Abstract
A review of the literature accessed 234 papers that referenced farm or farming systems research in New Zealand hill country. These were categorised into resource allocation/productivity, modelling, farm studies and sociology. Sociology was further categorised into social, cultural, resilience, policy and regulation, and system behaviour and change. Farming systems research developed over the 5 decades studied from 9 papers in 1960-1975, to a peak of 60 papers during the 1986-1995 decade. The number of papers accessed during the latest decade, 2006-2015, was 57. The focus of research has changed significantly from an initial emphasis on biophysical processes and productivity, peaking in the 1976-1985 decade and then tapering off. This provided data for the development of models that could generate many more comparisons at lower cost. Modelling of the biophysical farm and economic outcomes has been steady through the decades from 1986 to present. The impacts of policy and regulation have featured strongly in the 1986-1995 decade after agricultural deregulation, and again in the 2006-2015 decade as consumer and societal concerns about the environment have emerged. Resilience of the farming system, encompassing production, economic, social and environmental trade-offs, has emerged as a topic being most prevalent in the most recent decade from 2006-2015. The discipline of farm systems research has also matured over this time as a greater range of research techniques, over a wider range of subject matter have been applied. An evolution of the discipline has also seen the integration of the principles of complex adaptive systems into the work.

Keywords: cultural, economic, environmental, farm systems, modelling, policy, production, regulation, resilience, social

Key messages
• Future farm systems research will be an amalgam of techniques and disciplines (including farmers) to create robust solutions and new farming systems in hill country.

Introduction
Farm systems research is a discipline that examines farming systems to understand the relationships between the elements of the system and the outcome as a whole (Darnhofer et al. 2012). It is research to investigate the interactions between the components of the system and the behaviour of the system to external influences. The research is about the system, not the components and so is termed holistic, rather than reductionist.

When examining the conditions of systems research, the definition of the boundary is an essential element. This then determines what is in and out of the research. The second element of systems research is the ability of the approach to examine emergent properties. These two factors provide a definition for systems research in comparison to component or reductionist research, where conditions are controlled to limit the influence of external factors.

So where have we come from in this realm in New Zealand hill country? Understanding the interactions between the components and emergent properties of a system are key to capturing the benefits of changes and improvements. The expansion of research from plot trials and reductionist thinking, to large scale, inclusive trials where interactions could be seen was an early response by scientists as they were confronted by the realities of farming. Sears (1951) stated ‘At the outset I emphasise that all these aspects are interdependent and equally important; also that we must at all times be prepared to modify our outlooks and practices to fit in with changes in plant populations, fertiliser supplies and general production and marketing policies.’ He was referring to understanding the role of plant genetics, soil fertility, grazing practice and animal requirements in a farm systems context, and describes running self-contained farmlets at Palmerston North, Lincoln and Gore. While these trials were intensive farm systems, the lessons were transferable to hill country and experiments were established at Te Awa (Suckling 1954). Grant et al. (1972) noted, however, that slope was the complicating factor.
Sears (1951) introduced the concept of influences beyond the farm gate, when he mentions marketing policies. The framing of influence has developed over time and those trends are investigated in this paper. Realms of influence that we are now familiar with include those relating to ‘sustainability’: production, economic, environmental, social and cultural. These realms are nominally representative of the outputs of the system, either direct (product) or indirect (economic), and primary (product), or secondary (environmental, social and cultural).

Two facets of system behaviour are most commonly studied. The first is internal interactions. This is when elements within the system respond to one another and new properties may emerge. An example may be the interactions between plant species, soil fertility and grazing management. Sears (1951) provided an early example of this type of systems research where pasture alone is compared with hay supplementation and cropping and the outcome is measured as overall profitability. The second is external interactions where adaptation or evolution may be a result as the system adapts to new conditions. This may be how the farm system as a whole might respond to external influences, or how elements within the farm system evolve and react to those influences. This type of response is documented by Wallace (2014) as the emergence of activities such as deer farming and kiwifruit production from the deregulation of the agricultural economy in the 1980s.

Before examining the history of hill country farm systems research some terms have to be defined. The following descriptions are proposed to ensure clarity when referring to the type of research being undertaken. Farms do not sit in isolation. Farms are grouped into catchments, regions, suppliers, value chains and so on. This moves the research from farm to farming systems, by extending the boundaries and changing the unit of interaction.

**Farm system** – the workings and configuration of a farm.

**Farming system** – the conglomerate of farms and associated industries with common linkages (to be determined by the purpose of the study).

**Farmlet** – a small-scale replica of a biophysical farm. These systems are deemed closed as all activities must be supported within the system.

**Put and take open grazing systems** – experiments where livestock numbers can be adjusted to reflect changes in pasture growth and demand. These experiments provide a proxy for a closed system by accounting for changes in stocking rate.

The purpose of hill country farm systems research in New Zealand has been of a pragmatic nature, identifying issues or opportunities for farmers and providing solutions through research. A second purpose has been to identify causes of major change in farming systems and document changes in practice and the rural communities that resulted. A third purpose of the research that is currently emerging is the opportunity to design future farm systems in the face of current requirements to change.

This paper reviews the literature reporting farm systems research and demonstrates the evolution of purpose and techniques of that research. The history and focus of farm systems research to date is outlined. Finally the paper provides some analysis of the impacts of hill country systems research and suggests a potential future for farm systems research in hill country.

**Methods**

A review of farm systems research in New Zealand was conducted through a literature search. Resources searched included CAB Abstracts, Scopus, Google Scholar, WWW and New Zealand Institute of Primary Industry (NZIPIM) (until 2014). The search strategy included the keywords; hill country, hill pastures, hill farms, down lands, farm systems, farmer decision making, production and management. Reference to high country was not explicitly used as a term, but articles which were identified as high country were retained as relevant.

This search returned approximately 120 papers over the period 1951-2014.

The search strategy was expanded to include the terms social, sociology, socio-economic, attitudes, perceptions, adaptation to change, deregulation of agriculture, education, employment, capability, health, resilience, farm governance, succession and management. The inclusion of these terms added another 84 papers, though few papers had hill country as their specific focus.

Other papers known to the authors were added to make a total of 234 papers accessed. While the number of papers accessed is large, it is not exhaustive. Many reports commissioned by government agencies and producer boards, such as the Ministry of Agriculture and Fisheries and the New Zealand Meat and Wool Economic service, are now hard to access electronically. These also provide insight into the situation and thinking that moulded decision making and hence research topics. However, the relative abundance of each type of paper will provide an insight into the distribution of research. To be included in the analysis the research had to exhibit the opportunity for interaction to be expressed between at least two factors, e.g. fertiliser and grazing management, or examine the
farm or farming system reactions to external influences, e.g. policy making.

On examination of the papers, the research was characterised into a set of topics based on the authors’ insight. From the original review the categories of resource allocation/productivity research, modelling of biophysical processes and economics, and farm studies, which often involved surveys and case studies of practice and practice change, were identified.

The second literature search, identifying social research, was characterised by the following topics; social, cultural, resilience, policy and regulation, and system behaviour and change. The papers were then grouped in decades from 1966 to 2015 to indicate changes of emphasis over time. The papers were also characterised by the types of data collected and the methodology that was chosen for analysis.

Finally the combined literature search was grouped into realms of research and represented in decade time steps, again to indicate the evolution of the research.

Results
An analysis of the results provided the following insights.

Resource allocation/productivity research
This research has been mainly to characterise the interactions between key components of the grazing systems and made up approximately 50% of the initial search and 27% of the total literature pool accessed. These have been grouped in Table 1 under the subject of main interest in each paper, and the main output from each paper. Productivity was the specific focus for approximately 90% of these papers, with grazing, animals and soils being the major focus. The research described the interactions between various components, such as grazing management and fertiliser inputs and often used animal productivity as a primary measure of outputs. The research ranged from simple put and take open grazing systems to farmlet systems.

A financial analysis of farmlets was presented in only 6% of papers. This generally used the productivity results from the farmlets and applied general financial criteria from farm scale statistics of the time. Often financial analysis was unable to be assessed directly because of the limited size of the farmlets and became included in modelling/virtual analysis.

Environmental outputs were the focus of only 5% of these productivity-based studies and they included sustainability indicators, physical soil damage and biology.

Modelling research
The use of virtual investigations into hill country farming systems made rapid progress during the 1980s as computer use and computing power increased. A total

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<th>Technology</th>
<th>Productivity</th>
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<th>Environmental</th>
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<td>Forage</td>
<td>Allan et al. 1985; Allan &amp; Keoghan 1994; Stevens &amp; Casey 2014</td>
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<td>Sheath &amp; Boom 1997</td>
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<td>Enterprise</td>
<td>Nicoll et al. 1978; Rattray 1981; McRae 1988; Sheath et al. 1990; Mackay et al. 1991; Mackay et al. 1998</td>
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<td>Mackay et al. 2006</td>
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of 46 papers were accessed, making up approximately 20% of the total. The rise of modelling coincided with an increasing body of information coming from the biophysical systems experiments that allowed production functions to be developed and tested (Table 2). These papers have been grouped into development or use of models, and into biophysical, financial or environmental predictive outputs.

The development and testing of models primarily for biophysical prediction made up 24%, while finance was the primary driver of 11% of the models. Two models describes an environmental function (Synge et al. 2013; Vogeler et al. 2014).

The use of models is evenly balanced between biophysical (29%) and financial (27%) outputs with only 7% describing environmental outputs. Again, the progression in this sequence moves from developing and using biophysical models, to adding finances and then moving to environmental impacts. This emphasises the general shift in focus from primary production to profitability impacts and then to secondary impacts.

Farm studies
The use of direct farm studies as a farm systems research tool represented 20% of the total literature search and fell into four categories when broadly characterised by research method. This was then stratified by the focus of the research (Table 3). The first was farmer survey research, 32% of the papers, of which the majority were involved in characterising farming systems. Topics included new enterprise implementation, feed management, variability, animal productivity and financial resilience.

Case studies were the second category, representing 40% of the papers, and characterising equally the farm system, decision making and change. A subsection of this group that documented progress on the Beef + Lamb New Zealand monitor farm programme made up 25% of these papers. This programme was a major source of innovation from 1991 until the late 2000s. These papers identified the role of monitoring programmes in effecting change through the implementation of management, financial and technological change.

Farmer directed research included 24% of the results and generally documented a range of projects that accessed government and industry funding (Beef + Lamb New Zealand, TechNZ and Sustainable Farming Fund) to explore, understand and innovate to include new technologies within the farm system. Topics included forages, fertiliser, animal genetics, feed quality, animal production and constraints to change.

Finally, two papers (4%) used data from many farms over a number of years in a wide range of environments to investigate first principles of animal and pasture production to drive on-farm changes in productivity.

Many of the papers in this category has been driven by the researcher involved and their desire to document the activities or progress of various groups. A key feature of this work is their representation in the New Zealand Grassland Association proceedings. Much of the work has been funded by industry and government bodies. This indicates how important these funding sources are in ensuring that new technologies and practices are tested and reported for wider uptake. The frequency and continuity of paper publication reflects the relative sources of funding. For example, the documentation of Beef + Lamb New Zealand monitor farms covers the period when they were most productive.

The main contributors to this documentation have been Massey University, Lincoln University and AgResearch. A smaller contribution has been from farm consultants.

Sociology research
The inclusion of sociological research acknowledges that people play an extremely important part in the

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<th>Parameter</th>
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development, implementation and evolution of farming systems. The papers describing sociology research provided an insight into the history of the evolution of farm systems focus and the development of tools for the discipline (Table 4).

The social category (Table 4) includes governance, labour, communities and the role of women. This category is about the people in the farming businesses and rural communities. Often the commentary examined the impact of external influences (such as policy and finance) on change. While much of this characterised social impacts and responses, there were few metrics or underlying principles presented as desirable outcomes or as methods to achieve desirable outcomes in the future. The emergence of an increasing role for women in the physical and managerial roles in farming, as well as the diversification of income are key elements of this work.

Only two papers represented cultural elements. This may be reflective of the more recent development of Maori agribusiness as a force in hill country. Again, as with farm studies, a driving impetus to publication may be the researcher themselves and this lack of publication may represent the slow development of important relationships as Māori agribusiness emerges from Waitangi Treaty settlements. Underlying philosophies are identified that drive the needs of the community that must be met by the farm system.

Resilience (Table 4) provided an overall reference to sustainability, stress and shock as well as encompassing papers that combined production, social, environmental and economic drivers. The inclusion of this topic demonstrated a major shift in thinking away from the sustainability paradigm of the 1990s and early 2000s. This paradigm presented sustainability as minimising environmental impacts, often with little acknowledgement of economic performance. The philosophy of resilience encompasses an expansion away from a reductionist approach of environmental damage to an optimisation approach measuring net benefit of combined economic, social and environmental indicators (e.g. Dodd et al. 2008a; Darnhofer & Rosin 2012). Dodd et al. (2008) preceded the terminology but enacted a community-based approach to researching the trade-offs between landscape, production, economic returns and environmental impacts. The environment sits across many of the categories, often as a potential outcome measure. It is finally encompassed in the resilience category as one of the trade-offs to be

Table 3 A collation of papers regarding farm studies with hill country farming systems research grouped by research method and research focus.

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<tr>
<th>Research method</th>
<th>Characterisation</th>
<th>Decision making</th>
<th>Change</th>
<th>Influence of policy</th>
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<td>Beck &amp; Dent 1984;</td>
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<td>Parker 1984;</td>
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<td>Parker &amp; Townsley 1986;</td>
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<td>Frengley &amp; Johnston 1992;</td>
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<td>Fairweather &amp; Keating 1994;</td>
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<td>Tarbotton &amp; Webby 1999;</td>
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<td>Rhodes &amp; Willis 2000;</td>
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<td>Mulet-Marquis &amp;</td>
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<td>Fairweather 2008;</td>
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<td>Hawkins &amp; Wu 2011</td>
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<td>McLaren 1976;</td>
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<td>Linton &amp; Snodgrass 1978;</td>
<td>Hanna et al. 2001;</td>
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<td>Gray 1987;</td>
<td>Gray et al. 2004;</td>
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<td>Journeaux et al. 1987;</td>
<td>Gray et al. 2005;</td>
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<td>Page et al. 1996;</td>
<td>Gray et al. 2006;</td>
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<td>Rosin et al. 2007b;</td>
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<td>Meikle &amp; Green 2012</td>
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<tr>
<td>Farmer directed research</td>
<td>Litherland &amp; Lambert 2000</td>
<td>Webby et al. 2001; Mackay et al. 2008</td>
<td>Webby &amp; Sheath 1991; Reid et al. 1993; Cocks et al. 2002; Collins 2013; Macfarlane et al. 2014</td>
<td>Crofoot et al. 2010; Rhodes et al. 2011; Reid &amp; Brazendale 2014</td>
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<td>Meta analysis</td>
<td>Townsley &amp; Parker 1987</td>
<td>Stevens &amp; Young 2013</td>
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considered. This development into resilience heralded a true step forward into full farm systems research as the trade-offs and potential systems change that may emerge, were recognised.

Policy and regulation drew together the expressions of external forces on farm systems, including consumer demands. These reflected the changes of the time, with a strong emphasis on the deregulation of the Table 4

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<td>Cultural</td>
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<td>Kerckhoffs &amp; Smith 2010; White &amp; Sheath 2011</td>
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<td>Resilience</td>
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<td>Cotman 1996; Rhodes &amp; Willis 2000; Rhodes et al. 2003; Shadbolt &amp; Morriss 1999</td>
<td>Cradock-Henry 2011; Darnhofer et al. 2010; Dodd et al. 2008a; Dodd et al. 2008b; Dodd et al. 2008c; Dodd et al. 2008d; Nettle et al. 2015; Parsonson-Ensor &amp; Saunders 2011; Rosin et al. 2012; Smith et al. 2011; Smith et al. 2007</td>
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<td>Methodology</td>
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Methodology:
- Survey Sector/trend analysis
- Interviews Case studies Multi-agent simulation
- Focus groups Workshops Participant observation Multivariate analysis

Survey:
- Sector/trend analysis Interviews
- Case studies Focus groups Workshops Participant observation Multivariate analysis
- Temporal repeat interviews Segmentation
- Longitudinal matched panels Causal mapping Narratives of change Network analysis Principle components analysis
agricultural economy during the 1980s and then the rise of consumer/supermarket audit and quality assurance programmes during the 2000s.

Behaviour change is characterised in papers that analysed or categorised the expression of behaviours, the potential to influence behaviour and the mapping of factors affecting behaviour and decision making.

The development of the discipline as a tool (Table 4) began as sector statistics, case studies and surveys and moved to focus groups, workshops, in-depth interviews and longitudinal studies. Data analysis moved from trend analysis to principle components, cluster and multivariate analysis, and causal loop mapping and multi-agent-based rural simulation modelling.

Reviews of farm systems research
A total of 28 papers were characterised as review or discussion papers analysing aspects of hill country farm systems (Table 5). These were grouped according to topic. Those discussing the role, or impact, of research made up 20% of the total. Benchmarking of the industry was the topic of 7%. Opportunities for improved productivity were a feature in 31% of the papers. The influence of policy was a subject in 14% of papers while the role of external forces such as markets added another 14%. Finally, reviews of enterprises and their implementation also made up 14%.

Development of farming systems research through the literature
The progression of hill country farm systems research has gone from biophysical to economic, social, and on to policy and regulation. Over time it has moved from internal to external drivers of farming systems (Figure 1). The environment has had little specific research at the farming system scale for hill country. More recently, resilience, and the trade-offs required to achieve it, has become the focus which has included environmental impacts (e.g. Dodd et al. 2008a; Darnhofer et al. 2010).

The development of the research approaches and topics has been closely aligned with both Government

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<th>Type</th>
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<td>Role of, or impact of research</td>
<td>Molloy 1980; Floate et al. 1987; McCall et al. 1994; Parke et al. 1994; Hodgson et al. 2005; Clark 2013</td>
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<tr>
<td>Benchmarking at the industry level</td>
<td>Ward 1962; Davison 2002</td>
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<tr>
<td>Opportunities for improved productivity</td>
<td>Tripe 1965; Wright 1965; Hight 1976; Hight 1979; Tripe 1979; Taylor 1983; Sheath 1988; Garden 2009; Sheath 2011; Stevens &amp; Garden 2014</td>
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<tr>
<td>Influence of policy</td>
<td>Tavendale 1984; Le Heron 1989; Rhodes &amp; Willis 2000; Stevens &amp; Garden 2014</td>
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<tr>
<td>Role of external forces (e.g. marketing)</td>
<td>Mauger 1979; MacLeod &amp; Moller 2006; Copland &amp; Stevens 2012; Morris &amp; Kenyon 2014</td>
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<td>Enterprise review</td>
<td>Wright et al. 1990; Webby &amp; Thomson 1994; Morris 2013a; Morris 2013b</td>
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Figure 1  The development of New Zealand hill country farm systems research as represented by the literature, from the 1960s until 2015. Each decade is represented and numbers within each research type represents the percentage of papers accessed within that decade.
policy and farmer need. Increased productivity was a clear focus of Government throughout the 1960s to early 1980s. This was characterised by farming subsidies and tariff protections, many introduced in the 1960s, which saw up to 40% of farmer income being subsidised by Government (Wallace 2014) by the early 1980s. Programmes such as the Livestock Incentive and Land Development Encouragement Loan schemes saw an increase in sheep numbers from 55 to 70 million from 1976 to 1984. This drive for production at any cost was also reflected in government research programmes such as the dry hill country improvement programme, as market signals were ignored.

The changing policy and deregulation of the 1980s opened the farm system to severe pressure from beyond the farm gate (Wallace 2014). This gave rise to change in the farm system and farming systems in general, as farming was subjected to market forces and changed from quantity to quality as a production model. These changes were documented, new programmes to facilitate change were implemented (Rhodes & Aspin 1993) and farm systems evolution was observed (Neely & Parminter 1993).

Over this time the value of the product mix from hill country farms has shifted from a relatively equal balance between wool and meat as income streams, to the reduced importance of wool as an income source, as synthetic fibres have become dominant, especially for carpet manufacturing. This has also shifted the focus of research from stocking rate to individual animal performance metrics.

As the cost structure of farming shifted with subsidy removal and exposure to market forces, research also shifted from maximising production to reducing costs, e.g. fertiliser use, and to optimising resource use, including more production from individual animals to reduce the feed required for capital stock. This was also manifest with the rise of bull beef both as research (McRae 1988) and on farm implementation (Journeaux et al. 1987), as calves were generated from the dairy herd, removing the direct capital cost structure for beef production in hill country.

The progression of research also documents the growing maturity of both knowledge and thinking. This progression is required as it is not until first principles, or simple rules, are discovered, that we can develop tools to investigate system behaviour. For the biophysical elements of the farming system, this was during the 1960s to 1990s and was acknowledged in a review by Parker et al. (1994). This then provided the knowledge to develop tools, such as models, that could aid us in examining potential futures, or alternative options.

Growing concern and increasing consumer pressure over declining water quality has led to further expansion of the research into the impacts of external drivers on farming systems. While the initial creation of the Te Awa research site in 1944 was prompted by a soil conservation effort, the reporting from that site was about maximising productivity, albeit using best grazing management practice to maintain pasture cover. Sustainability as a concept was not readily introduced until the 1980s. This has been replaced by resilience which has provided insight into understanding the trade-offs at the systems level, including off-farm impacts and profitability implications.

**Impacts of hill country farm systems research**

Impacts of research are hard to directly quantify, and the impact of then combining the research into a systems context even more so. One of the most direct measures was undertaken by McIvor & Aspin (2001) when they quantified the impacts of research and development funding from Meat New Zealand (now Beef + Lamb New Zealand). The net present value of the investment in the Monitor Farm Programme was estimated to be 21.4:1. Farmers associated with the programme estimated that they had increased their net annual benefit by $6 700, or approximately 9% of the benchmark farm cash surplus of $74 000 (MAF 2000). This was attributed to increased knowledge of feed allocation and matching of feed supply and demand to improve both ewe and lamb performance. This direct application of the research results, proven through farm systems research, by hill country sheep and beef farmers provides some quantification of the potential benefits of the research being done in advance of the requirement to shift from a stocking rate to a per head performance system as the New Zealand hill country farmer was exposed to market forces.

Farming systems research can cover a wide range of topics. This is why it may not exhibit a clearly defined body of research. Of importance in the literature search was the body of work presented at the New Zealand Grassland Association conference. This made up nearly 25% of all papers recovered, indicating that the conference forum has been an important focal point for presenting farm systems research. Barbier et al. (2012) provided a unique insight into the International Farming Systems Association community of authors and found that, though they were well connected within the IFSA conference publication network, they were indistinguishable in international literature as a cohort. This suggests that authors were combining to present farm systems approaches to problems at conference time, but were publishing in their disciplines in formal journals. This may suggest that the Farming Systems approach has not gained the respect of the International science community as a discipline.

The progression shown in Figure 1 indicates the logical development of the requirements for farm
systems research. In the first instance biophysical research provided the basis for the evolution of hill country farming in the post-regulation/government support era. Farmers adapted and farming systems evolved as the principles, developed through the strong body of research in the 1960-1980s, were applied. This is well documented through the Monitor Farm Programme and others (e.g. McIvor & Aspin 2001; Cocks et al. 2002).

The documentation and analysis of the external drivers of farming systems has provided insights into the evolution of farming systems, especially since the removal of agricultural protections in the 1980s (e.g. Le Heron 1989; Burton & Peoples 2014). Recent investigations are beginning to investigate how the decision making process, in response to external drivers, is shaped (e.g. Morgan & Daigneault 2015). This then moves this type of research from description towards the design of potential options that may guide future farm system design and development (e.g. Foran & Wardle 1995; Wedderburn et al. 2011).

Development of modelling, and the increase in computing power, has enabled the investigation of the dynamics of the farm system and its re-configuration (e.g. Rendel et al. 2013). These models have been of two types; simulation (e.g. Farmax) and optimisation (e.g. INFORM). Simulation models provide the opportunity to examine potential interactions of biophysical processes and an investigation of current known situations. Optimisation models provide an opportunity to explore unknown situations, resource optimisation, and to optimise specific criteria, such as profit, in the face of other constraints. Understanding the dynamics has given rise to insights about how the farm system may change or evolve, in response to changing conditions. This initially took place within the farm system, but more recently tools such as causal mapping have been used to examine farm systems in general (e.g. Fairweather & Hunt 2011). These tools give rise to the opportunity to test the potential for new configurations and enable the linking of production, economic, social and environmental outcomes and the trade-offs that may occur.

The shift towards resilience in New Zealand has mirrored research throughout Europe (Darnhofer et al. 2012). The growing maturity of thought and understanding of a growing range of methodologies to interpret properties observed at a systems level has also reflected a growing understanding of systems research internationally.

Challenges for the future

The challenges for future hill country farm systems will be present at several different levels. These include internal (within the farm gate) and external (from society and the market) influences. They may be formal (regulation) or informal (societal pressure). Future farm systems may not be directly linked to biophysical processes optimised for production as they have in the past. Secondary outputs from the farm system have already come under the spotlight as regional councils develop water plans that restrict sediment and nutrient loss to water. The type of inputs and practices within the farm system, such as chemical inputs, animal welfare and work safety practices, are also undergoing scrutiny. All of these potential changes influence the configuration of the farm and the farming system, and so produce an evolution of those systems.

Recent opinion pieces in the Proceedings of the New Zealand Grassland Association (now the Journal of New Zealand Grasslands) have highlighted a long list of challenges. These include freedom to operate (Hay 2012), resource use optimisation (Garden 2009), farm business structure and financing (Sheath 2011); climate change (Garden 2009; Sheath 2011), ecosystems services (Garden 2009; Sheath 2011; Stevens & Garden 2014), biophysical challenges (Garden 2009; Sheath 2011; Stevens & Garden 2014), land use competition (Garden 2009; Sheath 2011; Copland & Stevens 2012; Stevens & Garden 2014), and the sustainability of communities (Sheath 2011; Stevens & Garden 2014). This list is not complete, and these challenges continue to provide topics for research. Interestingly, most of these topics have always been on the list. Lionel Corkill, in his presidential address to the NZGA (Corkill 1958) described productivity increases in both meat and wool production of approximately 90% in the previous 25 years. He also described future challenges of market prices, land use competition, potential phosphate supply limitations and labour and social issues in rural communities. What may be different will be the fullness of the answers that are developed to address those challenges as complexity increases.

This means that farming systems research will also face challenges to ensure it can provide answers. As was stated in the introduction, the development of farm systems research has been driven by need. The purpose was to provide practical answers to the questions farmers were facing. Research beyond the biophysical documented how change was made and the outcomes of those changes. Over the past 60 years the research has shifted from farm systems and farm management research which has worked within the farm boundary to optimise biophysical parameters, to farming systems research which encompasses the broader domain of influences beyond the farm gate, such as markets and social needs.

Much of the basic principles of biophysical processes are now known and incorporated into computer models that will provide the opportunity to examine farm
systems responses to changing biophysical conditions such as climate change. These models will also provide insight into the impacts of farm practise on secondary outputs such as greenhouse gases and nitrate in water, as well as helping to predict future farm systems configurations when farming under limits.

The influence of factors beyond the farm gate are becoming more and more a focus as societal and consumer pressure is exerted through regulation and market requirements. Research has begun to investigate how systems might change in the face of these pressures (e.g. Wedderburn et al. 2011). The range of techniques for social investigations has greatly expanded and all of those techniques will continue to have a role in generating understanding. The more traditional outside assessments using the techniques found in rapid rural appraisal will be augmented with approaches such as co-development and co-innovation, as they provide different insights and can be used in different situations. The current developing body of research into the social sciences is beginning to provide insights into how farm systems may change as a result of market and societal pressures through multi-agent simulation models (e.g. Morgan & Daigneault 2015), and the continued development of this approach will provide power when examining potential farm systems of the future.

The role of traditional approaches, such as farmlet experiments, is often limited to providing biophysical outcomes which may not address greater societal influences. A new approach, created from an amalgam of physical on-farm and farmlet measurement linked with modelling tools, will provide further opportunities and insights that can be developed in partnerships between farmers, agribusiness and science. This will enable a much greater range of environments to be included and broader farming systems questions, not just farm systems questions, will be answered. This approach may lose some science precision but adds practical application and innovation. Uptake of results may also be aided with this co-development approach.

This approach can be used as a basis for exploratory programmes that investigate what the future might bring. These programmes will interpret the current and potential future drivers of farming systems evolution and explore the futures that may develop. This approach will provide regulators with an understanding of policy impacts and give retailers and marketers insights into changes that may be created by pricing and audit processes. Most importantly, it will provide farmers with new opportunities and scenarios that will enable resilience for future hill country farming systems.

A final requirement is an active move from single or even multi-disciplinary approaches towards trans-disciplinary approaches. This requires team members who have knowledge of the wider issues and understand a range of disciplines, and recognition that the most important trans-disciplinary team member is often the farmer. Future work then becomes built on a deeper understanding of farming systems. Training such 'generalist specialists' will need to include a sound knowledge of systems properties as well as underlying familiarity with both biophysical processes and market, social and cultural influences to aid development of future farming systems solutions through research.

Farm systems research is not without significant cost, both financially and culturally. The combining of disciplines and the inclusion of the wider community to create new farming systems for the future will only be productive when important issues are identified and teams can develop an appropriate cultural ethos for true cooperation.

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