Farm Management and Soil Quality

An Investigation into the Effects of Conventional and Organic Crop Rotation Systems on Soil Quality Indicators

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Abstract

The physical and biological properties of soil from the pasture phase of organic and conventional crop rotation systems were compared. At the same time, a similar comparison was made of soil from the crop phase versus soil of the pasture phase of organic plots.

A search was started for a new biological indicator of soil quality. The potential use of the relative abundance of fluorescent pseudomonad bacteria in rhizosphere soil and on the rhizoplane of plants in conventional and organic plots was explored.

Soil respiration was also evaluated as an indicator of soil quality. Several soil amendments including earthworm casts, rhizosphere soil, compost material and biodynamic "preparation 500" were examined for their effect.

The research has concluded that;

1. The pasture phase of organic crop rotation had superior soil quality to the similar pasture phase of the conventional plot.
2. Though recently cultivated, the pasture phase of the organic rotation system was able to restore appropriate levels of soil quality.
3. The relative abundance of fluorescent soil pseudomonad bacteria was greater in soil from the organic plot.
4. Based on soil respiration activity, none of the organic amendments were able to show a stimulation of soil biological activity in soil from organic or conventional crop rotation plots.

Preface and Acknowledgements

Environmental issues are a hot item in many parts of the world. I have seen the contribution of farming towards environmental pollution in Europe and Central America. This made me realise that something was wrong with our attitude towards the environment. During my agricultural education I found out that the problem originated from our analytical way of thinking. This way of thinking made it possible that man analysed via a chemical approach all phenomenon's. Man discovered, for example, that plants consisted out of the elements N, P, K, S and other micro elements. With the support of Liebig's theory that plants take up nutrients in inorganic form it became the break through for mineral fertilisers especially soluble nitrogen compounds, phosphorus and potassium.

With the introduction of inorganic fertilisers a new era in the history of agriculture appeared. On every living phenomenon a chemical approach was practised.

Another consequence is that on the basis of sound physical and chemical analysis, individual factors are incorporated into farming practices. The totality of the living system is often lost. This is not only true for plants and animals but also for the

farm and environment. Through this way of thinking a rapid development took place in science and technology that brought us a high level of materialistic welfare. This way of thinking is also considered to be the main cause of our ecological crisis and welfare distribution.

Analytical thinking also causes alienation. The alienation from man and Nature, but also from man to man; man is manipulating nature, but also fellow human beings. A characteristic of alienation is a big emphasis upon thinking. Thinking controls the emotion, feelings, the experience of being connected with your own powers and the powers of nature and other human beings.
All of this turned agriculture into the industry it is today.

To counter act the mode of analytical thinking a new way of thinking has emerged namely systems thinking or holistic thinking. This reaction is becoming stronger every day and I feel obliged to support it as much as practically possible in this thesis.

Chapter 1 of this thesis gives some background information on the research project that is in line with the former mentioned holistic thinking mode. It gives a brief description of the two farming systems that were compared and evaluated on soil quality namely 'conventional farming' and 'organic farming'. It introduces soil quality that is a holistic idea. Soil quality indicators are used to compare and evaluate the plots. Chapter one also gives comprehensive information about the use of crop rotations as the basis of sound agricultural methods. The research objectives and methods will be introduced.

Chapter two gives a holistic literature study on `organic' crop rotation to show the value of a holistic approach as a complementary tool next to the analytical method. This chapter also includes a literature review of soil quality and the other studies which were; (1) the potential use of fluorescent pseudomonads as possible soil quality parameters, and (2) a laboratory experiment to evaluate the biological activity of some biological soil amendments and their influence on the biological activity of soils that have been treated with these soil biological amendments.

Chapter three comprises the comparison of the different plot management on soil quality indicators. It deals with materials and methods, and results and discussion respectively.

The next Chapter is about the potential use of fluorescent pseudomonads as indicator Species for soil quality.

Chapter five consists of materials and methods for the laboratory study on soil amendments and the results and discussion of this experiment. Chapter six is the overall discussion of the thesis.

Although the research did not develop smoothly, the encouraging motivation of some kept me going and I especially like to thank Dr. Neil Macgregor for this. He also broadened my horizons during the thought provoking meetings we had. Furthermore thanks to my other supervisor Dr Dave Scotter for his guidance during this work. Thanks also to Dr Ian Valentine who gave me a clearer insight into the changing world of Science, the incorporation of systems thinking in this University is clearly useful. I would also like to thank AgResearch; especially Willy Stiefel and Dr Alan Gillingham for the use of the plots on the organic unit of Flock House and their co-operation and information. Last but not least I like to thank my spouse Josje for her support during this whole process and Dick Kuiper for his last minute contribution in the editing of this thesis.

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1
Research Background

In the early sixties, Rachel Carson (1962) expressed her concerns about the abundant use of pesticides in agriculture, and its detrimental effects on the environment. Shortly after, Lynn White (1967) wrote an article in Science about "the historical roots of our ecological crisis". Their concerns about `modern day farming' were not widely recognised at the time.

In the last thirty years the problems have multiplied. High productivity has its costs: nutrients such as nitrate are lost to the environment causing disturbances to the natural flora and fauna; soils and soil life can be deteriorated by farm equipment, high stocking rate and agrochemicals; pesticides contaminate air, soil and water; their residues levels in food are rising and cause health risks (Watts, 1994), more and more land brought under irrigation to increase production is lost due to increased salinity; concerns about animal welfare are growing.

Nowadays, `modern-day farming' methods are the subject of constant concern of many throughout the world. Most European governments realise the magnitude of the problems and promote environment-friendly farming practices through legislation, subsidies and extension (Zoeteman, 1989). In many developing countries where the green revolution caused social, health and environmental problems, such as Indonesia, India and China, the governments promote integrated pest management practices (Van de Fliert, 1993). In Australia, Landcare is tackling environmental issues in catchment areas; its major goal is "to enable all landholders to understand and adopt sustainable land-use principles by the year 2000" (Melville, 1995). In all, one can say that more and more, and world-wide, ecological principles are being incorporated on farms to preserve the environment and to cater for the food concerns that consumers have. A new paradigm is coming up and challenging the old one: `organic farming'.

This chapter provides the background that allows the reader to put the literature review (Chapter 2) and research (Chapter 3, 4 and 5) into perspective. Section 1.1 & 1.2 give a brief description of the two farming systems that were compared and evaluated, namely `conventional farming' (what we used to call `modern-day farming' back in the sixties) and `organic farming'. The next section describes and defines crop rotation, which is the basis of sound agricultural practices. Subsequently, Section 1.4 introduces the concept of `soil quality', which will be used to compare and evaluate soils under different management systems. Finally, Section 1.5 presents the research questions and introduces the methodology used.

1.1 Conventional Farming

Since the eighteenth century, the joint efforts of modern agricultural science and technology development have changed farm management dramatically. Agriculture became technology-driven, with farmers constantly adopting innovations in order to increase yields, maximise profit, minimise year to year instability in production, and prevent long-term degradation of the productive capacity of the agricultural system (Watt, 1973). This development is sometimes referred to as "a race without a finish" (Coehoorn, 1995).

The emphasis on maximum production resulted in the exploitation of nature, made possible by the indifference of western Christian morals and values to the feelings of natural objects (White, 1967). Furthermore, conventional farming made us forget an important part of the management of a system, namely `system maintenance' (Hill *et al*, 1994). Lack of system maintenance creates long-term degradation of the productive capacity of an agricultural system (such as a plot, crop rotation, or farm). Some examples of such mismanagement are: leaving the soil bare (which causes soil erosion); applying soluble nitrogen under wet conditions (which increases leaching); and high stocking rates (which impoverishes soil structure). The folly of our emphasis on production over maintenance is especially evident in agro-ecosystems, where paying farmers only on the basis of yield has resulted in the degradation of everything, from gene pool, to soil, to natural systems of pest control, to rural communities (Hill *et al*, 1994). This has been accompanied by increasing dependence on inputs, subsidies and relief programs to keep things from `ticking over' and to avoid the inevitable drop in productivity. In this way the illusion of sustainability is maintained (Hill *et al*, 1994).

These problems originate mainly from a materialistic and reductionistic approach; scientists assume that the universe consist ultimately of matter, and concentrate their research efforts on a small segment of that universe, while ignoring higher order relationships with other segments. By "taking the whole to be the sum of its

parts the reductionistic method has been leading humankind into chaos" (Edelglass, 1992). In agriculture, soil science focused more and more on the relationship between soil nutrients and plant growth, while ignoring soil biology (which was regarded as belonging to a different discipline). From this research, soil scientists have often made recommendations about fertiliser use to increase production that disturbed the soil's mineral balance and impoverished soil flora and fauna (Zoeteman, 1989).

Reductionism, and the focus on increasing production, made us forget that more input into the farming system might cause disturbances on a higher level, due to losses of the farming system to the environment. Therefore, it can be concluded that agricultural phenomena must be researched on several levels, and from a variety of angles. In organic farming this more holistic approach to agriculture and agricultural science is taken.

1.2 Organic Farming

The earlier mentioned concerns about conventional farming were already felt by groups of farmers in Germany in the twenties. They asked Rudolf Steiner, a German scientist and visionary, to develop a more sustainable farming system. Steiner saw a farm as a living system within a hierarchy of living systems (Steiner, 1977). He promoted sound husbandry and research that would take into account the influences of farmers' action on higher levels of the hierarchy, such as the catchment area or region. Out of these farmer groups, the bio-dynamic movement emerged. A similar movement, inspired by Howard and Balfour, was set up in Britain (Balfour, 1975). This organic movement also promoted a more holistic approach towards farming. The world-wide organisation of both these movements is called IFOAM (International Federation of Organic Agricultural Movements).

The New Zealand Biological Producers & Consumers Council, who gives out the Bio-Gro certificate is accredited by this federation, their Organic Production Standards define organic agriculture as follows:

> *Organic agriculture - which includes such terms as biological husbandry, eco-agriculture, natural, sustainable and bio-dynamic - seeks to produce food of optimum quality and quantity, and to manage productive ecosystems according to a total concept that endeavour to make them sustainable and non-polluting of the environment, while providing an appropriate level of income to the producer(s), families and communities.* (Certified Bio-Gro Organic Production Standards, 1994).

Some of the main principles defined within the Bio-Gro Organic Production Standard are given in Appendix I. The most important principle of organic farming is that it is a `throughput' system, instead of the conventional `high-input high-output' system. It is a more or less closed system or a `low-input system', which works with Nature rather than trying to control or manipulate it. As a logical consequence of such a system, the burden on the environment should be as low as possible.

This is where modern, holistic, scientific research comes in; it has to evaluate which farming practices contribute towards a relatively closed system. Instead of reductionistic, analytic research methods, a more holistic approach is needed, which is often called `systems thinking' (Checkland, 1981).

Systems thinking has its origin in organismic biology. Early this century, organismic biologists doubted if reductionism was the best approach to answer the question: "what is a living organism?" (Sheldrake, 1981). They felt they needed a different approach, and developed systems thinking. The core of systems thinking is that we choose an entity, which we call a system, that can survive in a changing environment. This entity shows hierarchical structure, emergent properties (properties which characterise the whole but not the parts, they are hard to detect and measure with analytical tools) and cybernetic control (communication and feedback loops that allows the system to direct itself towards a (defined) goal).

1.3 Organic Crop Rotation

Crop rotation can be defined as:

> *Repeated cultivation of a succession of crops (as sole or mixed crops), possibly in combination with fallow, on the same land. One cycle often takes several years to complete* (Reijntjes *et al*, 1992).

Although crop rotation used to be common practice until the second world war, it is not any more. Some conventional farmers still use very short crop rotations (2 to 3 years), but they do not have all the emergent properties crop rotations could have. Organic farmers make better use of these emergent properties by using a longer crop rotation (3 to 8 years).

Organic crop rotation contributes towards a throughput system. Its purpose is twofold: to enhance biological diversity, and to reduces the dependency on agrochemical inputs (Reijntjes *et al*, 1992). A farm's biological diversity (a wide diversity of genetic resources) is important because it improves flexibility, which gives the system opportunity to react to changing circumstances (cybernetic control). With biological diversity, an ecological equilibrium becomes established, which makes the natural control of weeds, pests and plant pathogens more likely to be effective. Therefore, the farming system becomes less vulnerable to an occurrence of an population explosion of a specific pest or disease.

Crop rotation can also make farming systems less dependent on agrochemicals, such as soluble fertilisers and pesticides. For example, integrating legumes into the crop rotation system provides the soil with biological nitrogenous compounds through nitrogen fixation.

An effective organic crop rotation can be achieved on the basis of the following guidelines (Biologische landbouw, 1992):

(1) create a balance between crops which fix or contribute nitrogen, and crops which utilise nitrogen;

(2) create a balance between crops with a closed canopy (which stimulate soil life and suppress weeds), and crops which discourage abundant soil life and do not suppress weed growth;

(3) delay the reappearance of a crop in the same plot, so soil borne pests and diseases become more manageable;

(4) create a balance between crops that improve soil structure, and crops that impoverish soil structure;

(5) fresh animal manure as fertiliser should only be used in limited amounts because it might cause a dangerous rise in P and K levels (Janssen, 1986; Werff, 1992). Composted manure is preferred as its emergent properties contribute towards a better soil balance (Koepf, Pettersson and Schaumann, 1976).

Two very important factors in organic crop rotation need further explanation: nitrogen supply to plants; and pest and disease management possibilities.

1.3.1 Nitrogen Supply to Plants

In most cases the `ideal situation' and what we can achieve in practice are not the same thing. Because soluble fertilisers are not promoted in organic farming, the ideal situation would be when all the nitrogen used on the farm would come from biological nitrogen fixation. As P and K are quite easy to balance, and can easily be supplied by using e.g. organic wastes and rock phosphate, the farm lay-out or `crop rotation' composition should start with the nitrogen balance.

Nitrogen is fixed by rhizobium bacteria in the root nodules of leguminous plants. But not all legumes are capable of fixing large amounts of nitrogen. There are important differences between legume species and the rhizobium bacteria which colonise the legume roots. Nitrogen fixation also depends on the local conditions. The amount of nitrogen fixed can vary between 0 and 500-600 kg/ha/y. It is therefore important that in selecting the crops for a rotation scheme, the farm, farm location, and socio-economic considerations are taken into account.

The most common organic crop rotation schemes have a 2 year pasture of grasses and clover (or herbal leys), which suppresses perennial weeds, increases the soil organic matter content and improves soil structure (Lampkin, 1990; Werff, 1992).

1.3.2 Pests and Diseases

Crop rotations are used to prevent a build-up of soil borne pests, and to prevent an outbreak of plant and animal diseases (Lampkin, 1990; Altieri *et al*, 1982; Koepf *et al*, 1976; Oomen, 1992). To be effective, crop rotations should provide plants with a balanced supply of nutrients that originate from the soil. This balanced supply creates the right environment for stable plant development, and therefore produces a more resistant plant. A crop rotation of 2 to 5 years prevents many diseases and pests, such as soil fungi and nematodes.

On the other hand, crop rotation does not prevent outbreaks of pests and diseases that have a lot of host plants, as is the case with grubs and slugs. Neither does crop rotation protect against organisms which do not spent part of their life cycle in the soil, such as aphids, caterpillars, botrytis, mildew and rust. Furthermore, many pests and diseases spread because adult insects fly or because spores are picked up by wind currents, which crop rotation cannot prevent. But even if crop rotation will not stop these mentioned pests and diseases from occurring, it is still beneficial for the general health of a plant, and therefore increases its chances of surviving a major pest or disease outbreak.

1.4 Soil Quality

Farm management practices, such as crop rotation, influence soil characteristics, and therefore soil quality. The importance of air and water, two other great natural resources that can be degraded by human activity, is widely recognised. For the assessment of air and water quality, international accredited standards have been developed (Doran *et al*,

1992). For the assessment of soil quality, however, such standards do not yet exist. It is only recently that scientists became more concerned about the role of soils in sustainable production, and the linkages between soil characteristics and plant-human health (Doran *et al*, 1992). The recent recognition of Soil Quality by the Soil Science Society of America (Agronomy News, June 1995) and their conceptual definition of Soil Quality makes it possible to use soil quality indicators for a sustainability evaluation.

At the moment there is animated scientific debate about what soil quality actually is. To understand soil quality one must first be aware of the complexity of siol and its intrinsic value. According to the SSSA statement on soil quality `soil is a living system that represents a finite resource vital to life on earth. It forms the thin skin of unconsolidated mineral and organic matter on the earth's surface. It develops slowly from various parent materials and is modified by time, climate, macro- and micro-organisms, vegetation, and topography. Soils are complex mixtures of minerals, organic compounds, and living organisms that interact continuously in response to natural and imposed biological, chemical, and physical forces. Vital functions that soils perform within ecosystems include:(i) sustaining biological activity, diversity, and productivity; (ii) regulating and partitioning water and solute flow; (iii) filtering, buffering, degrading, immobilising, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric depositions; (iv) storing and cycling nutrients and other elements within the earth's biosphere; and (v) providing support for socio-economic structures and protection of archaeological treasures associated with human habitation.'

In general terms, soil quality is the capacity of the soil to function effectively at present and in the future. As this is still rather vague, the following definition of the SSSA (Agronomy News, June 1995) was adopted for this research:

> *Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.*

Although unstated, the definition also presumes that soil quality can be expressed by a unique set of characteristics for every kind of soil. It recognises the diversity amongst soils, and that a soil has excellent quality for one function or product can have very poor quality for another. Soil quality in its broadest sense is enhanced by land-use decisions that weigh the multiple functions of soil, and is impaired by land-use decisions that focus on single functions. Soil quality can be degraded by using inappropriate tillage and poor cropping practices; through excessive livestock grazing or poor timber harvesting practices; or by misapplication of fertilisers, animal manures, irrigation water, pesticides, and municipal or industrial by-products. To enhance soil quality, everyone must recognise that soil resource affects the health, functioning, and total productivity of all ecosystems.

It is clear from the definition that the concept of soil quality looks beyond soil fertility and maximum production; the definition stresses the importance of system maintenance. To sustain system maintenance, basic soil quality indicators are needed that monitor the effects of soil management, and that identify soil management problems.

A set of basic indicators of soil quality that is acceptable to all is, at this stage, not available. Several sets of indicators have been put forward (Doran *et al*, 1992; Reganold *et al*, 1993; Macgregor *et al*, 1995). The indicators that were used in this research to compare and evaluate organically and conventionally managed plots are derived from Macgregor *et al* (1995), and have proven themselves useful under similar conditions. They will be presented in Chapter 2.

1.5 Research Questions and Methodology

A comparison was made between two farm management systems which could be considered to be contrasting in their ability to sustain production in the long term: conventional farming and organic farming.

In organic farming, crop rotation is an essential part of the farming system. In conventional farming systems it is relatively unimportant. To sustain crop growth the conventional system uses nitrogenous fertilisers, while organic farms depend on biological nitrogen fixation by legumes such as pasture and greenfeeds. This usually reflects in a wider crop rotation on organic properties. Besides the decreased dependency on agrochemicals, pest and disease management seems to profit from wider crop rotation, as mentioned in 1.3. Organic crop rotation can therefore have a positive contribution towards sustainable land-use.

The first and main part of the research looked at how organic crop rotation, based on pasture phases, influenced a number of soil characteristics. The **research questions** that this segment tried to answer were:

(1) *Is there a difference in soil quality indicators between a pasture phase in a conventional crop rotation and a pasture phase in an organic crop rotation?*

(2) *Is there a difference in soil quality indicators between the cropping phase (disturbed) and the pasture phase (undisturbed) in an organic crop rotation?*

These questions were answered by using several soil quality indicators, partly in the field and partly in the laboratory.

Furthermore, the potential use of soil bacteria such as fluorescent pseudomonads as soil quality indicators of pasture/crop management was explored. Biological parameters seem to be more sensitive to changes in soil quality then chemical and physical parameters. The **Hypothesis** put forward in this thesis is that *the effect of each specific management regime (conventional versus organic) has a quantitative effect on the ecological niches available for occupancy by microorganisms.* The **research questions** formulated for this part of the research were:

(3) *Is there a potential use for fluorescent pseudomonads in the rhizosphere of pasture plants as soil quality indicators?*

(4) *Is there a potential use for fluorescent pseudomonads in the rhizoplane of pasture plants as soil quality indicators?*

In conclusion, a laboratory experiment was conducted to evaluate the biological activity of biological soil amendments. Furthermore it was investigated if these biological soil amendments influenced the biological activity of soils under organic management and soils under conventional management. The **research questions** that this experiment tries to answer, are:

(5) *Do the biological soil amendments have a high biological activity?* If so;

(6) *Do biological soil amendments affect the biological activity of soils under organic management and under conventional management?*

These questions were answered by measuring the biological activity of the biological amendments and soil samples with and without the amendments.

2
Literature Review

This chapter consists of three parts. First, a literature review that provides a holistic approach to the study of organic crop rotation. Second, a literature review of soil quality and a literature evaluation of fluorescent pseudomonads as potential soil quality indicators. And third, a literature review of the influence of soil amendments on soil biological activity

The purpose of Section 2.1 is to present a framework for studying the sustainability of agricultural systems; it complements the research described and discussed in Chapters 3, 4 and 5. The purpose of Sections 2.2 and 2.3 is to prepare the reader for reading these chapters.

2.1 Organic Crop Rotation within a Systems Hierarchy

Because the research presented in next three chapters is relatively reductionistic (it focuses on specific components of the crop rotation namely the soil of the selected plots), this literature review will introduce a more holistic view on agricultural systems.

2.1.1 Systems Thinking and Hierarchies

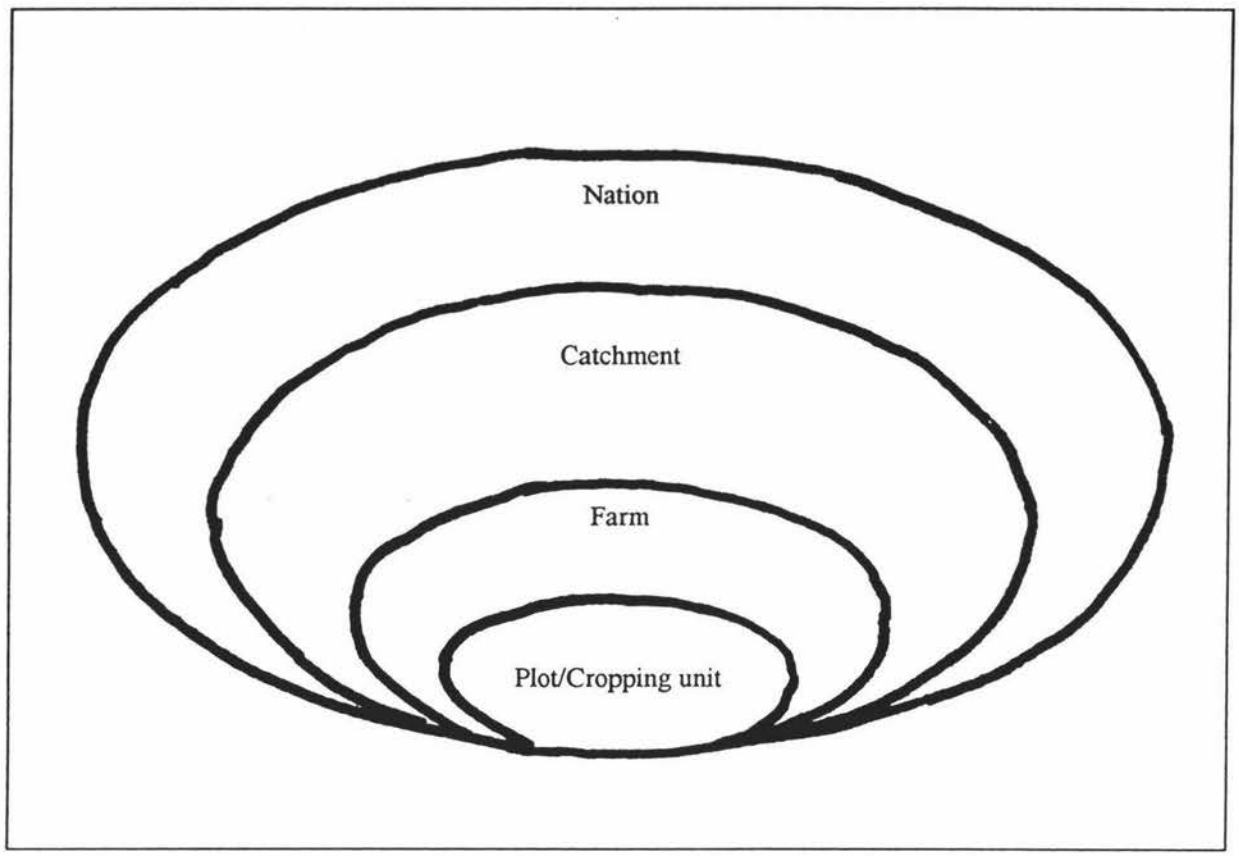
An introduction to systems thinking was given in Chapter 1. Agriculture consists of a hierarchy of ecosystems, ranging from the individual plant, animal or micro-organism, through to the global food system. Checkland (1981) implies that the behaviour of higher systems in such a hierarchy is not readily discovered simply from a study of the properties of lower systems, and vice versa. The well-being of each level (each system) depends on the successful functioning of the levels below (the system's components) and the level above (the system's environment) (Valentine, 1991).

To estimate the effects of organic crop rotation on the different ecosystem levels, an hierarchy of four levels is sufficient: (1) the field plot (pasture or cropping unit in the rotation); (2) the farm level; (3) the catchment area level, and; (4) the national level.

The field plot level includes the population dynamics that make up the plants, animals and microbes, which are the focus of organic crop rotation (including the immediate soil, air and water resources upon which these populations depend). On this level, biological processes and management actions determine what occurs within the field plot. At a level higher in the hierarchy, we find the first semi-autonomous social unit; the farm. The farmer sets goals by using management strategies, and works in a physical and socio-economic environment. The third level comprises the immediate environment of the farm: the catchment area. Finally, the national level combines all lower level systems. At this level the well-being of agriculture is vital for the maintenance of the whole hierarchy (Valentine, 1991).

On all four levels, human beings try to intervene by designing strategies, such as organic crop rotation. Each level can therefore be seen as a Human Activity System (HAS). A HAS is goal-oriented: on the one hand the system has developed, through time, some inherent mechanism to respond to outside stimuli and attain its goals; on the other hand the human element provides the possibility to redesign the system to achieve new goals (Valentine, 1991).

Figure 2.1: Hierarchical Levels



2.1.2 Indicators of Sustainable Agricultural Systems

Researching organic crop rotation in the light of sustainability as proposed by Conway (1985) and Valentine (1991) leads to the following theoretical approach. Conway and Valentine recognise sustainability as an emerging property of an agro-ecosystem. With the sustainability indicators that Valentine (1991) suggests, one could (in theory) come to a reasonable assessment of the contribution that organic crop rotation makes towards the sustainability of each ecosystem level. Table 2.1 lists for each level in the ecosystem hierarchy, the indicators suggested. Table 2.1 also shows the influence (positive or negative) of organic crop rotation on the indicators of each level (ranging from ++ = good; + = acceptable; $\pm$ = doubtful, to: ? = uncertain). The table is followed by a discussion and explanation of these rankings.

Table 2.1: Indicators of Sustainable Agriculture for Each Level in an Ecosystem Hierarchy (adapted from Valentine, 1991)

Field plot	farm	catchment	nation
soil organic matter ++	biological and economic diversity ++	water/air contamination +	secure genetic resource base ++
soil biological activity ++	balanced nutrient cycles +	water management ?	secure mineral resource base (P) +
soil pollution levels ++	controlled waste disposal ++	positive added value in foreign currency per unit of resource used in agriculture ++	positive balance of payment in agricultural sector ?
species invasion +	efficient water use ++		social acceptable commodities (residues, TB, etc) +
soil depth ++	profitable enterprises, job satisfaction +	rural community survival and support +	
++=Good; +=Acceptable; ±=Doubtful; ?=Uncertain			

1. FIELD PLOT LEVEL

Soil organic matter (++/good). Within an organic crop rotation, the organic matter content should stabilise because there is no demand from the crops on the stable humus content of the soil (Werff, 1992). My hypothesis would be that mineralization of fresh organic matter will create a balance between the synthesis and break down of humus molecules by micro-organisms. This balance should prevent a decrease in organic matter because all nutrient requirements for the crops

need to be met with legumes, crop residues, animal manure and compost (Werff, 1992; Lampkin, 1990). This is only possible with good maintenance/management, and needs proper monitoring.

Soil biological activity (++/good). Soil biological activity regulates soil organic matter, soil structure, and eventually crop productivity. Soil biological activity will also stabilise if there is sufficient supply of fresh organic matter (C is especially limiting in ecosystems; Gupta & Roper, 1994) to cover the food demand for the soil microbial population and the crop. Again, this means maintaining or increasing the soil organic matter. Soil organic matter will supply food for soil life and it creates an optimum environment for most of the useful soil organisms. Preventing the use of agrochemicals will also contribute toward a more harmonious biological activity in the soil (Bolton *et al.*, 1985; McGill *et al.*, 1986; Alef *et al.*, 1988; Dick *et al*, 1988). If mineral balances in the soil and ecological balances are not disturbed than a more harmonious and stable environment is created for soil life.

Soil pollution levels (++/good). When using a proper organic crop rotation, soil pollution levels will be low (depending, though, on the history of the site). Soil pollutants are substances that have accumulated to a concentration that is disturbing for all life depending on that soil (ranging from micro-organisms to plants, animals and humans). Most agrochemicals (certainly persisting agrochemicals like most of the pesticides) are not promoted. Increasing nutrients to a dangerous level is not likely under recycling conditions. Off-farm inputs need to be checked.

Species invasion (+/acceptable). Species invasion (weeds, pathogens, pests and diseases) in organic crop rotations will not be totally prevented but it will be manageable. Massive invasions are unlikely because of the ecological stable environment created by time and spatial diversity (Reijntjes, 1992). Existing ecological balances can be disturbed by excessive use of agrochemicals. The most disturbing factors will be the climate and other environmental factors. One should try to stay within those `natural boundaries' when designing a crop rotation.

Soil depth (++/good). Diversity of species in an organic crop rotation also includes diversity of root depth and root distribution. Deep rooting and well distributed rooted crops are part of the crop rotation (Lampkin, 1990; Werff, 1992). This will develop the soil structure and depth to an optimum level for crop production (which, in my opinion, in fact is deeper than the tillage layer normally used for accounting fertiliser requirements).

2. FARM LEVEL

Biological and economical diversity (++/good). Here trade-offs will have to be made to meet the criteria for an optimal organic crop rotation. It is not always sensible to use crops with the highest profits. Although it is not clear yet which degree of diversity is needed for productive ecosystems it is clear that diversity is needed to stabilise the agro-ecosystem. This will create a biological as well as an economic balance (UNDP, 1992).

Balanced nutrient cycles (+/acceptable). N, P and K requirements are mainly met by balancing demanding crops and giving crops (and organic farm wastes) (Lampkin, 1990; Werff, 1992). The discussion is that produce that leaves the farm will deplete the soil eventually. Nitrogen requirements can be supplied by biological fixation. P and K can be bought in as organic wastes or as mineral dusts (Lampkin, 1990; Werff, 1992).

Controlled waste disposal (++/good). Waste production is low because organic wastes are (re)cycled and agrochemicals are not used (NZBPC, 1994). Wastes will come from maintenance and cleaning of farm buildings and equipment. Problems with leaching of nitrogen from mineralization are not serious and can be reduced with the use of `catch' crops (Lampkin, 1990; Werff, 1992).

Efficient water use (++/good). The stability of the soil created with the help of optimum soil organic matter levels improves soil structure and the water retention capacity (Lampkin, 1990; Werff, 1992). This makes efficient water use dependent on the farmer's management skills; the soil is in an optimum condition.

Profitable enterprises, job satisfaction (+/acceptable). Trade-offs have to be made on the amount of highly profitable crops in the rotation scheme. Compared with a conventional farm the profits are likely to be less, but this is not necessarily so (Reganold *et al*, 1993). The organic farmer, being an idealist and nature lover, will be satisfied with a possibly lower but stable income and better balanced environment for the unforeseeable future.

3. CATCHMENT LEVEL

Water/air contamination (+/acceptable). The main water and air contaminants from organic crop rotation will come from maintenance and cleaning farm buildings and equipment, and fuel burning. Leaching and volatilisation losses will be very limited due to the ecological balance in

the soil created by the relative high organic matter content, of good quality (neutral colloidal humus), in the soil (Lampkin, 1990; Werff, 1992). Fuel burning caused by mechanisation of the cropping methods puts a constrain on the organic biological image because they are non-renewable resources. In the future electric motors might be an option because they can be used on wind or solar energies.

Water management (?/uncertain). Climatic stress will provide the boundaries for crop rotation. In dry areas trade-offs have to be made in the choice of crops and amounts of crops. Crop rotation might not be suitable.

Positive added value in foreign currency per unit resources used in agriculture (++/good). Organic crop rotation can be seen as a low input production system with produce for a niche market. The demand for organic produce is rising each year and premium price in Europe, USA and Japan are not exceptional (MAF Policy Position Paper 2).

Rural community survival and support (+/acceptable). Organic farming is establishing a better image with the public at large. Not too long ago it was not taken seriously. Rural communities could be partially self sufficient and thus independent, with a diversity of crops and animal products produced by local organic farmers. This will stabilise rural communities.

4. NATION LEVEL

Secure genetic resource base (++/good). The genetic resource base is secured because a crop rotation depends upon its environment. Shelter belts, natural corridors and forests in the neighbourhood of the farm would increase diversity and stabilise the system (Lampkin, 1990; Koepf *et al*, 1976). There will be a suitable environment for most species; micro flora and fauna, plants and animals.

Secure mineral resource base (+/acceptable). Organic farming, and thus crop rotation, does not have a high demand on agrochemicals. Nutrient recycling is the underlying principle of organic farming. This principle should secure the mineral resources in the system.

Positive balance of payment in agricultural sector (?/uncertain). Organic farming is likely to experience a decrease in production. It will definitely give a decrease in cash crops because the emphasis will be on a broader range of crops, not just commercially attractive crops (Lampkin, 1990; Koepf *et al*, 1976). The question will be to find a suitable market for these crops. At this

stage everything is still rather unpredictable. The major advantages of the products will be that they are really `clean and green'.

Socially acceptable commodities (+/acceptable). Diversity makes outbreaks of pest and diseases manageable; it creates conditions unfavourable for epidemic outbreaks. Nutrient balanced measurements should prevent environmental pollution, just like the low agrochemical use.

2.1.3 Conclusion

A general conclusion, at least in theory, is that a well designed and managed organic crop rotation will be beneficial for all four levels. It will possibly have a more favourable influence on the sustainability of these levels than most conventional agricultural practices.

Because of these findings, it was decided to take a closer look at the soil quality under such a system in practice. Comparisons were made between different stages of the organic cropping system, and between a pasture phase on the organic crop rotation and a pasture phase on the conventional crop rotation.

I would have preferred a more holistic approach including higher and lower levels of the hierarchy, but that would have asked for the combined efforts of a wider team of scientists and disciplines, a set-up beyond the scope of a normal M.Agr.Sc. thesis. Although research conducted on just one level will not clarify all management challenges, it will be a start.

In 2.1 we have been looking upwards from the field plot level to the other levels in the ecosystems hierarchy, and discussed how organic crop rotation influences these levels. In 2.2 and 2.3 the focus will shift downwards; we will look at the soil, an essential building block of each ecosystem, and how organic crop rotation influences some soil properties.

2.2 Soil Quality

The concept of soil quality was briefly explained in Chapter 1. The economic well-being of New Zealand and most other nations depends greatly on the soil and how well its productivity is maintained. Soil is the essence of human life and health, as it is the source of most of our food.

The soil, however, does far more for society than just produce food. A healthy or good quality soil can act as an environmental filter by cleansing air and water. If soil is managed properly it can favourably affect the carbon-dioxide balance, and therefore help us in combating global climate change. Soil is the ultimate receptor and incubation chamber for the decomposition and detoxification of organic wastes, and for recycling nutrients from these materials back to plants. But if the ecological balance in the soil is damaged permanently (mismanagement), the soil can work against us; it can pollute the air and water, and cease producing abundant and nutritious food. Many people believe that, within a community, there is a strong link between the health or quality of the soil, food quantity and quality, and health, well-being and prosperity of the people who are part of the community (Doran *et al*, 1992).

There is new emphasis on soil quality as a more sensitive and dynamic way to document the condition of our soils, how they respond to management changes, their resilience to stresses imposed by natural forces or farming practises. Possibilities for developing a soil quality index are being explored (Doran *et al*, 1992; SSSA, 1995). The emphasis given to physical and chemical properties as indicators of soil quality rather than to biological properties, is also changing. Biological and ecology-based indicators of soil quality are believed to be more dynamic and sensitive than those based on physical and chemical properties, and can therefore serve as early signals of soil degradation, or aggradation in the case of soil improvement (Doran *et al*, 1992). Reliable indicators will make it possible to monitor/evaluate the long-term impact of land use and management on soil and environmental quality.

2.2.1 Basic Soil Quality Indicators

A set of basic soil quality indicators that receive broad scientific recognition is not yet available, largely due to difficulties in defining and identifying what soil quality represents and how it can be measured. Our ability to identify basic soil properties that are able to serve as indicators of soil

quality is complicated by the many physical, chemical and biological factors involved and their varying interactions in time, space and intensity. Identifying a basic list of measurable soil properties can be a start. In order to be of practical use for a wide range of people, like scientists, farmers, extension workers and policy makers, a set of basic soil quality indicators should meet the following suitability criteria (adapted from Doran & Parkin, 1992):

(1) encompass ecosystem processes and relate to process oriented modelling;

(2) integrate soil physical, chemical and biological properties and processes;

(3) be accessible to many users and applicable to field conditions;

(4) be sensitive to variations in management and climate;

(5) where possible, be components of existing soil data bases.

Doran & Parkin (1992) proposed the set of basic indicators outlined in Table 2.2. They meet most of the above mentioned suitability criteria. This set is already a combination of other sets, such as the one put forward by Larson & Pierce (1991). Work done by Reganold *et al* (1993) and Macgregor *et al* (1995) on soil quality used several of the former mentioned indicators.

The emphasis of Reganold *et al* (1993) and Macgregor *et al* (1995) is on biophysical indicators. Macgregor *et al* (1995) report on the ability of specific biophysical measurements to distinguish between the quality of soil under organic land management from soil under conventional management. Their soil biophysical parameters include earthworm activity, microbial respiration, biologically mineralizable nitrogen, water infiltrability, physical penetration, and bulk density. They state that these parameters collectively have the ability to distinguish between soils receiving continual stewardship of soil organic matter and soils under conventional farming systems. Earlier, Reganold *et al* (1993) made the same point.

2.2.2 Fluorescent Pseudomonads as Potential Soil Quality Indicators

Several biological properties were suggested as potential soil quality indicators. The most acceptable one sofar is biological activity (Macgregor *et al*, 1995; Oades *et al*, 1993; Doran *et al*, 1993; Nannipieri, 1993; Jordan *et al*, 1993; Elliot, 1993). Other possibilities are being explored by varies scientists (Pankhurst *et al*, 1993). Rovira (1993) would be surprised if changes in farming systems did not lead to changes in the general soil biota as well as functional groups. Fluorescent pseudomonads are a functional group of micro-organisms (Rovira, 1993) and are relatively easy to

isolate from the soil around plant roots (rhizosphere) and from the surface of plant roots (rhizoplane). If one could identify their ecological value for soil and crops, they could become suitable indicators for soil quality. With this study a start was made to assess their potential value as a soil quality indicator.

Table 2.2: Proposed Soil Physical, Chemical and Biological Characteristics to be Included as Basic Soil Quality Indicators (adapted from Doran & Parkin, 1992)

SOIL CHARACTERISTIC	METHODOLOGY
Physical	
* Soil texture	* Hydrometer method
* Depth of soil and rooting	* Soil coring or excavation
* Soil bulk density and infiltration	* Field determined using infiltration rings
* Water holding capacity	* Field determined after irrigation of rings
* Water retention characteristics	* Water content at 33 and 1500 kPa tension
* Water content	* Gravimetric analysis; wt.loss, 24 h at 105 ^{0}C
* Soil temperature	* Dial thermometer or hand temperature probe
Chemical	
* Total organic C and N	* Wet or dry combustion
* pH	* Field or lab determined, pocket pH meter
* Electrical conductivity	* Field or lab, pocket conductivity meter
* Mineral N (NH_{4+} & NO_{3-}), P & K	* Field or lab analysis
Biological	
* Microbial biomass C & N	* Chloroform fumigation/incubation
* Potentially mineralizable N	* Anaerobic incubation
* Soil respiration	* Field measured using covered infiltration rings, lab measured in biomass assay
* Biomass C/Total org. C ratio	* Calculated from other measures
* Respiration/biomass ratio	* Calculated from other measures

The hypothesis adopted in this research is that the effects of each specific management presents unique ecological niches available for occupancy by micro-organisms, some beneficial and some detrimental to plant growth. Since no two farms, and probably no two paddocks, are managed in exactly the same way, farms and paddocks present a range of habitats and ecological niches, certainly at a micro-habitat level. Organisms best adapted to those habitats and niches will gradually replace those not so well adapted. An example given in the literature is the appearance of a root disease in one field, but not in the neighbouring field which reflects differences in management history (Cook, 1984).

Fluorescent pseudomonads were used in this research to test the hypothesis. If the research showed different numbers of fluorescent pseudomonads colonies under the two different agricultural systems, it is highly likely that they can be used as soil quality indicators. Which will be supportive of our hypothesis. Fluorescent pseudomonads were chosen for the research because they are relatively easy to isolate from the soil and the plant roots (rhizosphere and rhizoplane).

Older literature mentions fluorescent pseudomonads as plant pathogenic (Sands & Rovira, 1970). In recent literature there are indications that fluorescent pseudomonads can also be beneficial for plant growth. Sarathchandra *et al* (1993) observed that some fluorescent pseudomonads are antagonistic to some of the damping-off fungi. Wong (1993) mentions this antagonism in wheat. These antagonisms were shown in the field. Laboratory studies by Germida & de Freitas (1993) showed growth promotion of cabbage, lettuce and onion with fluorescent pseudomonads inoculations. Fluorescent pseudomonads have also been use as biocontrol agents (Moulin *et al*, 1993; Peixoto *et al*, 1993; Park & Yeom, 1993; Andrade *et al*, 1993; Lam *et al*, 1993; Lemanceau *et al*, 1993).

Rovira (1993) expects that we will be able to manage certain functional groups of the soil biota, such as fluorescent pseudomonads, by changing farming practices.

2.3 A Comparison of the Influence of Soil Biological Amendments on Biological Activity

The purpose of this study (Chapter 5) was to find out if certain biological amendments stimulate the biological activity of soils. The microbial biomass of a soil is a labile pool of soil organic matter,

with a high nutrient content and rapid rate of turnover (van Veen *et al*, 1985). It also represents a substantial pool of soil nutrients (Sparling *et al*, 1992) and is an active participant in nutrient cycling (McGill *et al*, 1986). Their important role in nutrient transformation (Doran, 1987) influences the fertility status of the soil. This means that loss of organic matter and of microbial activity can adversely affect the physical, biological and chemical status of soils (Carter, 1986; Carter and White, 1986). Soils managed with biological amendments generally have larger and more active microbial activity than those managed with agrochemicals (Bolton *et al*, 1985; McGill *et al*., 1986; Dick *et al*., 1988). The reliance of organic farming systems upon the activities of key soil biota to supply adequate levels of plant nutrients and the soils physical condition makes it worthwhile investigating some new biological soil amendments.

Claims are made that certain soil biological amendments increase soil biological activity. To examine some of these claims we selected several soil biological amendments for comparison: earthworm casts; rhizosphere soil; bio-dynamic preparation 500 (Koepf, *et al*., 1976); organic compost and; a commercial compost.

2.3.1 Earthworm Casts

Edwards & Lofty (1972) found indications in their research work that earthworm casts contain greater numbers of microbes then the surrounding soil. They also suggest that earthworms play a role in the dispersal of micro-organisms by excreting their spores. Because the excreted cast material from earthworms is usually rich in nitrogenous compounds, large numbers of earthworms in an organic soil not only help to decompose organic material in the soil by ingestion, disintegration and transport, but their waste products may also stimulate other microbial decomposition processes (Edwards & Lofty, 1972). Janssen (1988) concludes in his work on soil organic matter and soil fertility that earthworm casts are chemically and microbially richer then the surrounding soil. Because of these claims earthworm casts material was measured by the respirometer on biological activity. Earthworm cast material was also added to actually respiring soil to see if this would create a higher microbial activity in comparison to soil respiring without added earthworm cast material.

2.3.2 Rhizosphere Soil

There are numerous reviews of microbial occurrences and activity near plant roots (Curl & Truelove, 1986; Vancura & Kunc, 1988) and of the effects of micro-organisms on nutrient turnover and supply to plants (Clarholm, 1985; Coleman, 1986; Whipps & Lynch, 1986).

There is usually no distinct boundary between the rhizosphere soil and bulk soil. Bacterial populations most often dominate the rhizosphere (Curl & Truelove, 1986). There is a clear rhizosphere effect over a distance of a few microns, with an increase in numbers and diversity of morphologies near the root. It also seems that rhizosphere bacteria are, in general, larger than those in bulk soil, possibly reflecting better nutrition (Foster, 1986). Many bacteria contain storage materials. Considering these factors, it appeared that rhizosphere soil could be a useful soil biological amendment to stimulate soil microbial activity, and therefore it was included in this study.

2.3.3 Preparation 500

Biodynamic farmers claim that with the proper use of Preparation 500 one can enhance the biological activity of soils. To come to a better understanding of the use and benefits of this preparation, a brief introduction to biodynamics is needed. According to prominent biodynamic practitioners (Koepf *et al*, 1976) the following views are important to understand the way these preparations work.

The rationale underlying the preparations is different from the conventional approach to living nature (organicists and vitalists excluded (Sheldrake, 1981)) that searches for distinct metabolic mechanisms or active ingredients of one kind or another. The reality of life does not lie in individual components or mechanisms but rather in their interplay and their relation to the cycle of life. This cycle is completed under the influence of the forces that stream from the surrounding environment. Figure 2.2 shows two sets of environmental influences.

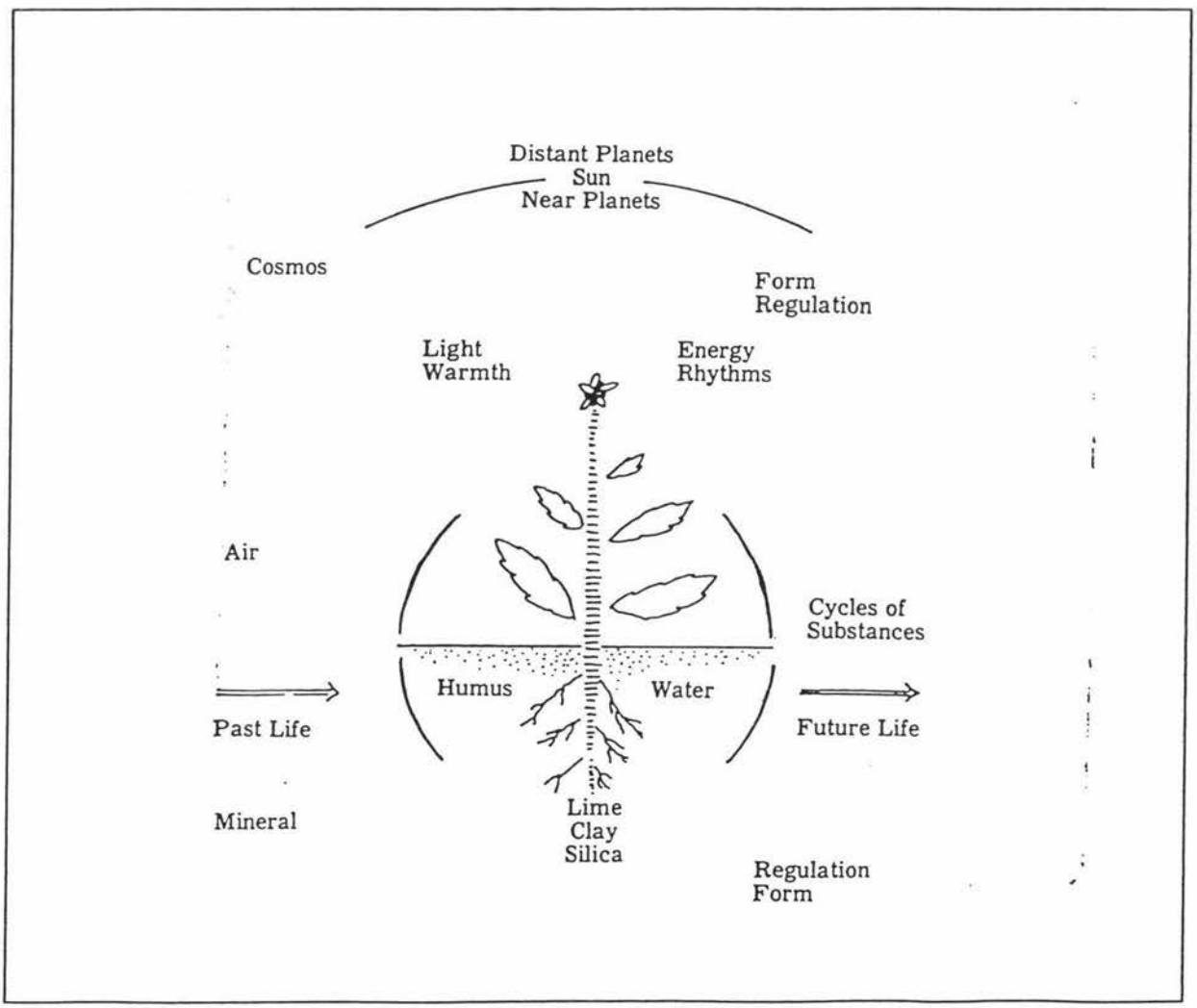
The plant is composed of substances that enter it from the soil, such as water, carbon and nitrogen. The carbon-dioxide pool in the atmosphere, from which the plant draws its carbon, is mostly replenished by the decomposition of organic residues in the soil; that is, it comes from past plant life. Nitrogen from the atmosphere is fixed by soil life.

Light, warmth and rhythms make up another set of environmental forces. Some mineral elements, such as magnesium, calcium and phosphorus, are contained in compounds that have

important physiological functions. Minerals regulate and fashion a multitude of metabolic processes, making energy transfer and enzymatic activities possible. In other words, earthly mineral elements play a correlating role to the cosmic pole of formative and regulative influences found in light and warmth and their seasonal rhythms (Koepf, 1986).

Plant growth unfolds between these two polar opposite sets of environmental forces, referred to as the earthly (or terrestrial) and the cosmic pole. Preparation 500 is supposed to stimulate these environmental forces. Plant growth under these two polar opposite influences is explained in detail in Koepf *et al* (1976).

Figure 2.2: Factors Influencing the Growth of Plants (adapted from Koepf, 1989)



Balancing these environmental conditions is very important. The preparations are claimed to be a tool for this purpose. Although research on these preparations has been conducted within the biodynamic movement (Koepf *et al*, 1976) it is still not widely excepted that there is an influence of the preparations on soil life and plants. This because research outside the movement has not been successful in replicating effects shown in biodynamic trials. The biodynamic movement claims that the scientists conducting this research did not understand the principles behind the use of the preparations, and therefore their experimental designs were not valid.

2.3.4 Compost

The microbial activity should be high because there is a high availability of nutrients in the medium. Organically made compost could be higher in microbial activity because the source of original material should be non-polluted. Therefor a n organic and a commercial compost were included in the research.

3

The Influence of Soil Management Practices on Soil Quality

This chapter compares plots on their soil quality. The plots compared have different management histories, as explained in Section 3.1. First, a number of soil quality indicators will be used to compare conventional crop rotation phase namely pasture with the same organic crop rotation phase. Second, the same indicators will be used to compare different stages within the organic crop rotation.

At the start of the research (spring 1993), five plots were chosen for the research. As time went on, it became apparent that not all the planned measurements could be conducted. Therefore, in the autumn of 1994 two plots had to be dropped. It was decided to continue with Plots 1, 3 & 5, in order to be in line with on-going soil fertility research conducted on these three plots (Sutassanamalee, 1995). The reason for concentrating on these plots is that it made shared publication of research results in a scientific journal possible.

3.1 Site Description

This part of the field research (looking at soil quality) was conducted at the Flock House Biological Development Research Unit (BDRU), administered by AgResearch New Zealand. The BDRU consists of two parts, namely a conventional farming system and an organic farming system (Figure 3.1).

The conventional system is a mixed farm of about 30 ha, with a conventional crop rotation, where all the usual conventional agrochemical inputs are being used. The organic system is a 44 ha mixed farm that has not received inputs of conventional fertilisers and pesticides since June 1988.

The plots chosen for the research are on an identical soil type. As they have different management histories, the influence of farm management on soil quality can be assessed.

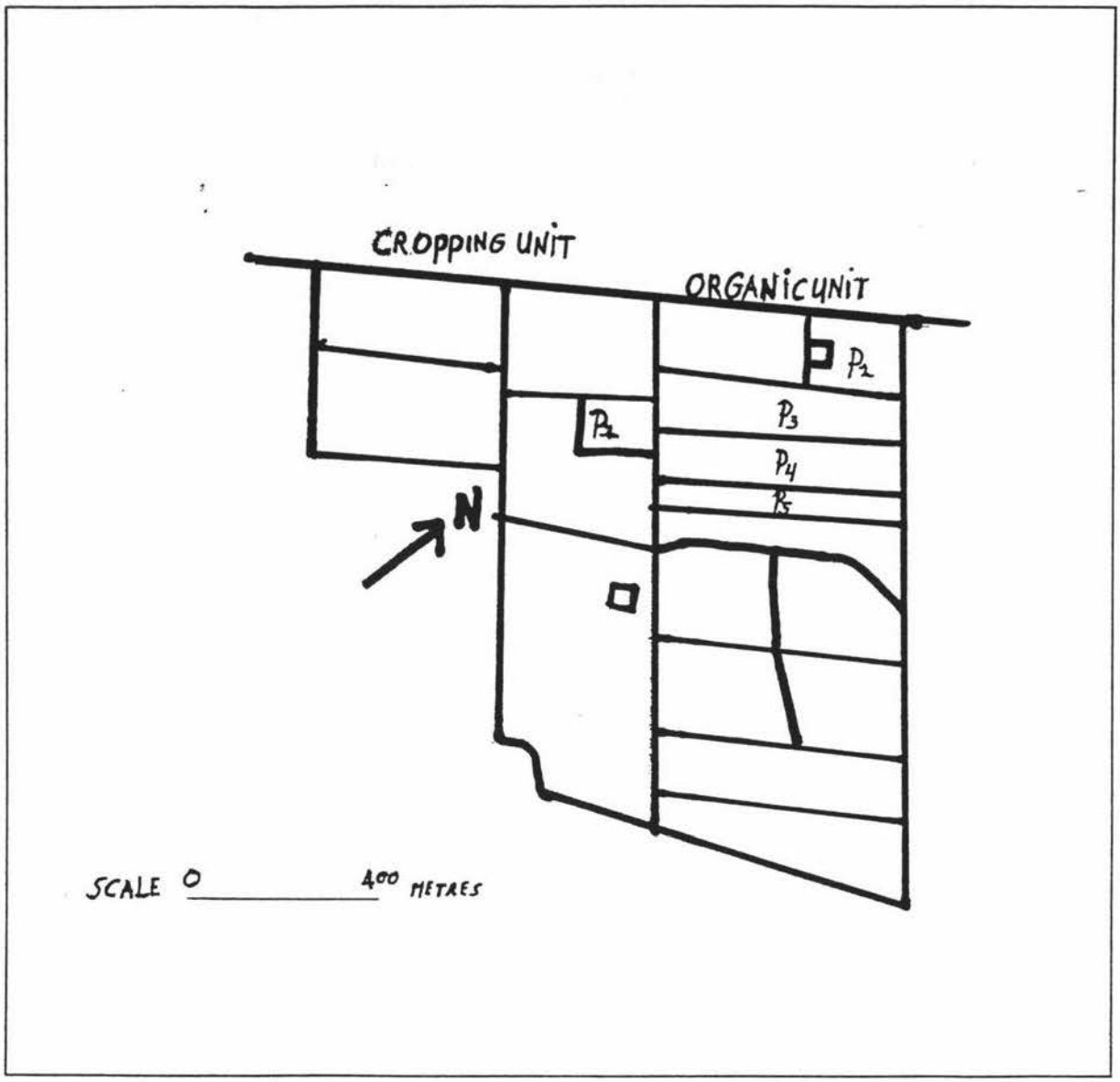


Figure 3.1: Flock House BDRU

3.1.1 Manawatu Silt Loam

The soils of the Manawatu region differ on a number of aspects from the soils of other North Island regions. The influence of volcanism is relatively minor as the area exists almost entirely of sedimentary rock. The climate differs as well. Temperatures are not much below those in the rest of the North Island, but the prevalence of strong to gale-force winds and lower annual rainfalls (800-1200 mm) can result in pronounced soil moisture deficits during summer and autumn (Molloy, 1988).

The parent materials of the soils in the Manawatu are shown in Figure 3.2. Nearly all soils have developed in drift materials (loess, windblown sands, or erosion debris in the hill country) or alluvial deposits (the stony and sandy materials of the youngest cold-climate floodplain, and the silty material of the Holocene floodplains) (Molloy, 1988).

The Manawatu silt loam, which is the soil type of the research site, is an alluvial soil developed at a higher level on the broader levees of the Rangitikei River. These higher soils are less susceptible to flooding than the lower Rangitikei soils which are sandy textured recent alluvial soils. The Manawatu silt loam soils are deep, with such good internal drainage and friability that they can be cultivated in all seasons (Molloy, 1988). They are the most versatile soils in the district and are suitable for market gardening, horticulture, cropping and dairying (Molloy, 1988).

3.1.2 History of the Plots

The research started off with five plots. Plot 1 is part of the conventional crop rotation at Flock House, which was set up as a comparison for the organic crop rotation. In 1993, Plot 1 was sprayed with Round Up and resown in Nui rye grass (high endophyte). The plot became part of a horse grazing rotation in 1993. Sward development was slow; up until November 1994 the drilling pattern was still visible (nearly closed). Plot 1 will be abbreviated as Conventional Plot (CP)

3.2 Materials and Methods

The soil quality indicators used can be divided into two categories, namely soil physical and soil biological indicators.

3.2.1 Soil Physical Indicators

Five soil physical indicators were used: (1) bulk density; (2) porosity; (3) macroporosity; (4) infiltrability, and; (5) penetration resistance.

1. BULK DENSITY

Cylindrical metal samplers, about 50 mm in diameter and 50 mm in length, were pressed into the soil at the desired sampling depth. The samplers, containing a known volume of sample, were then withdrawn from the soil and material outside of the sample volume removed. The samples were oven-dried at 105 ^{0}C, and weighed. Bulk density was calculated as the oven-dry mass of soil divided by the volume of the sample.

2/3. MACROPOROSITY AND POROSITY

Thin-walled cylindrical aluminium samplers, about 50 mm in diameter and 35 mm in length, were pressed into the soil at the desired sampling depth. The samplers and soil were then removed. In the laboratory the samplers were saturated and then placed on a suction plate at a pressure potential of -5 kPa for three days and then weighed. After oven-drying at 105 ^{0}C the samples were weighed again.

Particle density was determined by using 100 ml volumetric flask. Particle density measurements were needed to determine the porosity and macroporosity of the soil samples, as described in the following equations.

$$w = \frac{M_w}{M_d}(kg / kg)$$

w = gravimetric water content at -5 kPa (kg/kg)

M_w = mass of water in sample, pressure potential of -5 kPa (kg)

M_d = mass of dry soil (kg)

$$\Theta = w\frac{p_b}{p_s}$$

The volumetric water content at -5 kPa was obtained from the gravimetric water content at -5 kPa.

Θ = volumetric water content (m^3/m^3)

w = gravimetric water content at -5 kPa (kg/kg)

p_b= bulk density (kg/m^3)

p_s= particle density (kg/m^3)

$$f_m = f - \Theta$$

The total porosity (f) was determined from the particle density and the bulk density as $f=1-p_{b/p}s$. Total porosity minus the volumetric water content at -5 kPa gives the macroporosity (f_m):

f_m = macroporosity (m^3/m^3)

f = porosity ($m^{3/} m^3$)

Θ = volumetric water content (m^3/m^3)

4. INFILTRABILITY

Infiltrability, or infiltration rate, of the topsoil was determined using large cylindrical steel rings (200 mm wide and 150 mm high) in which water was pounded. The rings were pressed just

far enough into the soil to prevent water from leaking out. For subsoil measurements a circle (250 wide) was excavated to 350 mm depth. Within this circle a column of about 250 mm was left standing. This column was removed with care by breaking it off with the help of a spade. The bottom of the hole, created in this manner, was cleaned out with a vacuum cleaner before putting in the infiltration ring. Infiltration was allowed to proceed for 20 to 30 min. before measurements were taken. Readings were taken at regular intervals by recording the fall of the water level in the cylinder.

5. PENETRATION RESISTANCE

This was measured with a cone penetrometer (brand name=RIMIK). The penetrometer was pushed into the soil by hand at a constant rate. The pressure on the cone was recorded at regular depth intervals by a data recorder.

3.2.2 Soil Biological Indicators

The soil biological indicators used to assess soil quality were: (1) soil organic matter; (2) soil respiration; (3) earthworm counts and population development, and; (4) soil pH.

1. SOIL ORGANIC MATTER

Soil organic carbon was determined by two different methods:

A. Soil organic carbon determined by chemical oxidation. This method involves the oxidation of organic carbon using potassium dichromate under acid conditions. When concentrated H_2SO_4 is used, the heat-of-dilution may raise the temperature to 120 ^{0}C, sufficient to oxidise the bulk of the organic carbon. A correction factor of 1:33 is employed to account for the incompletely oxidised carbon. To calculate the percentage of soil organic matter soil carbon was multiplied with the factor 1.724 (Wakley-Black);

B. Soil organic carbon determined by combustion with the Leco furnace. The method involves the dry combustion of a sample in a stream of oxygen and trapping the produced CO_2 in ascarite (NaOH absorbed on asbestos). The amount of CO_2 trapped is calculated by weighing the ascarite trap before and after each oxidation.

Calculations:

$$C = \frac{CO_2 * 0.2729}{M_s}$$

C = total carbon percentage (%)

CO_2 = mass of CO_2 (Mg)

M_s = mass of sample (Mg)

2. SOIL RESPIRATION

The method involves measurements of oxygen consumption during biological oxidation of soil substrates by soil organisms (Reganold et al, 1993). Oxygen consumed is measured by manometry using a Gilson differential respirometer to compare the respiration activity of different soil samples which will reflect microbial activity. The procedure involves taking a soil sample and preparing a soil: water slurry and incubating the slurry with shaking in a closed manometric system. To measure only O_2 consumption during soil respiration CO_2 is removed by absorption onto KOH impregnated filter paper. Gas changes are measured in microlitres over the course of four hours of incubation and expressed on a dry soil basis. In general, additional oxidiseable substrate in the form of glucose was added to get clearer differences between the comparisons. This gives us a substrate induced respiration (O_2) with glucose amendment (Anderson and Domsch, 1978).

3. EARTHWORM COUNTS AND POPULATION DEVELOPMENT

Earthworm counts were performed over the winter period. Although there are many species of earthworms, for this research no distinction between different species was made. Soil samples were taken, first with a cylindrical sampler and later with a spade. Earthworms were counted by crumbling soil samples with a known volume.

4. SOIL pH

10 g of dry soil was stirred in 25 ml of distilled water, which was left over night. The pH was measured after calibrating the equipment (standard method).

3.3 Results and Discussion

As with the section on materials and methods, Section 3.3 is divided into soil physical and soil biological indicators of soil quality.

3.3.1 Soil Physical Indicators

The results of all measurements taken are summarised per plot in Appendix II. In the following, the results will be discussed for the parameters which showed significant statistical differences.

1. BULK DENSITY

Bulk density is the density of the whole soil, including the volume of the pores, but excluding the mass of water. It is a good indicator of the degree of soil compaction and varies widely from 0.04 Mg/m^3 for some peats to 1.8 Mg/m^3 for some sands or fragipans. As a rough guide, in finer-textured soils such as silt loams root penetration may be inhibited if the bulk density is greater than 1.5 to 1.6 Mg/m^3.

The bulk density was measured three times; in summer, autumn and spring of 1994.

(A) Summer 1994. The topsoil (0-5 cm) was sampled from all five plots, the results were analysed with Duncan's Multiple Range Test of the SAS software package.

Looking at the summer results (Table 3.2), it seems fair to say that the three pastures (Plot 1, 2 & 3) had the greatest bulk density. An explanation might be the regular cultivation (disturbance) of the cropping plots (Plots 4 & 5). Comparing the pasture plots (1, 2 & 3) with each other there is some evidence that the soil under organic pasture had a lower bulk density than the conventional pasture soil; as Plot 3 was significantly different from Plot 1.

Table 3.2: Topsoil (0-5 cm) Bulk density (summer 1994)
Duncan's Multiple Range Test

Plot	*N*	*Bulk density ((Mg/m³)*	*DUNCAN GROUPING*				
			Plot 1 CP	Plot 2 OP	Plot 3 OP	Plot 4 OP	Plot 5 OP
Plot 1 CP	9	1.30	*	NSD	SD	SD	SD
Plot 2 OP	10	1.28	NSD	*	NSD	SD	SD
Plot 3 OP	9	1.23	SD	NSD	*	SD	SD
Plot 4 OP	10	1.16	SD	SD	SD	*	NSD
Plot 5 OP	9	1.15	SD	SD	SD	NSD	*

N=Number of samples; α (designed significant level of error rate)= 0.05);

SD=Significantly different; NSD=Not significantly different

There was no significant difference between the two cropping plots (4 & 5).

(B) Autumn 1994. Samples were taken from all five plots at four depths; 0-5, 10-15, 20-25, and 30-35 cm. The results for the first depth (0-5 cm, called `topsoil') and the last depth (30-35 cm, called `subsoil') were analysed with Duncan's MRT (SAS). As the subsoil analyses with Duncan's MRT (SAS) showed no significant differences, Table 3.3 only shows the results for the topsoil. The topsoil analyses in autumn (Table 3.3) gave a similar picture to those in summer, although the differences were not as clear any more. This means that the earlier conclusions ("soil under organic pasture had a lower bulk density when compared to soil under conventional pasture") has to be treated with care. There seems to be a slight decrease in the bulk density of the pastures (Plots 1, 2 & 3), which could be an indication of a positive influence of the pasture phase on soil bulk density.

Table 3.3: Topsoil (0-5 cm) Bulk Density (autumn 1994)
Duncan's Multiple Range Test

Plot	*N*	*Bulk Density (Mg/m^3)*	*DUNCAN GROUPING*				
			Plot 1 CP	Plot 2 OP	Plot 3 OP	Plot 4 OP	Plot 5 OP
Plot 1 CP	10	1.28	*	NSD	NSD	SD	SD
Plot 2 OP	10	1.25	NSD	*	NSD	SD	NSD
Plot 3 OP	9	1.22	NSD	NSD	*	NSD	NSD
Plot 4 OP	10	1.15	SD	SD	NSD	*	NSD
Plot 5 OP	10	1.20	SD	NSD	NSD	NSD	*

N=Number of samples; α (designed significant level of error rate)= 0.05);
SD=Significantly different; NSD=Not significantly different

There was a big increase in bulk density for Plot 5, which is explainable because just before the first measurement (summer measurement) it had been cultivated. After cultivation the bulk density is relatively low and will, as shown, increase due to the aggregates settling. From the detailed data in Appendix II it can be seen that bulk density increases with depth, which is common.

(C) Spring 1994. From Plot 1, 3 and 5, samples were taken at four depths; 0-5, 10-15, 20-25, and 30-35 cm. The first depth (0-5 cm, called `topsoil') and the last (30-35 cm, called `subsoil') were analysed with Duncan's MRT (SAS). Again in the subsoil analyses there were no significant difference between the plots, so only the 0-5 cm data are shown in Table 3.4. The spring analyses of Plot 1, 3 and 5 (Table 3.4) would be surprising without an explanation. Several changes occurred which were not anticipated when the research started. Plot 3 was cultivated just before the measurements were made (November 1994) as a preparation for a pumpkin crop over summer, which explains the drop in bulk density.

Table 3.4: Topsoil (0-5 cm) Bulk Density (spring 1994)
Duncan's Multiple Range Test

Plot	*N*	*Bulk density (Mg/m^3)*	*DUNCAN GROUPING*		
			Plot 1 CP	Plot 3 OP	Plot 5 OP
Plot 1 CP	10	1.21	*	SD	NSD
Plot 3 OP	9	0.99	SD	*	SD
Plot 5 OP	8	1.27	NSD	SD	*

N=Number of samples; α=0.05;
SD=Significantly different; NSD=Not significantly different

this means that it no longer could be compared with Plot 1. Due to the very wet conditions, Plot 5 had been water-logged and partly pugged. This might explain the high bulk density of Plot 5. The bulk density under Plot 1 tends to be lower than earlier. It went from 1.30 Mg/m^3 (summer) to 1.28 Mg/m^3 (autumn) to 1.21 Mg/m^3 (spring). The management interruption of Plot 3 left only two valid measurements (summer and autumn), and they tend to decrease as well over time. A statistical analysis was not performed due to lack of proper data for a comparison of the plots.

Comparing the conventional pasture plot (1) with the organic pasture plots (2 and 3) for bulk density over the measured time gave no confincing evidence of a negative influence of agro-chemicals on bulk density since the differences between the conventional pasture and the organic pasture in general were not significant (1 out of 4 comparisons showed a significant difference).

2/3. POROSITY AND MACROPOROSITY

Porosity is the fraction of the soil volume consisting of pores. The porosity is between 30% and 75% in most soils, although peats can have much higher values. Macroporosity (as used in the research) is defined as the volume of macropores (> 0.06 mm in diameter) divided by the total soil

volume. As an approximate guide a macroporosity greater than 0.08 is desirable, while a value of less than 0.05 may imply aeration problems.

Porosity and macroporosity were measured on two occasions (summer and spring 1994). There was no significant difference in the subsoil (30-35 cm) between the plots, for either the porosity or for macroporosity.

Table 3.5: Topsoil (0-5 cm) Porosity (summer 1994)
Duncan's Multiple Range Test

Plot	*N*	*Porosity* (M^3/M^3)	*DUNCAN GROUPING*				
			Plot 1 CP	Plot 2 OP	Plot 3 OP	Plot 4 OP	Plot 5 OP
Plot 1 CP	9	0.50	*	SD	SD	NSD	NSD
Plot 2 OP	10	0.58	SD	*	NSD	SD	SD
Plot 3 OP	9	0.54	SD	NSD	*	SD	SD
Plot 4 OP	10	0.51	NSD	SD	SD	*	NSD
Plot 5 OP	9	0.49	NSD	SD	SD	NSD	*

N=Number of samples; α=0.05;
SD=Significantly different; NSD=Not significantly different

Comparing the results for the pasture plots (1, 2 & 3) gives the following indications. The two organic pasture plots (2 & 3) were significantly different from the conventional pasture plot (1) in the summer measurements (Table 3.5). The cropping plots (4 & 5) showed no significant difference between each other; they were also not significantly different from the conventional pasture plot (1).

These result might be a bit misleading because an average particle density (over the five plots) was used to calculate the porosity. This because with the measurements of organic matter content, which also reflect particle density, it seemed not necessary to do particle density as well (at

that time). This might explain the difference between Table 3.2 and Table 3.5. The sampling for the summer bulk density was done at an other time and with other aluminium cylinders than for the summer porosity (and macroporosity). I realise now that the data of Table 3.5 are suspicious as are the data from Table 3.7 which come from the same sampling and calculation procedure.

Table 3.6: Topsoil (0-5 cm) Porosity (spring 1994)
Duncan's Multiple Range Test

Plot	*N*	*Porosity* (M^3/M^3)	*DUNCAN GROUPING*		
			Plot 1 CP	Plot 3 OP	Plot 5 OP
Plot 1 CP	10	0.54	*	SD	NSD
Plot 3 OP	9	0.62	SD	*	SD
Plot 5 OP	8	0.53	NSD	SD	*

N=Number of samples; α=0.05;
SD=Significantly different; NSD=Not significantly different

The spring results (Table 3.6) seem to confirm the conclusion from Table 3.5; Plot 3 is still significantly different from Plot 1. This means a greater porosity for Plot 3, probably due to cultivation, when compared to the conventional pasture phase. Within the organic crop rotation it is clear that the recent cultivated pasture plot (3) has greater porosity (Plot 3 & 5 are significantly different).

The result of macroporosity (Table 3.7 & 3.8) were similar to the results of porosity (due to correlation). The same conclusion can be drawn for the summer results of macroporosity as before with porosity. These conclusions should be looked at with care as it was the case with porosity. From the spring results of macroporosity the same conclusion can be drawn as with the spring results of porosity. Also the conventional pasture plot (1) is not significantly different from the two cropping plots (4 & 5), which was also the case with porosity.

Table 3.7: Topsoil (0-5 cm) Macroporosity (summer 1994)
Duncan's Multiple Range Test

Plot	*N*	*Macro-porosity* (M^3/M^3)	*DUNCAN GROUPING*				
			Plot 1 CP	Plot 2 OP	Plot 3 OP	Plot 4 OP	Plot 5 OP
Plot 1 CP	9	0.12	*	SD	NSD	NSD	NSD
Plot 2 OP	10	0.18	SD	*	NSD	SD	SD
Plot 3 OP	9	0.14	NSD	NSD	*	NSD	NSD
Plot 4 OP	10	0.12	NSD	SD	NSD	*	NSD
Plot 5 OP	9	0.10	NSD	SD	NSD	NSD	*

N=Number of samples; α=0.05
SD=Significantly different; NSD=Not significantly different

4. INFILTRABILITY

Infiltrability of the soil at a particular site is defined as the maximum rate at which it can absorb rainfall or irrigation.

Infiltrability was measured during summer and winter, at two different depths: 0 cm and 35 cm (respectively called topsoil and subsoil measurements). The subsoil results showed no significant differences in summer or in winter, and are therefore not included in this chapter. Tables 3.9 and 3.10 indicate that there is a difference between the long-term pastures organically managed (Plot 2 & 3) and the long-term pasture conventionally managed (Plot 1).

Table 3.8: Topsoil (0-5 cm) Macroporosity (spring 1994)
Duncan's Multiple Range Test

Plot	*N*	*Macro-porosity (M^3/M^3)*	*DUNCAN GROUPING*		
			Plot 1 CP	Plot 3 OP	Plot 5 OP
Plot 1 CP	10	0.16	*	NSD	NSD
Plot 3 OP	9	0.19	NSD	*	SD
Plot 5 OP	8	0.14	NSD	SD	*

N=Number of samples; α=0.05;
SD=Significantly different; NSD=Not significantly different

In summer (Table 3.9) both organic pasture plots (2 & 3) have a higher mean than the conventional pasture plot (1), with Plot 2 significantly higher than Plot 1.

In winter (Table 3.10) Plot 1 is significantly lower than Plot 3. It seems fair to say that under organic conditions the infiltrability is slightly better on long-term pasture. On the other hand, the significant difference between Plot 2 and Plot 3 in the summer result might indicate that other management factors masked clear differences between organic and conventional pasture. Grazing management could be a factor as well. Within the organic crop rotation, pasture (undisturbed; Plot 2 & 3) seems to be better than the cultivated (disturbed; 4 & 5) plots.

Table 3.9: Topsoil Infiltrability (summer 1994)

Duncan's Multiple Range Test

Plot	*N*	*Infiltra-bility (mm/h)*	*DUNCAN GROUPING*				
			Plot 1 CP	Plot 2 OP	Plot 3 OP	Plot 4 OP	Plot 5 OP
Plot 1 CP	7	135	*	SD	NSD	NSD	NSD
Plot 2 OP	7	364	SD	*	SD	SD	SD
Plot 3 OP	7	228	NSD	SD	*	NSD	NSD
Plot 4 OP	7	140	NSD	SD	NSD	*	NSD
Plot 5 OP	7	167	NSD	SD	NSD	NSD	*

N=Number of samples; α=0.05;

SD=Significantly different; NSD=Not significantly different

Table 3.10: Topsoil Infiltrability (winter 1994)

Duncan's Multiple Range Test

Plot	*N*	*Infiltra-bility (mm/h)*	*DUNCAN GROUPING*		
			Plot 1 CP	Plot 3 OP	Plot 5 OP
Plot 1 CP	7	142	*	SD	NSD
Plot 3 OP	7	397	SD	*	SD
Plot 5 OP	7	197	NSD	SD	*

N=Number of samples; α=0.05;

SD=Significantly different; NSD=Not significantly different

5. PENETRATION RESISTANCE

Penetration resistance of a soil is its resistance to penetration with a cone of a given diameter. Measuring penetration resistance is important because it can detect compacted layers that inhibit root development.

Penetration resistance measurements were performed on the same day in spring 1994 to make fair comparison between the plots possible. Plot 2 and 3 were just cultivated for a cropping period, which was not anticipated. This makes a topsoil (< 200 mm) comparison between long-term pastures (Plot 1, 2 & 3) no longer valid, as the cultivation clearly influenced the results. Subsoil (> 200 mm) comparisons between all plots are still valid.

Figure 3.3 shows the comparison. Overall, Plot 3 showed the lowest penetration resistance at all depths. For the topsoil this was not surprising because of recent cultivation; for the subsoil the conclusion can be drawn that the organic pasture phase gave a lower penetration resistance. Plot 2 went from being a good second in the topsoil (due to recent cultivation) to being the most resistant at greater depth. This contradicts the conclusion that an organic pasture phase leads to decreased penetration resistance. An explanation may be that Plot 2 had a shorter pasture phase than Plot 3. Overall, Plot 4 was the one with the second lowest penetration resistance. Plot 1 (conventional pasture) had an overall high penetration resistance, especially around cultivation depth (100-225 mm), This is probably due to the fact that it is the only plot without cultivation during recent years. Plot 5 (organic cropping) had a high penetration resistance in the topsoil and at greater depth (>325 mm). This is remarkable, especially for the topsoil, because there had been recent cultivation's on this plot similar to Plot 4 (organic cropping). An explanation might be that Plot 5 suffered from water logging and pugging due to a high stocking rate in spring 1994. Table 3.11 shows a comparison between the penetration resistance for the plots, using Duncan's MRT's. At a depth of 225 mm there were no significant differences between the plots. This indicates a compaction layer in all plots, due to (former) cultivation. Above and below this level there were significant differences.

Figure 3.3: Penetration Resistance

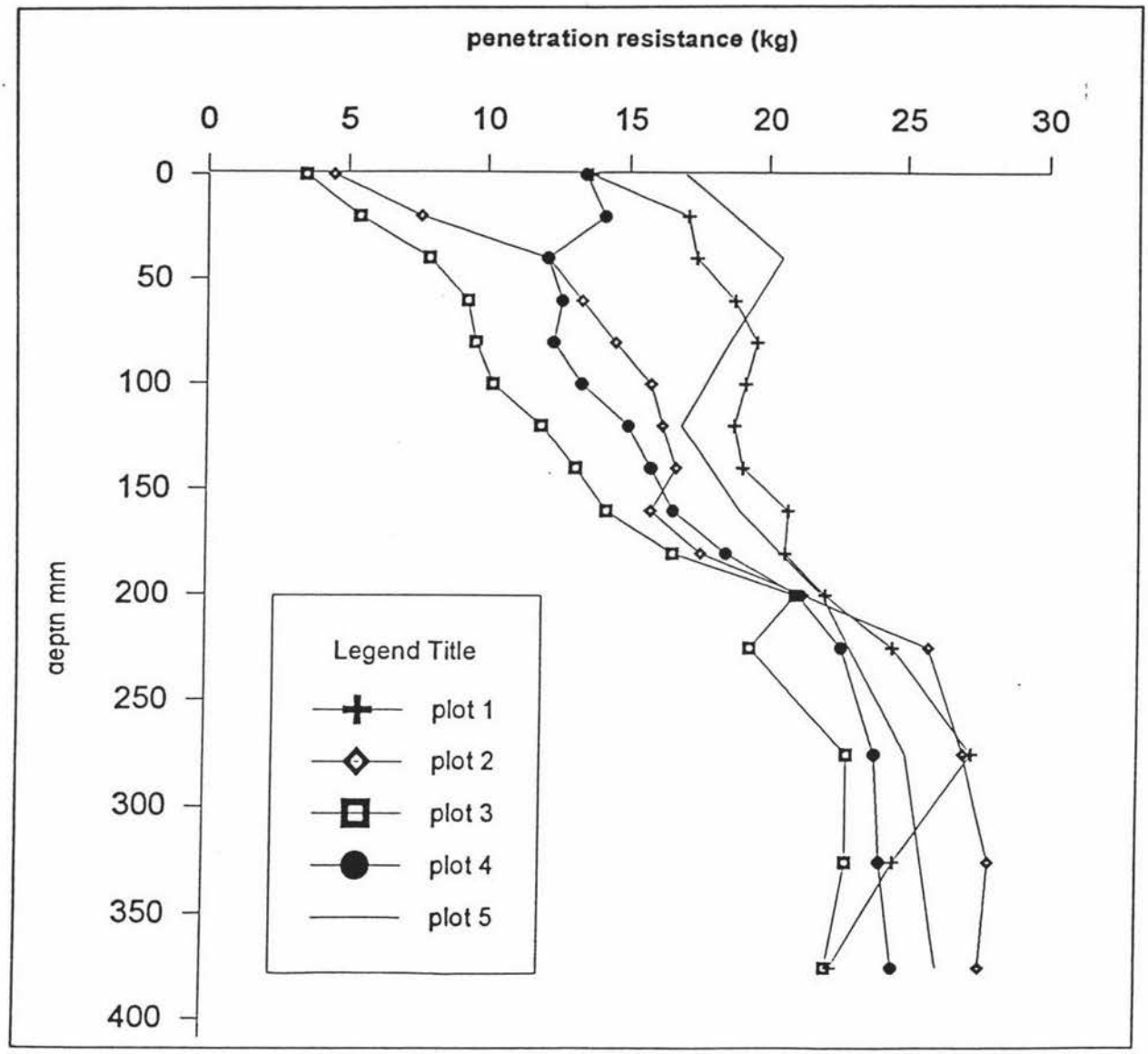


Table 3.11: Penetration Resistance (kg)

Duncan's Multiple Range Test

Depth (mm)	*Plot 1* *CP*	*Plot 2* *OP*	*Plot 3* *OP*	*Plot 4* *OP*	*Plot 5* *OP*
0	13.6^{A}	4.5^{B}	3.5^{B}	13.4^{A}	17.0^{A}
20	17.1^{B}	7.6^{C}	5.4^{C}	14.1^{B}	21.5^{A}
40	17.4^{A}	12.1^{B}	7.9^{C}	12.8^{B}	20.5^{A}
60	18.8^{A}	13.3^{B}	9.3^{C}	12.6^{B}	18.9^{A}
80	19.6^{A}	14.5^{B}	9.6^{C}	12.3^{BC}	18.6^{A}
100	19.2^{A}	15.8^{BC}	10.2^{D}	13.3^{C}	18.3^{AB}
120	18.8^{A}	16.2^{A}	11.9^{B}	15.0^{AB}	16.9^{A}
140	19.1^{A}	16.7^{A}	13.1^{B}	15.8^{AB}	17.4^{A}
160	20.8^{A}	15.8^{BC}	14.2^{C}	16.6^{BC}	19.0^{AB}
180	20.7^{A}	17.6^{AB}	16.6^{B}	18.5^{AB}	19.4^{AB}
225	22.2^{A}	21.4^{A}	21.1^{A}	21.2^{A}	22.1^{A}
275	24.6^{A}	25.9^{A}	19.4^{B}	22.8^{AB}	23.9^{A}
325	27.5^{A}	27.2^{AB}	23.0^{C}	24.0^{BC}	25.1^{ABC}
375	24.7^{AB}	28.1^{A}	23.0^{B}	24.2^{B}	25.6^{AB}
425	22.5^{B}	27.8^{A}	22.3^{B}	24.7^{AB}	26.3^{AB}

^{A,B,C}=Data in the same row with the same letter are not significantly different; α=0.05

One would expect a similar behaviour for Plot 1, 2 and 3 below the cultivation layer (top soil comparisons were no longer valid due to the not anticipated cultivation of Plot 2 & 3) because they all have a long-term pasture history. There are some significant differences between the three plots, but Plot 1 (conventional) is not significantly different from both organic pasture plots (2 & 3) at any depth.

6. OVERALL CONCLUSION FOR SOIL PHYSICAL INDICATORS.

In our situation it seems fair to conclude that other management factors, like grazing masked any clear difference between the organic and the conventional pasture.

It is also clear that cultivation, within the organic crop rotation, has an influence on soil physical indicators. On the basis of this research it is not possible to conclude if there will be a short-term or long-term negative or positive influence on soil physical properties.

3.3.2 Soil Biological Indicators

1. SOIL ORGANIC MATTER

Soil organic matter is all material in the soil that originates from life, such as humus, roots, bacteria and fungi. It is an important component of the soil and the most difficult one to grasp and interpret.

In spring 1993, a preliminary study was carried out to see if there was scope for a follow-up. Plot 1 to 5 were analysed on four depths with the following results (Figure 3.4). In Figure 3.4 there is no difference between the pasture phases of Plot 2 and 3. The pasture phase of Plot 1 shows a similar pattern, but is overall lower in soil organic matter content. The organic matter content data for the two cropping plots (4 & 5) look similar.

Figure 3.4: Organic Matter Distribution (spring 1993)

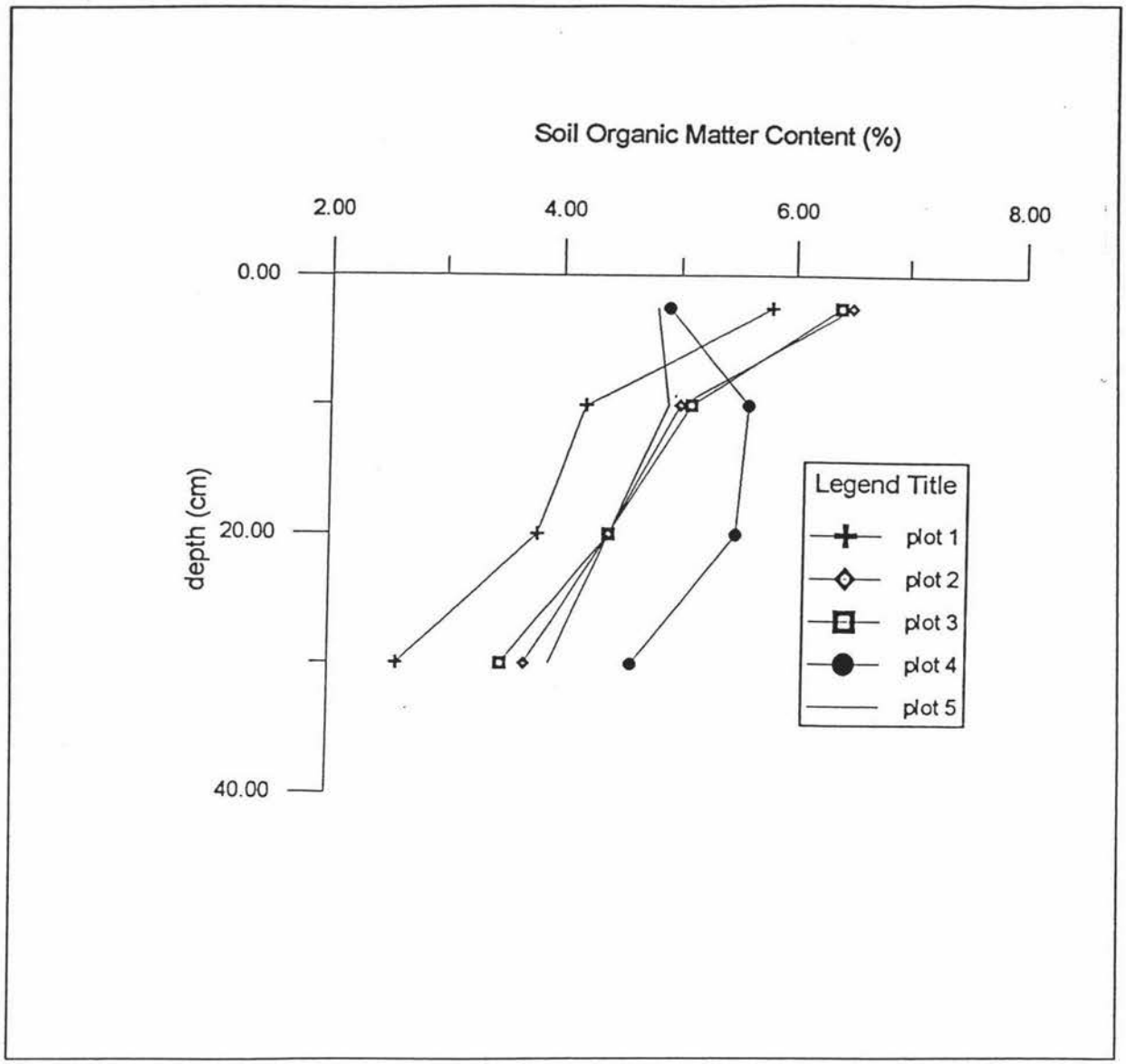


Figure 3.4 indicates that follow-up research would be valid. There is a difference between the two organically managed pastures (Plots 2 & 3) and the conventionally managed pasture (Plot 1). There is also a difference within the organic crop rotation (Plots 2 & 3 versus Plots 4 & 5). This demonstrates a difference in soil organic matter content due to management history. A detailed analysis was performed with SAS in the form of a factorial design, which is attached in Appendix III.

In autumn 1994, a second analysis was conducted to make a comparison for the topsoil (0-5 cm) with the results of spring 1993.

Table 3.12: Topsoil (0-5 cm) Organic Matter Content (autumn 1994)
Duncan's Multiple Range Test

Plot	*N*	*Organic Matter Content (%)*	*DUNCAN GROUPING*				
			Plot 1 CP	Plot 2 OP	Plot 3 OP	Plot 4 OP	Plot 5 OP
Plot 1 CP	8	6.1	*	SD	NSD	NSD	NSD
Plot 2 OP	8	7.2	SD	*	NSD	SD	SD
Plot 3 OP	8	6.5	NSD	NSD	*	NSD	NSD
Plot 4 OP	8	6.2	NSD	SD	NSD	*	NSD
Plot 5 OP	8	5.9	NSD	SD	NSD	NSD	*

N=Number of samples; α=0.05
SD=Significantly different; NSD=Not significantly different

There is some evidence in Table 3.12 to suggest that organically managed pasture has a higher organic matter content in the topsoil than conventionally managed pasture: Plot 1 is significantly different from Plot 2. However, the evidence is not exclusive because there is no significant difference between Plot 1 (conventional) and Plot 3 (organic), although Plot 3 has a higher average. Looking back at the data from the preliminary research (Table 3.13) might help us to draw some firm conclusions.

Table 3.13: Topsoil (0-5 cm) Organic Matter Content (spring 1993)
Duncan's Multiple Range Test

Plot	*N*	*Organic Matter Content (%)*	*DUNCAN GROUPING*				
			Plot 1 CP	Plot 2 OP	Plot 3 OP	Plot 4 OP	Plot 5 OP
Plot 1 CP	19	4.2	*	SD	SD	SD	NSD
Plot 2 OP	20	4.9	SD	*	NSD	NSD	NSD
Plot 3 OP	39	4.9	SD	NSD	*	NSD	NSD
Plot 4 OP	40	5.2	SD	NSD	NSD	*	SD
Plot 5 OP	38	4.5	NSD	NSD	NSD	SD	*

N=Number of samples; α=0.05
SD=Significantly different; NSD=Not significantly different

Table 3.13 confirms the former interpretation: organically managed pasture gives a higher organic matter content in the topsoil than conventionally managed pasture. The organic matter content of the topsoil of Plot 1 (conventional) is significantly different from that of that of Plot 2 and 3.

Additional evidence is gathered when we compare the spring 1993 results for the top 35 cm of the soil (Appendix III) with Table 3.12 and 3.13. There is no change in ranking between the different plots, and there is significant difference between Plot 2 & 3 on the one hand, and Plot 1 on the other hand.

When we compare Table 3.12 and 3.13, there is a rise in organic matter content in all the plots. This rise is remarkably high, and can partly be explained by the difference in analytical methods (Leco furnish versus Walkey-Black).

Interpretation of the organic matter content within the crop rotation (Plots 2 & 3 versus 4 & 5) is difficult. It looks like the topsoil organic matter content of the two pasture soils within the rotation is greater (Table 3.12), although the evidence is not very convincing. Only Plot 2 (pasture)

is significantly different from the two cropping plots (4 & 5). The SAS analyses for subsoil (Appendix III) showed a significant difference between Plot 4 (cropping plot) and the other plots. This might be due to the fact that Plot 4 had a long pasture and a very short cropping history, Plot 5 had a long cropping history and has `used up' the organic matter, while the two other pastures might still be in a `build-up' phase.

2. SOIL RESPIRATION

Soil respiration is a way of expressing soil biological activity. All soil organisms respire; aerobic organisms consume O_2 and, generate CO_2. By measuring O_2 or CO_2 levels, statements about overall soil biological activity can be made.

The method of determining soil respiration is described in Section 3.2. It was decided to use glucose (1% w/v) as an additional oxidiseable substrate because of the low levels of natural substrate in the subsoil. The first data was obtained by collecting two bulk samples, each containing ten cores, from Plot 1, 3 and 5. They represent the 0-15 cm layer of the plots.

Table 3.14: Topsoil (0-15 cm) Soil Respiration (µl/g/h) (winter 1994)
Duncan's Multiple Range Test

Respiration	*N*	*Plot 1 CP*	*Plot 3 OP*	*Plot 5 OP*
winter	2	42.5 b	59.9 a	45.0 b
spring	3	54.2 a	23.1 b	49.2 a

N=Number of samples; Means with a common letter in a row are not significantly different(α=0.05)

These data (Table 3.14) show a significant difference between plot 1 (conventional pasture) and Plot 3 (organic pasture) for the winter results: The long-term pasture that is organically managed has a higher soil respiration than the conventional managed pasture. The winter results also show a difference between the two plots in the organic crop rotation (Plot 3 & 5): pasture within the organic crop rotation seems to improve soil respiration.

To get an impression of the effects of time and cultivation, a follow-up determination was performed in spring 1994 (Table 3.14). Plot 1 was still in pasture, Plot 3 was cultivated (November 1994) to grow a pumpkin crop, and Plot 5 was returned to pasture.

Cultivation seems to have a negative effect on soil respiration. The soil from Plot 3, which earlier had the greatest level of respiration, became the lowest. Cultivation had a negative effect on soil respiration of the top 5 cm. The soil of Plot 1 and 5 had the greatest rate of respiration, and were more or less the same as in the first measurement (Table 3.14). No cultivation took place on these plots.

Cultivation seems to give a significant drop in soil respiration. An explanation could be that with turning the soil, the substrate for the micro-organisms disappears from the top 5 cm. To get this confirmed, and to determine if there are differences between the plots below 5 cm, a new study was started. Again bulk samples were collected, now at four different depths (0-5, 5-15, 15-25 & 25-35 cm). Data gathered for Plots 1, 3 and 5 gave the following results (Table 3.15).

Table 3.15: Soil Respiration (µl/g/h) Plot 1, 3 & 5 (spring 1994)
Duncan's Multiple Range Test

Plot	*N*	*Depth* *0-5 mm*	*5-15 mm*	*15-25 mm*	*25-35 mm*
Plot 1 CP	4	46.1 a	15.3 b	7.2 c	2.4 d
Plot 3 OP	4	20.0 b	29.0 a	18.3 b	6.6 c
Plot 5 OP	4	54.4 a	21.3 b	11.9 c	4.6 d

N=Number of samples; Means with a common letter in a row are not significantly different(α=0.05)

These data (Table 3.15), and Figure 3.5 (Soil Biological Activity) give confirmation that soil from cultivated (disturbed) plots differs from plots in pasture (undisturbed) for microbial activity. The respiration rate in Plot 3 is greatest in the 5-15 cm layer. This is probably the layer with the highest organic matter content after turning the soil. Figure 3.5 looks similar to Figure 3.4 (the results obtained for the organic matter content). The cropping plots (4 & 5) of Figure 3.4 show a similar pattern as Plot 2 of Figure 3.5, and the undisturbed pastures (Plot 2 & 3) of Figure 3.4 look similar to Plot 1 and 5 of Figure 3.5.

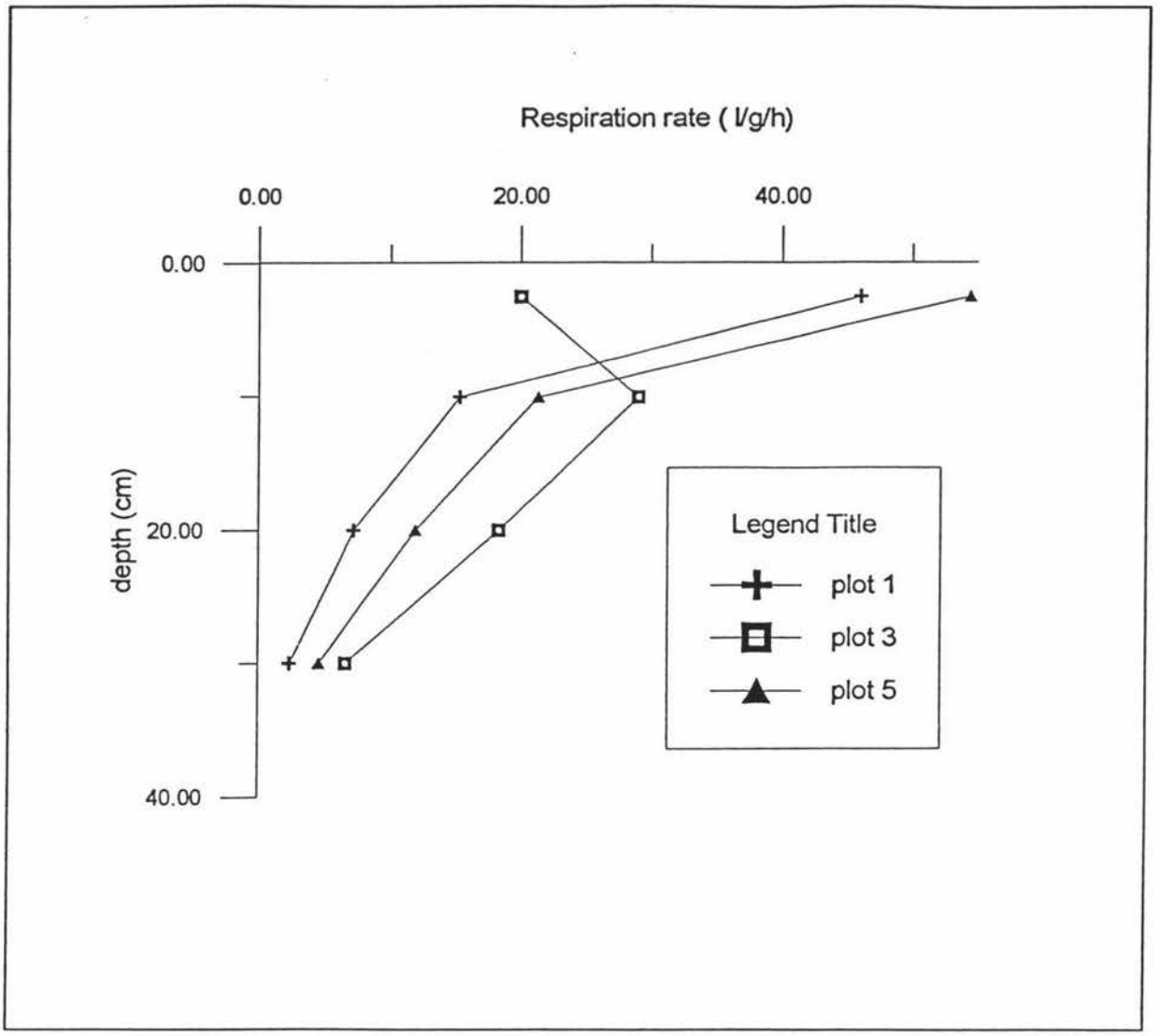


Figure 3.5: Soil Biological Activity (µl/g/h) with Soil Depth
(as measured by soil respiration, spring)

Comparing the depth layers with each other gives us an insight of the effect of management on soil respiration at lower levels. In Table 3.16 (Depth 1) the ranking has not changed which confirms my former interpretation. In Table 3.16 (Depth 2), Plot 2 has the highest respiration rate, which was already explained; For this layer Plot 2 has more substrate than the other plots.

Table 3.16: Soil Biological Activity (µl/g/h) with Depth (as measured by soil respiration)
Duncan's Multiple Range Test

Depth	*Plot*		
	Plot 1 CP	*Plot 3 OP*	*Plot 5 OP*
0-5 cm	46.1 a	20.0 b	51.8 a
5-15 cm	15.3 c	29.0 a	21.3 b
15-25 cm	6.9 c	18.3 a	11.9 b
25-35 cm	2.4 c	6.6 a	4.6 b

Number of samples=4; Means with a common letter in a row are not significantly different(α=0.05)

In Table 3.16 (Depth 2), soil respiration of Plot 3 (recently cultivated) is significantly better than that of Plot 1 (long-term conventional pasture). This could mean that although cultivation has a negative influence on soil respiration, cultivation of long-term organically managed pasture still gives a higher respiration than long-term pasture under conventional management. This difference might be due to the higher availability of substrate. Comparing Plot 1 with 5 also gives a significant difference, which sustains the conclusion that organic management gives a higher respiration rate at depth 2. Depth 3 and 4 also give significantly higher respiration rates for the organically managed plots.

Table 3.17: Earthworm Count (numbers/$m^{2)}$ (June and September)
Duncan's Multiple Range Test

Time	*Plot*		
	Plot 1 CP	*Plot 3 OP*	*Plot 5 OP*
June	411 b	684 a	79 c
September	312 b	719 a	159 c

Number of Samples=10; Means with a common letter in a row are not significantly different; α=0.05

When Plot 3 and 5 are compared for Depths 2, 3 & 4, they are significantly different, which might indicate that there was a positive influence on soil respiration from the pasture phase.

3. EARTHWORM COUNTS AND POPULATION DEVELOPMENT

Earthworms are important because they contribute to soil structure and plant nutrient availability. There are many different species of earthworms, all with their own characteristics and role to play in the soil. As explained in Section 3.2, the earthworms counting procedure did not differentiate between earthworm species.

The results of two earthworm counts over the winter period are shown in Table 3.17.

Both pasture phases (Plots 1 & 3) have significantly higher amounts of earthworms than Plot 5 (cropping). The organically managed pasture (Plot 3) is higher in total earthworms than the conventional managed pasture (Plot 1). On the organic plots the population has increased over the counting period.

4. SOIL pH

The pH was measured once (winter 1994) over four different depths (0-5, 5-15, 15-25, and 25-35 cm). At the time of measurement no significant differences were found. The pH were all around 6.0, even at a depth of 25-35 cm.

3.4 Conclusion

Chapter 3 tried to answer the following **research questions**:

(1) *Is there a difference in soil quality between a pasture phase in a conventional crop rotation and a pasture phase in an organic crop rotation?*

(2) *Is there a difference in soil quality between the cropping phase (disturbed) and the pasture phase (undisturbed) in an organic crop rotation?*

Although the physical soil quality indicators mask clear differences between the conventional and organic pasture phase, there are indications that for the topsoil, soil quality under an organic pasture phase is better than under a conventional pasture phase. Plot 3, which has been in pasture for the same time as Plot 1, has better soil biological indicators than Plot 1.

Even Plot 2, which has been in organic pasture for a shorter period than Plot 1, has better soil physical properties (at least for the indicators measured).

There appears to be no measurable differences in the soil physical properties of the subsoil (below 15 cm) of the different plots. But soil respiration and organic matter content gave significant differences `in favour' of the organic crop rotation. Even the cropping plots showed significantly better biological properties than the conventional pasture.

4

The Potential Use of Fluorescent Pseudomonads as Soil Quality Indicators of Pasture/ Crop Management

The function of fluorescent pseudomonads in the rhizosphere and rhizoplane is not clearly understood yet (see Chapter 2). This part of the research tries to contribute towards a better understanding of fluorescent pseudomonads, and investigates if they can be used as indicators of soil quality. Because the rhizoplane material used for the research came from another site, a new site description is included in this chapter. Section 4.2 (materials and methods) consists of two parts; one for the rhizosphere study, and one for the rhizoplane study. The results and discussion section (4.3) is organised in the same way.

4.1 Site Description

The rhizosphere study on fluorescent pseudomonads was conducted at the Flock House Biological Development Research Unit (see Chapter 2). Plot 1 (CP), Plot 3 (OP) and Plot 5 (OP) were sampled for rhizosphere soil. To examine the effects of soil management on soil pseudomonads bacteria in the rhizosphere, both farming systems (conventional and organic) were included.

The field study for the rhizoplane pseudomonads bacteria required identical plant species, grown under different soil management regimes (conventional and organic). As at Flock House it was impossible to fulfil these requirements, two Manawatu dairy farms were included in the research; one conventional and one organic farm. These farms were on the same soil type (Manawatu silt loam) as Flock House (see Chapter 1). Turf samples of these farms were gathered, and used for the rhizoplane study on pseudomonads bacteria.

4.2 Materials and Methods

The isolation method for fluorescent pseudomonads bacteria from soils (the rhizosphere) and roots (the rhizoplane) was based on the methodology of Sands &

Rovira (1970). The isolation is based on the selective culture of fluorescent pseudomonads with resistance to the antibiotics penicillin, novobiocin and cycloheximide. Martin (1975) compared this selective medium with other media and concluded that for a routine estimation of fluorescent pseudomonads from soil the medium of Sands & Rovira is preferable.

To be sure of the selective media, a trial was run with a known strain of Pseudomonads fluorescens, (# 1 NC1B 9494, Dept. Microbiology and Genetics, Massey University). This strain was plated on the medium and incubated for 3 days at 30 °C, and produced clearly fluorescent colonies when viewed under UV light.

4.2.1 The Rhizosphere Study

The soil was sampled at three different times. Each sample consisted of 10 randomly taken core samples from each plot (Plot 1, 3 & 5). These bulk samples were thoroughly mixed. The next step was to determine the right dilution rate for the sampled soil. Therefore, 10 gram of soil was vigorously shaken for 15 min in 100 ml of sterile distilled water. The dilution's were made from this slurry. All dilution's were made with a water extract of soil (1% w/v); autoclaved and filtered since viable counts of some fluorescent pseudomonads bacteria decline rapidly in distilled water but not in soil extracted water (Sands & Rovira, 1970).

After making the preferred dilution (1 in 10) from the bulk soil samples, 0.1 cm^3 was spread onto the selective medium with a sterilised glass rod. The samples were replicated three times on the plates. Counting the colony forming units (cfu's) was done after an incubation period of 3 days at 30 °C.

4.2.2 The Rhizoplane Study

Five turf samples with cocksfoot (*Dactylis glomerata*) and five turf samples with white clover (*Trifolium repens*) were collected from the organic plot. The same was done for the conventional plot. The turf samples were immediately transported to the laboratory. Root systems of the cocksfoot and white clover plants were recovered from the turf,

gently rinsed under running tap water and sterile distilled water, to remove soil particles. The freshly washed roots (approximately 0.5 g wet weight) were ground in a sterile mortar and pestle, then serially diluted in sterile water and plated on the selective medium for fluorescent pseudomonads.

The dilution made from the ground roots was plated, incubated and counted in triplicate in the same manner as for the rhizosphere study.

4.3 Results and Discussion

The results of the rhizosphere and rhizoplane studies are dealt with separately, an overall conclusion is given in Section 4.4.

4.3.1 The Rhizosphere Study

The results were analysed using SAS. This experiment was treated as an experiment with two factors and 'blocking' (replicas) (Table 4.1).

The Analyses of Variance (ANOVA) of this factorial design gave the following results (see Table 4.2).

Table 4.1: Number of Fluorescent Soil Pseudomonad Bacteria in Rhizosphere Soil

Plot	*Bulk Soil Sample*	*Replicas (no. of cfu's per Mg dry soil)*	
		Mean	SD
Plot 1 CP	A	330	28
	B	391	28
	C	412	32
Plot 3 OP	A	16	8
	B	259	32
	C	30	17
Plot 5 OP	A	571	102
	B	611	13
	C	595	96

cfu's=Colony forming units; SD=Standard deviation; α=0.05

Table 4.2 indicates that there might be an interaction (p=0.0048) between plots and bulk soil samples. It is clear from the table that the plots differ significantly from each other (p=0.0001), and that there is also significant difference between soil samples (p=0.0011). The replicas are not significantly different (p=0.6103), indicating that there is homogeneity between them; the method for obtaining the data is sound.

Since the interaction between bulk soil sample and plot is not highly significant, it was decided to look at the main effects of the two factors using the overall means. An Multiple Comparison Procedure (MCP) is useful for interpreting the behaviours of the mean of the colony counts from the three different plots (see Table 4.3).

Table 4.2: SAS Output; Analysis of Variance (ANOVA) of Rhizosphere Data (Number of Fluorescent Soil Pseudomonad Bacteria in Rhizosphere Soil)

Source	*Degrees of freedom*	*Type I SS*	*Mean square*	*F value*	*Pr > F*
Replicas	2	2,860	1,430	0.51	0.6103
Bulk soil sample	2	60,753	30,376	10.82	0.0011
Plot	2	1,089,1	544,579	193.99	0.0001
Bulk soil sample * plot	4	63,926	15,981	5.69	0.0048
Error	16	44,915	2,807		
Corrected total	26	1,261,6			

Class:	**Replicas**	**Soil Samples**	**Plot**
Levels:	**3**	**3**	**3**
Values:	**1,2,3**	**A, B, C**	**1(CP),3(OP),5(OP)**

Number of observations in data set=27; *=interaction effect; α=0.05

When we look at Table 4.3, we see that there is significant difference between all three plots. The rhizosphere soil of Plot 5 (organic cropping) produced the highest amount of colony forming units. The organic pasture phase is significantly the lowest in colony numbers on a dry soil base. Table 4.1 shows the means and the standard deviations. The means show no real homogeneity of variance across the bulk soil samples.

Table 4.3: Number of Fluorescent Soil Pseudomonad Bacteria in Rhizosphere Soil (MCP) Duncan's Multiple Range Test

Plot	*N*	*Fluorescent pseudomonads (cfu's/Mg dry soil)*	*DUNCAN GROUPING*		
			Plot 1 CP	Plot 3 OP	Plot 5 OP
Plot 1 CP	9	378	*	SD	SD
Plot 3 OP	9	102	SD	*	SD
Plot 5 OP	9	592	SD	SD	*

N=Number of samples; cfu's=Colony forming units; α=0.05
SD=Significantly different; NSD=Not significantly different

4.3.2 The Rhizoplane Study

The results were analysed using SAS. The data were treated as an experiment with two factors and 'blocking' (replicas).

1. COCKSFOOT

The Rhizoplane data for cocksfoot is given in Table 4.4. It was clear from the ANOVA that there is no significant interaction between plant and plot (p=0.6128).

The ANOVA shows that the plots differ significantly from each other (p=0.0017). There is no significant difference between the colony counts from the cocksfoot roots (p=0.6359). The replicas are not significantly different (p=0.3246), which indicates that there is homogeneity between them; the method for obtaining the data is sound.

Table 4.4: Number of Fluorescent Pseudomonads on the Rhizoplane of Cocksfoot Roots

Plot	*Cocksfoot root*	*Mean(cfu's)*	*SD*
Organic	A	21.3	33.5
	B	5.3	3.1
	C	33.3	7.1
	D	18.0	5.3
	E	20.7	17.2
Conventional	A	0.7	1.2
	B	1.3	1.2
	C	0	0
	D	2.0	2.0
	E	5.3	6.1

cfu's=Colony forming units; SD=Standard deviation; α=0.05

Since there was no significant interaction between the number of cfu's associated with cocksfoot root and plot, we can interpret the main effects of the two factors (cocksfoot root & plot) using the overall means. Interpretations of the behaviour of the means for the plants would be inappropriate when the main effect of this factor was not significant. A MCP may be useful for interpreting the behaviours of the mean of the colony counts from different plots (Table 4.5).

This clearly indicates (Table 4.5) a significant difference: the organically grown cocksfoot has a higher population of fluorescent pseudomonads in the rhizoplane than conventionally grown cocksfoot. The high standard deviation (Table 4.4) is inherent for this experiment.

Table 4.5: Cocksfoot Rhizoplane Data (MCP); Number of Fluorescent Pseudomonads on the Rhizoplane of Cocksfoot Roots

Plots	*N*	*Mean (cfu's per µg dry roots)*	*DUNCAN GROUPING*	
			Organic	Conventional
Organic	15	18.3	*	SD
Conventional	15	1.9	SD	*

N=Number of samples; cfu's=Colony forming units
SD=Significantly different; α=0.05

2. WHITE CLOVER

Table 4.6 shows the data gathered of the rhizoplane from white clover. The ANOVA shows that the replicas are not significantly different (p=0.8916). This means that there is some homogeneity between them.

The two main effects (plot & white clover root) are significant, which means: the colony counts of the white clover roots are significantly different from each other (p=0.0030), and; the plots are significantly different from each other (p=0.0028). There is also an interaction effect, which means that the plants have an effect on the colony counts of the plot, or the other way around (age of the roots ?). Normally it is useful to interpret this interaction factor before explaining the behaviour of the main effects of plant and plot treatment separately. In this case the interaction effect is not important because it is not a real treatment as the plants were collected at random from the plots.

Duncan's MCP is used to interpret the colonies counted from the white clover roots of the two plots (Table 4.7).

Table 4.6: Number of Fluorescent Pseudomonads on the Rhizoplane of White Clover

Plot	*White Clover Root*	*Mean*	*SD*
Organic	A	45.3	17.0
	B	2.0	2.0
	C	152.0	68.4
	D	12.0	6.0
	E	94.0	25.0
Conventional	A	5.3	2.3
	B	29.3	23.7
	C	20.7	22.3
	D	42.7	32.1
	E	22.7	8.1

cfu's=Colony forming units; SD=Standard deviation

Table 4.7: White Clover Rhizoplane Data (MCP)

Duncan's Multiple Range Test

Plots	*N*	*Mean (cfu's per µg Dry Roots)*	*DUNCAN GROUPING*	
			Organic	Conventional
Organic	15	61.0	*	SD
Conventional	15	24.1	SD	*

N=Number of samples; cfu's=Colony forming units;
SD=Significantly different; α=0.05

Table 4.7 clearly indicates that white clover roots are more colonised by fluorescent pseudomonads spp. in the organic pasture than in the conventional pasture.

Table 4.6 shows the means and the standard deviation. The high standard deviation is inherent for this experiment.

4.4 Conclusion

The results of these studies clearly indicate the validity of our **hypothesis**, which is that the effect of each specific management regime (conventional versus organic) has a quantitative effect on the ecological niches available for occupancy by micro-organisms.

In our case, there is a management effect on the rhizosphere and the rhizoplane: there are clear differences in fluorescent pseudomonads colony counts (cfu's) when we compare rhizospheres and rhizoplanes of the two farming systems. The research questions formulated for this part of the research can be answered:

(3) *Is there a potential use for fluorescent pseudomonads in the rhizosphere of pasture plants as soil quality indicators?*

(4) *Is there a potential use for fluorescent pseudomonads in the rhizoplane of pasture plants as soil quality indicators?*

I can conclude that there are significant differences with, in general, significantly greater numbers of fluorescent psuedomonads under organic management. Both the fluorescent pseudomonads in the rhizosphere and rhizoplane seem to have a potential use as soil quality indicators because they act differently under differently managed plots.

There is no homogeneity within individual plots when we look at bacterial spreading in the rhizosphere. Bulk soil samples of the same plot showed high variations of fluorescent pseudomonads amounts. This might indicate a relatively great influence of the micro environment on fluorescent pseudomonads populations in the rhizosphere.

Root populations of fluorescent pseudomonads on white clover is not totally site specific in this study because there is significant difference between the clover plants in a plot. This in contrast with cocksfoot. This could indicate that white clover influence the population more individually than cocksfoot.

Further interpretation with these data is merely hypothetical. Older literature mention fluorescent pseudomonads spp. as being pathological (Sands & Rovira, 1970). In more recent literature, there are reports that fluorescent pseudomonads might be beneficial for plant growth (see Chapter 2). At this stage it is to premature to confirm this, because there is not enough knowledge about ecological interactions of fluorescent pseudomonads with other micro-organisms and plant roots. Including soil environmental factors would make interpretation even more difficult.

5
Biological Soil Amendments

This laboratory experiment was conducted to obtain information about the behaviour of biological activity by measuring the respiration of soil samples of the two management systems, conventional and organic, after applying biological soil additives. Five biological soil amendments were evaluated: earthworm casts; rhizosphere soil; preparation 500; organic compost, and; commercial compost. Commercial compost was added to contrast the organic compost to see if there is a difference between these two materials. This experiment could give us some indications about the influence of the amendments on soil biological activity and thus indirectly on soil quality which also

relates to biological activity. Organic management is largely based on stimulating soil life by using organic matter or biological amendments, therefor more information is needed on soil biological amendments.

For all five amendments, first the biological activity was measured. After these measurements the amendments were added to soil slurries, made from bulk samples of Plots 1 (conventional) and 3 & 5 (organic), which where then diluted. Later, the dilutions were compared on biological activity.

5.1 Site Description

The site description is given in Chapter 3. Plots 1 (conventional pasture), 3 (organic pasture) and 5 (organic pasture) were chosen for the experiment.

5.2 Materials and Methods

Five bulk samples were gathered from each plot (1, 3 & 5), each consisting of 10 randomly collected core samples of the topsoil (top 50 mm).

The biological activity of these samples was determined by measuring soil respiration with the Gilson differential respirometer (as explained in Chapter 3). Measurements of the five bulk samples were replicated twice in the respirometer (Table 5.1).

Plot 3 (organic pasture) had the greatest soil respiration rate. From the five bulk samples of each plot, one was chosen as being representative for the plot. This was the sample closest to the mean for the plot from which it originated:

Plot 1 (CP): sample P1-E = 49 µl/g/h (P1-E = bulk sample # E of Plot 1)

Plot 2 (OP): sample P3-A = 56 µl/g/h

Plot 3 (OP): sample P5-B = 53 µl/g/h

These representative samples were used to determine the distribution of the soil sample respiration with glucose added (standard substrate induced respiration measurement). Each of the three samples was replicated five times to determine the variation between the replications (Table 5.2).

Table 5.1: Soil Sample Respiration of the Plots

Plot	*N*	*Mean Respiration Rate (µ l/g/h)*
Plot 1 CP	10	43 b
Plot 3 OP	10	60 a
Plot 5 OP	10	45 b

N=Number of Samples; µl/g/h=micro-litre O_2/gram of soil/hour

Earthworm casts and rhizosphere soil were collected from Plot 3. Preparation 500 was obtained from the Biodynamic Farming and Gardening Association in Napier; its preparation method is described in Appendix IV. The organic compost was bought from a local outlet. A process description was not available. A commercial compost/potting mix was bought in a local shop without processing specifications.

Table 5.2 Co-variance of Selected Bulk Samples

Plot-bulk sample	*Mean respiration rate (µl/g/h)*	*Co-variance (%)*
P1-E	32.3	13
P3-A	60.3	12
P5-B	42.4	9

µl/g/h=micro-litre O_2/gram of soil/hour

The biological activity of the amendments was determined with the respirometer (Table 5.3). No additional oxidiseable substrate was required, due to the high endogenous biologically oxidiseable substrate available in the amendments (Table 5.3).

Table 5.3 Biological Activity of Amendments without Glucose

Amendment	Mean respiration rate (µl/g/h)	Co-variance (%)
Earthworm casts	**94.6**	**9**
Rhizosphere soil	**44.6**	**10**
Preparation 500	**154.1**	**7**
Organic Compost	**132.1**	**11**
Commercial Compost	**60.4**	**6**

µl/g/h=micro-litre O_2/gram of soil/hour;

The next step was to compare directly the respiration rate of selected plot bulk samples (P1-E, P3-A, P5-B) without amendments, with the selected plot bulk samples (P1-E, P3-A, P5-B) to which small amounts of amendments were added.

From the selected bulk samples duplicate slurries were made from each soil. Slurries were made by first suspending 20 g soil to 40 ml H_2O, then adding 0.5 ml glucose to 5 ml of this slurry, and then adding 0.3 ml of KOH to the centre-well in order to absorb CO_2.

A dilution of amendments was made of 5 g of amendment stirred for 15 min in 100 ml of water. This dilution (5% w/v) was allowed to settle for 15 min, before 0.5 cm^3 of it was added a slurry of each soil.

5.3 Results and Discussion

Table 5.3 indicates that all the amendments have a high endogenous respiration rate. Most of them are even higher than the soil sample respiration rates of the plots. This is even more remarkable because the plot samples were measured with glucose added (exogenous respiration rate). Preparation 500 and the organic compost have a very high endogenous respiration rate from which we can conclude that there is a high microbial activity. From Table 5.4, the overall impression is that soil samples without amendments have a higher biological activity. They have, in general, higher means of soil respiration. But as there are only two significantly different soil respiration rates, there is no strong evidence for this interpretation. Although in general the amendments seem

to have a negative influence on soil sample respiration, an exception could be the rhizosphere additive.

Table 5.4: Respiration Rate of Samples With and Without Amendments

Plot	*Amendments*	*Soil without amendments*		*Soil with amendments*	
Plot 1 CP	Earthworm casts	30.9 *	A	24.8	B
	Rhizosphere soil	31.3		35.9 *	
	Preparation 500	36.9 *		31.5	
	Organic compost	30.2		30.7 *	
	Commercial compost	34.8 *		29.4	
Plot 3 OP	Earthworm casts	53.9 *		49.6	
	Rhizosphere soil	56.7		61.8 *	
	Preparation 500	62.6 *		59.4	
	Organic compost	62.4 *		59.3	
	Commercial compost	69.6 *		62.4	
Plot 5 OP	Earthworm casts	34.6 *		32.8	
	Rhizosphere soil	39.6 *		32.5	
	Preparation 500	42.0 *	A	36.3	B
	Organic compost	37.6 *		35.8	
	Commercial compost	35.6		44.3 *	

***=Higher mean than compared sample; A=Significantly higher than B (p=0.05)**

These results bring forward more questions then answers. No real insight is gained into the claims made about the biological soil amendments, except that they have a high endogenous respiration rate which means high biological activity

Furthermore, there is no consistency in the behaviour of soil sample respiration with amendments for the differently managed plots. The biological soil amendments do not cause significant differences in soil sample respiration reactions for plots under different management.

5.4 Conclusion

For this laboratory research, the questions:

(5) *Do the biological soil amendments have a high biological activity?*,

and if so;

(6) *Do the biological soil amendments affect biological activity of soils under organic management and under conventional management?*

can be answered for this research:

(5) there is evidence in this research that the biological activity of the soil amendments is relatively high;

(6) there is no evidence in this research for a quantitative difference in response on respiration rates for these biological amendments under conventional or organic management.

6
Discussion

In this chapter the three parts of the research will be reviewed and discussed.

6.1 Soil Quality Comparison

The conclusion of the comparison from the plots with different management histories on soil quality seems to be quite clear. The questions are:

(1) *Is there a difference in soil quality between a pasture phase in a conventional crop rotation and a pasture phase in an organic crop rotation?*

(2) *Is there a difference in soil quality between the cropping phase (disturbed) and the pasture phase (undisturbed) in an organic crop rotation?*

Can be answered as follows:

(1) The pasture phase in the organic crop rotation has better soil quality than the pasture phase in the conventional crop rotation (although the physical soil quality parameters mask clear differences);

(2) The pasture phase in the organic crop rotation has better soil quality than the cropping phase in the organic crop rotation.

There is are no distinct differences, in the subsoil, between the pasture phase of the conventional unit (Plot 1) and the cropping phases of the organic unit (Plot 4 & 5) on physical properties of soil quality. The biological soil quality indicators, although, do indicate a difference, in the subsoil, between these plots in favour of the organic crop rotation. This could mean that agrochemicals (or conventional management) have a stronger negative influence on soil quality than cultivation's.

The difference in sensitivity between physical and biological indicators seems to confirm the view that biological indicators are more dynamic than physical indicators. Therefore it would be sensible to do more research on biological soil quality indicators.

6.2 Potential Use of Fluorescent Pseudomonads as Soil Quality Indicators

The research questions formulated for this part of the research:

(3) *Is there a potential use for fluorescent pseudomonads in the rhizosphere of pasture plants as soil quality indicators?*

(4) *Is there a potential use for fluorescent pseudomonads in the rhizoplane of pasture plants as soil quality indicators?*

Can be answered now.

Both seem to have potential use as soil quality indicators because both, the rhizosphere and the rhizoplane, show different amounts of fluorescent pseudomonads for differently managed plots.

I will start with discussing the rhizosphere results. The pasture phase under organic management (Plot 3) has the best soil quality of all plots. Table 4.3 shows that

Plot 3 (organic pasture phase) has the lowest colony counts of fluorescent pseudomonads (102 cfu's/Mg dry soil) of all plots. Its results are significantly different from the results for Plot 1 (conventional pasture phase; 378 cfu's/Mg dry soils) and Plot 5 (organic cropping phase). Therefore, it may be that lower colony counts of rhizosphere fluorescent pseudomonads' colonies represent better soil quality.

For the rhizoplane study I can put up a similar hypothesis. I assume that the biodynamic farm has better soil quality than the conventional farm, which is supported by other research (Reganold et al, 1993; Macgregor et al, 1994). The cocksfoot and white clover rhizoplane data (Tables 4.6 & 4.9) show significant higher amounts of fluorescent pseudomonads for the biodynamic farm. The hypothesis, therefore, is that higher amounts of fluorescent pseudomonads in the rhizoplane of cocksfoot and white clovers represent better soil quality.

Both these hypotheses need to be tested further; all biological and ecological properties are interactive and therefore difficult to measure and evaluate. We still lack sufficient knowledge to fully understand ecological interactions of fluorescent pseudomonads with other micro-organisms and plant roots. Including environmental factors would make interpretation even more difficult.

So far, the literature suggests that high amounts of fluorescent pseudomonads in the rhizoplane tend to reflect high amounts of fluorescent pseudomonads in the rhizosphere (Curl & Truelove, 1986; Vancura & Kunc, 1988). The two hypotheses seem to suggest that this is not necessarily so for all soils and crops.

6.3 Biological Soil Amendments

The **research questions** that this experiment tried to answer, were:

(5) *Do the biological soil amendments have a high biological activity?* If so;

(6) *Do the biological soil amendments affect the biological activity of soils under organic management and under conventional management?*

The conclusion is that:

(5) The biological activity of the biological soil amendments is relatively high;

(6) **There is no evidence in this research for a quantitative difference in response on respiration rates for these biological amendments under conventional or organic management.**

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APPENDIX I

New Zealand Biological Producers & Consumers Council (Inc);
Certified Bio-Gro Organic Production Standards:

ection A

INTRODUCTION

1 Preamble

1.1 **New Zealand Biological Producers & Consumers Council, Inc.,** was founded in 1984 to promote the interests of organic production in New Zealand. Its principal activities include the setting of organic production standards; inspection and verification of *Bio-Gro* licensees and licence applicants; research and education. The Council is an independent, non-profit society funded entirely by membership and inspection fees, licensing levies, donations and grants: it has no commercial affiliations.

1.1.1 The NZBPC was formed by representatives of the Soil & Health Association NZ, Inc., the Bio-Dynamic Farming & Gardening Association NZ, Inc., and the Doubleday Research Association NZ, Inc.

1.2 *Certified Bio-Gro Organic Production Standards* shall be the formal basis and reference point for all questions and decisions concerning *Bio-Gro* certification, subject however to the following qualifications:

1.2.1 **Amendment/Revision.** Because the Council faces a continually changing commercial and technological environment, its systems and procedures demand constant revision and modification. The Council, therefore, reserves the right to alter, amend, or revise its *Standards*, procedures and/or requirements at any time, as it sees fit, without being bound to give notice. Notification, however, is usually made either directly by post to members and licensees or through the Council's newsletter "Bio News".

1.2.1.1 **Standards Review:** The *Standards* are continually being developed. A completely revised version is produced approximately every two years.

1.2.2 **Interpretation.** The interpretation given to the meaning of and descriptions used in these *Standards* shall be that of the Council's Board of Directors, in its sole and absolute discretion. In all appropriate cases the singular includes the plural and the masculine includes the feminine and *vice versa.*

1.2.3 **Discretion.** Licences to use the *Bio-Gro* trademark are issued in the Council's unqualified discretion, and are not automatic just because fees are paid and inspections carried out. A mere absence of technical breaches of the *Standards* is insufficient to qualify for *Bio-Gro* certification: applicants must be able to demonstrate the implementation of a positive management system based on the principles and/or precepts of the *Standards.*

1.2.4 The *Bio-Gro* certification trademark is not a guarantee of the efficacy its production complies with the Council's *Standards*. [Refer A1.2]

A1.2.5 **Precedence.** The laws of the land at all times take precedence over these *Standards.*

A 2 Principles of Organic Production

A2.1 **Organic production**, which includes such terms as biological husbandry, eco-agriculture, natural, sustainable and bio-dynamic, seeks to produce food of optimum quality and quantity, and to manage productive ecosystems according to a total concept that endeavours to make them sustainable and non-polluting of the environment, while providing an appropriate level of income to the producer(s), families and communities. Some of the main principles and methods that are employed aim to:

A2.1.1 Foster beneficial processes and interactions such as occur in natural ecosystems, thus encouraging internal stability rather than heavy reliance on external control measures.

A2.1.2 Reduce external control to the absolute minimum required for maintaining the chosen state of production. Inputs used should aim to work as far as possible in conjunction with natural cycles, rather than trying to dominate such cycles.

A2.1.3 Achieve cycles/flows of nutrients and materials that have as few losses as possible. This requires the conservation and recycling of nutrients and organic material.

A2.1.4 Sustain and enhance the fertility and life supporting ability of the production medium, including its biological, physical and chemical components. For land-based production systems great emphasis is placed on the importance of soil organic matter, and soil organisms, especially soil bacteria and earthworms.

A2.1.5 Minimise any deleterious environmental effects of particular management practices including any that may reduce the natural diversity to the detriment of plant and wildlife habitats.

A2.2 The use, therefore, of appropriate stocking rates, consideration of animal welfare, sound rotations using diverse stock and cropping strategies with the extensive but rational use of animal manure and other vegetative residues, the use of appropriate cultivation techniques, the avoidance of soluble mineral salt fertilisers, and the prohibition of nearly all chemical pesticides, forms the basis of organic agriculture

Section C MATERIALS AND PRACTICES

C1 Permitted Materials & Practices.

C1.1 **Definition.** Permitted means materials or practices within the guidelines of these *Standards* that are acceptable for relevant and reasonable use on any certified production or property. When available certified materials shall be used. **Caution**: materials listed as permitted herein are required to have not been adulterated, contaminated or augmented with prohibited or restricted materials.

C1.2 **Manures, Composts and Mulching Materials.** The objective of fertility management is to ensure that adequate levels and mixtures of nutrients are available to plants, animals and micro-organisms. Addition of organic matter shall not lead to pollution of surface or subterranean waters. Nor shall plants, and hence animals, be subject to excessive nitrate levels from organic matter additions. Caution must also be exercised to ensure that prohibited and restricted materials are not inadvertently brought on to certified properties when obtaining manure, compost or mulching materials. Hence:

C1.2.1 Animal manures and products, both solid and liquid, from any source must go through an acceptable aerobic or anaerobic decomposition process. These include acceptable hot composting processes, liquid brews such as of fish or seaweed, and biodigesters. Exceptions to this requirement, such as returning dairy shed effluent to paddocks must be approved in advance by the Council as part of the Management Plan.

C1.2.2 **Composts** from certified sources are preferred. Those obtained from conventional sources must have gone through an acceptable hot composting process. Caution must be exercised to ensure that ingredients in such compost do not contain unacceptable contaminants. [Refer C1.2.4/5 below]

C1.2.3 **Plant materials for mulching** are permissible when all ingredients are from certified sources.

C1.2.4 **Mulching material** from conventional sources must not have had any prohibited substances applied to it and must have documentation to confirm this. Residue tests may be required by the Council.

C1.2.5 Every effort must be made to ensure that all brought-on materials are free from contamination from prohibited materials. Particular attention should be paid to heavy metal contamination.

C1.2.6 When using materials with a relatively high heavy metal content the principle that is used is that the heavy metal content of the soil must not increase over time.

C1.3 **Biological Activators.**

- Bio-Dynamic preparations - prepared by methods approved by BDFGA.
- Microbial activators.
- Plant based preparations. [NB: Caution in C1.1]

C1.4 **Fertilisers.** The underlying principle is that all fertilisers must be worked on by soil or compost organisms before the nutrients are plant assimilable. Note: heavy metal analysis may be required.

- *Calcium sulphate* (gypsum).
- Elemental sulphur.
- Feldspar.
- Limestones.
- Dolomite (Magnesium limestone).
- Glauconite (greensands).
- Rock phosphate
- Rock minerals e.g. durite, magnesite, borax, chalk,
- Sulphur - Pelletised with bentonite.
- Unadulterated seaweed and fish products.
- Unrefined unadulterated rock or sea salt.

C1.5 **Pest and Disease Control.**

The natural enemies of pests and diseases shall be protected and encouraged through provision of conditions favourable to them (hedges, shelterbelts, nesting sites etc)

- Biological controls (parasites, predators or disease organisms).
- Diatomaceous earth
- Herbal sprays. [NB: C1.1]
- Homoeopathic preparations.
- Gas saturation using *argon carbon dioxide* or *nitrogen*.
- *Hydrogen Peroxide* (H_2O_2).
- Mechanical controls (e.g. traps, barriers, sound scares, lures).
- Natural purgatives, e.g salt water.
- Pheromones (but not directly on plants).
- Soft soaps (potassium based soaps).
- Stockholm tar.
- Thermal sterilisation.
- Water, salt and fresh.
- Sulphur burning.
- Vegetable oils.
- Waterglass (*Sodium silicate*).

C1.6 **Animal Health Remedies**

- Homoeopathic remedies.
- Plant based remedies (e.g. garlic drenches, tea tree oil, propolis, seaweed, cider vinegar). [NB Caution in C1.1]

C1.7 **Vegetation Control.**

- Thermal techniques.
- Mechanical techniques.

C1.8 **Cleaning Agents.**

- Citric acid
- *Hydrogen peroxide.*
- Soda ash
- Soft and hard soaps

C2 Restricted Materials & Practices

C2.1 **Definition.** Restricted means materials which may be used but only in accordance with the principles specified in these *Standards*. There shall be a gradual reduction in dependence on such materials. These materials may be used only until more acceptable alternatives are available and only **after** notification of the relevant Inspector or consultation with an adviser acceptable to the Inspector or the Council.

C2.2 **Fertilisers.**

- Basic slag.
- Trace elements.
- Langbeinite rock (*Potassium magnesium sulphate*).
- *Magnesium sulphate* (Epsom Salt)
- *Potassium sulphate*. [NB: regular use may preclude Full *Bio-Gro*]
- [redacted] blood, bone and feather products. [NB:. Permitted if go through an acceptable hot composting process]

C2.3 **Pest and Disease Control.**

C2.3.1 **Mineral.**

- Bordeaux, Burgundy mixtures.
- *Copper hydroxide.*
- Lime sulphur.
- *Metaldehyde*, in closed containers only.
- Mineral oils.
- *Potassium permanganate.*
- Sulphur preparations.
- Rodenticides, in closed containers only: *Brodifacoum, Bromadiolone, Warfarin.*

C2.3.2 **Botanical.**

- Quassia.
- Rotenone (derris).
- Ryania.
- Neem
- *Pyrethrum*, pure or with the synergist, *Piperonyl butoxide.*

C2.4 **Vegetation Control.**

- Herbicides derived from fatty acids which are a product of saponification of naturally occurring oils. Note: some products use prohibited substances eg added emulsifiers.
- Other herbicides may be allowed for the establishment of fully enclosed shelter belts/woodlots on Transition properties provided they are applied by knapsack as a spot spray only. Prior written permission must be obtained from the Council.

C2.4.1 **Burning Off of Crop Residues** can only be done with prior written permission of the Council and will only be granted in cases of real need such as for disease control.

C2.5 **Animal Health Remedies.**

- *Copper sulphate.*
- Iodine preparations.
- Mineral supplements [Refer E1.4.17].
- *Sulphanilamide* as spot treatment for external use only.

C2.6 **Cleaning Agents.**

- Caustic soda.

C2.7 **Interim Animal Health Remedies.** The following restricted interim animal health remedies may be used subject to all of E1.4 herein. Treatment with any other prohibited materials compounds is not permitted except where prior written authorisation has been received from the Council.

C2.7.1 **All stock so treated lose certification immediately. This period will extend after the last treatment for double the withholding period of the remedy followed by a further 12 months.** Records of every administration of antibiotics must be kept.

C2.7.1.1 **Internal Parasiticides.**

- *Levamisole* based drenches.
- *Morantel citrate* and *tartrate* based drenches.

C2.7.1.2 **External Parasiticides.**

- *Cyromazine.*
- Synthetic pyrethroids
  - *Cyano-pyrethroids*
  - *Deltamethrin.*
  - *Cis-cypermethrin*
  - *Cypermethrin.*
  - *Flumethrin .*

C2.8 **Quarantine Periods.** All stock so treated must be kept in the Quarantine Area for **double** the label recommended withholding period (or minimum of 48 hours). **Always** check the product label and apply the appropriate quarantine procedures.

C2.9 **Quarantine Area.** This is a designated area of the property where replacement and brought-in livestock, and livestock treated under the interim animal health remedies regulation can be run for the duration of the required quarantine period. The quarantine area shall be clearly designated in the farm plan.

C2.9.1 The quarantine area is not to be used for the grazing of certified stock or the production of crops for 12 months following the last use as a quarantine area. It is in the interests of the producer to use those materials having the shortest possible withholding periods. This will ensure the smallest possible area designated as a quarantine area.

C3 Prohibited Materials & Practices.

C3.1 **Definition.** Except as otherwise provided in these *Standards*, all other materials are prohibited from use in/on certified properties/products unless prior written agreement has been received from the Council. Except where so agreed to by the Council, their use will cancel an existing *Bio-Gro* certification and the property may be required to go through at least a 12 month conversion period before certification is regained.

C3.1.1 Except for properties with Partial Certification, no prohibited materials may be stored on a *Bio-Gro* certified property.

C3.2 **Use of Equipment for Spraying.** The objective is to minimise the risk of contamination of certified properties with either prohibited or restricted substances. This will be best achieved through the use of dedicated spray equipment. Equipment, no matter who owns it, which is to be used on certified organic properties and which has had prohibited or restricted substances used in it at any time, must follow the cleandown requirements in C3.2.1. This is of particular relevance on Partial and Transition properties.

C3.2.1 Spray equipment that has had prohibited or restricted substances in it and which is to be used on certified property must go through the following processes. It is important that flushings do not enter water ways or contaminate growing areas.

- Flush tank, boom and hoses with clean water for 10 minutes
- Circulate a solution of a cold water alkaline detergent at 500g/100 litres [or with the addition of washing soda that has been dissolved in hot water, at 100g/100 litres final concentration] for 10 minutes, then flush with clean water
- Circulate a 1% solution of household ammonia containing and then leave to stand for 24 hours before flushing out with clean water
- Circulate a 1% solution of chlorine bleach containing 3% sodium hypochlorite then flush out with clean water

C4 Residue Levels in Certified Systems.

C4.1 **Introduction.** The *Bio-Gro* trademark is a guarantee that the product has been produced according to the Council's *Standards*. It is not a guarantee that the product is free from the residue of environmental pollution as the distribution of synthetic chemicals is now so widespread that such an assurance would be meaningless. Nor is it a guarantee of efficacy. [Refer A1.2.4]

C4.2 **Environmental Pollution.** Contamination from chemical residues is not acceptable in a certified product unless the reason is general environmental contamination.

C4.2.1 Unavoidable contamination may preclude a property or product from certification. Where certification is granted, product contamination must be declared to the purchaser. For this reason any producer may be required to provide, at their expense, such analytical data as the Council may require on soils, waters, produce or product.

C4.3 **Residue and Contamination.**

C4.3.1 **Conversion.** Whenever residue or contamination levels, due to previous and neighbouring practices, are expected by the Council produce from a property in conversion will require analysis for specified substances to determine their acceptability to the Council This requirement shall be at the Council's sole discretion, and shall be at the cost of the applicant or licensee. The Council may also require the results of such analyses to be declared to purchasers of such produce.

C4.3.2 Residue levels in excess of those acceptable to the Council, as determined by the best currently available knowledge and techniques for minimum detectable levels may preclude certification.

C4.3.3 **Residue Levels.** The permissible level of residues used by the Council on food products is based on 10% of the maximum permissible residue level listed in the U.S. Food and Drug Administration or New Zealand Food Regulations, which ever is appropriate. At the time of printing the following were relevant examples:

Chemical	N.Z.Food Regulation mg/kg	Council Standard mg/kg
D.D.T.	2	0.2
Dieldrin	0.1	0.01
Aldrin	0.1	0.01
Lindane	2	0.2

[Refer New Zealand Food Regulations, 1992]

APPENDIX II

PLOT RESULTS FROM THE SOIL QUALITY COMPARISON

Plot 1

Indicator	*Depth*	*Spring*	*Summer*	*Autumn*	*Winter*	*Spring*
O.M. (%)	5 cm	5.8		6.1		
	10 cm	4.4				
	15 cm	4.1				
	25 cm	3.8				
	35 cm	2.6				
B.D. (Mg/m^3)	5 cm		1.30	1.28		1.21
	15 cm			1.29		1.29
	25 cm			1.35		1.32
	35 cm			1.32		1.30
f (%)	TS		50			54
	SS					40
f_m (%)	TS		12			16
	SS					4
Infiltrability (mm/h)	TS		135		142	
	SS		21		28	
Penetration resitence (kg)	Results are printed in Chapter 3.					
Soil respiration (µl/g/h)	5 cm				42.5	46.1
	15 cm					15.3
	25 cm					7.2
	35 cm					2.4
Earthworm counts (m^2)					411	312

TS=Top Soil; SS=Sub Soil; O.M.=Organic Matter Content; B.D.=Bulk Density; f=Porosity; f_m=Macroporosity.

Plot 2

Indicator	*Depth*	*Spring*	*Summer*	*Autumn*
O.M. (%)	5 cm	6.5		7.2
	10 cm	5.3		
	15 cm	4.8		
	25 cm	4.4		
	35 cm	3.7		
B.D. (Mg/m^3)	5 cm		1.28	1.25
	15 cm			1.28
	25 cm			1.27
	35 cm			1.27
Infiltrability (mm/h)	TS		364	
	SS		36	

TS=Top Soil; SS=Sub Soil; O.M.=Organic Matter Content; B.D.=Bulk Density; f=Porosity; f_m=Macroporosity.

Plot 3

Indicator	*Depth*	*Spring*	*Summer*	*Autumn*	*Winter*	*Spring*
O.M. (%)	5 cm	6.4		6.5		
	10 cm	5.0				
	15 cm	5.1				
	25 cm	4.4				
	35 cm	3.5				
B.D. (Mg/m^3)	5 cm		1.23	1.22		0.99
	15 cm			1.24		1.11
	25 cm			1.23		1.23
	35 cm			1.25		1.31
f (%)	TS		54			62
	SS					40
f_m (%)	TS		14			19
	SS					6
Infiltrability (mm/h)	TS		228		379	
	SS		51		54	
Penetration resitence (kg)	Results are printed in Chapter 3.					
Soil respiration (μl/g/h)	5 cm				59.9	20.0
	15 cm					29.0
	25 cm					18.3
	35 cm					6.6
Earthworm counts (m^2)					684	719

TS=Top Soil; SS=Sub Soil; O.M.=Organic Matter Content; B.D.=Bulk Density; f=Porosity; f_m=Macroporosity.

Plot 4

Indicator	*Depth*	*Spring*	*Summer*	*Autumn*
O.M. (%)	5 cm	4.9		6.2
	15 cm	5.6		
	25 cm	5.6		
	35 cm	4.6		
B.D. (Mg/m^3)	5 cm		1.16	1.15
	15 cm			1.22
	25 cm			1.25
	35 cm			1.33
Infiltrability (mm/h)	TS		140	
	SS		19	

TS=Top Soil; SS=Sub Soil; O.M.=Organic Matter Content; B.D.=Bulk Density; f=Porosity; f_m=Macroporosity.

Plot 5

Indicator	*Depth*	*Spring*	*Summer*	*Autumn*	*Winter*	*Spring*
O.M. (%)	5 cm	4.8		5.9		
	15 cm	4.9				
	25 cm	4.4				
	35 cm	3.9				
B.D. (Mg/m^3)	5 cm		1.15	1.20		1.27
	15 cm			1.22		1.27
	25 cm			1.26		1.26
	35 cm			1.32		1.31
f (%)	TS		49			53
	SS					40
f_m (%)	TS		10			14
	SS					4
Infiltrability (mm/h)	TS		167		197	
	SS		31		34	
Penetration resitence (kg)	Results are printed in Chapter 3.					
Soil respiration (µl/g/h)	5 cm				45	54.4
	15 cm					21.3
	25 cm					11.9
	35 cm					4.6
Earthworm counts (m^2)					684	719

TS=Top Soil; SS=Sub Soil; O.M.=Organic Matter Content; B.D.=Bulk Density; f=Porosity; f_m=Macroporosity.

NDIX III SAS ANALYSIS FOR THE PRELIMINARY RESEARCH

/sis of Organic matter content - factorial design;ANOVA MCPs and contras

:al Linear Models Procedure
s Level Information

s	Levels	Values
)CK	5	1 2 3 4 5
i	4	5 15 25 35
:E	10	1 2 3 4 5 6 7 8 9 10

:r of observations in data set = 200

ıdent Variable: CONTENT

:e	DF	Type III SS	Mean Square	F Value	Pr >
)CK	4	18.21752917	4.55438229	5.42	0.00
i	3	71.81523911	23.93841304	28.51	0.00
)CK*DEPTH	12	39.39995643	3.28332970	3.91	0.00
:	136	114.1893639	0.8396277		
:cted Total	155	233.6729897			

R-Square	C.V.	Root MSE	CONTENT Me
0.511328	19.19545	0.916312	4.773589

This factorial design is unbalanced (each treatment is not sampled the same number of times) and so it needed to be analysed with the least-squares-means (LSM) in SAS. The LSMeans statement computes the least-squares-means for main effects and interactions; adjusted treatment means. This had the following results.

The main effect of paddock (organic matter content) is significant.

The main effect of depth (organic matter content) is significant, so is the interaction effect between depth and paddock. This means that management has influence on all three effects, so it has influence on the organic matter content.

The R-Square, which indicates the goodness of fit of the model fitted is 51%. this is not very high. It would be good to make comparisons with transformed data to check if improvement is possible. (pag. 140 SAS).

Transformed data did not improve the goodness of the model. This means that the results of the analysis are questionable. They can not serve as prove for the hypothesis but only as an indication. Other determinations will have to be conducted to find more solid scientific prove.

n's Multiple Range Test for variable: CONTENT

This test controls the type I comparisonwise error rate, not the experimentwise error rate

with the same letter are not significantly different.

n Grouping	Mean	N	DEPTH
A	5.5769	39	5
B	5.0480	40	15
C	4.6008	39	25
D	3.8376	38	35

's Studentized Range (HSD) Test for variable: CONTENT

This test controls the type I experimentwise error rate, but general

higher type II error rate than REGWQ.

with the same letter are not significantly different.

Grouping	Mean	N	DEPTH
A	5.577	39	5
A			
B A	5.048	40	15
B			
B	4.601	39	25
C	3.838	38	35

The raw or unadjusted means declared significant differences between depths.
0-5 being the highest in organic matter content and 25-35 being the lowest in organic matter content. Duncan MCP declares also a difference between 5-15 and 15-25 cm. Tukey's MCP is more concervative.

n's Multiple Range Test for variable: CONTENT

This test controls the type I comparisonwise error rate, not the experimentwise error rate

with the same letter are not significantly different.

n Grouping		Mean	N	PADDOCK
	A	5.1608	40	4
	A			
B	A	4.9175	20	2
B	A			
B	A	4.8790	39	3
B				
B	C	4.4795	38	5
	C			
	C	4.1789	19	1

's Studentized Range (HSD) Test for variable: CONTENT

This test controls the type I experimentwise error rate, but generally has a higher type II error rate than REGWQ.

Grouping		Mean	N	PADDOCK
	A	5.161	40	4
	A			
B	A	4.918	20	2
B	A			
B	A	4.879	39	3
B				
B	C	4.479	38	5
	C			
	C	4.179	19	1

The raw or unadjusted means declares the conventional paddock(1) as having the lowest organic matter content in both MCP's. The field(4) that has a first years crop after pasture has the highest organic matter content and is significantly different from the rest in both MCP's. Recent pasture(2), which has an unclear history, old pasture(3) and old cropping(5) field are not significantly different in concern to their organic matter content.

. of	CONTENT	
N	Mean	SD
39	5.57692308	1.22155241
40	5.04800000	0.74405748
39	4.60076923	0.99207752
38	3.83763158	1.22302557

of CK	N	CONTENT Mean	CONTENT SD
	19	4.17894737	1.62616076
	20	4.91750000	1.28262426
	39	4.87897436	1.40237917
	40	5.16075000	0.98891909
	38	4.47947368	0.82353866

of CK	Level of DEPTH	N	CONTENT Mean	CONTENT SD
	5	5	5.80200000	1.63069617
	15	5	4.21000000	0.87946006
	25	5	3.75400000	1.11860628
	35	4	2.64250000	1.33437563
	5	5	6.49400000	0.93478875
	15	5	5.04400000	0.42009523
	25	5	4.39800000	0.61840116
	35	5	3.73400000	1.08015277
	5	10	6.44200000	1.06975387
	15	10	5.08000000	0.53387473
	25	10	4.38600000	0.74175767
	35	9	3.46666667	1.20936967
	5	10	4.85500000	0.83661022
	15	10	5.62900000	0.72446839
	25	10	5.54700000	0.78834637
	35	10	4.61200000	1.24246887
	5	9	4.78333333	0.62757470
	15	10	4.85600000	0.59970734
	25	9	4.37111111	0.91104946
	35	10	3.92700000	0.86020734

The standard deviation are in general high and range between 15% and 40% of the means. This means that the variance of the samples is high.

of CK	N	CONTENT Mean	CONTENT SD
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```
ce          Type III Expected Mean Square
OCK         Var(Error) + 7.597 Var(PADDOCK*DEPTH) + 30.388 Var(PADDOCK)
H           Var(Error) + 6.9413 Var(PADDOCK*DEPTH) + Q(DEPTH)
OCK*DEPTH   Var(Error) + 7.6077 Var(PADDOCK*DEPTH)

s of Hypotheses for Mixed Model Analysis of Variance

ndent Variable: CONTENT
ce: PADDOCK
r: 0.9986*MS(PADDOCK*DEPTH) + 0.0014*MS(Error)

                          Denominator     Denominator
 DF     Type III MS             DF              MS       F Value     Pr >
 4     18.21752917            136       4.55438229          5.42     0.0(


ce: DEPTH
r: 0.9124*MS(PADDOCK*DEPTH) + 0.0876*MS(Error)

                          Denominator     Denominator
 DF     Type III MS             DF              MS       F Value     Pr >
  3    23.938413038          12.60    3.0692699813          7.799     0.00:

ce: PADDOCK*DEPTH
r: MS(Error)
                          Denominator     Denominator
 DF     Type III MS             DF              MS       F Value     Pr >
 12    3.2833297023            136    0.8396276757          3.910     0.00(
```

Adjusting the design for a mixed effect model (depth sampling is in fact fixed and the paddock sampling is random) does not change the conclusion. All the main effects and the interaction effect are still significant.

```
t Squares Means
H       CONTENT       Std Err      Pr > |T|    LSMEAN
         LSMEAN        LSMEAN    H0:LSMEAN=0    Number

      5.67526667    0.15454042         0.0001         1
      4.96380000    0.15332832         0.0001         2
      4.49122222    0.15454042         0.0001         3
      3.67643333    0.15988120         0.0001         4

 |T| H0: LSMEAN(i)=LSMEAN(j)

./j     1        2        3        4
    .       0.0014   0.0001   0.0001
2  0.0014    .       0.0317   0.0001
3  0.0001   0.0317    .       0.0004
4  0.0001   0.0001   0.0004    .
```

As with both MCP's there is significant difference in the adjusted means (LSM).
There is no confincing effidence in the data to suggest that

there is a difference between 5-15 (2) and 15-25 cm (3)(see also MCP's)

CK	CONTENT LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
	4.10212500	0.21119948	0.0001	1
	4.91750000	0.20489359	0.0001	2
	4.84366667	0.14688011	0.0001	3
	5.16075000	0.14488165	0.0001	4
	4.48436111	0.14885174	0.0001	5

|T| H0: LSMEAN(i)=LSMEAN(j)

j	1	2	3	4	5
1	.	0.0064	0.0046	0.0001	0.1414
2	0.0064	.	0.7701	0.3341	0.0895
3	0.0046	0.7701	.	0.1266	0.0880
4	0.0001	0.3341	0.1266	.	0.0014
5	0.1414	0.0895	0.0880	0.0014	.

The organic matter content from the conventional pasture (1) is not significantly different from the old cropping field (5).
The organic matter content from the conventional pasture (1) is significantly different from recent cropping field (4). There is no strong effidence to suggest a difference between the conventional pasture (1) on one hand and the two other pastures (2 and 3). The unadjusted MCP's gave a similar conclusion.
The organic matter content from the recent pasture (2) is not significantly different from the recent cropping field (4), it is significantly different from the conventional pasture (1), although the evidence is not very strong, old pasture (3) and old crop field (5).

CK	DEPTH	CONTENT LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
	5	5.80200000	0.40978718	0.0001	1
	15	4.21000000	0.40978718	0.0001	2
	25	3.75400000	0.40978718	0.0001	3
	35	2.64250000	0.45815600	0.0001	4
	5	6.49400000	0.40978718	0.0001	5
	15	5.04400000	0.40978718	0.0001	6
	25	4.39800000	0.40978718	0.0001	7
	35	3.73400000	0.40978718	0.0001	8
	5	6.44200000	0.28976330	0.0001	9
	15	5.08000000	0.28976330	0.0001	10
	25	4.38600000	0.28976330	0.0001	11
	35	3.46666667	0.30543733	0.0001	12
	5	4.85500000	0.28976330	0.0001	13
	15	5.62900000	0.28976330	0.0001	14
	25	5.54700000	0.28976330	0.0001	15
	35	4.61200000	0.28976330	0.0001	16
	5	4.78333333	0.30543733	0.0001	17

15	4.85600000	0.28976330	0.0001	18
25	4.37111111	0.30543733	0.0001	19
35	3.92700000	0.28976330	0.0001	20

|T| H0: LSMEAN(i)=LSMEAN(j)

j	1	2	3	4	5	6	7	8	9
	.	0.0068	0.0006	0.0001	0.2345	0.1931	0.0167	0.0005	0.2044
	0.0068	.	0.4327	0.0119	0.0001	0.1524	0.7461	0.4129	0.0001
	0.0006	0.4327	.	0.0728	0.0001	0.0277	0.2684	0.9725	0.0001
	0.0001	0.0119	0.0728	.	0.0001	0.0001	0.0050	0.0780	0.0001
	0.2345	0.0001	0.0001	0.0001	.	0.0135	0.0004	0.0001	0.9176
	0.1931	0.1524	0.0277	0.0001	0.0135	.	0.2669	0.0254	0.0061
	0.0167	0.7461	0.2684	0.0050	0.0004	0.2669	.	0.2539	0.0001
	0.0005	0.4129	0.9725	0.0780	0.0001	0.0254	0.2539	.	0.0001
	0.2044	0.0001	0.0001	0.0001	0.9176	0.0061	0.0001	0.0001	.
	0.1526	0.0853	0.0092	0.0001	0.0056	0.9429	0.1764	0.0082	0.0011
	0.0055	0.7264	0.2101	0.0016	0.0001	0.1920	0.9810	0.1961	0.0001
	0.0001	0.1481	0.5749	0.1368	0.0001	0.0025	0.0706	0.6018	0.0001
	0.0613	0.2009	0.0300	0.0001	0.0014	0.7071	0.3641	0.0271	0.0002
	0.7309	0.0054	0.0003	0.0001	0.0871	0.2458	0.0154	0.0002	0.0493
	0.6122	0.0087	0.0005	0.0001	0.0613	0.3180	0.0236	0.0004	0.0307
	0.0191	0.4245	0.0896	0.0004	0.0003	0.3909	0.6705	0.0825	0.0001
	0.0483	0.2639	0.0460	0.0002	0.0011	0.6109	0.4522	0.0420	0.0001
	0.0616	0.2002	0.0298	0.0001	0.0014	0.7086	0.3631	0.0270	0.0002
	0.0059	0.7531	0.2294	0.0021	0.0001	0.1902	0.9581	0.2147	0.0001
	0.0003	0.5738	0.7309	0.0192	0.0001	0.0277	0.3497	0.7012	0.0001

|T| H0: LSMEAN(i)=LSMEAN(j)

j	10	11	12	13	14	15	16	17	18
	0.1526	0.0055	0.0001	0.0613	0.7309	0.6122	0.0191	0.0483	0.0616
	0.0853	0.7264	0.1481	0.2009	0.0054	0.0087	0.4245	0.2639	0.2002
	0.0092	0.2101	0.5749	0.0300	0.0003	0.0005	0.0896	0.0460	0.0298
	0.0001	0.0016	0.1368	0.0001	0.0001	0.0001	0.0004	0.0002	0.0001
	0.0056	0.0001	0.0001	0.0014	0.0871	0.0613	0.0003	0.0011	0.0014
	0.9429	0.1920	0.0025	0.7071	0.2458	0.3180	0.3909	0.6109	0.7086
	0.1764	0.9810	0.0706	0.3641	0.0154	0.0236	0.6705	0.4522	0.3631
	0.0082	0.1961	0.6018	0.0271	0.0002	0.0004	0.0825	0.0420	0.0270
	0.0011	0.0001	0.0001	0.0002	0.0493	0.0307	0.0001	0.0001	0.0002
	.	0.0926	0.0002	0.5839	0.1826	0.2564	0.2554	0.4822	0.5855
	0.0926	.	0.0307	0.2544	0.0029	0.0053	0.5822	0.3470	0.2534
	0.0002	0.0307	.	0.0012	0.0001	0.0001	0.0074	0.0028	0.0012
	0.5839	0.2544	0.0012	.	0.0611	0.0936	0.5542	0.8651	0.9981
	0.1826	0.0029	0.0001	0.0611	.	0.8417	0.0143	0.0466	0.0614
	0.2564	0.0053	0.0001	0.0936	0.8417	.	0.0241	0.0719	0.0940
	0.2554	0.5822	0.0074	0.5542	0.0143	0.0241	.	0.6847	0.5525
	0.4822	0.3470	0.0028	0.8651	0.0466	0.0719	0.6847	.	0.8632
	0.5855	0.2534	0.0012	0.9981	0.0614	0.0940	0.5525	0.8632	.
	0.0945	0.9718	0.0381	0.2524	0.0033	0.0060	0.5682	0.3416	0.2515
	0.0056	0.2646	0.2762	0.0251	0.0001	0.0001	0.0969	0.0439	0.0250

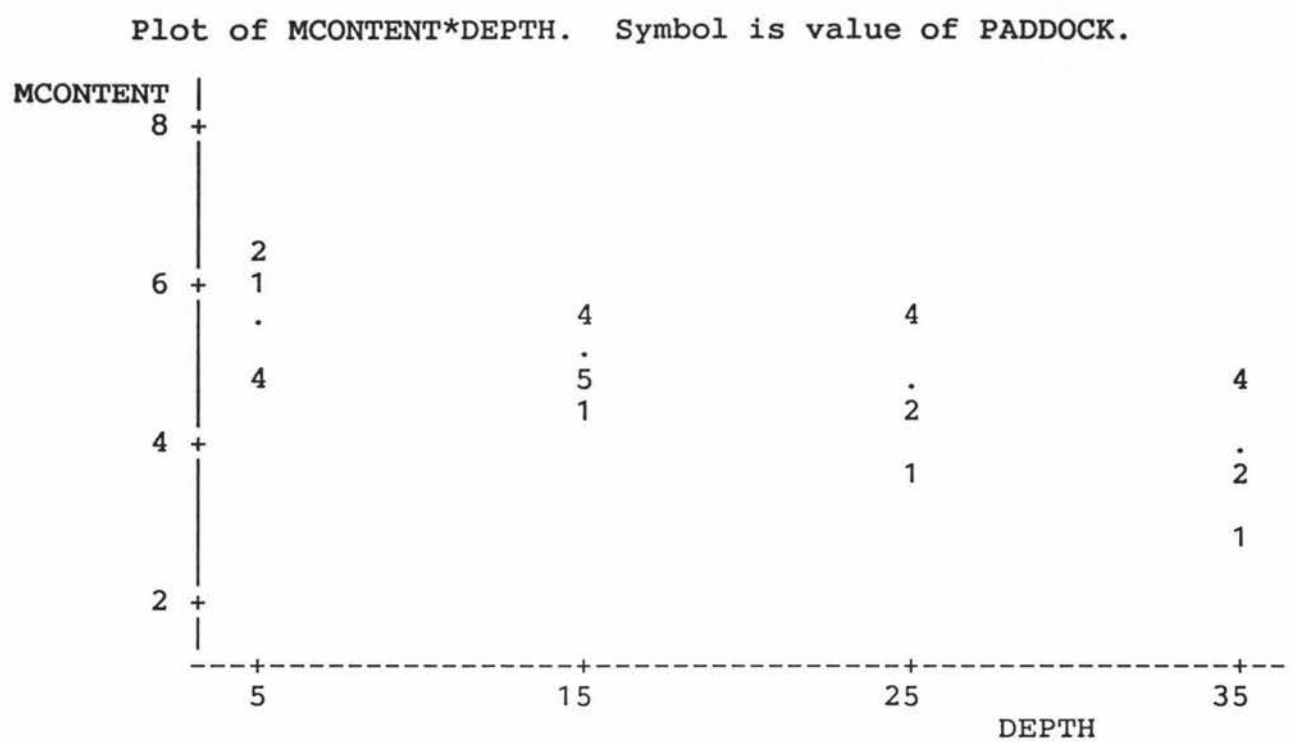
|T| H0: LSMEAN(i)=LSMEAN(j)

/j 19	20
0.0059	0.0003
0.7531	0.5738
0.2294	0.7309
0.0021	0.0192
0.0001	0.0001
0.1902	0.0277
0.9581	0.3497
0.2147	0.7012
0.0001	0.0001
0.0945	0.0056
0.9718	0.2646
0.0381	0.2762
0.2524	0.0251
0.0033	0.0001
0.0060	0.0001
0.5682	0.0969
0.3416	0.0439
0.2515	0.0250
.	0.2934
0.2934	.

All intresting interaction effects can be found in the fomer table. Any specific comparisons for different depth from different paddocks can be found here.

	DEPTH				
	5	15	25	35	ALL
	CONTENT	CONTENT	CONTENT	CONTENT	CONTENT
	MEAN	MEAN	MEAN	MEAN	MEAN
DOCK					
	5.80	4.21	3.75	2.64	4.18
	6.49	5.04	4.40	3.73	4.92
	6.44	5.08	4.39	3.47	4.88
	4.85	5.63	5.55	4.61	5.16
	4.78	4.86	4.37	3.93	4.48
	5.58	5.05	4.60	3.84	4.77

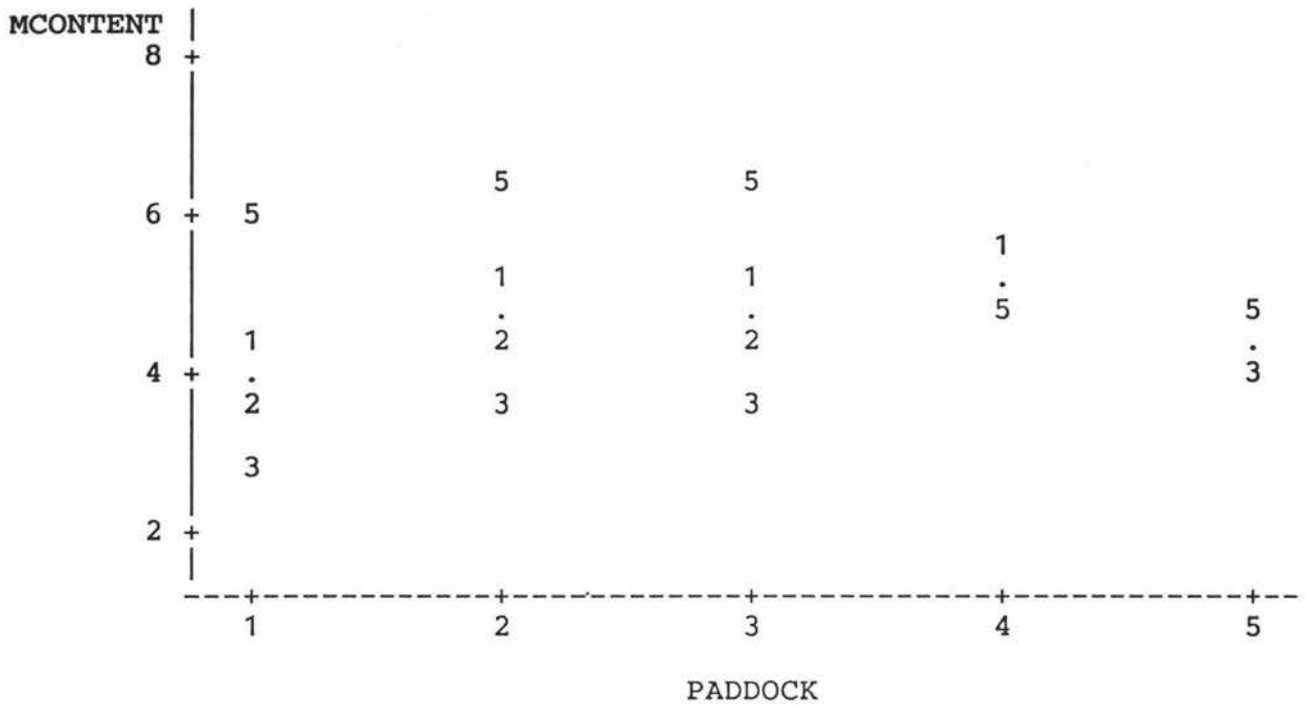
of factorial means depth vs paddock



: 6 obs had missing values. 8 obs hidden.

The most remarkable in this plot is that below 15 cm the conventional paddock as definitly the lowest organic matter content. This could indicate that the 'extra's' from the fertilizer free rotation come from the higher organic matter content in the subsoil. The paddock(4) with the first year crop has the highest organic matter content from 15 cm down. This seems logical because the organic matter content should build up under pasture. The strang thing is that it has the lowest organic matter content in the 0-15 cm layer. It would have been nice if the old(3) and recent(2) pasture were more visible. Nevertheless details can be found in the LSMeans table.

Plot of MCONTENT*PADDOCK. Symbol is value of DEPTH.



5 obs had missing values. 4 obs hidden.

The organic matter content of the recent pasture and the old pasture seem to have a similar distribution. They look also similar to the conventional paddock, only the convetional paddock is overall lower. The cropping paddocks seem to have less difference in organic matter content within the different depths.

APPENDIX IV PREPERATION FIVE HUNDRED

How to Make Biodynamic Preparations 500 and 501

Cow horns can be obtained from any cooperating slaughterhouse, and do not have to come from biodynamically fed cattle. But they should be from cows, not bulls or steers. Cow horns are generally thicker and heavier.

To clean, place the horns in fifty-five-gallon drums full of water; cover with plastic to prevent the spread of odors. After a couple of weeks, the thin layer of flesh surrounding the bony core of the horn will rot away; the bones can then be removed, leaving the horns empty. A less smelly method is to leave the horns to dry out. After a certain loss of moisture between bone and horn, the bone will fall out if the horn is struck sharply with another horn. Thereafter the horns may be stored indefinitely.

Manure

In a Northern-Hemisphere temperate zone, cow manure is collected between the fall equinox and the winter solstice. It is desirable that the animals still be grazing, or have part-time pasture or good hay plus some green feed.

In the Western Hemisphere, the horns should be well and tightly stuffed with manure that has been sieved to remove twigs or other foreign objects.

The stuffed horns are buried about two feet below the surface in good rich earth, in the fall, prior to the winter solstice (December in the Northern Hemisphere, June in the Southern), and are left there until the end of winter.

Biodynamic farmer Hugh Lovell, of Blainsville, Georgia, recommends placing the horns tip down, pointing toward the center of the earth, claiming the bovine horn to be an antenna that picks up the telluric forces of winter. Hugh Courtney stacks them in a circle, point down; but in Australia they are laid flat in rows, separated by a thin layer of earth. All methods seem to be effective.