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# Systems Research: the need for a change of thinking - Presidential Address 2016

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Farm systems research has a long history of success in New Zealand. Recent reviews have highlighted the progress made through the traditional and pragmatic approaches that we have used (Clark 2013, Stevens et al 2016). However, as the world and technologies change ever more rapidly around us, is it time to change from the problem solving approach to one of deeper understanding?

Professor Shaun Hendy defined the need for new thinking at the launch of the recently formed Te Punaha Matatini, the Centre of Research Excellence for Complex Systems and Networks. He said "by understanding the networks that underlie each of these complex systems we will get insights into how to influence them and how to develop better strategies for managing them". The power of systems research provides the opportunity for New Zealand to define its own path and make its own decisions. These opportunities come through understanding how systems will respond, or how they can be reconfigured, to capture benefits specifically to meet our needs, rather than the needs of others.

A science critic and past research director suggested in a recent article that a focus on farm systems research (or application) was in the realm of primary industry farm advisory professionals, not the science effort (Allison 2016). He based his view on the notion that farmers will take up and incorporate technologies into their farming systems if and when the technology offers an improvement in value to the farmer. This belies the common belief that farm systems research is about demonstrating the value of technologies at a farmlet scale. Unfortunately this belief is flawed.

The argument presented is that farm systems research is about demonstrating the fit of technology into current systems. While this may be one option or outcome, the more fundamental reason for farming systems research is to understand what drives the system and alters the value of the system. Then we can begin to develop new systems that may return greater value. The concept of putting technologies into a current system has a tendency to rely on incremental gain. While this has some merit, it locks us into the current paradigm, rather than imagining new futures.

The key to understanding systems research is to understand the holistic nature of the approach. Traditional research is reductionist in approach, (catabolic), breaking the system into its constituent parts and examining these in isolation, in the attempt to understand the base function of each component. This requires tight control to reduce internal variables and external influence. Systems research embraces this variation and examines the system in reference to the variables around the system that drive its performance. It is about synthesis (metabolism) of processes into functioning systems.

Systems science uses an holistic approach to study the system as a whole to understand the outcomes and properties of the system rather than the component parts. To demonstrate the nature of the difference between reductionist and holistic approaches we can use the bicycle as an analogy.

Do you own a bicycle? Most of the population of the world has ridden a bicycle. Is yours an old faithful for riding quietly to work, or a state of the art road bike or mountain bike? Do you ride it for pleasure, necessity, exercise, competition or thrills? How much did your bicycle cost, and how much technology is embodied in your bicycle?

When disassembled into its component parts a reductionist approach would examine the gears, chains, levers, wheels etc. Each component may be high or low tech, made of steel or carbon fibre, be precision made or roughly hewn.

When assembled the bicycle can do something that any one of the parts cannot. It exhibits emergent properties – it evolves into a mode of transport. That outcome cannot be readily seen from examining the components in isolation. Even when assembled, it is not finished. It needs a rider to complete a function – have meaning or purpose. Then we have an operating system.

The system has a boundary that sits around the bicycle and the rider. The system sits within other systems, the road network or the track for example, and so exhibits nesting. The system interacts with its surroundings; the friction of the road, the drag of the wind, and the motorists around it.

And so it interprets its environment and learns from feedback. The gears need to change, the effort of the rider has to increase, the brakes need to be applied, the car dodged. The system evolves. The penny farthing is replaced by the chain-driven cycle, the 10 speed with the 18 speed, and the mountain bike emerges as a subspecies.

The needs of the system define the application of the needs for the components. If I ride to work I choose a different option than if I careen madly downhill. The technology is different, the complexity of components increases, and the needs are much different. Sometimes the need is transport to work, sometimes the requirement for exercise, or the emotional thrill of speed and danger. And so the systems, though all based on a bicycle and a rider, produce different outcomes, or products, and so meet different needs. There are an underlying set of needs, there are an underlying set of first principles about riding a bike, and there are an underlying set of base components. But in combining those three elements the outcomes from the 'bicycle system' are diverse. This diversity leads to further emergent properties and further evolution.

If we were to examine a single bicycle/rider combination what would we learn? If I were to examine myself I would find different purpose, different technical needs, different investment and training over a broad temporal horizon. In my youth I used a bicycle for exercise, to pursue the love of my life, to get to lectures. The bicycle was fast and light, and as expensive as I could afford. Now my bicycle was bought on TradeMe for $20, is heavy and relatively unused.

My son's bicycles have become more and more expensive, with greater investment in technology culminating in an $8000 purchase. The need for speed outgrew the skill to go faster and so skill was replaced by technology. These bicycles require full face helmets and body armour, disc brakes and titanium frames. His needs are for exercise and gratification of the senses – the thrills of riding downhill fast. And so who is right? Which technology should the next cyclist choose, or invest in, based on our case studies?

The role of systems science is to examine the 'system' and understand the drivers of the system. These occur both inside the system and outside, from the environment. The examination of the system does not then prescribe which is 'best', but provides an understanding of what makes them different, as is the case in the bicycle analogy. This understanding can direct how the attendant system properties create the outcomes and outputs from the system, the meaning (or purpose) for the system and how the system might evolve in response to different needs, stimuli or pressures.

What we might have viewed as a simple system of a bicycle and its rider becomes complex as we add need and technology.

And so sits systems research as a distinctly different entity to traditional science. Do the components of the research always need to be holistic? The answer is no. The vision and initial testing of ideas may sit at the systems level. That helps imagine what might become and helps to determine the potential value, but the subsequent research programme may have elements of both holistic and reductionist elements. This places the two approaches alongside one another. By using an holistic approach the needs of the end user are placed much more at the centre of the development of future solutions or technologies. The old model of scientists knowing what is best and presenting the science as a 'fait accompli' is a thing of the past. The holistic approach sits at the centre of co-innovation and better-by-design processes.

An example of the power of both approaches comes from the Lucerne for Lambs Sustainable Farming Fund project. In brief, the project aimed to increase the use of spring grazing of lucerne in Central Otago. It was hypothesised that using lucerne as a grazing option in spring would increase the profitability and resilience of Central Otago farmers (Stevens et al 2012).

The question may be asked, why choose this environment where lucerne was already known? This belies the belief that farmers take up new technologies as required. Farmers in the region knew the product but put it to different use, fulfilling a different need. This created a specific set of traditional expectations and biases. These became a significant impediment to introducing a new concept that would change the farm system.

Examining the current set of beliefs became key to developing a research programme. The research needed to provide answers in a way that changed expectations and introduced a change in the farming system (Casey et al 2015).

Matching the new understandings of lucerne grazing management, developed through reductionist science, to the needs of the whole farm system provided the mechanisms to demonstrate potential profitability and resilience (Stevens & Casey 2014). Without the fundamental science principles then the project could not have worked. Without the systems view of understanding the drivers of the farm system then the fundamental principles would not have been adopted. This demonstrates the power of combining the two approaches.

Interestingly, the farm systems that have emerged to capture this benefit are wide and varied. They range from the integration of lucerne into large scale properties to empower the productivity of native hill country, through to intensive finishing systems (Stevens et al 2012). So the lessons of the first principles of science are incorporated into a range of system types based of the needs and skills of the participants, all developed from an understanding of the resources that each farmer had available. Answering the underlying questions that affected the system provided the opportunity for adaptation (Casey et al 2015).

Systems science requires a different range of methodologies from reductionist science to ensure its success. An example comes from an emerging branch of chemistry, computational chemistry. This approach has been developed out of quantum mechanics and has been supported by the availability of the power of supercomputers. It uses theoretical knowledge of the behaviour of electrons to understand how atoms and molecules interact. The equations involved must be solved using approximations, due to some aspects of electron behaviour being infinitely complex. Solving these equations is still not a trivial effort. These approaches are metabolic, building a view of processes from first principles. New insights are being gained into, for example, the functioning of catalysts used in the Haber-Bosch process (used as the first step to make nitrogenous fertilisers).

Systems science can then be seen being used at completely different ends of farming, and at completely different scales, from the smallest atom to the largest farm.

The methodologies used in this discipline are similar to those that may be used in farm systems research. The use of model systems is a starting point to examine potential pathways. Then the outcomes can be subjected to analytical techniques such as Bayesian network analysis and Monte Carlo simulation approaches to determine variability and error terms. These techniques are common to both computation chemistry and social science.

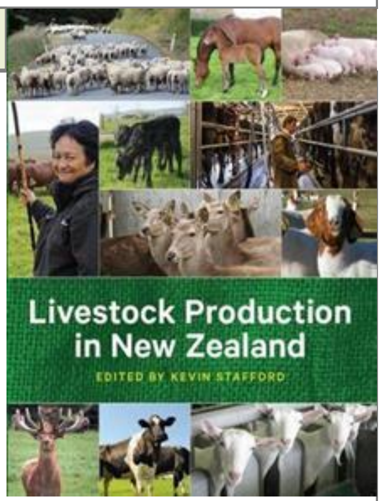
This provides a classic example of a systems approach to science. Known or near known first principles are used and combined through modelling to generate new understandings that are difficult to examine through experimentation. While this research is in its infancy, the potential outcomes from the understanding it will provide are considerable, and help augment traditional approaches to chemistry.

So how do we reconcile the research into nanoparticle behaviours with farming systems research? Several similarities come to mind. The first is the research techniques that can be used. Another is the creation of surface maps of hydrogen atom energy gradients that provides insight into the pathways that hydrogen atoms may use to move around a system. If we take this as analogous of, for example, the movement of finance through a farming community then we could better define the relative probabilities of investment in one sector or enterprise over another.

The Rural Futures Multi-agent Simulation (RF MAS) project modelled exactly this type of process when examining the rise of dairy farming in the Southern region of New Zealand over a twenty year period (Kaye-Blake et al 2014). RF MAS is currently the only fully integrated, spatial, simulation model of agriculture for New Zealand regions. The value of this work was not in the retrospective calibration of the model, but in the creation of the model itself. The model required specific inputs about farming practices and profitability, rural social influences and financial liabilities, as well as land use capability. That those variables were then able to be assigned values that predicted land use change provides us tools to examine the impacts of a range of changes, such as relative profitability of sectors, government policy, and social pressures on farming.

So, do we continue to apply a pragmatic problem solving approach to researching the questions one at a time attempting to fit new technology to an old system? Do we change focus and take a lesson from the bicycle? The techniques of systems science can span the breadth and depth of the systems that we use, from the hydrogen atom to whole farm systems and beyond. A holistic approach to examining the underlying first principles of farming systems will provide new insights. Then research programmes will have new understanding of the real power of transformational change. New Zealand Inc., will be better placed to take control of our future, exactly as envisioned by Professor Shaun Hendy at the inauguration of The Meeting Place of Many Faces, our Centre for Research Excellence in Complex Systems and Networks.

## Livestock Production in New Zealand




In releasing 'Livestock Production in New Zealand', editor Professor Kevin Stafford is reported to have said "I hope they (people) get an understanding of how complicated some aspects of livestock production are, and how it is not simple to farm animals and make a living. But also, I hope readers get to understand how ruminant livestock farming in New Zealand is so unique and how innovative our farmers and animal scientists are".

The words warmed the cockles of my heart. I would have added rural professionals to the list, recognising the important role they play in providing information, challenging thinking and supporting change, but overall, the sentiment is spot on. And the evidence is all in the book.

Livestock Production in New Zealand covers dairy, beef, sheep, deer, goats (milk, meat and fibre), pigs, poultry, horses and working farm dogs. Each chapter has been written by a discipline expert (mostly from Massey University, but with industry and Lincoln University as well). History, industry structure, production systems and 'environmental considerations' are discussed, as well as animal welfare and disease. Although the headings for each chapter vary, the basic information is the same, with important information on shearing, egg production and intensive indoor systems (with sections on waste management) where appropriate.

The environmental, waste management, and carbon footprint sections reflect the increased emphasis by consumers on impact of agriculture on the environment. The authors explain that New Zealand is ahead of other developed countries in many aspects – which most people in agriculture already know, but the general public does not appreciate. Although some already know that our production is with minimal use of antibiotics (third lowest user of active ingredients per kilogram of liveweight) and hormones, they probably don't know that it is also considered to be a "low-chemical almost 'organic' type of farming".

This goes for intensive as well as pastoral-based animals. Professor Stafford suggests that fans of fast food "should appreciate how good our chicken farmers are; maybe they should read how that drumstick is produced and, when they are paying, thank our poultry farmers for doing it so efficiently".

The same could be said for any of the New Zealand productive industries.

The chapters on the horse industry and on working dogs are somewhat different… because the goal isn't food production. Both are fascinating for the outsider, and add interest for those trying to understand the different activities involving animals in New Zealand.

The book has good graphs and tables with important data for students, or those trying to do some comparisons of effort and income (such as those contemplating life-style block ownership). The photographs illustrate points appropriately, and show beautiful New Zealand as well as magnificent animals. The glossaries are useful and the references can be followed for more information. Experts have spotted the odd mistake, none of which are critical (rising-two year old wapiti don't have rounded ends to their spikes; the photograph is of 'spikers'). Overall, the book is a good addition to any library with the aim of education – public, school and university.

From the lists of topics covered in 300 pages, it is clear that the book is an overview of the complications and possibilities associated with livestock production in New Zealand. For anybody interested in livestock, or the way New Zealand brings money into the country through exports, it is ideal. It is also a good starting place for anybody contemplating activities on a lifestyle block, or simply wanting to know more about agriculture in New Zealand – students, for instance, who come from a dairy farm, but want to know about other sectors. For more detail, or up-the-minute information, the industry websites should be investigated. And, of course, the Grassland website should always be searched for the latest research.

*Reviewed by Jacqueline Rowarth, one-time lifestyle block dweller and with current farm debt.*

Editor: Kevin Stafford; Massey University Press RRP $55

**NZGT 2016 Winners**
**Warren and Andrea Leslie**

**Alvin and Judith Reid**

**Ray Brougham Trophy**
**Prof Derrick Moot**

## NZGA Administration

***Membership dues***

It's nearing the end of our financial year so we are trying to get the last of the tardy members to pay their membership. Currently we have too many members 2 years in arrears and over 60 who are in arrears for the current year. All of these members appear to have active email accounts so they have received the NZGA newsletters and conference Journal. In return, payment of outstanding accounts would be appreciated.

***Whanganui 2017***

The local team are once again doing a fantastic job for NZGA pulling together a conference that is going to be the highlight of your year!

The papers submitted this year cover a wide range of topics with something for everyone. Mark the calendar now for November 7-9th.

For authors the full papers are due to be submitted by May 20th via the online portal—**Journal of NZ Grasslands**

***Hill Country Position Paper***

The final paper from the symposium is available for download ***here***. It is a good summary of the discussion and outcomes from the conference.

Frank Scrimegour presented a further paper summarising the symposium at the Timaru conference in November and this can be read ***here***.

***Conference Survey***

Many thanks to those who answered our post conference survey. The insights have been integrated into our ongoing strategy however the Executive were pleased to see that most attendees thought we delivered a great conference.