Effect of land management systems on rainfall infiltration capacity and the stability of red-brown earths

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Summary Tillage, rotation and stubble handling experiments have been carried out on red-brown earths at Halbury and Tarlee, in South Australia, since 1978 and 1983 respectively. Rainfall simulation studies made after seeding showed that infiltration at Halbury increased from 70% to 100% of the rainfall applied, as the surface cover increased from 20% to 100%; was similar for the no-till (NT) and conventional cultivation (CC) treatments in the wheat-pasture (W-P) rotation and the NT treatment in the wheat-barley-grain legume (W-B-G1) rotation, but 10% lower for the W-B-G1 (CC) treatment, with comparable surface covers. At Tarlee, infiltration increased from 25% to 75% as the surface cover increased from 15% to 100%; these increases were also positively related to average annual amount of stubble residue retained (0.5 to 5 t/ha). The soil loss in the run-off was inversely related to the surface cover at both sites with values ranging from 0.1 to 2.5 t soil/ha at Halbury and 0.3 to 1.7 t/ha at Tarlee. At Tarlee, the losses of N in the sediment were about 5.4 and 4.6 kg/ha respectively for the two lower, and the highest. stubble retention treatments; P losses were similar for each treatment (0.4 kg/ha). Soil OC values in the 0-4 cm depths ranged from 1.3% to 2.0% at Halbury, with values for the W-P(NT) treatments being higher than those for the W-B-G1(CC) treatments. At Tarlee, values in the 0-4 cm depths ranged from 1.3% to 1.7% OC. being positively related to the amount of stubble retained. Treatment effects on OC in the 5-10 cm depths were not consistent. The results are discussed in relation to other research and the development of sustainable land management systems for farm production.

Introduction

Red-brown earths and other similar textured soils have been commonly used for cropping since early settlement in southern Australia and they arc now used extensively for cereal, pasture and grain legume production. These soils are susceptible to degradation due to an inherently poor structure and low organic matter contents. Interest by farmers and researchers in conservation land management systems (CLM) has increased considerably since the early 1970's, as the need for developing more sustainable methods of land use and farm production was recognised. The results presented in this paper were obtained from two experiments assessing the longer term effects of tillage, stubble handling and rotation systems on the structure and productivity of red-brown earths in South Australia. A rainfall simulator has been used to obtain surrogate measurements of soil structure and stability after crop harvest, after seeding, and at about cereal anthesis. This paper presents results from simulation runs made after seeding (a time when the soil can be particularly susceptible to degradation by rainfall, as ground cover is at a minimum and final cultivations for the crop have been completed) together with complementary data on soil organic carbon (OC) and earthworm populations. It was hypothesised that CLM practices such as a substantial reduction of tillage, an increase in soil surface cover (e.g. with stubble residues), and the inclusion of legume-based pastures in rotation with cereals, will (i) increase the rainfall infiltration capacity, soil OC content and earthworm contents of red-brown earths, and (ii) decrease associated soil and nutrient losses due to detachment, slaking or dispersion of aggregates.

Methods

Sites and soils

Halbury (begun in 1978): Latitude 34^0 6'S and longitude 138^0 31'E; Calcic Haploxeralf; 0-2% slope. Tarlee (begun in 1983): Latitude 34^0 I7'S and longitude 138?46'E: Calcic Haploxeralf; 5-7% slope.

Experimental details

Results for selected, contrasting, treatments only are presented. Halbury - rotations (2 phases per year): wheat-pasture (W-P) and wheat-barley-grain legume (W-13-01); tillage with an autumn fallow and stubble retention: no tillage (NT; chemical fallow; narrow points for seeding) and conventional cultivation (CC; cultivation for fallow weed control and seeding); nitrogen (40 kg/ha with cereals); replicates: 2. Tarlee - stubble retention: an annual average of 0.5, 3 and 5 t/ha; tillage: mean of 4 treatments including NT and CC: nitrogen: 40 kg/ha with cereals; rotation: W-B-GI (I phase per year); replicates: 2. Rainfall simulation (100 mm/hr for 18 minutes on two adjacent frames each 1.0m x 0.5m; see (I) for further details) - Halbury: June-July 1991, after seeding wheat (W-P) and peas (W-B-GI) respectively; Tarlee - August 1990, after seeding peas. Surface cover at simulation: existing stubble residues from the previous crop or pasture, or 100% cover with shade cloth: nutrient contents in the sediment (nitrogen, N; phosphorus, P) are reported for Tarlee. Soil organic carbon (OC) values were also determined (soil sampled at lcm intervals to 10 cm) - Halbury: May 1990; Tarlee: November 1992. Earthworm numbers in the 0-10cm depth were determined at both sites in August 1991 by Mr J.C. Buckerfield and associates (2).

Results

Rainfall infiltration at Halbury (i) increased from about 70% to 100% of the rainfall applied, as the surface cover increased from 20-25% (existing stubble) to 100% (shade cloth); (ii) was similar for the W- P (NT and CC) and the W-B-GI (NT) treatments but lower for the W-B-G1 (CC) treatment, with comparable surface covers (Fig. la). At Tarlee, the infiltration increased from 25% to 50% as the existing cover increased from 15% to 80%, while comparable infiltration values were 55% to 75% for the 100% cover treatments; these increases in infiltration were also positively related to the average annual amount of stubble residue retained (Fig. 2a). The soil loss was inversely related to the surface cover at both sites with values ranging from 0.1 to 2.5 t/ha at Halbury (Fig. 1 b) and 0.4 to 1.7 tlha at Tarlee (Fig. 2b). At Tarlee, the losses of N in the sediment were about 5.2-5.4 and 4.6 kg/ha respectively for the two lower, and the highest, stubble retention treatments (Fig. 2b); P losses were similar for each treatment (1 kg/ha).

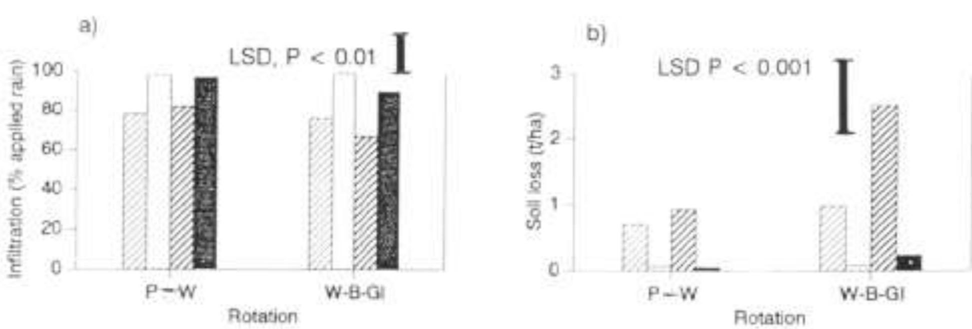

Figure 1. Effects of tillage and rotation systems, and surface cover (pasture and wheat stubble) during rainfall simulation, on infiltration capacity and soil loss; Halbury, S. Australia [ ] NT with approximately 60% and 20% stubble cover for P-W and W-B-G1 respectively, and [ ] CC with 60% and 25% cover for W-P and W B-GI; [ ] [ ] 100% cover with shade cloth for P-W(NT) and W-B-GI(CC). Simulations were done in June-July 1991, soon after seeding wheat and peas respectively.

Soil OC values in the 0-4 cm depths ranged from 1.3% to 2.0% at Halbury, with values for the W-P(NT) treatments being higher than comparable values in the W-B-GI(CC) treatments (Fig. 3a). At Tarlee, values in the 0-4 cm depths ranged from 1.3% to 1.7% OC, being positively related to the amount of stubble retained (Fig. 3b). Treatment effects on OC in the 5-10 cm depths were not consistent. Earthworm numbers in the 0-10cm depths at Halbury were 140 and 100/m^2 for the W-P(NT and CC) treatments, and 100 and 45/m^{-2} for W-B-GI(NT and CC). Numbers at Tarlee were 100, 240, and 270/m2 for the 0.5, 3 and 5 t/ha stubble retention treatments.

Discussion

The results generally support the hypotheses, implying that CLM practices, such as a substantial reduction of tillage. e.g. from 3-4 cultivation passes per year to an average of less than 1-2 passes per year (seeding with narrow points taken as 0.5 passes); the maintenance of an adequate surface cover during rain events. e.g. with at least 3 t/ha of cereal stubble or 80% cover of residues or growing plants; retaining annually, on average, at least 3 t/ha of crop stubbles; and the inclusion of legume-based pastures in rotation with cereals, will improve the structure and stability of red-brown earths. These improvements are also associated with higher levels of OC. an increase in earthworm numbers (2), and less surface waterlogging during wet spells (and consequently less delays in seeding and other field work). In contrast, continuous cropping together with stubble removal and cultivation for fallow weed control and seeding, e.g. at least 3-4 cultivation passes each year, can be expected to degrade the soil structure, reduce OC levels and earthworm numbers, increase the incidence of surface waterlogging during wet spells, and increase the risk of both water erosion on sloping land and the associated loss of soil nutrients. Results from other rainfall simulation studies at the present sites, after harvest and at cereal anthesis, support those presented in this paper.

Research elsewhere complements the present findings. The inclusion of legume-based pastures and the use of NT produce more stable soils than those with more intensive cropping and cultivation (3). Continued cultivation severely weakens the fabric joining soil aggregates together. The increased stability of soils under pastures and with NT is associated with fine roots. mycorrhizal fungi and organic matter (4), earthworm casts (5). and increases in the continuity of soil pores (6). Earthworm burrows can increase the infiltration capacity of soils by 2-10 times (7).

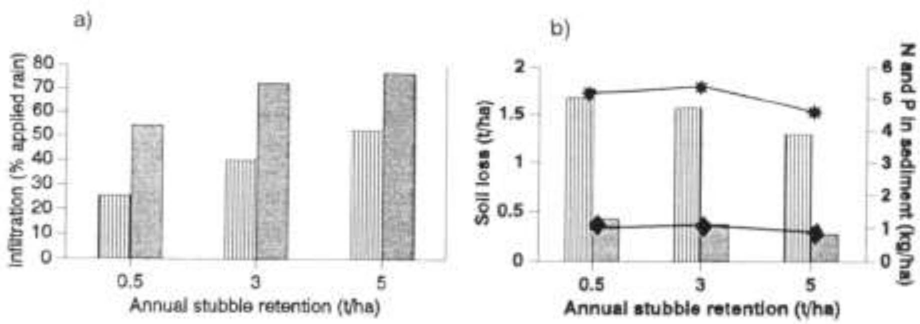

Figure 2. Effects of average annual retention of stubble (0.5, 3, and 5 t/ha) and surface cover with wheat stubble during rainfall simulation, on infiltration capacity, soil and nutrient loss; Tarlee, S. Australia. [IIIIII] 15%, 60% and 80% cover with wheat stubble respectively; [ ] 100% cover with shade cloth; (*) N loss; (.) P loss. Simulations were done in May 1990, soon after pea emergence.

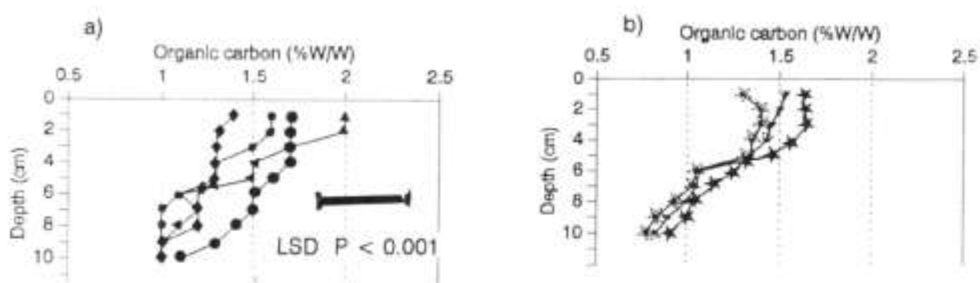

Figure 3. Effects on soil organic carbon contents in the 0-10 cm depth with (a) tillage and rotation systems at Halbury, S. Australia; May, 1990; (*) W-B-GI (CC), (.) W-BGI (NT), (•)) P-W (CC), (•) P-W (NT); and (b) of average annual stubble retention at Tarlee, S. Australia; November 1992; (4) 0.5, (v) 3, (•) 5 t/ha per year.

Sustainable productivity depends very much on how much water has entered the soil profile and the water holding capacity of the profile (8). Cornish, in a study of the influence of rainfall on wheat yield over a 4.6 year period in South Australia, showed that 14-83% of year to year variations in yield in the different wheat growing districts was accounted for by rainfall variates (9). The June-August period of rainfall had the highest influence on yield. Management systems that increase or at least maintain the stability and rainfall infiltration capacity of cropping soils during this period, can therefore be expected to improve potential crop productivity.

The results from the present studies relate directly to the development of more sustainable systems of land use for farm production. In practice, other factors such as weed, pest and disease control, farm equipment. the role of livestock, and continued economic viability, also need to be considered in the development of such systems.

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