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Soil Properties on ARGOS Dairy and Sheep & Beef Farms 2007

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1 Executive Summary

The New Zealand Agriculture Research Group On Sustainability (ARGOS) is seeking to identify pathways to improved sustainability and resilience for New Zealand agriculture. One of these pathways is the maintenance and enhancement of soil quality. Dairy and Sheep & Beef comprise two of the agricultural sectors that ARGOS is examining through investigating the effects of differing management systems on soil quality. Both sectors have 12 clusters each (Dairy 10 clusters in 2005) comprising of matched pairs of Organic and Conventional farms (24 total) for Dairy, and matched trios of Organic, Integrated and Conventional farms (36 total) for Sheep & Beef (S&B). The former are located in the North Island, mainly in the regions of Waikato, Taranaki and Manawatu, whilst the S&B farms are located along the eastern half of the South Island, from Marlborough to Southland.

Available-P values for Conventional Dairy farms in 2007 were unchanged from those in 2005 with more than two-thirds having Olsen-P values above the optimal values (Olsen-P >40; for the top 25% of producers) compared to only 15% for Organic Dairy. Organic values appear to be continuing to decline. Available-P values were also similar between years for S&B Conventional/Integrated but Organic values appear to have declined below, on average, what would be considered optimum for clover production and N fixation. In 2007, Dairy Organic systems generally had greater organic-C, C/N ratios, mineralisable-N, microbial-C and pH (slightly) than their Conventional counterparts whilst S&B Organic farms had larger C/N ratios and microbial-C, and lower SBD. Basal respiration and metabolic quotient were higher overall for S&B Organic suggesting that for some farms in this system are under greater stress. The three main affected Organic farms had Olsen-P values <10 so any increased stress may be related to lower quality organic matter returns. Substrate-induced respiration (SIR), deaminase and FDA hydrolysis microbial activity values were not found to significantly different between management systems for either Dairy or S&B except the SIR values for S&B. However, the SIR method had several complicating issues regarding the choice of fungicide and further work is required to improve the suitability, performance and precision of this method, and that of the enzyme activity methods. Soil bulk density was found to be less for S&B Organic farms compared with Integrated, probably because of stocking rate differences, but no differences were found between systems for Dairy.

Landform differences for both Dairy and S&B were mostly centred on the transfer of excreta to crest sites where stock camping mostly occurs leading to accumulation of P, C and N in these areas. Deaminase and FDA hydrolysis activity, however, were not found to significantly different. Crest sites were generally found to have lower SMB and/or activities per unit soil-C suggesting that these fractions may be associated with a smaller, more labile component of the SOM. For S&B, crest sites were found to have slightly greater SMC than slope/flat areas.

Although some variability was evident between years for the chemical analyses, mainly in SOM, trends between systems for both Dairy and S&B were generally consistent over the sampling period. Organic Dairy had lower available-P and greater organic-C, C/N ratios, mineralisable-N and SMB-C&N whilst Organic S&B had larger C/N ratios, SMB-C&N, metabolic quotient and SMC but lower available-P, mineralisable-N and SBD than their respective Conventional/Integrated counterparts.

Overall, soil quality was not remarkably different between systems for either Dairy or S&B but there remains areas of concern. Available-P is higher than recommended for Dairy Conventional farms and while losses are agronomically small, environmental costs could be considerably greater. Conversely, low available-P for a number of S&B organic farms may be reducing their production potential and Organic farms need to be aware of maintaining their nutrient levels. The difference in soil-C between Dairy systems is also of interest in times of concerns about GHG emissions and carbon credits. If these differences are repeatable, then considerably more carbon might be retained under Organic Dairy systems. Generally, however, soils for Dairy and S&B farms retained good-to-excellent soil quality and showed that Organic and Conventional systems can produce similar soil quality.

2 Introduction

Principles of sustainability and resilience in agricultural systems resonate strongly with current issues of soil quality and the desire to ensure that soils remain healthy and productive. It is important that soils don't become sources of contaminants to the wider natural environment nor large scale net emitters of greenhouse gases. Many consumer groups now demand that food production standards have these principles in mind and that production isn't at the local and global environment's expense. To this end, some production systems have moved to embrace these principles but the international realities of commodity trading and land costs has meant the bulk of New Zealand's agricultural producers are still experiencing pressure to intensify production so as to remain economically viable. The market premiums that organic produce can often earn over conventional produce can ensure economic viability in the face of often lower overall production (Pacini *et al.* 2003; Reganold *et al.* 1993; Springett *et al.* 1994) but economic subsidies and differing production costs between countries can distort such comparisons.

This report follows on from that issued in 2006 by the New Zealand Agriculture Research Group On Sustainability (ARGOS) as it seeks to identify pathways to improved sustainability for New Zealand agriculture. In this study we resample S&B and Dairy farms that were the focus of a study in 2005-6 (Carey *et al.* 2006) to investigate whether any trends or differences recorded then still remain.

A major part of any comparison of resilience between production systems includes soil quality and whether commercially intensive systems are more damaging of the soil's biological function than an arguably more "natural" (ie. Organic) system. Whilst this report revisits a number of key analyses performed over 2005-6, the intention this round was to measure a greater number of soil biological variables in order to obtain a wider range of comparisons between the soil chemical, biological and physical indices.

3 Monitoring approach

This was dealt with in more detail in our previous report (Carey *et al.* 2006) but in short our approach was to concentrate on groups (clusters) of commercial farms that are under the target management systems and are in close proximity. To mitigate the effects of large spatial variability, paddocks were selected that represented the dominant landforms within each cluster using permanent soil monitoring sites (SMS). This scheme is especially good for comparisons between agricultural and management systems (the prime aim), but is weak for characterising whole farms. Establishing permanent long term monitoring sites and sampling and test guidelines for each sector is essential to ensure continuity and consistency are maintained throughout the ARGOS program. With expectations that the program will continue to monitor sites for between 5 and 20 years means that the robustness of comparisons needs to be ensured at an early stage, especially if the focus shifts to the effects of management systems on differences between individual farms.

Structures used for comparison were:

1. between agricultural system (i.e. S&B or Dairy)
2. between management system (i.e. Organic, Integrated or Conventional)
3. between landform (i.e. flat, slope or crest).

3.1 Agricultural system

Each set of Sheep & Beef (S&B) and Dairy farms selected by ARGOS to represent a sector comprises 12 clusters. Each S&B cluster consists of an Organic farm with a matched Integrated and Conventional counterpart. Each Dairy cluster consists of an Organic farm matched with a Conventional counterpart. In 2007 a further two clusters of farms were added from the Manawatu region to the Dairy sector group.

The properties within a cluster are within close geographic proximity with similar landforms, soil type and climatic conditions. For dairy there are 12 clusters all located in the North Island at Waikato (4), Taranaki (3), Manawatu (3), Waihi (1) and Auckland (1). For S&B there are 12 clusters located throughout the south island from Marlborough to Southland but broadly grouped into three regions; upper (2-USI), central (5-CSI) and lower (5-LSI) South Island.

3.2 Management system

By definition, Organic farms use accredited organic production protocols and have achieved organic accreditation status. Integrated farms follow industry protocols that although not to organic status, may require reduced pesticide and herbicide use, higher environmental performance and/or animal welfare standards. Conventional farms represent the *status quo*. By virtue of the aforementioned clusters and management systems, each sector is ostensibly represented by 36 farms or properties barring withdrawal of properties from the study through circumstance.

3.3 Landform

This term is used to describe the different geomorphology within a property. The principal landforms monitored here can be broadly described as river terrace (flats), hill crest (crest) and mid-slope (slope). Given the huge variation in soils and landscape across the properties being studied, we study the two most dominant of these landforms within the cluster. For hill country clusters, the same two landforms will be studied on each property. For clusters on the Canterbury Plains, or river terraces of Taranaki, Waikato and the Manawatu, only one landform (flats) will be studied.

3.4 Management unit

Management unit (MU) is the smallest land area to be managed by the farmer on an individual basis and for both S&B and Dairy farms this constitutes a paddock. For each landform, three management units (paddocks) will be monitored. Thus on the hill country farms, six paddocks (two landforms each with three paddocks) will be monitored. On the flat land farms with only one landform present (Canterbury Plains), three paddocks will be monitored.

Paddocks or MU's were chosen randomly from farm maps but had to be stratified similarly for farms within the same cluster so that they had common slope, topography, aspect, and altitude across landforms as mush as possible. Where possible, paddocks from different areas of the farm were selected, however this was constrained by the amount of information from farm maps. Airstrip and dedicated hay or silage paddocks were excluded because of their unique land use within the farm.

Within each management unit three soil monitoring sites (SMS's) were randomly selected and their waypoints recorded for future return as permanent SMS. SMS were selected on the criteria that they were:

Further than 5 metres from a fence

Further than 30 metres away from trees, troughs and gateways

Not a waterway, pond or swamp

Not a unique landuse e.g. rubbish site

Where more than one landform was present within a paddock, selection of SMS's were from the dominant landform. In 2007 no visual soil assessment was made but soil bulk density (SBD) was measured at each SMS. All nutrient and biological analyses were assessed from bulking the three SMS samples representing a single MU prior to analysis.

3.5 Statistical analysis

The results were analysed using analysis of variance using Genstat version 8.0 (Lawes Agricultural Trust, 2003) using an unbalanced ANOVA approach. This was necessary to gain the greatest possible number of data points and where balanced comparisons were possible, results did not generally contradict those of the unbalanced ANOVA. A general linear regression model (GLM) was also used for establishing relationships between some parameters. The data for ANOVA for this sampling round was structured with the following hierarchy:

Sector

Cluster

Management system

Landforms

Management unit (replicate)/ SMS's within management units (replicate)

The management system is applied across the entire property, so the MU's (paddocks) represent repeated measures within the property. Within systems, landforms are also analysed and compared across each system.

Chemical soil tests, where appropriate, were transformed to both volume (ha; 0-7.5 cm) and weight (per kg soil) units. Biological measurements, because of their inextricable links with soil organic matter (SOM) are presented on both a per unit soil and carbon weight basis. Means, coefficient of variation (CV%), and the range of values are given for each variable. Least significant differences to the 5% level ($LSD_{0.05}$) are given for data that is normally distributed. If the difference between treatment means are greater than the least significant difference, there is a less than 5% probability these differences are due to a random effect.

3.6 Measurements

Priority One

The first priority indicators are a suite of meaningful field observations that can be integrated into one or more qualitative soil quality scores and the criteria to ensure repeatability were discussed in Carey et al. (2006). Suffice to say priority one measurements were conducted at each individual soil monitoring site but these were not conducted to the same level as in 2005 and only soil bulk density (0-15 cm) and soil moisture content at field capacity are reported here.

Priority Two

These consisted of soil chemical analyses for a mostly standard suite of test indices (Blakemore *et al.* 1987) where substantial literature is available to assist interpretation. These were contracted out to commercial soil testing laboratories with additional tests conducted by Land Research Services Ltd based at Lincoln University using established soil chemical and biological techniques. Soil samples were collected from the standard sampling depth for pasture (0-7.5 cm). This may not represent the total availability of nutrients from the entire root zone but should still be representative of plant available nutrients and chemical conditions in the soil. Priority two samples are collected at the management unit level.

The suite of chemical analyses performed in 2005 were reduced to five key analyses in 2007. These were:

Soil pH (level of acidity or alkalinity of the soil sample);

Olsen P (µg/ml); a measure of the phosphorus readily available to plants;

Potentially mineralisable N (kg N/ha) as an indication of the nitrogen that may become available to plants through mineralization of organic matter through a growing season;

Total organic C%. Organic matter is important as it supplies nutrients to the soil, improves soil physical fertility and moisture retention (Haynes and Naidu 1998). Soil carbon is directly proportional to the soil organic matter (%C x 1.72 = %SOM); and

Total N%. Nitrogen present in the soil is a big determinant of the quality of soil organic matter and C/N ratios.

Priority Three

Priority three indicators use the same sampling depth as priority two measurements and relate to the biological activity of the soil. These were increased in 2007 to include two enzyme tests and a more sensitive respiration test using substrate induced respiration. The latter test was only performed on bulked samples representing an individual landform within each farm or property i.e. at the level of the landform unit of each farm. Soils were taken fresh from the field, sieved and refrigerated at 4° C. Tests in total included:

Soluble carbon, a measure of labile organic matter that serves as an index both of available substrate for microbial respiration (Milne and Haynes 2004) as well as aggregate stability (Haynes 2000).

Soil microbial biomass (SMB) carbon, a measure of the total amount of living microbes in a soil (Jorgenson 1995a; Jorgenson 1995b).

Basal respiration measures the ambient CO_2 levels of the soil (20° C) within a closed vessel after a fixed time using an infra-red sensor.

Metabolic quotient is the ratio between SMB carbon (the size of the soil microbial population) and basal respiration (the activity of the soil microbial population) is a useful indicator of the metabolic efficiency of, and stresses facing, the microbial population.

Substrate-induced respiration (SIR) is a method designed to measure the relative proportions of fungi and bacteria within the soil SMB after adding a readily-respired substrate such as glucose (Lin and Brookes 1999a). This is used to determine to whether farm management systems are influencing these proportions and the soil's microbial make-up. Due to the unavailability of the fungicide cycloheximide a substitute, natamycin, was used after literature suggested that this could be a suitable replacement (Pedersen 1992).

Table 1. Soil quality indicators selected for the 2007 ARGOS program.

Priority	Indicator	Depth (cm)	Measured how?	Rationale	Possible values
1	Field soil dry bulk density	0-7.5 7.5-15	Samples taken using bulk density corer and sent to lab.	Values and time trends are a useful indicator of compaction. Values are essential to convert soil chemical results into nutrient contents in kg/ha	Continuous scale of values
2	Chemical properties[2]	Std[3]	Samples taken using soil corer then sent to laboratory	Values have considerable use as indicators of soil chemical fertility.	Continuous scale of values
2	Organic C and total-N	Std[3]	Same samples as for chemical properties	Values have considerable use as indicators of soil biological condition, and contribution to global CO_2 balance.	Continuous scale of values
3	Soluble-C and soil microbial biomass (SMB) C&N	Std[3]	Same samples as for chemical properties	Useful and well-accepted indicator of the amount of living material in the soil.	Continuous scale of values
3	Basal respiration	Std[3]	Same samples as for chemical properties	Useful indicator of the rate of microbial activity in the soil under standardised conditions.	Continuous scale of values
3	Metabolic quotient	Std[3]	Simple ratio of values obtained for biomass C and basal respiration.	Useful indicator of the metabolic efficiency of the microbial population.	Continuous scale of values
3	Deaminase activity	Std[3]	Same samples as for chemical properties	Measures ability of microbial biomass to convert amino acids endocellularly to ammonium and serves as an N index of microbial activity.	Continuous scale of values
3	FDA activity	Std[3]	Same samples as for chemical properties	Measures general activity of microbial biomass and serves as a basic index of activity and organic matter turnover.	Continuous scale of values
3	Substrate induced respiration	Std[3]	Same samples as for chemical properties	Respiration technique to discern approximate proportions of soil bacteria vs. fungi.	Scale 0-100%

[1] Measurements should be made at the same date and locations.

[2] Soil pH, Olsen P, organic-C, total-N and potentially mineralisable N measured using NZ standard techniques

[3] The standard depth is 0-7.5 cm for pastoral farms

4 Results

4.1 Soil Chemistry

System and landform

Dairy

As in 2005, Olsen-P (mg P/L soil) and soil-P (mg P/kg soil) values for Conventional farms were significantly higher (Table 2; P<0.01) than those for Organic. Approximately half of Dairy farms overall had Olsen-P values greater than 40 and of these, two-thirds were from Conventional farms. Soil pH, although also significantly different (P<0.05), was only slightly higher (0.1 units) overall, for Organic compared with Conventional. Small, but significant increases (P<0.05) were found overall for both organic-C and C/N ratios for Organic farms compared with Conventional. Although no significant difference between systems was found for total-N, significantly higher mineralisable-N (P<0.05) was found under Organic but the difference was relatively small at less than 7%. This difference disappeared when calculated on a per weight soil-N basis (Table 2). Whilst there was a significant regression relationship between mineralisable-N and N%, there was no discernable difference between systems and the overall relationship was fairly weak (R^2=0.2).

Significant differences between landforms within the Dairy farms were generally related to higher soil-P, soil-C and total-N values and lower C/N ratios in crest areas versus slope areas (Table 2). A significant system-by-landform interaction showed that the biggest difference in C/N ratios between systems (9.7 Conv. vs. 10.4 Org.) was on flat landforms. Generally, chemical test values for farms with predominantly flat landforms were similar to those for crest landforms on Conventional farms but this pattern was less clear for Organic farms.

Sheep & Beef

Strongly significant differences in Olsen-P and soil-P values were found for Organic systems vs. Integrated/Conventional systems over all sheep and beef farms (Table 3; P<0.001). Organic S&B farms had on average P levels about half that of Conventional and Integrated farms. Approximately 14% of S&B farms had Olsen-P values above the guideline value of 30 mg P/L (Morton *et al.* 1994), the overwhelming majority of these from Integrated and Conventional farms. About 60% of S&B farms had Olsen-P values below optimal values (ie. <20 mg P/L) with about 60% these being Organic farms (~75% of Organic farms overall). Approximately equal numbers of Integrated and Conventional farms made up the remaining 40%. Similar differences were found for soil available-P values calculated on a soil weight basis (Table 3). A small but significant difference was found in pH values between systems with Organic on average 0.2 units higher that Integrated and Conventional.

Soil organic carbon and total nitrogen were not significantly different between S&B systems but C/N ratios were significantly higher for Organic (10.1) over Integrated (9.7) with Conventional intermediate (9.9; Table 3). Potentially mineralisable-N, like C and N, was very similar between systems and not significantly different on either a soil or soil-N basis. The relationship between mineralisable-N and total-N was strong (R^2=0.61) but essentially the same for all three systems (Figure 1).

Significant increases in available-P (both Olsen-P and soil-P; P<0.05), total-N and mineralisable-N (P<0.05) were evident in crest/flat landforms over slope. Whilst there was no general difference in C/N ratios between landforms, there was a significant system-by-landform interaction where C/N ratios for Organic crest sites were higher than crest sites for the other systems (Table 3).

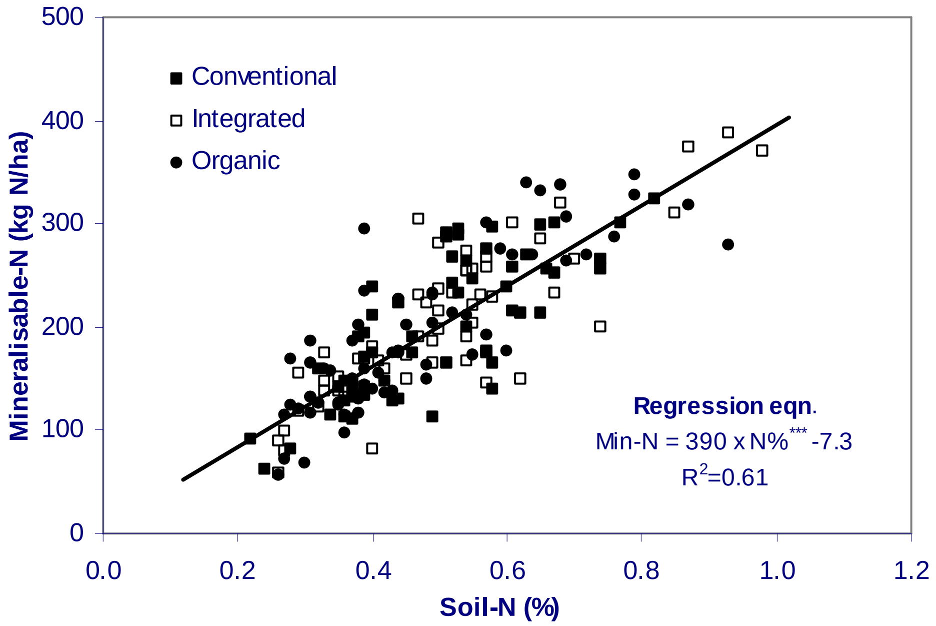

Figure 1. Relationship between mineralisable-N and Soil-N for all Sheep & Beef farms.

4.2 Soil Physical Assessment

Systems and Landforms

Dairy

Soil bulk density (SBD) and water content at field capacity were the only soil physical assessment parameter recorded in this round. No significant differences in SBD or soil moisture content (SMC) were found between systems or landforms (Table 2).

Sheep & Beef

SBD was found to be significantly lower overall under Organic farms than for Integrated with Conventional intermediate. No significant differences were found for SMC values between systems but crest landforms were all found to have significantly higher values across all systems (Table 3).

4.3 Soil Biology

System and Landforms

Dairy

There were few significant differences between Conventional and Organic systems for soil biology measurements with only soluble carbon significantly higher for Conventional (Table 4). Whilst Organic values were about 10% greater for SMB-C, SMB-N, and basal respiration than for Conventional, these were not significantly different (at $P<0.05$). Soil microbial biomass C/N ratios, deaminase activity and FDA hydrolysis were also not significantly different although Conventional values were about 10% and 25% greater, respectively, than for Organic. Mean metabolic quotient values were similar for both. The relationship between SMB-C and soil-C was less close than in 2005 (r^2= 0.30 vs. 0.54) but still highly significant (Figure 2). No significant difference was found between bacteria and fungal proportions between systems which were split approximately 50% each.

Differences in SMB-C between landforms were significant ($P<0.05$) with values about 50% greater for flat landforms that those for crest and slope. Values for SMB-N (per kg soil-N) were greater for slope over crest and flat but only for Organic. There were no significant landform differences for soluble-C, SMB-C&N C/N ratios, deaminase activity, FDA hydrolysis, basal respiration, metabolic quotient or SIR.

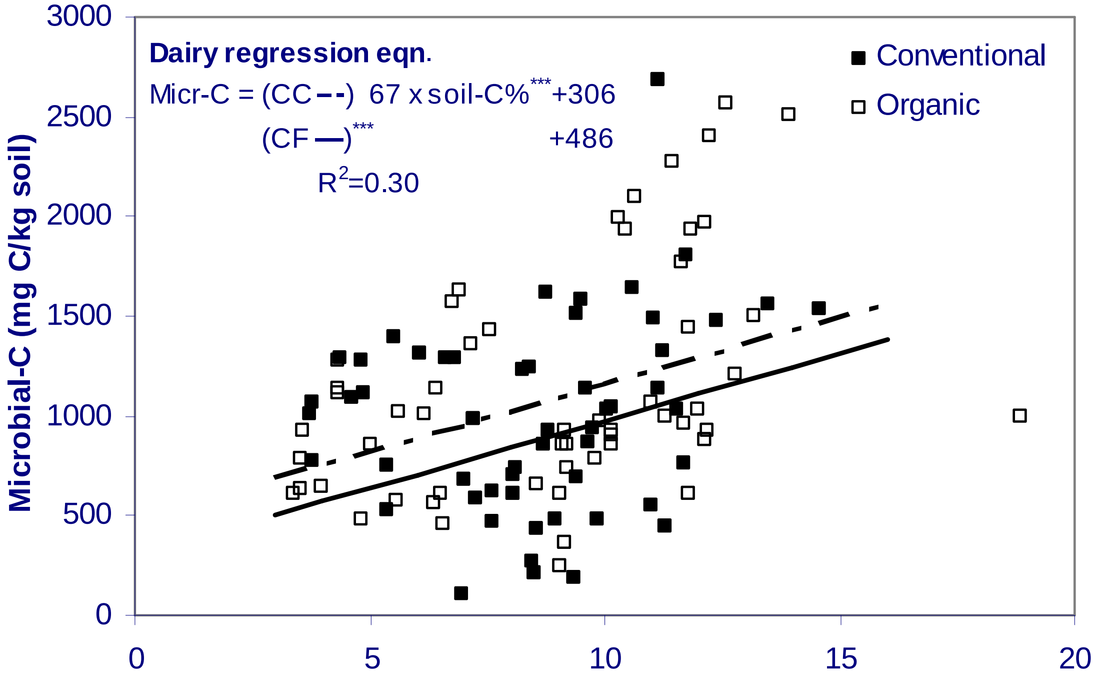

Figure 2. Regression relationship between SMB carbon and soil-C for Conventional (—) and Converting (- – -) Dairy farms.

Sheep & Beef

Significant differences (P<0.01) in SMB-C and basal respiration on both a soil and soil-C basis were found for Organic/Integrated over Conventional (Table 6). Metabolic quotient was also found to be significantly higher (P<0.01) for Organic over Conventional. The relationship between SMB-C and soil-C was moderately strong and showed a clear and significant difference between Organic/Integrated and Conventional (Figure 3). Despite more than a 15% average increase in deaminase activity (per g SMB carbon) for Conventional over Organic/Integrated, this was not significantly different at the 5% level. Similar, but smaller differences were evident for FDA hydrolysis rates but these were not significant either. SMB C/N ratios were about 15% lower on average for Integrated compared with Conventional/Organic but again these were not significant. No difference between systems was found for soluble-C. SIR analysis showed a significantly higher bacteria fraction (or lower fungi proportion) for Organic compared with Conventional although proportions were still around the 50:50 split (Table 5).

Soluble-C (per unit soil-C) and SMB-C values were substantially lower (both per unit soil or soil-C) for crest and slope landforms than flat and statistically significant (Table 4). Crest landforms also tended to be lower for SMB nitrogen (per unit soil-N) than slope or flat but differences weren't statistically significant. Metabolic quotient values were also significantly lower for flat landforms than crest and slope. SIR analysis showed a significantly higher fraction of bacteria present in flat landforms overall compared to crest and slope (Table 5).

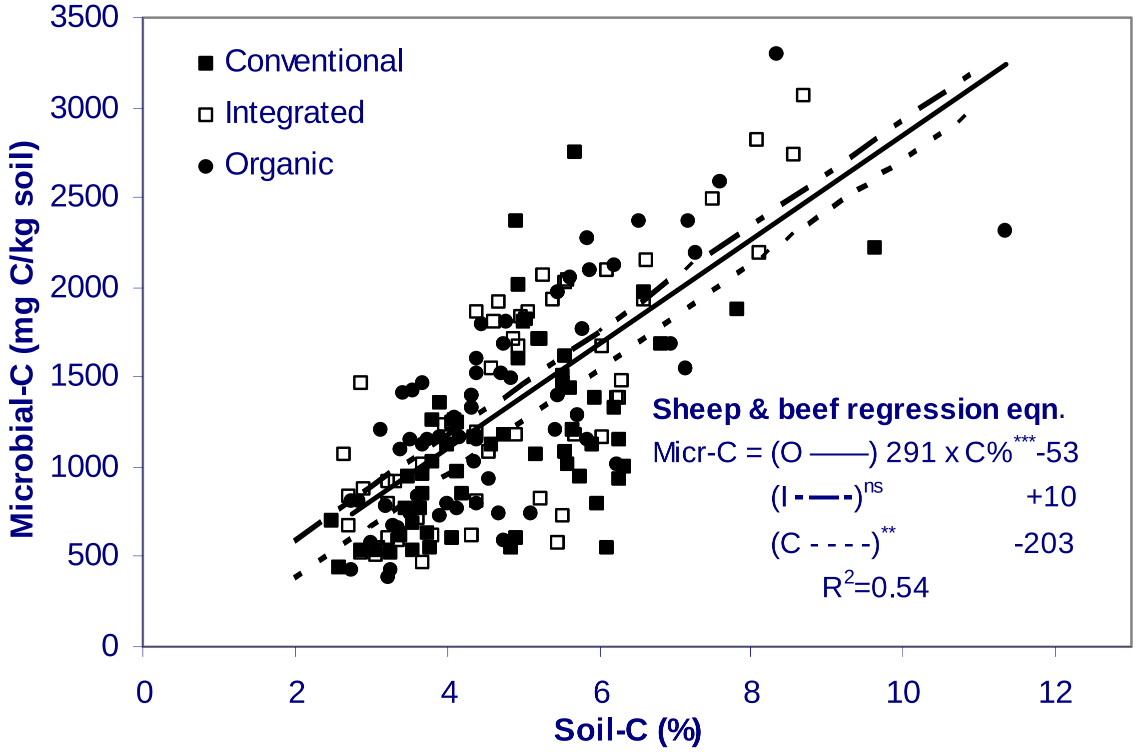

Figure 3. **Regression relationship between SMB carbon and soil-C for Organic (—), Integrated (- –– -) and Conventional (- - -) Sheep & Beef farms.**

Table 2. Some soil chemical and physical property means and results of unbalanced ANOVA for Dairy systems and landforms from the ARGOS 2007 sampling round.

System	Landform	pH	Olsen-P	Soil-P	Organic-C	Total-N	Soil C/N	Mineralisable-N		Soil BD	Soil MC
			mg P/L soil	mg P/kg soil	w/w %		ratio	kg N/ha	g N/kg soil-N	g/ml	ml/g
	Crest	6.2	40	69	9.5	0.98	9.6	248	19.0	0.76	0.48
	Slope	6.1	29	48	8.1	0.81	10.2	258	25.0	0.77	0.55
	Flat	6.2	29	45	9.5	0.92	10.4	256	21.8	0.79	0.52
Organic	**Mean**	**6.2**	**32**	**53**	**9.1**	**0.91**	**10.2**	**254**	**21.9**	**0.78**	**0.52**
	Range	5.7-6.8	9-79	12-141	3.4-19	0.3-1.4	9.2-13.3	123-376	12-41	0.5-1.1	0.2-0.9
	CV%	3%	54%	59%	37%	37%	7%	17%	40%	19%	31%
	Crest	6.1	59	97	8.3	0.85	9.8	238	19.9	0.80	0.50
	Slope	6.0	34	56	8.1	0.81	10.1	228	21.4	0.79	0.50
	Flat	6.1	48	74	8.8	0.91	9.7	249	19.8	0.78	0.48
Conventional	**Mean**	**6.1**	**47**	**76**	**8.4**	**0.86**	**9.9**	**239**	**20.3**	**0.79**	**0.49**
	Range	5.3-7.0	9-117	17-198	3.7-15	0.3-1.5	8.9-11.3	123-317	11-43	0.5-1.1	0.2-0.7
	CV%	5%	43%	45%	30%	31%	6%	17%	41%	20%	29%
Significance	**System**	*****	******	*******	*****	**ns**	*****	*****	**ns**	**ns**	**ns**
	Landform	*****	*******	*******	**ns**	******	******	**ns**	******	**ns**	**ns**
	average lsd (5%)	0.1	10	15	0.7	0.08	0.3	15	1.8	0.03	0.05
	System•Landform	**ns**	**ns**	**ns**	**ns**	*****	*****	**ns**	******	**ns**	**ns**
	average lsd (5%)	0.2	14	20	1.2	0.12	0.4	27	2.5	0.07	0.08

Table 3. Some soil chemical and physical property means and results of unbalanced ANOVA for Sheep and Beef systems and landforms from the ARGOS 2007 sampling round.

System	Landform	pH	Olsen-P	Soil-P	Organic-C	Total-N	C/N ratio	Mineralisable-N		Soil BD	Soil MC
			mg P/L soil	mg P/kg soil	w/w %			kg N ha^{-1}	g N/kg soil-N	g/ml	ml/g
	Crest	5.7	10	14	6.3	0.55	11.3	286	30.1	1.03	0.48
	Slope	5.9	9	12	4.8	0.48	10.1	206	29.1	1.09	0.39
	Flat	6.1	14	17	4.7	0.48	9.9	167	28.5	1.16	0.36
Organic	**Mean**	**6.0**	**11**	**14**	**4.8**	**0.49**	**10.1**	**196**	**28.9**	**1.12**	**0.38**
	Range	5.2-6.6	3-71	4-86	2.7-11.3	0.2-0.9	6.2-12.9	57-347	16-54	0.8-1.4	0.3-0.6
	CV%	5%	84%	79%	33%	34%	10%	39%	23%	12%	26.0%
	Crest	5.7	29	38	5.4	0.59	9.5	305	30.6	1.04	0.47
	Slope	5.9	21	29	4.7	0.48	9.8	216	29.3	1.16	0.37
	Flat	5.8	27	34	4.7	0.48	9.8	169	27.9	1.21	0.34
Integrated	**Mean**	**5.8**	**25**	**32**	**4.8**	**0.50**	**9.7**	**203**	**28.8**	**1.17**	**0.37**
	Range	4.9-6.5	5-96	7-103	2.7-8.7	0.2-0.9	8.4-13.8	58-388	14-46	0.9-1.5	0.2-0.6
	CV%	6%	54%	49%	32%	33%	9%	37%	20%	15%	32.4%
	Crest	5.7	22	30	5.0	0.49	10.0	283	32.4	1.02	0.47
	Slope	5.8	22	28	4.9	0.49	10.1	206	28.9	1.13	0.37
	Flat	5.9	25	32	4.9	0.50	9.9	173	27.3	1.18	0.34
Conventional	**Mean**	**5.8**	**23**	**30**	**4.9**	**0.49**	**10.0**	**199**	**28.5**	**1.14**	**0.37**
	Range	5.2-6.6	6-97	8-123	2.5-9.7	0.2-0.8	8.4-12.5	62-324	16-42	0.7-1.4	0.2-0.7
	CV%	5%	58%	56%	28%	27%	7%	34%	22%	13%	29.1%
Significance	**System**	**	***	***	**ns**	**ns**	*	**ns**	**ns**	*	**ns**
	average lsd (5%)	0.1	5	6	0.4	0.04	0.3	31	2.2	0.04	0.03
	Landform	**ns**	*	*	**ns**	*	**ns**	*	**ns**	**ns**	*
	System•Landform	**ns**	**ns**	**ns**	**ns**	**ns**	*	**ns**	**ns**	**ns**	**ns**
	average lsd (5%)	0.2	11	13	1.0	0.09	0.7	70	5.2	0.09	0.06

Table 4. Some soil biological means and results of unbalanced ANOVA for Dairy systems from the ARGOS 2007 sampling round.

System	Landform	Soluble-C		Soil microbial biomass-C		Soil microbial biomass -N		SMB* C:N	Deaminase	FDA	Basal respiration		Metabolic quotient
		mg C/kg soil	g C/kg soil-C	mg C/kg soil	g C/kg soil-C	mg N/kg soil	g N/kg soil-N	ratio	mg N/g MC/h	abs/mg MC/h	mg CO_2/kg soil/min	mg CO_2/kg soil-C/min	mg CO_2/g MCB/min
	Crest	301	3.3	933	11.0	382	41.0	3.9	12.1	0.178	107	1191	124
	Slope	273	3.6	951	13.2	394	54.9	2.8	11.3	0.174	104	1358	126
	Flat	237	2.7	1432	16.4	353	40.4	4.6	10.6	0.143	121	1369	99
Organic	**Mean**	**267**	**3.1**	**1138**	**13.8**	**374**	**44.8**	**3.8**	**11.3**	**0.163**	**112**	**1311**	**115**
	Range	97-452	1.1-5.8	248-2563	3-30	27-676	4-126	0.7-20	5-45	0.04-0.4	42-290	552-2306	29-388
	CV%	37%	32%	50%	47%	47%	54%	44%	56%	64%	41%	30%	40%
	Crest	295	3.5	876	11.5	282	32.4	3.6	15.4	0.245	98	1209	111
	Slope	300	3.7	797	11.3	331	41.5	2.8	14.2	0.224	94	1194	163
	Flat	274	3.1	1378	15.7	346	41.5	4.9	10.7	0.154	113	1295	95
Conventional	**Mean**	**289**	**3.5**	**1040**	**13.0**	**321**	**38.6**	**3.7**	**13.3**	**0.204**	**102**	**1237**	**121**
	Range	122-529	1.4-6.3	252-3373	4-30	21-707	3-134	0.4-16	5-54	0.05-1.3	47-201	511-1950	30-554
	CV%	39%	30%	55%	56%	51%	60%	40%	79%	102%	35%	29%	29%
Significance	**System**	**ns**	*****	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	average lsd (5%)	36	0.4	166	1.5	60	8.9	1.5	3.3	0.06	12	125	30
	Landform	**ns**	******	*******	******	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	*****
	System•Landform	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	average lsd (5%)	52	0.7	302	2.7	106	15.8	2.5	5.8	.012	21	221	54

*SMB- soil microbial biomass

Table 5. Substrate-induced respiration values and results of unbalanced ANOVA for the Dairy and Sheep & Beef 2007 sampling round.

System	Landform	Dairy		Sheep & Beef	
		Bacteria	Fungi	Bacteria	Fungi
		%		%	
	Crest	49.5	50.5	58.6	41.4
	Slope	48.0	52.0	53.8	46.2
	Flat	41.6	58.4	60.6	39.4
Organic	**Mean**	**46.6**	**53.4**	**57.5**	**42.5**
	Range	26-66	34-74	20-86	14-80
	CV%	21.6	18.8	36.5	43.6
	Crest			42.1	57.9
	Slope			47.0	53.0
	Flat			50.9	49.1
Integrated	**Mean**			**48.0**	**52.0**
	Range			28-73	27-72
	CV%			24.2	25.0
	Crest	46.6	53.4	45.8	54.2
	Slope	49.1	50.9	45.6	54.4
	Flat	54.1	45.9	64.3	35.7
Conventional	**Mean**	**49.4**	**50.6**	**54.1**	**45.9**
	Range	25-87	13-75	31-82	18-69
	CV%	27.2	26.5	28.2	33.3
Significance	**System**	**ns**		*****	
	average lsd (5%)	7.9		6.3	
	Landform	**ns**		*****	
	System•Landform	**ns**		**ns**	
	average lsd (5%)	24.6		13.2	

Table 6. Some soil biological means and results of unbalanced ANOVA for Sheep & Beef systems from the ARGOS 2007 sampling round.

System	Landform	Soluble-C		Soil microbial biomass-C		Soil microbial biomass-N		SMB[*] C/N	Deaminase	FDA	Basal respiration		Metabolic quotient
		mg C/kg soil	g C/kg soil-C	mg C/kg soil	g C/kg soil-C	mg N/kg soil	g N/kg soil-N	ratio	mg N/g MC/h	abs/mg MC/h	mg CO_2/kg soil/min	mg CO_2/kg soil-C/min	mg CO_2/g MCB/min
	Crest	123	1.8	1362	20.5	410	60.6	4.6	4.4	0.064	66	895	65.6
	Slope	115	2.5	1433	28.5	334	64.5	5.3	6.5	0.077	68	1370	68.5
	Flat	90	2.3	1286	26.6	303	77.7	4.4	5.5	0.070	80	1926	79.9
Organic	**Mean**	**104**	**2.3**	**1330**	**26.7**	**327**	**70.7**	**4.8**	**5.8**	**0.071**	**74**	**1596**	**73.9**
	Range	36-454	0.6-12	384-3289	12-41	74-791	20-198	1.7-11	1.6-18	0.02-0.29	29-262	685-5734	29-262
	CV%	55%	63%	47%	30%	50%	55%	46%	59%	63%	56%	57%	56%
	Crest	139	2.2	1577	27.7	345	51.5	7.2	4.8	0.046	69	1031	68.9
	Slope	100	2.1	1395	28.5	350	72.4	4.2	6.0	0.059	66	1260	65.8
	Flat	95	2.4	1322	27.7	322	80.0	3.6	6.3	0.067	64	1483	63.5
Integrated	**Mean**	**102**	**2.3**	**1374**	**28.0**	**336**	**72.4**	**4.2**	**6.0**	**0.066**	**65**	**1346**	**65.0**
	Range	19-252	0.3-5.3	464-3065	11-51	101-734	21-148	1.6-17	2.2-15	0.02-0.13	19-186	483-3421	19-186
	CV%	41%	43%	48%	32%	38%	42%	50%	49%	44%	54%	48%	54%
	Crest	95	1.7	1006	22.4	321	59.4	4.5	7.2	0.080	58	961	57.8
	Slope	105	2.2	1243	26.6	304	67.1	4.5	6.6	0.070	59	1271	59.4
	Flat	103	2.3	1148	23.0	252	57.9	5.2	7.0	0.072	57	1253	57.3
Conventional	**Mean**	**103**	**2.2**	**1171**	**24.4**	**304**	**63.5**	**4.9**	**6.8**	**0.072**	**58**	**1230**	**58.2**
	Range	49-203	0.8-4.5	431-2748	9-48	53-656	14-124	1.4-14	2.8-27	0.02-0.18	20-103	611-2250	20-103
	CV%	33%	36%	45%	35%	49%	44%	62%	52%	47%	35%	31%	35%
Significance	**System**	**ns**	**ns**	**	**	**ns**	**ns**	**ns**	**ns**	**ns**	**	**	**
	average lsd (5%)	14	0.3	138	2.2	46	9.8	0.8	1.1	0.012	10	211	11
	Landform	**ns**	**ns**	**ns**	**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	System•Landform	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	*	**ns**	**ns**	**ns**	**ns**	**ns**
	average lsd (5%)	31	0.8	307	4.9	103	21.9	1.7	2.5	0.027	22	470	25

[*]SMB- soil microbial biomass

Table 7. Some soil fertility and physical condition means and results of unbalanced ANOVA for Dairy for 2005 and 2007 sampling rounds.

System	Year	pH	Olsen-P		Organic-C	Total-N	C/N ratio	Mineralisable-N		Soil BD	Soil MC
			mg P/L soil	mg P/kg soil	C%	N%		mg N/kg soil	mg N/kg soil-N	g/ml	ml/g
Organic	2007	6.2	34	59	9.7	0.97	10.1	257	19.4	0.73	0.58
	2005	6.1	47	65	9.2	0.88	10.5	324	26.9	0.80	0.57
	Mean	**6.1**	**41**	**62**	**9.5**	**0.93**	**10.3**	**290**	**23.1**	**0.76**	**0.58**
Conventional	2007	6.1	47	76	9.3	0.96	9.8	240	17.4	0.73	0.56
	2005	5.9	58	75	8.5	0.84	10.2	309	26.7	0.80	0.55
	Mean	**6.0**	**52**	**76**	**8.9**	**0.90**	**10.0**	**276**	**22.2**	**0.77**	**0.55**
Significance	**Year**	**	**ns**	**ns**	*	***	***	***	***	***	***
	System	***	**	*	*	**ns**	**	**	**ns**	**ns**	*
	average lsd (5%)	0.1	6	10	0.6	0.06	0.20	12	1.7	0.03	0.03
	Year•System	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	average lsd (5%)	0.14	9	15	0.8	0.08	0.27	17	2.4	0.04	0.05

Table 8. Some soil fertility and physical condition means and results of unbalanced ANOVA for Sheep & Beef for 2005 and 2007 sampling rounds.

System	Year	pH	Olsen-P		Organic-C	Total-N	C/N ratio	Mineralisable-N		Soil BD	Soil MC
			mg P/L soil	mg P/kg soil	C%	N%		mg N/kg soil	g N/kg soil-N	g/ml	ml/g
	2007	6.0	11.1	13.8	4.8	0.45	10.8	196	28.9	1.12	0.38
Organic	2005	5.9	14.9	15.2	4.5	0.40	11.3	229	37.7	1.11	0.35
	2003	6.0	15.0	19.4	4.7	0.38	12.3	223	38.7	1.20	0.30
	Mean	**5.9**	**13.7**	**16.2**	**4.7**	**0.41**	**11.5**	**217**	**34.1**	**1.14**	**0.35**
	2007	5.8	24.5	31.3	4.8	0.46	10.3	203	28.8	1.17	0.36
Integrated	2005	5.9	27.0	26.8	4.6	0.41	11.1	249	41.5	1.15	0.34
	2003	5.9	26.5	34.2	4.7	0.40	11.9	241	41.7	1.21	0.29
	Mean	**5.9**	**26.0**	**30.8**	**4.7**	**0.42**	**11.1**	**231**	**37.6**	**1.18**	**0.33**
	2007	5.8	23.0	29.3	4.9	0.47	10.6	199	28.5	1.14	0.36
Conventional	2005	5.9	24.7	25.2	4.4	0.39	11.3	239	41.3	1.16	0.33
	2003	6.0	28.6	36.1	4.9	0.41	12.2	231	39.1	1.21	0.30
	Mean	**5.9**	**25.5**	**30.3**	**4.8**	**0.42**	**11.4**	**223**	**36.3**	**1.17**	**0.33**
Significance	**Year**	**ns**	**	***	***	***	***	***	***	***	***
	System	**ns**	***	***	**ns**	**ns**	**	*	**	**	*
	lsd (5%)	0.1	2.6	3.0	0.2	0.02	0.2	5	1.6	0.02	0.02
	Year•System	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	average lsd (5%)	0.1	4.4	5.1	0.6	0.03	0.4	8	2.8	0.04	0.03

Table 9. Effective area, stock number and stocking rate of 2007 Sheep & Beef (a) and Dairy (b) farms and system means

Farm (A)	Effective Area	Total stock units	Stocking rate
	ha	*SU*	*SU/ha*
SB2A	296	1494	5.0
SB3A	340	4164	12.2
SB4A	300	2110	7.0
SB5A	135	998	7.4
SB6A	210	1134	5.4
SB7A	413	4816	11.7
SB8A	510	5017	9.8
SB9A	500	4800	9.6
SB10A	459	7502	16.3
SB11A	590	4574	7.8
SB12A	200	2173	10.9
Av. Org	**348**	**3111**	**8.5**
SB1B	569	4541	8.0
SB2B	774	8588	11.1
SB3B	280	3104	11.1
SB4B	515	3908	7.6
SB5B	444	4901	11.0
SB6B	210	1369	6.5
SB7B	700	12641	18.1
SB8B	1370	8159	6.0
SB9B	495	6091	12.3
SB10B	176	3018	17.1
SB11B	207	2055	9.9
Av. Intg	**465**	**4387**	**11.4**
SB1C	497	2763	5.6
SB2C	678	5814	8.6
SB3C	325	6035	18.6
SB5C	242	2565	10.6
SB6C	420	4308	10.3
SB7C	308	3682	12.0
SB8C	666	6690	10.0
SB9C	477	4967	10.4
SB10C	258	2552	9.9
SB11C	1585	7853	5.0
SB12C	318	5280	16.6
Av. Conv	**400**	**4310**	**11.7**

Farm (B)	Effective Area	Cows	Stocking rate
	ha	*No.*	*cows/ha*
SB2A	94	301	3.2
SB3A	40	113	2.8
SB4A	68	250	3.7
SB5A	215	616	2.9
SB6A	110	280	2.5
SB7A	78	190	2.4
SB8A	80	195	2.4
SB9A	73	215	2.9
SB10A	86	220	2.6
SB11A	135	443	3.3
SB12A	76	210	2.8
Av. Org	**234**	**123**	**2.3**
SB1C	95	233	2.5
SB2C	65	158	2.4
SB3C	80	255	3.2
SB5C	59	160	2.7
SB6C	65	140	2.2
SB7C	123	245	2.0
SB8C	75	156	2.1
SB9C	71	250	3.5
SB10C	70	160	2.3
SB11C	130	206	1.6
SB12C	115	240	2.1
Av. Conv	**291**	**101**	**2.9**

4.4 Comparisons Between Sampling Rounds

Soil chemistry and physical condition

Dairy

Soil pH for clusters 1-10 was significantly higher overall for 2007 compared with 2005 but the actual differences were slight (~0.1-0.2 units) although Organic was slightly higher than Conventional overall for pH (Table 7). Olsen-P appeared to decrease overall between 2007 and 2005 but when values were transformed using laboratory SBD values to a gravimetric basis, differences largely disappeared. Organic Olsen-P values in both rounds were significantly lower than those for Conventional. Organic-C and total-N appeared to increase for all systems between rounds whilst C/N ratios decreased. Overall, however, both organic-C and C/N ratio values remained significantly greater ($0.01<P<0.05$) for Organic systems over Conventional. Mineralisable-N was also significantly higher for Organic ($P<0.01$) although not on a soil-N basis. Mineralisable-N, however, decreased overall between 2007 and 2005. SBD values remained similar between rounds with no significant differences but Organic had a small but significant increase ($P<0.05$) in SMC over Conventional over both rounds.

Sheep & Beef

Soil pH for S&B was essentially unchanged over the period 2003-7 and no differences were found between systems overall (Table 7). Olsen-P levels on the whole, dropped significantly between 2003 and 2005 (but not between 2005 & 2007) with strong differences remaining between systems ($P<0.001$) through all years. Organic Olsen-P values were consistently about half those of Conventional/Integrated. Organic-C values appeared to show a minima in 2005 from 2003 and 2007 (about 5% lower) although N levels increased by about 10% in 2007 over 2003-5 with a resulting decrease in C/N ratios. Between systems, however, there were no significant differences in organic-C and soil-N values, although C/N ratios were significantly greater ($P<0.01$) for Organic. Mineralisable-N was significantly lower ($0.01<P<0.05$) for all systems between 2007 and 2005, whether on a soil or soil-N basis (Table 7), by about 20%. Organic mineralisable values were about 6% lower than Integrated on a soil weight basis ($P<0.05$) and slightly lower again (~9%) on a soil-N basis. Whilst there were some changes in SBD and SMC since 2003 (lower and greater, respectively), Organic had consistently lower SBD and higher SMC values than for Integrated or Conventional systems ($0.01<P<0.05$) with differences of ~3-4% (Table 7).

Soil Biology

Dairy

Generally, soluble-C and -N were significantly greater in 2007 than in 2005 whilst microbial-C was about 10-20% lower. These differences ($P<0.001$) were on both a soil and soil-C&N basis. Consequently, similar magnitude differences ($P<0.001$) were also reflected in SMB C/N ratios that were, in 2007, about half of those in 2005. Overall, SMB-C and SMB-N were significantly greater for Organic systems over Conventional by about 10% on both a soil and soil-C&N basis ($0.01< P<0.05$; Table 10). Although SMB C/N ratios were also higher for Organic, the difference was not significant. Differing metabolic quotient methods were used between 2007 and 2005 so differences between years were not comparable. However, no differences were found between systems for either year.

Sheep & Beef

Whilst soluble-C was significantly lower in 2007 than 2005 by about one-third, SMB-C&N were ~1.5-3 times higher in 2007 compared with 2005 and statistically significant ($P<0.001$; Table 11). Soil microbial biomass C/N ratios were statistically lower ($P<0.001$) in 2007 by about a third compared with 2005. Biological differences between systems were mainly restricted to microbial-C where Conventional was found to be significantly lower than either Organic or Integrated by about 10-15% on both a soil (P<0.01) and soil-C&N (P<0.001) basis. Soil microbial biomass-N was also about 10% lower for Conventional but this difference was not significant at the 5% level. Metabolic quotient values were significantly (P<0.001) higher for Organic than for either Conventional or Integrated (Table 11).

Table 10. Some soil biology means* and results of unbalanced ANOVA for Dairy from 2005 and 2007 sampling rounds.

System	Year	Soluble-C		Soil microbial biomass C		Soil microbial biomass N		SMB C/N	Metabolic quotient
		mg C/kg soil	mg C/kg soil-C	mg C/kg soil	g C/kg soil-C	mg N/kg soil	g N/kg soil-N	ratio	mg CO_2/g MC/min
	2007	303	3.3	1096	11.6	414	43	2.7	127
Organic	2005	223	2.6	1292	14.4	206	24	6.5	69
	Mean	**263**	**2.9**	**1194**	**13.0**	**310**	**34**	**4.9**	**98**
	2007	330	3.6	975	10.3	376	39	3.3	139
Conventional	2005	241	2.9	1097	13.0	180	22	6.5	68
	Mean	**284**	**3.2**	**1038**	**11.7**	**275**	**30**	**4.6**	**101**
Significance	**Year**	***	***	***	***	***	***	***	**na****
	System	**ns**	*	**	*	**	*	**ns**	**ns**
	average lsd (5%)	24	0.3	99	0.8	25	2	0.5	19
	Year•System	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	average lsd (5%)	34	0.4	140	1.2	36	4	0.7	27

* Clusters 1-10 only; ** Method changed between sampling rounds so comparisons not valid.

Table 11. Some soil biology means* and results of unbalanced ANOVA for Sheep & Beef from 2005 and 2007 sampling rounds.

System	Year	Soluble-C		Soil microbial biomass C		Soil microbial biomass N		SMB C/N	Metabolic quotient
		mg C/kg soil	mg C/kg soil-C	mg C/kg soil	g C/kg soil-C	mg N/kg soil	g N/kg soil-N	ratio	mg CO_2/g MC/min
	2007	104	2.3	1356	27.6	327	71	4.6	69
Organic	2005	156	3.6	750	16.5	124	31	6.6	75
	Mean	**132**	**3.0**	**1029**	**21.6**	**217**	**49**	**5.6**	**72**
	2007	102	2.3	1374	27.8	337	74	4.4	53
Integrated	2005	158	3.5	832	17.8	126	30	7.7	67
	Mean	**132**	**3.0**	**1096**	**22.7**	**230**	**50**	**6.1**	**60**
	2007	103	2.2	1151	23.7	297	62	4.8	57
Conventional	2005	159	3.7	732	16.5	121	30	7.2	54
	Mean	**131**	**2.9**	**936**	**20.1**	**207**	**46**	**6.1**	**56**
Significance	**Year**	*	***	***	***	***	***	***	**na***
	System	**ns**	**ns**	**	***	**ns**	**ns**	**ns**	***
	average lsd (5%)	8	0.2	81	1.3	24	5	0.8	9
	Year•System	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
	average lsd (5%)	12	0.3	115	1.8	33	7	1.1	13

** Method changed between sampling rounds so comparisons not valid.

5 Discussion

5.1 Soil Chemistry and Physical Condition

Dairy

The addition of a further two clusters of farms from the Manawatu region meant that were some changes in means for Dairy from 2005 as the Manawatu soils were generally lower in organic matter and P than the bulk of the farms that from the Taranaki and Waikato regions (Carey *et al.* 2006). Nevertheless, strong differences in available-P were maintained between Conventional and Organic farms as in 2005 with some suggestion that the differential between them is increasing although the decline of 6 units for Organic from 2005 to 2007 was not significant (Table 7). Overall, 45% of farms had means above the optimum guide values (Roberts and Morton 1993) for the top 25% of producers with two-thirds of these Conventional farms. Olsen-P values reported in 2005 appeared initially to be about 25% higher than those in 2007 but this was due to problems with the Olsen-P calibration used by the soil test laboratory. Once an adjustment factor was applied and differences in laboratory soil bulk density adjusted for, Conventional values were remarkably similar between years and suggests that farm P fertilizer application rates have remained static. Higher pH, C/N ratios and organic-C values for Organic farms is not unusual given that that artificial N fertilizers aren't used and consequently, lower rates of mineralization of soil organic matter (SOM) are likely to occur than under an intensive Conventional system (Marschner *et al.* 2003; McLaren and Cameron 1990). However, most reports cite tillage systems and there is little data regarding the effects of intensifying pastoral systems. This data suggests that increasing intensity of pastoral farming, especially dairying, could lead to a loss of soil carbon, at least in the topsoil. Currently, the difference between Organic and Conventional farms is about 10% and it remains to be seen whether further divergence will occur.

As in 2005, there was a strong difference between landforms with both available-P and SOM showing some accumulation in Crest areas through excreta transfer at the expense of slope areas. Interestingly, although mineralisable-N was found to be largely similar between systems and within landforms, it was actually less on a total soil-N basis for crest compared with slope areas suggesting that this N fraction is more closely tied with a smaller labile N fraction than total soil-N.

Data analysis between the two sampling rounds was restricted to clusters 1-10 to ensure comparisons between years were equal as clusters 11 and 12 were only added in 2007. Increases in SOM (organic-C and total-N) and decreases in mineralisable-N and SBD between sampling years (2005-2007) may more likely indicate variation in laboratory testing and testing methodologies than any firm trend, especially as there were no Year-by-System interactions. The value of a monitoring program such as ARGOS, however, is only in the long-term and establishing any trend now would be premature. Nevertheless, their are some strong persistent system differences in available-P and SOM already evident despite the fact that the Organic systems are still early in their development. Maintaining a high degree of nutrient sustainability and profitable production levels in Organic dairy farms requires careful and more long-term management to ensure nutrients are not overly limiting (Watson *et al.* 2002b). To date, there is no evidence of this occurring and reports show that this needn't necessarily be an issue although the sustainability of practices that require the importing of feed or other amendments is questionable (Watson *et al.* 2002b). Maintaining available-P levels to ensure that legumes continue to fix N and that losses of major cations such as K and Mg are adequately replaced will be required long-term for NZ Organic farms. The options available to European Organic farms may not be economic or sustainable for NZ where stock is housed externally all year round and there is less dependence on feed imports and manure spreading to replace nutrients. However, Conventional farms also face increasing energy costs, the use of more imported feed and potentially environmentally damaging nutrient losses thus, they too, may also prove unsustainable.

Sheep and Beef

Generally, there were few differences between the chemical and physical properties tested for S&B in 2007, restricted as it was to lower available-P, a higher C/N ratio, and a small, but significant, decrease in SBD for Organic over Integrated systems. This is mainly due to Organic farms' lower applied rates of P and N, and lower stocking rates compared with Integrated (Table 9). Although their was a strong relationship between mineralisable-N and total-N generally, the lack of any differences in SOM between the systems (and landforms) suggests that none of the S&B management systems offer a particular advantage in seasonally available-N or sequestering SOM to date. Other studies have shown that often soil type is a more important determinant of SOM content than management and differences are probably likely only to be significant if cropping and any subsequent tillage is a bigger component of one system than another (van Diepeningen *et al.* 2006);. Tillage operations reduce both SOM and mineralisable-N, reversed only by a restorative phase back into pasture or similar (Haynes 2000; Watson *et al.* 2002a). With most S&B Organic systems older than 7 years, the lower SBD overall is probably an indication of Organic's lower stocking rates, especially compared to Integrated.

Differences between landforms were, as with dairy, mainly in increases in available-P, mineralisable-N, organic-C and total-N from excreta transfer of dung and urine to crest sites where stock camps are more likely to occur (Haynes and Williams 1999).

Monitoring chemical changes between the S&B sampling rounds extends to 2003 when the first sampling round began. Although the sampling design of this round was later found to be deficient, it nevertheless provided an opportunity to monitor system movements over the four years. Although there were some significant differences in SOM properties between sampling years it seems that laboratory variation may be the biggest source of this given that 2005, the middle year, was the minima for organic-C but total-N was largest generally in 2007. This had a subsequent effect on C/N ratios that decreased significantly over the period. Mineralisable-N was also least in 2007 but the reasons for this are also unclear. To avoid interpreting temporal changes related more to laboratory variance than system changes, further sampling rounds will see more internal standard checking of ARGOS samples to ensure results are as consistent as possible from year-to-year. Nevertheless, there were a number of significant differences in soil properties that were consistent from year-to-year including lower available-P, C/N ratios and mineralisable-N for Organic systems that have the potential to reduce production. Foremost of these is available-P which needs to be maintained at levels higher than currently (Roberts 1994) for a number of Organic farms if they are to maintain a strong reliance on N_2 fixation . Whilst there is ample evidence to show that Organic production systems needn't be in deficit for most nutrients, including N (van Diepeningen *et al.* 2006), a significant percentage of ARGOS Organic farms do not appear to be applying sufficient P to maintain maximal N fixation. Possibly the reason for this is the larger size of farms in NZ generally, compared with overseas, and less reliance on imported feed and spreading of manures common in Europe to supplement nutrient budgets and maintain nutrient surpluses (Watson *et al.* 2002b).

5.2 Soil Biology

Dairy

A larger range of biological soil analyses were undertaken in 2007 to ostensibly measure the relative proportions of soil fungi-to-bacteria and whether soil enzyme activity differed significantly between systems. On the whole, system differences were very few and may reflect that most Organic farms were still relatively newly certified and any management-induced effects will occur more in the mid-to-long-term. Whilst Organic farms had greater biomass-C and N, and lower soluble-C ($P<0.05$) and deaminase activity, possibly reflecting a lack of applied N fertilizer and lower stocking rates (Table 9), respectively, none of these differences except soluble-C were statistically significant.

The significantly larger SMB-C values for flat landforms was initially thought due to higher stocking rates of farms with predominantly flat landforms but stocking rates between hill and flat dairy farms are essentially similar with both ~2.6 cows/ha. With SMB-N not showing such differences between landforms it suggests that this might be due to analytical variation although a similar bias, if not as large, was evident in 2005 results. It remains to see if this bias continues. Apart from lower soluble-C for flat landforms, which could reflect its use as a substrate by a larger SMB population, no other significant differences were evident. Whilst enzyme activity appeared to be higher in crest sites of all systems, none were significantly different despite the priming effect of excreta transfer on levels of soil micro-organisms and enzymes being well documented (Haynes and Williams 1999).

Results for substrate-induced respiration (SIR) were influenced by there appearing to be some overlapping of the fungicide action in suppressing bacterial activity. Consequently, this affects the overall results by increasing the relative proportion of bacterial-to-fungal respiration. Other authors indicate that fungal:bacteria ratios for grassland soils should more approximate an 80:20 split (Lin and Brookes 1999a) but there were a number of confounding issues. Foremost of these was the choice of fungicide that was required to be changed with the unavailability of cycloheximide, the first choice of a number of earlier reports (Beare *et al.* 1990; Lin and Brookes 1999b). Further work, currently in progress, is ongoing on this method to select the most appropriate fungicide and conditions for its use.

Sheep and Beef

Strong differences were found for SMB-C&N for both Organic and Integrated over Conventional and suggests that both management systems lead to larger soil microbial populations. Integrated, with its larger inputs of fertilizers and stocking rates (Table 9) will build microbial populations on the basis of more excreta inputs but the outputs and losses are also greater and therefore the nutrient flows are larger. Conversely, Organic systems are less intensive and the nutrient flows also less but so is the quality of SOM (higher C/N ratios) and therefore microbial populations have to deal with slightly more recalcitrant SOM. Microbial populations would tend to have to work harder to decompose this SOM and this can be inferred by a higher metabolic rate and reduced efficiency. It is difficult to infer how enzyme activities might have also reflected these differences but high variability and the complicating effects of tillage on some of the farms can make interpreting enzyme activities difficult, especially as most published comparisons are between grassland and arable systems (Mijangos *et al.* 2006; Milne and Haynes 2004). In selecting the most appropriate enzyme tests, recent reports suggest that possibly other tests may be more suitable (García-Ruiz *et al.* 2008) and this is currently being investigated.

Substrate-induced respiration for S&B was also complicated by non-target suppression of bacteria by the fungicide. Although there was a significantly greater proportion of bacteria in Organic systems than either Integrated or Conventional this was not expected and a review of the method is underway. There was however, also a greater number of bacteria under flat landforms that may reflect the greater microbial biomass also recorded there but this link is still unclear.

Differences between years did not seem to reflect any particular trend with Dairy SMB-C increasing between years but S&B decreasing, whilst SMB-N increased for both. The lack of any interactions suggest that this is not indicative of any particular trend despite some strong differences. In any year some seasonal variability will be expected and laboratory variation will also cause some fluctuations. Nevertheless, the summaries of results for the two dairy sampling rounds and the three for S&B show that, of the microbial tests in common between years, there were significant increases of about 10% in SMB-C and SMB-N in Organic Dairy and of SMB-C for S&B over Conventional. Integrated S&B farms also produced greater SMB-C than Conventional and this may reflect that intensifying inputs can also stimulate greater microbial biomass production (Haynes and Williams 1993; Haynes and Williams 1999). Higher soluble-C for Conventional dairy underlines that more productive pastoral systems generally have higher rates of SOM turnover (Haynes and Williams 1993), that in turn produce higher concentrations of soluble organic matter (Haynes 2000). Metabolic quotient was consistently higher for Organic in both years reinforcing that microbial biomass in some Organic farms may be under increased stress. In the three most affected farms, all had low available-P values (Olsen-P <10) so the implication may be that the quality of SOM has declined, although does not mean that SOM quality is poor as the great majority of pastoral farms showed good-to-excellent soil quality overall (Carey *et al.* 2006). The steps to remedying any decline will rely on maintaining satisfactory nutrient levels.

6 Summary

Available-P values for Conventional Dairy farms in 2007 were unchanged from those in 2005 with more than two-thirds having Olsen-P values above the optimal values (Olsen-P >40; for the top 25% of producers) compared to only 15% for Organic Dairy. Organic values appear to be continuing to decline. Available-P values were also similar between years for S&B Conventional/Integrated but Organic values appear to have declined below, on average, what would be considered optimum for clover production and N fixation. In 2007, Dairy Organic systems generally had greater organic-C, C/N ratios, mineralisable-N, microbial-C and pH (slightly) than their Conventional counterparts whilst S&B Organic farms had larger C/N ratios and microbial-C, and lower SBD. Basal respiration and metabolic quotient were higher overall for S&B Organic suggesting that for some farms in this system are under greater stress. The three main affected Organic farms had Olsen-P values <10 so any increased stress may be related to lower quality organic matter returns. Substrate-induced respiration (SIR), deaminase and FDA hydrolysis microbial activity values were not found to significantly different between management systems for either Dairy or S&B except the SIR values for S&B. However, the SIR method had several complicating issues regarding the choice of fungicide and further work is required to improve the suitability, performance and precision of this method, and that of the enzyme activity methods. Soil bulk density was found to be less for S&B Organic farms compared with Integrated, probably because of stocking rate differences, but no differences were found between systems for Dairy.

Landform differences for both Dairy and S&B were mostly centred on the transfer of excreta to crest sites where stock camping mostly occurs leading to accumulation of P, C and N in these areas. Deaminase and FDA hydrolysis activity, however, were not found to significantly different. Crest sites were generally found to have lower SMB and/or activities per unit soil-C suggesting that these fractions may be associated with a smaller, more labile component of the SOM. For S&B, crest sites were found to have slightly greater SMC than slope/flat areas.

Although some variability was evident between years for the chemical analyses, mainly in SOM, trends between systems for both Dairy and S&B were generally consistent over the sampling period. Organic Dairy had lower available-P and greater organic-C, C/N ratios, mineralisable-N and SMB-C&N whilst Organic S&B had larger C/N ratios, SMB-C&N, metabolic quotient and SMC but lower available-P, mineralisable-N and SBD than their respective Conventional/Integrated counterparts.

Overall, soil quality was not remarkably different between systems for either Dairy or S&B but there remains areas of concern. Available-P is higher than recommended for Dairy Conventional farms and while losses are agronomically small, environmental costs could be of considerably greater concern. Conversely, low available-P for a number of S&B organic farms may be reducing their production potential and Organic farms need to be aware of maintaining nutrient levels. The difference in soil-C between Dairy systems is also of interest in times of concerns about GHG emissions and carbon credits. If these differences are repeatable, then considerably more carbon might be retained under Organic Dairy systems. Generally, however, soils for Dairy and S&B farms retained good-to-excellent soil quality and showed that Organic and Conventional systems can produce similar soil quality.

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