Challenges and opportunities for conducting on-farm research

Graeme J. DOOLE[1*], Katherine N. TOZER[1], Christian SAUERMANN[2], J on SHERLOCK[3], Bill GARLAND[4], David R. STEVENS[5], Jamie F. WARD[5]

[1] *AgResearch, Ruakura Agricultural Centre, 10 Bisley Road, Hamilton 3124.*
[2] *AgResearch, Grasslands Research Centre, Tennet Drive, Palmerston North 4410.*
[3] *Otorohaea Ltd, 369 Otorohaea Trig Road, RD2, Ngaruawahia 3794.*
[4] *Rahiri Farm, 94 Dillon Road, Roto-o-rangi 3432.*
[5] *AgResearch, Invermay Agricultural Centre, 176 Puddle Alley, Mosgiel 9092.*
*Corresponding author: Graeme.Doole@agresearch.co.nz

Abstract

Availability of research farms owned by research institutions is declining due to their high operational cost, asset value, and limited distribution. The goals of this paper are to review their role and value in pastoral science and to identify challenges and opportunities for on-farm research. Research and commercial farms as trial sites may be mutually exclusive, complementary, or substitutes. Research farms are essential where science requires expensive facilities and/or rigorous control to maintain ethics and quality commitments. They can also provide information independent of scientific and commercial bias. Commercial farms provide access to more diversity, help scientists understand benefits and identify and resolve on-farm issues, and build industry credibility. Since the number of research farms is unlikely to increase, several lessons are important. Delivery, ethical, and science quality risks can accrue when the full cost of working with commercial farms is not considered or work most suited to a research farm is conducted in a commercial setting. Improved integration with farms owned by educational institutions; private trusts; regional and national government; and commercial companies offers opportunities for efficiency improvements. When working with commercial farmers, clear communication, flexible protocols, frequent oversight, and mutual respect are essential to maintain science quality. Paying farmers under a contractual agreement appears pragmatic. The value of opportunities to build farmer and researcher capability in the context of field experiments on research and commercial farms is identified.

Keywords: agronomy, commercial farms, field trials.

Introduction

The food and fibre sectors remain critical to the New Zealand (NZ) economy, producing around 11% of Gross Domestic Product (GDP), 13% of employment, and 81% of goods exports in 2022 (MPI 2022). Research and innovation are inputs that fuel the growth of the agricultural sector and consequently the national economy. Estimates of the rate of return for investments in agricultural research and development (R and D) vary but are usually high, with one study estimating an average benefit: cost ratio around 10: 1 for a portfolio of $60 bn (Alston et al. 2022). Likewise, McIvor and Aspin (2001) highlighted a return of 8: 1 for investments in pastoral-industry research by Meat New Zealand.

Field experimentation is an essential component of agricultural research. Laboratory experiments allow processes and mechanisms to be identified in controlled conditions, but results need to be tested under the conditions in which they must perform. A research farm is one that is maintained for the principal function of conducting scientific investigation. These are often owned by a scientific institution (e.g. Crown Research Institutes), state-owned enterprise (e.g. Landcorp), levy body (e.g. Scott and Lye farms are owned by DairyNZ), private trust (e.g. Dairy Trust Taranaki, Northland Agricultural Research Farm), educational institution (e.g. Owl Farm, Ashley Dene Farm), commercial company (e.g. drug companies), or other entity. Such a 'field laboratory' allows for an improved understanding of the complex interactions that occur between animals, climate, humans, plants, and soils and how these are affected, both individually and together, by experimental treatments. Scientific rigour within these experiments is enhanced by control of decisions related to farm management, which is most readily enabled on research farms. Ideas developed by farmers, researchers, and rural professionals can be tested, validated, and refined on-farm, with the relevance and scientific credibility of the research demonstrated as a matter of course. This approach increases confidence in outcomes and can contribute positively to the social license of NZ's agricultural sector.

Research farms have played a critical role in pastoral science in NZ. Ruakura Experimental Station was seen as a world leader in grazing-systems research, after its establishment in 1901 (Roche et al. 2017). However, the role and value of research farms—particularly those

ISSN 2463-2872 (Print) ISSN 2463-2880 (Online) https://doi.org/10.33584/jnzg.2023.85.3659

owned by public organisations, such as Crown Research Institutes and universities—has been questioned over the last 30 years. This is because:

1. Challenges facing agriculture increasingly occur at a complex, system level.
2. On-farm research is expensive as it principally contains multiple components.
3. Funding for pastoral system research is highly contested and often short-term.
4. Funding for pastoral agriculture has fallen in real terms for the last 20 years.
5. On-farm research is one priority among many at research institutions.
6. Value of research farms falls as staff with aligned experience leave.
7. Research farms require continued investment to stay commercially relevant.
8. Research farms require continued investment to maintain the infrastructure necessary for cutting-edge research.
9. Loss of farms reduces inter-farm variation (e.g., climate, soil), decreasing the broad relevance of research, especially in short-term studies.
10. Using research farms for diverse research projects and purposes can be difficult due to varying priorities and personal conflicts.
11. High cost of on-farm research can prompt scientists to use other options.
12. Research farms are valuable capital assets with low annual returns.
13. Underfunded research farms are not agile enough to adapt to change.

These and other barriers have led to a steady reduction in the availability of NZ research farms. For instance, the area of AgResearch land used for research has declined by around 85% over the last 30 years, from more than 13,000 ha in 1992 to less than 2,000 ha in 2022. One implication has been the increasing use of commercial farms for scientific experiments, with pros and cons for research outcomes.

Within this operational context for research in pastoral agriculture, the goals of this paper are to determine lessons, challenges, and opportunities for performing field experiments across different types of farms (cf., research and commercial), from a scientific perspective. This approach allows us to capture, integrate, and interrogate valuable insights from practitioners with diverse experience. These lessons are important for the institutions that fund and manage these assets, as well as scientists, industry, and farmers. The Six Capitals framework (Gleeson-White 2020) is used.

The focus here is on research and commercial farms. Yet, farm classification is complex. First, multiple research institutions can share a given research farm. An example is the Southern Dairy Hub that is run as a partnership between AgResearch, DairyNZ, and the Southern Dairy Development Trust. Second, research can be done on farms that have a demonstration focus (e.g., Owl Farm in the Waikato). Last, many farms managed by research institutions have key performance indicators related to profitability and productivity, to increase relevance and support viability.

Materials and Methods

The paper summarises insights from the diverse experiences of the authors. These insights were tested through informal discussions with multiple scientists.

The output of the discussions are categorised and compared using the Six Capitals model (Gleeson-White 2020), to explore the relative strengths and limitations of working on research versus commercial farms. The standard Six Capitals are: Natural Capital (e.g., soil, water, livestock), Financial Capital (e.g., cashflow, assets, liabilities), Human Capital (e.g., skills and knowledge of staff and stakeholders), Intangible Capital {e.g., brand, intellectual property (IP)}, Manufactured Capital (e.g., infrastructure, facilities), and Social Capital (e.g., relationships with communities). The Six Capitals model allows for clearer, holistic comparison of how alternate options impact research delivery.

Results

In some cases, the demand for research and commercial farms by scientists is independent and mutually exclusive of one another. Research farms are essential for work that could have a long-term negative impact on business performance (e.g., introduction of weeds, pests and disease) or requires specific resources (e.g., rumen-fistulated animals to study methanogens or quarantine facilities to study disease). Research farms might also be required in farmlet (i.e., small, replicated farm) studies where an elevated level of control, measurement, and monitoring is required (e.g., Macdonald et al. 2008, Macdonald and Roche 2023). In contrast, commercial farms are essential to identify how innovations work at scale, across different regions, and/or under less-controlled conditions, such as exploring how best to defer grazing over summer to improve pasture resilience (e.g., Tozer et al. 2020).

In other cases, carrying out investigations on either research or commercial farms can be seen as complementary since both work together to provide a broader and enhanced view. An example is the use of research farms during the development of an innovation and the use of commercial farms to explore its implications for on-farm management (e.g., a drug to increase ewe fertility; Juengal et al. 2013).

Another instance is where research and commercial farms are substitutes. As access to research farms declines, commercial farms are increasingly being used

to deliver science that was once done on research farms. It is in these circumstances that the relative strengths and limitations of either choice have a considerable influence on R and D outcomes (Table 1). Table 1 shows that while research farms have major advantages for conducting research, they are by no means a panacea for field trials.

Discussion

The loss of research farms in NZ reflects strong economic pressures placed on the science sector across the last 30 years. Also, the importance of the pastoral sector to the nation is being questioned (MBIE 2022). The decline in the stock of research farms has impacted the delivery of agricultural science.

Research farms are essential where science requires expensive facilities and/or rigorous control to maintain ethics and quality commitments. They can also provide information independent of scientific and commercial bias. However, several risks are apparent with their use: (1) limited breadth of farm systems evident within the stock of farms available; (2) high ongoing cost of establishment, maintenance, and staffing; (3) competition for scarce resources (e.g., facilities, staff) by different trials and teams; (4) low ongoing commercial relevance of farm systems; and (5) low replicability of research outcomes due to high degree of management required and/or limited scale. These risks have potentially grown in magnitude with the decline in the scale and scope of research farms across the last 30 years.

A reduction in the availability of research farms has motivated a shift towards using commercial farms for equivalent or similar trials used therein. Research on commercial farms increases access to diverse farm systems, reduces expenses as farmers often bear more of both the fixed and variable costs, improves credibility and industry relevance, and helps to isolate and resolve implementation issues. The following factors encourage successful research performance on commercial farms—assessed from resource use, science quality, and industry-uptake perspectives:

1. Potential opportunity exists to increase financial returns for the host farm.
2. Farmer can test a new practice or innovation on their own farm.
3. Research is tailored to the farm type being used for assessment.
4. Component-level work involving plot-based, not farmlet-based, experiments.
5. Demonstrable science outcomes of relevance to farmers are expected.
6. Farmers and scientists are energised by contact with different people.
7. Diverse opportunities exist for farmers and scientists to interact.
8. Reasonable scale and duration of project with minimal monitoring.
9. The farmer is enthusiastic about the subject area and its potential impact.
10. Minimal risk in terms of animal and human ethics, plus health and safety.
11. Investment in new and/or complex facilities is not required.
12. The farm retains substantial operating flexibility, especially at busy times.
13. The experience, insight, and skills of the farmer are valued by the scientist.

Researchers can also bolster the success of their research on commercial farms through paying careful attention to several principles. Central to success are effective communication, managing expectations, engaging the full farm team, providing adequate context, and starting to plan early. Coproduction is important to bring together diverse experiences to enable the farmer to understand and buy into the proposed goals, plan, and treatments. It also helps ensure scientists craft clear and practical lessons for implementation. A challenge to maintaining science quality is actions taken by the farmer that affect research outcomes but are not planned; for example, where a paddock in fallow is grazed due to a scarcity of feed elsewhere. Here, researchers need to be flexible, pragmatic, and adaptive to address unforeseen risks.

The loss of research farms in the last 30 years has potentially had several deleterious impacts. First, it may have motivated the termination of certain lines of enquiry requiring tightly-controlled conditions, bringing into question the relevance of institutional brands, ethos, staff, teams, and on-farm assets (e.g., livestock strains). Second, it could have been costly to science organisations in terms of lost revenue opportunities, given less access to the research facilities required to undertake robust field research. Last, while performing research on commercial farms has appeared cheap in comparison to research farms, there remain barriers (Table 1) to successfully implementing field research with stringent requirements within commercial systems. This is particularly observable in field research that focuses on issues that are difficult to explore on commercial farms, such as drench resistance (e.g., Miller et al. 2012), system-level management (e.g., Macdonald and Roche 2023), or animal behaviour (e.g., Zobel et al. 2019).

A primary determinant of success within trials maintained on commercial farms is the level of control that science staff have that, in turn, relies on the level of investment and alignment of the Six Capitals (Table 1). Here, Human Capital is central to success. A key constraint on commercial farms is that farm staff may

Table 1 Comparison of research and commercial farms in terms of the Six Capitals (Gleeson-White, 2020; see Materials and Methods section). For each Capital, reasons for (labelled "Pros") or against (labelled "Cons") the use of that facility (research or commercial farm) are listed.

Research farms	Commercial farms
Natural capital	
Pros · Ongoing use of a farm asset allows investment in better understanding of its natural capital (e.g., soils, weather). · Enhanced tracking of experimental animals throughout their lifetime, in line with regulation. *Cons* · Limited breadth of farming systems in terms of climate, plants (pasture and crop), soil, and animal type. · Hard to fit new research into the existing plan if a lot of research programmes are already in place. This grows in incidence as the stock of research farms declines. · Long-term effects of earlier experiments can influence results of new experiments.	*Pros* · Broad and numerous farming systems potentially available for research. · A farmer gains an improved understanding of a new practice or innovation, in the context of their own system. This is much more valuable to them than seeing how it works on another farm. *Cons* · Limited capacity to undertake research that may introduce new risks to a farming system (e.g., internal parasites resistant to an anthelmintic). · Lack of some baseline data (e.g., management and input history). · Limited understanding of the farm's physical environment (i.e., soils, climate). · More difficult to conduct system-based research that requires tight control over multiple farm elements. · Single commercial farms may lack the number of livestock available to conduct large-scale trials, which challenges replication requirements for robust statistical analysis.
Financial capital	
Pros · A research farm is a financial asset that accrues capital gain across time and produces revenue, often with little ongoing need for debt repayment. · Capacity to investigate novel approaches or innovations that cannot be studied on commercial farms due to the high financial risk they pose. These include projects requiring quarantine (e.g., Johne's disease, pneumonia), specific forms of sampling (e.g., methanogen research), or the introduction of new challenges (e.g., novel form of drench resistance). *Cons* · Prohibitive cost of expanding land area used for research purposes close to increasingly-urbanised sites (e.g., Ruakura, Lincoln). · High cost of maintaining quantity and quality of research staff, facilities, and equipment required. It is difficult to determine how to allocate a limited maintenance budget across different research assets, when the short duration of programmes, uncertainty in funding outcomes, and changes in funding priorities are considered. (Some of these costs are associated with the type of research done therein, rather than the type of farm per se.) · Competition between researchers for farm resources.	*Pros* · Low operating costs associated with access to farmland (often just goodwill and travel). · Farmers benefit from the relationship and access to an expert (Blackmore and Doole 2014), which can increase the performance of their business. *Cons* · Higher costs associated with finding relevant farms. · Higher implementation costs and time required for building relationships, planning, communication, monitoring of experiments, and training farm staff. These 'engagement' costs can reduce or reverse the potential economic advantages and increase with high staff turn-over. · Higher variable costs (e.g., accommodation, fuel, meals, time) and greenhouse-gas emissions associated with travel to more-distant farms. · Can increase time allocated to administration (e.g., animal ethics), given a need to adapt processes and procedures to new context. · Farmers need to be adaptable to unexpected events (e.g., their need to destock under adverse climate and/or price volatility can impact the execution of research). · Farmers may sell farm or change farm systems during a trial due to internal or external influences (e.g., consultant persuading a farmer there is a better way to improve income).

Human capital

Pros

- Research farm staff perform a lot of science work as part of their role and thus are more experienced in doing things according to an experimental protocol.
- High level of control before, during, and after the course of an experiment, including long-term studies across multiple years (decades, in some cases).
- Complex trials and changing protocols may be more easily accommodated.
- Communication can be easier because staff are usually available inside of standard working hours. This is because of the proximity of research farms to urban centres and/or because science delivery is a primary focus.
- More likely to have staff available for fieldwork than commercial farms at distant locations from where staff are based.

Cons

- Communication can be difficult due to number and diversity of science and farm staff involved.
- Farm staff have multiple responsibilities, which can impact the time spent on a certain trial. This is particularly risky if timeliness of treatment is significant. This can be overcome by experiments having dedicated staff.

Pros

- Opportunity for researchers to learn more about the farming context of their work, especially regarding barriers to uptake.
- Improved opportunity for scientists to develop ideas of high relevance to current industry challenges.
- Increased exposure to scientists and experiments can build a farmer's capability and understanding of an innovation. This can lead to farmers championing the innovation/research results, which supports uptake by other farmers.

Cons

- Potentially difficult to identify suitable farmers.
- Farm staff can have less experience in managing experimental protocols and may require upskilling; for example, in the specific sampling and procedures required.
- Contractors can be used on commercial farms, due to a lack of suitable equipment (e.g., mowers, sprayers). This can mean treatments do not occur at the planned time.
- Lower awareness of compliance needs (e.g., animal ethics, Health and Safety).
- Experiments can be onerous in terms of scale and duration, demotivating farmers.
- Distance from where research staff are based and commercial farm staff capability and capacity can limit the frequency and intensity of monitoring.
- Farmers can interpret instructions differently from what is intended. For example, in a cohort study of young goats, over 2% of goats remained unaccounted for despite rigid experimental protocols (Todd et al. 2019). This can be due to many things including different interpretations of what is required, a lack of precision relative to scientific norms, and/or lower prioritisation of research tasks relative to standard farm operations.
- It is hard to predict the exact level of interference to farm management that will transpire in each trial.
- Need for regular turnover of farmers involved in trials to prevent burn-out.
- Experimental treatments may be altered, introducing the risk of compromising the study entirely. Glassey et al. (2001) identified two potential sources: (1) performing research on a commercial farm can change the quality of operational decision making across a trial's duration, and (2) a farm can learn about the superior performance of a new system, motivating them to exit the trial prematurely.
- Communication can be more difficult if farmers do not have phone or data coverage throughout the day. (This is changing with the proliferation of cell phones and improved signal reception.)
- Sharing staff between commercial and science tasks can be a risk to execution and quality of the research tasks, especially at certain times of the year (e.g., docking, shearing).
- Farmers are required to learn and adhere to new rules and practices for research on their farm to be compliant with legislation; for example, in the domain of animal ethics.
- On larger farms, agreement with farm owners or directors may not translate to full buy-in of farm managers and staff, risking inadequate execution of experiments or data collection.

Intangible capital

Pros
- Improved science credibility and independence of research findings, assuming the level of control attained is superior to that achievable on a commercial farm.
- A science institution can improve its brand with farmers and industry if it is impact-focused, including through conducting field trials and demonstrations on research farms.

Cons
- Farms must be commercially relevant and of sufficient scale if the brand of the research institution is to be enhanced by research done there.

Pros
- Improved science credibility and independence of research findings, if level of control is high enough.
- A science institution can improve its brand with farmers and industry if it is impact-focused.
- Provides more opportunities to build connections with broader farming community, including rural professionals (e.g., fertiliser and seed companies).

Manufactured capital

Pros
- Availability of both standard and specialised facilities and infrastructure.
- Potential to invest in novel equipment, seeing this provides enduring value to an organisation.

Cons
- Studies on research farms may be small—for example, the number of animals may be low. This may affect the scalability and credibility of the results.
- The need to continuously invest in novel equipment to remain relevant.
- Potential lack of standard/specific farm facilities and infrastructure. An example is an Automatic Milking System (AMS).

Pros
- A commercial farm may provide advantages through scale, scope, and structure.
- A farm(s) can be selected that has the required infrastructure or that is based in a region best suited to address the research question.

Cons
- Lack of facilities and infrastructure (e.g., irrigation, weather stations, electricity, portable yards, crush, shelter) for specific research. This increases the cost of establishing new research programmes.
- Lack of facilities required to be compliant with animal-ethics legislation (e.g., handling equipment and shelter). This increases the cost of establishing new research programmes.
- Inconsistent facilities and technologies can be present on different commercial farms in the same trial.
- Four- or two-wheel motorbikes may be the only vehicles available on some farms, thus requiring additional expenditure for providing a vehicle compliant with institutional Health and Safety policy.

Social capital

Pros
- More opportunities for multi-disciplinary research teams due to their proximity to research stations.
- Improved availability of students.
- Improved access to diverse stakeholders (e.g., public, regional councils).

Cons
- Lack of relevance of some research undertaken under more-controlled conditions.
- Scientists can use their observations to form incorrect conclusions, particularly if only trialled for a short time (e.g., one year). This can influence messages to peers.

Pros
- Stronger link to industry improves legitimacy of research, enhancing pace and level of adoption.
- Improved accessibility of research to broad farmer audience.
- On-farm research promotes credibility for extension.
- Potential to employ farmers' social networks for extension.
- Demonstration of actions can be a powerful extension tool.
- Increased opportunities for group learning and building linkages between farmers and scientists.
- Many farmers can be ideal champions for research outcomes, especially if keen to participate in extension activities such as field days, podcasts, and published case studies.
- Demonstration of an application at commercial farm scale supports taking an innovation to market.
- Commercial farmers can add richness to an interpretation of research outcomes, by commenting on practical matters and system fit.

Cons
- Less control of public access to experiments, potentially impacting social perception of research (e.g., issues around the ethical treatment of animals).
- Farmers can use their observations to form incorrect conclusions, particularly if only trialled for a short time (e.g., one year). This can influence messages to peers.
- Need for regular turnover of farmers involved in research to maintain credibility and enthusiasm of farmer champions. This increases the continued cost associated with finding farmers, building relationships, investing in facilities, and training farm staff.

also be required to perform science-related tasks. Science and farm staff alike have varying skills when it comes to designing or implementing farm trials; this can be especially problematic on commercial farms. The issue is amplified by rapid staff turnover. Moreover, the knowledge and skills held by experienced scientists, research farm staff, and commercial farm staff used to working on research projects are valuable resources that take many years to develop and can be difficult to replace, highlighting a role for careful succession planning. Risks related to staff capability and capacity can be amplified; for example, where episodic monitoring is required (e.g., in response to high-rainfall events; McDowell and Paton 2004).

The Te Ara Paerangi initiative proposes restructuring of the public research, science, and innovation (RSI) system over the next five years (MBIE 2022), with important implications for field research. A focus on broader national priorities could reduce investment in agricultural and environmental science, to increase funding of research in the energy, health, industrial, and social domains. On the other hand, more funds are mooted to be available for partitioning across research priorities, helping to counter this impact. A key avenue for this will be in the domain of climate-change adaptation and mitigation research, which requires field trials to test innovations throughout their development phases. This type of research is likely to attract funding from levy bodies (e.g., DairyNZ), with leverage from public funds, because of the economic significance of pastoral agriculture and the on-farm/sectoral benefits associated with developing solutions that can be adopted at scale. The greater deployment of resources to the regions, particularly to support Māori aspirations in a way that enhances mana, proposed in Te Ara Paerangi could increase opportunities for field research. Moreover, Te Ara Paerangi promotes improved integration of science agencies, thus promoting improved sharing of resources, such as research farms.

A focus on science that has an impact on farms, driven by levy bodies and science priorities, has implications for staff capability and capacity. It takes time, motivation, experience, and knowledge to establish effective relationships between farmers and researchers. Moreover, it takes time to pass knowledge onto emerging researchers who wish to grow in this space. This is difficult in an environment where there is a scarcity of research funding, and during a time where scientists with rich experience in conducting field experiments are now reaching or are past retirement age. Here, clear communication, allowing time for review and reflection, and maintaining hybrid teams of early-, mid-, and late-career researchers will help effect staff succession. Mentoring emerging researchers is crucial to mitigate risks to do with credibility and set them up for success.

Conclusions

The economic pressures that have driven a decline in the availability of research farms within commercial science institutions across time will continue. A pragmatic strategy to retain access and generate the greatest benefit from these key assets is through improved communication and integration across diverse institutions (e.g., Crown Research Institutes, government entities, levy bodies, private trusts, universities). A considerable number of farms are held by such institutions although access is often limited. Many of these vary by location and system, thus if they were available for communal use, they would alleviate some of the research farm 'cons' listed in Table 1. In particular, they would help overcome the narrow breadth of farm systems available, increase the availability of resources for trials, reduce the cost of having to establish new research farms, improve payoffs for investing in particular infrastructure, and increase opportunities for cross-organisation research.

These farms are typically well-managed and have a strong focus on industry-good research. Yet, the use of shared farms is not straightforward. A focus on demonstration, the diverse objectives of different stakeholders, high existing utilisation making it hard to fit in new trials, lower prioritisation of research led by new partners, working within the complexity of existing governance models, establishing trust among new partners, and an ongoing lack of resources in certain regions (e.g., West Coast) or industries (e.g., sheep and beef) are all relevant.

Options for better linking science institutions, researchers, and farmers are:

1. Contracts between farmers and researchers can secure the quality of implementation. This could raise costs and concern among farmers though.
2. Having a single staff member in a large research institution overseeing relationships with farmer partners could be beneficial, though raise overhead.
3. Having a key contact person for each farmer is useful, to help improve communication and ensure research activities on that farm are well coordinated.
4. More discussion and collaboration with farmer bodies, such as Federated Farmers and levy bodies, could help streamline the engagement of suitable farmers and farms.
5. Institutions could save costs by maintaining a database of commercial farmers who are enthusiastic to work with scientists. It is important to maintain privacy standards, plus keeping

abreast of commitments to avoid burnout.

6. Stronger linkage between farmers and scientists through various groups (e.g., New Zealand Grassland Association, levy bodies) could help lay the social foundations for greater connectivity (Chapman et al. 2022).
7. Increasing payments to farmers could help to secure greater control and help compensate them for negative impacts on their operation.

Additional opportunities for impact are also available. For certain types of field research (e.g., mowing trials of a new plant variety, fertiliser-response trials), lifestyle blocks could be useful. They are often closer to research institutions and therefore could be less costly than working on more-distant farms. Nevertheless, a lack of facilities, livestock, management, scale, and staff does restrict the type of research that may be suitable for this type of enterprise. Additionally, Māori possess diverse land resources, varying in their natural capital and farm system, and improved cooperation between scientists and Māori can open new opportunities (Sheath et al. 2003). Overall, commercial farms hold opportunities for many aspects of research, yet research farms remain essential to answer some science questions.

Acknowledgements

This research has benefited from the insights of many people. We would like to acknowledge the contributions of Nigel Bell, Vicki Burggraaf, Bill Carlson, Terry Copeland, Gerald Cosgrove, John Coxhead, Jim Crush, Tracy Dale, Mike Dodd, Sandeep Gupta, Laura Hunter, Warren King, Stewart Ledgard, Stuart Lindsay, Jiafa Luo, Alec Mackay, Chris Miller, Cheryl O'Connor, Natalie Parlane, Grant Rennie, Karin Schutz, and Gosia Zobel.

REFERENCES

Alston JM, Pardey PG, Rao X. 2022. Payoffs to a half century of CGIAR research. American Journal of Agricultural Economics 104: 502-529.

Blackmore L, Doole GJ. 2014. Practitioner versus participant perspectives on conservation tenders. Biodiversity and Conservation 23: 2033-2052. https://doi.org/10.1007/s10531-014-0702-x

Chapman D, Stevens D, King W, Kerr G, Dodd M, Casey M, Catto W, Caradus J. 2022. Greener pastures: priorities for a low-footprint, high-value food producing future. Resilient Pastures Symposium; Grassland Research and Practice Series 17. https://doi.org/10.33584/rps.17.2021.3604

Glassey CB, Blackwell MB, MacDonald KA, Lawrey PC, George P, George J. (2001) Experiences with evaluating two farming systems in a split herd comparison on a commercial Waikato dairy farm. Proceedings of the New Zealand Grassland Association 63: 189-194. https://doi.org/10.33584/jnzg.2001.63.2406

Gleeson-White J. 2020. Six capitals. Allen Unwin, Sydney, Australia.

Juengel JL, Proctor LE, Wearne K, Olliver D, Hudson NL, Jensen D, Davis G, Johnstone PD, McNatty K. 2013. Effects of immunisation against androstenedione or bone morphogenetic protein 15 (BMP15) on reproductive performance in sheep. Journal of Animal Science 91: 5946-5953. https://doi.org/10.2527/jas.2012-6085

Macdonald KA, Penno JW, Lancaster JAS, Roche JR. 2008. Effect of stocking rate on pasture production, milk production, and reproduction of dairy cows in pasture-based systems. Journal of Dairy Science 91: 2151-2163. https://doi.org/10.3168/jds.2007-0630

Macdonald KA, Roche JR. 2023. Farm systems research at Ruakura—a 60-year legacy underpinning profitable and sustainable pasture-based dairy systems. New Zealand Journal of Agricultural Research. https://doi.org/10.1080/00288233.2023.2168707

McDowell RW, Paton RJ. 2004. Water and soil quality in an Otago deer farm. Proceedings of the New Zealand Grassland Association 66: 187-193.https://doi.org/10.33584/jnzg.2004.66.2534

McIvor SD, Aspin MD. 2001. R and D success stories and principles to practice. Proceedings of the New Zealand Grassland Association 63: 23-27. https://doi.org/10.33584/jnzg.2001.63.2436

Miller CM, Waghorn TS, Leathwick DM, Candy PM, Oliver AB, Watson TG. 2012. The production cost of anthelmintic resistance in lambs. Veterinary Parasitology 186: 376-381. https://doi.org/10.1016/j.vetpar.2011.11.063

Ministry of Business, Innovation, and Employment (MBIE). 2022. Te Ara Paerangi: future pathways white paper. MBIE, Wellington, New Zealand.

Ministry of Primary Industries (MPI). 2022. Situation and outlook for primary industries: December 2022. MPI, Wellington, New Zealand.

Roche JR, Berry DP, Bryant AM, Burke CR, Butler ST, Dillon PG, Donaghy DJ, Horan B, Macdonald KA, Macmillan KL. 2017. A century of change in temperate grazing dairy systems. Journal of Dairy Science 100: 10189-10233. https://doi.org/10.3168/jds.2017-13182

Sheath GW, Webby RW, Wedderburn M. 2003. Researchers working with Māori-our experiences. Proceedings of the New Zealand Grassland Association 65: 53-54. https://doi.org/10.33584/jnzg.2003.65.2518

Todd CG, Bruce B, Deeming L, Zobel G. 2019. Survival of replacement kids from birth to mating on commercial dairy goat farms in New Zealand.

Journal of Dairy Science 102: 9382-9388. https://doi.org/10.3168/jds.2019-16264

Tozer KN, Muller K, Craven T, Tarbottom I, Coster A, Burke R, Sherlock J, Cameron C. 2020. Effect of deferred grazing during late spring and summer on pasture productivity in Waikato and Bay of Plenty hill country. Journal of New Zealand Grasslands 82: 111-119. https://doi.org/10.33584/jnzg.2020.82.448

Zobel G, Neave HW, Webster J. 2019. Understanding natural behaviour to improve dairy goat (Capra hircus) management. Translational Animal Science 3: 212-224. https://doi.org/10.1093/tas/txy145