

# **Effects of Biodynamic and Conventional Farming on Soil Quality in New Zealand**

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## **Abstract**

Biodynamic farming practices show promise in mitigating some of the adverse effects of conventional agriculture on the environment. Biodynamic farming is like organic farming in that no synthetic chemical fertilizers and pesticides are used. Unlike organic farmers, biodynamic farmers add eight specific preparations (made from cow manure, silica, and various plants) to enhance soil quality and plant growth. This paper summarizes soil quality data from previous and current studies on 16 commercial biodynamic and conventional farms in New Zealand. Physical, chemical, and biological soil properties were measured as an index of soil quality. Although two different statistical designs were used for analyzing the data, the conclusions in each case were the same. The biodynamic farms proved to have soils of higher biological and physical quality than did the conventional farms: significantly greater organic matter content and microbial activity, better soil structure, lower bulk density, easier penetrability, and greater depth of topsoil. The results of the soil chemical analyses were variable.

## **Introduction**

Growing concerns about the environmental, economic and social impacts of chemical-based conventional agriculture have led many farmers and consumers to seek alternative practices and systems that will make agriculture more sustainable. Alternative farming systems include but are not restricted to “organic,” “regenerative” “biodynamic “ecological”, and “low input.” However, just because a farm is, for example, “organic” or “biodynamic” does not mean that it is sustainable. To be sustainable, it must produce adequate food of high quality, be environmentally-safe, protect the soil resource base, and be profitable and socially-just (Reganold et al., 1990).

Recently, there has been an increasing interest in biodynamic farming in New Zealand, Australia, the European Community, and the United States. Like other organic farming systems, biodynamic farming uses no synthetic chemical fertilizers and pesticides and emphasizes building up the soil with additions of compost and manures, controlling pests naturally, rotating crops, and diversifying crops and livestock. One difference is that biodynamic farmers add eight specific preparations to their soils, crops, and composts with the intent of enhancing soil and crop quality and stimulating the composting process. The eight preparations, designated by their ingredients or by the numbers 500 through 507, are made from cow manure; silica; flowers of yarrow, chamomile, dandelion and valerian; oak bark; and the whole plant of stinging nettle (Koepf et al., 1976).

Although much has been published in the news media about the biodynamic movement, specific details are often lacking and the biodynamic system and practices have not received a rigorous scientific assessment by traditional soil scientists, agronomists, or agricultural economists (Koepf, 1993). In addition, few studies examining biodynamic farming methods or comparing biodynamic farming with other farming systems have been published in the refereed scientific literature. This paper discusses soils data from a previous study (Reganold et al., 1993), conducted on 16 working, commercial biodynamic and conventional farms in New Zealand. The soils data were statistically analyzed using two designs: the original absorption method by Reganold et al. (1993) and a block design. The objective was to test for any differences in soil quality between the biodynamic and conventional farms using these two statistical methods of analysis.

## **Study Area and Methods**

Soil properties were measured on adjacent pairs or sets of biodynamic and conventional farms on the North Island of New Zealand (Reganold et al., 1993). A farm pair consisted of two side-by-side farms, one biodynamic and one conventional; a farm set consisted of three adjacent farms, one

biodynamic and two conventional. There were five farm pairs and two farm sets in this study totaling seven biodynamic and nine conventional farms.

The biodynamic farms had been biodynamically-managed for at least eight years, with the oldest for 18 years. This longevity ensured that sufficient time had elapsed for the biodynamic farming practices to influence soil properties. No chemical fertilizers and pesticides were applied on the biodynamic farms during the period of biodynamic management, whereas all conventional farmers used chemicals in their particular crop or livestock enterprises. The biodynamic farmers applied varying rates of organic fertilizers and composts, and some or all of the eight biodynamic preparations, depending on their farm enterprise.

The seven biodynamic/conventional farm pairs or sets included a range of representative farming enterprises in New Zealand: vegetables, apples, citrus, grain, sheep/beef, and dairy. Farms in each pair or set had the same crop and livestock enterprise. Fields chosen for study in each farm pair or set were located at the juncture of adjoining farms. Each adjacent field pair had the same type of soil (within a single soil profile class). Some farm pairs and sets had more than one pair of side-by-side fields to compare, resulting in a total of 11 field pairs from the 16 farms. There were 130 soil samples collected and analyzed from the 22 fields.

The field procedures, soil sampling patterns, and laboratory methods used for the physical, biological, and chemical analyses were reported earlier by Reganold et al. (1993). Soil properties chosen to measure soil quality were the following: structure; consistence; bulk density; cone or penetration resistance; organic carbon; respiration; mineralizable nitrogen; ratio of mineralizable nitrogen to carbon; topsoil depth; cation exchange capacity; total nitrogen and phosphorus; extractable phosphorus, sulfur, calcium, magnesium, and potassium; and pH.

All data for each soil property from the 16 farms were originally pooled by management system (biodynamic vs. conventional) and analyzed with ANOVA using an absorption method (SAS Institute Inc., 1988). The absorption method included all sample points in each field (about 6 samples per field) and at the same time removed the variation due to different soils and enterprises in each of the 11 field pairs. In this study, a second statistical method known as the block design was employed (SAS Institute Inc., 1988), where each field pair comprised a block or replicate. The block design used the mean value of all sample points (for each soil property) for each field. There were two treatments (biodynamic and conventional) and 11 blocks (fields), making an 11 x 2 block design. This design eliminates concern about pseudoreplication of treatments that arises from studies comparing a single farm pair (Hurlbert, 1984).

## **Results and Discussion**

In six of the seven farm sets, the biodynamically-farmed soils had better structure and tilth which allowed the development of a seedbed, moreso than the conventionally-farmed soils (Reganold et al., 1993). The biodynamic farms had predominantly nut and crumb soil structure, while the conventional farms were predominantly blocky and nut, and in some cases had a high proportion of clods. Crumb and nut structures provide better aeration and drainage for crop or grass growth compared with blocky and clod structures (Gibbs, 1980; McLaren and Cameron, 1990). Soil consistence was more friable on four of the seven biodynamic farms compared with their conventional neighbors (Reganold et al., 1993). Soil consistence is a measure of the ease with which a soil can be reshaped or ruptured and is relevant to tillage and traffic by farm machinery (FitzPatrick, 1986).

The surface soil bulk density was significantly lower on the biodynamic farms than the conventional farms, using either the absorption method or the block design (Table 1).

**Table 1. Mean Values of Soils Data from 16 Biodynamic and Conventional Farms in New Zealand. Abbreviations: Bio. = Biodynamic; Con. = Conventional.**

Soil Property	Absorption Method <sup>1</sup>		Block Design (11 x 2)	
	Bio. Farms	Con. Farms	Bio. Farms	Con. Farms
Bulk Density (Mgm <sup>-3</sup> )	1.07	1.15**	1.07	1.15*
Penetration Resistance (0-20 cm) (MPa)	2.84	3.18**	2.80	3.14 <sup>+</sup>
Penetration Resistance (20-40 cm) (MPa)	3.55	3.52	3.57	3.50
Carbon (%)	4.84**	4.27	4.92*	4.35
Respiration ( $\mu$ l O <sub>2</sub> h <sup>-1</sup> g <sup>-1</sup> )	73.7**	55.4	71.2**	51.3
Mineralizable N (mg kg <sup>-1</sup> )	140.0**	105.9	147.3**	110.9
Ratio of mineralizable N to C (mg g <sup>-1</sup> )	2.99**	2.59	3.11**	2.68
Topsoil thickness (cm)	22.8**	20.6	22.6*	20.4
CEC (cmol <sup>(+)</sup> kg <sup>-1</sup> )	21.5**	19.6	22.6	20.8
Total N (mg kg <sup>-1</sup> )	4840**	4260	4868*	4331
Total P (mg kg <sup>-1</sup> )	1560	1640	1657	1747
Extractable P (mg kg <sup>-1</sup> )	45.7	66.2**	52.4	73.9
Extractable S (mg kg <sup>-1</sup> )	10.5	21.5**	10.9	22.2
Extractable Ca (cmol <sup>(+)</sup> kg <sup>-1</sup> )	12.8	13.5	14.1	14.5
Extractable Mg (cmol <sup>(+)</sup> kg <sup>-1</sup> )	1.71	1.68	1.91	1.77
Extractable K (cmol <sup>(+)</sup> kg <sup>-1</sup> )	0.97	1.00	1.15	1.09
pH	6.10	6.29**	6.14	6.29*

<sup>1</sup>Absorption method data taken from Reganold et al. (1993).

<sup>+</sup>P<0.08; \*P<0.05; \*\*P<0.01.

Bulk density is related to mechanical impedance and soil structure, both of which affect root growth. Penetration or cone resistance is another assessment of mechanical impedance. Soils on the biodynamic farms had a lower penetration resistance at the 0-20 cm depth compared with the conventional farms. The difference was significant at the 0.01 percent level of probability with the absorption method and at the 0.08 percent level of probability with the block design; there were no differences between the two farming systems at the 20-40 cm depth.

Organic matter content, soil respiration, mineralizable nitrogen, and the ratio of mineralizable nitrogen to organic carbon were significantly higher for the biodynamically-farmed soils compared with the conventionally-farmed soils for both statistical methods (Table 1). The higher amount of organic matter on the biodynamic farms has contributed to better soil structure and consistence, and to lower bulk density and cone resistance than those of their conventional neighbors. It has also been shown that soil organic matter increases water storage, nutrient supply, and soil biological activity; improves soil productivity; and helps to reduce soil erosion (Johnston, 1986; Reganold et al., 1987).

Soil respiration is an indication of the soil microbial activity. The ratio of mineralizable N to C measures the activity of microorganisms that are specifically mineralizing N, which also gives some indication of soil microbial activity. Microbial activity is essential for maintaining and improving soil quality and productivity, and is responsible for the recycling of vital nutrients such as N, P and S for plant growth (Russell, 1988).

Earthworms were enumerated on the two vegetable farms for a further indication of biological activity. From 30 soil cores (15-cm diameter by 15-cm depth) taken on each field, we found the biodynamically-farmed soil to average 175 earthworms m<sup>-2</sup> compared to 21 earthworms m<sup>-2</sup> in the conventionally-farmed soil (Reganold et al., 1993). By mass, the biodynamically-farmed soil had 86.3 g of earthworms m<sup>-2</sup> while the conventionally-farmed soil had 3.4 g of earthworms m<sup>-2</sup>, more than a 25-fold difference. The larger earthworm numbers and mass on the biodynamic farms were most likely related to the use of pesticides on the conventional farms which have been shown to reduce earthworm populations (Reddy and Reddy, 1992; Springett and Gray, 1992) as well as the

higher organic matter content on the biodynamic farms (Marinissen, 1992).

Topsoil depth was significantly greater (average of 2.2 cm) on the biodynamic farms than on their conventional neighbors with both the absorption and block designs (Table 1). This difference in topsoil depth was partly related to the significantly lower bulk density on the biodynamic farms. The higher organic matter content and resulting biological activity contributed to a more rapid rate of topsoil formation on the biodynamic farms. Soil erosion was not significant on any of the fields in this study.

The results showed that of the nine chemical parameters evaluated, five gave statistically significant differences between the two farming systems. Using the absorption method, cation exchange capacity and total nitrogen were significantly higher on the biodynamic farms, while available phosphorus, available sulfur and soil pH were significantly higher on the conventional farms (Table 1). The results with the block design indicated only two differences; total nitrogen was significantly higher on the biodynamic farms and soil pH was higher on the conventional farms. There were a number of statistically significant differences in the amounts of phosphorus, sulfur, potassium, calcium, and magnesium between individual farm pairs (Reganold et al., 1993), although few differences were of biological significance (i.e., almost all soils were of adequate fertility for their respective crops) (Cornforth and Sinclair, 1984; Clarke et al., 1986).

## **Conclusion**

The biodynamic farms (compared with conventional farms) proved to have soils of higher biological and physical quality, significantly greater organic matter content and microbial activity, better soil structure, lower bulk density, easier penetrability, and greater depth of topsoil. The results of the soil nutrient analyses were variable. Earthworms were much more numerous on the biodynamic vegetable field than on the conventional vegetable field. Reganold et al. (1993) also found that the biodynamic farms were just as often financially viable on a per hectare basis as their neighboring conventional farms, as well as representative conventional farms in each study region. The data indicate that the principles and practices of biodynamic farming can contribute significantly to our goal of achieving a more sustainable agriculture and environment.

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