TILLAGE AND NO-TILLAGE EFFECTS ON PHYSICAL CHARACTERISTICS OF A SILT LOAM UNDER 5 YEARS OF CONTINUOUS OATS-MAIZE CROP ROTATION

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Abstract

Conservation tillage is one of the conserving practices recognized worldwide despite its empirical benefits still largely undergoing continuous research. This research is part of a sequence of studies carried out at Massey University tillage trial. The soil type is Ohakea silt loam representing youngest yellow-grey earth with poor natural drainage on fine texture material, and topsoil moderately to strong acid enleached soils. Selected soil physical properties under different tillage systems i.e. no-tillage (NT), moldboard plough (MP) and permanent pasture (PP) (as control) were measured and compared. The important soil properties considered were soil aggregate stability, soil penetration resistance, water infiltration rate, soil bulk density, soil water content, crop dry matter, water runoff and leachate and soil pH (H_2O), total C and N. Results from both the field and laboratory experiments suggested that 5 years of continuous no-tillage have improved soil characteristics relative to conventional tillage.

Soil penetration resistance was significantly lower in the MP plots soon after cultivation and at the early oats growing season, compared to the NT and PP plots. However, this trend was reversed within six months, following winter grazing and spring fallow when soil was recompacted.

Bulk density measured during early oats growing season indicated a remarkably higher density at the top 0-5 cm soil layer under the NT compared to the MP treatment suggesting that NT plots' soils were more compacted at the time of planting and had lower total porosity than soils in the MP plots. On the other hand, water infiltration rates measured over one year period indicated an average value significantly higher under the NT and PP treatments than the MP plots. These results suggest that macropore continuity, water-filled porosity and other hydraulic properties were improved under NT.

A substantially higher level (11%) of water content was found in the NT plots compared to that in the MP plot. These suggested that although the NT soils were more resistant to penetration and had high levels of bulk density, these soils retained more water. These further suggested that the water-filled porosity under the NT soil was higher, thus helped increase the water availability for plant growth. The results also demonstrated that the

NT soil produced comparable winter oats and summer maize DM to those under MP treatment.

Regression analysis results indicated, not unexpectedly, a strong linear relationship between bulk density and soil penetration resistance with R^2 values of 0.97, 0.99, and 0.73 for the PP, MP, and NT treatments respectively. Similar analyses between soil water content and soil penetration resistance demonstrated a strong, moderate, and no correlations under the NT, MP and PP treatments respectively.

The NT soils were substantially more stable than the MP soils but were similar to the PP soils. The surface soil (0-10 cm soil depth) water-stable aggregates remaining on sieve for the PP, MP, and NT were 75.2, 26.2 and 70.8 % respectively. The macroaggregates (> 2 mm diameter) made up a large proportion of the pasture soil (54.7 %) and the un-tilled soil (37.4%), whereas the ploughed soils had macroaggregates at 4.8%. The ploughed soil was consisted of 73.8% of 0.5 mm water-stable aggregates. Prolonged sieving for 60 minutes also confirmed the above results that the detachment of soils by water in the continuously ploughed land was much easier as compared to the NT and PP management. Thus making the MP soils most vulnerable to water erosion.

Runoff and leachete experiments had produced rather inconclusive results as compared to the results on the same plots three years ago. However the trend was obvious that the MP treatment had caused more surface runoff than the other two treatments. By contrast, water runoff was lower in NT plots, which was also reflected by the occurrence of more water leaching under this treatment compared to the MP treatment.

The NT soils were relatively more acidic (lower pH) both at 0-10 and 10-20 cm soil layers. Both the MP and NT had resulted in a marked decline in total C level compared to PP at the 0-10 cm soil layer. The decline of total C content after 5 years of continuous double cropping in the 0-20 cm soil layer was about 12% in the MP plots and 2.65% in the NT plots. At the 10-20 cm soil depth, total C and N showed no differences among all treatments. Total N at the 0-10 cm soil layer was significantly lower under MP treatment compared to the other two treatments.

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Chapter 1

General Introduction

1.1 Introduction

Sustainability of the agriculture management system and its capacity to continue producing on a long term basis is a problem when human activities cause ecological changes that undermine agroecosystem function (Barrow, 1995). In agricultural systems, tillage is the principal agent resulting in soil perturbation and subsequent modification in soil structure. From an ecological point of view, such perturbations strongly influence the distribution of energy-rich organic substances within the soil and thus impact on energy flow and the dynamics of soil geochemical cycles (Carter, 1994).

In recent decades, the possible adverse effects of conventional tillage have become increasingly apparent and attention has been devoted to alternative management methods. Many of these alternatives have been based upon the principle of reducing the number and intensity of tillage operations (minimal tillage or reduced cultivation), which are commonly known as conservation tillage practices (Briggs and Courtney, 1985). The most obvious advantage of conservation tillage from an environmental viewpoint is its role in minimizing the risk of erosion. Surface residues protect soil structural conditions at the surface from the energies of raindrop impact and surface flow. Aggregate breakdown, surface sealing and crusting, and clogging of worm holes or voids between structural units is reduced (Bradford and Huang, 1994).

Riley et al. (1994), suggested that many of the changes caused by conservation tillage practices are interrelated, and their consequences may be of greater or lesser importance, depending on the soil type and on the external constraints of the climate. These changes can be summarized as follows:

- accumulation of available nutrients (phosphorus and potassium) and organic matter near the soil surface;
- increased bulk density and penetration resistance in upper and central topsoil layers;

- lower air-filled porosity and gaseous exchange and, sometimes, higher water-holding capacity;
- lower surface infiltration rates, but in some cases, increased hydraulic conductivity between topsoil and subsoil; and
- greater aggregate stability, greater earthworm activity, and more favourable conditions for promoting pore continuity.

No-till is the most extreme form of conservation tillage (Gish and Coffman, 1987). This involves no seedbed preparation at all, and crops are sown into the untilled soil by a machine that cuts a narrow seed-slot. Crop residues are normally allowed to decompose *in situ*, herbicides are used to control weeds and pests, and rooting and drainage conditions by encouraging earthworm activity. This practice is also known as direct-drilling in Britain or zero tillage in the USA (Briggs and Courtney, 1985).

Massey University is one of the leading advocates of conservation tillage in New Zealand and internationally. Research and development of the direct-drilling practice as well as studying its effects on soil and crops has been continuing since 1970's. To mention some of the studies which were conducted more than two decades ago, were those concerning the effects of no-till on soil properties conducted by Hughes and Baker (1977) and Choudhary (1979) regarding the drilling equipment performance and its relationship to seed emergence and soil micro-environment. In 1995, an experimental site was established, over which a series of specific studies on soil characteristics in regard to different mechanical treatments have been carried out (Guo, 1997; Aslam , 1998; Hou, 1999).

This research is part of a sequence of studies on the experimental site mentioned above. The experiments cover measurements of selected soil physical parameters, which in fact, will be the core of discussion. Soil physical characteristics such as soil penetration resistance, bulk density, water infiltration rate, soil aggregation stability, and organic matter content are assessed through both field and laboratory experiments. Changes in these properties may help characterize the effects on soil structure due to tillage practices and pasture management. As background of the whole study, chapter two which contains a review of literature, reflects the efforts to view the topic of this research in a broader spectrum of agricultural sustainability, especially in regard with conservation of soil and water resources. This implies also the literature research on interactions of tillage, cropping systems and pesticides, which attract increasing concern lately in the case of no-tillage practice. In short, attempts of this enlarged literature study, were to partly enrich the discussion of the results and to some extent fill the gaps on some other soil physical parameters not able to be covered by this research. Chapter three describes the methodology of the research, and the consequent results are presented in chapter four. It is recognized that the results based on the experiments are limited and specifically related to soil physical properties. Therefore, to enhance a comprehensive outlook of no-till and tillage performance on the experimental site, analysis will also cover some results previously obtained from other studies. Lastly, chapter five points out the conclusions of the study and recommendations for further researches.

1.2 Rationale

Changes in soil physical properties that occur as a result of changing from moldboard ploughing and permanent pasture to conservation tillage might be expected to develop slowly after the initiation of conservation tillage. In this context, a time period of 5 years after the implementation of conservation tillage, is viewed as an appropriate time frame for the comparison among mechanical treatments of the soil being studied in this research.

The hypothesis underlying the attempts of this study is that under conservation tillage some important soil properties are enhanced, although as a method, conservation tillage has a number of advantages and disadvantages. Particular focus of this study would be on soil physical properties as there is very limited information concerning tillage-induced changes and documentation on long-term tillage effects on soil physical properties.

1.3 Objectives

The specific objectives of this research are :

(a) To measure selected soil physical properties under different tillage systems i.e. no-tillage, moldboard plough and permanent pasture (as control treatment). The important soil properties considered in this research are soil penetration resistance, water infiltration rate, soil bulk density, soil water content, crop dry matter, soil aggregation stability, water and sediment runoff, leachate, and selected soil chemical properties such as soil pH, total C and N.

(b) To examine the relationship between soil physical characteristics mentioned above. Furthermore, the investigation would focus on the extension of improvement of such soil properties in the untilled plots relative to the conventionally cultivated plots.