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# Soil sustainability in organic agricultural production

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## Summary

Traditionally, the assessment of soil sustainability and the potential impact of cultivation are based upon the application of chemical procedures. In the absence of a biological context, these measurements offer little in understanding long-term changes in soil husbandry. Detailed microcosm investigations were applied as a predictive tool for management change. The microcosms were designed with homogenised soils treated with organic amendments. Key soil functional relationships were quantified using stable isotope techniques, biochemical measurements and traditional approaches.

**Keywords:** Organic management, conventional management, microbial activity microbial biomass, ecological indicators, soil health

## Introduction

An ongoing challenge for both scientists and policy makers is to preserve agricultural efficiency whilst using the natural resilience of the soils to establish sustainable production in unimproved and degraded systems, in the face of continuous population growth (Griffiths *et al*., 2001). From this, a particular interest has grown in understanding soil processes particularly in terms of the relationship between biodiversity and function. It is now considered to be the key in estimating the influence of farming practices on the fertility and quality of soil, and thus on the environment (Bohme *et al*., 2005).

Productivity of soils, with regard to their utilization is determined by properties and attributes of the whole soil body (Arnold *et al*., 1990). Thus, a chief concern for societies should be the impact of soil management practices on the physical, chemical and biological processes of soils that influence the sustainability of agriculture (Karlen *et al*, 2003).

## Materials and Methods

Comparisons of conventional and organic based production systems were made using two neighboring farms, Kirkbog and Kirkland, located in Dumfries and Galloway. The selected fields for soil analyses were adjacent to each other to ensure the same pedological conditions as farm management varied. The crop rotation of the conventional system was similar to the organic system. The agricultural management of the four fields differed but was typical of organic and

conventional practices in the UK. In 2005, the rotational field from the organic farm had been utilized to grow grass, peas and triticale in rotation for the past three years. The rotational fields of the conventional farm had been utilized to grow grass and maize in rotation. At the time of sampling the rotational fields of both the organic and conventional farm were under grass ley. Pasture fields of the conventional farm had not been ploughed for 16 years, whereas pasture fields of the organic system had not been ploughed for 25 years, both were utilised as permanent pasture for livestock.

A microcosm study was established to determine differences in key functional soil processes between conventional and organic husbandry. Soils were amended with a $^{15}N$ plant residue (rye grass) and incubated for a 90-day period with growing barley plants acting as a plant sink for N. Microcosms were destructively sampled, to test a large suite of indicators, as a variety of parameters should be investigated when considering the impact of management on soil sustainability.

Both available nitrate ($NO_3^-$-N) and ammonium ($NH_4^+$-N) were determined by colorimetric methods after extraction from soil with 1 M KCl. Microbial biomass C (MBC) was determined by chloroform fumigation extraction method, using 0.5 M $K_2SO_4$ as an extractant. The C contents in the fumigated and non-fumigated were estimated as reported by Vance *et al*. (1987).

Acid phophatase (PNP), alkaline phophatase (PNP*) and dehydrogenase (DH) activities were measured as indicators of soil enzymatic activity. Acid and alkaline phosphatase was assayed according to methods described by Skujins. *et al*. (1962). The procedure involves the spectrophotometric determination (wavelength 410 nm) of *p*-nitrophenol (*p*NP) released by 1 g of soil during 60 min at 37°C.

Dehydrogenase activity was determined using methods adapted from Casida *et al*. (1964) and Trasar-Cepeda *et al*. (2000), and based on the spectrophotometric determination of iodonitrotetrazolium formazan (INTF) released by 1 g of soil during 24 h at room temperature.

## Results and Discussion

Table 1. *Biological and chemical indicators of organically and conventionally managed pasture soils during a 90-day incubation period.*

| | Day 0 | | Day 45 | | Day 60 | |
|---|---|---|---|---|---|---|
| | Organic | Conventional | Organic | Conventional | Organic | Conventional |
| Biological indicators | | | | | | |
| Biological | | | | | | |
| PNP (µmol pNPg$^{-1}$ soil h$^{-1}$) | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.04 ± 0.00 | 0.03 ± 0.00 | 0.11 ± 0.01 | 0.11 ± 0.01 |
| PNP* (µmol pNPg$^{-1}$ soil h$^{-1}$) | 0.09 ± 0.00 | 0.09 ± 0.00 | 0.09 ± 0.00 | 0.08 ± 0.00 | 0.25 ± 0.02 | 0.22 ± 0.05 |
| DH (µmol INTF g$^{-1}$ soil h$^{-1}$) | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| MBC (mg 100$^{-1}$) | 115 ± 4.13 | 135.15 ± 4.14 | 304.99 ± 7.12 | 168.39 ± 8.77 | 297.14 ± 35.3 | 176.64 ± 10.27 |
| Available nutrients | | | | | | |
| $NO_3^-$-N (mg kg$^{-1}$) | 27.22 ± 0.26 | 21.84 ± 0.082 | 1.30 ± 0.07 | 0.4 ± 0.00 | 3.07 ± 0.22 | 2.09 ± 0.24 |
| $NH_4^+$-N (mg kg$^{-1}$) | 4.12 ± 0.41 | 5.43 ±0.16 | 1.73 ± 0.49 | 1.98 ± 0.22 | 2.5 ± 0.33 | 2.18 ± 0.01 |

Table 2. *Biological and chemical indicators of organically and conventionally managed rotational soils during a 90-day incubation period*

| | Day 0 | | Day 45 | | Day 60 | |
|---|---|---|---|---|---|---|
| | Organic | Conventional | Organic | Conventional | Organic | Conventional |
| Biological indicators | | | | | | |
| PNP (μmol pNPg$^{-1}$ soil h$^{-1}$) | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.03 ± 0.00 | 0.03 ± 0.00 | 0.15 ± 0.04 | 0.03 ± 0.00 |
| PNP* (μmol pNPg$^{-1}$ soil h$^{-1}$) | 0.08 ± 0.00 | 0.07 ± 0.00 | 0.08 ± 0.00 | 0.08 ± 0.00 | 0.29 ± 0.01 | 0.22 ± 0.05 |
| DH (μmol INTF g$^{-1}$ soil h$^{-1}$) | 0.01 ± 0.00 | 0.02 ± 0.00 | 0.01 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| MBC (mg100$^{-1}$) | 151.09 ± 2.93 | 140.81 ± 3.03 | 369.23 ± 9.94 | 229.19 ± 1.56 | 292.07 ± 35.3 | 248.11 ± 1.82 |
| Available nutrients | | | | | | |
| $NO_3^-$-N (mg kg$^{-1}$) | 20.98 ± 0.57 | 19.5 ± 0.77 | 0.47 ± 0.03 | 0.29 ± 0.07 | 2.92 ± 0.14 | 2.74 ± 0.74 |
| $NH_4^+$-N (mg kg$^{-1}$) | 2.22 ± 0.05 | 3.27 ± 0.12 | 2.04 ± 0.27 | 2.88 ± 0.05 | 2.3 ± 0.2 | 2.09 ± 0.08 |

Despite the fact that soil management influences most soil parameters, several authors (Nannipieri, 1984; Bergstrom *et al*., 1998) reported that microbial biomass and enzyme activity respond more quickly to management and land use. Thus, microbial biomass and the enzyme activities are considered to be more sensitive indicators of soil sustainability than chemical properties (Beyer *et al*., 1999). In this study, enzymatic activities (Tables 1 and 2) as indicators of microbial activity presented broadly similar patterns for pasture and rotational fields, irrespective of management. So far, weak correlations were found between dehydrogenase and microbial biomass C, which may be due to a significant proportion of dormant microbes.

Preliminary investigations of available soil nitrogen in the forms of nitrate and ammonium are presented in Tables 1 & 2. The effect of management was more pronounced for nitrate; furthermore, concentrations of ammonium decreased during the first 45 days, suggesting that a high level of nitrification in an aerobic environment is being maintained in both soil types.

Soil nitrate availability was always higher in organic than in conventional fields in both rotation and conventional, although this was insignificant. A possible explanation of the difference in nitrate concentration may be to the higher activity of microbial nitrifying bacteria, which may be affected by different fertiliser application in the conventional system (Chao *et al*., 1996), although residual N effects from previous management regimes should also be considered.

For matched soils under contrasting management practices, there have been no marked changes, to date, in terms of soil mineral N concentrations, microbial biomass C and enzyme (dehydrogenase) activities. Statistical analysis revealed differences only with time, but not with management practices. This suggests that a period of 5 years of contrasting management was not enough to produce consistent differences in soil microbial activity.

This may well relate to the intrinsic dynamics of change due to the organic conversion rather than a lack of change. However, by continuing to monitor biomass carbon, the study is focusing on the main barometer of change in the soil. In terms of N mineralisation, there is no evidence to date to suggest this is enhanced under organic management, although $^{15}N$ data will confirm whether the

efficiency of N transfer from the residue to the crop is changed under organic husbandry.


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