Maximising the subterranean clover content on a summer-dry Wairarapa hill-country farm through grazing management

Sonya T. OLYKAN[1*], Richard J. LUCAS[1], Dan J. NICHOLSON[2], Crile DOSCHER[3] and Derrick J. MOOT[1]
[1] *Dryland Pastures Research, Field Research Centre, Faculty of Agriculture & Life Sciences, PO Box 85084, Lincoln University, Lincoln 7647, New Zealand*
[2] *Tokaroa Farm, 1106 Ponatahi Rd, Carterton 5792, New Zealand*
[3] *Faculty of Environment, Society and Design, PO Box 85084, Lincoln University, Lincoln 7647, New Zealand*
* Corresponding author: Sonya.Olykan@lincoln.ac.nz

Abstract
Tokaroa Farm is a 608-ha sheep and beef farm, in the Wairarapa. 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 average summer dry is three months. Resident subterranean (sub) clover (*Trifolium subterraneum* L.) populations were identified on an uncultivatable north-west facing hill slope in 2015, and a management plan devised to increase its contribution to pastures.

Exclosure plots showed that an eight-week spell in spring 2016 increased resident sub clover groundcover from 13 to 54%, while in the lightly grazed paddock control sub clover increased from 10 to 28%. There was a positive linear relationship (R^2=0.51) between the total number of established sub clover seedlings on 30 March 2017 and the previous spring sub clover groundcover (%) on 25 November 2016. In October 2017, the effect of the spring 2016 exclosure treatments was still evident with 57% sub clover groundcover in the eight-week spelled areas compared with 37% in the control despite all the exclosures being grazed in 2017.

Sub clover management strategies were developed, using slope and aspect, and applied to a GIS map of Tokaroa Farm. This suggested that 53% of the farm could have sub clover overdrilled into it and 29% could have the resident sub clover population actively managed and/or oversown with sub clover seed.

Keywords: aspect, exclosure, farm map, germination, GIS, grazing management, hill country, populations, potential evapotranspiration, PET, rainfall, reestablishment, soil moisture deficit, slope, spelling, sub clover, *Trifolium subterraneum*

Introduction
The benefits of managing resident subterranean (sub) clover (*Trifolium subterraneum*) populations in grazed pasture on a Marlborough hill country property 'Tempello' where annual rainfall is ~500 mm and the summer dry season is about five months were outlined by Grigg et al. (2008). Several Wairarapa farmers visited Tempello in 2014 which renewed interest in identifying and managing appropriate legume species for increasing hill country productivity on their dry east coast farms where rainfall is > 800 mm and the summer dry seasons are about two months shorter.

Dryland systems need to maximise the amount and quality of feed in winter and spring when soil moisture is not limiting so that more stock are finished before the onset of drought (Macfarlane et al. 2014). This can be done by appropriate use of perennial and annual clovers in higher rainfall environments. Gillingham et al. (1998) found more white clover on southern aspects, where there were better soil moisture conditions throughout most of the year, and more sub clover on northern aspects.

Ecotypes of the sub clover cultivars 'Mt Barker' and 'Tallarook' are resident in many North Island east coast hill-country pastures (Suckling et al. 1983; Macfarlane & Sheath 1984) from oversowing from the 1930s to 1960s (Smetham 2003). Sub clover can produce high-quality feed early in spring (Brown et al. 2006; Mills et al. 2008) and fix about 30 kg N/t clover dry matter (DM) (Lucas et al. 2010) which improves productivity and maximises water-use efficiency of sub clover–grass pastures (Tonmukaykul et al. 2009).

According to Dodd et al. (1995a, 1995b), the success factors for sub clover cultivar persistence in North Island hill country are: late maturity; strong autumn regeneration; a long growing season; and a prostrate growth habit. A prostrate growth habit allows resident sub clover to reseed and regenerate under traditional intensive spring set stocking (Chapman & Williams 1990; Sheath & Macfarlane 1990). However, this type of grazing management does not allow the resident sub clover population to thrive and produce sufficient DM to supply up to 50% of feed in spring. Grigg et al. (2008) recommended focussing pasture management on controlling competing grasses during summer to allow sub clover to re-establish each autumn, 'express itself' during spring rotational grazing, and periodically set seed in late spring.

The aim of this 'on-farm' demonstration was to determine whether or not a seasonal management

ISSN 2463-2872 (Print) ISSN 2463-2880 (Online) https://doi.org/10.33584/jnzg.2019.81.391

approach for sub clover could be implemented successfully in higher rainfall summer dry hill country. Tokaroa Farm is a 608-ha sheep and beef farm owned and managed by Dan and Reidun Nicholson. The terrain varies from valley flats to steep hill slopes with a predominance of sunny facing aspects. The annual rainfall is ~800 mm and there is a summer dry period from late December to early March when soil moisture deficits are >110 mm (NIWA 2019). A site visit in 2015 identified resident sub clover on an uncultivatable northwest hill slope. Exclosure plots were used to investigate the effect of spring spelling time and light grazing on resident sub clover groundcover over two seasons. The farmer also direct drilled sub clover cv. 'Antas' into an existing pasture in autumn 2016.

Based on these results, Tokaroa Farm was used as an example to identify how a whole-farm map can be developed to stratify clover management across land classified on the basis of aspect and slope.

Methods

Site details

The experimental site, approximately 80 m by 50 m, was located in a 12-ha paddock on hill country, with a north-west aspect, and a slope range of 10 to 25°, at an elevation of 160 to 180 m a.s.l. (GPS coordinates are -41.1570, 175.5435).

The resident pasture grass was mainly browntop (*Agrostis capillaris*) with perennial ryegrass (*Lolium perenne*), Yorkshire fog (*Holcus lanatus*) and various annual grasses being present to a lesser extent. Sub clover was the predominant resident legume and the cultivars 'Mt Barker' and 'Tallarook' were identified. Other annual legumes identified were suckling clover (*T. dubium*), clustered clover (*T. glomeratum*), striated clover (*T. striatum*), lotus (*Lotus* sp.) plus perennial white clover that together averaged only 1% of the ground cover.

Site history

The paddock was not managed specifically for sub clover prior to 2015. The previous grazing regime started in early spring with six to seven ewes with twin lambs/ha, or 10 ewes with singles, and was set stocked until weaning on 1 November. During this time, cattle (usually at one per hectare) would graze, as needed, to keep pasture height down to about 50 mm. After this period, the paddock was usually quite bare (assessed from photographs). Any sub clover plants were very small after intensive selective grazing. In the summer, the paddock was usually lightly grazed by ewes or cattle depending on the season. In autumn, hoggets or ewe lambs were set stocked while the sub clover seedlings were germinating. The paddock was top dressed with ~250 kg/ha of sulphur super 30 (P 7, S 30) every autumn and 2.5 tonnes of lime/ha was applied every 6–7 years.

Soil chemical data

The soils were classed as Argillic Pallic and are moderately deep (0.6 to 0.9 m) with poor drainage (S-MAP 2018). A soil sample (0–75 mm depth) taken in October 2016 was analysed by Hill Laboratories Ltd. The pH was 5.6, Olsen P 28 µg/mL, calcium 8 me/100 g (QTU of 6), potassium 0.32 me/100 g (QTU of 4), magnesium 1.4 me/100 g (QTU of 20), sulphate-S 6 µg/g and extractable organic S 8 µg/g.

Exclosure experiment

Three exclosure plots, approximately 0.015 ha (~5.6 × ~27 m) with the longest dimension across the slope, were established on 26 September 2015 using waratahs and solar-powered electric tape. There was an exclosure at each of three locations on a hill slope described as 'upper', 'middle' and 'lower' slope. The initial exclosure experiment in 2015 was conducted during a dry spring (22 mm of rain in October and 28 mm in November) and the results from cage cuts taken after 3, 6 and 9 weeks of spelling (unreplicated treatments) were inconclusive, data not shown.

On 29 September 2016 (Week 0 of the experiment), each exclosure plot was divided in half, to provide replication, with one half randomly allocated to be spelled for 4 weeks (i.e. during early sub clover flowering) and the other for 8 weeks i.e. (early to late flowering) as outlined below. Permanent 11 m transect lines were pegged inside each of the six exclosure sub-plots, 3 × four-week and 3 × eight-week spell from grazing. Wooden pegs were also used to position six paired adjacent 'control' transects in the set stocked 'control' paddock. This gave a total of 12 transect lines. The percentage of sub clover groundcover, and other legumes, were assessed in a 0.1 m^2 quadrat at each 1-metre point along each transect line (representing week 0) and then the spelling treatments started. The paddock control was grazed with a set-stocking rate of 1 heifer/ha and 5 hoggets/ha to simulate 'average' hill management in spring for the district. Repeated sub clover groundcover visual assessments were carried out at the same points along the transect lines after 4 weeks (26 October 2016) and after 8 weeks (25 November 2016). An abundance of feed on the farm at the 8-week point allowed the whole paddock to be closed to allow the sub clover to reseed. Some sub clover runners reached 1 m in length during December 2016. The exclosures were not installed again after 25 November 2016. In 2017, all 12 transects and surrounding paddock were grazed in common using a new regime implemented with a focus to promote resident sub clover regeneration in paddocks where populations are

Table 1 New grazing management regime for paddocks identified for sub clover enhancement to promote sub clover regeneration from 2017, at Tokaroa Farm, Wairarapa.

Month	Grazing management
Jan–Feb	Beef cows intensively graze last of mature reproductive grass down to 600 kg DM/ha pasture cover. May use electric wires to pressure stock to avoid patch grazing.
Feb–Mar	Look for sub clover germinating after early autumn rain and spell until seedlings have 3–4 trifoliate leaves
Apr–Jun	When required, use a mob of 100 hoggets/ha to control grass cover down to 50 mm for 1 to 2 days
Jul–Aug	Set stocked ewes with twins at 6/ha from late July with 1.5 heifers/ha
Sep	From late September, as sub clover starts to flower, take ewes and lambs off to legume-dominant lowland paddocks. Leave 1.5 heifers/cows/ha in the block during Oct.
Oct	If sufficient sub clover exists after weaning lambs on 1 Oct, put in 250 weaned lambs (~20/ha) to graze down to 1200 kg DM/ha.
Nov–Dec	No stock until end of December to allow sub runners to spread and set seed.
Late Dec	Depending on feed quality, run hoggets or ewes through first. Then graze cattle, e.g. trade heifers, to clean-up the mature grass and graze as seasonal rainfall allows.

low (Table 1).

On 30 March 2017, the number of established sub clover seedlings was assessed within a 0.1 m^2 quadrat along the fixed transect lines. Two age-groups were counted: the first was at the 1–2 trifoliate-leaf stage from a germination event likely to have occurred in mid-February, after 50 mm of rain over two days; and the second was at the cotyledon stage from a germination event likely to have occurred in mid-March, after 24 mm rain over 4 days. On 26 October 2017, the percentage of sub clover groundcover was visually assessed at 1-m intervals on the 12 transect lines. The same observer made all visual assessments over both years.

Whole-farm plan for sub clover management

A 15-m resolution elevation grid was downloaded from an online spatial data portal (Koordinates.com) and used to generate slope and aspect layers for the farm using ArcGIS 10.6 (ESRI 2018). These layers were then reclassified into appropriate slope and aspect categories for the farm plan. Slope categories were based on Land Use Capability classes (Lynn et al. 2009) with flat to undulating (0–7°), drillable rolling hill country (8–20°), and undrillable moderately steep to very steep hill country (≥21°). The two aspect categories were "sunny" facing (west, north west, north and north east) and "shady" facing (east, south east, south and south west). Combining the two categories (Figure 1) resulted in five clover management classes. From a management perspective, the farm was divided into three sections: 'Flats'; 'Middle' (flat and rolling hills that were historically disked); and 'Ranges' where, regardless of slope, no drilling is feasible due to the more broken, rough terrain (Figure 1).

Climate data

The 30-year long-term average (LTA) annual maximum and minimum air temperatures were 17.8°C and 7.7°C, respectively. The 30-year long-term annual rainfall for Tokaroa Farm is 810 mm with 32% of this during the winter months of June to August (~87 mm rain per month) when monthly PET of ~24 mm is at its lowest (Figure 2). During the summer months of December to February, the LTA rainfall averaged 52 mm per month while PET averaged 128 mm per month. The 30-year LTA data showed that average monthly PET exceeded rainfall for six months from October until March (Figure 2) particularly from November to February, with a maximum potential soil moisture deficit of ~120 mm in January and February.

In 2016, monthly rainfall was below the LTA in February (13 mm), March (21 mm) and April (45 mm) and sub clover germination did not occur until late May when there was 88 mm of rain over a 10-day period. The average monthly rainfall from June to October was 63 mm, which supported sub clover growth, and in November there was 112 mm of rain. The total rainfall for 2016 was 690 mm.

In 2017, the first sub clover germination occurred in mid-February after 52 mm of rain over two days. These plants established and an average monthly rainfall of 100 mm from April to September promoted growth into the spring. In October and November, there was 33 and 16 mm of rain respectively, with evapotranspiration of 85 and 92 mm. The total rainfall for 2017 was 886 mm.

Statistical analyses

The raw data were analysed with Genstat (18th edition; VSN International). The exclosure factors were control, four-week or eight-week. The location factors were

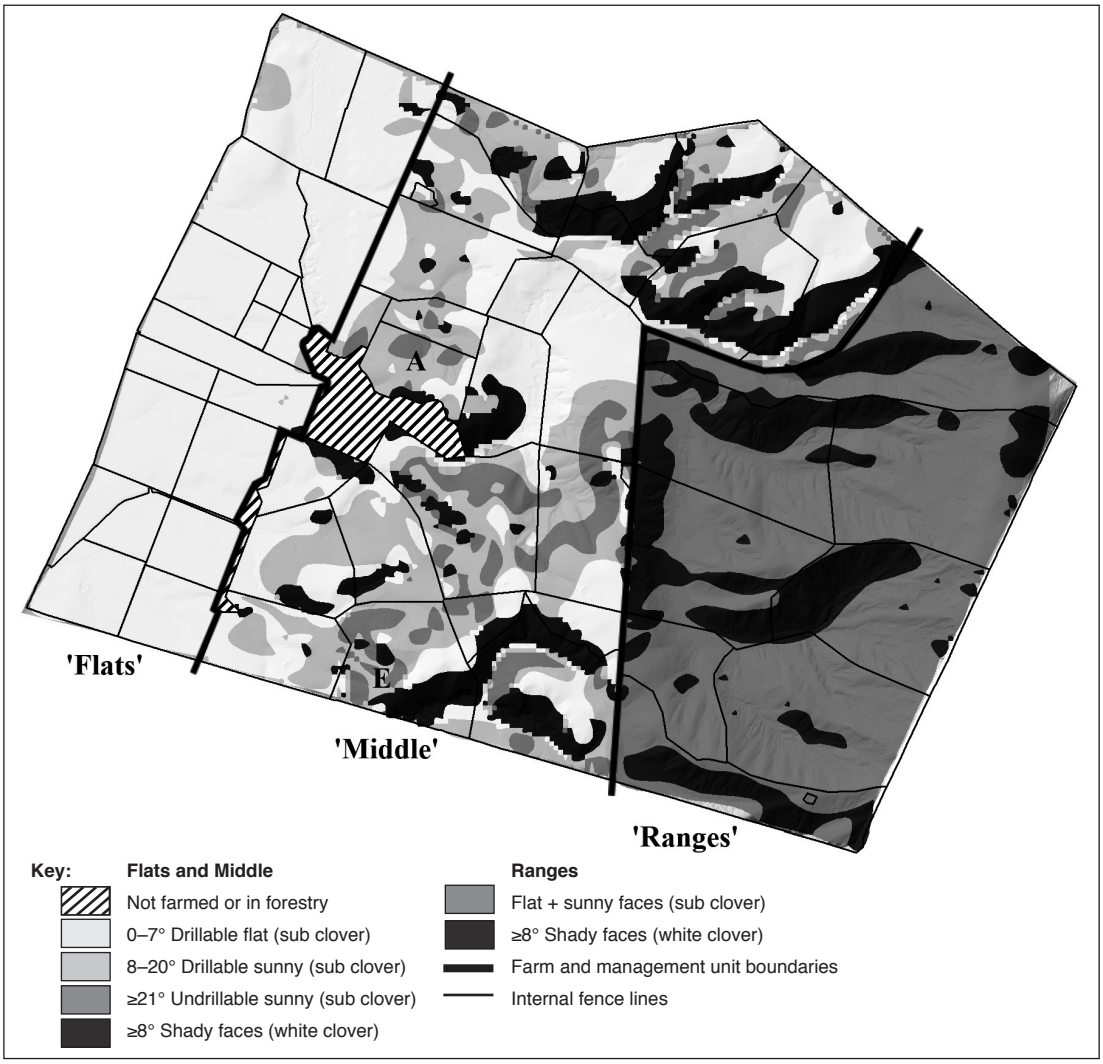

Figure 1 Clover management classes, based on slope and aspect, for the three management units named Flats, Middle and Ranges, at Tokaroa Farm, Wairarapa. 'E' marks the location of the exclosure experiment and 'A' marks the paddock where sub clover cultivar 'Antas' was direct drilled.

upper, middle or lower slope.

The 29 September 2016 quadrat data were allocated to the following categories: 0% (no sub clover), 1–9% (very low), 10–19%, (low), and 20+% (satisfactory) sub clover groundcover. The number of quadrats/category in each transect were calculated and analysed by two-way ANOVA (exclosure + location). The raw data in the sub clover groundcover categories were analysed separately for the 26 October and 25 November 2016: 1–9% (SQRT transformed, back-transformed means presented), 10–19% and 20+%; by analysis of unbalanced design using Genstat regression (exclosure + location) and predicted means presented.

The 2016 control and eight-week % sub clover groundcover data (excluding quadrats that had 0% sub clover groundcover on 29 September) on 26 October and 25 November 2016, and 26 October 2017 were analysed by 2-way ANOVA (exclosure + location).

The 30 March 2017 total (February + March per quadrat) sub clover seedling numbers (square-root transformed (SQRT), back-transformed means presented) and the 26 October 2017 % sub clover groundcover were analysed by two-way ANOVA (exclosure + location).

Tukey's honest significant difference (HSD) test was used for multiple comparisons of factor means for the two-way ANOVA and Fisher's Unprotected LSD for means from an analysis of unbalanced design using Genstat regression. Least squares linear regression was used to relate 2016 % sub clover ground cover (SQRT

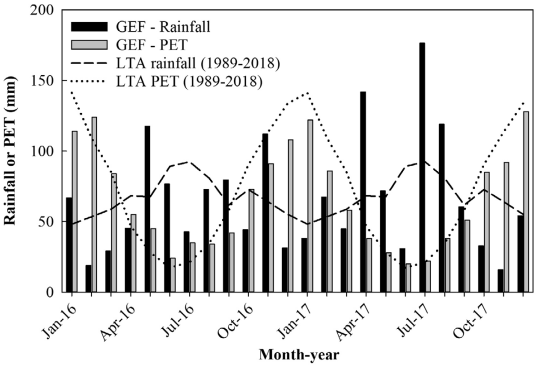

Figure 2 Total monthly rainfall and evapotranspiration (PET) from January 2016 to December 2017 for Tokaroa Farm, Wairarapa. Data accessed from Glen Eden Farms (GEF) weather station located ~1.9 km W of the site (Harvest.com 2016). 30-year LTA averages were obtained from the NIWA VCSN at GPS -41.175, 175.525, located 2.6 km SSW of the site (NIWAData 2019).

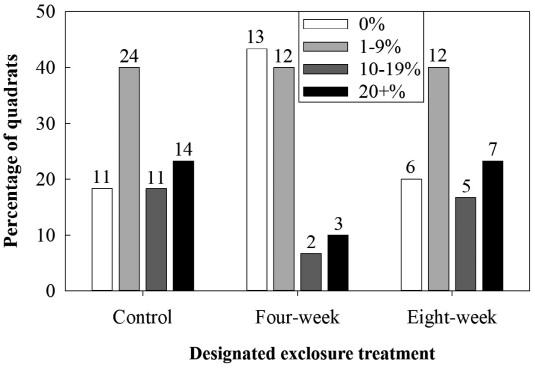

Figure 3 Percentage of quadrats in four sub clover groundcover categories (0, 1–9, 10–19 and 20+%) in the designated exclosure treatments at the start of the experiment on 29 September 2016 at Tokaroa Farm, Wairarapa. Total number of quadrats per category per treatment shown on top of the bar.

transformed) with 2017 total seedling numbers, and 2017 total seedling numbers by 2017 % sub clover groundcover (constant omitted so line went through the origin).

Results

Effect of spelling on sub clover groundcover in 2016

Irrespective of slope, at the start of the experiment on 29 September 2016 there was a difference (P=0.006) in the proportion of quadrats with 0% sub clover (Figure 3) in the exclosure treatments. The transects set aside for four-week spelling had 0% sub clover in 43% of the 30 quadrat positions, more than twice (P<0.05) that in those marked as controls or assigned for eight-week spelling with 18 and 20% respectively. There were no differences between treatments in the 1–9%, 10–19% or 20+% categories. The transects designated for the zero weeks (control) and eight-week spelling had similar distributions across the four % sub clover categories.

Regardless of subsequent exclosure treatment, quadrats with 0% sub clover at the start of the experiment (29 September 2016) had no or very low % sub clover by 25 November 2016 (Figure 4a). On 29 September 2016, 30 quadrats across the 12 transects, i.e. 25%, had 0% sub clover groundcover. By 25 November 2016 this had declined to 20 quadrats. Almost a year later, on 26 Oct 2017, only 5 quadrats (4%) had 0% sub clover groundcover highlighting the spread of sub clover across the grass dominant areas in the pasture.

The % sub clover in quadrats that started with 1–9% (Figure 4b) was affected by exclosure treatment (P<0.001) on 26 October and 25 November 2016. On both dates, the eight-week exclosure treatment had higher (P<0.05) % sub clover, at 15% and 38%, than the control with 5% and 11%, respectively. The sub clover ground cover in quadrats starting with 10-20% (average of 12%) nearly tripled to 35% by 25 November (Figure 4c); however, there was no exclosure treatment affect (P=0.604). For quadrats starting with 20+% sub clover on 26 September (average of 45%), the exclosure treatment affected % sub clover cover (P=0.004) on 26 October (Figure 4d). The four-week quadrats had 88% sub clover cover which was higher (P<0.005) than the control at 47% but not different from the eight-week quadrats with 73%. There was no exclosure effect in the 20+% category on 25 November and the average sub clover content of the quadrats was 76%. There was some evidence of the new fresh growth in the four-week sub-plots being grazed intensively when sheep had access after four weeks without grazing (Figure 4d).

Comparing the % sub clover in the eight-week transects with their paired paddock control transects (excluding those quadrats with 0% sub quadrats on 29 September 2016 in both treatments) identified a treatment effect on 26 October (P=0.009) and 25 November 2016 (P=0.002) (Figure 5). The % sub clover in the eight-week exclosure treatment was greater (P<0.05) than the paddock control on 26 October, 35% versus 17%, and on 26 November, 54% versus 28%. The four-week data were excluded from this analysis because these transects were randomly allocated to sites that had poor sub clover groundcover compared with the controls at the start of the experiment (Figure 3).

Re-establishment in 2017

On 30 March 2017, two age groups of sub clover seedlings were identified. On average, 36 sub clover plants/m^2 had germinated in mid-February and an

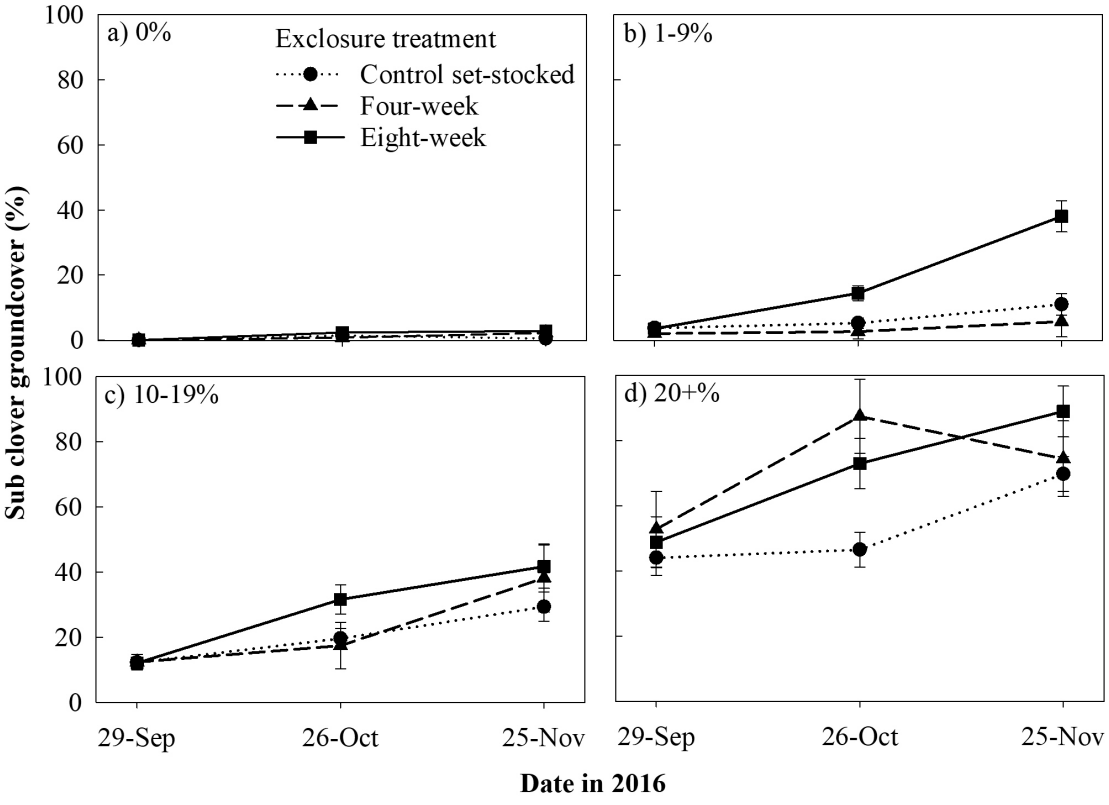

Figure 4 Sub clover groundcover (%) from transects in the exclosure experiment based on four sub clover (%) categories on 29 September: a) 0% sub clover, b) 1–9% (back-transformed means), c) 10–19% (predicted means) and d) 20+ % (predicted means) at Tokaroa Farm, Wairarapa. Error bars represent standard error of the mean.

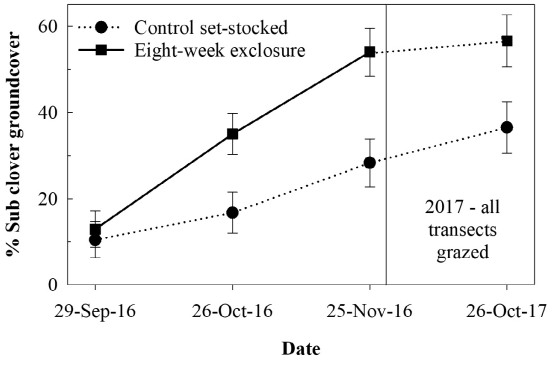

Figure 5 Sub clover groundcover (%) assessed from transects in the control and eight-week exclosure experiment in 2016 and 2017 at Tokaroa Farm, Wairarapa. Note: all transects grazed in 2017. Error bars represent standard error of the mean.

additional 24 plants/m^2 in mid-March. The 2016 exclosure duration did not affect (P=0.136) total sub clover seedling numbers on 30 March 2017 but location on the slope did (P<0.001). The mid-slope location had 74 seedlings/m^2 (P<0.05) compared with 33 seedlings/m^2 on the upper and lower slope.

There was a positive linear relationship (P<0.001) between the total number of established sub clover seedlings (SQRT transformed data) on 30 March 2017 and the sub clover groundcover (%) assessed on 25 November 2016 (SQRT y = 0.089 x + 4.27; R^2=0.51).

Sub clover groundcover in 2017

On 26 October 2017, the % sub clover groundcovers across all transects were affected (P=0.062) by the 2016 exclosure treatments. The 49% average sub clover in the eight-week transects was higher (P<0.10) than the four-week average of 30% but not different from the 37% in the paddock control. Location on the slope affected (P<0.001) the % sub clover groundcover irrespective of treatment. The mid-slope location had 59% cover (P<0.05) compared with 30% on the upper slope and 26% on the lower slope.

Comparing the % sub clover in the eight-week transects with their paired paddock control transects (excluding quadrats with 0% sub quadrats on 29 September 2016) identified a treatment effect on 26 October 2017 (P=0.022) (Figure 5). The 57% sub clover in the eight-week transects was greater (P<0.05) than the 37% paddock control. Note that all of these

transects were grazed during 2017.

There was a strong positive linear relationship ($P<0.001$) with % sub clover groundcover on 26 October 2017 and total number of established sub clover seedlings on 30 March 2017 ($y = 5.67(SQRT(x))$, $R^2=0.44$).

Whole-farm map

An analysis of the areas in the sub clover management categories on Tokaroa Farm found that 213 ha of flat land in the 'Flats' and 'Middle' areas and 94 ha of drillable sunny slopes, predominantly in the 'Middle' area were suitable for drilling with sub clover. There were 170 ha of undrillable sunny slopes of 'Middle' and all 140 ha of the flat and sunny slopes of 'Ranges' where management of the resident sub clover could be improved and/or oversown with additional seed where appropriate. Across the farm, 104 ha of shady slopes are more suitable for growing white clover and 28 ha is not farmed.

Discussion

Sub clover groundcover

The % 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 exclosure experiment at Tokaroa Farm showed that the proportion of sub clover groundcover tripled during a season when grazing management and climate allowed. Despite a late start to the 2016 growing season, sub clover groundcover increased from 13% to 54% when the pasture was spelled for eight weeks (29 September to 25 November). The sub clover groundcover doubled from 10% to 28% in the grazed paddock control over the same time period indicating that a paddock can be lightly grazed by cattle and the sub clover groundcover will still increase.

There was 112 mm of rainfall in November 2016, which meant the onset of summer dry was delayed and soil moisture did not go into deficit (>75 mm) until early December. At that time, the spring and early summer of 2016 was described as a 'one in ten' season. After closing the paddock at the end of November, some of the sub clover runners were observed to extend to over 1 m long by late December. The consequence was a large mass of ungrazed low quality grass in February and electric fencing was needed to push the stock (cattle) to get the pasture DM cover down to around 600 kg DM/ha.

On 26 October 2017, the difference in % sub clover groundcover between the control and eight-week exclosure treatments was still evident. Both treatments were grazed in common during 2017 however the % sub clover was trending upwards in the control indicating that the new grazing regime described in Table 1 should promote sub clover groundcover in the long term.

Re-establishment

In 2017, the re-establishment of sub clover (plants/m^2) was higher where the proportion of sub clover groundcover was higher in the previous spring. This result indicates that management practices and site characteristics that encouraged the spread of sub clover promoted the establishment of more seedlings the following year. This result confirms those of Ates et al. (2006) and Ates et al. (2008) for sub clover pastures at Ashley Dene, a Canterbury dryland farm (620 mm annual rainfall) in finding the balance between allowing the sub clover to set seed and keeping grasses under control by grazing.

Grazing management

Prior to 2016, the old grazing management approach of set-stocking encouraged selective grazing and resulted in small prostrate sub clover plants that were in survival mode with little opportunity to spread runners. Two seasons after changing the grazing regime, the experimental area had 60% sub clover groundcover in mid spring. Management was focussed on two important stages in the lifecycle of the sub clover: germination in autumn and time of first flowering from late-September (see Table 1).

At Tokaroa Farm, the biggest challenge for maintaining a sub clover pasture is grass control. Sheep grazing is now rotational, using mob stocking, with hoggets being preferred. The sub clover pasture is lambed on in late winter but ewes and lambs are moved off by the end of September. Cattle are used to control grass height during the growing seasons and are especially important in summer to consume low-quality herbage.

The results from Tokaroa Farm show that it is possible to lightly graze a sub clover pasture, particularly in a wetter spring season, with a variety of stock to maintain pasture cover above 1200 kg DM/ha. Under these grazing conditions, the proportion of clover increased but not as much as when the paddock was spelled for a number of weeks during sub clover flowering and seed set. On a farm scale it is recommended that sub clover pastures are spelled in late spring 1 in 5 years to build up the seed bank and enable sub clover to remain dominant.

The farmer direct drilled sub clover cv. 'Antas' in one paddock in 2016, which demonstrated successful uptake of the new management approach. The proportion of sub clover in the pasture increased in the second season under continuous light grazing by cattle that encouraged the runners to extend through grass dominant patches. These results reflect those from the South Island where pastures have been successfully

renovated with sub clover cultivars released since 1993 (Costello & Costello 2003; Ates et al. 2010). This outcome is consistent with the recommendations of Brown et al. (2006) that new sub clover pastures are spelled for 6 to 8 weeks from October in the first year to develop a seed bank and that in the years following lighter grazing or de-stocking will encourage further seed production when necessary.

Managing sub clover at the farm scale

The clover landscape categories across Tokaroa Farm shown in Figure 1, were feasible from a farm management perspective once the three large management areas (Flats, Middle and Ranges) of the farm were prescribed, and the maximum drilling slope was set at 20°. In the future, sub clover development will continue with appropriate grazing management and overdrilling into unsprayed ground when necessary.

The Tokaroa Farm plan indicated that sub clover could be managed and/or oversown on 82% of the 580 ha of farmable land with 307 ha overdrilled in the 'Flats' and 'Middle' areas and a further 170 ha, predominantly in the 'Ranges' area, managed with grazing to promote the resident sub clover and also oversown with sub clover seed if necessary.

The farmer is considering more paddock sub division on the back hills of the 'Ranges' to enable improved grazing management, especially when controlling dry summer herbage to create a suitable environment for resident sub clover re-establishment.

The long-term climate data highlighted that there is a 2- to 3-month dry period over summer on Tokaroa Farm, which is consistent with the life cycle of the winter active annual sub clover. Climate change predictions for the Wairarapa include more hot days (>25°C), a 10 to 15% decline in winter and spring rainfall, and increased drought risk for inland Wairarapa (Pearce 2017). This suggests that sub clover will be an increasingly valuable legume component of these North Island East Coast dryland pasture systems.

Conclusions/Practical implications/Relevance

A new grazing management regime based on observing the sub clover lifecycle, rotational grazing and light set-stocking cattle increased the resident sub clover content of the hill pastures. This resulted in improved hill pasture feeding value and was also effectively used on pastures renovated with direct-drilled sub clover. Success relied on the farmer understanding the sub clover lifecycle, and looking for autumn germination and spring flowering. The biggest challenge was to keep the pasture grasses under control throughout the year.

These results are indicative of what could happen on a large area of New Zealand's dryland east coast where sub clover is currently resident but is at low levels in the pasture.

ACKNOWLEDGEMENTS

Malcolm Macfarlane (then On-Farm Research) installed and monitored the original exclosures at Tokaroa Farm but sadly passed away in April 2016. Paul Muir and Kaye Ward (On-Farm Research) maintained the exclosures. Melissa Macdougall (Greater Wellington Regional Council) provided the Tokaroa Farm boundary and fence line shapefile.

This work was funded by the SFF Project 408090 "Sub 4 Spring", co-funded by Beef + Lamb New Zealand, Luisetti Seeds and Seed Force™ Ltd, and "Regenerating Hill Country Pastures" funded by Beef + Lamb New Zealand. Mr Roland Stead also provided financial assistance.

REFERENCES

Ates S, Brown HE, Lucas RJ, Smith MC, Edwards GR. 2006. Effect of ewe stocking rate in spring on subterranean clover persistence and lamb liveweight gain. *Proceedings of the New Zealand Grassland Association 68*: 95-99.

Ates S, Lucas RJ, Edwards GR. 2008. Pasture production and liveweight gain from cocksfoot-subterranean clover pastures grazed at two stocking rates and closed at different times during spring. *Proceedings of the New Zealand Grassland Association 70*: 225-232.

Ates S, Tongel MO, Moot DJ. 2010. Annual herbage production increased 40% when subterranean clover was over-drilled into grass-dominant dryland pastures. *Proceedings of the New Zealand Grassland Association 72*: 3-10.

Brown HE, Moot DJ, Lucas RJ, Smith M. 2006. Sub clover, cocksfoot and lucerne combine to improve dryland stock production. *Proceedings of the New Zealand Grassland Association 68*: 109-115.

Chapman DF, Williams WM. 1990. Evaluation of clovers in dry hill country 8. Subterranean clover at "Ballantrae", New Zealand. *New Zealand Journal of Agricultural Research 33*: 569-576.

Costello T, Costello A. 2003. Subterranean clover in North Canterbury sheep pastures. Presented at: *Legumes for Dryland Pastures: Proceedings of a New Zealand Grassland Association (Inc.) Symposium*. Lincoln University. Pp. 189-192.

Dodd MB, Sheath GW, Richardson S. 1995a. Development of subterranean clover (*Trifolium subterraneum* L.) genotypes for New Zealand pastures 1. Whatawhata persistence evaluation. *New Zealand Journal of Agricultural Research 38*: 33-47.

Dodd MB, Sheath GW, Richardson S. 1995b. Development of subterranean clover (*Trifolium*

subterraneum L.) genotypes for New Zealand pastures 2. Wairakei persistence evaluation. *New Zealand Journal of Agricultural Research 38*: 49-56.

ESRI. 2018. *ArcGIS Desktop*. Version 10.6. Redlands, CA: Environmental Systems Research Institute.

Gillingham AG, Gray MH, Smith DR. 1998. Pasture responses to phosphorus and nitrogen fertilisers on dry hill country. *Proceedings of the New Zealand Grassland Association 60*: 135-140.

Grigg DW, Grigg JM, Lucas RJ. 2008. Maximising subterranean clover in Marlborough's hill country is key to weaning 80% of sale lambs prime. *Proceedings of the New Zealand Grassland Association 70*: 25-29.

Harvest.com. 2016. *Glen Eden Farms Ltd Weather Station*. Retrieved various dates from 01/10/2016 https://live.harvest.com/.

Lucas RJ, Smith MC, Jarvis P, Mills A, Moot DJ. 2010. Nitrogen fixation by subterranean and white clovers in dryland cocksfoot pastures. *Proceedings of the New Zealand Grassland Association 72*: 141-146.

Lynn IH, Manderson AK, Page MJ, Harmsworth GR, Eyles GO, Douglas GB, Mackay AD, Newsome PJF. 2009. *Land Use Capability Survey Handbook - a New Zealand handbook for the classification of land*. 163 p.

Macfarlane MJ, Sheath GW. 1984. Clover – What types for dry hill country? *Proceedings of the New Zealand Grassland Association 45*: 140-150.

Macfarlane MJ, Thomson BC, Crofoot EW, Hamilton G, Ashby H, Muir PD. 2014. Evaluating new forage systems for East Coast dryland. *Proceedings of the New Zealand Society of Animal Production 74*: 108-114.

Mills A, Smith MC, Lucas RJ, Moot DJ. 2008. Dryland pasture yields and botanical composition over 5 years under sheep grazing in Canterbury. *Proceedings of the New Zealand Grassland Association 70*: 37-44.

NIWA. 2019. *Soil Moisture Deficit (SMD)* https://www.niwa.co.nz/climate/nz-drought-monitor/droughtindicatormaps/soil-moisture-deficit-smd.

NIWAData. 2019. *VCSN climate data for -41.175, 175.525*. Retrieved 06/03/2019 from https://data.niwa.co.nz.

Pearce PR. 2017. *Wellington Region climate change projections and impacts*. [NIWA Client Report for Greater Wellington Regional Council, 2017148AK]. 6 p. http://www.gw.govt.nz/assets/Climate-change-2/FINAL-WellNCC-projectionsimpacts.pdf.

S-MAP. 2018. Retrieved 13/12/2018 from https://smap.landcareresearch.co.nz.

Sheath GW, Macfarlane MJ. 1990. Evaluation of clovers in dry hill country 4. Components of subterranean clover regeneration at Whatawhata, New Zealand. *New Zealand Journal of Agricultural Research 33*: 541-547.

Smetham ML. 2003. Subterranean clover (*Trifolium subterraneum* L.): its history and current use and future research in New Zealand. Presented at: *Legumes for Dryland Pastures: Proceedings of a New Zealand Grassland Association symposium* held at Lincoln University, New Zealand, 18-19 November 2003. Pp. 61-72.

Suckling FET, Forde MB, Williams WM. 1983. Naturalised subterranean clover in New Zealand. *New Zealand Journal of Agricultural Research 26*: 35-43.

Tonmukaykul N, Moot DJ, Mills A. 2009. Spring water use efficiency of six dryland pastures in Canterbury. *Proceedings of the Agronomy Society of New Zealand 38*: 81-94.