THE EFFECT OF FORAGES ON SOIL STRUCTURE IN NEW ZEALAND MIXED CROPPING ROTATIONS

G.S. Francis, F.J. Tabley and K.M. Bartley
Crop & Food Research, Private Bag 4704, Christchurch, New Zealand

ABSTRACT

The objective of this experiment was to determine the rate and extent of changes in soil structural conditions under a range of forage plants and management practices. During the first experimental phase (years 1-6), the rate of soil structural improvement was slow even in the most effective treatment, with the greatest changes apparent in the surface soil (0-10 cm). Plants that produced the greatest above-ground dry matter and root mass were the most effective at improving soil structure, especially when annual tillage was avoided. In the second phase of the experiment (year 7), a spring wheat test crop was grown to measure the effect of contrasting soil structural conditions on crop yield. Harvest yields were significantly greater following treatments that had improved soil structural conditions. The decline in soil structure under cropping was rapid, although some benefit was still apparent after the first test crop. The longevity of this residual effect is under investigation.

KEYWORDS

Ryegrass, clover, wheat, lupins, soil structure, aggregate stability, yields, earthworms

INTRODUCTION

Mixed cropping is a major land use on the Canterbury Plains of New Zealand, a region that covers over 750,000 ha. In this farming system, grazed ryegrass/white clover pastures are grown in rotation with arable crops, with the relative lengths of the pastoral and arable phases traditionally determined by soil type (Haynes and Francis 1990). It is well known that soil physical conditions for plant growth are often best under long-term pasture and worst under long-term arable. However, the rate and extent of change in soil physical conditions over a mixed cropping rotation is not well documented. This information is required as farmers are under increasing pressure to increase the amount of cropping in their rotations, with the overall degradation of soil physical conditions a major possible limitation to continued cropping. Such degradation can lead to a greater cultivation requirement to produce a seedbed and increased wind erosion of soil. In addition, degradation of soil structure can lead to reductions in crop yields for a variety of reasons including poor crop emergence, inadequate soil aeration, reduced rooting depth, greater susceptibility to drought and nutrient deficiency.

MATERIALS AND METHODS

A long-term field experiment was established in 1989 on a Wakanui silt loam soil that had been structurally degraded by previous arable cropping. The first phase of this experiment (years 1-6) examined the effect of a range of plants and their management on the rate and extent of change in soil structural form and stability. The eight treatments in the randomised block experiment could be divided into perennial and annual treatments. The perennial treatments (that were all grazed unless otherwise stated) were ryegrass (*Lolium perenne*), mown ryegrass, white clover (*Trifolium repens*) and ryegrass/white clover. The annual treatments (that were all established by conventional cultivation unless otherwise stated) were ryegrass, direct drilled ryegrass, barley (*Hordeum vulgare*) and lupins (*Lupinus angustifolius*). The second experimental phase was established in year 7, when a spring wheat test crop (September 1995) was sown in all plots. This examined the influence of contrasting soil physical conditions on crop growth and yield. The rate of soil structural degradation was also measured in the second phase of this experiment to assess the persistence of soil structural conditions that had developed during the initial experimental phase. The experiment was sampled each autumn, after the harvest of the grain crops.

RESULTS AND DISCUSSION

In general, during the first experimental phase annual treatments produced less dry matter than perennial treatments as their growing season was shortened by an eight week fallow period each year (Table 1). Compared with grazed, the mown perennial ryegrass treatment produced less dry matter, probably because of the suppression of growth following the development of a surface mulch from returned residues. Differences between treatments were much more pronounced for root mass. When sampled in early summer, root mass to 20 cm depth in annual treatments (1.6-3.8 t/ha) was much less than in perennial treatments (6.6-11.5 t/ha). Perennial clover was the exception (3.7 t/ha) due to its sparse, stoloniferous root system.

Treatments that produced the greatest above-ground dry matter and root mass returned the largest amount of organic matter to the soil. In turn these treatments supported the greatest microbial biomass and earthworm population. Soil aggregates were stabilized through earthworm casting and through exocellular polysaccharide material produced by the microbial biomass. By the end of the first experimental phase (yr 6), all the perennial treatments had developed reasonably stable aggregates in the surface 0-5 cm. However, stability in these treatments declined significantly with depth (data not shown). Annual treatments had less stable aggregates, and soil with MWD less than 1.5 mm is regarded as likely to suffer from physical impediments to crop growth (Haynes and Francis, 1990). Macropore volumes were greatest in the lupins and mown ryegrass treatments as grazing caused compaction of the surface layers of the other treatments. The contrasting soil conditions that developed during the first experimental phase had significant yield effects in the second phase of the experiment. Harvest yields of the first spring wheat test crop ranged from 9.6 t/ha following the perennial ryegrass grazed treatment to 7.7 t/ha following lupins. The beneficial soil conditions that had developed in some treatments declined rapidly under cropping. In the perennial treatments, there were declines of 35-50 % in biomass C contents, 60-90 % in earthworm numbers and 20-35 % in aggregate stabilities (Table 1). In contrast, macropore volumes increased due to a relief of surface compaction caused by grazing. The extent of further soil structural degradation under continued cropping is currently being investigated.

REFERENCES

Haynes, R.J. and Francis, G.S. 1990. Effects of mixed cropping farming systems on changes in soil properties on the Canterbury Plains. N.Z. J. Ecol. **14:** 73-82.

Table 1
Cumulative above-ground dry matter production, and biomass C (0-5 cm), earthworm numbers, aggregate stabilities (0-5 cm) and macroporosities (0-5 cm) at the end of the first (yr 6) and at the start of the second (yr 7) experimental phases.

	DM (t/ha)	Biomass C (mg/g)		Earthworms (no./m^2)		Aggregate stability (MWD; mm)		Macroporosity (%, vol/vol)	
Treatment	yrs 1-6	yr 6	yr 7	yr 6	yr 7	yr 6	yr 7	yr 6	yr 7
Per rye grazed	56.7	1108	561	1333	128	2.65	1.93	0.09	0.13
Per rye mown	42.3	1060	607	959	212	2.56	2.02	0.12	0.13
Per clover	50.4	821	520	808	228	2.12	1.48	0.10	0.13
Per rye/clover	52.3	967	538	1136	448	2.53	1.61	0.09	0.10
Ann rye	46.2	668	458	748	444	1.91	1.24	0.08	0.14
Ann rye DD	36.9	848	463	412	172	2.19	1.34	0.09	0.11
Lupins	44.9	505	456	236	244	1.23	0.99	0.13	0.15
LSD	5.83	62.5	41.1	484.6	292.5	0.370	0.378	0.032	0.030