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Applied agricultural research, where is the future?

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Pat Garden, in his 2013 Levy Oration, raised the question 'are we running out of ideas?' He posed the argument that research and ideas function under the law of diminishing returns and so, as we solve more of the problems, then the next solution takes more effort and more resources to develop. This is decidedly true of the situation where you are working towards incrementally improving the production or efficiency of a process. Take the development of the internal combustion engine for example. While improvements were significant in the early development of the petrol engine, many of the major improvements were in place by the time Ford cast the single block for the V8 engine in the early 1930s. Progress since then has required more and more investment for less and less return.

So too has the productivity and efficiency gains in agriculture. This poses the question where to next? Should we continue to polish the present or seek a new rough diamond?

Callaghan (2009) in his book, 'From Wool to Weta; Transforming New Zealand's Culture and Economy', outlined a manifesto of science investment that prompted a significant change in the research landscape in New Zealand. Nine years ago the incoming National government put the manifesto into play with the beginning of the Primary Growth Partnership programme. Implicit in this strategy were two objectives. The first was to encourage partnership between agricultural businesses and science providers. The second was to entice agribusiness to invest in research and development.

Applied agricultural research, especially in the pastoral space, has been an unfortunate casualty in the implementation of both the Callaghan and PGP strategies. While significant funding has been leveraged from agribusiness, this has not been a replacement for applied research in the agricultural sector for research providers.

We should take a moment to analyse the situation. Science is a specialised process. Scientists often hold a doctorate qualification taking between 7 and 10 years to complete. Technicians are most likely to hold a science degree and potentially post-graduate training, along with the guidance of on the job training in science technique for 5 years or more before being considered fully trained. This is the depth of training that is required to fully understand the scientific method and to be able to apply it.

So the first issue with placing control of funding in the hands of agribusiness is a lack of capacity to effectively engage in the science process. A second, and related, issue is that the understanding of the science process then provides an appropriate dialogue between the holders of the funding and those able to deliver it. When this dialogue is ineffective then disengagement occurs. Learning the language of science has been described as being as difficult as learning the language of another country and so it is not surprising that communications break down.

The science community is a significant repository of knowledge. This provides the opportunity to use that knowledge to filter ideas and identify things that may have been done in the past, and therefore what to avoid. The lack of knowledge of previous science can lead to re-inventing the wheel. The saying that you don't know what you don't know becomes extremely important here, and engaging the science community can help avoid this trap.

Examples of the where the PGP process worked as expected happened when the agribusinesses understood the science process, or took time to understand the process (e.g. Ravensdown, Ballance and Fonterra). When this understanding was lacking then investment into applied science has been less successful. Further to this are the positive outcomes from industries that were singularly focused, such as the wine industry, where the science sector is part of the broader wine community. This means that trust and understanding are already in place to capture the benefits of new funding models.

Another factor which emerged was the trend to attempt to do research with in-house resources. Again, if expertise about the science process was lacking then focus shifted to the familiar, which often precluded science.

Finally, a significant proportion of the funds went not to innovation and science, but to marketing and extension. While this may not have been the original intent of the funds, it did become a focus. This focus was because a real and significant gap in extension was identified. This gap is one of the last hangovers from the imposition of 'Rogernomics'. With the dismantling and reorganisation of our agricultural support structures, the

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main provider of extension services, the MAF Advisory service was disbanded and dispersed. While those trained under this service have been available to support industry, the gap was less evident. Now, however, those workers are retiring in ever increasing numbers revealing a massive skills shortage in extension. This has led to a focus on rebuilding those networks and skills at the expense of applied science.

Finally, the companies rightly identified products and value chains as opportunities to explore. Often these areas have received little funding in the past, even though being identified as the future for agriculture for a long time. So this comes full circle to Callaghan (2009), who espoused the position that we need to add value, not cost or more production.

So what of applied research? Two trends are evident. The balance of power has shifted away from government owned entities such as CRI's, and shifted into the hands of agribusiness. This is evidenced by the decline in employees in institutes such as AgResearch, which has had a reduction in science staff from 650 to 390 during the past 9 years. Whether this balance of power will remain may be dependent upon politics with the recent shift from a National to a Labour-led government.

The second trend is the identification of gadgets, widgets and value chains as a focus for the future. These trends don't preclude applied agricultural science, but do provide a much more succinct target than the production and efficiency that drove the recovery of agriculture in the post-neoliberal era after the deregulation of the economy in the 1980s.

These focii should reinvigorate our applied science sector. Changes in MBIE Endeavour funding criteria actually encourages the taking of risks and long-term thinking. For the applicants though, thinking big often tends towards trying to get everything done at once. This leads to overambitious projects that are too expensive. This rush may be an artefact of the past 25 years of incremental, predictive requirements for the funding agencies. Or it may be an expression of the undying optimism of our science community, focused on proving a massive benefit for their sector.

And so we must examine where the agricultural industry will go into the future, and explore the opportunities that may present themselves to disrupt the way we farm.

Often the real impacts of technologies are hard to see when the first introduced. For example, the introduction of pregnancy scanning was sold to farmers as a way to reduce the winter feed costs by selling dry ewes early. This would pay for the scanning. While these gains were small, the application of the technology showed that many more, much more valuable outcomes were available. Now we identify twins and triplets and use foetal aging to match feed supply and demand to increase lambing success. This technology has allowed many of the major improvements in sheep production over the last 20 years.

Sometimes technologies combine. For example, farmers often had problems implementing differential feeding options that were available from pregnancy scanning. When 4-day shifting in winter was introduced to replace daily shifting in Southland, farmers had more time to feed budget, and to move mobs in winter (Stevens *et al*. 2011). Therefore the development of 4-day shifting enabled greater utilisation of pregnancy scanning information.

However, we must recognise that technologies sometimes need time for the right circumstance to be implemented. Often the technology may be developed before its time. A current case in point is once-a-day milking. This technology has been around for some time and has an enthusiastic though small following. Real gains in uptake may depend on several factors. Further shifts in land use may help. Just as red meat finishing has been displaced by dairying in many lowland regions, dairying itself may be displaced by vegetable and seed growing and plants for synthetic meat production. When this happens, milk processors will look to the hill-country for supply, and once-a-day milking systems may be an answer. Genetic progress towards cows suitable for once-a-day milking may accelerate with farmer demand stimulating investment. Technologies may combine to empower once-a-day milking. Those genetics, combined with robotic milking systems may help to reduce labour costs and make hill-country dairying systems viable.

So what are some of the disruptive technologies that we should be working towards or watching for? This question is raised without the author having foresight into what may happen in the course of disruption.

Maurice Yorke, in his presidential address, identified two papers at the 2001 Grassland Conference that he thought may influence the future. One was the identification of changes in the fatty acid content of meat when different pasture species were fed to lambs.

What we were seeing, in hindsight, is the potential beginnings of a new value chain. This product, a pasture-fed, high health, high eating experience meat, could fulfil a niche to discerning consumers to meet their taste, ethical and health needs. Nearly 20 years later we see brands emerging that may be linked to this.

So what of today's revolution, digital agriculture? Again this year we see papers in the Journal of New Zealand Grasslands and presented at this conference, that provide a glimpse of progress towards the future.

Digital agriculture encompasses a range of enterprises that all comprise of collecting and using data. The British government have recognised this opportunity and have poured over £120 million in the last year into developing research centres to investigate and progress the aims for agriculture. They have identified 3 areas, big data (AgriMetrics), little data (Precision Livestock Farming) and robotics (AgriTech). In the big data space the AgriMetrics group are developing the thinking, techniques and applications for using nationally collected data to better inform decisions and processes of agribusinesses. In the little data space (data collected by individuals, often on individual animals), tools for precision measurement of, for example, animal health and efficiency, are being developed, as well as options to link individual animals into the value chain. For example, image analysis is being tested to identify the predicted carcase characteristics of a beef animal coming to feed to determine the optimum slaughter time to meet supermarket requirements. Robotics science is concentrating on miniaturisation of current processes like weed control, sowing and harvesting to suit the cropping environments in intensive and diverse agriculture.

What the collection and use of vast amounts of data brings with it are new questions about not only data collection, validity, management and storage, but also who we need to empower the decision making from those data. The issues we now see are that we need data scientists and mathematicians working alongside our applied scientists, shifting the balance of skills required. The investment to make a step change into this space is significant, and initial progress towards commercialisation or implementation, like all new enterprises, is always slow.

Our own examples in New Zealand provide testament to this. Take, for example, the FarmIQ project. A total of $124 million was invested in this project over 7 years. The Farm IQ software provides farmers with options to capture individual livestock records, paddock histories, stock movements, health and safety and environmental planning. The investment in this one part of the programme has been rumoured to be half of the total spend. Will this investment be recovered by commercialisation of the product? That question is open, but one consequence is the growing awareness that software of this type is available and what it may mean for farm management. As the next generation of farmers take over managing the land, they are more familiar with tools such as these. Just like the beginnings of pregnancy scanning, the full picture of the power of this next step in applying science to farming is yet unknown.

One of the questions around data that remains almost completely ignored is that of which data are required? Currently tools and methods are being developed to capture and use data that are available or easier to quantify and capture (for example, individual animal liveweights). Unfortunately, these may not be the data that are most useful to the farmer. Knowing the quality of the feed in the paddock may be much more informative than knowing the individual liveweights of all of the animals that are going to be put into that paddock.

Critical questions must accompany this development and obsession with data. New applications of technologies such as hyperspectral analysis adds new information to our applied agricultural research toolbox. However, there is still a lack of research in data interpretation and understanding as it becomes applied to the farm system. What is lacking is the understanding of how much data or information are needed to make effective decisions. One paper (Beukes *et al*. 2015), published in the Journal of New Zealand Grasslands, explored the relative gain in profitability when increasing the accuracy of pasture supply data. This exhibited, with the limited number of scenarios used, the classical law of diminishing returns. However, there are many more technologies and data sets that need to be explored. Further complications to interpreting data are the concepts of precision and accuracy. Often the concept of precision (how many decimal places you can measure something to) overrides that of accuracy (is the number a true representation of the situation) when taking measurements. This causes confusion in the end user, as there is a perception that the more precise the number is, the better (and by default more accurate) the number is. This is not often the case, and it is much more important to have an accurate number than a precise one.

These concepts are introduced to start a conversation about data and what we must know before we can apply the skills and experience of applied agricultural research to the interpretation and application of these new tools and technologies of the future.

We must recognise the evolution of research and science. Applied research comes from basic discovery science. The science of numbers appears to be evolving into a significant force in agriculture and so we need to engage new minds with new skills. However, the final interpretation of the information gained from collecting more numbers will still require people with an understanding of the biological systems that fuel our farming communities. Our next steps must be to embrace new skill sets and learn how to capture the benefits of the technologies that are being developed to provide us with the data to generate new insights and new actions. Using that power will enable us to take the next steps in honing our farming practices or reconfiguring the next farming system to provide value to our customers.

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