	• DeLaval Alpro (in-shed desktop software) • CRV Insight-Web (online software) • CRV Insight-Mobile app • CRV's Portabull app (used by CRV A.I technician) • Fonterra's Farm Source website • Fonterra’s Farmsource app • Own Microsoft Excel spreadsheets	• Own Microsoft Excel spreadsheets • FarmKeeper (desktop software) • Farmax Pasture Growth Forecaster website • MyRavensdown and Smartmaps website	N/A
Farmer 5	• Jantec software (in-shed desktop software, including cups on terminal) • NAIT website	• LIC's MINDA Land and Feed (part of MINDA Live online software) • LIC’s MINDA app (Pasture feature) • TracMap website • Zoho app, used to create own feed calculator	• UDDER (desktop software)
Farmer 6	• Tru-Test's MiHub (in-shed desktop software that synchronises with online software) • LIC's MINDApro (desktop software) • LIC’s MINDA Live (online software) • LIC’s MINDA app (Look-up and Calving features) • LIC's Datamate app (used by LIC A.I technician) • FarmIQ (online software) • Fonterra's Farm Source website • Fonterra’s Farmsource app	• Farmax Professional (desktop software) • FarmIQ (online software) • Pasture Coach (desktop software) • 'DPR' (Farmer 6’s own benchmarking software) • LIC’s MINDA Land and Feed (part of MINDA Live online software) • LIC’s MINDA app (Pasture feature)	• OVERSEER (online or desktop software) • Farmax Professional (desktop software) • UDDER (desktop software)

4.3 Case 1 and Case 2 Feed and animal information systems

As stated in the method, the cases in this research are (1) feed IS and (2) animal IS. The six participating dairy farms provided evidence used to firstly, identify these IS, and secondly, to explore the software used as part of each case.

4.3.1 Feed and animal information systems and software use

Feed and animal software is used in feed and animal IS (Hammond, 2015). These IS provide valuable information for farm management decision making and also for compliance purposes (Hammond, 2015).

To illustrate how and why (for what purpose) agricultural software is used, models of feed and animal information sub-systems have been created from evidence provided by the six dairy farming businesses which can be seen in Appendix 3.0 (feed information sub-systems) and Appendix 4.0 (animal information sub-systems).

The sub-systems (identified in the following pages) together form the wider generic feed and animal IS. These sub-systems have been categorised according to their primary purpose of providing data and information for feed and animal management decision making, and for compliance (if applicable). The sub-systems were categorised in a similar way to that used in Hammond (2015). Each farm uses these IS throughout the production year in order to make the following feed and animal decisions, or meet compliance requirements.

Case 1 - Feed decision making sub-systems

- Purchasing supplementary feed decisions (Appendix 3.1);
- Paddock rotation decisions (Appendix 3.2);
- Feed allocation decisions (Appendix 3.3);
- Fertiliser application decisions (Appendix 3.4);
- Paddock regrassing or renovation, and/or crop planting decisions (Appendix 3.5);
- Strategic management decisions (Appendix 3.6);
- And, Irrigation (if applicable) decisions (Appendix 3.7).

4.3.1.1 Case 1 Example – Feed allocation sub-system

This sub-system depicted below in Figure 22 is the system used to make feed allocation decisions daily. The diagram identifies what output information is required to make this decision, and what input data is processed into useful information, as well as the frequency of data/information requirements or collection. Appendix 3.8 details the complete feed IS including - input data, output information, tool, frequency and sub-system use.

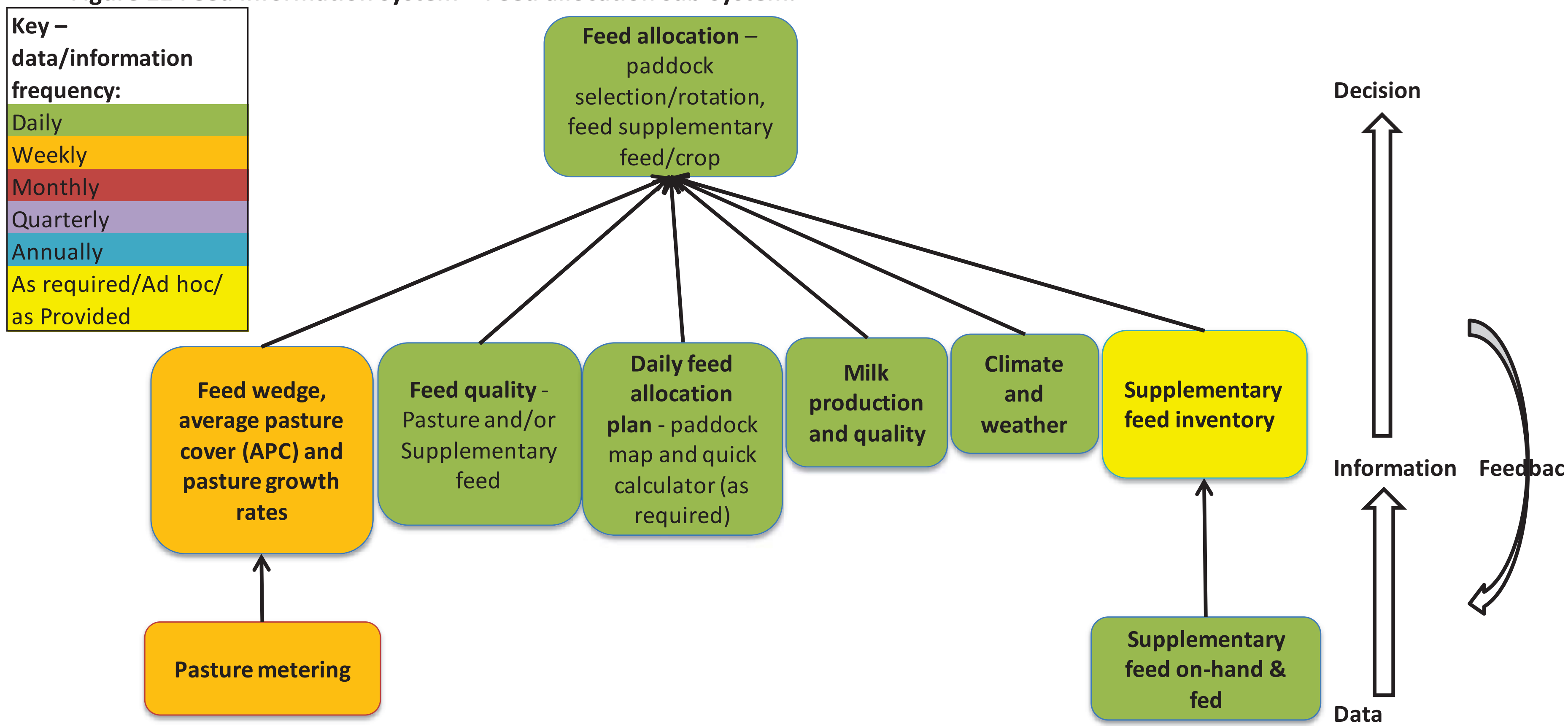
With regard to software use in this particular system, Table 7 shows where software is used (input data and/or output information), and the various software options that were mentioned by interviewed farmers.

Table 7 Software use (and options) in the feed allocation sub-system.

Information output	Software use – including various options mentioned by farm interviewees
Daily feed allocation plan - paddock map and quick calculator (as required)	• Microsoft Excel • Online spreadsheet app • Google maps • TracMap online
Milk production and quality	• Milk processor website and app (if available) (Fonterra and Open Country)
Climate and weather	• Online information from weather station • Weather app • Online weather websites.
Irrigation water access (as required)	• Online council website
Optional - Soil moisture and soil temperature (could also include - evaporation, air temperature, humidity, rainfall, wind speed and water-flow information)	• Website - access using user login on smartphone
Feed wedge, average pasture cover (APC) and pasture growth rates	• LIC's MINDA Land and Feed • LIC's MINDA app (Pasture feature) • Pasture Coach • Microsoft Excel • FarmKeeper
Paddock rotation plan and length	• DairyNZ's Spring Rotation Planner online
Seasonal feed budget (created annually, adjusted as required) - cow numbers, supplementary feed, cropping/pasture renewal, silage making and fertiliser use	• Microsoft Excel • Farmax Professional • UDDER Farmax and UDDER may be operated by a consultant, for the farmer.

Paddock performance –pugging and plant health, and tonnage of DM grown	• Pasture Coach • FarmKeeper + Microsoft Excel
Collated paddock records - fertiliser applied, effluent applied, spraying, seeds planted, cultivation and other	• AgHub; • LIC's MINDA Land and Feed • FarmIQ
Supplementary feed inventory	• LIC's MINDA Land and Feed • UDDER • Farmax Professional • Microsoft Excel Farmax and UDDER may be operated by a consultant, for the farmer.
Detailed fertiliser application	• TracMap website

Figure 22 Feed information system – Feed allocation sub-system.



When compared to the breeding sub-systems, the feed allocation sub-system has less prominence of the key software, therefore, more variety of software, as well as no software used for recording or collecting data. However, of the software that was identified, LIC's MINDA Land and Feed, FarmKeeper (owned by LIC), Pasture Coach, UDDER and Farmax were the most highly used software by this group of six farmers. Also of note was that Microsoft Excel was used widely, particularly for daily feed allocation planning information; feed wedge, average pasture cover (APC) and pasture growth rates information; feed budgeting information; paddock performance information; and, supplementary feed inventory information. This software gives farmers the ability to create their own spreadsheets according to how they see fit.

Case 2 - Animal decision making and compliance sub-systems

- Breeding, culling, drying off and animal movement decisions (Appendix 4.1);
- Animal health decisions (Appendix 4.2);
- Purchase/sell livestock decisions (Appendix 4.3);
- Strategic management decisions (Appendix 4.4);
- And, Compliance – NAIT (National Animal Identification and Tracing) (Appendix 4.5).

4.3.1.2 Case 2 Example – Breeding, culling, drying off and animal movement sub-system

This sub-system, depicted below in Figure 23, is the system used to make breeding, culling, drying off and animal movement decisions on an 'as required' basis, meaning that they could occur daily, or not at all. The diagram identifies what output information is required to make these decisions, and what input data is processed into useful information, as well as the frequency of data/information requirements or collection. Appendix 4.6 details the complete animal IS including - input data, output information, tool, frequency and sub-system use.

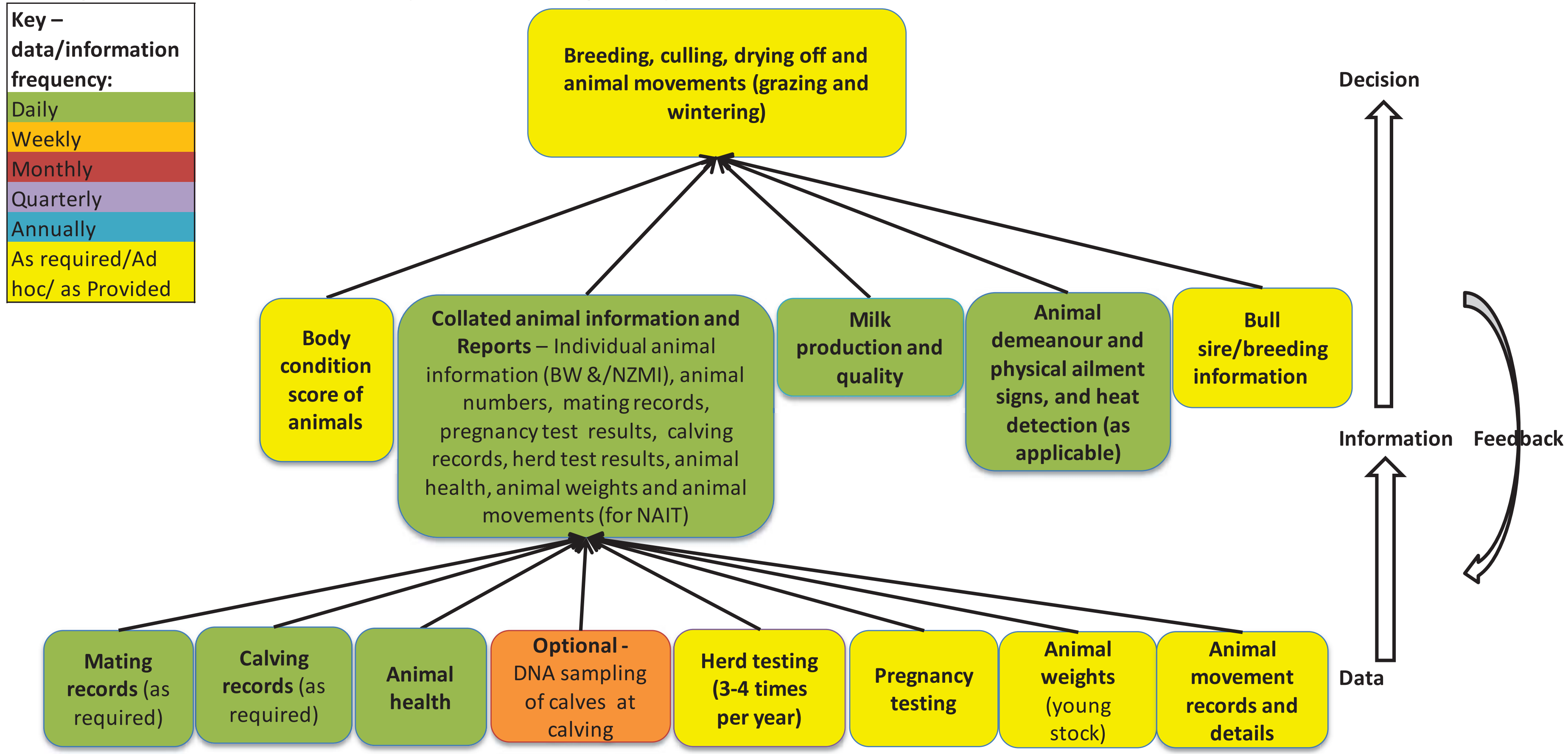
With regard to software use in this particular system, Table 8 shows where software is used (input data and/or output information), and the various software options that were mentioned by interviewed farmers.

Table 8 Software use (and options) in the breeding, culling, drying off and animal movement sub-system.

Input data	**Software use – including various options mentioned by farm interviewees**
Mating records	• LIC's Datamate app • CRV's Portabull app Both used by artificial insemination technicians (service providers)
Calving records	• LIC’s MINDA app (Calving feature)
Animal health - treatments	• LIC’s MINDA app (Health feature) • CRV Insight - Mobile
Information output	**Software use – including various options mentioned by farm interviewees**
Collated animal information and Reports – Individual animal information (BW &/NZMI), animal numbers, mating records, pregnancy test results, calving records, herd test results, animal health, animal weights and animal movements (for NAIT)	• LIC’s MINDApro and/or MINDALive • LIC’s MINDA app • CRV Insight – Web • CRV Insight - Mobile • Jantec (limited features). • Tru-Test MiHub • DeLaval Alpro (for health and weights)
Milk production and quality	• Milk processor website and app (if available) (Fonterra and Open Country)
Seller's animal condition and animal records (LIC's MINDA and CRV's Insight)	• LIC’s MINDA animal records • CRV animal records

Both LIC and CRV Ambreed software is used prominently in this animal sub-system, for both data collection purposes, as well as collating (and processing) information. For example, either MINDApro (or MINDA Live) or CRV Insight-Web play important roles in this system (and the other animal information sub-systems) for bringing together eight different sources of data, which includes data farmers have collected themselves (either formally or informally), and data that was collected by external providers, such as the A.I technician and vets. Smartphone apps were also highly used, particularly for data recording, and to a lesser extent accessing information.

Figure 23 Animal information system - Breeding sub-system



4.4 Software attributes that influence the use and impact of feed and/or animal management software - farmers

The software attributes section refers to features of software and software provision that influence the use and the impact of feed and/or animal management software. The attributes have been identified and described in Table 9. Evidence and examples of each attributes are then explained with reference to farmers software use. Following this section, desirable improvements of software are presented, which have been categorised according to attribute.

Table 9 Attributes of software and software provision that influence the use and impact of software – farmers.

Attributes	Description (as interpreted from farmer results)
Simplicity (or simple)	Software is 'easy to use' (easy to navigate), intuitive (has logical step processes), is 'user friendly' (easy to understand or interpret) and displays data/information in an appropriate way and/or appropriate language
Value proposition and software fit	Software addresses the problem or need of farm users, and fits well in IS
Accessibility, permissions and sharing	Data and information on software is readily accessible for decision making anywhere, anytime. It can also be easily accessed by, and shared with, others
Integration with hardware and software	Data and information from one software (or hardware) can be exchanged seamlessly with other software
Support and training, feedback and development	Services provided by software providers, or someone else, to help farm users to use software effectively, and to ensure software is developed and upgraded considering farmers feedback

Reliability, accuracy and speed of software	Software can be relied on to provide up-to-date, timely and secure data and information that is sufficiently accurate, and quick to acquire

4.4.1 Simplicity (or simple)

Simple software was highly desired by all six farmers. It was evident that simplicity of software was linked to navigation, step processes, ease of understanding or interpretation, and display of data/information. These aspects play a critical role in ensuring that software was simple, and therefore, easy to use, intuitive, user friendly and display data and information in an appropriate way/language.

FarmKeeper software was identified as software that exemplifies simplicity for a number of farmers (Farmer 2; Farmer 4; Farmer 5). It was easy to use, had good step-process and provided useful, easy to interpret information in the form of a feed wedge (Farmer 4; Farmer 5).

Software that was not as simple were often discarded (when possible), this was the case for PasturePlus for Farm 2, "the interface and the mapping system is hard to use, making it difficult to change paddock boundaries" (Farmer 2).

Furthermore, for information outputs specifically, reports were not always in the most appropriate language or unit that farmers wanted, therefore making the software outputs less simple to interpret and use. This was the case for certain animal reports and also the processing of feed wedge information. For example, most farmers wanted their feed wedges in management blocks, not whole farm feed wedges, as they commonly were provided (Farmer 3; Farmer 5; Farmer 6).

4.4.2 Value proposition and software fit

It was evident that a small number of software, used by interviewed farmers, meets their requirements very well. In contrast, a large number of software was either partly addressing their requirements, or not fulfilling their requirements at all. For example, both LIC's and CRV's software for animal management met the majority of the needs of the five interviewed farmers who used either software. Furthermore, these software fit well in farmer IS by collating together a wide number of animal data sources (see Appendix 4.0 for examples of this).

On the contrary, many commercially provided software for feed management did not fit well in existing IS. This is demonstrated by the fact that the number of commercially provided software used by farmers ranged from 1 (Farmer 2) up to 5 (Farmer 6), with most farms using between 2-3 different software for feed management purposes. Additionally, four farmers chose to develop their own spreadsheets for feed management purposes, as alternative to commercial products, or if something was missing from commercial feed software (Farmer 1; Farmer 2; Farmer 3; Farmer 4).

4.4.3 Accessibility, permissions and sharing

Smartphone apps and cloud-based software enhanced accessibility of data collection and information access for all six interviewed farmers, allowing for 'third party' access, and sharing of data or information. Apps and cloud-based software were highly desired by all six farmers largely because they often had time in there day where they could be entering data or accessing information when they were physically on the farm, and not in the office. Apps and cloud-based software was used most commonly for accessing milk production (both apps and cloud-based software used by every farmer), inputting pasture records (apps and/or cloud-based software - four farmers), inputting animal health records (apps and/or cloud-based software - three farmers) and reviewing feed and/or animal information (cloud-based software – five farmers).

The ability to permission third party user access was also used prominently by five of six farmers across a range of feed and animal software (Farmer 1; Farmer 3; Farmer 4; Farmer 5; Farmer 6).

4.4.4 Integration with hardware and software

It was identified that specific relationships between different software providers to enable seamless exchange of data/information improved farm users' use of software by all farmers. For example, MiHub and MINDA (software to software), and C-Dax pasture meter and FarmKeeper (hardware to software) are examples of software and hardware that allow for seamless exchange of data and information. These types of integrations were highly desired by all farmers, especially to reduce double entry of data; this issue was a particular problem for the largest farm, Farm 6, which has many staff and many different software in use, which would compound the issue of double entry of data and information.

4.4.5 Support and training, feedback and development

A range of support and training services were identified. For support this included -phone and email support, software 'help' features, remote access and face – face (via farm visits). Some level of training was provided via the support services but many farmers have also attended software training events/days. Support and training opportunities were also used to provide feedback, which complemented ad hoc farm feedback requests (surveys etc.), and software development trials (Farmer 2; Farmer 3; Farmer 4; Farmer 6).

LIC's training and support was recognised positively by all interviewed farm users. This included a highly recognised 0800 number that provided support and opportunities for farmers to provide feedback (Farmer 1; Farmer 2; Farmer 3).

For development and upgrades, MINDA software (for herd management) was also recognised as software that was regularly updated (Farmer 6). Software that wasn't updated frequently, according to farmer feedback, or not updated at all, was perceived badly by all farmers.

4.4.6 Reliability, accuracy and speed of software

To ensure reliability and accuracy of software outputs for feed management, four farmers used their own Microsoft Excel spreadsheets. They choose to create these because the spreadsheets were sufficiently reliable and accurate enough for their operation because they created them, and because alternative commercially provided software did not exist (in their eyes) (Farmer 1; Farmer 2; Farmer 3; Farmer 4). Excel did not however allow for quick access to data and information because it does not integrate seamlessly with hardware or software (Farmer 4). This means double handling of information, and a missed opportunity to use 'batch' entry and accessibility benefits of commercially provided software alternatives.

For accuracy of commercial software, every farmer was careful in allowing staff to input data or information directly into software, often they would avoid allowing staff to input important records, instead doing it themselves (Farmer 1; Farmer 3). Perceived accuracy of modelling software was mixed. Two farmers used these widely and were happy with the accuracy of the outputs (Farmer 5; Farmer 6), whilst two others were sceptical of their accuracy because of the knowledge of the consultants that use them (Farmer 4), or the fact that farming conditions change quickly and therefore render the model inaccurate (Farmer 3).

4.5 Desirable improvements categorised by attribute

4.5.1 Simplicity (or simple)

- More graphical software interfaces, and more customisation abilities (of information display on software and apps) – Both useful for improving the simplicity of software (Farmer 2; Farmer 4). For example, MINDA Land and Feed farm map could be changed to an actual farm map (using GPS coordinates), rather than just a photo. This could be used to measure distances of paddocks and breaks (for feeding) (Farmer 5).
- “Networked farm” – a map of the farm that shows information from hardware situated all around the farm, including data from the dairy shed (vat temperature), fences, water system and other things that are being measured, a "kind of virtualisation of the farm, using a map" (Farmer 5). Taking hardware that is used for measurement at the dairy shed and applying that across the farm (Farmer 5).

4.5.2 Value proposition and software fit

- “Bolt-on modular systems” - Software that is able to be upgraded with additional features or functions as farm users learn to use it effectively (Farmer 4).
- Try before you buy software – Greater use of trialling software before investment of time and money. This would enhance farmers’ abilities to choose software that best meets their needs and fits with their IS (Farmer 1; Farmer 4).
- Cost structure – A one-off payment is more preferable than a monthly, 12 month commitment (Farmer 2).
- Improvement in feed software offerings -
    - Feed management software like MINDA Land and Feed, and FarmKeeper should be able to break the farm into individual management blocks, so you can view feed wedge information (APC and growth rates) separately, rather than just whole farm information (Farmer 3; Farmer 5). This would reduce work for farmers who currently have to pull those number out manually (Farmer 5), or use an alternative software for this specific purpose (e.g. Pasture Coach) (Farmer 3).
    - Farmer 3 wanted something that brings a wide range of feed data sources together, including feed budgeting, weather and projected pasture growth rates (Farmer 3).

- Farmer 5 believed a combination of FarmKeeper, MINDA Land and Feed and TracMap (specifically for its mapping, fertiliser ordering and spraying features) would make for an improved feed and paddock management software (Farmer 5).
- Whilst Farmer 4 is after a cloud-based software, that covers all of the features of his Excel spreadsheets (daily allocation plans, tactical and strategic feed budgets) and includes a farm map that can be used to plan and record break feeding, "it records where the cows have been so all of that is recorded, then you could link that to milk production and it would be quite seamless". This could use a similar temporary fence feature that was previously in FarmKeeper (Farmer 4).

- Improvement in animal software offerings –
  - For CRV Insight-Web, Farmer 4 is wanting improved animal weights features, like what MINDA Weights does with the ability to track animal weight, relative to genetic potential of that animal (Farmer 4).

4.5.3 Accessibility, permissions and sharing

- Greater use of smartphone apps for wider information access and more functions (Farmer 2; Farmer 4; Farmer 5).
  - Apps should be used more to access information that farmers currently have, but is currently isolated to a desktop or cloud software (e.g. from MINDA Live onto the MINDA app) (Farmer 2). For example, Farmer 1 wanted the ability to pull up daily information on which cows are ready to enter the milking mob, from the colostrum mob at calving, from his smartphone app (Farmer 1).
  - Specifically, Farmer 4 was looking for apps to perform somatic cell count readings, or, for recording and monitoring milk with-holding period information (Farmer 4).
  - More complete apps, not more - Farmer 1 does not want individual apps for everything function of farm management, he would rather a smaller number of more complete apps (Farmer 1).

4.5.4 Integration with hardware and software

- One integrated online software – This solution would bring together animal, feed, milk production and other data and information in one online place automatically (Farmer 1; Farmer 2; Farmer 3; Farmer 4; Farmer 6). This will help avoid the need for synchronisation, which delays access to farm information (Farmer 1) and avoid double entry of data or information (Farmer 6).

- Software and ICT hardware providers should have their software like the "Windows model" – Farmers would be able to have a range of different branded hardware or software linked together (Farmer 5). This could be fixated around a cowshed or farm house Wi-Fi network, that brings together data from hardware around the farm. For example, "I am at the point I want to be able to shop around, find the best herd recording software that I can just download into my cowshed computer, which can then talk to all the hardware I already have in place" (Farmer 5).

4.5.5 Support and training, feedback and development

- Newly released software is ready for immediate use and not full of bugs or problems - Software needs to be set-up well prior to release, if not, it must be clear it is a trial version, otherwise farmers will discard it if it does not work first time, or they will require a significant amount of support (Farmer 1; Farmer 4).
- Training requirements of software and training opportunities must align with the potential value that it will provide to the farmer – For instance, for a complex software, requiring a substantial amount of farm user training, the benefits of using the software must be highly valued (Farmer 1).
- Farmer and farm staff skillset and knowledge in relation to feed management on dairy farms needs to be improved. "A lot people record pasture data for so long and then figure out they are not actually using it to make decisions" (Farmer 4), therefore improvement in support and training to interpret pasture information would help farmers make better use of their software, and ultimately their feed.

4.6 Drivers and inhibitors of software use and impact - farmers

The drivers and inhibitors section refers to the following issues evident on-farm and in the wider dairy industry which have an influence (both positive and negative) on the use and impact of software. The drivers/inhibitors have been identified and explained in Table 10. Evidence and examples under each driver/inhibitor are then presented and explained.

Table 10 Drivers and inhibitors of software use and impact – farmers.

Driver/inhibitor	Description (as interpreted from farmer results)
Internal and external motivation (including compliance)	Entities, business units or people inside and outside of the farm that discourage or encourage the use of software
User preferences (and motivation), skillset, knowledge and role	Farm owners, managers and farm staff preferences toward using software or informal means; skillset and knowledge in relation to ICT and/or informal farm skills and knowledge; and, farm users role on the farm. These farm user traits all have a collective influence of the use of software as part of farm IS
Credibility and trust of software providers	Farm user's confidence that software provided to them from recognised providers will add value to their business by improving their IS
Technology infrastructure and supporting hardware	Technology and hardware that supports the successful use of software for agriculture
Industry collaboration and competition	Industry initiatives that influence the level of software integration in agriculture, and competition between different software providers

Farm scale	The size (the number and size of individual farms) of the farming business has an influence of software use
Seasonality	Seasonal changes (due to climate and weather) and planned farming activities both have an influence on the software used by farmers because they influence the data and information required and available for decision making and compliance

4.6.1 Internal and external motivation (including compliance)

Internally (inside the farm business), farm users were motivated or demotivated to use software by a number of people – including farm staff, the farm owners and/or trustees, family and upper management (in the case of large or corporate farms).

Internal motivators either enable or inhibit use of software, as explained by Farmer 5, "each step down the line has to be into it, you can't have the juniors really keen to use it, the herd manager that is not and the farm manager that is. You could have a farm owner that is totally disinterested in it, but a farm manager who is interested and staff that are, then that would work with some of the phone apps and the little stuff. But big picture stuff, like the in-shed hardware and software, the farm owner will just not invest" (Farmer 5).

Furthermore, corporate farms or other non-owner-operator ownership structures (sharemilking, equity partnership) are more likely to have an additional issue whereby upper management, equity partners or owners require the farm management team to use software, so they can get access certain reports, even when the farm management team do not see any value in using the software (Farmer 2; Farmer 6). This has resulted in low motivation to use software on Farm 6.

Externally (outside the farm business), one major motivator for using software was from regulators, for the purpose of meeting compliance requirements. This may come from entities such as Regional Councils. On the contrary, Q Conz (quality assurance) encouraged one farmer to use paper-based reporting (the Dairy Diary) because they were not satisfied with the software recorded alternative (DeLaval Alpro) for managing withholding periods (Farmer 4).

Another major motivator came from processors (e.g. Fonterra) and from input suppliers (LIC or CRV Ambreed for genetics and Ravensdown or Ballance fertiliser). These businesses encourage farmers to use greater amount ICT (Farmer 3).

Other external entities that influenced farmers use of software included consultants (farm system experts and agronomists) (Farmer 5; Farmer 6).

4.6.2 User preferences (and motivation), skillset, knowledge and role

This factor has a large influence on the likelihood that software will be used successfully on any given farm, principally because people working on farms play such an essential role in existing IS (Farmer 5; Farmer 6). For instance, every interviewee saw value in the use of software, however the actual range of software (and ICT hardware) in place, on any of the operations, was heavily influenced by the motivation and capabilities of on-farm staff to physically use the technology in a way that satisfies the farm manager (or superiors) desires or needs.

In the case of Farmer 1 and Farmer 3, they would choose to limit the use of apps by staff (for recording certain activities) simply because they did not want to risk them recording incorrectly, and therefore wasting time (Farmer 1; Farmer 3).

In contrast, Farm 4 and 5, required farm staff to use software more often because it was such an integral part of their IS for feed and animals (partly because they had in-shed dairy hardware for recording).

Farm 6, the corporate farming operation, with a wide range of ICT and software, left a lot of the choice up to the eight individual farm managers that worked for this business. Minimum levels of software use was required, but not always enforced, with the slack being taken up by the farm technician and business analyst.

For example, Farmer 6, stated that 70 per cent of their farm managers would say that their software is too complex, and therefore they struggle to use it. On the other hand, staff in charge of managing software specifically (the farm technician and business analyst) were happy with the complexity of their software, partly because it is part of their role and also because they have the skills and knowledge to use the software. This shows how farm user skillset, knowledge and role have an influence on farm user's perception and subsequent use of software.

4.6.3 Credibility and trust of software providers

Recognised farming businesses, brands and other farmers were identified as credible and trusted software providers. LIC (and LIC's MINDA) and Fonterra were two examples of businesses that have developed farmer trust, by being around for a significant amount of time (Farmer 3). Therefore, software coming from these companies is more likely to be adopted and used.

Farmers would also talk to other farmers regularly via social media and verbal conversation. This would help farmers make decisions on which software (if any) to use (Farmer 2).

4.6.4 Technology infrastructure and supporting hardware

A lack of internet and mobile coverage was identified by all farmers as a major potential limitation to the use of software, particularly restricting for smartphone apps and cloud-based software. For instance, "the first key point is cellphone coverage, if you haven't got cell coverage, or at least internet connection, nothing else is possible" (Farmer 5).

Hardware was also important, the C-Dax tow-behind pasture meter used by three farmers only integrates with certain software, and therefore this encouraged farmers to use that software, especially because feed management was heavily driven from pasture metering (Farmer 4).

4.6.5 Industry collaboration and competition

All six farmers mentioned the fact that industry collaborations and/or competition have an influence on software use by farmers. Collaborations to create improved data and information integrations and sharing were viewed positively, yet a number farmers believed competition amongst providers (particularly large providers like LIC) was restrictive to future data sharing and integration of software (Farmer 3; Farmer 5). "What I find frustrating at the moment is that there are companies lining each other up, some are working with some and others with others. I do not think there will ever be one software that will cover everything on farm so there needs to be cooperation and there needs to be data sharing" (Farmer 3). Furthermore, market leaders like LIC are somewhat restrictive in the adoption and use of best innovations for dairy farming (Farmer 4; Farmer 5), but because they dominant the market farmers inclined to use their offerings, even though it may not be the optimal software (Farmer 5).

4.6.6 Farm scale

The scale of a farming business, or business unit, has a large influence on the software used by farm managers and their team, this was evident on all six farms. The general consensus was that as scale increases so too does the use of software and ICT, in order to manage large amounts data and information (Farmer 3; Farmer 6), and also distance between farms (Farmer 1).

This does not mean that increased relative scale cannot be managed without the use of 'more' software. This evident on Farm 3 which uses less software than smaller operations such as Farm 4 (see Appendix 2.3 and 2.4). However, it is more likely that large scale farms will use software in their feed and animal IS.

A good example of this was Farm 6, their "small farms", anything with ~200 cows or less would not have in-shed hardware and software for data collection or recording. Whereas, on "big farms", ~200+ cows, they had Tru-Test MiHub software and in-shed hardware (includes individual animal ID, milkmeters and somatic cell count) installed at their shed. This extra technology, used primarily due to size/scale, meant that these big farms could use MiHub software for animal management, alongside MINDA which was also used the by smaller farms.

4.6.7 Seasonality

The seasonal nature of NZ agricultural has an influence on the use of software according to three of the six interviewed farmers (Farmer 1; Farmer 2; Farmer 3). Furthermore, all six farmers implicitly identified that software use would be influenced by the time of the year, and therefore the planned operations.

For example, calving time is the most likely time that a farm user would use software for recording calved cows and progeny records. Other than this period of three-four months, software that is useful for this purpose wasn't used, and therefore if the software is a standalone app or software it may not be used for many months (Farmer 1). The same could be said about animal health apps, which were only used for young stock health recording at key times in the year (Farmer 3), and pasture recording software which is used far less frequently during winter because of the seasonally low pasture growth (Farmer 1; Farmer 3; Farmer 4). The weather, climate and biological factors influence the timing and length of software use (Farmer 3).

4.7 The impact of feed and animal software - farmers

The six farmers interviewed for this research all recognised, and valued, the impact of using agricultural software components of their feed and animal IS, as evident from the IS presented above. The IS did not, however, detail what was the most valued impact of software in use. Therefore, the following quotes, provided by farmers, explain the primary impact of agricultural software.

Farmer 1 emphasised the planning, control and feedback impact of using software. “It is the power of knowing. It is knowing where you are heading. It enables you to plan, and to look back at what you have done in order to learn” (Farmer 1). For feed software, the most valuable piece of information is the feed wedge, used for both planning and control purposes, which he gets from MINDA Land and Feed. “We could not do it without a feed wedge. So we pay to get that” (Farmer 1). This demonstrates that this farmer, in general, recognises the impact of software on his business; and specifically, the feed wedge information proponent of MINDA Land and Feed fits his IS.

Farmer 2 stated that without MINDA software (used for animal management), “it would all just be on paper, so you wouldn’t be able to make an accurate decision. It would be subjective” (Farmer 2). Furthermore, making the “best” decisions by using software generated reports in relation to their cows was particularly important because this represents wealth and future earning potential as herd-owning sharemilkers (Farmer 2). Therefore, this farmer highly value the impact software has on improving his accessibility to farm data and information, which enable him to make accurate decisions. Furthermore, he highly values the impact of herd management software’s (in this case MINDA) ability to show the value of his herd, which shows that the value proposition of this software aligns with what this farmer is looking for.

For Farmer 5, “the main thing that they allow you to do is improve accuracy in what you are doing. You can’t manage what you do not measure. If you are not out there measuring and recording you can’t look back and reflect on what went right and what went wrong” (Farmer 5). Software is especially important for this farm because they rely on in-shed hardware to collect individual cow milk production and cell count information daily. Their Jantec software collates records together with other animal records to help drive all animal management decisions, where other farmers would choose to use herd testing and other sources of data. This shows that the value proposition and accuracy attributes are equally important for this farm. The software he currently uses has a large impact on his IS and meets his current requirements (the value proposition); however, this can only be achieved through collecting accurate and reliable of data, which shows that this is a very important attribute for this farm.

Farmer 3 explained that feed software can help inform feed decision making, especially regarding which supplementary feed to use, when to use it and how much. The impact of this "is worth tens if not hundreds of thousands of dollars" (Farmer 3). Currently, this farmer uses his own feed budgets, as well as FarmKeeper and Pasture Coach, to help make supplement decisions, which indicates that the value proposition and software fit attributes are important, but individual feed software are currently meeting his requirements.

For animal software (such as MINDA), the generated information informs decision making for culling of animals from the herd and breeding/reproduction, which can be in part achieved by using information on the "best and worst" cows (Farmer 3). Farmer 3 recognised the impact that software has on improving animal decision making, which he can achieve by having readily accessible, and valued information (the accessibility and value proposition attributes).

Farmer 4 agreed that the impact of software is in decision making, and also added planning. Additionally, for his wife and him (who only have six years of farming experience) he explained that "when we first started out we could not rely on a lot of built up knowledge, although we had general farming knowledge, we did not have specific farming knowledge. So we relied on measurement and technology, and decision making support tools to get us through" (Farmer 4).

Technology, including software, enabled them to make "more informed and quicker decisions" in the absence of years of experience (Farmer 4). This shows that the value proposition and software fit attributes are particularly important for this farm, as well as reliability, accuracy and speed, because Farmer 4 was one who relied heavily on his own Microsoft Excel spreadsheets to make decisions, which in his eyes were more reliable and accuracy than commercial alternatives.

Farmer 6 also suggested that the decision making impact of software were highly valued, and this relates to improved profits. This farm added that software is used to ensure “we have a paper trail (e.g. stock movements/sales/purchases) and an obvious decision making process”, and to help them align their systems with their “values and strategy” (Farmer 6). This is particularly important for them because they are owned by the government, and therefore their business is “an easy target for media slander” (Farmer 6). Therefore, for Farmer 6, the value proposition and software fit, along with reliability, accuracy and speed were highly desirable for this operation.

4.8 Software provider interviewees

4.8.1 Description of the software providers

Five different agricultural software providers took part in this research. These businesses were selected using evidence provided by the 'farmer' group, from which commonly identified software were chosen to investigate further.

In total eight participants representing the five software providers were interviewed. The number of interviewees depended on a combination of, 1) the size/scope of the software (for example, if certain people looked after certain features or functions of the software); 2) who was available, and willing, to be interviewed.

Table 11, provides an overview of each business to be used in this research, as well as what type of software they provided (animal and/or feed); if they provide somewhat of an 'integrated system' (software that communicates with other software for the purpose of data and information exchange and/or collation); and if they have any mobile device apps for their software. Provider 1-4 provided animal and/or feed management software. Provider 5 does not directly provide either type of software for dairy farming; instead they are involved in the development of agricultural software on behalf of their clients.

Table 11 Software Providers.

Name/Type of Software	Animal management software	Feed management software	Integrates with other software[2]	Online (or cloud) software	Mobile device app/s
Provider 1	Yes	Yes	Yes	Yes	Yes
Provider 2	Yes	No	Yes	Yes	Yes
Provider 3	No	Yes	No	Yes	Yes
Provider 4	Yes – considers both feed and animal management in their farm modelling software		Yes	Yes	Yes
Provider 5 (Developer)	N/A	N/A	N/A	N/A	N/A

[2] An integrated system refers to software that communicates with other software for the purpose of data and information exchange and/or collation.

4.9 Case 1 Feed management

4.9.1 Software provider case introduction

Provider 1, Provider 3 and Provider 4 all provide agricultural software that is used for feed management in the NZ dairy industry.

Provider 1 supplements their core business of animal genetics, including their provision of animal management software, with software that is catered for helping dairy farmers manage feed (and other paddock related resources) and dairy automation.

For Provider 3, the interviewee primarily works as an agricultural consultant. The software he and his business partner (also his brother in-law) provides is largely used to complement this consultancy role; used to provide clients with software to help manage pasture on dairy farms. The software does not generate a huge return, rather it was, “set it up with the idea that this program would generate for us a nice holiday for our families each year; that was our goal and that is about what it does” (Provider 3).

Provider 4 is primarily in the business of providing agricultural software for both dairy and, sheep and beef customers. Their customers were historically consultants who would use the software on behalf of farmers. Today, they have both consultants and farmers using the software prominently. This software was called a “decision support tool”, which “fundamentally is an electronic model of a biological system, which we call a farm” (Provider 4). Variations of the core software cater for every level of farm management, from operations, through to tactical and strategic management, and “accommodate a complex interaction between feed and animals” (Provider 4).

4.10 Case 2 Animal management

4.10.1 Software provider case introduction

Provider 1 and Provider 2 are both providers of agricultural software that are used for animal management in the NZ dairy industry. Together these two businesses amass ~100 per cent of market for users of dairy herd recording software.

Provider 1 is the market leader in this field with 90 per cent of the market (Provider 1 – Interviewee 2), while Provider 2 provides dairy herd recording software for approximately 10 per cent of the market (Provider 2). Both of these businesses are significant providers of animal genetics and animal reproduction services for the NZ dairy industry.

The software provided by both Provider 1 and Provider 2 is largely used to record animal data, and then provide information back to farmers (and other relevant users) in the form of reports. Animal data records are also of critical importance for both businesses and the dairy industry because the data is used to 'prove' the value of the animal genetics that is provided to farmers for artificial insemination of their animals (Provider 2). "It allows us to prove the value of our animals and the genetics that we are breeding" (Provider 1 – Interviewee 1).

The 'proving' function of both software is enabled by the uses of indices (used for animal evaluation), which "the majority of people trust" (Provider 1 – Interviewee 2). The indices of note are "breeding worth (BW), production worth (PW) and lactation worth (Fulweiler)" (Provider 2). Calculations for these indices are determined via 'The Dairy Industry Good Animal Database' (DIGAD) of which DairyNZ operate and maintain (DairyNZ). The "DIGAD holds all animal data required to complete animal evaluation functions" (DairyNZ).

The origins of the software provided by Provider 1 began with a desire to link dairy farmers with the national database. This was explained by Provider 1 – Interviewee 2, "the whole idea of the program (CRS Software Ltd) was to create a link between the farmer and the National Database – ultimately it is all linked to what the Dairy Board had established for the industry"; and, "we (Provider 1) can use that information to determine where we are taking the dairy industry" (Provider 1 – Interviewee 2). A schematic overview of how and where animal management software functions within the NZ dairy industry can be seen in Figure 24.

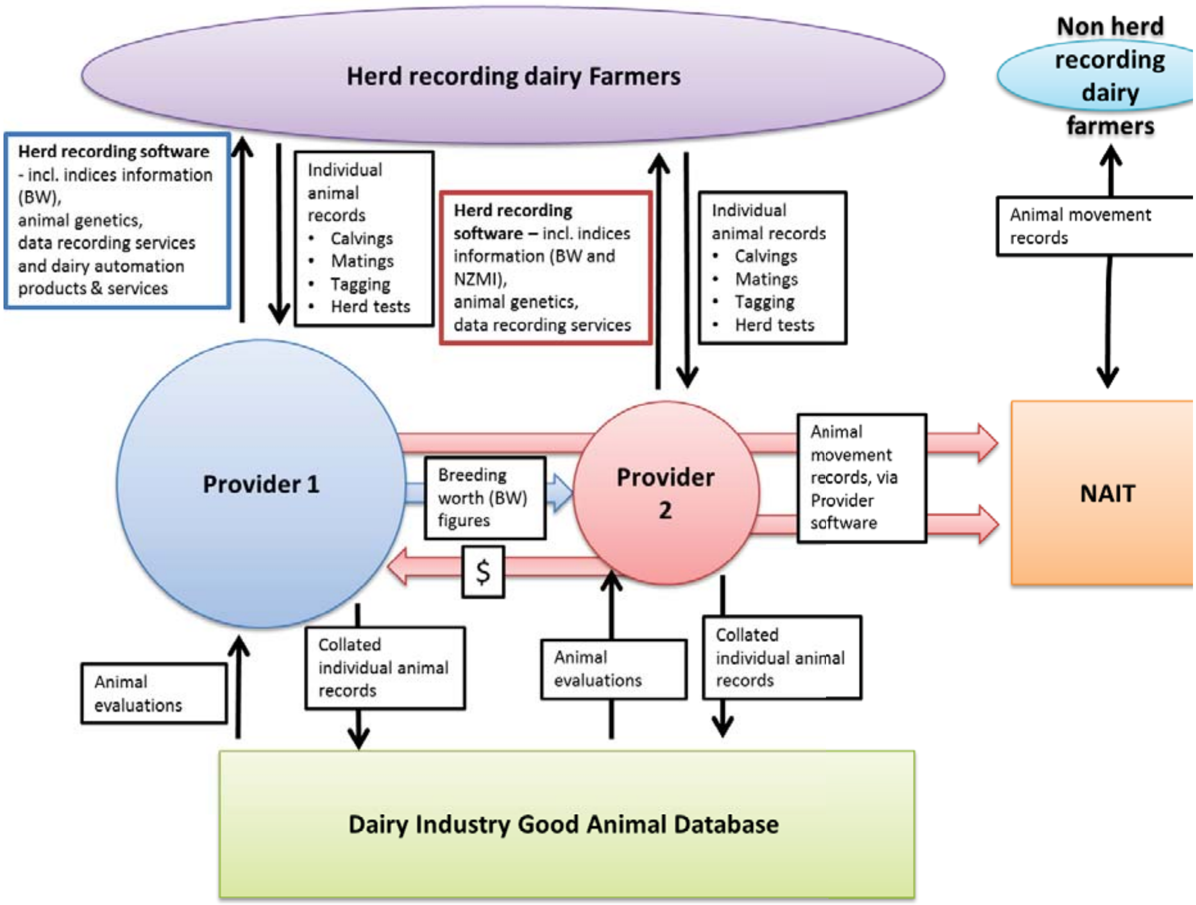


Figure 24 Schematic overview of how and where animal management software operates in the NZ dairy industry.

4.11 Software attributes that influence the use and impact of feed and/or animal management software - software providers

The software attributes section refers to features of software and software provision that influence the use and the impact of animal and/or feed management software. The attributes have been identified and described in Table 12. Evidence and examples of each attributes are then explained with reference to software providers' products and services.

Table 12 Attributes of software and software provision that influence the use and impact of software – software providers.

Attributes	Description (as interpreted from software provider results)
Speed and repeatability of data entry, processing and information output	The time required to input data, process it and acquire useful information for decision making and compliance
Simplicity (or simple)	Software is : user-friendly – anyone can use it, allowing for both "normal users" or "super-users" (those requiring greater complexity); intuitive – the layout and navigation of software enhances ease of use (with the least amount of clicks and customisation abilities), keeps the main features at forefront and complexity hidden; and, software is accessible – allowing for greater speed (of data entry) and ease of use
Value proposition of software	Software addresses the problem or need of farm users and/or software provider, at an acceptable cost. This includes the ability to input relevant data and produce useful information
Accessibility, storage and safety, permissions and sharing	Data and information is accessible and safely stored for use in decision making. It can also be easily accessed by, and shared with, others

Accuracy, data input and information output	Accurate data is required to be input by farm users (or others) to enable processing into information, useful for farmers and software providers
Integration with hardware and software	Data and information from one software (or hardware) can be exchanged seamlessly with other software
Display and interface	Visual features of the software that enhance successful software use
Support and training	Services provided by software providers to ensure successful software use by farm users (and others)
Feedback and development	The process of communicating with farmers (and other parties) to capture feedback, in order to develop software that meets farmer and provider needs

4.11.1 Speed and repeatability of data entry, processing and information output

All providers expressed the challenge of providing software with sufficient speed and repeatability attributes, especially for data entry and processing.

For example, Provider 1 – Interviewee 2 believed "the single hardest hurdle (to enhancing further software use by farmers) is actually getting people to record". This was especially the case for collection of pasture cover data for feed management (Provider 4).

Another significant challenge is the speed of processing, once and if data is collected. Processing speed is an essential attribute for enabling the successful use of any software because, "there is nothing that can kill a product more than if you are trying to use software but you can't" (Provider 1 – Interviewee 2). Therefore, "the faster you can turn that data around and back onto their devices, then the faster they can make decisions" (Provider 2).

One major factor that influences data entry was put succinctly by Provider 4, “farmers, generally speaking, do not like to collect data, it is a ‘pain in the arse’, particularly around pasture cover information, which is a key requirement for our software” (Provider 4). This indicates that farmer’s preferences, and the impact this has on IS has a large influence on use software, regardless if speed and repeatability attributes are enhanced.

4.11.2 Simplicity (or simple)

Each interviewee’s definition of simplicity differed from then next, although it was clear that simple software incorporates traits such as: user-friendliness, intuitiveness and accessibility. Collectively these enable software to be simple, yet complex (if desired), which is what all providers believed farmers require.

The major reason why this attribute is important for farmers, as described by Provider 1 – Interviewee 1, it that simplicity makes software easy to use, so farmers can “put information in and pull information out, so they can make smart decisions so they are profitable on farm” (Provider 1 – Interviewee 1). Having simple software is also beneficial for providers because it also reduces their requirements for software support (Provider 1 – Interviewee 1).

In order to provide information that farmers desired, it was highlighted by Provider 1 and Provider 2 that the ability to process and create customisable reports was an important simplicity feature. Therefore, Provider 1 created their cloud-based software to allow for easy creation of customisable reports, an improvement on their desktop software which is limited in this function (Provider 1 – Interviewee 1). Whereas, Provider 2 has yet to incorporate this ability into their cloud-based software, however they can do this on their older, desktop based software. This has resulted in their clients deciding to continue to run their desktop software, as well as their online software (Provider 2).

4.11.3 Value proposition of software

Ultimately, all interviewed software providers aimed to provide software to farmers that they believed would address farm users’ needs or problems. However, it was also evident that software was also used to meet their own business needs.

For example, for Provider 1 and Provider 2, providers of animal management software, their offerings are critical for both businesses and the dairy industry because collected animal data is used to 'prove' the value of the animal genetics that are sold to farmers (Provider 2); "it allows us to prove the value of our animals and the genetics that we are breeding" (Provider 1 – Interviewee 1).

Likewise, for Provider 3, their feed management software is largely used to complement a farm consultancy business, of which the interviewee works for. Accordingly, the software does not generate a huge return, rather it was, "set it up with the idea that this program would generate for us a nice holiday for our families each year; that was our goal and that is about what it does" (Provider 3).

In contrast, Provider 4 is primarily in the business of providing agricultural software for both dairy and, sheep and beef customers, and therefore generating a return from providing software that is valued by their customers is their primary focus. Although, a major difference between this software and the other software is that this software is historically catered at consultants who would use the software on behalf of farmers, rather than solely farm users.

These examples indicate that the value proposition attribute of software will differ according to the business needs, and what each business values from software may differ from farm users.

4.11.4 Accessibility, storage and safety, permissions and sharing

For this attribute, cloud-based software and smartphone apps were highly spoken about by all five providers as a means of improving accessibility, safety (and storage), ability to permission and share farmer data and information. Refer to Table 13 below for a summary of each providers cloud and app features.

Table 13 Summary of Provider's cloud and smartphone app features.

Name of provider	Type of software (cloud, desktop or hybrid)	User access levels and sharing	Type of app (data entry or data entry + information viewing)	Bulk entry of data
Provider 1 – Animal management software	Online software is fully cloud-based. Also, runs desktop only version.	Yes	Data entry and information viewing	Yes (but not on the app)

Provider 1 – Feed management software	Fully cloud-based	Yes	Data entry	Yes
Provider 2 – Animal management software	Online software is fully cloud-based. Also, runs desktop only version.	Yes	Data entry and information viewing	Yes (but not on the app)
Provider 3 – Feed management software	Hybrid cloud	Yes	Data entry and information viewing	Yes
Provider 4 – Feed management software	Hybrid cloud	Yes, but limitations on the number and type.	-	Yes

Every provider has some degree of cloud-based software (which could be either fully cloud-based software or a 'hybrid' cloud system, which involves using desktop based software that synchronises with a cloud database). As explained by providers, the use of the cloud provides a number of key improvements over traditional desktop only software, including – improved access to software from any computer or smartphone with internet connection; improved storage and safety of farm data/information as these are not restriction to a single desktop software; and, cloud software integrates with apps to allow for enhanced data and information access.

For apps, of the provider group of five, three providers have an app available for data entry, and all of these could be used in varying degree for displaying information for on-the-go decision making. The ability to use apps via a mobile device (laptop, tablet or smartphone) in some cases has enhanced data entry by farmers (and people entry data on behalf of farmers, like A.I technicians), as well as the overall adoption of software (Provider 3).

For instance, Provider 3 explained, "we are finding that the uptake and use of the app is extremely strong and farmers have a preference for using an app, people that are using our tool certainly want to use an app. The adoption rate of the app has been faster than that of the PC version" (Provider 3). And, "we have also had people come over to the software simply because we have built the app as well" (Provider 3).

For Provider 1, the benefits of apps are obvious, and they are seen as “one of the ways of the future, in terms of recording” (Provider 1 – Interviewee 2). These testaments were reiterated by Provider 5, who stated that, “if you can get it (CRS Software Ltd) on a mobile phone, then you are right in his/her pocket. They do not need to come home tired, then look over at the computer and say no (I won’t enter my data)” (Provider 5).

One of the negatives of apps for improving accessibility of software is that the touchscreen on many mobile devices has yet to be optimised for farm users’ dirty and wet fingers. “We still have to deal with capacitive and responsive touch-screens because wet fingers on your iPhone do not work. This is not ideal when your hands are covered in water” (Provider 1 – Interviewee 1). This is a technological factor that constrains many farmers use of smartphones for data entry in certain farming activities like calving records; in this case the “yellow notebook” (a recognised notebook for calving records) is still the preferred option for “even the most proactive farmers” (Provider 1 – Interviewee 2).

4.11.5 Accuracy, data input and information output

All providers have some strategies, rules or restrictions built into their software to help ensure accuracy in both data recording and information output. There is however a major difference between how important accuracy is (for the provider) and how this is managed in feed software, compared to animal software.

For feed software, information output is considered only as useful as the data that is put in. For Provider 1, Provider 3 and Provider 4, so called “dumb data” is not such a worry, because it is up to the users to be responsible for what they put it (Provider 1 – Interviewee 3; Provider 3; Provider 4). There are rules and restrictions in place to limit what users can put in, forcing users to re-check their data. For example, both Provider 1 and Provider 3 have prompts to make sure that a negative pasture growth rate is not possible. However having data 100 per cent accurate is not the highest priority.

For Provider 4, their entire software is built around showing the feasibility of a biological model. In this sense, as long as the model shows a plan is feasible, then whatever the data inputs are, or the information outputs, it does not matter. They are just concerned with ensuring users models are feasible, via their helpdesk and other support (Provider 4).

In contrast for animal management software provided by Provider 1 and Provider 2, accuracy of data and information is critical for their businesses and the dairy industry's National Database (the database of all registered animal data). Subsequently, Provider 1 and Provider 2 both have a number of strategies to ensure the quality of data and information. These include – performing their own data entry (herd testing) which has to meet a certain industry standard; providing excellent support and training functions; validation of data in their own software and also when it synchronises with the National Database; in software alerts, which need to be addressed; and if all else fails, they have staff who can physically visit farmers to check animal records.

Together these functions enable an extremely high level of accuracy, which is widely demonstrated in the animal evaluation indices (BW, PW, LW and NZMI), which people recognise and value (Provider 1 – Interviewee 2; Provider 2).

Providers with cloud-based software can to an extent utilise this to manage data entry, by having all records easily accessible for support services to view. Furthermore, Provider 1 uses what they call the "holding pen", this works when a farm is using the app for data entry, "it is a place where all the recorded data can be double checked. It won't be uploaded straight away, but there are certain events which can be auto approved" (Provider 1 – Interviewee 2). This helps to improve accuracy of records and subsequent information, and also has the added benefit of helping "farm owners identify potential training gaps with staff on-farm, because they can see everything and see who entered it as well (Provider 1 –Interviewee 1).

4.11.6 Integration with hardware and software

All five providers mentioned the benefits, either realised of potential, of integration of software with other providers of data and information. Within this group of providers, Provider 1, Provider 2 and Provider 4 all have some form of integration with other providers. Furthermore, Provider 1 also had purchased feed management software, in order to combine this with their online animal management software; and Provider 4 includes animal management features in their modelling software. Refer to Table 14 for a summary of software integration by the different software providers.

Table 14 Integration of software by Software Providers.

Name of provider	Type of integration
Provider 1 – Animal management software	Integrated with their own Feed software; NAIT; and shortly milk production.
Provider 1 – Feed management software	Integrated with their own Animal software; NAIT; and shortly milk production.
Provider 2 – Animal management software	Integrated with NAIT and Tru-Test MiHub software.
Provider 3 – Feed management software	No integration.
Provider 4 – Feed management software	Their software includes both feed and animal software functionality. Is also integrated with Ag Hub, CashManager and FarmIQ.

The major benefit of a software provider integrating their software with another provider (either through a special relationship or direct ownership) is the elimination of double entry (Provider 1 – Interviewee 1; Provider 2; Provider 4). "Farmers do not have to enter data twice because we know from all of our feedback, that this is a big no-no. They have better things to do" (Provider 4).

There are also benefits from collating information together, therefore improving the quality of information outputs (Provider 1 – Interviewee 3; Provider 2; Provider 4). This is especially the case if specific information is highly desired by farmers, like breeding worth indices (Provider 1 – Interviewee 2; Provider 2).

4.11.7 Display and interface

Across all providers, the importance of how data and information is displayed was emphasised. In particular, Provider 1 has made a great effort in improving the way that information outputs are displayed. Now they use "visual filters", lots of coloured graphs, and "quadrants" which can be used to help guide decision making (without telling users directly what to do) (Provider 1 – Interviewee 2).

Likewise, Provider 4 sees a lot of value in improving the way that they display data, what they call "data visualisation". Historically they have tended to report "information in boring tabular graphs that require a lot of time and effort". What they are trying to do going forward is "displaying information in such a way that prompts action" (Provider 4).

4.11.8 Support and training

The amount of support and training services available to farm users depended on the business model of the providers, and the resources available to offer support and training opportunities, which in part depended on the size and market share of the businesses. Refer to Table 15 for a summary of the support and training services offered by each provider.

Table 15 Summary of Software Provider support and training.

Name of provider / Type of support and training	'Help section' or FAQs	Extension services	Call centre/ helpdesk	Email/online	Training days	Training –online (incl. remote login)
Provider 1 – Animal management software	Yes	Yes	Yes	Yes	Yes	Yes
Provider 1 – Feed management software	Yes	Yes	Yes	Yes	No	Yes
Provider 2 – Animal management software	Yes	Yes	Yes	Yes	Yes	No
Provider 3 – Feed management software	Yes	No	No	Yes	No	No
Provider 4 – Feed management software	Yes	No	Yes	Yes	Yes	Yes

Every provider offered some form of support. This ranged from solely email support and 'Help' features, but also went to the extent of providing support via extension services and call centre support (including remote access and data entry services). Both Provider 1 and Provider 2 offered the full range of support methods, whilst Provider 4 chooses to rely heavily on a 'support desk' that is "hugely important" for their software, particularly for "dealing with people who have relatively complex, technical questions" (Provider 4).

Provider 1 – Interviewee 1 suggested that their contract centre support was exceptionally good; “we are probably one of the best contact centres in the country if you talk to any farmer”. This helps to accommodate for farmers desires to speak to someone about their software.

In contrast, Provider 3 offered very little support at all; they had no ‘help desk’, or even a method of contacting them via phone. The only method that farm users could contact someone for direct support was via email. Instead of direct support, Provider 3 endeavoured to provide software that was “simple to run”, that could “self-teach” and provided a “comprehensive ‘Help’” feature located in the software itself (Provider 3). Their business model was built around offering minimal support because they did not want to charge a significant amount of money to farmers, who simply would not pay if they did.

4.11.9 Feedback and development

All providers have processes in place in order to capture useful feedback for development. They also communicate with a range of people in order to get valuable feedback, not just farmers.

Naturally, the feedback and development processes and the people involved do differ between the different providers. Refer to Table 16 below for a summary of the feedback and development functions.

The major difference between the providers is the process of development used. Provider 1 uses a “design thinking” – iterative process (Provider 1 – Interviewee 2), whereas Provider 2, 3 and 4 use more of a “waterfall” like approach, as described by Provider 5.

Table 16 Summary of software provider feedback and development functions.

Name of provider	Development process	Own development team	People involved in feedback
Provider 1 – Both feed and animal management software	‘Design thinking’ – iterative development process	Yes	Internal feedback (including sales teams, contact centres and within the business experts); their own “market integrators”; and, direct farmer feedback
Provider 2 – Animal	Ad hoc, more like the	No, outside developers	Internal feedback (including sales teams, contact centres and within the business

management software	‘waterfall model’ – non – iterative process		experts); outside “marketing people” – used to gather farmer feedback as required for large developments; and direct farmer feedback
Provider 3 – Feed management software	Ad hoc, more like the ‘waterfall model’ – non – iterative process	No, outside developers	Owners (through farm consultancy role); direct farmer feedback; and, DairyNZ
Provider 4 – Feed management software	Ad hoc, more like the ‘waterfall model’ – non – iterative process	No, outside developers	Internal feedback (own staff/contact centre) ; research entities (DairyNZ and AgResearch; users - consultants and farmer, via an annual survey

4.12 Drivers and inhibitors of software use and impact – software providers

The drivers and inhibitors section refers to the following issues evident on-farm and in the wider dairy industry which have an influence (both positive and negative) on the use and impact of software. The drivers/inhibitors have been identified and described in Table 17. Evidence and examples under each driver/inhibitor are then presented and explained.

Table 17 Drivers and inhibitors of software use and impact – software providers.

Driver/inhibitor	Description (as interpreted from farmer results)
Industry collaboration and competition	Software providers (and industry) either working together to enhance software integration, or, competing with each other to maintain or enhance market share
Internal and external motivation (including compliance)	Entities, business units or people inside and outside of farms, and/or the provider business, that discourage or encourage the use of software
Technology infrastructure and supporting hardware	Technology and hardware that supports the successful use of software for agriculture
User preferences (and motivation), skillset and knowledge	Farm user and software provider traits that influence of the use of software
Supply and demand of agricultural software	The amount of software available for adoption and use by farm user, versus the amount of demand for them
Farm scale and ownership structure	The size of individual dairy farms (e.g. cow numbers, staff and hectares) and the ownership structure of these farms has an influence on software use by farm users

Seasonality	Seasonal workload changes (due to climate and weather) and planned farming activities both have an influence on the software used by farmers
Age of users	Farm user age, and differences in the ages of the farm management team can influence software use
Trust	Farmers trust in software providers offering

4.12.1 Industry collaboration and competition

Industry collaboration, competition and the effect this has on integration of software and hardware, was undoubtedly the factor that was highlighted the most by all providers. The consensus was that collaboration between providers, resulting in further integration of software (including data and information) and hardware will enable improved adoption and use, which will greatly enhance the impact that software has on farmers and the dairy industry.

Currently there are examples of this already happening amongst providers, as shown in Table 14. However, it was also explained that, "this (collaboration and integration) is the one thing that holds us back, and it makes it harder to have software uptake. We are not very good, as an industry, at collaborating and sharing information" (Provider 1 – Interviewee 2).

An example of a lack of collaboration and subsequent integration influencing software use involves the C-Dax pasture meters. This hardware was identified a popular means of collecting pasture data, to be uploaded into software by Provider 1 and Provider 3. For both providers their latest software does not integrate with this hardware, and therefore farm users cannot make best use of the top model C-Dax (Provider 1 – Interviewee 3).

New collaborations are happening, for instance, Provider 1 is developing what is being called "Agrigate" - a joint venture with Provider 1 and Fonterra, to bring together animal, feed and production data and information; "we are talking to their system; they are talking to our system. It is giving us something that farmers have been asking for" (Provider 1 – Interviewee 1). And Provider 1 also currently incorporates animal management software, with their feed (and other paddock related resources) management software and dairy automation (Provider 1 – Interviewee 3).

4.12.2 Internal and external motivation (including compliance)

Internal motivation for software provision and software use by farmers, or not, comes from people within the business due to attributes like 'value proposition', and, factors including farm scale and farm user preferences (and motivation), skillset, knowledge and role factors (see these sections for examples). Whereas, external motivation stems from specific entities outside the business (farm or provider) and includes – compliance and regulatory entities, processors, research entities, farmers, competitors or partners.

The most highly identified motivator was coming from compliance, especially environmental compliance. As explained by Provider 4, environmental compliance is "the train coming down the track", and, "potentially a huge constraint on farms" (Provider 4). 'OVERSEER' is an example of software that is being used to guide and implement nutrient management on dairy farms (Provider 1 – Interviewee 3). In the past farmers may have been able to get by with alternative (often paper-based) system, however with greater compliance (and regulatory) requirements, systems including software can be used to handle important compliance information, and ensure that it is easily provided when need be (Provider 1 – Interviewee 3).

There are also many "supply programs" in place, requiring farmers to meet provide records and information for the right to supply processing companies (Provider 1 – Interviewee 3). For example, the Fonterra Dairy Diary, sections of this paper Diary can already be recorded online (nzfarmsource.co.nz) (Provider 1 – Interviewee 1 and 2).

Competitors and their offerings also have an influence on both farmer and provider inclination to use certain software. For instance, breeding worth (BW), intellectual property of Provider 1, is highly desirable information most farmers, including their competitor Provider 2 (Provider 2). Farmers seeking this information can get it from Provider 1, or for extra cost via Provider 2, therefore these farmers may be more inclined to stay with Provider 1, rather than Provider 2 (Provider 2).

Another example is research entities like DairyNZ. The publications they produce have had a strong influence on the types of reports (information) that are introduced and marketed to farmers. “Fertility Focus and the Mastitis report” (Provider 2), and the “Incalf program” (Provider 1 – Interviewee 2) are reports that have originated from DairyNZ and were subsequently included into software. This influences farmers’ motivation to use software.

4.12.3 Technology infrastructure and supporting hardware

The restricted availability of high-speed internet was identified as an issue that had inhibited the adoption and use of agricultural software by all providers. Furthermore, now that all providers are providing cloud (or hybrid cloud) software, this will continue to restrict certain farm users, especially given that the cloud versions of software are “resource hungry”, requiring reliable internet connection and high internet speed (Provider 1 – Interviewee 1).

The continued speed of development of ICT both enables and inhibits adoption, use and impact of agricultural software. In many instances, ICT development has improved farmers’ abilities to use data and information for improved decision making, for example the use of smartphones and apps. Accordingly (and as demonstrated above), software providers have made great use of apps and cloud-based software to improve their offerings.

However, the faster development occurs, the more demanding it is for software providers to keep up to date with new technological improvements. For instance, one of the primary reasons for Provider 1 changing to the cloud software was that it is difficult to find programmers that are able and willing to support the older programming language, “no one support Delphi anymore” (Provider 1 – Interviewee 1). For Provider 4, which has a relatively small user base, one of changes in ICT is one of their biggest issues in providing software, “if we have a look at what has caused the most crashes or issues for us, or adoption problems, it is changing technology”. This includes changes that occurred in the software of their competitors such as MINDApro, past updates on this software have caused Provider 3’s software to crash (Provider 3).

Again, the flipside to this is that new or improved hardware could enable the greater capture of data, to be processed into useful information. One example of this is in-shed dairy hardware, including milkmeters. When this type of hardware is sufficiently accurate, data will “be acceptable to take that data into the National Database”, which it is currently not able to do (Provider 2). This type of development may open up the doors for farmers beginning to ask the questions, “why do I need to record with you, or either company’. ‘I can just stand alone, and I do not need all of that’” (Provider 2). The major incentive to keep this from happening is the National Database, which requires records to go through registered providers.

4.12.4 User preferences (and motivation), skillset and knowledge

As ICT changes, both farm users and technology providers face an issue in learning how to operate existing, or new systems that have evolved or arisen due to change. This means that both parties (farm users and software providers) must “learn multiple languages, they are trying to navigate using touch screen on software; and learning to manage their computer; and then learning to manage a piece of software, in a new operating environment” (Provider 3). Subsequently, in the eyes of Provider 3, many farmers see this is a limitation, and therefore avoid new technology; whilst developers endeavour to either upgrade their systems, or potentially stop developing their software altogether (Provider 3).

Conversely, there are many farmers who prefer to completely avoid this issue by choosing not to adopt and use ICT, in part due to their knowledge, skills or preferences (Provider 1 – Interviewee 3; Provider 5); or, they may use a combination of both ICT and informal systems (Provider 3). Provider 5 had a more extreme view, believing that “farmers inherently do not want to use software” (Provider 5), and consequently farmers will only choose to use software if they have to, or if it provides significant value, and is easy to use. “He/she will only use software if it is as easy as ‘falling off a log’, and if it is of considerable value. He/she won’t just go ‘wow’” (Provider 5).

4.12.5 Supply and demand of agricultural software

In general, it was deemed by all providers that there are too many agricultural software on offer. For instance, “the amount of data and information products from software packages throughout the industry has just got so big, it is everywhere” (Provider 2). Many of these offerings were deemed to have “marginal benefits” and were “poorly designed” according to Provider 5. The reason for this situation of oversupply was explained by a number of the providers.

Provider 3 believed that some companies have built feed software, used for managing pasture cover, primarily for the purpose of selling more hardware, such as tow behind pasture meters (Provider 3). Furthermore, Provider 4 believed that there are too many instances where "the wheel is reinvented, because people see NZ agriculture as 'low-hanging fruit'" (Provider 4). When this occurs, "it actually confuses the marketplace" and further exacerbates the issues around collaboration between providers, and integration of software (and hardware) (Provider 4).

4.12.6 Farm scale and ownership structure

A common factor identified by a number of providers was that the size of dairy farms is increasing, and there are increasing numbers of "corporate farms" – farms with many different stakeholders (and sometimes owners). This results in a need to provide IS (including software) that cater for enhanced sharing of data, and a "central place where everyone is seeing that same data and information" (Provider 1 – Interviewee 3).

In contrast, a smaller sized family-farm operation is less likely to desire the same software features, and in fact less likely to software in general (Provider 1 – Interviewee 3). For example, "a one-man band, owner-operator", is "less inclined to use software, because they know what is happening. Things are not a surprise or news, so they do not need to keep a record, to keep people updated" (Provider 1 – Interviewee 3).

The corporate and/or large farming operations are the "most demanding, they are looking for software features, including - simplicity, the ability to share data and information, and to manage permissions easily" (Provider 3). This demand has resulted in the creation of a number of additional features of software provide by Provider 3, like the app and cloud-based reporting; "their demand has helped us learn about what is going to happen next" (Provider 3).

4.12.7 Seasonality

According to Provider 1 – Interviewee 2 and Provider 4, for even amongst the most technologically savvy farm users, motivation to use software will fluctuate throughout the year, as the seasonal workload changes. For instance, at calving time, a time when software can be used to input calving records, farmers are extremely busy doing the essential day-to-day physical jobs. Therefore, their inclination to use software may be inhibited by their heavy workload (Provider 1 – Interviewee 2). Furthermore, the reliability of a paper-based system for recording in times of heavy workload like calvings may supersede the potential time-saving benefits of using an app, especially when the weather is poor (Provider 1 – Interviewee 2).

4.12.8 Age of users

There was a mixed response on whether or not the age of farm users is an influencing factor in the use and impact of software. On one hand it was suggested that the 'younger' farm users have an advantage over their 'older' counterparts because they had greater technical skillsets (Provider 1 – Interviewee 1; Provider 5).

On the other hand it was suggested that although younger farmers have better skills, they are in fact limited by time, "I know a lot of young farmers who have no time at all. I set up a young farmer group eight years ago, I could not even get them to use email to communicate" (Provider 5). In this instance, older farmers actually had more time available, to spend learning about ICT, to develop their skills and knowledge in using agricultural software.

It was also suggested that the 'younger generation' "rely on technology and software too much and they could not tell you how much grass is in a paddock on any given day". Therefore, from the older generations perspective, younger farmers may be "losing the art of farming" (Provider 1 – Interviewee 1).

Regardless of age and generational differences, Provider 1 – Interviewee 3 believed that software could be used for a means of training staff and therefore enhancing the speed of learning. "It definitely can provide people the opportunity to help them make better decisions quicker. Rather than having to spend 10-20 years trying to learn to do it the 'old school way'" (Provider 1 – Interviewee 3).

4.12.9 Trust

Although not overly reported by the Providers, trust was identified by one provider as a reason why farmers would choose to adopt their software, over alternative products. Provider 1's business has "have been around a long time and we have been giving solid information for a long time. I feel like farmers' value that" (Provider 1 – Interviewee 1). For their software, the brand name is “is really well recognised”, so farmers will consider that when choosing software to use (Provider 1 – Interviewee 1).

4.13 The impact of feed and animal software - software providers

4.13.1 Provider 1 – Animal management software

The primary impact of farmers using their software, as described by representatives of Provider 1, is improved decision making, compliance and inventory management.

For decision making, "it allows farmers to make decisions on animals that are robbing milk from the vat, which animals are drinking from the vat and not providing any return. So they can decide on when to dry animals off and when to cull them" (Provider 1 – Interviewee 1). Furthermore, "if they (the farmers) herd test, the only way it will give any value is if they use that information (for decision making) (Provider 1 – Interviewee 2).

For compliance, "it provides outputs for accountants in regard to ingoing's and outgoings of animals (Provider 1 – Interviewee 1). The software also provides an important means to manage NAIT records. For instance, "farmers need to have animal information recorded by a provider, and there are not that many in NZ. That is part of it. Therefore, they are paying for the use of the software to help with that" (Provider 1 – Interviewee 2).

Lastly, for inventory management, "the biggest thing for all farmers without question is that it is an inventory management software. It can be used to determine how many animals I have on the farm at any given time. That is a massive asset; those animals are worth a fortune so I want to know where they are (and how many animals are there) (Provider 1 – Interviewee 1).

The software also has immense value for Provider 1's business because it "allows us to prove the value of our animals and the genetics that we are breeding. This in-turn allows farmers to become more profitable because they can buy those genetic that they have helped to prove, which talks right back to the co-operative principle" (Provider 1 – Interviewee 1). And, "it allows us (Provider 1) to tweak our genetics quite a lot; it allows us to change how we report on herd testing, to ensure farmers are getting the best information from us; and, it allows us to be an essential partner on farm (Provider 1 – Interviewee 1).

4.13.2 Provider 2 – Animal management software

The primary impact of farmers using software, as described by Provider 2, is improved decision making, which is obtained by using indices that give farmers (and other users) “the ability to quick achieve and see what each animal is doing, and being able to compare animals, and rank them within the herd” (Provider 2).

This business also provides another index, different to their major competitor. “We also have another index, the NZ Merit Index (NZMI), this is different to BW. That is our own index that we have put together. It is based on the direction we think farmers should be driving their cows towards, things like - better production, health, udders etc. All of our bulls are ranked with NZMI and BW. Our major competitor has BW, we are not saying it is the wrong thing to do, but certainly the NZMI gives us a different picture of animals as well” (Provider 2).

4.13.3 Provider 1 – Feed management software

The primary impact of farmers using this software was summarised by Provider 1 – Interviewee 3.

> “As a feed management tool itself, it is (the software) trying to provide better information and insight into how farmers can be managing pastures; trying to encourage being proactive around feeding decisions – whether it be conserving feed or managing quality. Within the industry itself it can help align with the emphasis on using more pasture, to underpin a low-cost system. Tools like this can help farmers be on top of what is happening in that space (Provider 1 – Interviewee 3).

4.13.4 Provider 3 – Feed management software

The primary impact of this software comes directly back to what Provider 3 believes to be the main need of farmers, and that is information on average pasture cover and pasture growth rate; which is useful for day to day feed decision making. For instance, “I would like to see more farmers using it as a predictive management tool, but I have to be honest and say that probably 2/3rds - 75 per cent of users just want two numbers – average pasture cover and pasture growth rate. Half of them want to see a feed wedge, and then 25 per cent want management tools and about 5 per cent are using the “what if” features” (Provider 3).

4.13.5 Provider 4 – Feed management software

The primary impact of using this software is quantifiable information for planning and monitoring of feed (and animals), which can then be used for decision making. For example, "it is a slightly clearer 'crystal ball'. It will enable you to see a bit further into the future"; and, "it is a tool to understand how your business works and how to get the most out of it" (Provider 4). Furthermore, using this software can help with communications and interactions between a farmer and their consultant, it "is a bloody good tool as a common hymn sheet for a farmer and a consultant to work over (Provider 4).

Chapter 5 Discussion

5.1 Introduction

The discussion is broken into four parts: the feed and animal IS in brief; the primary impact of software; the software attributes that influence use and impact including any desirable improvements; and lastly, the drivers and inhibitors of software use and impact. These sections are aligned to the study objectives with the results discussed with reference to literature. The results compare and contrast farmer and software provider perspectives with respect to feed and animal IS.

5.2 Feed and animal information systems in brief

The feed and animal IS depicted in this research highlight the key decisions that are being made in each system; the data and information being used, the frequency of use, and how the data and information is obtained. The IS and the interconnections between data and information, and subsequent decision making or compliance are provided in detail in Appendix 3.0 and Appendix 4.0.

There is little literature on IS in NZ dairy research, or agriculture in general. This is partly because IS are difficult to depict and understand due to the variability and complexity of farming systems (Eastwood et al., 2016; Hammond, 2015; Jago et al., 2013; Sørensen et al., 2010; Yule & Eastwood, 2012). Furthermore, recent research has tended to focus on developing ICT and the identification and/or modelling of this (Allen & Wolfert, 2011; Fountas et al., 2015; Jago et al., 2013; Sonka, 2014; Sørensen et al., 2010), rather than focusing on the ICT used on-farm from a holistic and systematic IS view.

A systematic view is important because, as explained by McCown (2002a), more emphasis needs to be put on learning what farmers do and how they act, rather than emphasising the design of future systems. A systematic understanding would ensure that future systems take into consideration both formal (software and ICT), and informal (intuition, verbal communication), components which make up IS (Boehljie & Eidman, 1984).

5.3 The primary impact of software

Literature suggests that the task of making critical reflections of ICT experience is immensely challenging and rarely done (McCown, 2002b). However, this research produced a subjective, albeit unquantifiable, reflection of the impact of software which according to Myers (1994) is best definition of IS success. All farmers in this research were asked to summarise the primary impact of software on their farming operation, and, all providers were asked to summarise what they believe to be the major impact of their software on farmers, so that comparisons could be made between what providers believe the impact is, and what farmers actually realise

Farmers in this study indicated that software has an impact on improving farm decision making, especially planning and control decisions, making decisions more accurate, informed and timely. These beneficial impacts of software (or ICT) highlight and support literature which also found that ICT is particularly beneficial for improving decision making (Hammond, 2015; Jago et al., 2013), in particular planning and control decisions (Doye et al., 2000; Eastwood et al., 2016; Gray, 2005a).

Farmers in this study believed these improvements in decision making can be realised through enhanced accessibility and storage of accurate data and information that made readily available through the use of software. Furthermore, data and information stored on software can be used to help farmers learn and protect themselves from scrutiny (public and regulatory), as well as, helping them to keep aligned with their strategy and values. These views are supported by Eastwood et al. (2016) who identified that farmers already using DSS were motivated to continue to use DSS tools in order to get benchmarking, reporting, and farm team communication benefits. Flett et al. (2004) identified economic benefits as the main measure of technology usefulness; however, it was implied that improved decision making has an economic benefit. Therefore, improved decision making by farmers in this study should also have an impact on their profitability.

Software providers were more specific with their beliefs on what the impact of software is. As a group, they all expressed the view that their software would assist farmers with decision making, whether it was for feed or animals, by providing invaluable information such as animal indices or pasture information such as average pasture cover and growth rates. Their views align closely with what farmers stated as the major impact.

In addition to this, Provider 1 explained that their animal software was also useful for compliance, as supported by Jago et al. (2013), and inventory management of farmers, useful for NAIT compliance and meeting accounting requirements. Provider 1 and 2 also explained that farmer use of their software enables them to prove the value of their bull genetics because they can use farmer data to quantify the performance of their bull's progeny. This helps these providers make future breeding decisions (and set pricing of their genetics) and ultimately helps farmers become more profitable as they can get access to higher quality genetics, capable of producing high quality cows.

Farmers agreed that animal software was useful for meeting NAIT compliance, but, the inventory management and accounting benefits were not recognised and did not align with the beliefs of farmers in this study. The impact of 'improving profitability' suggested by providers did not align with the major impact of software identified by these farmers, although this was implied.

5.4 Major software attributes that influence use and impact of feed and/or animal management software

The two groups in this research, farmers and software providers, provided their views on their use, or provision, of feed and animal software for NZ dairy farmers. This data was then used to categorise, highlight and examine the software attributes that need to be considered when using software, or in the case of providers, providing software.

The Venn diagram in Figure 25 shows the key software attributes considered by both farmers and software providers as influencing software use. Two attributes were absolutely considered in the same way by both groups, these were 'simplicity' and, 'integration with hardware and software'. The other attributes differed to some degree between groups, either in how they were explained and categorised, or in the identification of an attribute that the other group did not explicitly highlight. All attributes are heavily interrelated, hence the use of the Venn diagram to demonstrate this fact.

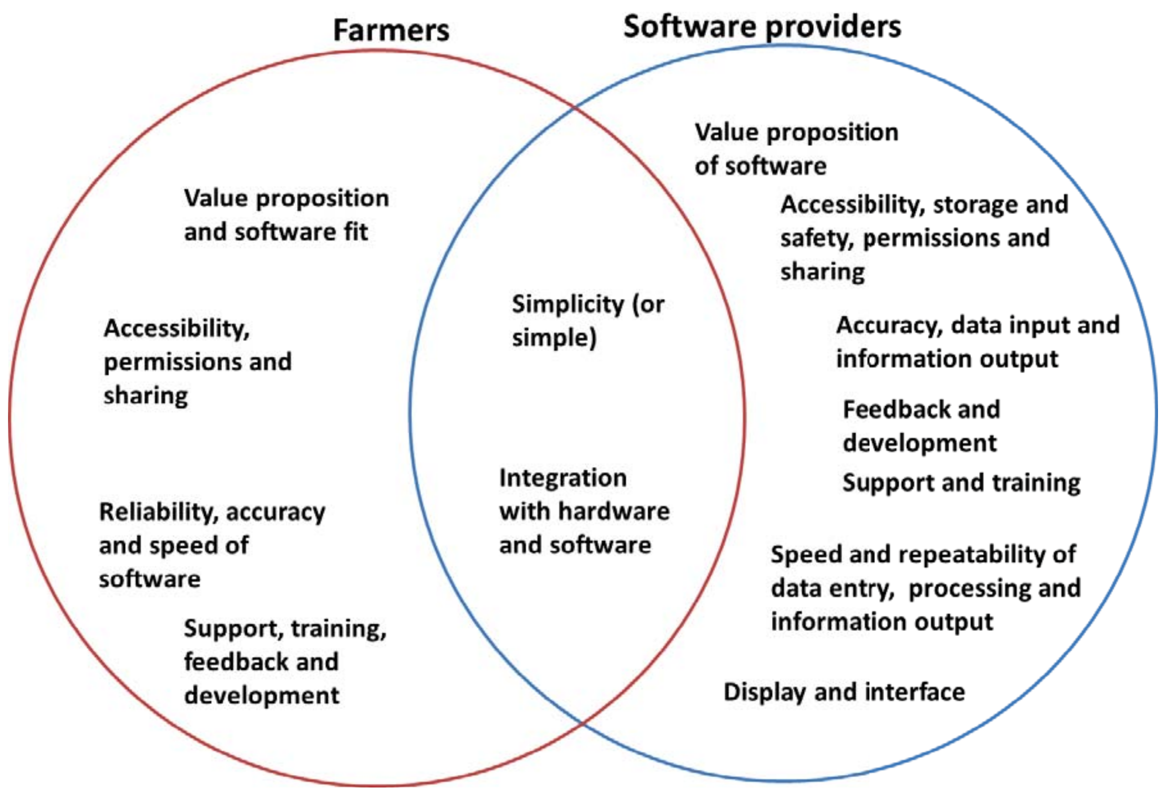


Figure 25 Software attributes that influence use and impact of animal and/or feed management software.

The similarities and differences highlighted by the two groups will be discussed using six major attributes identified by farmers; these include desirable improvements of software identified by farmers. These major attributes include – ‘simplicity (or simple)’, ‘integration with software and hardware’, ‘value proposition and software fit’, ‘accessibility, permissions and sharing’, ‘reliability, accuracy and speed’, and, ‘support, training, feedback and development’.

5.4.1 Simplicity (or simple)

Simplicity was highly desired by all farmers in this study. Likewise, the software providers all emphasised their efforts to provide software that is simple. As literature referring to farmers’ use of agricultural software suggests, simplicity or complexity is the most highly recognised reason why software is used for agriculture, or why it is not. As explained by Tarofder et al. (2017), complexity can be the main hindrance of adoption and use of internet technology (like cloud software) for SMEs, as has also been found in literature (Kuhlmann & Brodersen, 2001; McCown, 2002a; McEwen, 2016).

Despite the fact that both farmers and providers identified simplicity as a key attribute, it was clear that each individual’s definition of simplicity differed amongst participants. The major similarity in definitions presented by both groups was that simple software meant that it is ‘user-friendly’ so anyone can use it (all farm staff), understand the software and interpret the software output (both normal and ‘super users’); and, it is ‘intuitive’ with logical step processes, navigation, and a layout and display that enhances ease of use. Questions relating to simplicity, such as what makes technology easy to use and learn, were identified as an area needing to be studied by Flett et al. (2004) which this study somewhat addresses.

A difference between the two groups was that farmers strongly emphasised their desire for software that can process and produce information in a language or unit that they could readily interpret so use of the outputs was straightforward. Better interpretation of information can somewhat be achieved through enabling customisation features (Eastwood et al., 2015) or flexibility (Eastwood et al., 2016), and through more graphical software interfaces, all of which are attributes highly desired by interviewed farmers. Some software providers are aware of these desires and have incorporated these features into their latest software upgrades.

Software providers additionally emphasised their efforts to improve the simplicity of software by enabling greater access or accessibility to software, therefore enhancing speed of data entry. For example, it was believed by certain providers that simplicity could in part be implemented by creating and providing smartphone apps which can be used for data entry in the field. Three of four providers (excluding Provider 5 - the developer) have apps available for farmers to download and use, with the idea that in doing so, this will improve accessibility and therefore the simplicity of their software.

Based on farmers' descriptions of previous software use in this study, if software is not simple is likely to be discarded for decision making purposes straight away, unless other drivers of use overrule simplicity shortcomings, such as upper management reporting requirements (internal motivation). This finding is supported by Tarofder et al. (2017) who found that at an organisation level, 'top management support' was the most important determinant of effective diffusion of internet technology, but at an individual level, complexity is one of the foremost negative factors influencing adoption and use of technology, especially when individuals do not have access to resources to aid learning (Tarofder et al., 2017).

5.4.2 Integration with software and hardware

Every interviewee valued integration between software and software, or, software and hardware, to allow for seamless exchange of data or information. Farmers provided specific examples of good software integration, including: Tru-Test MiHub and LIC's MINDA (software to software), and, C-Dax pasture meter and FarmKeeper (hardware to software). The providers explained their efforts to create further integration, including direct ownership of software or hardware (e.g. purchasing feed software specifically to align with the providers existing animal software), and, the development of a number of relationships between commercial providers enabling integration. Conversely, every farmer and provider was expressed frustrations as a result of restricted integration. The importance of integration and recognition of the current lack of integration is also documented in NZ literature (Eastwood et al., 2016; Jago et al., 2013; McEwen, 2016; Yule & Eastwood, 2012).

For feed IS limitations in integration between software and the C-Dax pasture meter (hardware used by three of six farmers) was identified by both farmers and providers. This limitation has been alleviated somewhat by the provision of apps for pasture data collection;

however, this solution does not work for all farmers, with three interviewees choosing to use the older and unsupported FarmKeeper software to enable integration.

For animal IS, the degree of integration of data between software was superior to feed IS, but it was less of an issue here as well due to the prominence of 'focal software' collating all eight different data sources together, including data captured by farm managers or farm staff, along with data/information captured as a service by external entities (herd testing, pregnancy testing, DNA sampling). For five of six farmers the focal software used was either LIC's MINDApro and/or MINDALive, or, CRV Insight – Web, both of which have apps available for data collection and information access.

Amongst other benefits, the single largest benefit of integration, as expressed by farmers and providers, is the reduction (or elimination) of double entry. Double entry problems, partly due to a lack of integration, were found to be especially prominent on large scale, multi-farm operations in this research and also by Eastwood et al. (2016).

In the case of the large scale multi-farm operation in this study (Farm 6), and in Eastwood et al. (2016), in-house software had been developed for benchmarking and reporting, which did not always integrate well with other software they used. There are two major problems with in-house software. One, it creates more work for farm staff in inputting data, which compromises the reliability and accuracy of this data because less care in data entry can occur. Two, they are difficult to upgrade or integrate. The latter issue is similar for firms' proprietary products. These products have historically limited integration of software because the cost is directly linked to functionality, and therefore this makes it difficult to continue to upgrade while still keeping the cost affordable (Fountas et al., 2015; Kaloxylos et al., 2013).

Another major benefit of integration according to all providers and the larger farmers in this study is an increase in the quality of data and information recorded by software. Incidentally, all farmers expressed their desire for 'one integrated online solution' that can automatically bring together animal, feed, milk production and, other data and information in one place online; something not too dissimilar to the conceptual model presented in Sørensen et al. (2010) or Kaloxylos et al. (2013).

An alternative to this, as suggested by one farmer, would be if software and ICT providers changed their business model to enable different software and brands of hardware to integrate (and link) easily together, then farmers could effectively shop around for software or hardware that fitted their systems best, thus, avoiding the need for one online solution. This desirable attribute was also identified in Eastwood et al. (2016).

5.4.3 Value proposition and software fit

For software to be utilised, it must provide recognisable value as part of the farm manager's decision making processes, and have acceptable costs and risks (McCown, 2002a). Farmers in this study confirmed this by stating their desire for software that would address their needs, as well as fitting well into their IS alongside existing software, hardware and informal components.

The providers all believed that their software addressed farm users' needs or problems, as well as meeting providers' business needs. However, the two needs were not always aligned. As was the case for Provider 1, "it allows us to prove the value of our animals and the genetics that we are breeding", suggesting that Provider 1 sees their software as a tool for meeting their own business needs, rather than for meeting the needs of farmers directly.

In the case of the farmers, it was clear that only a small number of software satisfied all farmers' needs or problems, whereas a larger number of software only partly met their requirements. As indicated previously, for animal management, LIC's MINDApro and MINDA app; and, CRV Insight and Insight app, are examples of software that satisfies most of farmers' needs, and fits well with their system, however these software also had their limitations.

A number of farmers also used in-shed dairy hardware (or precision agriculture) which had specific software for communicating with the hardware, including Tru-Test MiHub, DeLaval Alpro, Protrack or Jantec. These software are highly valued by farmers when they integrate well alongside other animal software, which enables them to fit well in IS. This was the case with MINDA and Protrack. However, if in-shed software did not integrate (Jantec software), or integrate well (DeLaval Alpro software), with focal animal software (MINDA or CRV-Insight) this had a major impact on farmer IS and their ability to access information for animal decision making, and was a source of major frustration for two of six farmers in this study. For example, Farmer 5 could not access recognised industry animal indices because his Jantec software did not integrate with MINDA or CRV-Insight, therefore, he does not have access to animal information that indicates the value of his herd, and effectively his wealth.

In contrast to the animal IS, farmers' feed IS incorporated a far wider range of software with most useful having limited use and a specific function, indicating a mismatch in what farmers are wanting from software, and what is being provided to them. On average, farmers used 2 to 3 different software, with up to 5 used by the largest farm. This result is in contrast to Eastwood et al. (2016) who suggested that the use of pasture measurement tools and DSS for grazing management remained limited, and shows that for certain farmers, those willing and able to use software, this ICT will play an important role in their feed IS. It also shows that individual feed software used by these farmers is currently not meeting their needs.

In this study, the reason for the higher number of software used for feed management was primarily because no one individual software package met all of the farmers' requirements, therefore, the value proposition of each individual software was unsatisfactory, making it fit poorly within farm IS. This supports literature which suggests that unsatisfactory value proposition and software fit are important attributes that influence software use (Alvarez & Nuthall, 2006; de Olde et al., 2016; Eastwood et al., 2016; McEwen, 2016). Limitations on the functionality of NZ commercial DSS for grazing management was also identified in Eastwood et al. (2016). In this respect, functionality that meets users' desires is even more important to get right than aspects of simplicity such as ease of use (Eastwood et al., 2016).

For example, it was often the case with feed software that one software was good at mapping, whereas another integrated with their pasture meter. This situation is not ideal for farmers, software providers or anyone involved in data/information provision because it means double (or more) entry (Alvarez & Nuthall, 2006; Gray et al., 2014; Kuhlmann & Brodersen, 2001; McCown, 2002a), double the investment in time, and more training and support for each software (Alvarez & Nuthall, 2006; Hammond, 2015; Kuhlmann & Brodersen, 2001), basically more work.

Part of the difference between the two IS can be explained by the fact that the benefits of software used in animal IS, compared to feed IS, is more observable. In other words, the benefits of using software and information obtained from feed software are difficult to observe. In Tarofder et al. (2017) it was explained that the greater the observability, the greater the rate of adoption of internet technologies. In the context of the systems in this study, animal management software seems to produce more observable benefits than that of feed software. For example, frequently produced animal information (in particular animal indices) clearly show farmers the subsequent result of decisions made from using animal software, whereas the observability of decisions made from using feed software is less obvious.

Farmers in this study desired improvements in feed software toward software that is more complete, rather than a number of software that partly meet their requirements. These improvements could include software features that assist in obtaining feed information useful for operational, tactical and strategic planning; and software capable of bringing together the full range of feed-related data (pasture covers, supplements, weather, and daily feed allocations).

Farmers were also seeking changes in software providers' business models to improve individual software value propositions. One suggestion was a shift towards "bolt-on, modular systems", that is, software that is able to be upgraded as farmers want more features, and/or as their operation increases in scale. Furthermore, farmers desired greater opportunities to 'try before you buy', in order to test software suitability in their IS. This supports ideas identified in Eastwood et al. (2016), who presented seven potential attributes of grazing DSS, which included "trialable" (farmers can test DSS before investment of time and money) and "scalable" (DSS can be used across multiple farms and link to farm advisors).

Lastly, a number of farmers desired improvements in the cost structure, with their preference being one-off or annual payment as opposed to monthly/quarterly payments. On a similar note, Alvarez and Nuthall (2006) suggested that software should be priced according to size of the business, on a per unit (cow or hectare) basis, instead of a fixed price. This type of per unit pricing is utilised by Provider 1 and 2 for animal software but not for Provider 1, 3 or 4 for feed software.

5.4.4 Accessibility, permissions and sharing

Both farmers and providers emphasised the benefits of enhancing accessibility, permission access to software, and allowing greater sharing of data and information, all of which can ultimately result in more timely decision making. Similarly, the benefits of "mobility" were recognised in Eastwood et al. (2016).

Providers explained that cloud-based software and smartphone applications are two relatively new ICT developments that have enhanced accessibility, permissions and sharing attributes immensely, as well as improving the storage and safety of data/information. These developments can be used to address farmers' limited desire to record data which was viewed by providers as a bottleneck for further use of software. In particular, providers viewed apps and cloud-based software as the "way of the future" in terms of improving farmers' abilities to record data. Apps are also useful for providing users with a feedback loop on performance, as recognised in Eastwood et al. (2016).

Accordingly, all six farmers used apps and some form of cloud-based software, and all of them wanted expanded and customisable access to data entry and information viewing from more comprehensive apps (rather than lots of individual apps for different solutions). Currently, apps and cloud-based software were commonly used in feed IS for viewing milk production information, inputting pasture records and reviewing collated feed information. For animal IS, apps were used for viewing milk production information, inputting animal health records and reviewing collated animal information. Desktop software was more commonly used for all other functions and features of feed and animal software such as viewing reports, although, as suggested by both groups, sole reliance on desktop software will become less popular in the future.

The ability of software to permission third party user access via the cloud was also used prominently by five of the six farmers across a range of feed and animal software. Therefore, providers able to provide clients with access to the cloud are better placed to deliver farmers what they want as long as ICT infrastructure (especially internet access) does not limit cloud access. Farmers desire to utilise the cloud aligns with providers efforts to develop cloud-based software capable of allowing third party access. Eastwood et al. (2016) found in their study that accessibility, permission and sharing attributes of software are particularly useful for large multi-farm operations for tracking performance and engaging with staff; thus, cloud-based software is likely to assist this growing group of farming businesses.

5.4.5 Reliability, accuracy and speed

Farmers want reliable software in order to ensure that they can accurately record data in a timely and secure manner, that is quick to access. This is one of the major benefits identified by farmers of using software over traditional paper-based systems. This finding is supported by literature (Boehljie & Eidman, 1984; Doye et al., 2000; Hammond, 2015).

Software providers also desire accurate data, in order to ensure that information produced in the form of reports for farmers is accurate (and relevant) for decision making, as well as being useful for their own purposes. For instance, Provider 1 and 2 both required accurate data in order to prove the value of the animal genetics which they sell back to farmers, and Provider 3 also uses aggregated data (collected from individual farmers) to provide regionally based pasture reports.

Providers also expressed their desire to provide software with speed and repeatability of data entry, processing and reporting information. Speed and repeatability were specifically identified as important attributes for providers because it was believed enhancement in these areas would go a long way toward alleviating the challenge of getting farm users to record.

Differences between the use of feed and animal IS account for some of the differences in reliability and accuracy of their respective software. In particular, the animal IS of the study farmers are heavily influenced by the NZ dairy industry National Database which is a database for all registered animal data. This database includes animal data from every recorded animal (both historic and current) in the industry and is used to create industry recognised animal indices. Animal genetics companies, including Provider 1 and Provider 2, use animal software as a means to collect their clients' animal data and collate/process information important for their own business decisions as well as for providing information to these clients for their own decision making. Therefore, the quality of data in the national animal database is critical for both providers and farmers for proving the value of their animal genetics, and providers have made considerable effort to ensure that data captured is reliable and accurate. Supporting hardware, support and training, and processes to validate farmer data/information (with the National Database) were also aligned with the animal software providers' desire to optimise the quality of data/information used in animal IS.

In contrast to this multifaceted approach used for animal IS, farmers have a greater responsibility than software providers (and other entities) for ensuring the accuracy, reliability and speed of data entry in feed IS. Incidentally, four farmers had chosen to develop their own Microsoft Excel spreadsheets for feed management, partly because they have total control of the accuracy and reliability of data and information, and partly because current commercial alternatives do not meet their needs and/or a not simple enough. In doing so, these farmers can miss out on batch entry benefits and accessibility attributes of commercial software, and they have to deal with more double handling of data.

For farm modelling software which is useful for both feed and animal management at a strategic level, farmers' perception of accuracy was mixed. Some were happy with the software outputs, whereas others believed they quickly became redundant due to changes in the farming conditions as also suggested in Kuhlmann and Brodersen (2001). Inaccuracies can also occur because the farm consultant using them was not knowledgeable enough. The one provider of a farm software modelling tool interviewed explained that their model is built around showing scientific 'feasibility', therefore their main accuracy concern is to support consultants and farmers using the software to produce a feasible farm model, and "nothing else". This provider's attitude suggests that the accuracy of farm models created using agricultural software could be compromised by both inaccurate data entry and also unskilled or unknowledgeable users (farm consultants or farmers). Therefore, farmer scepticism of the accuracy of models may be justified. Kuhlmann and Brodersen (2001) also suggest user scepticism could compromise software modelling tool use.

5.4.6 Support, training, feedback and development

All farmers appreciated a range of software support and training opportunities. Their preference for a support service was contact via the phone (with a call centre), and face to face with the providers. LIC's support services were identified as the most comprehensive and useful for enabling successful software use, especially for MINDApro software for animal management.

In contrast, providers appreciated the fact that farmers wanted support and training; however providers' service offering was influenced by their business model. For some software, this meant no phone support, no training and limited contact with farmers directly wanting assistance. In this case, software simplicity was emphasised, hence a comprehensive 'Help' feature was seen as sufficient.

What this evidence suggests is that farmers need to consider the business model of their software provider, and their relative software market share, when considering their options available for support and training. For example, if a software provider has a relatively high market share in the software they provide, then it would be highly advantageous to have support and training available in order to cater for a wide range of different users. If farmers are not able to get support or require additional assistance then they may need to look at alternative software, or support or training other than that provided by the software provider.

Furthermore, the amount of training available differs for feed software compared to animal software, which is indicative of the differences in IS and relative demand. For instance, Provider 1 offers greater training opportunities for its animal software than its feed software, because the animal software is more widely used, has greater features/functionality than their feed software, and because the provider requires the animal data for their own business purposes. This lack of training, in relation to feed management software is concerning, especially considering that a number of farmers believed that farmer skillset and knowledge in relation to feed management was insufficient to make best use of software. Therefore, it could be argued that providers need to improve their support and training opportunities to help farmers (and farm staff) in this area.

A lack of 'formal grazing management' skills and inadequate support, was also identified in Eastwood et al. (2016). Also, in their earlier work, 85 per cent of 83 farmer respondents in Eastwood et al. (2015) thought would benefit from extra support from providers of their management technology. Both studies reinforced the fact many farmers are not sufficiently skilled or supported enough to make best use of feed software.

With respect to feedback and development, again, LIC's MINDA was highly recognised by farmers as software that is regularly updated based on farmer feedback. Farmers also explained that when feedback is provided to any software that they use, it is expected that upgrades will occur, and if they are not, this is perceived badly.

A number of providers advocated the use of ‘design thinking’ for their development process. This process involves close involvement of end-users to help the providers understand what farmers do on farm businesses, what software/solution can make their lives better and easier and how. Software prototypes are then tested iteratively with farmers in order to identify what best meets their needs. In theory, this type of iterative and participatory development approach should ensure technologies have a valid value proposition and are fit for purpose (Jago et al., 2013). In this study, the software that was developed using the ‘design thinking’ process was well regarded by farmers, albeit not flawless.

5.5 Drivers and inhibitors of software use and impact

Additional to the software attribute results, farmers and software providers also explained drivers and inhibitors of software use by NZ dairy farmers. Alongside software attributes, which have a direct influence on performance and usability of specific feed and animal software, these are more exogenous drivers and inhibitors and should be considered when choosing software, or in the case of providers, providing software.

Figure 26 shows the key drivers and inhibitors identified by both farmers and software providers, categorised according to Laudon and Laudon (2013)'s three dimensions of IS – organisational, technological and people. This diagram highlights similar drivers/inhibitors identified by farmers and providers, and drivers/inhibitors identified by group according to colour and font (bolded and italics). Drivers/inhibitors will be discussed by dimensions in the next sections.

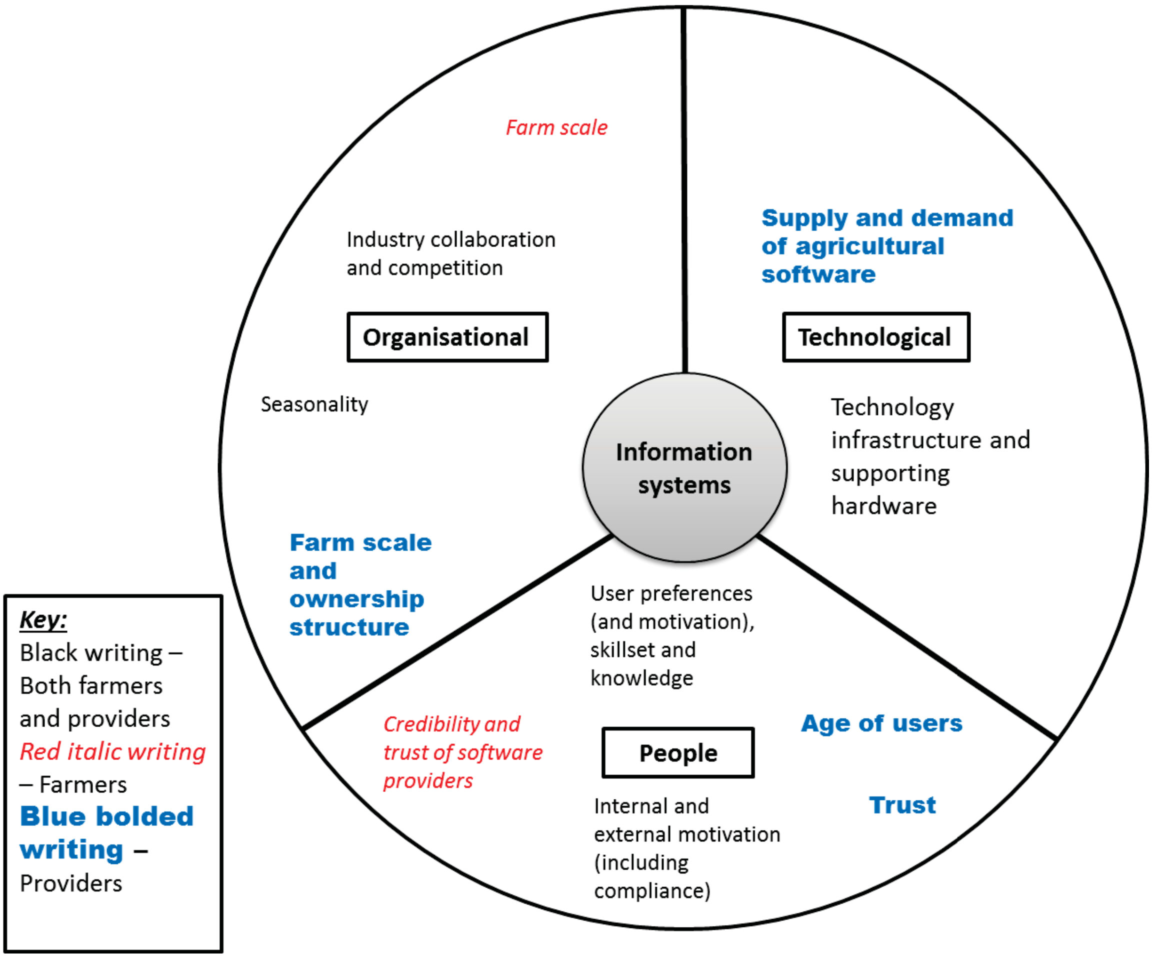


Figure 26 The drivers and inhibitors of software use and impact as identified by farmers and software providers, categorised by the dimensions of information systems (Laudon & Laudon, 2013).

5.5.1 Organisational drivers/inhibitors

The major driver or inhibitors in this dimension according to farmers and providers were 'industry collaboration and competition', 'farm scale', and to a lesser extent 'seasonality'.

The consensus of both farmers and providers was that industry collaboration and competition has a large impact on the software used by farmers, and has a direct effect on integration with software and hardware attribute. On one hand, positive collaborations, through further integration of software and hardware are constructive (Cooke et al., 2013). Whereas on the other hand, competition, through restriction of data and information exchange, and market dominance reduce farmers' abilities to use software successfully, as well as reducing the level of innovation occurring in the industry.

For example, a number of farmers believed that LIC's dominance in the market was somewhat restrictive to software and ICT innovation, because they control much of the data. Farmers are therefore more inclined to use their software and hardware rather than the alternative options, even when LIC's software or hardware may not be optimal.

One farmer believed that there will never be one software that can do everything (e.g. a fully-integrated system/software) therefore there must be collaboration and sharing. This view is supported Yule and Eastwood (2012) who suggested that a lack of integration will persist for some time. On the other hand, some integration is occurring. Provider 1 explained that they were in the process of creating a new software offering in collaboration with Fonterra (NZ's largest milk processor) which will bring together data and information from both businesses. This new software would add to Provider 1's existing animal and feed suite of software, as well as dairy automation hardware.

Large farm scale and ownership structure were identified as drivers that influence farmers likelihood to increase or adapt their use of software. It was accepted by both farmers and providers that generally as farm scale increases, so too does a farm businesses use of software in order to manage larger amounts of data and information. This supports literature that found a similar relationship between increasing scale, the type of ownership structure and further ICT use (Eastwood et al., 2016; Jago et al., 2013; Tocker et al., 2006; Yule & Eastwood, 2012). For example large scale farms with multiple farm owners are more likely to use software and ICT for farm management.

The large, multi-farm operation (Farm 6) in this study used cow numbers to determine which farms that they operated would use advanced hardware and software, particularly for animal management purposes. For example, a farm with 200+ cows used more in-shed hardware and software. This was the major ‘condition’ for introducing more advanced precision dairy technology to farms in their business. This condition provides some indication of the number of cows required before introducing ICT by one farm in this study, which was identified as an area needing to be understood in Jago et al. (2013).

Furthermore, providers suggested that an increasing number of large corporate farms with many stakeholders would encourage greater use of software capable of enhancing sharing and access to data and information, such as features enabled in cloud software and apps. This is supported by Eastwood et al. (2016) who found that large operations are more likely to use mobile phones and online platforms to track performance and engage with staff.

Accordingly, a number of providers have explicitly created apps and cloud-based features in order to accommodate large farms with multiple stakeholders. This also aligns with Yule and Eastwood (2012) who reinforced the fact that there are a growing number of large corporate farms with intentions to invest in ICT and IS to make their lives easier and more profitable.

With respect to seasonality, it was recognised by both farmers and providers that seasonal changes in workload and planned operations (e.g. mating or calving) have an influence of the software use by farmers. These factors were also identified in Eastwood et al. (2016) who suggested that DSS (CRS Software Ltd) could incorporate ‘seasonal triggers’ or prompts for suggesting farmers use software in alignment with critical success factors associated with different planned phases of the production year. Considering the above, the challenge for providers is to create and provide software that is essential for business operations, throughout the year, in order to encourage greater use and further the impact of software.

5.5.2 Technological drivers/inhibitors

The major technological driver/inhibitor was identified as ‘technology infrastructure and supporting hardware’. Both farmers and providers identified limitations in internet speed and coverage, and mobile coverage which can cause major restrictions on farmers’ access to software, especially cloud-based software and some smartphone apps. These limitations were also identified in literature (Ministry of Business Innovation & Employment, 2016; Poppe et al., 2015).

Furthermore, one particular driver and inhibitor for providers, identified by providers, was the speed of ICT development. Development speed drives greater use of technologies such as smartphones and cloud software which have been well utilised as shown in this study, and supported by DairyNZ research which found that 65 per cent of New Zealand dairy farmers use smartphones (Eastwood et al., 2016).

However, providers observed that the faster developments occur, the harder it is to keep software up-to-date and sufficiently supported. Any new developments can bring with them technical problems (bugs and glitches) which need fixing, as well as requiring additional support for farmers trying to adapt to new developments. Providers also need to contend with knowing when to cease development and support. At times, a lack of development and support can inhibit farmers use of software, as was the case with FarmKeeper which is no longer being updated, and therefore cannot be used on the latest model computer or smartphone even though it is still highly valued by farmers in this research.

Providers also suggested that there are too many agricultural software on offer, many of which fail to provide a value proposition that is highly sought after by farmers. This situation exists for feed software (indicated by participants in this study), where there are many different software, each offering only marginal benefits to farmers. Therefore, farm businesses need to ensure that the benefits of technology are likely to exceed the cost of implementing them, especially due to the short life cycle of internet technologies (including software) (Tarofder et al., 2017). Independent guidance and information could potentially help farmers to avoid adoption and use of marginally beneficial ICT solutions, allowing them to make more informed investments (Jago et al., 2013).

5.5.3 People drivers/inhibitors

The major drivers or inhibitors in this dimension were ‘user preference (and motivation), skillset and knowledge’, and, ‘internal and external motivation’ (Figure 26). ‘Age of users’, ‘trust’ of providers and ‘credibility’ were also identified as minor reasons why software would or would not be used.

Every interviewee in this research saw value in using software, however, all were well aware that not all users of software prefer using it over alternative methods. A summary of reasons for a discrepancy between theoretical farmer DSS use and actual practice was presented in McCown (2002a) who called this the "gap". Reasons for not using software were also presented in other literature. For instance, some farmers simply do not like software (or ICT) (Yule & Eastwood, 2012) and, many farm users often do not have the required skillset or knowledge to do so (Jago et al., 2013). User preference, and a lack of skills or knowledge, therefore both influence internal motivation to use software, and present a potential obstacle for farms wanting to use software in IS.

In Hammond (2015), both farmers in the two case studies identified a lack in skillset and knowledge in using ICT in management information systems, and one farmer believed it was up to the 'younger generation' to pick up the new technology (Hammond, 2015). However, it was unclear in this research whether young people would be the solution because both younger and older farmers used software, and as suggested in Eastwood et al. (2016), other psychological factors (such as 'the real reasons for adoption being hidden') may also influence use. Furthermore, as suggested in Jago et al. (2013), precision dairy (including software) can enable farmers to 'scale up and/or speed up'. This means that software (and other ICT) can enable farmers to enhance their learning (for those willing and capable) to the extent that they can "perform like a farmer with 30 years' experience after only 3 years" (Jago et al., 2013).

In the case of a farm with staff preferring not to use software, or without the required skills or knowledge to do so, the decision to use software or not comes back to organisational factors and the ICT in place (Laudon & Laudon, 2013). For instance, for the majority of farms in this research had software and hardware as integral parts of their IS, therefore if people in the farm management team lacked the skills or were not motivated to use software (or ICT), this would compromise their systems unless certain processes or people were in place to relieve this issue.

This was the case for the large corporate farm (Farm 6) in this study where specific people are hired to manage software use (especially data entry) because farm managers were not motivated or skilled enough to use software. Specific roles for people capable and willing to use and interpret ICT outputs may therefore become a solution in the future (Davenport, 2014).

Additionally, software providers also have limitations in their own skillset and knowledge of developing ICT. For instance, as new technologies are developed providers also have to adjust their software offerings to account for changes. Some changes could improve software providers' offerings and others may lessen their software's usefulness (to farmers or providers). This skillset and knowledge inhibitor was also identified in Jago et al. (2013), where it was shown that the use of precision dairy technologies (including software) on farm is progressing ahead of the industry "skill base in precision dairy best-practice" (Jago et al., 2013). For the potential value of software (and other ICT) to be fully realised, there needs to be improvement in the understanding of ICT capabilities of providers and other external entities by these entities, so that they are aware of, and can address, their own skills and shortcomings (Jago et al., 2013).

Another internal driver or inhibitor can come from upper management, owners or other people involved in a farming business in an off-farm or management role. For instance, upper management can drive farms to use software, as explained in the organisational dimension. Conversely, as suggested by one farmer in this study, upper management can inhibit (or stall) the farm management team from using more advanced software and ICT solutions simply because they do not want to invest their time or money into it. This result is also supported by Tarofder et al. (2017) who found that top management support was the most important determinant of effective internet technology diffusion.

External motivation comes predominantly from regulatory entities wanting farmers to use software for recording data for compliance purposes. Both farmers and providers agreed that this motivator will force farmers to use software to some degree, now and into the future. This supports literature that generally agrees that compliance will force farmers to collect greater amount of data and information (Cooke et al., 2013; Hammond, 2015; Jago et al., 2013; Sørensen et al., 2010).

Additionally, it was suggested by a number of farmers in this study that milk processors and input suppliers that encourage the use of software, such as Fonterra and LIC, have a large influence on farmers' likelihood to use software, especially as these businesses are highly trusted and they have farmer credibility, as well as being market share leaders in NZ.

Chapter 6 Conclusion

6.1 Introduction

This study was undertaken to answer the research questions: How do New Zealand dairy farmers use agricultural software in feed and animal information systems; what software attributes influence the use and impact of these software; and, what are the drivers and inhibitors of software use and impact. This conclusion chapter details the main conclusions, discusses the implications of this research, evaluates the methodology and outlines future research opportunities.

6.2 Major conclusions

This research illustrated the generic feed and animal IS used by six NZ dairy farmers that use agricultural software. These systems are used predominantly for decision making, as well as compliance and, are particularly useful for operational and tactical management, but also produce data and information that is critical for strategic management.

The impact of agricultural software was explained by both farmers and software providers in order to compare and contrast the beliefs of both interview groups, and to explain and summarise why agricultural software is used. Both groups of interviewees agreed that software can, and will, benefit decision making, especially planning and control decisions, although, the needs of farmers and providers do not always align. The use of software also makes decision making more accurate, informed and timely, provided the software is used by the 'right' (skilled and motivated) people, with suitable technology and within an organisation that allows effective software use.

In feed and animal IS there is a range of software that is used alongside other formal and informal components of the systems. The structure of IS used for animal management compared to feed management are significantly different with regard to the software used (especially the number of different software), and the degree of data and information collation.

Animal IS were streamlined, with data and information collected and collated together into a limited number of software, with 'focal' software (one or two key software) used as the centrepiece of the system. This situation is indicative of an IS that utilises software that meets most (but not all) farmers' requirements and fits their systems well (but not perfectly). In contrast, feed IS were less streamlined, with data and information flowing into a number of different software solutions, with no obvious focal software/s. This indicates that feed software does not meet farmers' current requirements, and therefore, this system has a number of areas that could be improved, starting with feed software value propositions (e.g. farmers don't want three or more different software for feed management), and improved integration of data and information between and into feed software (and hardware), so that farmers can access information from one or two key feed software.

This research identified the important attributes of agricultural software, highlighted by both farmers and software providers. The major attributes were – simplicity; integration with software and hardware; value proposition and software fit; accessibility, permissions and sharing; reliability accuracy and speed; and, support, training, feedback and development. Simplicity and, integration with software and hardware, were the most highly recognised attributes identified as being important by both farmers and software providers. Therefore, the use or provision of software that is simple and integrated will enable enhanced use and impact of software by dairy farmers. All identified software attributes were interrelated and should be considered by farmers when adopting and using agricultural software; and, they should also be thought-through by anyone providing software to farmers (or other users).

Lastly, exogenous drivers and inhibitors of software use were identified and explained by farmers and software providers. These were categorised into organisational, technological and people drivers/inhibitors which help to explain why software is, or is not, used, and why feed and animal IS differ from each other. From these drivers and inhibitors, opportunities and challenges for software (and wider ICT) use in NZ agriculture have been highlighted. Organisational and people drivers/inhibitors were widely recognised as being influential on use and impact of software, more so than technological drivers/inhibitors which are often emphasised. This indicates that these dimensions should be the focus of future improvements. Improvements could include training and education of farm users, and further collaboration or integration of software and hardware efforts.

6.3 Implications of the research

This research is useful for NZ farm management because it demonstrates how and why software, and to a lesser degree ICT hardware, is being incorporated into dairy farming feed and animal IS, and the impact that this has on these systems.

It also presents the key attributes of agricultural software, and software provision that are considered by both farmers and software providers, and highlights the significant similarities and differences. A greater understanding of these attributes are useful for farmers, software (and ICT) providers, academia and industry to consideration when using or providing software to farmers (or others).

The identified drivers and inhibitors of software help to paint a clearer picture of how and why software is used on NZ dairy farms, adding further explanation for consideration alongside the software attributes. Together the software attributes and driver/inhibitors are useful for developing ICT and strategising future use of ICT in the NZ dairy industry.

6.4 Specific recommendations

A number of specific recommendations in relation to agricultural software and IS improvements were identified as a result of exploring feed and animal IS, although, this was not the absolute focus of this study.

Feed software - There are opportunities for improvement in the value proposition of commercially provided feed software. At a minimum, current providers of feed software could make minor improvements that would address farmers' immediate needs, such as enhancing the software interfaces and display of data and information to enhance simplicity.

Ultimately, feed software needs to incorporate features and functions of existing individual software into a more complete cloud-based solution/s, or at least, fewer feed software packages that meet a wider range of farmer needs. Improved feed software solutions would reduce the occurrence of commercial feed software that has marginal value.

Improved integration of feed data sources together, by enabling enhanced use of apps and seamless transfer of data/information between software and hardware would improve the usefulness of feed software and reduce double entry of data. Key data that needs to be integrated includes pasture metering (pasture covers), supplementary feed on-hand and fed, paddock data, daily feed allocations, and, soil and weather data, all of which should be able to be recorded using apps, or populated (in software) through integration with other software or hardware.

To enable better use of feed software farmers require feed specific training to enhance their skills and knowledge. This will improve farmers' abilities to use software effectively in their feed IS. This training needs to come from, not only software providers, but also industry entities such as DairyNZ and universities.

Smartphone apps – Farmers want to use apps, but prefer not to have too many apps cluttering up their devices. Instead, farmers would like more complete and customisable apps (with a range of optional functions available), which integrate with a larger software/system and include not only data collection features but also information viewing features. This is for both feed and animal software.

Enhanced opportunities to learn about software and ICT use with information systems – Generally, farmers need greater opportunities to learn about software and ICT use. In the past, learning has come largely from trial and error, often incurring investment costs in time and money. Greater ability to trial individual software and ICT could increase learning and reduce investment cost. Furthermore, opportunities for general computer literacy training are needed to help farmers and staff utilise existing software. This could come from industry good bodies, independent agricultural training entities or software providers themselves.

Lastly, greater coverage (e.g. extension or media) of farmers successfully using software and ICT for feed and animal management could help other farmers to choose which solutions could work for them, and to help them to learn how to use them. The South Island Dairying Development Centre (siddc.org.nz/) is an example. Research farms could also be used to validate and report on selected technologies more regularly, as advocated in Yule and Eastwood (2012).

6.5 Assessment of the method

The case study method was appropriate for answering the research questions and objectives. This method enabled the primary researcher to explore and examine feed and animal IS, software attributes that influence use and impact, and, drivers and inhibitors of software use and impact, from a farmer and software provider perspective, all at the high level of detail that is required when examining agricultural IS from a systematic view.

The combination of an initial questionnaire, semi-structured interview, field observation and follow-up unstructured interview provided sufficient time and access to interviewees from each group in order to capture the required information for the study. In particular, the semi-structured interview process enabled the researcher to probe in the desired areas, varying the sequence of questions according the way interviewees spoke about their operations. The initial questionnaire was used to capture descriptive details and introduce the interviewees to the research and definitions before the primary interview, which was important in reducing interview time. This information also helped in planning the interview structure. Phone contact with interviewees after the primary interview enabled the primary researcher to gather additional and missing information, and also to clarify initial findings.

Collectively, these methods and the overall approach worked very well to gather research depth. When compared to other studies, this work used qualitative methods similar to other NZ research conducted in the same or similar fields (Eastwood et al., 2016; Hammond, 2015; Tocker et al., 2006), which shows it is an effective method for this type of work. Therefore, this study adds to existing IS and agricultural software use and impact knowledge.

The major weakness of this research method is that the results cannot be generalised (or averaged) to a population. In this case, the ISs described by the group of farmers are not representative of all NZ dairy farmers, as the farmers were chosen on the basis of them readily using agricultural software. Furthermore, the software attributes that influence software use and impact, and the drivers and inhibitors of software use and impact, as expressed by these farmers and providers, are not representative of all NZ dairy farmers, or all NZ agricultural software providers. To get greater research breadth, quantitative methods (e.g. survey) could utilise the framework (study questions), IS, attributes and driver/inhibitors presented in this work.

6.6 Further research

This research focussed on exploring the use of software in feed and animal IS, as well as the software attributes that influence the use and impact of the software; and, the drivers and inhibitors of software use and impact. No evidence was gathered on the performance of farmers that use software, from either the farmers' perspective or software providers' perspective. Therefore, it could be useful to explore the performance indicators of farmers that utilise software compared and contrast with select farmers who use relatively 'less' (or limited) agricultural software in their IS, as a means of indicating quantitative impact of software.

With regard to feed IS, more qualitative research could be conducted to determine value proposition of feed management software. This would include a greater emphasis on identifying what data is used, when, why and how this data is processed into useful information; and, what information is important, when is it used and why. Also, a rigorous exploration of the attributes of software that farmers identified as being highly desirable in this study could be applied to selected software solutions in order to gain greater insights into the most important attributes. This could be used to create a 'guideline for agricultural software development'.

To explore the possibility of an 'integrated, all-encompassing, dairy farming software/system', collaborative research involving NZ farmers and external entities could be conducted to develop a conceptual model of how this could work. This could consider the software attributes, and the drivers and inhibitors identified in this study.

Lastly, more research needs to be conducted on software (and ICT) useful for strategic management and how this is provided, especially on the use of modelling software by farmers versus modelling provided to farmers by farm consultants which is the predominant method. Is the current business model of commercial strategic management software working for farmers? What other software (and data and information) do farmers use for strategic management? These questions could be explored through an assessment of the existing situation, with findings used to make improvements or suggest alternative business models.

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8.0 Appendices

Appendix 1.0: Method supporting documentation (pre-selection checklist, guiding questions and definition), participation form and consent sheet

1.1 Pre-selection checklist

1. Does your farm use software or smartphone applications (apps) for farm management?
2. What kind of software or apps do you (or your farm management team) use?
3. Briefly, can you provide examples of what are these used for?
4. Could you provide a brief overview of your farming operation, including:
    - Size of your herd, staff, production system and ownership structure?
5. Lastly, would you be interested in being part of a Massey University study which looks at how and why agricultural software is used for feed and animal management?

1.2.1 Farmer questionnaire and definitions

Basic farm business information (*Please briefly answer each of these questions)*

1. What enterprise/s (e.g. dairy and dairy beef) do you farm?
2. What is your farm production system (1-5), herd size (no. of cows) and milking platform hectares?
3. What is the business ownership structure (e.g. owner-operator, equity partnership etc.)?
4. How staff do you have and what are their roles (e.g. Brett = 2IC, Joel= dairy assistant)?
5. What are your key software (including computer software and smartphone applications, see page 2 for definition) for management of your dairy farm? *Please detail the approximate cost of each software (if known), both initial and/or on-going.*

<u>Definitions</u>

For the purposes of this research an **information system (IS)** has been described as: *A system that uses formal and informal components (and procedures) to provide farm management at all levels, in all functions, with appropriate information, based on data from both internal (inside the farm) and external (outside the farm) sources. IS enable timely and effective decision making for planning, implementing and controlling the farming activities*.

Agricultural software – *Computer or smartphone based programs, or applications, that are used for the management of agricultural business*. It includes both computer-based software packages and smartphone applications as core components of individual solutions, and will consider other ICT (precision agriculture and ICT infrastructure) as part of a farmer's IS.

1.2.2 Farmer guiding questions

Question	***Prompts***
Background and, business overview and structure	
1. Brief overview of the farming operation	• Check that this section has been sufficiently covered off.
Information system – Feed and Animal	
2. Can you describe your **Feed and Animal information systems**?	**Use example tables from Honours as prompts** Start with Decisions, and then jump back to Data collection and Information/Processing. • **Decisions** – What? Who? When? • **Data collection** – What? How? Who? When? • **Information/Processing** – What? Who? How? When?
Attributes that influence software use and impact (from literature)	
3. What is **most useful** about (1) feed technology (CRS Software Ltd) (2) animal technology; and why? **4.** What is **least useful** about (1) feed technology (CRS Software Ltd) (2) animal technology; and why?? ***Using Feed and Animal software examples could you answer the following questions for both. If the computer is handy then use this to demonstrate examples***	• Opening questions to start the ball rolling.
5. **Simplicity and/or complexity**?	• Does software address your requirements in terms of simplicity and complexity? • Is software easy to use – navigate, is the interface usable, and language suitable? • Are data input requirements and output suitable? • Is integration of software with other software or systems sufficient, or is this a problem/desire? •
6. **Software fit** with your farm working patterns (including staff use)?	• Accessibility, input requirements, alerts etc.
7. **Training, skill and knowledge requirements**; and **servicing/support and back-up**?	• Is this a limiting factor for software use? • Have you and your staff been sufficiently supported in this area? By whom?

8. **Accuracy**? (of models, or input/outputs)	• How sensitive is used software to user input/knowledge? • Does software sufficiently cater for uncertainty or risk? Is this a concern?
9. What is the **primary value** you obtain from using software for Feed and Animal management?	• Decision making, recording, profit, compliance? • Does this value outweigh the cost? (Please indicate the examples of software costs – running and purchase cost estimates)
Drivers and inhibitors that influence software use and impact generally	
10. Could you please comment on and discuss **the main factors that promote or inhibit the use and impact** of software on your farm business information systems? **11.** Which of these **promote and inhibit the use and impact of software the most**?	**These could include:** **Task factors –** Things to do with **the use of software:** Such as the **task being too difficult or incompatible** with what software offers/can achieve. **User and social characteristics –** Things to do with the **people using software**, so could include you and your staff, as well as **relationships with providers/developers** and other supporting people or entities: • **Attitude**. • **Trust and Support** of or from providers. • **Enjoyment**. • **Experience with using software**. **Project** – Things to do with the adoption and subsequent use of software. Such as: • Servicing. • Participation in development. • Relationships with Developers. • You and your staff preferences for using software as an alternative to manual/informal methods. **Organisational** – Things to do with **the farm and its resources**. Such as: • ICT infrastructure. • Management Support (e.g. broad reporting requirements). • Non-dairy staff software use capabilities. • Management requirements e.g. owners wanting you to use certain software. • External motivation (like compliance e.g. OVERSEER).

12. **Of the software you use, what could be improved**? How and why? And **what other software (or ICT) would you really like**?	

1.3.1 Software provider questionnaire and definitions

Basic business and product information

(Please briefly answer each of these questions)

1. What does your software do, for dairy farmers and for you?
2. How important is this software to this business?
3. What is the farmer uptake or use like for this product in NZ, and by dairy farmers?
4. What is the cost to the user?

<u>Definitions</u>

For the purposes of this research an **information system (IS)** has been described as: *A system that uses formal and informal components (and procedures) to provide farm management at all levels, in all functions, with appropriate information, based on data from both internal (inside the farm) and external (outside the farm) sources. IS enable timely and effective decision making for planning, implementing and controlling the farming activities*.

Agricultural software – *Computer or smartphone based programs, or applications, that are used for the management of agricultural business*. It includes both computer-based software packages and smartphone applications as core components of individual solutions, and will consider other ICT (precision agriculture and ICT infrastructure) as part of a farmer's information systems.

1.3.2 Software provider guiding questions

Question	*Prompts*
Example - Run through of how this software works and why it is useful	
13. Overview of the software in action **14.** How does this **business come up with ideas for new software, and how to improve existing software**?	• **Focus on the areas that dairy farmers would use most and why (purpose) – The need they are meeting** • **Where do the ideas come from?** • **Who is involved in the development and how e.g. are potential users involved?**
Attributes (features) that influence software use and impact. ***To be answered from a business perspective and farmers' perspective***	
Using example features/functions of this software could you answer the following questions. **15.** What are the **most important attributes** of this software? (Including the provision of software related services e.g. training and support). **16.** Which of these **attributes do they believe mostly enables or inhibits successful use** by farmers; and how does this software provide these attributes (if so)? **17.** What is the **primary value** you believe that farmers can obtain from using this software? **18.** **For this software, what could be improved**? How and why?	• **Simplicity/complexity** and **usability.** • **Software fit** – accessibility in the farm. • **Accuracy** of records or models. • **Training, support and servicing, and back-up.** • **Other.**

Drivers and inhibitors that influence software use and impact generally	
19. Could you please comment on and discuss **the main factors that promote or inhibit the adoption, use and impact** of agricultural software for dairy farming businesses? **20.** Which of these **factors promote and/or inhibit the use and impact of software the most**?	**These could include:** **Task factors –** Things to do with **the use of software:** Such as the **farm task being too difficult or incompatible** with what software offers/can achieve. **User and social characteristics –** Things to do with the **people using software**, so could include farm staff, as well as your **business relationships with farm users** and other supporting people or entities: • **Attitude to software use**. • **Trust and Support**. • **Enjoyment**. • **Experience with using software**. **Project (adoption and use)** – Things to do with the adoption and subsequent use of software. Such as: • Servicing. • Participation in development. • Relationships with Developers. • You and your staff preferences for using software as an alternative to manual/informal methods. **Organisational (Farm)** – Things to do with **the farm and its resources**. Such as: • ICT infrastructure. • Management Support (e.g. broad reporting requirements). • Non-dairy staff software use capabilities. • Management requirements e.g. owners wanting you to use certain software. • External motivation (like compliance e.g. OVERSEER).
21. And **what other software (or ICT developments) would assist greater use of software by dairy farmer?**	**Data and information transferability/interoperability? The future of agricultural software and ICT?**

1.4 Farmer information sheet and consent form

Research information sheet - Farmers

Agricultural software – A case study of feed and animal information systems in the New Zealand dairy industry

The overall aim of the study to:

Explore how New Zealand dairy farmers use agricultural software in feed and animal information systems; and determine the software attributes, and, drivers and inhibitor that influence the use and impact of the software. A case study approach will be used to investigate this from the perspectives of both farmers and software providers.

Study information

You are formally invited to participate in this study. The following information provides details of the activities involved in your potential participation.

To fulfil the overall aim of this study, evidence will be gathered from a primary interview in person with "you", the participating interviewee/s, and a field observation at your business premises. This will be followed by a second shorter interview (possibly by phone), used to clarify and build on the initial findings of the primary interview.

At the primary interview, I would like to take you through a series of guiding questions pertaining to the feed and animal information systems used on your dairy farm, with a particular focus on the agricultural software in use. These questions will help to discuss how and why agricultural software is used, the attributes that influence the use and impact of software, and the drivers and inhibitors of software use and impact in general.

The primary interview will likely take 90 minutes of discussion time. Findings from the discussion will be supported by 30 minutes of time spent observing software in use (if possible) to further demonstrate and explain examples of how software is used, and the impact it has on the farming operation.

The second interview will take up to 30 minutes, used to clarify and elaborate on details from the first interview. The time and date of the second interview will be determined with you after the primary interview, but is expected to be within two weeks of the first. Interviews will be taped and transcribed with your permission. A transcription or summary of the interview can be provided on request.

The findings will be verified with you before being written up as a case study report. The verified findings will then be published into a thesis. The confidentiality of each case study will be preserved by **excluding** any name of participants (and specific farm name) in any subsequent publications.

You are under **no** obligation to accept this invitation. If you choose to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study at any time;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded, and;
- ask for the voice recorder to be turned off at any time.

The primary researcher of this project is Hamish Hammond, a Masters of AgriCommerce student at Massey University, Palmerston North.

Professor Nicola Shadbolt and Dr Liz Dooley, both from the Institute of Agriculture and Environment at Massey University, will provide supervision and support.

Researchers address in New Zealand:

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Telephone Number: +64 6 356 9099 ext 85683
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Supervisors' contact details:

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This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher named above is responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact: Mr Jeremy Hubbard, Chairperson of Research Ethics, School of Accountancy, telephone +64 4 801 5799 ext. 63487, email humanethicsoutha@massey.ac.nz

PARTICIPANT CONSENT FORM

Project Title: Agricultural software – A case study of feed and animal information systems in New Zealand dairy farming.

Researcher:

Hamish Hammond

I have been provided with information about this research project and have had the opportunity to clarify any questions I may have. **YES/NO**

I understand the information I provide is confidential and that my name will not be used in project reports or publications. **YES/NO**

I agree to participate in this study under the conditions set out in the information sheet.

YES/NO

I agree to the interview being sound recorded. **YES/NO**

I agree to abide by the above conditions.

Signature: .... **Date:** ....

Full Name - printed ....

Signature: .... **Date:** ....

Full Name - printed ....

1.5 Software provider information sheet and consent form

Research information sheet – Software providers

Agricultural software – A case study of feed and animal information systems in the New Zealand dairy industry

The overall aim of the study to:

Explore how New Zealand dairy farmers use agricultural software in feed and animal information systems; and determine the software attributes, and, drivers and inhibitors that influence the use and impact of the software. A case study approach will be used to investigate this from the perspectives of both farmers and software providers.

Study information

You are formally invited to participate in this study. The following information provides details of the activities involved in your potential participation.

To fulfil the overall aim of this study, evidence will be gathered from a primary interview in person with "you", the participating interviewee/s, and a field observation at your business premises. This may be followed by a second shorter interview (possibly by phone), to clarify and build on the initial findings of the primary interview.

At the primary interview, I would like to take you through a series of guiding questions pertaining to the 'agricultural software of interest'. These questions will help to discuss how and why this software is used, the attributes that influence the use and impact of software, and the factors that influence the use and impact of software in general.

The primary interview will likely take 60 minutes of discussion time. Findings from the discussion will be supported by 15-30 minutes of time spent observing software in use (*if possible)* to further demonstrate and explain examples of how software is used, and the impact it has on dairy farming operations.

A possible second interview will likely take up to 15-20 minutes, and be used to clarify and elaborate on details from the first interview. The time and date of the second interview will be determined with you after the primary interview, but is expected to be within 2-4 weeks of the first. Interviews will be taped and transcribed with your permission. A transcription or summary of the interview can be provided on request.

The findings will be verified with you before being written up as a case study report. A summary of the verified findings will then be published into a thesis. The confidentiality of each case study will be preserved by **excluding** the name of any participants and their business in any publications, including the thesis.

You will also be able to review the case study report and if this includes any sensitive information, that you are unwilling to share, you can ask for this to be excluded from any publications.

You are under **no** obligation to accept this invitation. If you choose to participate, you have the right to:

- decline to answer any particular question;
- ask for the voice recorder to be turned off at any time;
- withdraw from the study at any time prior to two weeks after the provision of write-up for rectification;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher; and;
- be given access to a summary of the project findings when it is concluded.

The primary researcher of this project is Hamish Hammond, a Masters of AgriCommerce student at Massey University, Palmerston North.

Professor Nicola Shadbolt and Dr Liz Dooley, both from the Institute of Agriculture and Environment at Massey University, will provide supervision and support.

Researcher's address in New Zealand:

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If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact: Mr Jeremy Hubbard, Chairperson of Research Ethics, School of Accountancy, telephone +64 4 801 5799 ext. 63487, email humanethicsoutha@massey.ac.nz

PARTICIPANT CONSENT FORM

Project Title: Agricultural software – A case study of feed and animal information systems in New Zealand dairy farming.

Researcher: Hamish Hammond

I have been provided with information about this research project and have had the opportunity to clarify any questions I may have. **YES/NO**

I understand that my name (and content provided under the name of my business) will not be used in project reports or publications. **YES/NO**

I agree to participate in this study under the conditions set out in the information sheet.

YES/NO

I agree to the interview being sound recorded. **YES/NO**

Signature: .... **Date:** ....

Full Name - printed ....

....

....

Signature: .... **Date:** ....

Full Name - printed ....

Appendix 2.0: Farmer feed and animal software use and impact overview

2.1 Farm 1

Table 18, Farm 1 software use, impact and cost

Software in use (for feed or/and animal management)	Major use	Major impact	Approximate cost (if known)
LIC's MINDA Land and Feed (part of MINDA Live online software), and MINDA Pasture app	Pasture management	Operational and tactical feed planning	Included in the cost of LIC's MINDA
Own Microsoft Excel spreadsheets	Feed inventory management	Operational and tactical feed planning	Microsoft Excel - ~$199
DairyNZ Spring Rotation Planner (online content)	Rotation length planning	Operational and tactical feed planning	Free
Harvest Electronics website and Greater Wellington District Council website	Water (and irrigation) management	Operational resource planning and control	$470 per annum for Harvest Electronics
LIC's MINDA Calving app	Calving records	Operational animal control	Included in the cost of LIC's MINDA
LIC's MINDApro (desktop software) and MINDA Mating app	Mating records	Operational animal control	Cost of LIC's MINDA, per month - $47.94 per herd and $0.24 per animal
LIC's MINDApro (desktop software) and MINDA Look up app	Herd record management	Animal management at every level	Included in the cost of LIC's MINDA
Fonterra's Farm Source website and app	Milk production quality and quantity information	Operational production control	Free
LIC's MINDA Weights (part of MINDA Live online software)	Young stock weights	Operational animal weight control	Included in the cost of LIC's MINDA
LIC's MINDApro (desktop software)	NAIT compliance	Operational implementation	Included in the cost of LIC's MINDA

2.2 Farm 2

Table 19, Farm 2 software use, impact and cost

Software in use (for feed or/and animal management)	Major use	Major impact	Approximate cost (if known)
Own Microsoft Excel spreadsheets	Feed budgeting	Operational and tactical feed and animal planning	Microsoft Excel - ~$199 one-off cost
FMG Rural Weather app	Weather	Operational feed planning	Free
LIC's MINDApro (desktop software) and MINDA Look up app	Herd record management	Animal management at every level	Cost of LIC's MINDA, per month - $47.94 per herd and $0.24 per animal
LIC's Datamate app	Mating records, via A.I technician	Operational animal mating control	Part of A.I service
DairyNZ 'Bull Team Builder' online content	Bull selection	Operational and tactical animal planning	Free
DairyNZ BCS app	Body condition scoring	Operational animal condition control	Free
Open Country website	Milk production	Operational production control	Free
LIC's MINDApro (desktop software)	NAIT compliance	Operational implementation	Included in the cost of LIC's MINDA

2.3 Farm 3

Table 20, Farm 3 software use, impact and cost

Software in use (for feed or/and animal management)	Major use	Major impact	Approximate cost (if known)
Own Microsoft Excel spreadsheets, FarmKeeper and Pasture Coach	Feed budgeting	Operational and tactical feed and animal planning	Microsoft Excel - ~$199 one-off cost; FarmKeeper - $250 one-off cost; PastureCoach - $145 per annum
Ag Hub - Paddock Diary - online	Paddock management (individual paddock-related records)	Operational resource implementation and control	$200 per annum
Sentek information (accessed online via smartphone) and Horizons Council website	Water (and irrigation) management	Operational resource planning and control	Free access to Sentek information. Cost of hardware and, repair and maintenance
Weather app	Weather forecast	Operational feed and animal movement planning	Free
LIC's MINDApro (desktop software), synchronised with Protrack Vector in-shed software	Herd record management and in-shed operations	Animal management at every level and function.	Cost of LIC's MINDA, per month - $47.94 per herd and $0.24 per animal
LIC's Datamate app	Mating records, via A.I technician	Operational animal mating control	Part of A.I service
LIC's Protrack Vector in-shed software	In-shed animal management - alerts and health recording	Operational in-shed implementation	~$1200 per annum
Fonterra's Farm Source website and Farmsource app, and Open Country website	Milk production quality and quantity information	Operational production control	Free
LIC's MINDA Health app	Young stock management	Operational implementation	Included in the cost of LIC's MINDA
LIC's MINDApro (desktop software)	NAIT compliance	Operational implementation	Included in the cost of LIC's MINDA

2.4 Farm 4

Table 21, Farm 4 Software use, impact and cost

Software in use (for feed or/and animal management)	Major use	Major impact	Approximate cost (if known)
Own Microsoft Excel spreadsheets; FarmKeeper (desktop software); and Farmax Pasture Growth Forecaster website	Feed budgeting	Feed management at every level, primarily used for planning and control purposes	Microsoft Excel - ~$199; FarmKeeper - $250 one-off cost; Farmax Pasture Growth Forecaster - free version
MyRavensdown and Smartmaps website	Fertiliser ordering, application and reporting	Operational fertiliser planning, implementation and control	Free as part of Ravensdown shareholders service
DeLaval Alpro in-shed desktop software	In-shed feed management	Operational feed planning and implementation, and used for tactical planning, implementation and control	~$6500 one-off cost
CRV Insight website and Insight app	Herd record management	Animal management at every level and function	$280 per annum. Animal costs of $2.70 per cow, and a $1.50 for 'young stock'
DeLaval Alpro in-shed desktop software	In-shed animal management and aspects of herd management (including individual cow milk production, individual cow weights and animal health)	Operational animal implementation and control	~$6500 one-off cost
Fonterra's Farm Source website and app	Milk production	Operational production control.	Free
Own Microsoft Excel spreadsheets	Young stock weights	Operational control	Microsoft Excel - ~$199 one-off cost
CRV Insight website	NAIT compliance	Operational implementation	Included in the cost of CRV Insight

2.5 Farm 5

Table 22, Farm 5 software use, impact and cost

Software in use (for feed or/and animal management)	Major use	Major impact	Approximate cost (if known)
LIC's MINDA Land and Feed (part of MINDA Live online software), and MINDA Pasture app; and TracMap website	Pasture, fertiliser and spraying management	Operational feed planning, implementation and control	LIC's MINDA Land and Feed - included in the cost of MINDA; TracMap - $0.20 per hectare (charged via contract fertiliser spreader)
Zoho app, used to create own feed calculator	Daily feed allocation	Operational feed planning	$100 per annum for Zoho app creator
Jantec in-shed desktop software (including cups on terminal)	In-shed animal management and overall herd management (including individual cow milk production and 'cell sense', animal alerts, animal health, mating and operation of the feed system)	Animal management at every level and function	Included in the cost of dairy shed hardware installation
UDDER (desktop software)	Seasonal planning	Feed and animal, tactical and strategic planning	Via farm consultant
NAIT website	NAIT compliance	Operational implementation	Free

2.6 Farm 6

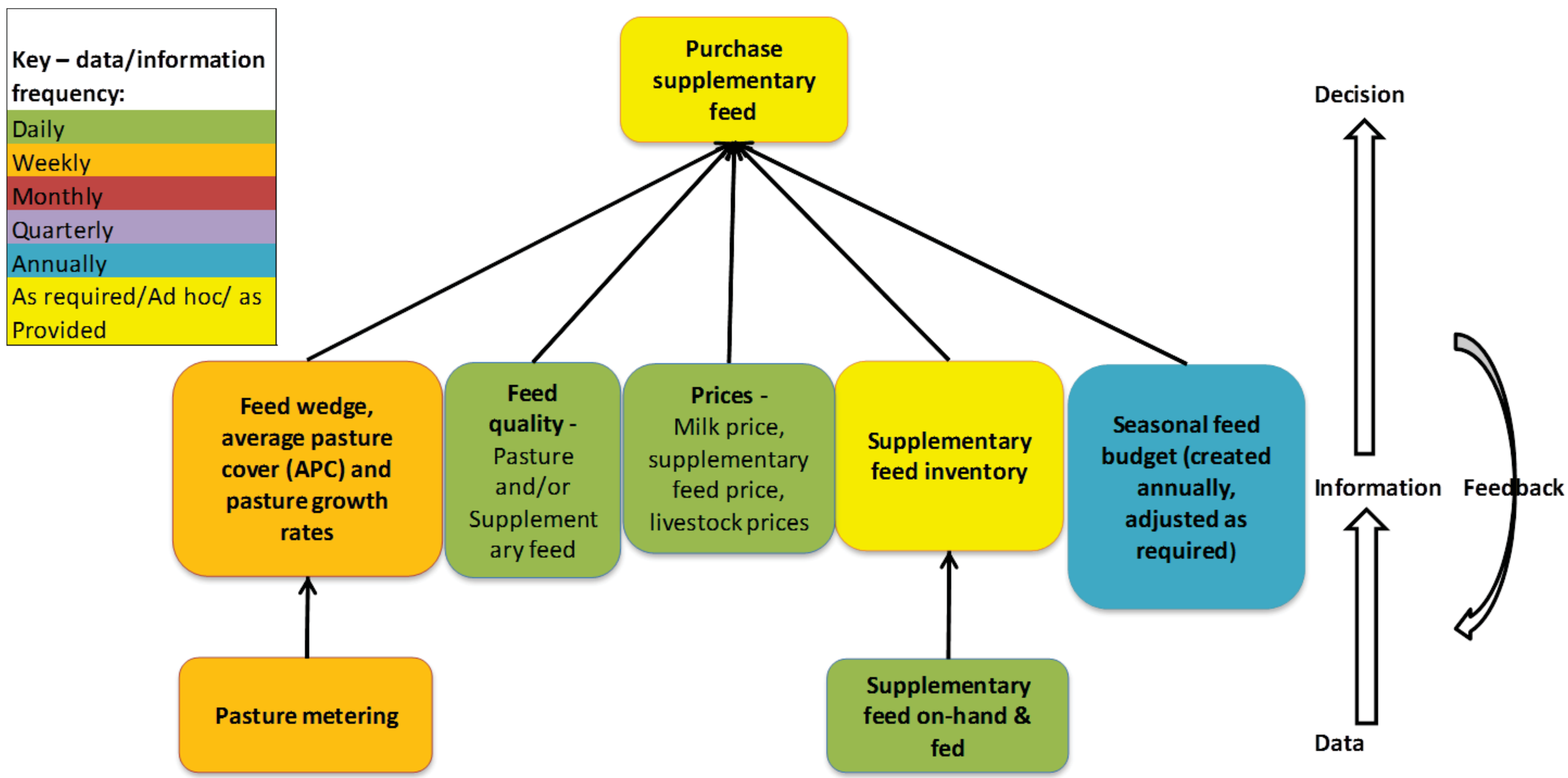
Table 23, Farm 6 software use, impact and cost

Software in use (for feed or/and animal management)	Major use	Major impact	Approximate cost (if known)
Farmax Professional desktop software, FarmIQ online software, Pasture Coach (desktop software) and 'DPR'. A few "small" farm managers use MINDA Land and Feed (part of MINDA Live online software) and MINDA Pasture app	Feed allocation, particularly for feed wedge creation; and feed benchmarking on DPR	Operational feed planning and control; DPR is used for management planning and control	Farmax - $150 per month; FarmIQ -?; Pasture Coach - $145 per annum; LIC's MINDA Land and Feed - included in the cost of MINDA. DPR is owned by this business
FarmIQ online software	Paddock management (individual paddock-related records)	Operational and tactical resource control	-
Tru-Test's MiHub (software at shed that is cloud based, and app), LIC's MINDApro desktop software (and MINDA Live) and FarmIQ online software	"Big farm" animal management (including in-shed) and individual cow milk production and cell count (from MiHub hardware)	Animal management at every level and function	Tru-Test's MiHub - ?; LIC's MINDA per month - $47.94 per herd and $0.24 per Animal; FarmIQ - ?
MINDApro desktop software (and MINDA Live), MINDA apps (Look-up and Calving) and FarmIQ online software	"Small farm" herd record management	Animal management at every level and function	LIC's MINDA per month - see above. FarmIQ - ?
LIC's Datamate app	Mating records, via A.I technician	Operational control	Part of A.I service
Fonterra's Farm Source website and app	Milk production	Operational production control	Free
FarmIQ online and LIC's MINDA Weights (part of MINDA Live)	Young stock weights	Operational control	FarmIQ - ?; LIC's MINDA Weights - included in the cost of MINDA

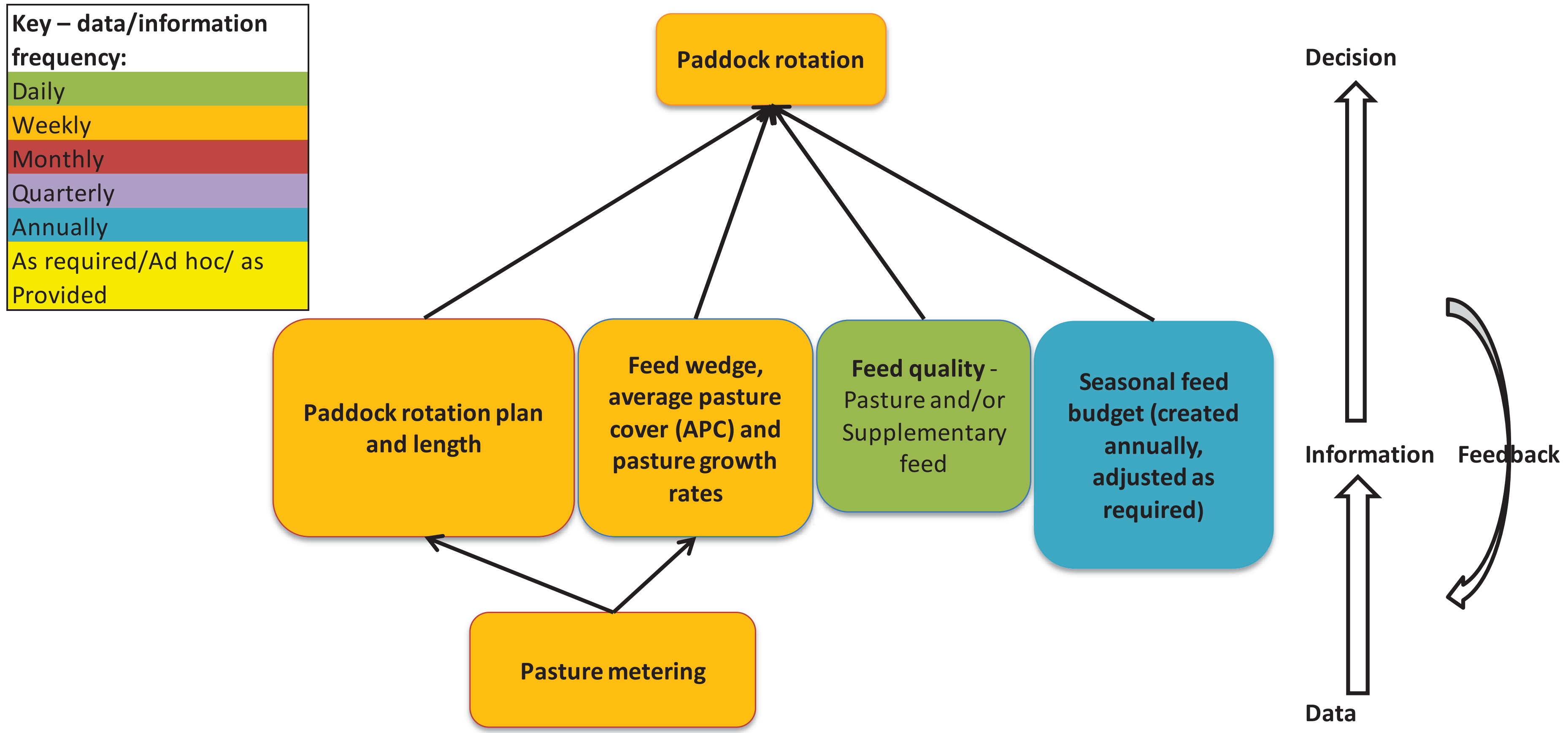
OVERSEER	Farm system development	Tactical and strategic planning and control	Provided by 'upper management'
Farmax Professional desktop software and UDDER desktop software	Seasonal planning	Tactical and strategic planning and control	Farmax Professional- $150 per month; UDDER is charged via farm consultant fees
FarmIQ online software	NAIT compliance	Operational implementation	-

Appendix 3.0: Diagrams of feed information systems according to farmers

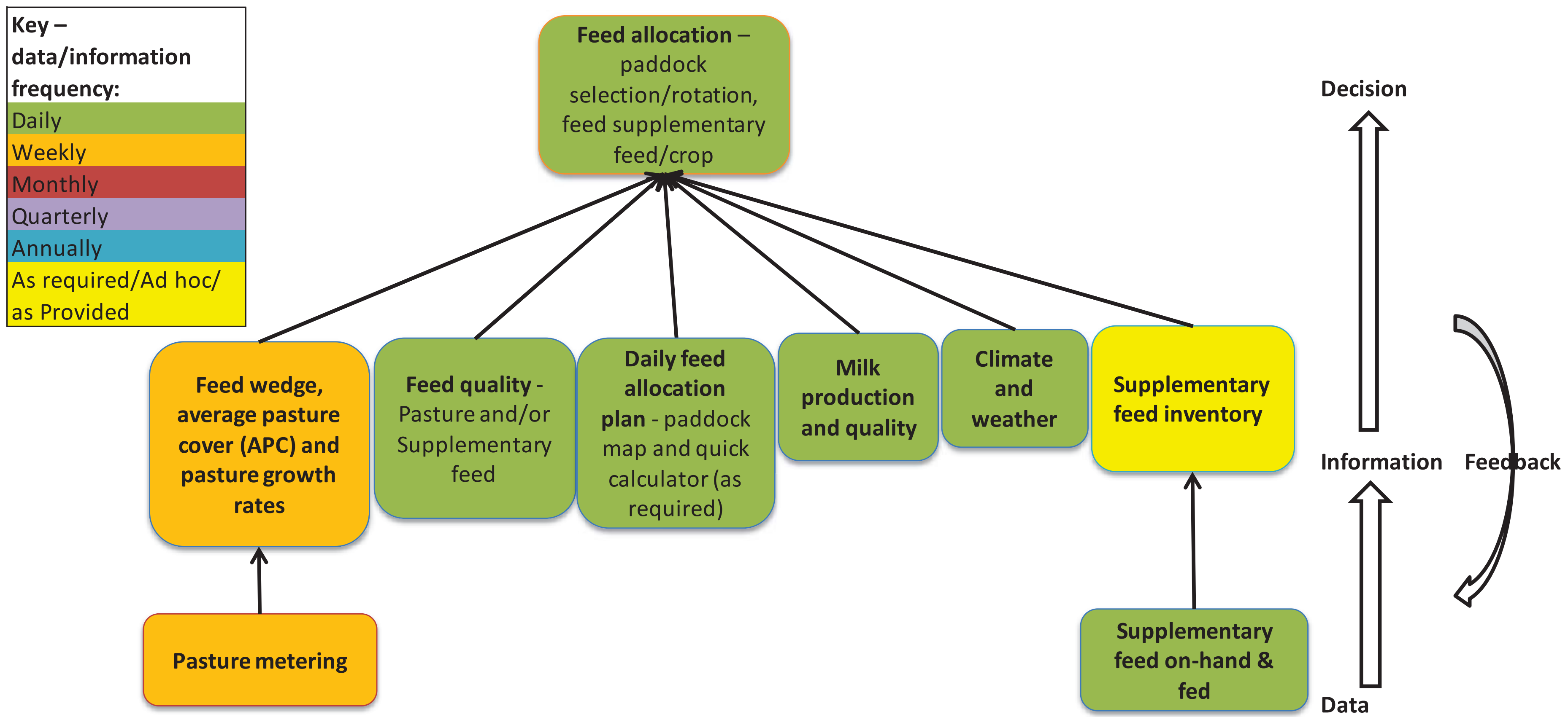
3.1 Feed information system - Purchase supplementary feed sub-system



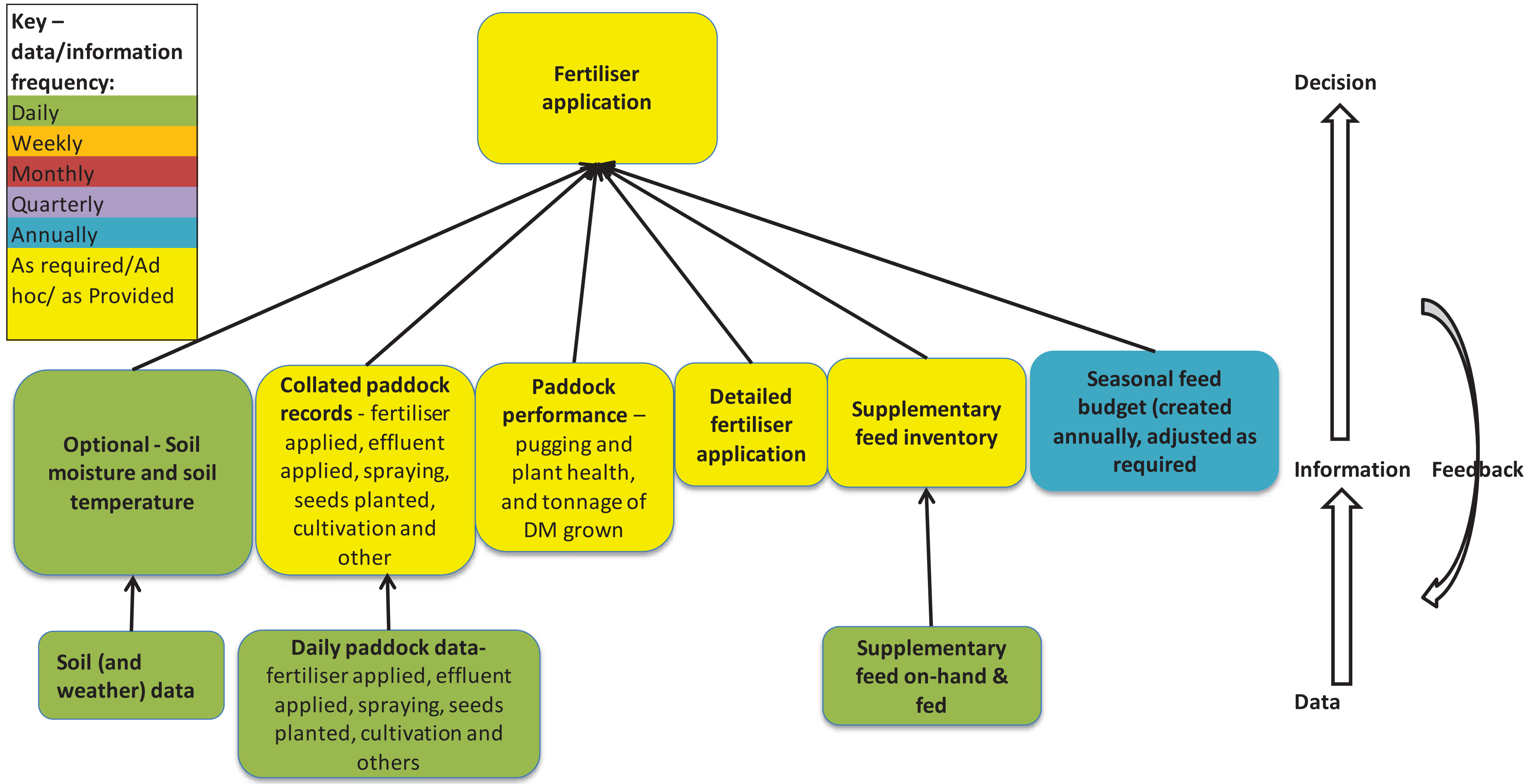
3.2 Feed information system – Paddock rotation length sub-system



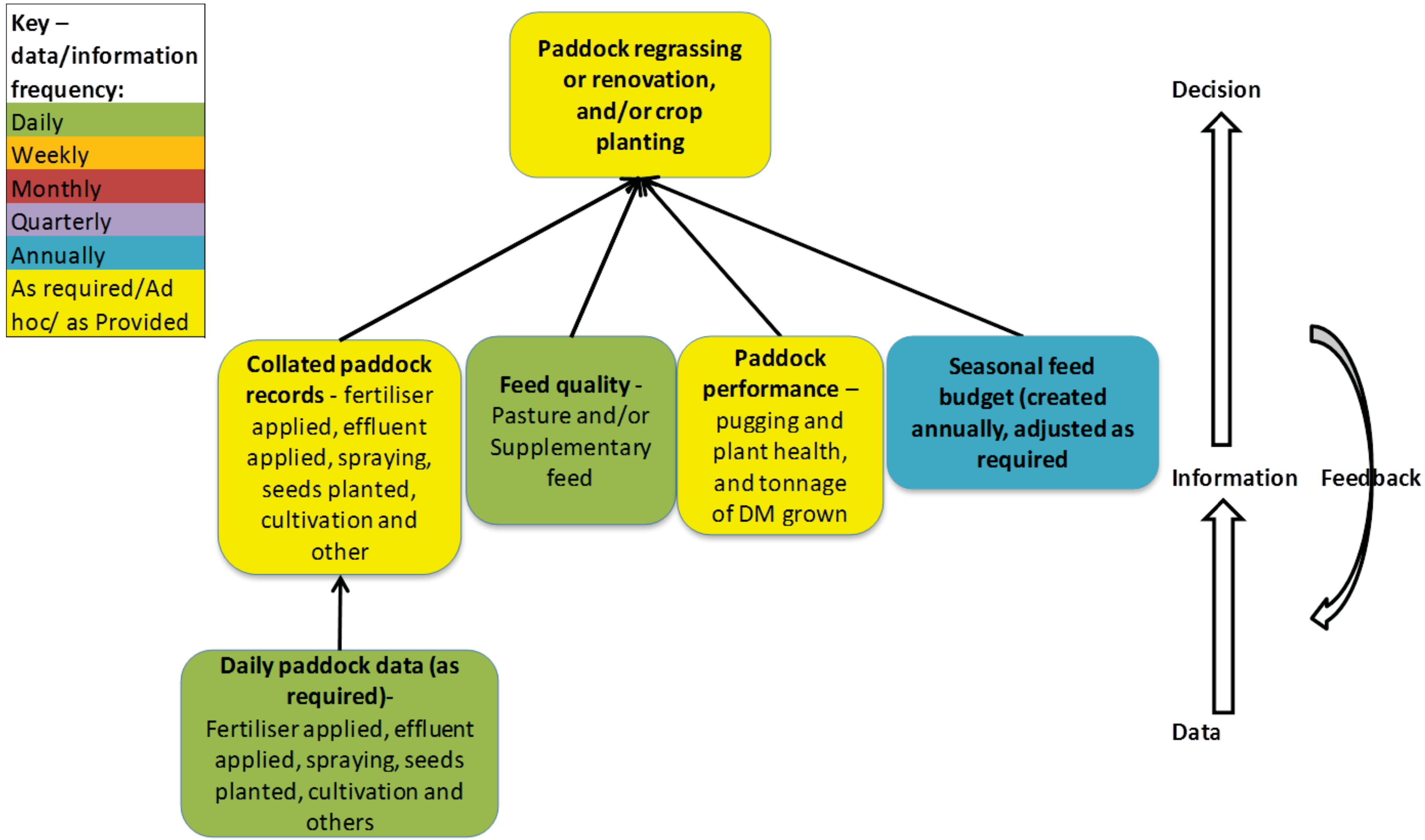
3.3 Feed information system – Feed allocation sub-system



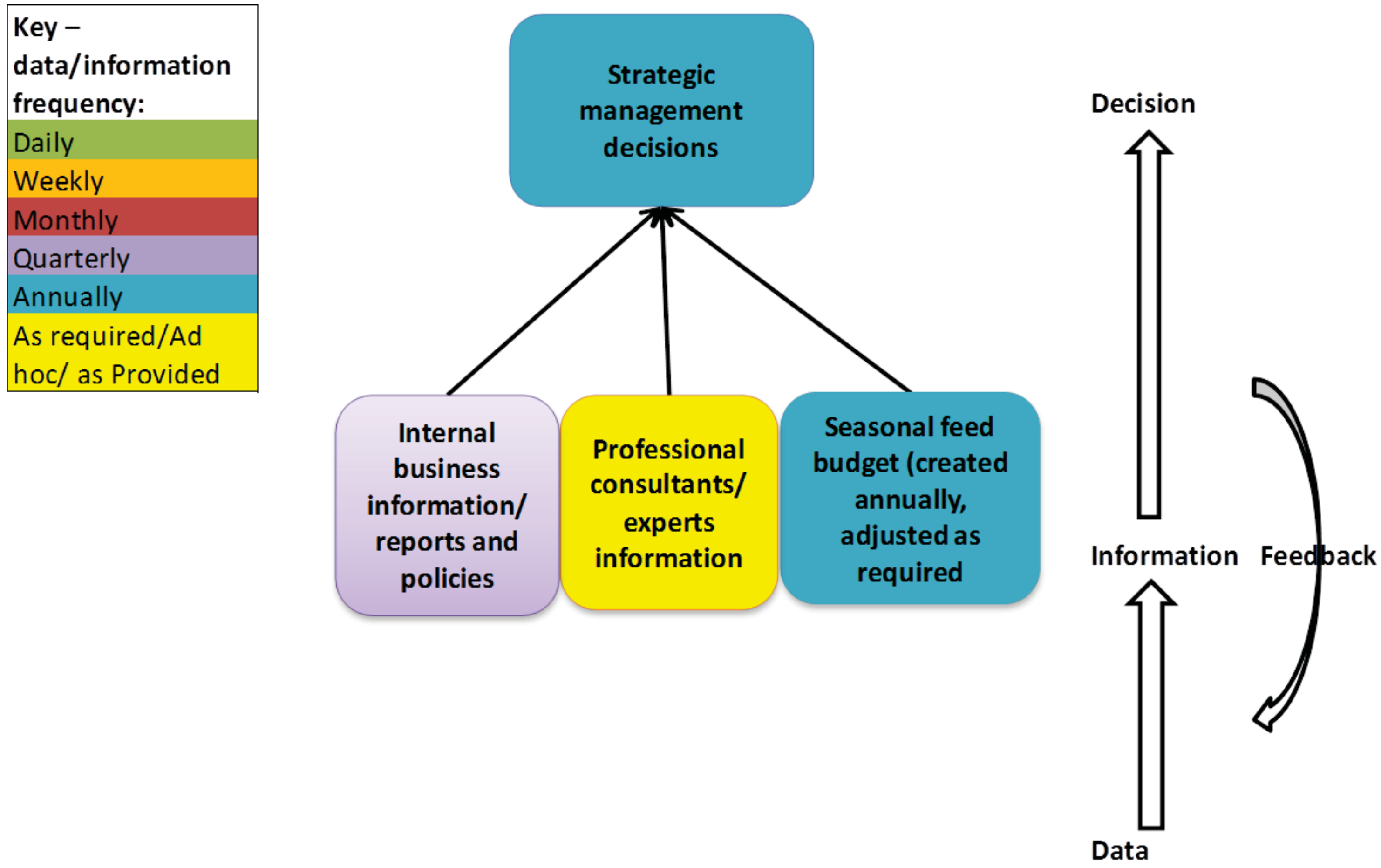
3.4 Feed information system – Fertiliser application sub-system



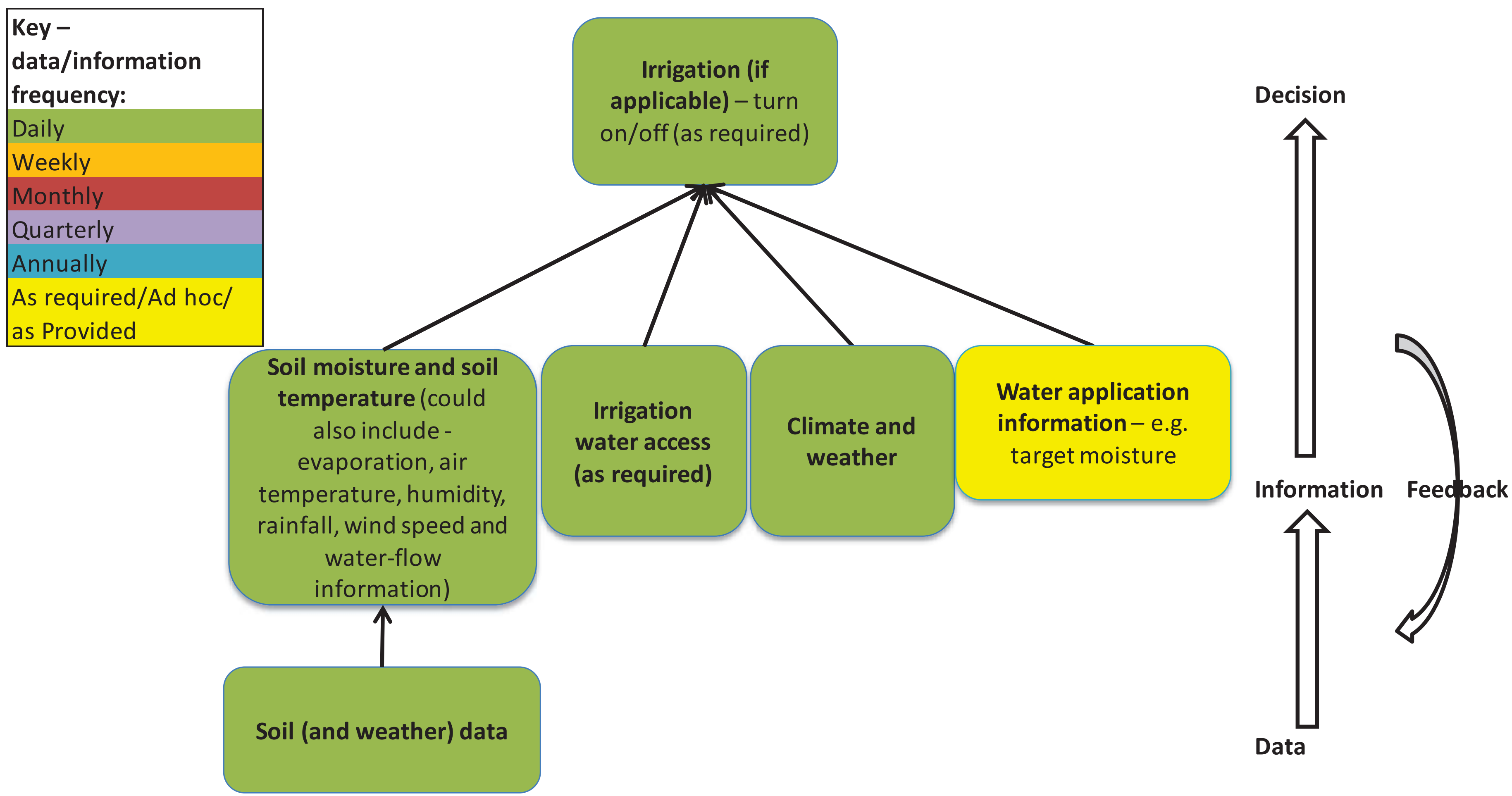
3.5 Feed information system - Paddock regrassing or renovation, and/or crop planting



3.6 Feed information system – Strategic management sub-system



3.7 Feed information system – Irrigation sub-system



3.8 Feed information system - Input data, output information, tool, frequency and sub-system use

Input data	Tool (How)	Frequency	Considered for which sub-system/s
Soil (and weather) data (if applicable)	Soil probes - for moisture and temperature data	Daily	Fertiliser application; Irrigation (if applicable)
Daily paddock data- fertiliser applied, effluent applied, spraying, seeds planted, cultivation and others	Visual or written assessment	Daily	Fertiliser application; Paddock regrassing or renovation, and/or crop planting
Supplementary feed on-hand & fed	Weigh scales (on tractor/wagon); and, visual assessment (for on-hand)	Daily	Purchase supplementary feed; Fertiliser application; Feed allocation
Pasture metering	Pasture meter and ‘eye’; or, tow-behind pasture meter	~Weekly	Purchase supplementary feed; Paddock rotation length; Feed allocation
Information output	**Tool (How)**	**Frequency**	**Considered for which sub-system/s**
Feed quality - Pasture and/or Supplementary feed	Visual assessment; and/or Lab testing (ad hoc)	Daily	Paddock rotation; Feed allocation; Purchase supplementary feed; Paddock regrassing or renovation, and/or crop planting

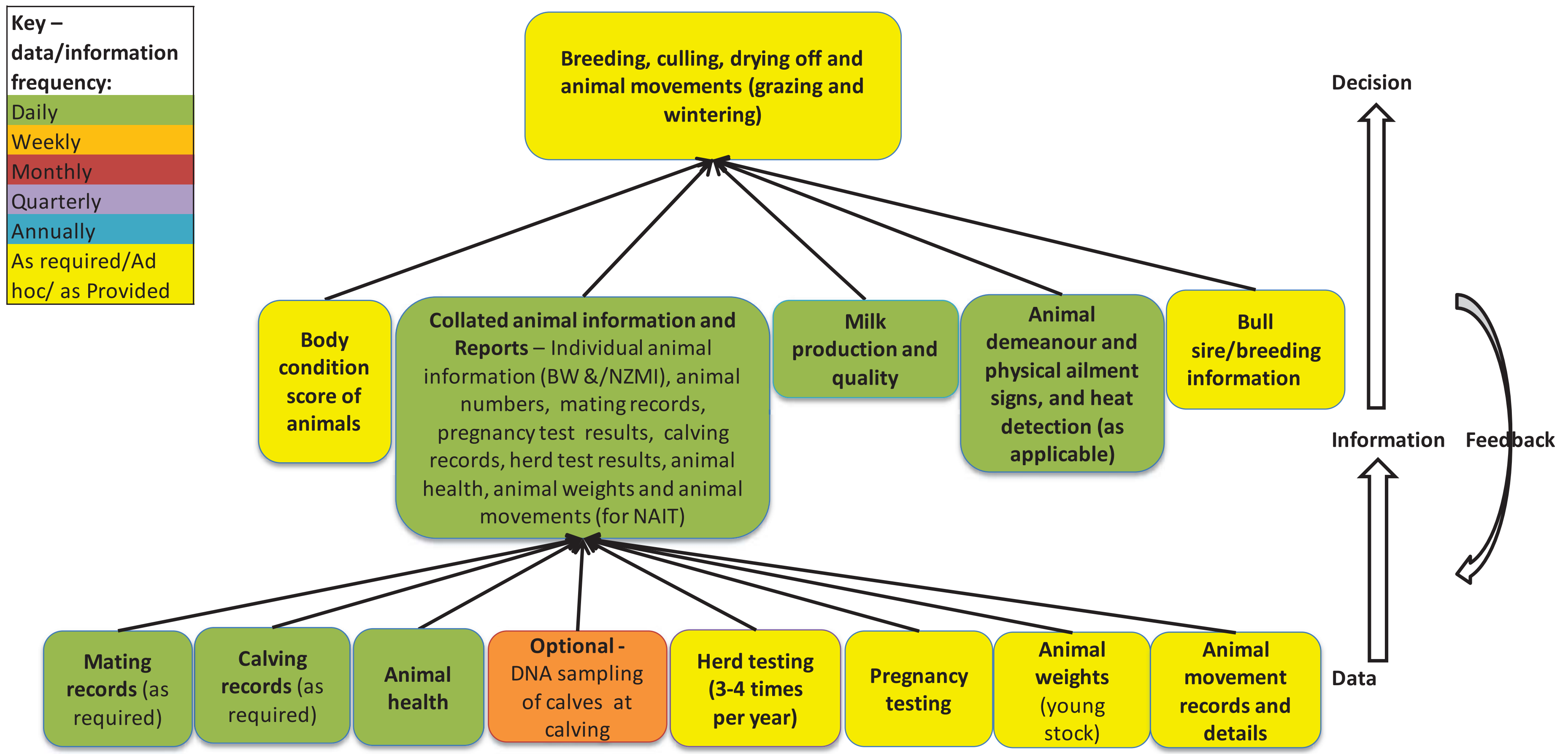
Daily feed allocation plan - paddock map and quick calculator (as required)	Options include (and variations of): Excel; online spreadsheet app; Google maps; TracMap online	Daily	Feed allocation
Milk production and quality	Milk processor website and app; and, milk docket	Daily	Feed allocation
Climate and weather	Options include (and variations of): Observation; weather gauge and online information from weather station; weather app; and online weather websites.	Daily	Feed allocation; Irrigation (if applicable)
Irrigation water access (as required)	Online council website – shows river-flow and restrictions	Daily	Irrigation (if applicable)
Optional - Soil moisture and soil temperature (could also include - evaporation, air temperature, humidity, rainfall, wind speed and water-flow information)	Website - access using user login on smartphone	Daily	Fertiliser application; Irrigation (if applicable)
Prices - Milk price, supplementary feed price, livestock prices	Company reps communications; meetings with reps; and company communications	Daily	Purchase supplementary feed

Feed wedge, average pasture cover (APC) and pasture growth rates	Options include (and variations of): MINDA Land and Feed (app and online); Pasture Coach; Excel; FarmKeeper; or, Paper report	Weekly	Paddock rotation; Feed allocation; Purchase supplementary feed
Paddock rotation plan and length	Options include (and variations of): Whiteboard at the dairy shed; DairyNZ SRP online; White board @ shed; and Farm map	Weekly	Paddock rotation
Seasonal feed budget (created annually, adjusted as required) - cow numbers, supplementary feed, cropping/pasture renewal, silage making and fertiliser use	Options include (and variations of): Excel; Farmax; and UDDER. Farmax and UDDER may be operated by a consultant, for the farmer.	Annually	Paddock rotation; Fertiliser application; Purchase supplementary feed; Paddock regrassing or renovation, and/or crop planting; Strategic management
Paddock performance –pugging and plant health, and tonnage of DM grown	Options include (and variations of): Visual/observation; Pasture Coach; FarmKeeper + Excel	As required	Fertiliser application; Paddock regrassing or renovation, and/or crop planting

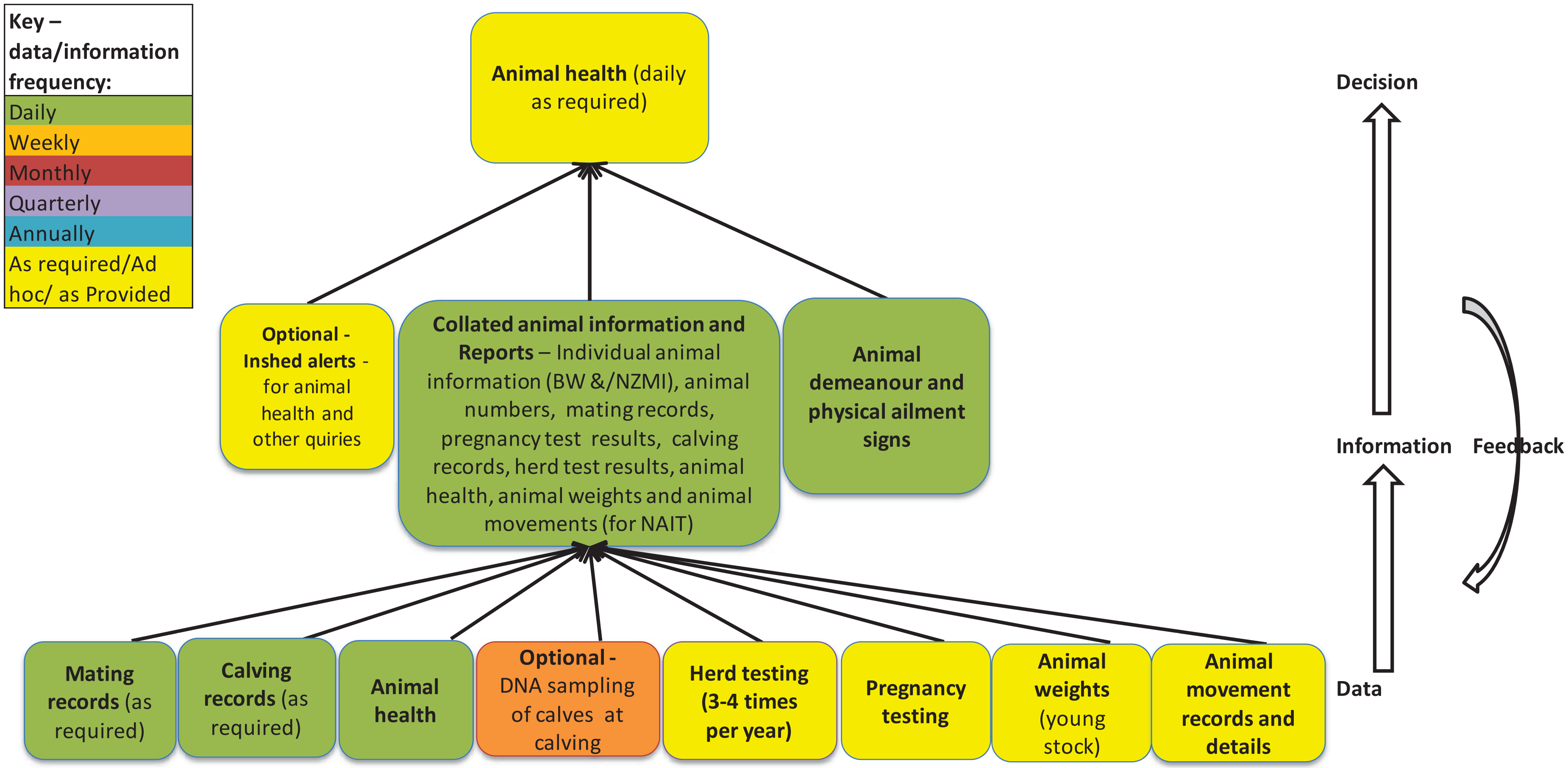
Collated paddock records - fertiliser applied, effluent applied, spraying, seeds planted, cultivation and other	Options include (and variations of): AgHub; MINDA Land and Feed; FarmIQ	As required	Paddock regrassing or renovation, and/or crop planting; Fertiliser application
Supplementary feed inventory	Options include (and variations of): MINDA Land and Feed; UDDER; Farmax; Excel	As required	Purchase supplementary feed; Feed allocation; Fertiliser application
Detailed fertiliser application	Printed map from spreader; TracMap website	As required	Fertiliser application
Water application information – e.g. target moisture	Discussion Groups – DairyNZ and Irrigation experts	As required	Irrigation (if applicable)
Decisions		**Frequency**	
Feed allocation – paddock selection/rotation, feed supplementary feed/crop		Daily	
Irrigation (if applicable) – turn on/off (as required)		Daily	
Paddock rotation length		Weekly	
Strategic management		Annually	
Purchase supplementary feed		As required	
Fertiliser application		As required	
Paddock regrassing or renovation, and/or crop planting		As required	

Appendix 4.0: Diagrams of animal information systems according to farmers

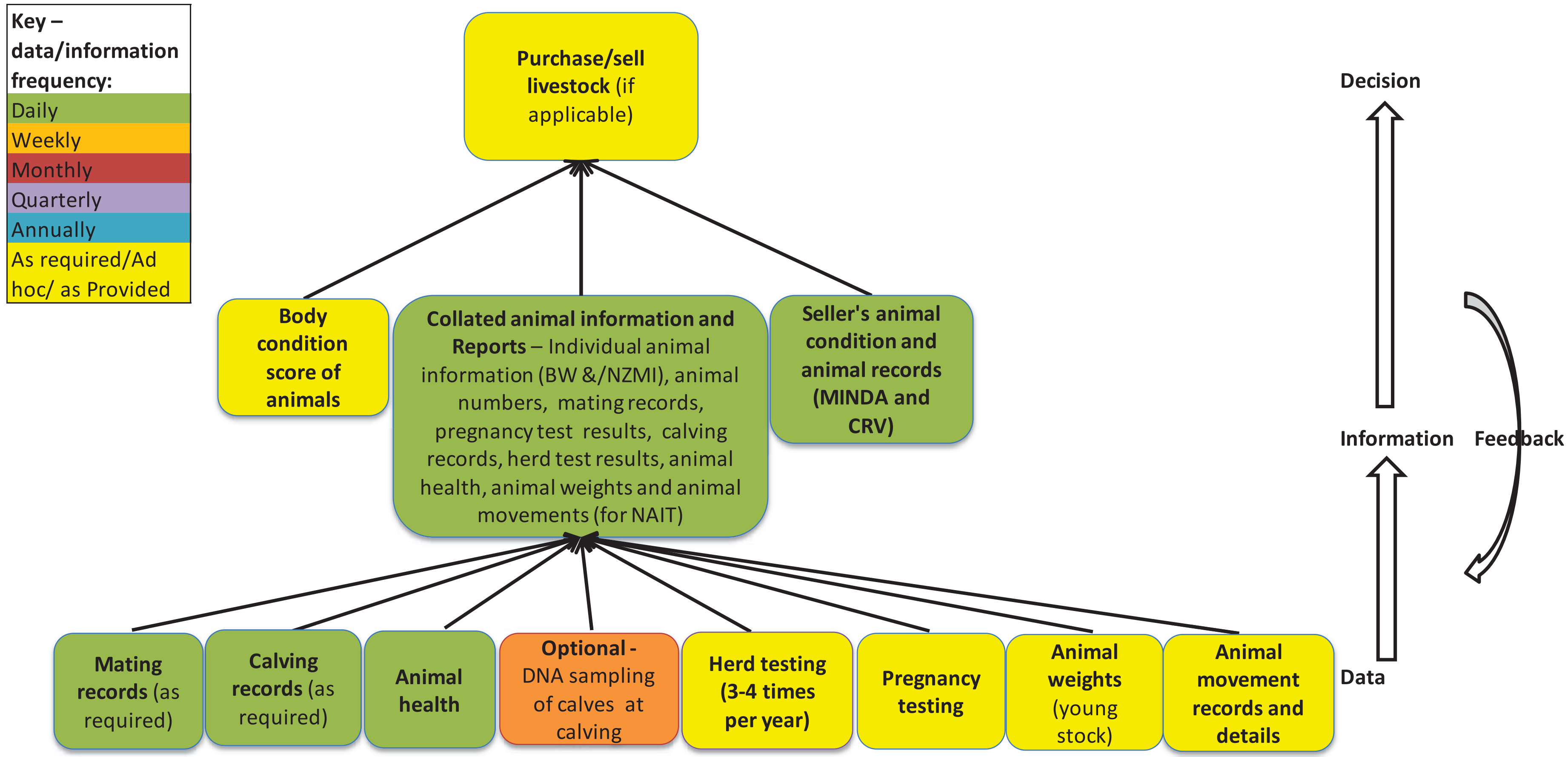
4.1 Animal information system - Breeding, culling, drying off and animal movement sub-system



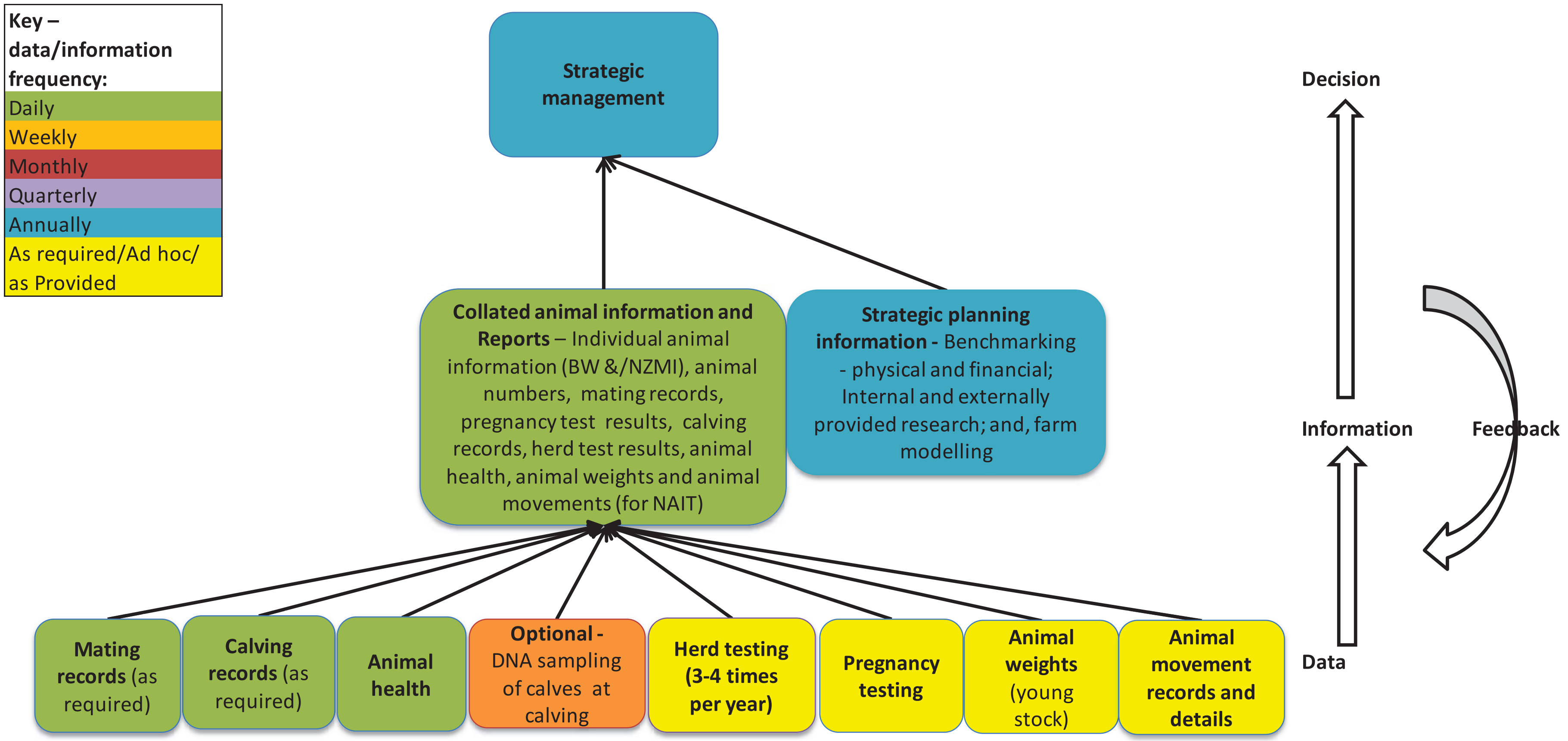
4.2 Animal information system - Animal health sub-system



4.3 Animal information system - Purchase/sell livestock sub-system

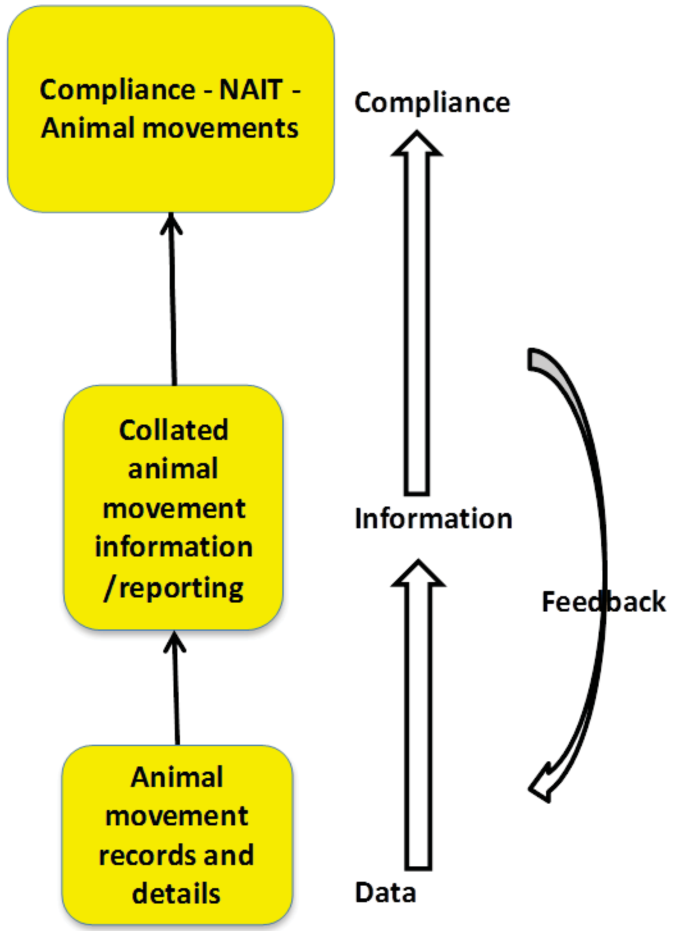


4.4 Animal information system - Strategic management sub-system



4.5 Animal information system - Compliance with NAIT sub-system

Key – data/information frequency:
Daily
Weekly
Monthly
Quarterly
Annually
As required/Ad hoc/ as Provided



4.6 Animal information system - Input data, output information, tool, frequency and sub-system use

Input data	Tool (How)	Frequency	Considered for which sub-system/s
Mating records (as required)	Recorded on paper or into an app (LIC's Datamate or CRV's Portabull) used by artificial insemination technician	Daily (as required)	All sub-systems
Calving records (as required)	Recorded on paper e.g. ‘yellow notebook’; some farmers may use MINDA app, but not in the paddock	Daily (as required)	All sub-systems
Animal health - treatments	Recorded on paper in treatment book and/or on a 'whiteboard'. Could also be recorded directly into an app (MINDA Health or CRV Insight - Mobile)	Daily (as required)	All sub-systems
Optional - DNA sampling of calves at calving	DNA sampling equipment. Sent to Lab.	Weekly (as required)	All sub-systems
Herd testing	Service provider's equipment. Results sent to software by provider	As required	All sub-systems
Pregnancy testing	Vet equipment. Results are either recorded and sent through to software by vet, or farmer records on paper at the time	As required	All sub-systems
Animal weights (young stock)	Weigh scales and phone/paper recorded. Could include daily weighing of MA cows at dairy shed	As required	All sub-systems
Animal movement records and details	Ear tag reader (wand) and EID ear tags; or paper records	As required	All sub-systems

Information output	Tool (How)	Frequency	Considered for which sub-system/s
Collated animal information and Reports – Individual animal information (BW &/NZMI), animal numbers, mating records, pregnancy test results, calving records, herd test results, animal health, animal weights and animal movements (for NAIT)	Options include (and variations of): MINDApro and/or MINDALive, and MINDA app; or, CRV Insight - Web and Insight - Mobile app; or, Jantec (limited features). May also include Tru-Test MiHub or DeLaval Alpro (health and weights)	Daily	All sub-systems
Milk production and quality	Milk processor website and app; and, milk docket. Also, could include individual cow production (and somatic cell count) for some farmers.	Daily	Breeding, culling, drying off and animal movements
Animal demeanour and physical ailment signs, and heat detection	Observation, and heat detection tools (e.g 'scratches'). Notes recorded on paper/phone	Daily	Breeding, culling, drying off and animal movements; Animal health
Optional – In-shed alerts - for animal health and other queries	Options include (and variations of): Protrack in-shed software; Tru-Test's MiHub in-shed software; and, Jantec in-shed software. All communicate with EID tag and RFID tag reader	Daily	Animal health
Strategic planning information - Benchmarking - physical and financial; Internal and externally provided research; and, farm modelling	Options include (and variations of): Online/physical benchmarking reports (DairyBase); benchmarking software; industry experts and consultants; UDDER and Farmax modelling software	Annually	Strategic management

Body condition score of animals	Visual assessment	As required	Breeding, culling, drying off and animal movements; Purchase/sell livestock
Bull sire/breeding information	Animal genetics catalogues; DairyNZ; 'Sirematching' services. Also, could include company policies	As required	Breeding, culling, drying off and animal movements
Seller's animal condition and animal records (LIC's MINDA and CRV's Insight)	Visual assessment; and MINDA and CRV Insight animal records	As required	Purchase/sell livestock
Collated animal movement information/reporting	Options include: MINDApro and/or MINDALive; or, CRV Insight - Web; FarmIQ; or, NAIT website	As required	Compliance - NAIT - Animal movements
Decisions/compliance		**Frequency**	
Animal health		Daily (as required)	
Strategic management – e.g. stock numbers, once-a-day, type of genetics etc.		Annually	
Breeding, culling, drying off and animal movements (grazing and wintering)		As required (daily at times)	
Purchase/sell livestock (if applicable)		As required	
Compliance - NAIT - Animal movements		As required	