

Regenerative grazing practices and the sustainability of a beef production system in New Zealand

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Abstract

‘Regenerative’ grazing practices are being promoted by some pastoral farmers. An on-farm study commenced in 2022 is testing if higher instantaneous stocking intensity, but shorter duration of grazing and longer intervals between grazing events, will improve phosphorus (P) and nitrogen (N) use efficiency, and carbon (C) sequestration in the soil, while maintaining or increasing pasture and animal productivity. This regenerative (‘Adaptive’) grazing practice was compared against a conventional ‘Control’ with lower pre-grazing and post-grazing herbage mass, and lower stocking intensity, under rotational grazing by cattle. This paper reports baseline soil physical and chemical measurements collected in autumn and spring of 2022, and pre- and post-grazing herbage mass measured over two years through to autumn 2024. While the 9-fold difference in instantaneous stocking intensity ($15,500 \pm 4,445$ and $150,400 \pm 39,280$ kg LW/ha for the Control and Adaptive treatments, respectively) was successfully imposed for each grazing cycle in the first two years, to date no statistical difference in pre- and post-grazing herbage mass has emerged between the two treatments. We suspect that the combined effect of the more intensive stocking and trampling of the pastures under the higher instantaneous stocking density of the Adaptive grazing treatment may negatively affect herbage growth rates in the days and weeks following grazing. The soil baseline data indicate good nutrient fertility (Olsen-P, pH, exchangeable cations), physical condition, biological and microbial biomass, and organic matter levels under both grazing treatments. In future, these soil and pasture data collected under the two grazing practices will be assessed against the baseline measures reported here when testing the merits of adopting an adaptive grazing strategy.

Keywords: biodiversity, nutrient cycling, regenerative farming, resilience, stocking intensity.

Introduction

‘Regenerative’ grazing practices have created considerable interest in recent years (Grelet et al. 2021, Tozer et al. 2022, Rowarth et al. 2020) and are being

promoted by some pastoral farmers as alternatives to conventional grazing practices. This includes practices such as maintaining higher pre-grazing and post-grazing herbage mass, less frequent grazing and higher instantaneous stocking intensity than more conventional grazing practices, particularly in summer dry regions.

Research to define and apply the principles of pasture growth and utilisation have led to the development of grazing management practices such as rotational grazing and continuous stocking. Within those systems, decision rules and grazing criteria such as spelling intervals, pre-grazing and post-grazing herbage mass, pasture height, grass leaf stage-of-growth, and leaf area index, have been developed and tested and refined in regions of New Zealand that have benign, temperate environments, for example, Taranaki, Manawatu, South Island West Coast, Southland (Harris 1996).

Comparatively few studies of grazing management have been conducted in hotter and drier environments to establish if those grazing criteria and decision rules are applicable. This factor may motivate farmers to question their current grazing practices and adopt practices that they believe are less stressful to plants, animals, and microbes in a soil-plant-animal ecosystem, and more holistically, a soil-plant-animal-farmer-environment ecosystem under current or future climates. From a farm systems perspective, maintaining higher pasture masses offers greater buffering on the margins of the seasons and during periods of extremes of weather (extended wet, cold, or hot and dry conditions), translating into greater certainty in the farming system, and in annual production. However, higher pasture masses may also reduce the leaf:stem ratio and feed quality, leading to greater pasture decay, lower utilisation, and overall, a reduction in pasture and livestock production (Harris 1996).

A planned long-term study was commenced in 2022 at Mangarara Station, a hill country sheep and beef farm located near Elsthorpe in Central Hawke's Bay, to compare aspects of control and regenerative grazing practices on pasture yield and composition, and soil physical and chemical characteristics, particularly soil carbon stocks, and animal performance. Specifically, the hypothesis tested was that higher instantaneous

grazing intensities coupled with a shorter duration of stocking, longer intervals between grazing and higher pasture masses in a rotational grazing system, will maintain or increase pasture and livestock production with a reduced reliance on nutrient inputs and an associated lower environmental footprint.

These benefits may accrue due to the following effects:

- Increase in photosynthetic carbon fixation, through higher average leaf area index.
- Improved animal nutrition through a higher carbohydrate: protein balance in the feed and higher per hectare herbage accumulation.
- Reduced aggregation of nutrients in dung and urine patches, due to the higher instantaneous stocking intensity, but shorter grazing duration.
- Reduced nitrogen (N) losses from urine patches due to the increase in labile carbon (C) in the litter that accumulates at the soil surface.
- Increased soil biological activity and nutrient turnover due to increased flows of C into soil.
- Reduced risks of sediment and phosphorus (P) losses in overland flow due to higher vegetative cover.
- Reduced requirements for synthetic fertiliser due to reducing the animal transfer factor and nutrient losses from the grazed pasture.
- Improved soil function by protecting the soil surface from raindrops and extremes of temperature by limiting the amount of bare ground.

This regenerative grazing practice, which we are terming 'Adaptive', with high stocking intensity, was compared against a conventional practice termed 'Control', with lower stocking intensity, under rotational grazing by cattle. The experiment has been designed to be long-term to be able to detect slow-changing effects, such as soil physical and chemical characteristics, in addition to changes in forage supply. Much of the data presented in this paper should be considered baseline, including a measure of the variance associated with each parameter, and is descriptive of the site. Data collected in future years can be compared against this baseline, and comparisons made between the grazing treatments after increasing periods of treatment imposition have elapsed.

Materials and Methods

Location and site

The trial is located on a commercial farm in Central Hawke's Bay Farm owners (Greg and Rachel Hart) have been exploring ways to improve the sustainability of their farm system, including reducing the dependency on external inputs (P fertiliser, non-renewable energy), increasing the use of trees for fodder, timber, shade and shelter, and sequestering C in their pastoral landscape,

with a strong ethos toward 'local' in farm inputs and outputs. The owners were considering regenerative grazing principles as part of their grazing system and in 2021 established a trial to see if the principles would suit their system. The experiment reported here was conducted within this context.

The trial site for this study, consisted of approximately eight ha of grazed pasture into which parallel, single rows of trees (poplar, tagasaste, Japanese fodder willow) had been planted at 18 m spacing between rows and 2 – 3 m spacing within rows. Half of the trial site had a tall fescue-dominant (*Lolium arundinacea* L.) pasture, and the other half had a perennial ryegrass-dominant (*Lolium perenne* L.) pasture. Both pasture species also contained white clover (*Trifolium repens*). Soils at the trial site are categorised as Land Use Capability (LUC) Class 3-4 (Lynn et al. 2009), and is representative of the Beef+Lamb New Zealand, North Island Finishing Farm class (BLNZ 2024).

Grazing treatments

The grazing method used in this study simulates 'rotational grazing' for the two grazing treatments, 'Control' and 'Adaptive', with the difference based on different instantaneous stocking intensities. The unit of area for grazing consists of a 'cell', covering an area of approximately 0.12 ha (18 m × 70 m). There were 66 cells in total. Each of the two Control groups were allocated 6 cells, and the Adaptive group was allocated 54 cells. The Adaptive grazing treatment consisted of 'high' intensity, short-duration stocking, with animals moved to a fresh grazing cell 3 times per day, compared with the Control grazing treatment which consisted of 'low' intensity, longer-duration stocking with animals moved to a new cell once every three days. This created a nine-fold difference between the two treatments in both instantaneous stocking intensities and liveweight loading.

Over the 2 years of the study there were 15 grazing cycles. The total duration of each grazing cycle (spelling interval plus grazing period) was the same for both grazing treatments, but within that total the grazing period was longer and the spelling interval shorter for the Control compared with the Adaptive grazing treatment (mean grazing cycle of 45 days, consisting of 42 days spelling plus 3 days grazing period for the Control, compared with 44 $\frac{2}{3}$ days spelling plus $\frac{1}{3}$ of a day grazing period for the Adaptive treatment, respectively). For each grazing cycle, the two Control groups each grazed 6 cells in sequence (6 cells × 3 days per cell = 18 days). The single, larger group of the Adaptive animals grazed 54 cells in sequence (54 cells × 3 cells per day = 18 days) and of the 54 cells, six cells (each 9th cell in the grazing sequence) were each paired spatially and temporally with one of the six Control

cells for soil and pasture measurements. The difference between treatments in the spelling interval (42 v. 44 $\frac{2}{3}$ days) is a co-lateral effect of the grazing treatment design, not a direct or intentional treatment effect. It is noted, however, that over time this component of the difference between the grazing treatments in the spelling interval may have some effect on results.

Based on the hypothesis, the expected outcome was that the contrasting grazing treatments would result initially in diverging pasture characteristics and over time, differences in soil-plant-animal nutrient cycling. The low stocking intensity Control grazing treatment would transition to shorter, leafier pasture with lower pre-grazing and post-grazing mass, whereas the high stocking intensity Adaptive grazing treatment would transition to higher pre-grazing and post-grazing pasture mass that is more mature with more stem and less leaf, and a pasture sward that is more heterogeneous in yield and composition.

Grazing animals

Fifteen grazing cycles were completed, the first starting on May 25, 2022, and the most recent ending on March 11, 2024. Different mobs of animals were used during this study. These were as follows: for grazing cycles 1 – 3, Rising 1-year (R1) Friesian dairy heifers (mean LW 270 kg); grazing cycles 4 – 8, R1 Angus beef heifers (370 kg); grazing cycles 9 – 13, R1 Wagyu-cross beef heifers and steers (293 kg); grazing cycle 14, R2 Angus heifers (515 kg); grazing cycle 15, Angus heifers and steers (440 kg).

Replication

For the soil and pasture measurements, the experimental unit was the cell. Replication consisted of two pasture types (tall fescue-based and ryegrass-based pasture), each with six, paired Control and Adaptive cells. This made a total of 24 cells (two pasture types $\times$ two grazing treatments $\times$ six replicates). For the grazing animals there were three groups: two, replicate Control groups, each consisting of six – eight heifers (heifers and steers for grazing cycles 9 – 13 and 15), one of which grazed the six tall fescue-dominant cells sequentially for three days each and the other the six ryegrass-dominant cells, also for three days each. Each of the 12 Control cells was paired with an identical, adjacent Adaptive cell and those 12 cells were grazed in sequence by a single, larger group of 40 – 60 heifers (heifers and steers for grazing cycles 9 – 13 and 15). The number of animals used to stock the plots varied for each grazing cycle depending on herbage mass available and the age and liveweight of the animals used, but the number in each of the three groups maintained the same relativity. The smaller group size for the two Control treatments

compared with the Adaptive treatment was a deliberate decision to minimise the workload running a trial with three treatment groups on a commercial farm, and not as a function of the treatment design. The stocking rate (number of animals per ha) was the same for each treatment group. The experimental unit was the individual animal, consisting of $n = 6 - 8$ for each of the two Control groups and $n = 40 - 60$ for the Adaptive group.

Measurements

Environment

Daily rainfall, soil and air temperatures and soil moistures were recorded continuously at the trial site, using two weather stations. These data and associated long-term means available for the Waipawa and Waipukurau district, are summarised in Table 1.

Herbage mass

Herbage mass was determined at the start and end of each grazing cycle. Approximately 20 rising plate meter (RPM) readings were taken in each grazing cell in a 'V' formation. The mean RPM reading was used as a basis to identify a representative site (mean RPM ± 2 units) to cut a single, 0.5 m² quadrat. Each pre-grazing and post-grazing sample was cut to within 10 mm above ground level with an electric sheep-shearing handpiece, and subsequently weighed fresh. A subsample of approximately 200 g fresh weight (FW) from each sample was oven dried (100°C) to determine % DM, and DM yield/ha was calculated from sample dry weight and % DM. Another subsample was separated into botanical components (ryegrass, tall fescue, white clover, other species and dead material), dried and weighed to calculate the proportions of each species and dead material. This sample was dried at 60°C, a lower temperature than for herbage mass, allowing for subsequent laboratory chemical measurements.

DM intake and trampling

For each grazing cycle the difference in herbage mass between pre-grazing and post-grazing provided an estimate of the combined DM intake plus herbage disappearance by animal trampling.

Soil

Soil measurements were conducted to monitor the effects of grazing treatments on soil physical characteristics (degree of compaction and water infiltration rates – as indicators of effects on water-holding capacity and run-off), biological activity, the labile organic C pool and total soil C stocks, and N and P cycling. Soil bulk density was assessed in April 2022, visual soil assessment and earthworm density were assessed in September 2022 and soil carbon stocks were assessed in October 2022.

Soil elemental tests

Table 1 Waipawa 30-year annual mean rainfall, mean and maximum and minimum air temperatures for the period 1991 – 2020, 30-year mean soil temperature at 100 mm, and comparable data (rainfall and mean air and soil temperature) for 2023 collected from two weather stations on Mangarara Station.

	Waipawa	Weather Station 1 ('Top')	Weather Station 2 ('Bottom')
	1991-2020	2023	2023
Rainfall (mm)	809.6 ¹	1012	1088
Mean air temperature (°C)	12.7	12.7	12.4
Mean maximum air temperature (°C)	18.5	30.3 ³	30.2
Mean minimum air temperature(°C)	6.9	-2.3	-3.9
Mean soil temperature (100 mm depth)	12.1 ²	13.0	12.5

¹ Waipawa 30-year mean data are annual mean rainfall, annual mean air temperature and maximum and minimum air temperatures.
² 30-year mean soil temperature was for the period 1981-2010, obtained from the weather station in Waipukurau, approximately 25 km from Mangarara Station.
³ Weather station maximum and minimum air temperatures are for individual days in 2023.

Soil subsamples were collected using a conventional soil corer (25 mm dia.) to a depth of 75 mm. The pH, Olsen-P, exchangeable cations, mineral N, total N, organic C, hot water extractable C and N, as described by Lambert et al. (2000), were measured in ten soil cores collected from 12 paired cells, comprised of 12 Control cells and 12 Adaptive cells.

Soil structure

Visual soil assessments (VSA) were conducted according to the Field Guide (Shepherd 2000). This is a scoring system to characterise soil quality based on soil structure, soil aeration, and compaction and treading effects. VSA score >20 was classified as Moderate-Good, and >25 was classified as Good. Bulk density was determined using soil cores taken to 600 mm depth. A bulk density ring (100 mm diameter) was used for the 0 – 75 mm core. A hydraulic corer was then used to extract a smaller core (50 mm diameter) to 600 mm depth and this core was then cut into the following segments: 75 – 150 mm, 150 – 300 mm and 300 – 600 mm.

Earthworm abundance

Earthworms were manually removed and counted in the turfs collected for VSA, described above (Schon et al. 2011; 2023). In addition to abundance, earthworms were identified by species and functional group.

Soil organic carbon

These were determined on soil core samples collected from 0 – 75 mm, 75 – 150 mm, 150 – 300 mm and 300 – 600 mm soil depths (using a 100 mm diameter corer for 0 – 75 mm, and a 50 mm diameter corer for the lower depths), as described by Mackay et al. (2021).

Animals

Cattle were weighed at the start and end of each grazing cycle. The mean of these two weights, in conjunction with the stocking rate of animals provided an estimate

of liveweight (LW)/ha for comparing instantaneous stocking intensity (kg LW/ha) and time-weighted stocking intensity (kg LW/ha/h). Further measures of animal performance such as average daily gain (ADG) and annual LWG (liveweight gain/ha) can be calculated. However, they are not presented in this paper so as to maintain the focus on soil and pasture baseline data.

Statistical analysis

The environmental data (e.g., rainfall, air temperature, and soil temperature) were described as a mean for the study period. Minimum and maximum daily temperatures are described as a mean.

Stocking intensity is described as a mean ± standard deviation (SD) for each grazing treatment.

The pH, Olsen-P, exchangeable cations, mineral N, total N, soil organic C, hot water extractable C and N) were described as a baseline value, stratified by grazing treatment. Anion storage capacity, total N, and organic C were described as a percentage.

Soil bulk density, VSA, earthworm abundance and soil organic C were described as a mean ± SD stratified by grazing treatment, pasture type, and where appropriate, soil depth.

Three estimates of herbage mass were calculated: pre-grazing herbage, post-grazing herbage and the difference between post-grazing and pre-grazing herbage, defined as dry matter intake plus trampling. Data were presented as means and standard deviations for the 15 grazing cycles, stratified by the four treatment groups (pasture type: tall fescue or ryegrass and grazing treatment: Control or Adaptive). Normality was assessed using histograms.

Mixed effects linear regression models were developed to investigate the associations between grazing treatment (Adaptive v. Control), pasture type (tall fescue v. ryegrass) and grazing cycle, for each outcome.

The grazing cell was included in the model as a random effect.

Results

Environment

Mean annual rainfall in 2023 collected from the two weather stations at Mangarara was 30% higher than the long-term mean rainfall for the Waipawa District (Table 1). The mean air temperatures were similar to the long-term means, and the mean soil temperature for 2023 was slightly warmer than the long-term mean. The Mangarara weather stations do not provide mean maximum or minimum temperatures, so the individual daily maximum and minimum temperatures for 2023 are presented (Table 1).

Over the first two years of the trial, the focus was on collecting base-line measures of soil and pasture parameters and imposing the two grazing treatments. Fifteen grazing cycles were completed during the two years, consisting of a mean of 45 days and a range from 28 to 68 days. The mean duration of grazing was 3 days for the Control grazing treatment and $\frac{1}{3}$ of a day (i.e., 8 h) for the Adaptive grazing treatment (the fractions of a day derived from 3 shifts per day, which is the equivalent of grazing each cell for one-third of a day – as described above). Spelling intervals between grazing cycles averaged 42 days for the Control group and $44\frac{2}{3}$ days (i.e., 44 days and 16 h) for the Adaptive group.

Stocking intensity

Animals were stocked on plots at rates to achieve a 9-fold difference in instantaneous stocking intensity (expressed as the number of animals per ha, multiplied by their mean LW) between the grazing treatments. The instantaneous stocking intensity was $15,500 \pm 4445$ kg and $150,400 \pm 39,280$ kg LW/ha for the Control and Adaptive treatments, respectively. When the instantaneous stocking intensity was adjusted for the duration of stocking (i.e., total liveweight/ha/h) the corresponding stocking intensities were 200 ± 70 kg LW/ha/h for the Control treatment and $16,400 \pm 7060$ kg LW/ha/h for the Adaptive treatment.

Pre-grazing and post-grazing herbage mass

Pre-grazing herbage mass varied significantly throughout the two-year period, despite attempts to start each grazing cycle at a consistent level of herbage mass (Fig 1a). Post grazing residual herbage mass showed a broadly similar pattern, but with greater variability, particularly in the later grazing cycles (Fig 1b). Across 15 individual grazing cycles, the greatest pre-grazing herbage mass was 4400 kg DM/ha at grazing cycle 6 (February 2023) and was greater than 3500 kg DM/ha for grazing cycle 5 (December 2022). However,

overall, the mean pre-grazing herbage mass for the 15 cycles was 2900 kg DM/ha and 2800 kg DM/ha for the Control and Adaptive grazing treatments, respectively, and the mean post-grazing herbage mass was 2190 kg DM/ha and 2100 kg DM/ha for the Control and Adaptive grazing treatments, respectively. There were indications that the post-grazing herbage mass for the Adaptive treatment was lower than for the Control treatment for grazing cycles 5, 6 and 7 (November 2022 – February 2023) and again for grazing cycles 10, 11, 12 and 13 (August to December 2023).

DM intake plus trampling

There was significant variability in DM intake plus trampling estimates among grazing cycles (Fig 2). There was no difference in DM intake plus trampling between the Control and Adaptive grazing treatments, with an overall mean of 720 kg DM/ha/grazing (760 and 670 kg DM/ha for the Control and Adaptive grazing treatments, respectively). Grazing cycles 3 (October 2022), 9 (August 2023) and 11 (October 2023) differed from the other cycles for all three measures. For these three cycles, the post-grazing residual mass (2280 kg DM/ha) was higher than the pre-grazing herbage mass (1840 kg DM/ha), indicating that herbage accumulation rates were greater than DM intake plus trampling for those cycles. For comparison, the pre-grazing and post-grazing masses for the other 12 cycles (excluding cycles 3, 9 and 11) were 3120 and 2110 kg DM/ha, respectively, and the estimated mean dry matter intake plus trampling was 1000 kg DM/ha.

Botanical composition

Overall, the mean pre-grazing botanical composition comprised 10% white clover, 70% grass (ryegrass plus tall fescue), and 20% other species. There were no differences in composition between the Adaptive or the Control pastures. However, there were seasonal differences in the proportion of white clover, ranging from 5% in winter, 7% in spring, 15% in summer and 10% in autumn. The tall fescue-based pasture contained approximately 50% tall fescue and 20% ryegrass, and the ryegrass-based pasture contained approximately 70% ryegrass and less than 10% tall fescue.

Soil physical and chemical characteristics

Soil nutrient status

Initial soil pH (pH and all other variables of nutrient status were measured on samples collected in April 2022) was 5.9 (5.95 for the Control grazing treatment and 5.85 for the Adaptive grazing treatment, respectively) and initial Olsen-P values were 24.0 mg/l for the Control grazing treatment and 25.5 mg/l for the Adaptive grazing treatment. Anion storage capacity was

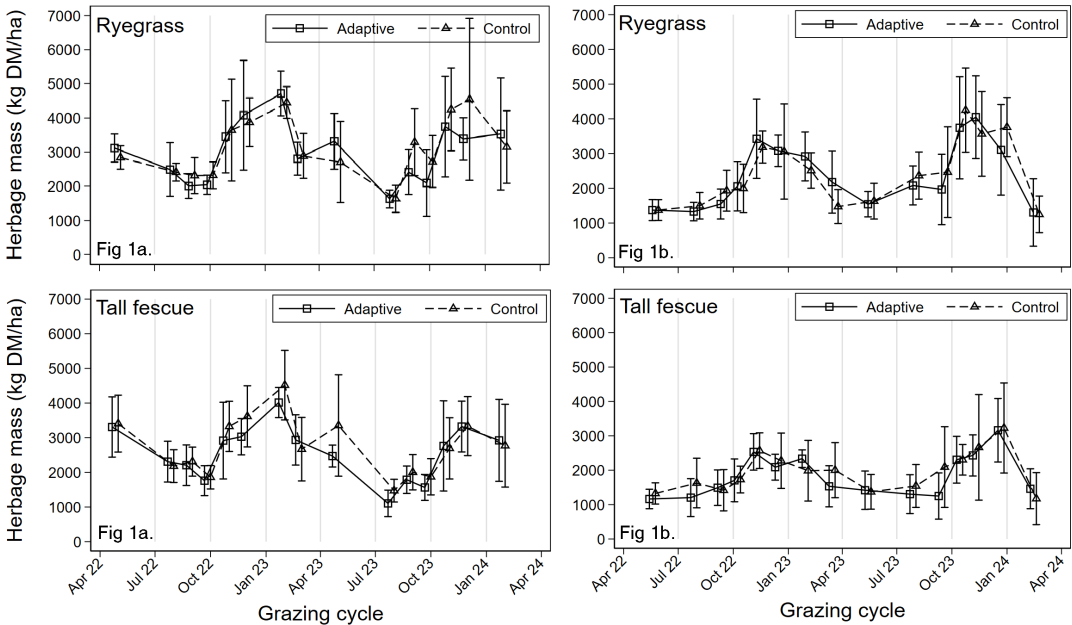


Figure 1 The means and standard deviations of pre-grazing herbage mass for the ryegrass Control and Adaptive grazing treatments (Fig 1a, upper frame), the tall fescue Control and Adaptive grazing treatments (Fig 1a, lower frame), and post-grazing herbage mass for the ryegrass Control and Adaptive grazing treatments (Fig 1b, upper frame), the tall fescue Control and Adaptive grazing treatments (Fig 1b, lower frame), for 15 grazing cycles from May 2022 to March 2024. NB Fig 1a (pre-grazing herbage mass) and Fig 1b (post-grazing herbage mass) are each split into two frames, one for ryegrass Control and Adaptive grazing treatments and one for tall fescue Control and Adaptive grazing treatments, for clarity in comparing treatment effects on herbage mass.

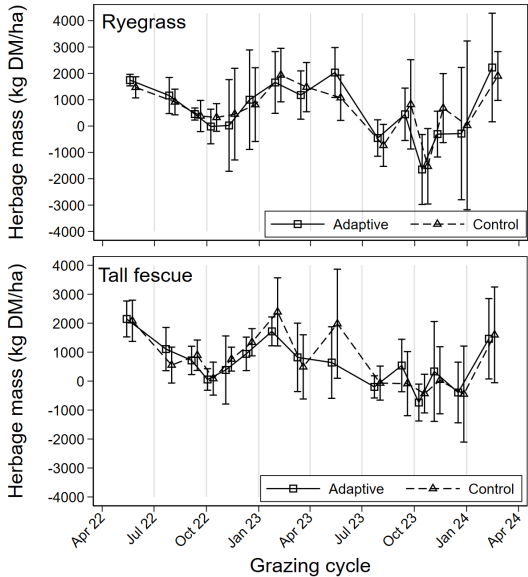


Figure 2 The means and standard deviations of dry matter intake plus herbage trampling for the ryegrass Control and Adaptive grazing treatments (upper frame) and the tall fescue Control and Adaptive grazing treatments (lower frame), for 15 grazing cycles from May 2022 to March 2024.

26% and 27% for the Control and Adaptive treatments, respectively. There were no treatment differences in exchangeable cations, with the Ca, Mg and K MAFQT values of 12, 45 and 8, respectively. Total N (%), organic carbon (%) or hot water extractable carbon (HWEC) or nitrogen (HWEN) were also similar between the two grazing treatments. The overall mean total N (%), organic carbon (%), HWEC and HWEN were 0.41% N, 3.92% C, 2556 mg C/g soil and 234 mg N/g soil, respectively. In the upper 40 mm of soil, HWEC and HWEN were greater at 3150 mg C/g soil and 320 mg N/g soil, respectively.

Soil bulk density (BD)

There was no evidence of baseline differences in the bulk density of the soil to a depth of 600 mm between the Control and Adaptive grazing treatments measured in April 2022, immediately prior to commencing the experiment. Similarly, there was no difference in the bulk density of the soils in the ryegrass or tall fescue cells, nor any grazing treatment $\times$ grass species interaction. There were differences in BD with soil depth, with the lowest BD for 0 – 75 mm (1.0 g/ml), intermediate for 75 – 150 mm and 150 – 300 mm (1.2 g/ml), and greatest for 300 – 600 mm (1.5 g/ml) (Table 2).

Visual soil assessment

Table 2 The number of samples, and the mean and standard deviation (SD) of bulk density of soil samples (g dry soil/ml) assessed on samples collected in April 2022, soil carbon stocks (t/ha) collected at four depths in the soil profile (0 – 75 mm, 75 – 150 mm, 150 – 300 mm and 300 – 600 mm) assessed on samples collected in October 2022, and the visual soil assessment score (VSA) and earthworm abundance (number of earthworms per m²) for the Control and Adaptive grazing management treatments on tall fescue and ryegrass plots, assessed on samples collected in September 2022.

Soil measurement	Control				Adaptive				
	Tall fescue		Ryegrass		Tall fescue		Ryegrass		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Bulk density	6	1.1	0.07	6	1.0	0.03	6	0.9	0.18
	6	1.3	0.07	6	1.2	0.10	6	1.3	0.22
	6	1.4	0.10	6	1.3	0.14	6	1.3	0.21
	6	1.5	0.07	6	1.6	0.06	6	1.5	0.10
Soil carbon stocks	6	30.8	13.21	6	29.0	2.53	6	27.7	5.22
	6	20.7	11.94	6	16.3	4.91	6	21.4	4.99
	6	17.2	14.14	6	15.7	3.91	6	15.6	7.26
	5	19.6	26.44	6	11.8	5.84	5	6.9	2.48
Visual soil assessment ^{1,2}		21.5	4.15		19.8	4.41		20.9	4.23
Earthworm abundance ²		876	419.2		693	342.7		782	568.3
								746	482.4

¹ A VSA score of >20 is considered Moderate - Good
² n = 18 for all means

There were no differences in VSA score between the grazing treatments, nor between the different grass species when assessed in September 2022, after two grazing cycles had been completed (Table 2).

Earthworm abundance

Earthworm abundance was determined in September 2022 in the soil samples collected for VSA. Overall, on average there were 16 earthworms/spade square, which equates to 710/m² (Table 2). The abundance tended to be lower in the Control cells (583/m²) compared with the Adaptive cells (644/m²). The abundance tended to be lower for ryegrass (566/m²) than for tall fescue (661/m²). Five endogeic earthworm species were identified, which is a diverse number and included *A-caliginosa*, *O-cyaneum*, *A-rosea*, a single epigeic species (*L-rubellus*), but no anecic (deep burrowing) earthworms.

Soil organic carbon stocks

There were no differences in soil organic C stocks (t/ha) to 600 mm between the grazing treatments sampled in April 2022, prior to the commencement of the experiment (Table 2). Variability in carbon stocks tended to be greatest at the 300 – 600 mm depth, particularly for the tall fescue-Control grazing treatment plots. This single high mean of 19.6 ± 26.44 t/ha was just for the deepest stratum of one sample out of 24 treatment × replicate combinations (each sample in Table 2 is the mean of three subsamples for that cell and stratum), but without any reason for its removal, it has been left in the Table.

Discussion

The purpose of this paper is to describe baseline, descriptive, herbage and soil measurements of an experiment that was initiated on a commercial beef grazing property in May 2022. The experiment was designed to test aspects of regenerative grazing practices that may improve nutrient use efficiency, increase soil organic C stocks, and reduce nutrient input requirements, while maintaining or increasing pasture and animal production in a changing climate. The data presented are the mean values and standard deviation to describe the spatial and temporal variability of soil and pasture parameters. Some are measured frequently, e.g., pasture growth, while others e.g., soil bulk density, soil nutrient fertility and VSA are evaluated intermittently. Parameters such as soil organic C stocks are typically measured even less frequently (5 to 10 years). Other than for the spatial variability there are no statistical comparisons of grazing treatment effects on soil parameters at this baseline stage. With the exception of VSA where the score was >20 and classified as Moderate-Good (but not >25 which is classified as Good), the experimental site has optimal levels of soil nutrient fertility (e.g., Olsen P >20 mg/l, pH close to

6.0, soil organic C >2.5%, and earthworm abundance (>400/m²) and are within the optimal range for pastoral soils (Shepherd 2000; Schon et al., 2023). Only two (epigeic, endogeic) of the three functional earthworm groups were found in the soil at the site, which is not unusual as all the earthworm species are exotic, and their introduction has been accidental (Schon et al. 2011).

The 9-fold difference in instantaneous stocking intensity (15,500 and 150,400 kg LW/ha for the Control and Adaptive treatments, respectively) was successfully imposed for each grazing cycle during the first two years. There was an expectation that, compared with the Control grazing treatment, the herbage mass of the Adaptive treatment would tend to increase over time. However, at this stage no detectable differences between the Control and the Adaptive grazing treatments have emerged in either the pre-grazing or post-grazing herbage mass, or in the calculated estimate of DM intake plus trampling. There was an indication that the post-grazing herbage masses may have declined in the second year under the Adaptive grazing treatment. In the current study no attempt was made at the start to impose differences in herbage mass between the grazing treatments. We suspect that the effect of the higher stocking intensity and trampling of the pastures under the Adaptive grazing treatment may have reduced herbage accumulation rates and recovery in the days and weeks following grazing. Despite no significant differences between the DM intake plus trampling or pre-grazing or post-grazing DM/ha in Adaptive and Control cells, residuals were consistently lower in Adaptive groups, particularly in November 2022 to January 2023 and May 2023 to January 2024. These lower residuals may have reduced pasture regrowth compared to the Control group, a finding that may become significant with further sampling. The benefit of the Adaptive group might be found in improved animal performance, and this will be investigated further in future. The outcome in pre-grazing and post-grazing herbage mass under the two grazing treatments has been the subject of discussion with the mentor group of farmers associated with the experiment.

The extremely wet winter and spring of 2022 and summer 2022/23 in Hawke's Bay, and Cyclone Gabrielle in February 2023, were atypical for the region and seriously disrupted the first year of this project (NIWA 2023). On several occasions animals had to be moved to the next cell more frequently than was originally planned (3 – 4 times per day for the Adaptive group rather than the planned 3 times per day, and every 2 days for each Control group rather than every 3 days). The animals had to be removed from the trial for a short period of time on occasions, due to the flooding of some

of the plots and the risk of excess soil damage from pugging due to prolonged periods when the soils were saturated. As this is year 2 of a 7-year project we do not think that the atypical weather will disproportionately affect the overall outcome across the 7-year timeframe. However, there may also need to be some relaxation of the adaptive grazing rules under extreme winter wet or summer drought conditions.

In a separate preliminary study as part of the research at Mangarara, Dewhurst (2023) showed that under the higher instantaneous stocking intensity of the Adaptive grazing treatment there was less clustering of dung patches than under the Control grazing treatment, suggesting a more even distribution of dung. Given that the animal nutrient transfer factor is the single biggest driver of annual nutrient requirements (Cornforth et al. 1982), differences in soil P fertility between the two grazing treatments over time might provide an indication of whether any improvement in nutrient return translates into a decrease in P requirements and risk of P losses to surface water bodies (McDowell et al. 2003).

Without the baseline data summarised here, comparisons between the Control and Adaptive grazing treatments would be limited. Baseline measurements provide confidence that any change can be measured over time and reflect the treatments imposed. The baseline data in providing an indication of the variability, will assist in calculating the number of samples required to detect treatment differences in the future. For example, given the variance measured in soil organic carbon stocks, 11 samples would be required to detect a difference of 5% units, or 5 t/ha, in soil C at the most variable depth of 300 to 600mm.

There are multiple facets to regenerative grazing practices imposed on commercial properties, and these farmers mostly consider regenerative practices in a holistic manner. The grazing treatment design applied in this study captured some of those facets within as few grazing variables as was possible. It acknowledges that multiple variables are still involved in this study, which may not have allowed the rigorous scientific comparisons that a single-variable study conducted under more controlled research station conditions would provide.

Conclusions

Soil and pasture parameters provide the baseline data against which future data can be compared. There is no evidence after two years that the high stocking intensity of the Adaptive grazing treatment affected pasture production compared with the low stocking intensity of the Control grazing treatment. In future, these soil and pasture data collected under the two grazing treatments should be assessed against the

baseline measures reported here when testing the merits of an adaptive grazing strategy. If the future outcome of this study supports the hypothesis, adopting aspects of regenerative grazing practices, as described here, may be a method to improve nutrient use efficiency, increase soil carbon stocks and reduce nutrient input requirements without any negative effects on soils, pasture or animal production.

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