

Hill Country Futures-Resilient farmers and forages for the future

Suzanne E. KEELING^{1*}, Mhairi A. SUTHERLAND¹, Derrick J. MOOT², Katherine M. DIXON³,
Angela N. MCFETRIDGE¹, Nathan P. ODGERS⁴, James P. MILLNER⁵,
Joan P. K. ROPIHA⁵, Cameron I. LUDEMANN⁶, Adam R. BARKER⁷, Daniel E. BRIER¹.

¹*Beef + Lamb New Zealand, 154 Featherston Street, Wellington 6011, New Zealand*
²*Dryland Pastures Research, Field Research Centre, Faculty of Agriculture and Life Sciences, PO Box 85084,
Lincoln University, Lincoln 7647, New Zealand*

³*Nature Positive, 80 Evans Street, Dunedin, New Zealand*

⁴*Manaaki Whenua – Landcare Research, Soils and Landscapes Team, PO Box 69040, Lincoln 7640,
New Zealand*

⁵*Massey University, Tennent Drive, Palmerston North, New Zealand*

⁶*Cameron Ludemann Consulting, Naell Tynnegieterstraat, Arnhem, Netherlands*

⁷*Scarlati, Stilwell Road, Mount Albert, Auckland 1025, New Zealand*

*Corresponding author: suzanne.keeling@beeflambnz.com

Abstract

A thriving hill country farming sector is crucial for New Zealand's economy and its regions. However, it faces numerous challenges, such as increased regulations, and changing societal expectations. To ensure the long-term success and well-being of farmers, farm systems, the environment, and rural communities, support is essential for building lasting resilience. To address some of these challenges, the Hill Country Futures Partnership programme was initiated, receiving \$8.1 million funding over five years. This programme, co-funded by Beef + Lamb New Zealand (B+LNZ), the Ministry of Business, Innovation and Employment, PGG Wrightson Seeds, and RAGT New Zealand, concluded in 2023. During the programme, the farming community were actively engaged, and a collaborative research approach was employed involving B+LNZ, farmers, universities, Crown Research Institutes, and consulting agencies. The programme consisted of interconnected workstreams with a focus on resilient farmers and future-oriented forages. It generated a wide range of resources, including easily accessible extension materials, tools, and scientific publications, covering social, environmental, and technical aspects to support New Zealand's hill country farming systems. And it showed how a collaborative approach, inclusive of researchers and farmers with diverse backgrounds and expertise, can help create a more resilient hill country future.

Keywords: resilience, farmers, forages, legumes, models, native shrubs

Introduction

A thriving hill country farming sector is critical to New

Zealand's economy and our regional communities. About 73% of sheep and beef farmed land is hill country, around 5.4 million ha (grazed + cropped, fodder), including 2.09 million ha of grazed tussock country (Beef + Lamb New Zealand Economic Service, pers. comm). The sector faces multiple challenges including land use change, climate change, increasing regulation and changing societal expectations. To help hill country farmers and their farms be more resilient, now and into the future, the Hill Country Futures (HCF) Partnership programme was developed. The programme aimed to help future-proof the profitability, sustainability and well-being of New Zealand's hill country farmers, their farm systems, the environment, and rural communities. To contribute towards this aim, HCF was designed with a strong emphasis on developing tools and resources to support farmer resilience and decision-making around future-oriented forages.

A key focus of HCF was to support farmer resilience by providing resources to help them make informed and strategic decisions to develop resilient farm systems for now and into the future. Hill country farmers farm diverse landscapes across New Zealand. Selecting plants to meet several criteria — ease of establishment, animal production, environmental challenges — is important and a key component to farming success. To do this, farmers need data, field trials and modelling to assist in strategic decision making. This includes decisions around what to plant and where, to assist in the creation of a resilient hill country farming future. However, there are several factors that contribute to decision making including the individual values and drivers of farmers. Farmers need support to recognise the strengths and limitations of their entire farm system. Farmers' personal recognition and understanding of the

drivers, challenges and opportunities within their own individual hill country farming context also directly influence how they achieve and maintain a resilient future.

Sheep and beef farming in New Zealand's hill country landscapes is subject to multiple pressures, including increasing competition by forestry, more stringent environmental regulation, direct and indirect impacts of climate change, changing societal expectations, and new market requirements. Given these numerous pressures, increasing the resilience of farmers to expected and unexpected events is key to future-proofing them and their farms. To help achieve this, we need to know how to measure resilience in hill country farming and how to monitor if progress is being made towards the goal of "future proofing".

The 'resilient farmer' component of HCF had several aims. First, determine a shared vision for the future of hill country farming based on key challenges and opportunities facing farmers and other stakeholders. Second, use this information to develop a resource package that can be used to measure and monitor farmer resilience and guide conversations about well-being and decision-making. Third, showcase to New Zealanders, including the consumer, how farmers are demonstrating continual improvement for the environment, livestock, and communities.

Legumes have long been recognised for their nitrogen-fixing ability, which is a feature that will become increasingly important in the future. New Zealand's diverse landscapes, climatic conditions and farm systems can make it difficult to decide which legume to grow where, including when to consider nitrogen-fixing properties. Due to diverse hill country landscapes, there is also a need to consider alternative forages that may be more suited for steep hill country, such as native vegetation.

The resilient forage component of HCF also had several aims. First, identification and collation of pasture/crop yield data and growth rate information. Second, evaluation and/or development of models to inform forage selection or predict legume yield for different land management units across New Zealand at farm and national scales. Third, consider the feasibility and investigate mātauranga knowledge of using native shrubs as forage.

Materials and Methods

Resilient farmers

This research determined the drivers, challenges and opportunities faced by hill country farmers, the vision they have for the future of hill country farming and how this vision can be used to achieve a resilient hill country future.

Hill country farmer and stakeholder interviews

Between July 2019 and March 2020, 298 people (n=169 farmers) participated in 170 interviews and six focus group discussions to understand the current and future challenges and opportunities facing hill country farmers. Interviewees were primarily sheep and beef farmers but also included rural professionals, academics, and industry leaders. Interviewees were asked to share their views on the future of hill country farming, the challenges, and opportunities they saw and how best to build enduring resilience and "future-proof" the industry. Interviews (recorded and transcribed) were conducted throughout New Zealand to maximise representation across the country (Human Ethics #NZE19_47).

To gain an overview of the interview topics discussed by farmers and stakeholders, a qualitative analysis of the data was undertaken by coding their testimonies to the 54 objectives described in the New Zealand Sustainability Dashboard (Matatihi Economic Research) using the Web Qualitative Data Analysis online software (About WebQDA 2022). A sustainability indicator framework was used as the analytical coding framework because there is considerable overlap between the objectives for sustainability and resilience.

A second, separate team of researchers conducted deductive research on the transcripts from all farmers interviewed. Non-farmer stakeholder interviews were not included in this analysis due to time and resource constraints. The interviews, data and associated analysis, were used for several different purposes: 1) create positive farming stories, 2) produce a series that shares farmers perspectives, 3) create an evaluation resource for farm system resilience and 4) identify a unifying vision for a successful hill country future.

Positive farming stories

A series of case studies and media articles were developed to showcase to New Zealanders how farmers are demonstrating continual improvement of the environment, livestock and rural communities.

Farmer Perspective Series

Topics more frequently raised by farmers interviewed were analysed in depth. A summary of the results was written up as the Farmer Perspective series (2021); a science communication series that detailed the key issues facing farmers and their views on how to resolve them.

An evaluation resource for farm system resilience

Preliminary results from the stakeholder interviews highlighted industry-wide concerns about declines in farmer well-being and found limited use of social metrics in existing farm evaluation frameworks. This identified a need for an evaluation resource for farm system resilience that focused on the health and well-being of the farmers.

Methods to design the tool were influenced by the

British Design Council ‘Double Diamond’ framework (Design Council 2019). This framework recommends two clear stages to a project, first to consult widely to “discover and define” the problem that needs to be resolved and, second, “develop and deliver” the product.

Stakeholder interviews, co-designed meetings and a gap analysis were undertaken to identify the design priorities. Multiple prototypes of the evaluation resource were created and tested with farmers and rural professionals. The evaluation resource was designed to be used by rural professionals to guide the farmer(s) through an evaluation of their farms’ resilience whilst simultaneously supporting the farmer(s) to reflect on their own well-being and how this impacts the resilience of their farm.

Identifying a unifying vision for a successful hill country future

A challenge for building a resilient hill country future is identifying what success looks like – that is to say, what is a common unifying vision that all stakeholders can work towards? During the stakeholder interviews, all participants were asked what they thought the best outcome for the hill country would be in the year 2030, and how this could be achieved. The results were analysed using deductive research techniques then incorporated to a vision for a successful hill country future.

Resilient forages

Hill country farmers, farm diverse hill country landscapes across New Zealand. Selecting plants that meet several criteria from ease of establishment to achieving animal production goals and tackling environmental challenges is crucial. Farmers need evidence to give them confidence to utilise different forage and farm system options. These include data from field trials, case studies and modelling to inform decisions about what to plant and how to manage it, to help create a resilient hill country farming future.

Forage growth trials and AgYields database

Data on the growth profiles of a range of forages (e.g red, white, and subterranean clover, lucerne, plantain, chicory) were collected from 13 research and commercial farms across New Zealand, including monocultures, mixtures and resident pastures. Data gained from these trials plus historic data sets were used to inform the development of the models described below and contributed to the AgYields national forage database (Moot et al. 2022a). AgYields was developed to provide farmers and rural professionals with ready access to localised yield data that can be used to inform decisions around pasture planning. Farmers can see which pastures and crops have been grown in their districts, how much they grew, and when, so they can

select more resilient pastures and crops to suit their farm systems.

Forage Value index

The feasibility of adapting the DairyNZ Forage Value Index (FVI) to sheep and beef farms was assessed using a case study approach. The sheep and beef FVI of perennial ryegrass cultivars were calculated using previously defined methods described by Chapman et al. (2017) but adapted for the eight B+LNZ farm classes of New Zealand. The potential benefits of adapting the DairyNZ FVI framework for use by the sheep and beef industry were then estimated following methodology described by Ludemann (2022). Various scenarios were modelled to test the sensitivity of the returns on investment from investing in a sheep and beef FVI. These scenarios included changing the expected adoption of the tool over time, as well as changing the initial and ongoing costs of the framework.

Modelling legume yield

Modelling legume yield drew on 20 years of lucerne, soil and water data from Lincoln University, along with on-farm experiments. Two methods, with contrasting complexity, were developed to simulate lucerne (*Medicago sativa*) yields across New Zealand. The first model — thermal time-based model — was a GIS- (Geographical Information System) derived from empirical data on seasonal responses of the crop to temperature (Moot et al. 2022b). It was designed to target a farmer or farm-consultancy end-user interested in estimating local lucerne yields. The second model — the Agricultural Production Systems sIMulator (APSIM) model — is a process-based model that also estimates lucerne yield but considers a detailed representation of underlying plant and soil processes that interact within the cropping system (e.g. carbon, water and nitrogen balance in both crops and soils) (Yang et al. 2021, 2022, 2023). This approach targeted researchers as end-users to develop a mechanistic tool that can be used to explain climate and land use changes on forage production and environmental impacts. Yield simulations were performed with both models at a 5 km resolution across New Zealand, in areas assumed to be suitable for lucerne growth. Specifically, these excluded locations with slopes >15 degrees and annual rainfall >1,800 mm giving a total of 5,228 grid cells of 25 km² across New Zealand (Teixeira et al. 2023). The APSIM model was also used to validate the outputs of the TGM lucerne yield model.

Mapping micro-indicators - soil temperature and moisture

Micro-indicators (soil temperature and moisture) were mapped at farm scale in hill country landscapes and these data were used to support the development of the legume yield models (described above). Wireless sensor networks (WSNs) were installed at six hill-

country sites across New Zealand in mid-2020. The sites were selected to represent a diverse range of hill country landscapes and add to existing data. Each WSN had 20 sensor nodes that were designed to make hourly measurements of soil temperature and moisture at 30 cm depth and transmit the data to a cloud database. At each site, sensors were distributed to account for differences in perceived drivers of the variation in soil temperature and moisture at the landscape scale, such as aspect and slope.

A generalised additive statistical model (Wood 2017) was used to relate the measurements of soil temperature and moisture to other environmental variables thought to influence their spatial and temporal dynamics (e.g. slope, aspect, elevation). The model also accounted for the day of the year. At modelling time, almost two full years of soil temperature and moisture data were modelled for most sites. At each site, the fitted models were used to produce daily maps of the soil properties at 30 m resolution for 1 year. The high resolution of the maps allowed for the spatial variability of the soil properties within individual hill slopes or paddocks to be assessed.

Natives as alternative forages

Hill country farmers are interested in revegetation with native species for several reasons, including enhancing biodiversity, improving health of waterways and erosion control. This is evident from the number of catchment group projects that have been initiated by local landowners (including farmers) that involve planting native vegetation on their farms (e.g. Motu catchment, Waimatā catchment). Native vegetation could also potentially be used as forage for sheep and cattle. To determine if native shrubs can be used as an alternative forage for animals - growth, forage quality, feed preference, economics and mātauranga knowledge of native shrub species were evaluated. Native species evaluated included: *Hoheria populnea* (Houhere), *Pittosporum crassifolium* (Karo), *Griselinia littoralis* (Pāpāuma), *Coprosma robusta* (Karamū), *Coprosma repens* (Taupata), *Melicytus ramiflorus* (Māhoe), *Pseudopanax arboreus* (Whauwhaupaku) and a shrub willow.

This pilot study research evaluated several different aspects of native shrubs including establishment, growth and forage value (field trials in the Manawatu and Mahia); metabolisable energy content and digestibility analysis of the foliage; feed preference in sheep; economics of planting natives based on modelling and mātauranga of native species.

Value of HCF and its outputs

Hill Country Futures was designed to assist in future-proofing hill country farmers and farms. To achieve this, a range of tools and resources were created to enable

farmers to make impactful and enduring changes on-farm. To understand the value of HCF and its outputs for the hill country sector, the impact of these outputs and accompanying interventions was estimated using the QUICK (Quantifying and Understanding the Impact of Capability and Knowledge) framework (Bell et al. 2023). This is a semi-quantitative approach that aims to place indicative values on the impact of the HCF resources and accompanying extension programme. In this analysis, value was estimated based on the assumption that they all have an independent chance of success of 30%.

Results

Resilient farmers

Hill country farmer and stakeholder interviews

The stakeholder interviews revealed multiple views on the future for hill country farming and how this could be achieved. Briefly, themes discussed included environmental stewardship, farm succession, challenges and impacts of changing land-use with emphasis on increasing afforestation in the hill country, options to diversify farm businesses and changes in management practices. Farmers were also asked to describe what they thought hill country farming could look like in 2030. There hopes for the future included environmental stewardship, achieving their financial goals and thriving communities. Aspects of the HCF programme were aligned with these hopes through the evaluation of growing native shrubs, development of tools / resources to help farmers select more resilient forages to suit their farm systems and the creation of a resource package to support farmer well-being. Findings are discussed in more detail in the Farmer Perspective Series (2021).

Positive Farmer Stories

The results of the stakeholder interviews revealed that many farmers would like their work and decision-making rationale to be better understood by the general-public. Farmers interviewed commonly expressed a sentiment that there was a negative bias towards farmers in the mainstream media. In response, a series of twelve farmer stories, intended for a mainstream media audience, that highlight positive social and/or environmental outcomes was created. Stories can be found on the Hill Country Futures website (<https://www.hillcountryfutures.co.nz/resources/our-stories>).

Farmer perspective series

Topics summarised in the Farmer Perspective series (2021) were: Barriers and opportunities to on-farm environmental action; Regenerative agriculture; Economic diversification; Succession; and Farmer Vision for 2030. A consistent theme during the interviews was the view that farmers voices are not being heard. This series provides public recognition of

farmer perspectives, and provides a farmer voice about the future of hill country farming.

Evaluation resources to support farmer well-being.

The FarmSalus resource package provides a simple overview of the whole farm system and prompts discussions about farmer health and well-being within their own specific farming context. FarmSalus is aligned to four pillars that represent the sum of what it means to be resilient in our farming communities - Healthy farmer, Healthy farm business, Healthy environment and Healthy connections to support networks. The FarmSalus resources package includes printable handouts to explain the concepts of farm system, farm resilience and how farmer health relates to this. The package includes notes for facilitators and resources for rural professionals and farmers.

The human centred design approach used to develop FarmSalus created considerable buy-in from a range of industry stakeholders during its development, which is evident as this process resulted in a resource package that has utility to the industry. FarmSalus assists users through its ability to unbundle resilience and opens up conversations about well-being. Feedback from rural professionals revealed this fills a gap from Aotearoa New Zealand's existing agricultural monitoring and evaluation tools and helps them to understand where and how to provide support for their customers.

Vision for success

Many interviewees communicated that a successful hill country future would involve an integrated approach to hill country farming with excellent environmental and social outcomes running alongside a good profitable business model. A successful vision for the future hill country included thriving rural communities, with lots of local collaboration and strong farmer networks for learning and sharing information. Although there was general agreement between stakeholders of what success could look like, there was a wide variation in views of how to achieve it. Topics covered included incentives for best practice from markets and/or government, recognition of all the carbon stored and sequestered on farms, diversification of incomes through new enterprises and the use of government regulations.

Resilient forages

Forage growth trials and AgYields database

The resilient forages component of the programme produced a range of resources underpinned by data integrity and relevancy to farmers. The greatest relevance to farmers is frequently from case studies, therefore, HCF documented a number of these. For example, the impact of increased areas of lucerne at Bog Roy station (Moot et al. 2019) and its flexible use for hogget mating at Willesden farm on Banks Peninsula

(Smith et al. 2023). For summer moist environments the impact of improved forages at Inverary station was described (Chapman et al. 2021) with comparisons of resident and improved forages documented over three years (Smith et al. 2023). Intensive data collection at Lincoln University, highlighted the importance of nitrogen for dryland systems (Talimini 2022) and how a mix of white clover, plantain and perennial ryegrass could provide the same yield and quality of pasture as those produced under current nitrogen limitations (Myint et al. 2021). More information about the forage growth trials can be found on the Hill Country Futures website, under our study sites.

The creation of AgYields has also led to the recovery of paper-based datasets that were in danger of being lost forever (Moot et al. 2022a). The AgYields national forage database is an open access central repository, for all past, present, and future pasture and crop yield and growth rate data collected in New Zealand.

Forage Value index

From the limited relevant data available, the modified internal rate of return estimated for adapting the DairyNZ FVI framework to the New Zealand sheep and beef industry varied between 27% to 62% over a 10-year period. The net present values ranged between \$6 million and \$45 million. This depended on whether the annual cost of the tool was \$0.5 million or \$1 million and what level of adoption was assumed over that period (Ludemann 2022). However, for multiple reasons this initiative was not progressed further. Reasons included insufficient appropriate data on ryegrass cultivars from hill country locations, pasture renewal challenges for hill country and ongoing cost and maintenance of the tool. It was decided that a tool that focused on species selection rather than cultivar was more appropriate. Modernisation of ForageMaster was actioned instead (Finlayson et al., 2004).

Modelling legume yield

The APSIM-NextGen lucerne model is available via APSIM initiative repository in GitHub. It can be used with lucerne / red clover to look at climate change scenarios, catchment run-off, and water quality issues. Compared with APSIM, the TGM is a simpler model. It can be used by farmers for predicting lucerne yield on their farms. The simple model is based on mean air temperatures (Moot et al. 2022b).

In areas assumed to be suitable for lucerne growth, yield results from both the APSIM and TGM models largely agreed for spatial patterns across New Zealand, ranging from 28 t dry matter/ha per year in the northern warmer regions to <5 t/ha per year in the driest and southern lands. The comparison between models showed greater agreement for yield estimates > 10 t/ha per year, with greatest divergence for very low yield estimates (< 5 t/ha) when temperature and water stress

constraints are greater. This analysis provides the yield potential for lucerne grown in different regions of New Zealand and whether it can be successfully established through cultivation (Smith et al. 2023) or oversowing (McCowan et al. 2003).

Mapping micro-indicators - soil temperature and moisture

Analysis of the sensor data revealed differences in soil temperature and moisture dynamics between different landscape positions. These differences were most strongly expressed in the soil temperature data. For example, soils on north-facing slopes warmed from their winter minimum, through a threshold of 10°C between 23 and 65 days earlier than soils on south-facing slopes, depending on the site.

The generalised additive models indicated that day of the year was the most important predictor of soil temperature and moisture, followed by elevation and aspect. Evaluation of the predictions using standard statistical measures of performance suggested that soil temperature was very predictable, but soil moisture was only moderately predictable. This is due in part to the regularity with which soil temperature varies through time compared to soil moisture, which is influenced by the frequency and intensity of rainfall events. The quality of the soil moisture predictions may improve if the model is trained on a longer time series (e.g. three full years of data rather than two), or if additional sensors are installed in under-sampled landscapes (e.g. on steeper slopes). Whilst this work was small in scale, it showed that a sensor network that accommodates the challenges of a hill country terrain can successfully be established in New Zealand, resulting in increased accuracy of future models.

Natives as alternative forages

Findings from the investigation into the application of mātauranga towards planting of native shrubs showed that traditional knowledge derived from the use of native plants is localised and reflected in names given to species by Māori in different areas. Survival of all native shrub species evaluated in the programme was much lower at Mahia than Manawatu after the first summer, except for Karamū. This was likely due to the warmer, drier conditions at Mahia. Survival in Manawatu was high (100%) in most species. Early growth was greater in Manawatu with the *Coprosma* species performing best. Metabolizable energy content of foliage ranged from 10 to 12 MJ ME/kg DM. Protein content was generally low (<10%). Digestibility analysis suggested that animals consuming native shrubs would produce similar rumen methane emissions to those on pasture (Wangui et al. 2022). Feed preference of some shrub species was greater than pasture. Initial analysis suggests that the *Coprosma* species have potential as a forage species based on good survival rates, early

growth and performance in feed preference trials with sheep. The profitability of planting natives was shown to be very dependent on the value of carbon credits. *Pinus radiata* was more profitable than either livestock or native shrubs at 2022 carbon prices (Wangui et al. 2021).

Value of HCF and its outputs

Assuming each of the resources developed by the HCF programme have a 30% chance of successful uptake, then the expected present value of the HCF programme's benefits is estimated to be:

- \$85 million in a scenario in which the resources are made available to hill-country-farmers but not actively promoted to them (an 11 to 1 benefit-to-investment ratio).
- \$100 million in a scenario with a limited investment in promotion and extension (a 12 to 1 benefit-to-investment ratio).
- \$110 million in a scenario with an increased investment in promotion and extension (a 14 to 1 benefit-to-investment ratio).

The modelling showed that profitability gains would account for 53% of the value created from the resources, followed by improvement in farmers' physical and mental health (18%), the health of their land (13%) and their resilience to adverse weather (9%).

Discussion

Hill Country Futures was a unique programme as it brought together researchers, farmers and other hill country stakeholders with diverse backgrounds and expertise. They had a common goal of future proofing the hill country through resilient farmers and farm systems based on resilient forages. The programme's approach was distinct from typical pastoral research as it considered both the technical aspects of farming and the social and cultural contexts within which these systems operate.

Resilient farmers

The breadth and number of stakeholders who were interviewed provided an in-depth and unique data set. This data set was used to gain insights into the drivers, challenges and opportunities faced by the hill country sector, which resulted in the telling of farmer stories, the Farmer Perspective series, FarmSalus and the creation of a vision for the hill country.

Farmer stories were created to illustrate to New Zealanders how some farmers are demonstrating continual improvement for the environment, livestock, and communities. Through these stories, the programme was able to showcase several hill country farmers, including: Matt Iremonger – general manager of Willesden Farm on the Banks Peninsula — who has increased production efficiencies and reduced

nitrogen use by growing lucerne. Trevor Johnson — owner of Paparata Station — who has made changes to their farming system based on sustainability. John Chapman showed the importance of on-farm pasture measurements to change his summer safe high country farm system. This work and others further demonstrated the value of on-farm data providing impetus for the creation of the AgYields database during HCF. This is an enduring legacy of the programme and an important repository created from a feeling that too much historic pasture data has been lost from the wider agricultural community.

A challenge for the hill country and the farming sector in general is how to reduce the distance between the various parts of the value chain from policy to legislators through to rural professionals and farmers. There is a need to build a common understanding about how to meet and work through some of the sectors biggest challenges. The Farmer Perspective series highlighted some of the biggest issues facing hill country farmers including environmental stewardship, farm succession, the challenges and impacts of changing land-use, options to diversify farm businesses and changes in management practices. To recognise farmer concerns of feeling unheard and to give voice to farmers perspectives and views, this series was disseminated through several avenues to ensure a broad range of stakeholders including the public are reached (e.g. social media, podcasts, rural magazines).

Several organisations have shown interest in the FarmSalus resource package including The Rural Support Trust, Ministry for Primary Industries, FarmStrong, Catchment leader's forum, The New Zealand Red Cross and Safer Farms, and it has been integrated into some courses offered by Agri-Women's Development Trust. It is expected with the support of other organisations, that FarmSalus will continue to evolve and be used by rural professionals and facilitators to guide conversations about resilience and decision-making.

Resilient forages

Forage legumes, such as lucerne and red clover, produce high protein yields through symbiotic nitrogen fixation. This is an important adaptive feature in agricultural systems as it reduces reliance on synthetic nitrogen fertiliser, as demonstrated when incorporated into satellite areas on hill country areas in this study (Chapman et al. 2021; Smith et al. 2023). Satellite areas are often intensively managed smaller farmlets within larger, more extensive blocks on hill country farms. These satellite farmlets take pressure off the hill country landscapes and allow these areas to recover and build pasture covers during spring and early summer which can then be used to increase the body condition of breeding stock over summer and autumn. However,

the yield potential to grow monocultures of forage legumes, across New Zealand was unclear. The data collected from trials run on commercial and research farms, and the APSIM and TGM models developed have increased the evidence base and understanding of the potential to grow these forages across New Zealand. They have shown that the introduction of monocultures of legumes can double, or triple dry matter production compared with resident species (Smith et al. 2023). Further development of the APSIM lucerne model for dryland is needed to explore the sustainability of legume monocultures under future climate scenarios across New Zealand. (Teixeira et al. 2023). This knowledge will help increase production, reduce greenhouse gas emissions and give farmers support to keep farming into the future.

Native vegetation has multiple potential uses and benefits for hill country farm systems, including biodiversity, mitigating soil erosion and as an alternative forage. The potential of native shrubs as an alternative forage for sheep, the economics associated with establishment and the mātauranga knowledge about these shrubs was evaluated in the context of hill country farming. Based on the metabolisable energy content of both foliage and fine stems of native shrubs, results from this pilot study indicated they would be palatable to livestock which was subsequently confirmed by sheep feed preference trials. However, one of the challenges facing farmers planting native shrubs is the cost of establishment including purchasing and planting the shrubs, weed control, as well as animal pest and stock control. In many situations this may be >\$10,000/ha. Reducing propagation costs will be necessary to reduce this cost significantly and make it a more viable option for farmers to consider when investigating alternatives forages on their farms.

Conclusions

The programme has created a range of social, environmental and technical solutions and provided an evidence base on which farmers can make impactful and enduring changes on-farm. With time and even with conservative adoption, the outputs will deliver a significant return on investment for the funders, but more importantly useful resources for farmers to support resilient farming systems in the face of increasing pressures and change were created. However, the true success of the HCF stems from the direct involvement of farmers and the value of fostering collaboration across a multi-disciplinary research team.

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