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Soil nutrient management in dairy farming: a systems comparison - year 4 report

Gillespie RN, Horrocks AJ, Meenken ED, Tregurtha CS, Gosden ML, Richards KK

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Soil nutrient management in dairy farming: a systems comparison - year 4 report. May 2017. PFR SPTS No.14744. This report is confidential to Lincoln University.

EXECUTIVE SUMMARY

Soil nutrient management in dairy farming: a systems comparison – year 4 report

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May 2017

- Farmers are showing increasing interest in biological nutrient management systems as a means of improving both environmental and economic performance.
- In the interests of undergoing a systems comparison between the Albrecht-Kinsey biological approach and a 'best management practice' conventional approach, in 2011, mid Canterbury farmers Jeremy Casey and Kim Solly converted a cropping farm into two dairying units (near Methven, Canterbury).
- Three pairs of focus paddocks across the two dairy farms were selected for comparison based on their soil fertility, cropping and management history.
- This report follows that of Horrocks et al. (2016) and documents soil quality monitoring (physical, chemical and biological) and pasture composition results from these focus paddocks as measured by Plant & Food Research for 2013–2016 (soils) and 2014–17 (pasture composition).
- It is possible that there will be seasonal variability in soil structural condition in both systems, with the primary drivers for this being organic matter returns and moisture content at time of grazing. Changes in soil quality in response to management may take longer to detect. To date (2017), indicators of soil quality are similar between the two systems, although small differences in penetration resistance, aggregate stability and macro-porosity in favour of the Albrecht-Kinsey managed paddocks may be emerging, but the results are variable over time.
- The population of earthworms is increasing under permanent pasture on both management systems, with greater numbers on the Albrecht-Kinsey managed farm. There were 24% more earthworms under Albrecht-Kinsey management compared with conventional management in the first year of monitoring in 2013. By 2016 there were 56% more earthworms under Albrecht-Kinsey management.
- There is more readily available sulphur and magnesium under Albrecht-Kinsey management than with conventional management as a result of differences in fertiliser inputs under the two systems. Average total carbon is slightly higher under Albrecht-Kinsey management, but is practically the same. Other fertility measurements were very similar between the two management systems.
- Although there has been some fluctuation, paddock South 26 (Albrecht-Kinsey management) has consistently had high clover content and this trend continues, following assessments over the 2016–17 season. Overall, there continues to be a trend for higher clover to grass ratios on the Albrecht-Kinsey farm. Weekly assessments of the proportion of grass and clover were carried out on additional paddocks over the 2016–17 season across both management systems, with results validating focus

paddock observations. This is likely to be partly a result of a reduced fertiliser N inputs on the Albrecht-Kinsey farm.

- It is anticipated that changes to both pasture composition and soil quality due to differences in farm management would only occur over long time frames. The four years of data collected are a starting place from which to document further changes over time. The project is expected to finish in 2018.

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1 INTRODUCTION

Farmers are showing increasing interest in alternatives to conventional nutrient management systems in an effort to improve both environmental and economic performance of their farms. In the interests of undergoing a systems comparison between the Albrecht-Kinsey (A-K) approach, referred to as ‘biological nutrient management’ in previous reports, and a ‘best management practice’ conventional approach, in 2011 mid Canterbury farmers Jeremy Casey and Kim Solly converted a cropping farm near Methven (Canterbury) into two dairying units with similar cropping histories. Although not a ‘replicated trial’, a system evaluation is being carried out to track changes in production, profitability and environmental over time.

Fertiliser management on the conventional farm follows a Ballance Agri-Nutrients Limited-advised fertiliser regime, with the Albrecht-Kinsey approach fertiliser management being advised by Healthy Soils using Albrecht-Kinsey soil fertility testing (http://www.kinseyag.com/Sampling.html). Soil nutrient and farm management on each farm will comply with the requirements of the relevant system, with a steering committee providing governance as required.

Three pairs of focus paddocks across the two farms were selected based on soil nutrient fertility, cropping history and management history. This report follows on from Horrocks et al. (2016) and documents soil quality monitoring (physical, chemical and biological) and pasture composition results from these focus paddocks as measured by Plant & Food Research for 2013–2016 (soils) and 2014–17 (pasture composition).

2 METHODS

Although there may be slight changes across the two dairying units, the soil type across both is a moderately deep Templeton silt loam.

Soil chemical fertility results (analysed by Hill Laboratories Ltd) from February 2010 show that, besides Olsen P (which was elevated on the Albrecht-Kinsey side), the focus paddocks were similar in terms of soil chemical properties (Table 1).

Table 1. Hill Laboratories Limited Basic Soil + SO_4-S results from February 2010 for each focus paddock under conventional (Conv.) and Albrecht-Kinsey (A-K) nutrient management.

Paddock ID	System	pH	Olsen P	S (MAF)	K (MAF)	Ca (MAF)	Mg (MAF)	Na (MAF)
North 3	Conv.	5.9	10	3	4	8	6	4
North 15	Conv.	6.1	19	6	4	10	8	6
North 22	Conv.	6.2	17	6	4	11	10	5
Average	**Conv.**	**6.1**	**15.3**	**5.0**	**4.0**	**9.7**	**8.0**	**5.0**
South 12	A-K	5.7	28	12	5	9	9	6
South 19	A-K	5.8	25	5	6	8	12	4
South 26	A-K	5.8	19	5	6	9	7	4
Average	**A-K**	**5.8**	**24.0**	**7.3**	**5.7**	**8.7**	**9.3**	**4.7**

The paired focus paddocks were also selected in a way that, where possible, aligned cropping histories (Table 2). However, in some instances detailed information on crop history was not available. Because of a variable cropping history on paddock North 22, only the south half was monitored. In 2015, paddock North 22 was not sampled as it had just been grazed and this would have been too disruptive to the measurements being carried out. Paddock North 24 was sampled as a substitute, because it was adjacent to paddock North 22 and had a similar grazing and cropping history.

Table 2. Cropping history in the three years prior to conversion to dairy farming for each focus paddock under conventional (Conv.) and Albrecht-Kinsey (A-K) nutrient management.

Paddock ID	System	Pairing	2008–09	2009–10	2010–11
North 3	Conv.	A	Triticale (cut and carry)	Peas (seed)	Feed wheat
North 15	Conv.	B	information not available	Milling wheat	Ryecorn (winter grazed)
North 22	Conv.	C	information not available	Milling wheat	Clover
South 12	A-K	A	Pasture (short term?)	Milling wheat	Feed wheat
South 19	A-K	B	Pasture/chicory mix	Chicory	Ryecorn (winter grazed)
South 26	A-K	C	Pasture?	Clover	Wheat

2.1 Soil (physical, chemical and biological)

The following methods outline the soil quality assessments carried out in each focus paddock in August in 2013, 2014 and 2015, and July 2016. As some soil nutrient management differences had already been imposed across the two farms prior to the 2013 sampling, the soil sampling carried out in 2013 was not a true baseline. Given that there were few differences in soil chemical fertility between the two farms, it is a good starting point from which to track changes over time.

2.1.1 Soil physical measurements

Penetration resistance

Penetration resistance is a measure of compaction and was measured in the field using a cone penetrometer at 0–10 and 10–20 cm depths. Readings were later normalised to a fixed soil moisture content (35% [w/w] soil moisture), based on soil texture and the field soil moisture when measurements were recorded at the time of sampling.

Macro-porosity and field capacity

Macro-pores are important for soil aeration, good root extension and drainage. The proportion of macro-pores can decrease rapidly if a soil is subjected to compaction (e.g. wheel traffic, animal treading). Macro-pores are defined as those larger than approximately 30 µm diameter. Macro-porosity is presented here volumetrically as % pore space.

The soil moisture content at field capacity is the maximum amount of water a soil can hold following drainage and indicates the water storage capacity of the soil.

In the field, an undisturbed core was collected from a depth of 0–7.5 cm by cutting a column of soil with a sharp knife whilst gently pressing a PVC ring over the column, a carving technique that avoids shattering the core. In the laboratory, worms were removed from the cores using a heat treatment to bring worms to the core surface, where they were removed by hand. Macro-porosity was measured on tension tables at -10 kPa and refers to the volumetric proportion of macro-pores in the soil. Field capacity is calculated from the soil moisture at -10 kPa and fine earth bulk density.

Aggregate stability

Soil aggregates need to be of a size, shape and packing that maintain the necessary soil porosity for roots to access air, water and nutrients easily. Soils with high aggregate stability are better able to withstand the degradation that may result from cultivation, compaction and raindrop impact. Aggregates with low structural stability are more prone to dispersion by wind and water. Particles dispersed by water tend to fill the surrounding pores, restricting the movement of water and air into the soil profile. Research has shown that soil with low aggregate stability also has lower crop productivity.

Aggregates 2–4 mm diameter were separated from the whole soil by non-forced sieving, and then air-dried at 25°C before aggregate stability determination using a wet-sieving method (Kemper & Rosenau 1986). The air-dried 2−4 mm aggregates (50 g) were sieved underwater for 20 min on a nest of sieves (2.0, 1.0 and 0.5 mm diameter). The soil remaining on each sieve was weighed after oven drying at 105˚C. The weight of material remaining on the 2 mm sieve was corrected for stone content. The aggregate stability was expressed as a mean weight diameter (MWD):

$$MWD = \sum_{i=1}^{n} x_i w_i$$

where Xi is the mean diameter of adjacent sieves and Wi is the proportion of the total sample retained on a sieve.

2.1.2 Soil chemical measurements

A composite of 16 samples was taken to a depth of 15 cm from transects across each focus paddock. From this composite, measurements were carried out to determine:

Anaerobically mineralisable nitrogen

Anaerobically mineralisable N (AMN) provides a measure of the amount of N that can be supplied to plants during the current growing season through the breakdown of organic matter. Mineralisable N represents a small part (1–4%) of the total organic N that is broken down and released as mineral N through a process called mineralisation. Mineral N is the form of nitrogen that plants can most easily utilise. The rate of mineralisation depends on soil conditions and is most rapid when soil is warm and moist. Topsoils commonly contain 50–200 kg/ha of mineralisable N. Mineralisable N is often referred to as “available N” by analytical laboratories.

AMN was determined following incubation of air-dried soil under waterlogged conditions at 40°C for 7 days (Keeney 1982), and corrected for mineral N in the non-incubated soil. In this method, 5 g of soil was extracted with 50 mL of 2 M KCl. Mineral N in the extracts was measured using a flow injection analyses technique on a Lachat Quikchem 8500 Series 2 Analyzer (Lachat Instruments, Loveland, Colorado, USA).

Total carbon (C) and nitrogen (N)

Each subsample of soil for total C and N analysis was mixed thoroughly, sieved <2 mm diameter and oven-dried overnight at 60°C. Total C and N was determined by Dumas dry combustion of 0.5 g soil samples on a LECO TruMac CN analyser (LECO Corporation, St. Joseph, Michigan, USA) at 1250°C.

Basic soil and SO_4^{2-}-S

Soil samples for Basic soil (Olsen P, pH, exchangeable cations, cation exchange capacity (CEC)) and sulphate sulphur analysis were air-dried at 25°C. Analyses were subcontracted to Hill Laboratories Limited in Hamilton.

2.2 Pasture species composition

Samples were taken for pasture dissection from each of the focus paddocks in October 2014, January, May and October 2015, February, May and October 2016, and February and April 2017. Approximately 30 samples were collected prior to grazing along four paddock transects. These were composited, then mixed and sub-sampled before being dissected and categorised as either grass, clover, chicory, plantain, weed or dead, and subsequently oven dried.

2.3 Statistical analyses

An important limitation of this comparative study is the lack of replication of farms under the two management systems, with only one farm representing the Albrecht-Kinsey system and one representing the conventional system. However, the measurements reported here are based on three replicated paddocks on each farm that were paired with those on the adjoining farm. A second limitation is that the spatial arrangement of the focus paddocks within these systems could not be randomised (the implication of this being that any overall system effects observed could be attributed to some cause other than the management system). This does not mean that the results are not meaningful, but care should be taken before attributing trends observed to all Albrecht-Kinsey 'biological' or all best management practice 'conventional' systems. A model exploring overall effects of management over time on pasture composition was fitted by restricted maximum likelihood (REML) in GenStat v. 14. This model allowed for the lack of independence between consecutive measurements at the same location. Differences in soil quality indicators were assessed at each time independently by a non-parametric Mann-Whitney test and t-test. Since there was no difference between the two methods, results are reported for the t-test only. T-test estimated *P* values in Tables 3 and 4 suggest differences may exist between the conventional and Albrecht-Kinsey systems when <0.1 (the smaller the *P* value, the greater the significance of this difference).

Figures are presented for selected indicator variables. Because of the small sample size and concerns regarding independence, the raw data are presented rather than modelled estimates of means and standard errors, to avoid potentially inappropriate parametric assumptions.

3 RESULTS AND DISCUSSION

3.1 Soil physical and biological monitoring

Results from the physical and biological monitoring carried out in the focus paddocks (and averaged across management system) are presented in Table 3. The data are presented in full in Appendix 1.

Soil structure is strongly influenced by management, with farming practices such as cultivation and stocking rates (especially when soil moisture is high) affecting the extent of soil compaction. Well-structured soils are better able to withstand the impacts of stock treading and will drain better, as well as having a greater capacity to retain water. Improvements in soil structure are usually well correlated with improvements in productivity. It is anticipated that there will be seasonal variation in soil structure with in each of the paddocks, primarily driven by differences in soil moisture content at the time of grazing. Changes in soil quality in response to management may take longer to detect and will require monitoring over time.

Overall most indicators of physical soil quality are similar between the two systems. However, trends may be emerging of differences in penetration resistance at 10–20 cm ($P = 0.10$), aggregate stability (MWD [$P = 0.09$] and % >1 mm [$P = 0.04$]), macro-porosity (NS), all favouring the Albrecht-Kinsey managed system. Nevertheless, the sizes of the absolute differences reported to date are relatively small and probably of little practical significance.

Earthworms are one of the most important groups of organisms that live in the soil. Through their feeding and burrowing activities, earthworms can enhance nutrient availability, increase the infiltration and movement of air and water, and improve structural condition and stability of soils. The population of earthworms was higher on the Albrecht-Kinsey managed farm at all sampling times, but with enough variability for these differences to be statistically insignificant until 2016, when counts were significantly different ($P = 0.04$). Differences in earthworm numbers would need to be maintained over a longer period of time before being considered attributable to management practices, as earthworm numbers are sensitive to their environmental surroundings (moisture, temperature, physical impact of stocking/cultivation, chemical sprays etc.), many of which are affected directly or indirectly by soil management.

Table 3. Means and t-tests for the physical and biological soil quality indicators measured in each focus paddock and averaged across conventional (Conv.) and Albrecht Kinsey (A-K) nutrient management systems in 2013–16.

	2013			2014			2015			2016		
	Conv.	A-K	t-test	Conv.	A-K	t-test	Conv.	A-K	t-test	Conv.	A-K	t-test
0–10 cm penetration resistance (MPa)	2.17	2.24	0.65	1.70	1.60	0.16	1.61	1.57	0.77	1.25	1.28	0.70
10–20 cm penetration resistance (MPa)	2.01	2.11	0.43	2.46	2.11	0.04	1.88	1.77	0.62	2.09	1.70	0.10
0–7.5 cm soil moisture at field capacity (% v/v)	40.5	40.8	0.87	44.3	43.9	0.71	43.9	43.5	0.61	42.4	42.2	0.75
0–7.5 cm macro-porosity (% v/v @ -10 kPa)	8.3	8.9	0.65	10.5	8.9	0.39	9.7	11.0	0.52	13.1	14.9	0.35
0–15 cm aggregate stability (mm, MWD)	1.84	1.83	0.92	1.50	1.57	0.53	2.01	2.09	0.29	1.99	2.12	0.09
0–15 cm aggregate stability (% >1 mm)	67	66	0.99	56	59	0.42	78	80	0.41	77	83	0.04
Earthworms per m^2	452	562	0.44	1144	1822	0.30	977	1349	0.48	1009	1577	0.04
Grass grubs per m^2	9	32	0.25	6	20	0.20	0	42	0.34	12	72	0.46
Clover root weevil adult per m^2	208	236	0.89	2	0	0.37	0	0	*	0	2	0.37
Clover root weevil larvae per m^2	ND	ND	ND	276	227	0.77	155	205	0.63	315	328	0.91
Porina per m^2	12	4	0.29	0	0	*	2	0	0.37	0	3	0.12

*t-tests cannot be generated where no variability in data
ND = no data
MWD = mean weight diameter

3.2 Soil chemical fertility monitoring

Soil chemical fertility results for the focus paddocks (averaged across farming systems) are presented in Table 4. The data are presented in full in Appendix 2.

Readily available sulphur has been higher in all years under Albrecht-Kinsey management than under conventional management and in 2015 and 2016 these differences were statistically significant ($P = 0.03$ for both).

Quick test results for soil magnesium were also significantly higher under Albrecht-Kinsey management in all years (Figure 1). This level of significance is now very high ($P = <0.0001$).

These differences are a result of variation in fertiliser inputs under the two systems.

There has been little change in the soil C concentrations (% C) measured under the two systems since 2013, when there was a 7% advantage to the Albrecht-Kinsey farm on average. This margin has been maintained to date. The results from measurements in 2015 and 2016, suggest that the system differences are now significantly different ($P = 0.05$ and $P = 0.07$ for the 2015 and 2016 years respectively).

Total N % differences are small with little between the management systems. Average values ranged from 0–7% between the two management systems, in favour of the Albrecht-Kinsey managed farm. Total N % differences did not quite reach statistical significance in 2016 ($P = 0.11$) compared with the 2015 measurements ($P = 0.06$).

Overall differences in the C and N concentrations under the two management systems are relatively small and unlikely to influence production.

Calcium concentrations are similar ($P = 0.10$). Over the past several years the Albrecht-Kinsey managed farm has had considerably more Ca applied than the conventional farm, yet the Ca (MAF) value has been lower. For example, over the 2016/17 season the Albrecht-Kinsey farm received 522 kg Ca/ha (across five applications, but with the bulk applied in two) and the conventional farm received only 50 kg Ca/ha (across three applications, with the bulk applied in two) (Casey 2017).

Other measurements of soil fertility are similar between the two management systems.

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Table 4. Means and t-tests for the chemical soil quality indicators measured in each focus dairy paddock and averaged conventional (Conv.) and Albrecht Kinsey (A-K) nutrient management systems in 2013–16.

	2013			2014			2015			2016		
	Conv.	A-K	t-test	Conv.	A-K	t-test	Conv.	A-K	t-test	Conv.	A-K	t-test
AMN (µg/g)	82.7	79.2	0.64	65.7	66.1	0.53	71.8	81.4	0.29	99.8	102.5	0.59
Soil moisture (% w/w)	24.7	25.0	0.78	29.9	30.8	0.28	30.9	29.9	0.21	31.5	32.3	0.53
Total C (%)	2.7	2.9	0.18	2.7	2.8	0.13	2.7	2.9	0.05	2.8	3.0	0.07
Total N (%)	0.26	0.27	0.47	0.26	0.26	0.47	0.26	0.28	0.06	0.27	0.28	0.11
Soil pH	6.0	6.1	0.51	6.1	6.0	0.56	6.3	6.1	0.40	6.1	6.0	0.74
Olsen P (mg/L)	16	17	0.70	12	14	0.55	14	13	0.59	14	14	0.58
CEC (me/100 g)	14.7	15.0	0.37	14.0	14.0	*	14.0	14.7	0.11	14.7	15.0	0.64
SO_4^{2-}-S (mg/kg)	10.7	16.0	0.22	11.0	16.0	0.46	11.3	25.0	0.03	10.7	22.0	0.03
K (MAF)	6.0	6.0	1.00	4.3	5.7	0.23	4.7	6.3	0.25	5.0	3.7	0.28
Ca (MAF)	8.7	8.7	1.00	8.3	7.3	0.35	9.7	8.3	0.23	9.7	8.7	0.10
Mg (MAF)	12.0	24.3	0.004	11.3	22.7	0.003	12.0	26.7	0.001	14.3	27.0	<0.001
Na (MAF)	3.0	2.3	0.12	2.7	2.0	0.12	2.3	2.5	1.0	2.3	2.0	0.37

*t-tests cannot be generated where no variability in data.
AMN = anaerobically mineralisable nitrogen

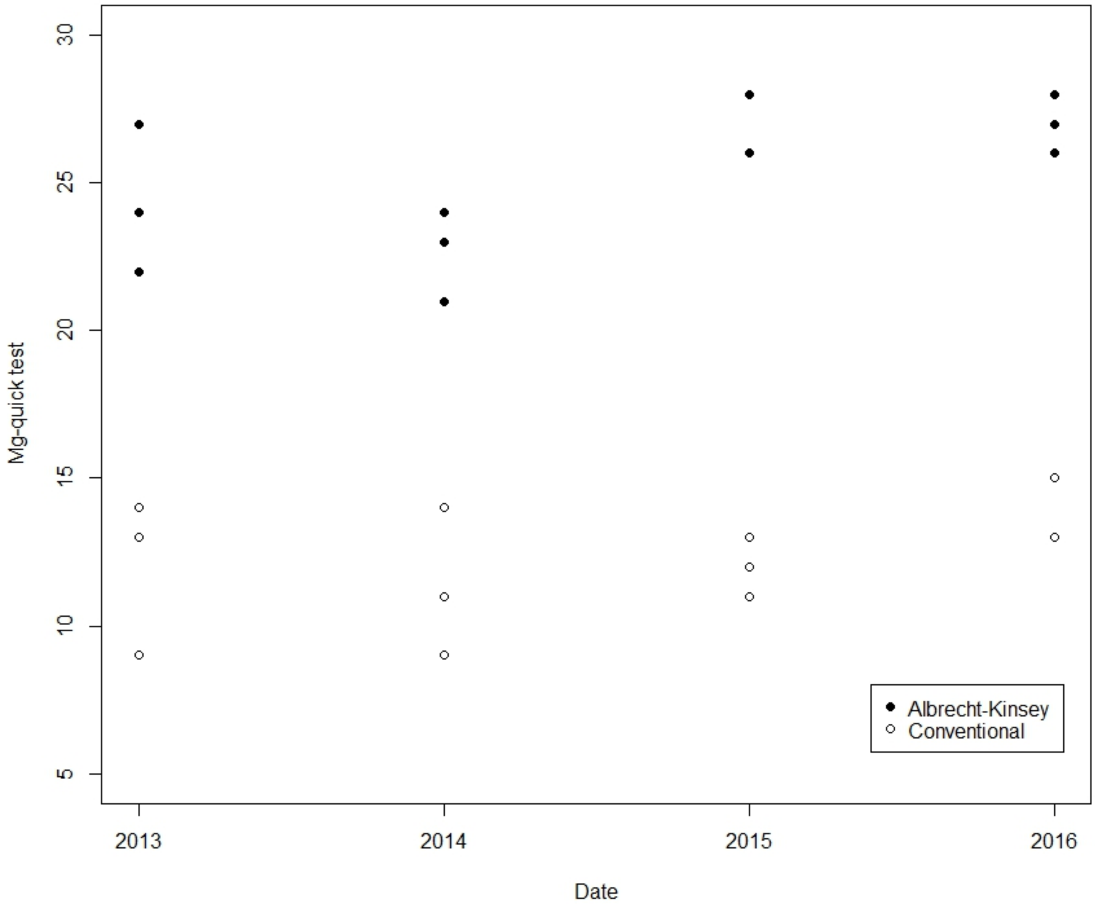

Figure 1. Quick test soil magnesium (Mg) (1 data point per focus paddock) for the conventional and Albrecht-Kinsey nutrient management systems in 2013–16.

3.3 Pasture species composition

Pasture composition data for the focus paddocks (averaged across farming systems) are presented in Table 5. The data are presented in full in Appendix 3. Figure 2 shows individual paddock proportions of grass and clover.

Table 5. Mean proportions of grass, clover, chicory, plantain, weed and dead as % total pasture sample weight measured in each focus paddock under conventional (Conv.) and Albrecht-Kinsey (A–K) nutrient management systems over nine sampling dates from October 2014 to April 2017.

Date	System	Grass%	Clover%	Chicory %	Plantain %	Weed %	Dead %
October 2014	Conv.	86.9	8.1	0.0	0.0	0.0	5.1
October 2014	A-K	82.8	11.0	0.7	0.3	0.1	5.2
January 2015	Conv.	63.0	23.5	0.0	0.0	0.2	13.3
January 2015	A-K	63.8	21.5	0.0	1.4	0.1	13.2
May 2015	Conv.	81.9	9.4	0.0	0.2	0.2	8.2
May 2015	A-K	75.8	14.5	0.2	1.4	0.1	8.0
October 2015	Conv.	88.5	7.1	0.0	0.0	0.2	4.2
October 2015	A-K	81.9	13.4	0.0	1.3	0.2	3.2
February 2016	Conv.	68.8	18.9	0.0	0.0	0.1	12.3
February 2016	A-K	61.9	23.5	0.2	1.2	0.1	13.1
May 2016	Conv.	88.2	4.6	0.0	0.3	0.1	6.8
May 2016	A-K	74.0	13.1	0.3	0.9	0.0	11.7
October 2016	Conv.	90.0	4.1	0.0	0.0	0.4	5.5
October 2016	A-K	82.6	12.4	0.9	1.3	0.0	2.8
February 2017	Conv.	71.2	11.9	0.0	0.0	0.0	16.9
February 2017	A-K	62.0	24.8	0.4	0.7	0.5	11.6
April 2017	Conv.	80.7	5.9	0.0	0.0	0.2	13.1
April 2017	A-K	72.7	12.8	0.0	0.4	0.0	14.1

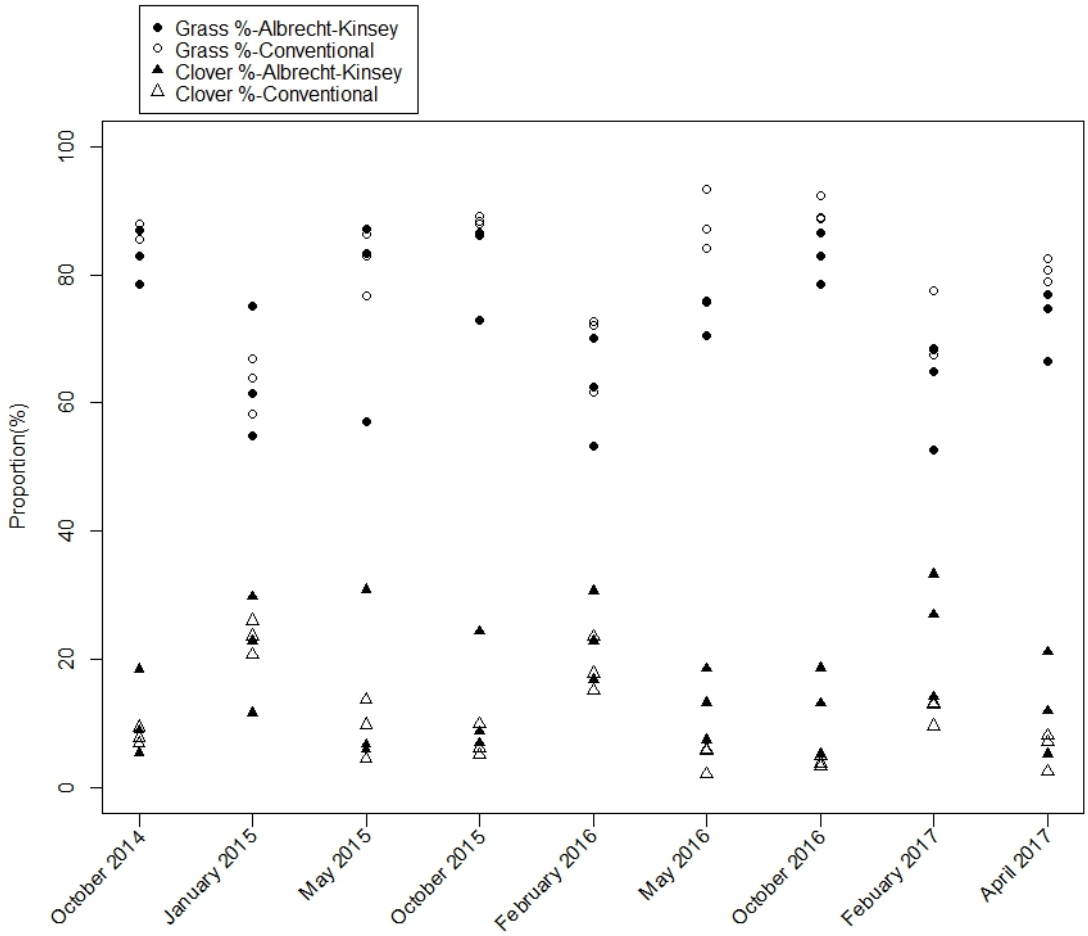

Figure 2. Proportions of grass and clover as % of total pasture sample weight at each sampling date for the Albrecht-Kinsey and conventional nutrient management systems.

Another year of data has shown consistency with the previous observations in that the Albrecht-Kinsey managed swards show a reduced proportion of grass (8.2%) and an increased clover content (9.3%) when compared to the conventionally managed paddocks, but data were variable and not statistically different.

Pasture grab samples taken at weekly intervals and dissected on farm for grass and clover content (Casey 2017) (data not shown) validate our data. The trends shown between the two methodologies are very comparable in both seasonal trends and in the relative proportions of grass and clover in the two systems, showing a similar reduction in grass content and a similar increase in clover content on the Albrecht-Kinsey managed farm.

Focus paddock South 26 (under Albrecht-Kinsey management) had consistently higher clover content than the other focus paddocks initially. By the autumn 2016 monitoring, this had reduced to be comparable to that in other Albrecht-Kinsey managed focus paddocks. However, clover content in this paddock over the last year has reverted to the previously higher proportions, with the paddock now showing similar seasonal trends and proportions to previous years. This recent increase is likely to be a seasonal effect, due to an extended hot and dry period from late January to early March 2017.

Table 6 shows that the ratio of clover to grass has varied over time but has been generally higher in the Albrecht-Kinsey managed paddocks, although there was high variability overall.

However, in May 2016, there was less variability (*P* = 0.066), possibly a result of less N fertiliser being applied to the Albrecht-Kinsey managed paddocks (conventional 120 kg N/ha/y v. Albrecht-Kinsey 80 kg N/ha/y). It is well known that increasing inputs of fertiliser N on clover/grass pastures results in a reduction in clover production and resulting nitrogen fixation. In trials carried out near Hamilton, Ledgard et al. (2001) found that the total estimated annual N_2 fixation decreased by an average of 0.27 kg N per kg N fertiliser applied.

The difference between the clover:grass ratios of the two systems in April 2017 was similar to that of the previous year, despite even further reductions of nitrogen applied to both systems from previous years.

Ongoing sampling is required to monitor these trends over time. The assessment of grass and clover content in additional paddocks from the two farms has supported focus paddock observations.

Table 6. Mean ratios of clover to grass for nine sampling dates during the 2014–15, 2015–16 and 2016–17 seasons over two nutrient management systems.

Date	System	Ratio clover:grass	t-test
October 2014	Conventional	0.09	0.467
October 2014	Albrecht-Kinsey	0.14	
January 2015	Conventional	0.38	0.878
January 2015	Albrecht-Kinsey	0.36	
May 2015	Conventional	0.12	0.519
May 2015	Albrecht-Kinsey	0.23	
October 2015	Conventional	0.08	0.329
October 2015	Albrecht-Kinsey	0.17	
February 2016	Conventional	0.28	0.359
February 2016	Albrecht-Kinsey	0.39	
May 2016	Conventional	0.05	0.066
May 2016	Albrecht-Kinsey	0.18	
October 2016	Conventional	0.05	0.17
October 2016	Albrecht-Kinsey	0.15	
February 2017	Conventional	0.17	0.12
February 2017	Albrecht-Kinsey	0.42	
April 2017	Conventional	0.07	0.23
April 2017	Albrecht-Kinsey	0.18	

Changes in clover proportion between the two systems may have flow-on effects on the incidence of clover root weevil. Measurements taken by Agresearch do, however, show high parasitism of clover root weevil on these two farms, so this may not be a concern (data not shown). Their results did not detect any differences in incidence of clover root weevil or degree of parasitism between the two management systems.

4 CONCLUSIONS

Further indications of differences between the Albrecht-Kinsey biological and ‘best management practice’ conventional management systems have emerged since the 2016 report. Soil magnesium and sulphur concentrations continue to be very different. Small differences are showing in soil carbon content, penetration resistance, aggregate stability, macro-porosity and earthworm populations, all favouring the Albrecht-Kinsey managed farm. However, in practical terms these trends are not different. Overall the soil quality of the two sites remained very similar from 2013 to 2017.

Pasture composition shows that, for the second consecutive season, there was higher clover and reduced grass proportions in the Albrecht-Kinsey biologically managed pastures.

Differences in both pasture composition and soil quality may become more evident over time.

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APPENDICES

APPENDIX 1. DATA FROM EACH PADDOCK UNDER CONVENTIONAL (CONV.) AND ALBRECHT-KINSEY (A-K) NUTRIENT MANAGEMENT FOR THE SOIL PHYSICAL AND BIOLOGICAL INDICATORS IN 2013–16.

Soil Quality Indicator	Year	Conv.			A-K		
		North 3	North 15	North 22/24*	South 19	South 26	South 12
0–10 cm penetration resistance (MPa)	2013	2.16	2.36	1.99	2.20	2.12	2.39
	2014	1.74	1.62	1.75	1.63	1.66	1.50
	2015	1.56	1.66	1.59	1.57	1.41	1.74
	2016	1.28	1.11	1.34	1.37	1.22	1.25
10–20 cm penetration resistance (MPa)	2013	1.82	2.16	2.05	2.03	2.15	2.14
	2014	2.37	2.42	2.60	1.92	2.21	2.19
	2015	1.62	1.75	2.28	1.75	1.77	1.78
	2016	1.90	2.09	2.28	1.45	1.70	1.95
0–7.5 cm soil moisture at field capacity (% v/v)	2013	39.17	41.62	40.78	41.02	43.30	38.16
	2014	43.48	44.89	44.44	42.61	43.81	45.32
	2015	44.69	44.01	42.93	42.76	43.98	43.84
	2016	30.3	33.4	30.9	32.3	33.0	31.4
0–7.5 cm macro-porosity (% v/v @ -10 kPa)	2013	8.63	8.60	7.61	10.45	6.48	9.79
	2014	13.05	8.45	9.99	10.80	8.51	7.29
	2015	7.43	9.66	11.90	14.07	9.54	9.54
	2016	14.48	11.84	12.84	13.07	17.87	13.61
0–15 cm aggregate stability (mm, MWD)	2013	1.94	1.82	1.76	1.98	1.78	1.74
	2014	1.61	1.44	1.44	1.73	1.53	1.44
	2015	1.95	2.11	1.96	2.18	2.07	2.02
	2016	1.92	2.02	2.04	2.05	2.12	2.19

Soil Quality Indicator	Year	Conv.			A-K		
		North 3	North 15	North 22/24*	South 19	South 26	South 12
0–15 cm aggregate stability (% >1 mm)	2013	70	66	63	71	65	63
	2014	61	54	53	65	58	54
	2015	75	81	78	83	81	77
	2016	75	79	78	80	86	84
Earthworms per m^2	2013	464	357	533	448	795	443
	2014	1250	1006	1177	1248	1435	2782
	2015	430	1190	1310	806	2093	1150
	2016	1074	1145	807	1288	1617	1826
Grass grubs per m^2	2013	16	11	0	64	11	21
	2014	0	0	17	35	15	10
	2015	0	0	0	118	7	0
	2016	14	0	22	0	203	14
Clover root weevil adult per m^2	2013	213	59	352	0	565	144
	2014	0	6	0	0	0	0
	2015	0	0	0	0	0	0
	2016	0	0	0	0	0	7
Clover root weevil larvae per m^2	2013	ND	ND	ND	ND	ND	ND
	2014	218	556	54	216	146	320
	2015	97	245	124	105	137	374
	2016	323	341	281	464	117	404
Porina per m^2	2013	27	5	5	5	5	0
	2014	0	0	0	0	0	0
	2015	0	5	0	0	0	0
	2016	0	0	0	5	5	0

*In 2015 Paddock 24 was sampled instead of Paddock 22
ND = no data
MWD = mean weight diameter

APPENDIX 2. DATA FROM EACH PADDOCK UNDER CONVENTIONAL (CONV.) AND ALBRECHT-KINSEY (A-K) NUTRIENT MANAGEMENT FOR THE SOIL CHEMICAL INDICATORS IN 2013–16.

Soil Quality Indicator	Year	Conv.			A-K		
		North 3	North 15	North 22/24*	South 19	South 26	South 12
AMN (µg/g)	2013	80.2	93.8	74.2	84.6	80.8	72.3
	2014	61.5	63.7	71.8	68.7	ND	52.2
	2015	68.5	75.3	71.5	86.3	91.7	66.2
	2016	98.0	95.7	105.8	103.1	108.2	96.3
Soil moisture (% w/w)	2013	23.1	26.6	24.5	25.8	24.7	24.6
	2014	30.1	29.1	30.5	30.3	32.0	30.2
	2015	30.1	30.5	31.9	30.3	30.2	29.1
	2016	30.3	33.4	30.9	32.3	33.0	31.4
Total C (%)	2013	2.6	2.9	2.6	2.8	3.0	2.9
	2014	2.6	2.7	2.7	2.7	2.9	2.9
	2015	2.6	2.8	2.6	3.0	2.9	2.9
	2016	2.8	2.9	2.7	3.0	3.2	2.9
Total N (%)	2013	0.25	0.28	0.25	0.26	0.27	0.26
	2014	0.25	0.26	0.26	0.26	0.28	0.25
	2015	0.26	0.27	0.25	0.28	0.28	0.27
	2016	0.27	0.28	0.26	0.28	0.29	0.28
Soil pH	2013	5.8	6.2	6.1	6.2	6.2	6.0
	2014	5.8	6.4	6.2	6.2	6.0	5.8
	2015	5.9	6.6	6.3	6.2	6.0	6.0

Soil Quality Indicator	Year	Conv.			A-K		
		North 3	North 15	North 22/24*	South 19	South 26	South 12
	2016	6.0	6.2	6.0	6.1	6.1	5.9
Olsen P (mg/L)	2013	14	19	15	15	14	23
	2014	10	14	13	12	11	20
	2015	14	16	11	14	11	13
	2016	15	13	15	15	12	14
CEC (me/100 g)	2013	15	15	14	15	15	15
	2014	14	14	14	14	14	14
	2015	14	14	14	15	14	15
	2016	15	15	14	14	16	15
SO_4^{2-}-S (mg/kg)	2013	15	11	6	11	17	20
	2014	18	6	9	8	25	15
	2015	15	8	11	26	31	18
	2016	11	6	15	20	20	26
K (MAF)	2013	5	8	5	4	7	7
	2014	4	3	6	6	6	5
	2015	5	5	4	7	8	4
	2016	6	3	6	3	4	4
Ca (MAF)	2013	7	9	10	9	9	8
	2014	7	9	9	8	8	6
	2015	8	11	10	9	8	8
	2016	9	10	10	9	9	8
Mg (MAF)	2013	9	14	13	27	24	22
	2014	9	11	14	24	23	21

Soil Quality Indicator	Year	Conv.			A-K		
		North 3	North 15	North 22/24*	South 19	South 26	South 12
	2015	11	12	13	28	26	26
	2016	15	13	15	26	28	27
Na (MAF)	2013	3	3	3	3	2	2
	2014	3	2	3	2	2	2
	2015	3	2	2	3	2	<2
	2016	3	3	4	3	3	3

*In 2015 Paddock 24 was sampled instead of Paddock 22
ND = no data
AMN = anaerobically mineralisable nitrogen
CEC = cation exchange capacity

APPENDIX 3. PROPORTIONS OF GRASS, CLOVER, CHICORY, PLANTAIN, WEED AND DEAD AS % TOTAL PASTURE SAMPLE WEIGHT FOR THE FOCUS PADDOCKS OVER NINE SAMPLING DATES FROM OCTOBER 2014 TO APRIL 2017 FOR THE CONVENTIONAL AND ALBRECHT-KINSEY (A-K) NUTRIENT MANAGEMENT SYSTEMS.

Paddock ID	Paddock Name	System	Sampling date	Grass %	Clover %	Chicory %	Plantain %	Weed %	Dead %
1	North 3	Conventional	October 2014	85.6	7.8	0.0	0.0	0.0	6.6
2	North 15	Conventional	October 2014	88.0	7.0	0.0	0.0	0.0	5.1
3	North 22	Conventional	October 2014	87.0	9.5	0.0	0.0	0.0	3.5
4	South 19	A-K	October 2014	86.9	5.4	2.0	0.9	0.4	4.4
5	South 26	A-K	October 2014	78.6	18.5	0.0	0.0	0.0	2.9
6	South 12	A-K	October 2014	82.9	9.0	0.0	0.0	0.0	8.2
1	North 3	Conventional	January 2015	63.9	23.7	0.0	0.0	0.0	12.4
2	North 15	Conventional	January 2015	66.9	20.7	0.0	0.0	0.0	12.4
3	North 22	Conventional	January 2015	58.3	26.1	0.0	0.0	0.5	15.1
4	South 19	A-K	January 2015	75.0	11.7	0.1	4.2	0.0	8.9
5	South 26	A-K	January 2015	54.9	29.8	0.0	0.0	0.0	15.3
6	South 12	A-K	January 2015	61.5	22.9	0.0	0.0	0.2	15.4
1	North 3	Conventional	May 2015	86.3	4.6	0.0	0.0	0.0	9.2
2	North 15	Conventional	May 2015	82.8	9.9	0.0	0.7	0.2	6.4
3	North 22	Conventional	May 2015	76.7	13.8	0.0	0.0	0.3	9.2
4	South 19	A-K	May 2015	83.2	6.0	0.6	4.3	0.2	5.6
5	South 26	A-K	May 2015	57.1	30.9	0.0	0.0	0.0	12.0
6	South 12	A-K	May 2015	87.1	6.7	0.0	0.0	0.0	6.2

Paddock ID	Paddock Name	System	Sampling date	Grass %	Clover %	Chicory %	Plantain %	Weed %	Dead %
1	North 3	Conventional	October 2015	89.1	5.2	0.0	0.0	0.6	5.1
2	North 15	Conventional	October 2015	88.0	6.2	0.0	0.0	0.0	5.8
3	North 22	Conventional	October 2015	88.4	9.9	0.0	0.0	0.0	1.7
4	South 19	A-K	October 2015	86.1	7.0	0.0	4.0	0.6	2.3
5	South 26	A-K	October 2015	73.0	24.4	0.0	0.0	0.0	2.7
6	South 12	A-K	October 2015	86.5	8.8	0.0	0.0	0.0	4.8
1	North 3	Conventional	February 2016	72.6	15.2	0.0	0.0	0.1	12.1
2	North 15	Conventional	February 2016	72.0	17.8	0.0	0.0	0.0	10.1
3	North 22	Conventional	February 2016	61.6	23.5	0.0	0.0	0.1	14.7
4	South 19	A-K	February 2016	62.4	22.9	0.6	3.7	0.3	10.0
5	South 26	A-K	February 2016	53.3	30.7	0.0	0.0	0.0	16.0
6	South 12	A-K	February 2016	70.0	16.9	0.0	0.0	0.0	13.1
1	North 3	Conventional	May 2016	84.2	5.8	0.0	0.0	0.2	9.8
2	North 15	Conventional	May 2016	93.3	2.2	0.0	0.9	0.0	3.7
3	North 22	Conventional	May 2016	87.2	6.0	0.0	0.0	0.0	6.8
4	South 19	A-K	May 2016	75.9	7.5	0.8	2.7	0.0	13.1
5	South 26	A-K	May 2016	70.5	18.6	0.0	0.0	0.0	10.9
6	South 12	A-K	May 2016	75.6	13.3	0.0	0.0	0.0	11.1
1	North 3	Conventional	October 2016	88.6	3.4	0.0	0.0	0.1	7.9
2	North 15	Conventional	October 2016	92.4	3.9	0.0	0.0	0.6	3.2
3	North 22	Conventional	October 2016	88.9	5.1	0.0	0.0	0.6	5.4
4	South 19	A-K	October 2016	82.9	5.2	2.7	4.0	0.1	5.2
5	South 26	A-K	October 2016	78.5	18.7	0.0	0.0	0.0	2.8
6	South 12	A-K	October 2016	86.4	13.2	0.0	0.0	0.0	0.4

Paddock ID	Paddock Name	System	Sampling date	Grass %	Clover %	Chicory %	Plantain %	Weed %	Dead %
1	North 3	Conventional	February 2017	77.4	9.6	0.0	0.0	0.0	12.9
2	North 15	Conventional	February 2017	67.5	13.0	0.0	0.1	0.0	19.4
3	North 22	Conventional	February 2017	68.6	13.2	0.0	0.0	0.0	18.2
4	South 19	A-K	February 2017	68.2	14.2	1.3	2.1	1.4	12.7
5	South 26	A-K	February 2017	52.7	33.3	0.0	0.0	0.0	14.0
6	South 12	A-K	February 2017	65.0	27.0	0.0	0.0	0.0	8.1
1	North 3	Conventional	April 2017	82.5	2.5	0.0	0.0	0.2	14.8
2	North 15	Conventional	April 2017	80.7	7.2	0.0	0.0	0.0	12.1
3	North 22	Conventional	April 2017	79.0	8.1	0.0	0.0	0.5	12.3
4	South 19	A-K	April 2017	76.9	5.2	0.0	1.3	0.0	16.5
5	South 26	A-K	April 2017	66.4	21.2	0.0	0.0	0.0	12.4
6	South 12	A-K	April 2017	74.7	12.0	0.0	0.0	0.0	13.3

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