# Hill Country Futures study sites

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beef+lamb new zealand

HILL COUNTRY FUTURES

# Hill Country Futures: Study sites

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# Introduction

Data was collected from 18 research and farm locations around New Zealand as part of the Hill Country Futures (HCF) Partnership programme. In many cases, farmers generously opened up their farms as study sites, enabling the collection of this valuable data.

This data contributed to:

- The development of models related to lucerne management for resilient hill country farms.

- The development of resources (e.g. AgYields, TGM online calculator) to help farmers make decisions about pastures and crops to suit their farm systems.
- The development of daily maps of soil properties (moisture and temperature), showing that soil temperature and moisture can be mapped at the farm scale in New Zealand hill country. These maps can be used to drive forage yield models and help inform decision-making on pasture management.
- Increased understanding of the potential for native shrubs as an alternative forage.
- Insights into the traditional knowledge (mātauranga) of native shrubs.

Below provides a summary of what was trialled and the key findings at the different study sites, including links to more information if you are keen to know more?

## Ashley Dene & Ladbrook

### Key message

- Generally, tall fescue failed to perform in this summer-dry environment.
- Cocksfoot / sub clover pastures appear to be most resilient in this summer-dry environment with variable spring rainfall.
- A pure sward of sub clover can potentially be established with the use of acetolactate synthase (ALS) inhibiting herbicides, which could be used to create a high legume base in pasture before overdrilling grass the following year.

### About the study site

Ashely Dene Research and Development Station near Burnham, Canterbury has been owned by Lincoln University since 1909. Separated into three blocks (Home, Main and Cemetery), the main area of dryland pastoral research occurs on the shallow soils, with low water holding capacity on Cemetery Block. It is a summer dry environment with annual rainfall of ~640 mm, with soil water deficits developing from September to April in most years.

## Study 1

*What was trialled*

- The production of four grass species — perennial ryegrass, brome, cocksfoot and tall fescue— was measured under dryland conditions, with (+N) or without nitrogen (-N).

*Key findings*

- Total annual yields ranged from 2.04 (ryegrass -N; Year 1) to 12.7 t DM/ha/yr (cocksfoot +N; Year 3).
- Sown grasses accounted for >89% of total DM yield in Years 1 and 2 but the proportion of total annual DM production from sown species declined from Year 3. By Year 6, sown species accounted for 48 ± 3.3 (tall fescue) to 64 ± 3.3% (brome, cocksfoot and ryegrass) of total annual DM production.
- +N pastures produced ~55% more yield than –N pastures in Years 3 and 5 when spring/summer rainfall was adequate to maintain growth.
- Generally, tall fescue failed to perform in this dryland environment. However, the production and persistence of the brome, cocksfoot and ryegrass were not different when subjected to water deficits alone.

### Keen to know more?

- Talamini junior et al. 2021: Annual yield and botanical composition of four dryland grass species with or without nitrogen over six years

## Study 2

*What was trialled*

- The production and persistence of mixed species pastures established with a combination of annual clovers, white clover and plantain with cocksfoot or perennial ryegrass was measured over 8 years.

*Key findings*

- Cocksfoot-based pastures had 60% of sown species present in the spring of Year 8, compared with 28% in ryegrass-based pastures.
- White clover did not persist in the dryland environment past Year 2.

- Sub clover yield depended on the time and amount of autumn rainfall but contributed up to 45% of the spring yield.
- Cocksfoot / sub clover pastures appear to be most resilient in this summer-dry environment with variable spring rainfall.

## Keen to know more?

- Taylor et al. 2021: Yield and botanical composition of four dryland pastures at Ashley Dene Research Farm over 8 years

## Study 3

*What was trialled*

- The effect of ALS inhibiting herbicides on subterranean (sub) clover was evaluated. The effect of herbicide was quantified by measuring yield and phytotoxicity scores from sub clover in repose to three herbicide treatments: 0.4 L/ha Spinnaker, 1.0 L/ha Headstart, 8 L/ha 2,4-DB and were compared with an untreated Control.

*Key findings*

- A pure sward of sub clover can potentially be established with the use of ALS inhibiting herbicides, which could be used to create a high legume base in pasture before overdrilling grass the following year.

## Keen to know more?

- Taylor et al. 2020: Yield of subterranean clover after post-emergence herbicide application for broadleaf weed control

# Early Valley

## Key message

- Increased understanding of how controlling resident grass species can promote subterranean (sub) clover growth during the spring and the value of applying fertilisers, particularly phosphorous, to improve clover yields.

## About the study site

Early Valley, on the Port Hills above Tai Tapu, on Banks Peninsula, Canterbury, is a 25 ha large hill country lifestyle property owned by D. Schiel. The site is a North-West facing dryland hill pasture ~200 m a.s.l. with no fertiliser programme. Grazing is done by stock sourced from a neighbouring property as required. The existing pasture was dominated by browntop, sweet vernal and some clumps of cocksfoot with low populations of resident white and sub clovers. This site had recovered from being burnt in the Port Hills fires of 2017.

*What was trialled*

- The effect of phosphorous, sulphur and molybdenum fertiliser additions on oversown subterranean (sub) clover on dryland hill pasture sites were investigated.
- The herbicide treatment (330 ml Centurion Xtra/ha) was established to investigate the competition between grass and sub clover for nutrient uptake with the aim to suppress the grass growth to promote clover growth.

*Key findings*

- Herbicide application was the primary treatment influencing sub clover yield, which more than doubled with the application of herbicide.

- In the plots where herbicide was applied the sub clover then responded to the addition of phosphorus.
- The herbicide application suppressed the grass yield by 15%.
- Yield of white clover was increased by the addition of phosphorus fertiliser but was not affected by the herbicide treatment.
- The results highlight the value of controlling the resident grass species in mid-summer to promote sub clover seedling establishment in autumn and growth during the spring.
- Applying phosphorous is important improve clover yields.

### Keen to know more?

- Morton et al. 2021: A summary of research results on pasture responses to fertiliser and lime in the South Island hill and high country

## Inverary Station

### About the study site

Inverary Station, in mid-Canterbury, is a 4,250 ha sheep and beef hill country farm. Inverary has about 3000 ha of the harder hill country with limited useful grazing and 650 ha of easier hill country with better soils that is suitable for grazing. The rest of Inverary is largely rolling or flat country with good cultivatable soils capable of growing large quantities of high-quality dry matter.

- Forage trials and soil monitoring were undertaken at Inverary Station.

## Forage trials

## Key message

- Increased understanding of the impact of sub surface lime application (lime injection) on soil pH and growth rates of legume-based pastures at Inverary station.
- Increased understanding of production differences between red clover (improved pasture) and unimproved pasture in this hill country environment.
- Increased understanding of difference in climate and soil properties in complex (aspect and altitude) hilly landscapes typical of summer moist (900-1000 mm) hill country farms.

  **Listen** to John Chapman talk about his journey to legume dominant pastures at Inverary Station

## Study 1

*What was trialled*

- This study aimed to establish if sub surface lime application (lime injection) had a positive impact on soil pH and growth rates of legume-based pastures at Inverary Station.
- A lime ripper was used to place pelletised, fine lime at two depths (100 mm and 350 mm) at rates of 0, 1 or 2 t/ha.
- The dry matter production of the two pastures was monitored over three growing seasons to gauge response and economic viability of lime injection for hill country farmers.

*Key findings*

- Lime injection at 1 or 2 t/ha rates did not give a consistent yield benefit after three years, and the dry matter yields with no lime were satisfactory.

- There were significant differences between sites, legume species and lime rates at different harvests over time.
- Because the summer rainfall was adequate in both years, the tap-rooted lucerne and red clover did not have an advantage over the volunteer shallow-rooted white clover. Red clover was moderately well adapted to the topsoil conditions.
- The lime blower can be used to modify sub surface pH but the technology requires further development to be used commercially.

## Study 2

*What was trialled*

- Regular quadrat cuts from exclosure cages on different pasture types across the farm were taken between August 2019 and January 2020 to determine the differences in production between lucerne, improved pasture and unimproved pasture in this hill country environment.

*Key findings*

- Over four growth seasons, improved pastures produced 2-3 times more DM than resident pastures. This was a result of increased growth rates, particularly during periods of increased animal demand.
- A lot of resident pasture was not eaten and decayed in the wet conditions which restricted new pasture growth.
- The addition of Phosphorous + Sulphur fertiliser added to the late spring surplus but accentuated the late spring problem of excess feed going to seed.
- Red clover was successfully introduced by aerial no-til as a monoculture. This enabled chemical control of weed grasses such as red fescue.
- Red clover grew a month earlier than the resident browntop which met the requirement for early spring lactation feed.
- Red clover was followed by Italian ryegrass to use the soil nitrogen and this combination produced over 30 t DM/ha.
- Satellite areas of high-quality feed substantially changed the feed supply, which enabled greater control of grazing management which subsequently increased pasture quality across the rest of the farm.
- The pasture growth rate data gave the farm manager confidence to renew pastures and understand feed supply in relation to aspect and altitude.

## Study 3

*What was trialled*

- On-farm climate data from different altitudes and aspects were compared to estimates generated by NIWA's Virtual Climate Station Network (VCSN) at the two closest sites.
- Environmental data were monitored at three locations.
- Two of these sites logged 10 cm soil temperature hourly while the weather station recorded 10 cm soil temperatures, air temperature, rainfall and solar radiation.

*Key findings*

- Solar radiation and air temperature estimates from VCSN data were reliable and consistent with onsite data.
- Rainfall data from VCSN and farm data was very similar (less accurate at rainfall <40mml/month or during extreme rainfall events).
- Soil temperature estimates from VCSN data underestimated soil temperatures on the north facing slope by ~1 °C but was reliable on the south facing slopes.
- The contrast between climatic data from Willesden and Inverary sites suggested temperature measurements are more reliable from VCSN in summer moist areas.

## Keen to know more?

- Chapman et al 2021: Legumes are the key to increasing productivity at 'Inverary', a summer moist hill/high country farm in mid-Canterbury.
- Smith et al. 2022: Total annual and seasonal DM production of improved and unimproved resident pastures at three farms in Canterbury

## Soil monitoring

## Key message

- A wireless sensor network was established that enabled some of the first daily farm scale mapping of soil properties in NZ hill country. These maps can be used

to drive forage yield models and help inform decision-making on pasture management.

*What was trialled*

- The trial investigated the potential for modelling the distribution of soil temperature and moisture in hill country landscapes at high spatial and temporal resolution.
- A WSN was installed at Inverary Station in July 2020. The WSN consisted of twenty sensors installed in the soil at 30 cm depth. The sensors were distributed across the farm in a way that accounted for topographic variation in elevation, aspect (the direction a hillslope faces) and the potential for water to accumulate (strongly influenced by slope gradient).
- The sensors were configured to measure soil temperature and soil moisture at hourly intervals and report measurements back to a cloud database via the cellular network. On the farm, LoRa technology was used to communicate between components of the WSN.
- Statistical models were fit to the soil temperature and moisture data in order to relate those soil properties to other topographic variables including elevation, aspect and slope.
- The models were used to predict soil temperature and moisture across the farm at 30 m resolution at daily intervals across a generic model year.

*Key findings*

- The WSN performed well.
- As expected, sensor data revealed that north-facing slopes tended to be warmer and drier than south-facing slopes, which reflects the influence of topography. Interestingly, soils on north-facing slopes warmed from the winter minimum temperature through an arbitrary threshold of 10°C about 42 days faster than soils on south-facing slopes (about 102 days versus 144 days in 2020).
- The soil temperature model performed very well, but the soil moisture model performed relatively poorly. The difference in performance is due in part to differences in predictability between soil temperature and soil moisture, the former varying more smoothly and more regularly over time than the latter.
- Soil moisture predictions derived from the model should be interpreted with caution, but should be good enough to provide a broad indication of when soils are near field capacity versus when they are near wilting point.
- It is expected that model performance should improve with a longer time-series of data, and better sensor calibration.

# Iversen Field, Lincoln University

## Key message

- Pasture mixes/pasture diversity and pastures with plantain are receiving a lot of media attention.
- This series of experiments showed that under irrigated conditions a simple mix of perennial ryegrass and white or red clover was the most suitable.
- The number of seeds sown of perennial ryegrass and white clover should be approximately equal to optimise yield and quality and there was no difference when sowing 1000 or 2000 seeds/$m^2$.
- If plantain was added to a perennial ryegrass/white clover sward then it only resulted in a yield advantage if nitrogen fertiliser was also used.
- Under rainfed conditions, sub clover was shown to grow a month earlier in spring than red and white clovers, which more closely algins with animal demand in early spring.

## About the study site

Iversen Field is a 20 ha pastoral research area at the south end of the Lincoln University campus. This site is a key area for detailed commercial and postgraduate experiments as proximity allows intensive measurements to be taken. The site is flat land on a deep (>2 m) Wakanui silt loam soil. Irrigation is available to allow potential yields to be determined when required. Mean annual rainfall is 590 mm (20002-2020) and, under dryland conditions, the site has a “summer dry” environment.

## Study 1 - Annual growth rates of clovers

*What was trialled*

- This experiment compared yield, growth rates and nutritive value of monocultures of annual (arrowleaf, balansa, Persian and subterranean) and perennial (white and red) clovers over two years.

*Key findings*

- Arrowleaf clover produced the highest yield in Year 1 but failed to regenerate from seed. This species is unsuitable for most pasture situations because of the hard seed issue.
- Sub clover produced the earliest dry matter yields of the legumes. It regenerated from seed in Year 2.
- Balansa clover was a prolific seeding species. However, hot dry conditions at the beginning of Year 2 meant no re-emergence occurred. This was unexpected and happened even when irrigation water was applied to stimulate emergence. The Balansa was observed to be producing seedlings in Year 3 – but its failure in Year 2 makes it unsuitable for most mixed sward situations.

### Keen to know more?

- Olykan et al. 2021: Growth rates and persistence of annual and perennial clovers.

## Study 2 - Sub clover annual growth rates

*What was trialled*

- Herbicide options for sub clover were investigated, as well as the ability of different sub species to cope with water logging.

*Key findings*

- Large leafed sub clover cultivars produced more dry matter than small leafed. This was because the large leafed cultivars reached canopy closure earlier so intercepted more of the available light.
- A combination a large and small leafed cultivar is recommended for oversowing/overdrilling into dry hill country.
- Several herbicides are available for weed control if monocultures of sub clover are established. Sub clover is not often listed as a safe species on product labels because the market is small or it hasn't been tested.

### Keen to know more?

- Taylor et al. 2020: Yield of subterranean clover after post-emergence herbicide application for broadleaf weed control.
- B+LNZ Fact Sheets. Broadleaf weed control in emerging subterranean clover.
- B+LNZ Fact Sheets. Subterranean clover tolerance to waterlogging.

## Study 3- Growth and composition of irrigated perennial ryegrass, white clover and plantain in monocultures and mixtures

*What was trialled*

- A simplex design approach was used to identify an optimum mixture of perennial ryegrass, white clover and plantain for maximum dry matter (DM) yield in an intensive pasture.
- Pastures were grown under irrigation with or without nitrogen (N) fertiliser.

*Key findings*

- For irrigated or summer moist regions a simple ryegrass/white clover mix optimised yield and quality.
- Equal numbers of seeds of each species sown at 1000/$m^2$ was the optimum sowing rate when N fertiliser was not used.
- The addition of plantain to this mix reduced yields because of a lack of N in the system due to it outcompeting the white clover.
- For irrigated or summer moist regions where N fertiliser is used an equal mix of perennial ryegrass, white clover and plantain gave the optimum yield and quality.

### Keen to know more?

- Black et al. 2021: Plant diversity with species drilled in the same or alternate rows enhanced pasture yield and quality over 4 years.
- Myint et al 2021: Nitrogen effects on species' contributions to grazed pasture mixtures under nitrogen loss and application restrictions.

## Study 4 - Growth and composition of irrigated perennial ryegrass, cocksfoot, plantain, white clover, red clover and subterranean clover in monocultures and mixtures

*What was trialled*

- This experiment examined the effects of plant species diversity and sowing method on seasonal patterns of pasture yield and quality of a total of 69 primary, binary, tertiary and quaternary pasture mixes grown under irrigated conditions in four reps (276 plots).
- The main objective was to identify the pasture mix which maximised pasture yield and quality over a 4-year period.

*Key findings*

- This comprehensive experiment confirmed the 50:50 perennial ryegrass, white clover mix as optimising yield and quality. Perennial ryegrass with red clover was equally successful for the four-year duration of this experiment.
- Plantain did not add to the yield or quality of the pastures and the centroid mix (6 species) was no more productive than the binary mixes and became perennial ryegrass was dominant after two years.
- After establishment the decision was made to irrigate the experiment. This meant sub clover was unable to regenerate after Year 1.
- These plots became an indicator of the weed burden and invasive potential of other species. The annual weeds were highly productive because winter and summer annuals grew which maximized seasonal growth.
- The yield of all plots was related to the ability of their canopy to intercept solar radiation through rapid recovery after grazing and a complimentary leaf arrangement. The grass plots became nitrogen deficient over time which reduced their radiation use efficiency and enabled a competitive advantage for the grass clover mixes.

## Māhia

### About the study site

The study site comprises Okepuha, Pongaroa Station and Taharoa Trust on the Māhia Peninsula, an area of about 11,400 ha. Native shrubs were planted at Pongaroa station.

- Trials on native shrubs and soil monitoring were both conducted at Māhia.

## Native shrub trials

## Key message

- Survival of native shrubs is reduced by hot dry conditions in the 1st summer after planting.
- Coprosma species had high survival at this site whereas other species suffered more than 50% losses.
- Controlling animal pests such as goats is essential when establishing native shrubs.

*What was trialled*

- Seven species were evaluated: 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 (Salix schwerinii) ('Kinuyanagi').
- Small plot trials (15 plants in each plot with four replicates) were used to assess the establishment and early growth of each species, and the nutritional characteristics of foliage and fine stems (<5 mm diameter).
- Shrubs were planted in rows with 1.5 m spacings between rows and 1.5 m between plants within rows to achieve a plant density of 4,400 plants/ha at 100% survival. Shrubs were planted on slopes of 20-30 degrees.
- All plants were trimmed to 40 cm height prior to planting.
- Weed control was achieved by spraying glyphosate around shrubs 8 weeks post planting using a knapsack sprayer.
- At the end of their 1st summer, shrubs were assessed for survival and growth.

*Key findings*

- Survival of native shrubs at Mahia ranged greatly depending on species, with the lowest survival observed in Mahoe (38%) and highest in Taupata (100%).

- Early growth (eight months post planting) was influenced by species. Coprosma species (Karamū and Taupata) had the greatest height and diameter growth increments over the time period.
- The Mahia trial was badly damaged by goats and was discontinued because very few live plants remained in June 2021.

## Soil monitoring

### Key message

- A wireless sensor network was established that enabled some of the first daily farm scale mapping of soil properties in NZ hill country. These maps can be used to drive forage yield models and help inform decision-making on pasture management.

*What was trialled*

- The trial investigated the potential for modelling the distribution of soil temperature and moisture in hill country landscapes at high spatial and temporal resolution. The spatial resolution of existing widely-available soil temperature and moisture data is too coarse to provide useful information at farm scale in hill country, and is unable to account for the influence of topography in these landscapes.
- A wireless sensor network (WSN) was installed at Māhia in September 2020. The WSN consisted of twenty sensors installed in the soil at 30 cm depth. The sensors were distributed across the farm in a way that accounted for topographic variation in elevation, aspect (the direction a hillslope faces) and the potential for water to accumulate (strongly influenced by slope gradient).
- The sensors were configured to measure soil temperature and soil moisture at hourly intervals and report measurements back to a cloud database via the cellular network. On the farm, LoRa (Long Range) technology was used to communicate between components of the WSN.
- Statistical models were fit to the soil temperature and moisture data in order to relate those soil properties to other topographic variables including elevation, aspect and slope. The models were used to predict soil temperature and moisture across the farm at 30 m resolution at daily intervals across a generic model year.

*Key findings*

- The WSN performed well.
- As expected, sensor data revealed that north-facing slopes tended to be warmer than south-facing slopes, which reflects the influence of topography. Interestingly, soils on north-facing slopes warmed from the winter minimum temperature

through an arbitrary threshold of 10°C about 45 days faster than soils on south-facing slopes (about 19 days versus 64 days in 2021).

- The soil temperature model performed very well, but the soil moisture model performed relatively poorly. The difference in performance is due in part to differences in predictability between soil temperature and soil moisture, the former varying more smoothly and more regularly over time than the latter.
- Soil moisture predictions derived from the model should be interpreted with caution, but should be good enough to provide a broad indication of when soils are near to capacity versus when they are near wilting point.
- It is expected that model performance should improve with a longer time-series of data, and better sensor calibration.

## Massey University: No. 4 farm

### Key message

- Native shrubs could be a potential forage resource as a browse to supplement livestock when pasture metabolizable energy values are low, especially in late summer and/or during winter when pasture growth is poor.
- Low browse protein content means that shrubs will be more suited to maintenance feeding.

### About the study site

The trial site is located on a steep south-facing slope on Massey University's Number 4 dairy Unit. The soil types are a mix of Tokomaru and Ohakea silt loam which are heavy textured soils prone to wetness.

*What was trialled*

- Seven species were evaluated: *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 (*Salix schwerinii*) ('Kinuyanagi').
- Small plot trials (15 plants in each plot with four replicates) were used to assess the establishment and early growth of each species, and the nutritional characteristics of foliage and fine stems (<5 mm diameter).
- Shrubs were planted in rows with 1.5 m spacings between rows and 1.5 m between plants within rows to achieve a plant density of 4,400 plants/ha at 100% survival. Shrubs were planted on slopes of 20-30 degrees.
- All plants were trimmed to 40 cm height prior to planting.
- Weed control was achieved using a herbicide combination of haloxyfop (Gallant) for grass weeds and clopyralid (Versatil) for broadleaf weed control using recommended label rates. Herbicide was spot sprayed using a knapsack sprayer 4 weeks after planting.
- At the end of their 1$^{st}$ summer (2020), shrubs were assessed for survival and growth.
- Height and basal stem diameter were assessed in August 2022.
- Foliage/fine stem samples were collected for analysis of nutritional traits in January and October 2020. Analysis of nutritional traits included metabolizable energy (ME), protein and fibre.

*Key findings*

- Survival was high (100%) in all species except Whauwhaupaku (90%).

- The Coprosma species (Karamū) had the greatest height and diameter growth increments among the native species at age 1 year.
- Measurement of growth in August 2022 (age 3 years) revealed that Karamū was still performing well but the other species, particularly Houhere, had achieved similar height growth.
- Salix performed better than the native species; mean height of Salix was 2.3 m, significantly greater than all native species.
- Stem diameter growth of Karamū was similar to Salix and significantly greater than all other species assessed.
- Metabolizable energy content of the foliage ranged from 10.5 MJ/kg DM (Salix) to 12.2 MJ/kg DM (Whauwhaupaku). Protein content was generally low (< 10% in all species apart from Houhere).
- Stem ME was lower than that for leaf in all species. Similarly, protein content in the stems was lower than the foliage in all species.

## Massey University: Tuapaka hill country unit

### Key message

- Native shrubs could be a potential forage resource as a browse to supplement livestock when pasture metabolizable energy values are low, especially in late summer and/or during winter when pasture growth is poor.
- Feed preference testing with sheep shows that most of the native shrubs assessed in the study are palatable.

## About the study site

Massey University's Tuapaka Farm in the Manawatu provides a facility for quality research, teaching and extension in sheep and beef farming. It is particularly used in research investigating aspects of hill country farming. It is hill country vulnerable to soil erosion and brush weeds, especially gorse. Previously used for grazing sheep and cattle.

*What is being trialled*

- *Griselinia littoralis* (Pāpāuma), *Coprosma repens* (Taupata), *Melicytus ramiflorus* (Māhoe) and *Salix schwerinii* (willow) were planted in a steep 2 ha paddock in August 2020 to achieve a stocking rate of 3,200 plants/ha at 100% survival.
- Plots of individual species included about 330 plants, each replicated three times.
- Weed control was undertaken prior to planting with an aerial application of glyphosate in July 2020 and an aerial application of Haloxyfop in November 2021 to control grass weeds.
- Currently livestock have been excluded from the site, but sheep will be given access to the shrubs to assess sheep preferences under field conditions and post browsing recovery of shrubs. This work will potentially be undertaken in February 2025 when it is anticipated all species will be sufficiently well grown to withstand limited browsing, that is, not completely defoliated by browsing animals. The objective is to remove some foliage but leave sufficient canopy to allow shrubs to recover.
- Sheep feed preference testing and intake rates were measured under controlled conditions to assess the palatability of native shrubs, willow, and pasture.

*Key findings*

- Shrub survival at 2 years of age differed among species. Survival was highest in Salix (few losses), intermediate in *Griselinia littoralis* (Pāpāuma) and *Coprosma repens* (Taupata), with 75 and 69% survival respectively and lowest in *Melicytus ramiflorus* (Māhoe) with 24% survival.
- Among the native species height growth at two years was greatest in *Griselinia littoralis* (Pāpāuma - 106 cm) and *Coprosma repens* (Taupata - 100cm) and lowest in *Melicytus ramiflorus* (Māhoe - 87 cm).
- It is expected that shrubs will be sufficiently well grown to browse with sheep without high risk of post browsing mortality in February 2025
- Native shrubs were more palatable to sheep than willow and pasture.

# Mount Grand Station


Mt Grand Trig Station 09/03/2017 (Photo: KM Pollock)

## Key Message

- Climate and soil property data can be used to develop farm-scale maps which can provide a platform to drive models that predict other agronomically relevant variables, such as pasture yield.
- These maps can be used to explore spatial and temporal dynamics at the farm scale and inform decision-making on pasture management to meet feed demands.
- The temperatures measured on the warm dry sites at Mt. Grand and Willesden suggest annual clovers such as subterranean clover may be more suited than white clover on many north facing slopes across New Zealand.

## About the study site

Mount Grant is a 2,127 ha high country run located in the Upper Clutha Basin, Central Otago. The farm is immediately east of Lake Hawea and the homestead has stunning views across Hawea Flat, towards Lake Hawea. The property was gifted to Lincoln University in 1988 as a bequest from LJ and LJ Struthers and operates as both a commercial farm and a resource for student research. Over 70% of the property is moderate to steep hill country, the rest of the farm consists of productive flats or alpine vegetation. Annual rainfall is between 600 to 700 mm and the altitude of the property ranges from 330 to 1400 m a.s.l. The property is predominantly west facing so subject to summer dry conditions.

*What was trialled*

- On farm climate data from different altitudes and aspects were compared with estimates generated by NIWA's Virtual Climate Station Network (VCSN) at the two closest sites.
- Climate data, including soil and air temperatures and precipitation, were monitored over a period of 17 years (2001-2018) at seven sites.
- The data, collected at six altitudes (450, 535, 620, 755, 920 and 1290 m a.s.l.) were compared with estimates from NIWA's VCS network at four nearby co-ordinates.

*Key findings*

- Air temperatures from NIWA's VCSN data were overall an accurate representation of the Mt. Grand temperature and climate.
- Rainfall data from VCSN and farm data was very similar.
- Soil temperature estimates from VCSN data were 1 to 4 °C lower than on-site data and there was an observed difference in soil temperatures recorded on north- and south-facing slopes.
- These results were consistent with the summer dry Willesden site which showed north facing slopes in dry environments are warmer than predicted from VCSN data.
- The temperatures measured on the warm dry sites at Mt. Grand and Willesden suggest annual clovers such as subterranean clover may be more suited than white clover on many north facing slopes across New Zealand.

## Oruamatua

## Key message

- A wireless sensor network was established that enabled some of the first daily farm scale mapping of soil properties (temperature and moisture) in New Zealand hill country.
- These maps can be used to drive forage yield models and help inform decision-making on pasture management.

## About the study site

Oruamatua is a 10,000 ha farm near Taihape.

### *What was trialled*

- The trial investigated the potential for modelling the distribution of soil temperature and moisture in hill country landscapes at high spatial and temporal resolution. The spatial resolution of existing widely-available soil temperature and moisture data is too coarse to provide useful information at farm scale in hill country, and is unable to account for the influence of topography in these landscapes.
- A wireless sensor network (WSN) was installed at Oruamatua in June 2020. The WSN consisted of twenty sensors installed in the soil at 30 cm depth. The sensors were distributed across the farm in a way that accounted for topographic variation in elevation, aspect (the direction a hillslope faces) and the potential for water to accumulate (strongly influenced by slope gradient).
- The sensors were configured to measure soil temperature and soil moisture at hourly intervals and report measurements back to a cloud database via the cellular network. On the farm, LoRa (Long Range) technology was used to communicate between components of the WSN.
- Statistical models were fit to the soil temperature and moisture data in order to relate those soil properties to other topographic variables including elevation, aspect and slope. The models were used to predict soil temperature and moisture across the farm at 30 m resolution at daily intervals across a generic model year.

### *Key findings*

- The WSN performed well.
- As expected, sensor data revealed that north-facing slopes tended to be warmer and drier than south-facing slopes, which reflects the influence of topography. Interestingly, soils on north-facing slopes warmed from the winter minimum temperature through an arbitrary threshold of 10°C about 23 days faster than soils on south-facing slopes (about 88 days versus 111 days in 2021).

- The soil temperature model performed very well, but the soil moisture model performed relatively poorly. The difference in performance is due in part to differences in predictability between soil temperature and soil moisture, the former varying more smoothly and more regularly over time than the latter.
- Soil moisture predictions derived from the model should be interpreted with caution, but should be good enough to provide a broad indication of when soils are near field capacity versus when they are near wilting point.
- It is expected that model performance should improve with a longer time-series of data, and better sensor calibration.

## Paparata Station

### Key message

- A wireless sensor network was established that enabled some of the first daily farm scale mapping of soil properties (temperature and moisture) in New Zealand hill country.
- These maps can be used to drive forage yield models and help inform decision-making on pasture management.

### About the study site

The study site has an area of about 3500 ha.

*What was trialled*

- The trial investigated the potential for modelling the distribution of soil temperature and moisture in hill country landscapes at high spatial and temporal resolution. The spatial resolution of existing widely-available soil temperature and moisture data is too coarse to provide useful information at farm scale in hill country, and is unable to account for the influence of topography in these landscapes.
- A wireless sensor network (WSN) was installed at Paparata Station in August 2020. The WSN consisted of twenty sensors installed in the soil at 30 cm depth. The sensors were distributed across the farm in a way that accounted for topographic variation in elevation, aspect (the direction a hillslope faces) and the potential for water to accumulate (strongly influenced by slope gradient).
- The sensors were configured to measure soil temperature and soil moisture at hourly intervals and report measurements back to a cloud database via the cellular network. On the farm, LoRa (long Range) technology was used to communicate between components of the WSN.
- Statistical models were fit to the soil temperature and moisture data in order to relate those soil properties to other topographic variables including elevation, aspect and slope. The models were used to predict soil temperature and moisture across the farm at 30 m resolution at daily intervals across a generic model year.

*Key findings*

- The WSN performed well.
- As expected, sensor data revealed that north-facing slopes tended to be warmer and drier than south-facing slopes, which reflects the influence of topography. Interestingly, soils on north-facing slopes warmed from the winter minimum temperature through an arbitrary threshold of 10°C about 30 days faster than soils on south-facing slopes (about 53 days versus 83 days in 2021).
- The soil temperature model performed very well, but the soil moisture model performed relatively poorly. The difference in performance was due in part to differences in predictability between soil temperature and soil moisture, the former varying more smoothly and more regularly over time than the latter.
- Soil moisture predictions derived from the model should be interpreted with caution, but should be good enough to provide a broad indication of when soils are near field capacity versus when they are near wilting point.
- It is expected that model performance should improve with a longer time-series of data, and better sensor calibration.

# Pemberley Farm

## Key message

- Dry matter production of tall fescue / white clover and red clover / white clover pastures were monitored in 2018/19 and 2019/20 on a commercial farm under irrigated conditions.

## About the study site

Pemberley Farm, at Charing Cross, Aylsebury, Canterbury is a 506 ha finishing farm about 40 km due west of Christchurch owned by the Cross brothers and we worked with manager Valerie Walpot. This flat land and about 331 ha (65% of the total area) is irrigated by water from the Central Plains Water Scheme. The pastures range from pure legume swards e.g. red clover or lucerne to pasture mixes of tall fescue/white clover to more conventional ryegrass and white clover. Pemberley's stocking rate is approx. 8 su/ha in winter and up to 28 su/ha in summer.

*What was trialled*

- Dry matter production of tall fescue / white clover and red clover / white clover pastures were monitored in 2018/19 and 2019/20 on a commercial farm.
- In Year 1 the pasture cuts were taken soon after each grazing event. In Year 2 exclosure cages were placed in each pasture type to make data collection more straight forward.
- This was an unreplicated pasture monitoring trial.

*Key Findings*

- In Year 1, the tall fescue / white clover pasture produced a total of 18.5 t DM/ha. Average botanical composition was 60% tall fescue, 20% white clover and 20% ryegrass.

- In Year 2, the same pasture produced 18.0 t DM/ha up to 18 January 2020. This was a 24% increase on that produced over the same period in Year 1. On average, swards consisted of 85% tall fescue and 5% white clover.
- In Year 1, the red clover / white clover pasture produced under 10 t DM/ha. The proportion of each clover varied throughout the year but averaged about 20% red clover, 40% white clover and 30% broadleaf weeds.
- In Year 2 dry matter production lifted to 11 t DM/ha, but by winter the proportion of clover had decreased, and the weeds increased up to 50%.

## Poukawa Research Station

### Key message

- Increased understanding of seasonal growth pattern and productivity of annual and perennial legumes in Hawkes Bay dryland.

### About the study site

Poukawa Research Farm is a 290 ha dryland farm (750 mm annual rainfall) located 14 km south of Hastings. The farm operates a 50:50 sheep cattle ratio. 800 ewes are mated to a terminal ram with all lambs finished. 50 cows are mated to a wagyu bull and all stock finished. Flexibility is maintained with winter trade lambs purchased and killed at heavy weights in spring and cull dairy cows purchased in early winter and slaughtered in early summer once clean-up duties are finished. Contour ranges from flat to moderately steep with a mix of north and south facing slopes. Approximately 80% of the property is cultivatable and approximately 25 ha are used for early season dryland squash.

Poukawa Research Farm is typically winter warm and summer dry with an annual rainfall of 730 ± 26.5 mm.

### Study 1 - Seasonal growth pattern of annual and perennial legumes in Hawkes Bay dryland

*What was trialled*

- Dry matter (DM) production and time of flowering of a range of annual (8) and perennial clovers (2) along with pure swards of annual ryegrass, perennial ryegrass, plantain and chicory were compared.
- Ten legume species, two grass species and two herb species were each sown as pure swards.
- Plots where managed under different cutting regimes in order to measure seasonal DM production of each species under repeated cuts versus a single end cut.

*Key findings*

- In a difficult year (dry autumn 2020 and 2021) the annual clovers were comparable in terms of dry matter (~8 tonne) with perennial ryegrass and plantain.
- Viper balansa and Woogenellup sub clover flowered early and produced the greatest amount of dry matter up to the beginning of November, however, the early flowering of these clovers may cause difficulties in enabling seed set under set stocking systems.
- The perennial clovers (Kopu 11 white clover and Relish red clover) had higher total yields but 38% of total production occurred in summer.
- Regular cutting produced higher total yields than a single end cut for the annual and perennial clovers with the exception of the arrowleaf cultivars.
- Arrowleaf clover is best utilised with a single grazing late in the season.

## Study 2 - Understanding the productivity and seasonality of hill country grass species in a dryland environment

*What was trialled*

- The productivity and seasonality of various hill country grass species in a dryland environment in both the presence and absence of fertiliser was compared.

- Dry matter production (DM) of a range of 6 hill country grass species (Perrenial Ryegrass, Browntop, Brome, Cocksfoot, Tall fescue, Phalaris) and 2 herb species (chicory, Plantain) with and without supplemental nitrogen fertiliser over a 3-year period was measured.
- At the end of the trial, an analysis of species composition and dead and bare ground was undertaken.

*Key findings*

- In the absence of grazing and with no fertiliser applied the ranking of total DM production was chicory > brome > Phalaris > cocksfoot > ryegrass > plantain > tall fescue > browntop.
- Production across this trial was generally poor, particularly for the unfertilised treatments. Though, for two years of the trial (2020 and 2021) there were significant autumn and winter droughts, yet production was still within the range of DM measured at Poukawa over a 20 year period.
- Across all species, the response to applied nitrogen was 14.6 kg DM/ha although the grasses responded better to nitrogen fertiliser than the herbs did.
- Browntop maintained very healthy plant populations over the three years of the trial. Cocksfoot, brome and ryegrass maintained high levels of sown species and low levels of other grasses and weeds in both fertilised and unfertilised plots.
- Plantain and chicory populations decreased over three years with a much higher proportion of other species and bare ground in the herb plots than in the grass treatments.

### Keen to know more?

- Mills et al. 2021: Resident hill country pasture production in response to temperature and soil moisture over 20 years in Central Hawke's Bay.
- Muir et al. 2020: Effect of cultivar, timing of establishment and cutting interval on yield and seed set of arrowleaf clover.
- Spall et al. 2019: Evaluating the benefits of mixed plantain/chicory/clover pastures in a Hawkes Bay sheep breeding and finishing farm.
- Muir et al. 2019: The performance and profitability of plantain/clover pasture mixtures in East Coast farming systems.

## Stockgrove

## Key message

- Increased understanding of the production benefits of improved (chicory) versus unimproved pastures.

## About the study site

Stockgrove, in the North Canterbury foothills just north of Amberley, is a 300 ha sheep breeding property owned by C. & K. Croft. The farm includes areas of flats, rolling downs and steeper hill country and a maximum altitude of 163 m a.s.l. It is summer dry with 600 mm annual rainfall with evapotranspiration exceeding rainfall from November to March. Pastures range from high quality finishing mixes to conventional perennial ryegrass / white clover with lower quality browntop pastures on the higher country. Typically, the property runs ~2000 ewes, 500 hoggets and 500 trading lambs.

*What was trialled*

- Annual and seasonal yield differences between improved and unimproved pastures where measured.
- Improved pasture mix included chicory, white clover, some plantain and unsown improved grasses (perennial ryegrass and cocksfoot).
- Unimproved pasture included sweet vernal, browntop, with some perennial ryegrass and white clover.
- In autumn 2019 pasture exclosure cages were placed at sample sites and sites were monitored for three growth seasons.

*Key findings*

- Improved pastures produced more than three times the dry matter (DM) of unimproved resident pastures annually (14.1 t DM/ha/yr compared with 4.36 t DM/ha/yr).
- Improved pastures produced more feed than the unimproved pastures in all seasons, and the spring and summer growth rates of these swards were also better.

- The metabolizable energy (ME) of improved pastures was greater than that of the unimproved pastures in spring.
- These herb-based pastures remained productive for three years but even when being renewed the establishing pasture grew more than the resident unimproved pasture.
- The additional feed supply provided by the improved pastures can provide more resilience and flexibility to the farm system.
- The results gave the farmer confidence to develop more land into improved pastures by being able to quantify and therefore value the extra feed grown.

### Keen to know more?

- Smith et al. 2022: Total annual and seasonal DM production of improved and unimproved resident pastures at three farms in Canterbury

## Te Awa Awa

### Key message

- Increased understanding of the limitations to clover growth in dry hill country.

### About the study site

Te Awa Awa is a 646 ha property owned by Richard and Becks Tosswill and located in the Gladstone district of the Wairarapa.

*What was trialled*

- A replicated fertiliser trial was established in autumn 2018 within a 3.1 ha north facing hill block.
- There were 7 nutrient treatments: control, lime, Phosphorus (P), Potassium (K), Sulphur (S), and Molybdenum (Mo), as well a combination of lime + Mo + S.
- In addition, there were sub-treatments involving suppressant spraying and oversowing of sub clover at 10 kg/ha.
- Plot size was 10 m x 5 m with fertiliser treatments randomised within each plot.
- In early and mid-spring, visual assessments of clover content were made.
- In mid-spring plots were mowing, then grazed off.
- Plots were re-scored for visual clover content in mid-summer.

*Key findings*

- Visual clover content at Te Awa Awa was 25% in August 2018, 48% in October 2018 and 7% in January 2019. Clover content varied widely across the plots.
- Oversowing with sub clover at 10 kg/ha had no effect on clover content at any of the assessment times.
- Only the combined treatment (lime + Mo + S) appeared to have an effect at the final visual clover assessment.
- Suppressant spray and oversowing had no effect on clover content.

## Tokaroa

*Location: Ponatahi Road, Carterton (North Island)*

### Key message

- Development of appropriate sampling procedures for clover species for diagnosis of nutrient status for fertiliser recommendations.
- Increased understanding of how subterranean (sub) clover content can be maximised on a summer-dry Wairarapa hill-country farm through grazing management.
- Increased understanding of the continuum from the summer-dry sub clover environment to summer-wet perennial white clover pastures.

### About the study site

Tokaroa Farm, in Wairarapa, is a 608 ha sheep and beef farm owned the Nicholson family. Paddock slopes range from flat to steep (>25°) with a predominance of

gentler north facing slopes and steeper south facing slopes. Annual rainfall is 810 mm and the average summer dry is three months.

## Study 1 - Sampling methods for clover species in grazed pastures

*What was trialled*

- The differences in nutrient concentrations between laminae (leaflets) and petioles (leaf stems) of sub clover and white clover were measured.
- Sub and white clovers were handpicked then separated into lamina and full petiole and chemically analysed for nitrogen (N), phosphorus (P), potassium (K) and sulphur (S).
- A subset of samples was also analysed for metabolisable energy (ME), crude protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF) to understand animal nutrition value of the two clovers.

*Key findings*

- The lamina concentrations of N, P and S were higher than in the petiole across both species. Therefore, the diagnosis of clover nutrient status for fertiliser recommendations should be based on lamina-only samples.
- Mixed pasture samples for nutritive value analysis should include clover laminae and petioles to simulate intake by grazing livestock.
- Lamina + petiole K concentrations were lower in sub clover than white clover.
- ME did not differ between lamina and petiole but crude protein was three times higher in the lamina than the petiole.

### Keen to know more?

Olykan et al. 2019: Sampling methods for clover species in grazed pastures to diagnose mineral deficiencies

## Study 2 - Maximising the subterranean clover content

*What was trialled*

- Resident sub clover populations were identified on an uncultivatable north-west facing hill slope and a management plan devised to increase its contribution to pastures.
- The effect of the management plan on resident sub clover was measured over two seasons.

*Key findings*

- The grazing management plan, which was based on observing the sub clover lifecycle, rotational grazing and light set-stocking cattle, increased the resident sub clover content of the hill country pastures.
- The percentage of sub clover groundcover increased in this summer-dry hill-country environment when the grazing regime was changed to focus on promoting its reseeding and re-establishment.
- The biggest challenge for maintaining a sub clover pasture was grass control throughout the year.

## Keen to know more?

Olykan et al. 2019: Maximising the subterranean clover content on a summer-dry Wairarapa hill-country farm through grazing management

## Study 3 - Mapping groundcover of clover species

*What was trialled*

- The distribution of resident sub and white clovers across four land classes were mapped based on slope and aspect.
- The proportion of sub and white clover groundcover within these land classes was visually assessed over two seasons.

*Key findings*

- The clover management classes used in this study can be used as a practical guide to the long-term management of clover on this, and similar properties.
- It was thought that sub clover was the best suited legume for this property, however, both sub and white clovers were observed co-existing on a west-facing hill slope. Therefore, the use of both clovers in environments that experience variable and inconsistent spring and summer rainfall should be encouraged.
- Though the farms pasture management was focused on promoting early season sub clover, the unexpectedly high groundcover of white clover provided feed during wetter than average summers.

## Keen to know more?

Olykan et al. 2022: Mapping groundcover of clover species in hill pastures in Wairarapa

# Tourere

## About the study site

Watergreen-Tourere, in the Flemington district of Central Hawkes Bay, is a 1250 ha property owned by Pete Swinburn and Suzanne Hoyt and Bruce Isles and Danelle Dinsdale. It is a sheep and beef farm with a mix of cultivatable and medium to steep hill country. Average rainfall is 1000 mm and soils range from heavy clay flats through to papa/sandstone hill country.

*Forage trials and soil monitoring were undertaken at Tourere.*

## Forage trials

## Key Message

- The combination of lime, Molybdenum and Sulphur increased visual clover content. But, suppressant spray and oversowing had no effect on clover content.
- Arrowleaf clover is a prolific seeder, but the challenge of managing it (slugs and poor strike of naturally hard seed) means that it is unlikely to have a role in a permanent pasture situation.

## Study 1 - Assessing nutrient limitations to legume growth on farm

*What was trialled*

- A replicated fertiliser trial was established in autumn 2018 within a north facing 4.5 ha hill country block.
- There were 7 nutrient treatments: control, lime, Phosphorus (P), Potassium (K), Sulphur (S), and Molybdenum (Mo), as well a combination of lime + Mo + S.
- In addition, there were sub-treatments involving suppressant spraying and oversowing of sub clover at 10 kg/ha.

- Plot size was 10 m x 5 m with fertiliser treatments randomised within each plot.
- In early and mid-spring, visual assessments of clover content were made.
- In mid-spring plots were mowing, then grazed off.
- Plots were re-scored for visual clover content in mid-summer.

*Key findings*

- Visual clover content was 13.1% in August 2018, 16.2% in October 2018 and 8.3% in January 2019. Clover content varied widely across the plots.
- The combination of Lime, Molybdenum and Sulphur had a significant effect on the amount of visual clover present at each scoring time.
- Suppressant spray and oversowing had no effect on clover content.

## Study 2 - Oversowing arrowleaf clovers on dry East Coast hill country

*What was trialled*

- The trial was undertaken on a steep dryland block of native grass pasture and all spray and seed applications were carried out by helicopter.
- Arrowleaf was oversown on uncultivatable hill country (after being sprayed out) and allowed to set seed to attempt to create a seedbank of arrowleaf seeds.
- The trial area was oversown post the arrowleaf crop with plantain.
- Arrowleaf growth rates were measured using 3 exclusion cages with measurements every 4-6 weeks.
- From Year 2, pasture growth rates were also measured in a resident pasture of similar aspect and contour. Seedling counts and amount of seed set was also measured.

*Key findings*

- Oversowing was very successful in terms of achieving a one-off high-quality crop of arrowleaf clover yielding 10 t/ha in an ungrazed situation.
- Despite large quantities of arrowleaf seed set in Year 1 (1380 kg seed/ha), germination in subsequent years was poor probably due to the hard seed (commercially available seed is scarified to increase germination).
- Beef cows found the plant material post seed set unpalatable and a large amount of trash was left which created a haven for slugs which negatively impacted seedling establishment of arrowleaf and oversown plantain.

- Arrowleaf clover is a prolific seeder, but the challenge of managing its means that it is unlikely to have a role in a permanent pasture situation.

## Soil Monitoring

## Key message

- A wireless sensor network was established that enabled some of the first daily farm scale mapping of soil properties (temperature and moisture) in New Zealand hill country. These maps can be used to drive forage yield models and help inform decision-making on pasture management.

*What was trialled*

- The trial investigated the potential for modelling the distribution of soil temperature and moisture in hill country landscapes at high spatial and temporal resolution. The spatial resolution of existing widely-available soil temperature and moisture data is too coarse to provide useful information at farm scale in hill country, and is unable to account for the influence of topography in these landscapes.
- A wireless sensor network (WSN) was installed at Tourere in July 2020. The WSN consisted of twenty sensors installed in the soil at 30 cm depth. The sensors were distributed across the farm in a way that accounted for topographic variation in elevation, aspect (the direction a hillslope faces) and the potential for water to accumulate (strongly influenced by slope gradient).
- The sensors were configured to measure soil temperature and soil moisture at hourly intervals and report measurements back to a cloud database via the cellular network. On the farm, LoRa technology was used to communicate between components of the WSN.
- Statistical models were fit to the soil temperature and moisture data in order to relate those soil properties to other topographic variables including elevation,

aspect and slope. The models were used to predict soil temperature and moisture across the farm at 30 m resolution at daily intervals across a generic model year.

*Key findings*

- The WSN performed well.
- As expected, sensor data revealed that north-facing slopes tended to be warmer and drier than south-facing slopes, which reflects the influence of topography. Interestingly, soils on north-facing slopes warmed from the winter minimum temperature through an arbitrary threshold of 15°C about 44 days faster than soils on south-facing slopes (about 90 days versus 134 days in 2020).
- The soil temperature model performed very well, but the soil moisture model performed relatively poorly. The difference in performance is due in part to differences in predictability between soil temperature and soil moisture, the former varying more smoothly and more regularly over time than the latter.
- Soil moisture predictions derived from the model should be interpreted with caution, but should be good enough to provide a broad indication of when soils are near field capacity versus when they are near wilting point.
- It is expected that model performance should improve with a longer time-series of data, and better sensor calibration.

## Wairakaia

### Key message

- Arrowleaf clover is a prolific seeder, but the challenge of managing it (slugs and poor strike of naturally hard seed) means that it is unlikely to have a role in a permanent pasture situation.

## About the study site

Wairakaia, located in Muriwai district near Gisborne, is a 600 ha property farmed by Rob and Sandra Faulkner. It is a sheep, beef and cropping farm that is a mix of cultivatable land and medium to steep hill country. Annual rainfall is 100 mm. The property has had a focus on high performance forages on its flatter country for some years.

*What was trialled*

- The trial investigated the potential role for oversowing arrowleaf clover on uncultivatable hill country to increase productivity.
- The trial was undertaken on 4 ha of uncultivatable easterly facing hill and all spray and seed applications were carried out by helicopter.
- Arrowleaf was oversown (after being sprayed out) and allowed to set seed to attempt to create a seedbank of arrowleaf seeds.
- In order to allow the arrowleaf clover to set seed it was left ungrazed until after the plants had set seed.
- The trial area was oversown post the arrowleaf crop with plantain.

*Key findings*

- Oversowing was very successful in terms of achieving a one-off high-quality crop of arrowleaf clover yielding 10 t/ha in an ungrazed situation.
- Despite large quantities of arrowleaf seed set in Year 1 (425 kg seed/ha), germination in subsequent years was poor probably due to the hard seed (commercially available seed is scarified to increase germination).
- Beef cows found the plant material post seed set unpalatable and a large amount of trash was left which created a haven for slugs which negatively impacted seedling establishment of arrowleaf and oversown plantain.
- Arrowleaf clover is a prolific seeder, but the challenge of managing its means that it is unlikely to have a role in a permanent pasture situation.

# Willesden Farm

## About the study site

Willesden Farm, located on Banks Peninsula, Canterbury, is a 5,500 ha sheep and beef property. The property is owned by Wongan Hills Ltd and managed by Matt Iremonger. Approximately 1,200 ha is flat and cultivatable while the remainder is mostly moderate to steep hill country. Rainfall and temperature vary significantly within a short distance on this property. Annual rainfall ranges from 550 to 1,100 mm while altitude ranges from sea level to above 850 m a.s.l.

- Forage trials and soil monitoring were undertaken at Willesden farm.

## Forage trials

## What was achieved

- Increased understanding of production differences between lucerne (improved pasture) and unimproved (resident) pasture in this hill country environment, as representative of east coast dry regions.
- Increased understanding of how the microclimates of different altitudes and aspects affect pasture production.

## Study 1

*What was trialled*

- Annual and seasonal yield differences between lucerne (improved) and unimproved resident pastures were measured.
- On Willesden Farm pasture sample sites (in autumn 2019), pasture exclosure cages were placed at sample sites on improved (lucerne monoculture) and unimproved pastures at two different altitudes (20 and 175 m a.s.l.).
- Sites were monitored for three growth seasons and to spring 2022/23.
- On Prices Valley meteorological data sites — six sites were established at three different altitudes.
- Each altitude had an exclosure cage for monitoring pasture growth and soil temperature, and a weather station monitoring air temperature, rainfall, and solar radiation.

*Key findings*

Yield at Willesden Farm

- Annual accumulated DM produced by the dryland lucerne monocultures over three annual growth seasons (14.3 t DM/ha/yr) was 150%, or 8.7 t DM/ha more than the 5.7 t DM/ha/yr produced from unimproved dryland pastures. The range of annual production was 10.7 to 19 t DM/ha for the lucerne and 3.3 to 9.3 t DM/ha for the resident pastures. The variability was related to in-season (Nov-March) rainfall.
- The quantification of the yield difference gave the owner confidence to increase the lucerne area from 30 to over 300 ha.
- The lucerne is now used strategically to feed 3000 hoggets during lactation.

  Watch the video series “Hill Country Futures: lucerne at Willesden” on the B+LNZ knowledge hub to learn more.

*Yield at Prices Valley sites*

- At low altitude, annual DM production from south facing slopes was consistently superior to that measured on north facing slopes – which highlights moisture was the main limitation.
- There was little difference at the mid-altitude sites, except in the final growth season which had above average summer rainfall, which allowed growth to continue for longer on the north slope before the soils dried and pasture growth rates slowed.

- At the highest altitude (450 m a.s.l.) annual DM yield was higher from north facing slopes in two out of the three growth seasons, highlighting the additional rainfall but lower temperatures.

## Study 2

*What was trialled*

- On farm climate data from different altitudes and aspects were compared to estimates generated by NIWA's Virtual Climate Station Network (VCSN) at the two closest sites.
- Environmental data (air temperature, rainfall, and solar radiation) was monitored at six sites over three different altitudes in Prices Valley, in Banks Peninsula.
- Each altitude also had an exclosure cage for monitoring pasture growth.

*Key findings*

- Solar radiation estimates from VCSN data was reliable and consistent with onsite data and was unaffected by altitude.
- Air temperature data from the VCSN was reliable and consistent at low and mid altitude sites but was underestimated at the 450 m a.s.l. altitude site. The warm temperatures drive evapotranspiration and explains why the north slopes were lower yielding at this altitude.
- Rainfall was well estimated by VCSN at the low altitude site (50 m a.s.l.). However, as altitude increased estimates were less reliable, particularly when observed monthly rainfalls were >100 mm/month. These data suggest that above 50 m accurate rainfall estimates can only be obtained from on-stie measurement.
- Soil temperatures from VCSN were closest to temperatures recorded on south facing aspects.
- Soil temperature was underestimated at higher altitude.
- On the north facing slopes, at all altitudes, soil temperatures were underestimated by 3.0 to 5.7 °C. This means pasture growth predictions based on VCSN temperature data will be late in their estimation of the start of spring growth.

## Keen to know more?

- Smith et al. 2022: Total annual and seasonal DM production of improved and unimproved resident pastures at three farms in Canterbury

## Soil monitoring

## Key message

- A wireless sensor network was established that enabled some of the first daily farm scale mapping of soil properties (temperature and moisture) in New Zealand hill country. These maps can be used to drive forage yield models and help inform decision-making on pasture management.

*What was trialled*

- The trial investigated the potential for modelling the distribution of soil temperature and moisture in hill country landscapes at high spatial and temporal resolution. The spatial resolution of existing widely-available soil temperature and moisture data is too coarse to provide useful information at farm scale in hill country, and is unable to account for the influence of topography in these landscapes.
- A wireless sensor network (WSN) was installed at Willesden Farm between June and August 2020. The WSN consisted of twenty sensors installed in the soil at 30 cm depth. The sensors were distributed across the farm in a way that accounted for topographic variation in elevation, aspect (the direction a hillslope faces) and the potential for water to accumulate (strongly influenced by slope gradient). The sensors were configured to measure soil temperature and soil moisture at hourly intervals and report measurements back to a cloud database via the cellular network. On the farm, LoRa technology was used to communicate between components of the WSN.
- Statistical models were fit to the soil temperature and moisture data in order to relate those soil properties to other topographic variables including elevation, aspect and slope. The models were used to predict soil temperature and moisture across the farm at 30 m resolution at daily intervals across a generic model year.

*Key findings*

- The WSN performed well.

- As expected, sensor data revealed that north-facing slopes tended to be warmer and drier than south-facing slopes, which reflects the influence of topography. Interestingly, soils on north-facing slopes warmed from the winter minimum temperature through an arbitrary threshold of 10°C about 65 days faster than soils on south-facing slopes (about 54 days versus 118 days in 2021).
- The soil temperature model performed very well, but the soil moisture model performed relatively poorly. The difference in performance is due in part to differences in predictability between soil temperature and soil moisture, the former varying more smoothly and more regularly over time than the latter. Soil moisture predictions derived from the model should be interpreted with caution but should be good enough to provide a broad indication of when soils are near field capacity versus when they are near wilting point.
- It is expected that model performance should improve with a longer time-series of data, and better sensor calibration.

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