A BATTLE FOR SUSTAINABLE PRODUCTIVITY OF FARM PRODUCE –DEVELOPMENT OF A VIABLE FARMING SYSTEM

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Abstract

Heavy soils such as red-brown earths comprise more than 3 fold the cropping land in southern Australia. Severe erosion of these soils occurred between 1930's and 1940's when the land was intensively cropped following a long fallow cultivated for up to 10 months. Some negative resultant effects of fallow are quick surface sealing and water logging resulting in delayed sowing. Amelioration of these soils started taking place in the 1950's when there was an emphasis on legume-based pastures for the production of wool and livestock. This period was followed by an increased intensity of cropping to cereals and other crops. Between 1960's and 1970's, concepts of reduced tillage, the sowing of crops with modified points, the retention of crop stubbles, and the inclusion of grain legumes in rotation with cereals, were being considered for use in the development of more conservative land management practices in order to improve soil physical, chemical and biological fertility, together with the design of appropriate farming equipment.

The Halbury tillage and crop rotation experiment was begun in 1978 and continued to 2002. A field rainfall simulator was used to assess soil structure change by measuring runoff and its constituents. This paper shows that the no-till system with a pasture phase and including surface cover increased organic carbon and reduced erosion and sediment load.

Additional Keywords: soil structure, organic carbon, surface cover, runoff, and tillage

Introduction

Soil compaction is a big problem in southern Australia. Research, development and adoption of tillage systems that will reduce subsoil compaction remain priorities in crop production. Tillage, crop rotation and stubble retention affect soil properties including organic matter (Hamblin, 1993). These effects can influence erosion and associated losses (Malinda, 1995). Runoff and erosion occur when precipitation exceeds infiltration rate and this is exacerbated by the formation of a surface crust in addition to reduced porosity and pore continuity (Malinda *et al.*, 1994a). The formation of soil surface crust is a function of the rate and cumulative kinetic energy (KE) of raindrops on bare soil surface and soil aggregate stability. Surface soil aggregates of red brown earths are vulnerable to impact stress from rainfall drops because of low stability. Resultant effects are soil detachment and subsequent transport by overland flow. The magnitude of soil aggregate detachability will depend mainly on the energy status of raindrops and the stability of the soil. We conducted research on the long term tillage x rotation experiment at Halbury to test the hypothesis that no-till pasture wheat (R-) and no-till continuous cropping (C-) improve the soil physical and chemical fertility by reducing runoff, soil and nutrient loss and increased OC over conventional cultivation with continuous cropping (C+) or with pasture wheat systems (R+).

Materials and methods

Site details

The experiment was located near Halbury in South Australia (Latitude 34° 06'S and Longitude 138° 31'E) on a fine, mixed thermic Calcic Haploxeralf; the sand-silt-clay values in the 0-10cm depth were 66%, 18%, and 16% respectively, with clay contents increasing to 45-50 % in the 25-85cm zone; calcium carbonate contents increased from 2-10% at 0-25 cm to 30-45% at lower depths. The average annual winter-dominant rainfall is 450 mm. The soil had an organic carbon content of 0.81% at the start of the trial in the 0-100 mm depth.

The long-term field experiment consisted of two phases of the rotations in adjacent blocks, each containing a 9 x (2) x 2 randomised split plot design with main plots: nine tillage x rotation treatments; split plots: two nitrogen treatments; and two replicates. The rotations were wheat-pasture (WP) normally volunteer species including medics (*Medicago spp*. sown), grasses and broadleaved species; wheat-barley-grain legume (WBGl) was either field peas (*Pisa sativa*) or Faba beans (*Vicia faba*) and wheat-pasture-long fallow (WpLF) begun in early spring (September). The tillage regimes included: (1) no tillage (NT) with herbicide only for fallow weed control and seeded with narrow points (<30 mm) resulting in minimal stubble incorporation; (2) reduced tillage (RT) with one initial cultivation using 265 mm shares at the start of the fallow, then herbicide only for weed control during the remainder of the fallow and seeded with tined seeder fitted with wide shares (265 mm) and with some stubble incorporation; (3) conventional cultivation (CC), with cultivation only for fallow weed control and seeded with wide shares (150 mm); stubble mostly incorporated by seeding time.

Rainfall simulation work reported in this paper had four treatments chosen from the above design. These treatments are: (no-till pasture-wheat (R- conservation treatments), conventional cultivation pasture-wheat, (R+ or semi-conservation), no-till continuous cropping, (C- conservation treatments) and traditional (exploitive) treatments (conventional cultivation continuous cropping C+).

The Northfield Rainfall Simulator (Malinda, *et al.*, 1992) based on a slotted spinning disc with microprocessor control was used to apply rain at one intensity (100 mm hr^{-1}) for 18 minutes. The kinetic energy content of the simulated rain was determined to be 28.57 J m^2 mm^{-1} by using the flour method (Kohl 1994). The use of this intensity and relatively short periods of application was a compromise between ensuring an effective assessment of rainfall effects on soil stability, continuing each run until steady state conditions, and the completion of up to 36 simulation runs (72 target areas) in 3-4 days. The latter objective was important in order to minimise interruptions due to changing weather conditions, and to have adequate sets of data for statistical analyses. Also, the rainfall intensity and amount of rain applied approximated severe rainstorms that, in the past, are known to have caused extensive erosion and degradation of bare-cultivated red-brown soils. The rainfall was applied to two adjacent target areas (each 1.0 x 0.5 m^2); whose coefficient of uniformity was 93.4%.

Simulation runs on +N 40 kg ha^{-1} plots only were made in autumn, before the start of seedbed preparation (May 1989) (25% stubble cover and 100% shade cloth cover); in winter after seeding the crops (July 1989 and 1991) (< 15% cover depending on treatment and 100% shade cloth cover) and in spring, at about maximum crop (phase 1, 100% shade cloth cover) and pasture at flowering (phase 2, with pasture cover), (October 1989). The 5 simulation runs were made in transects across the plots; a 'new' area selected for each transect.

The measurements included runoff rate, total loss of soil, N and P in the detached soil sediment in the runoff and soil OC. The data for soil OC are means of 2 reps and 2 phases and 2 samples per plot representing a total soil sample of 1680 cm^3 for every 1 cm of soil depth. The distribution of OC was obtained using a method devised by Malinda (1994b), where soil was sampled in succession of 1 cm to a depth of 10 cm. This was thought to be the best method in assessing the distribution of OC, N and P contents caused by tillage and where the relationship between loss of OC, N and P and erosion would be better understood. This soil was sampled in May/June 1991 when the ground was moist. Surface residue was not included in the samples. The soil organic carbon was measured by the method of Walkley and Black (1934). Soil loss (kg m^2 mm^{-1} of rain) was calculated from the runoff volume collected at time t (minutes) (Malinda, 1995). Total nitrogen and phosphorus in the sediment samples were determined by the Kjeldahl digestion method. The runoff volume from subplots on each treatment was used to calculate sediment loss (kg m^{-2} mm^{-1} rain) (Malinda, 1995). Total nitrogen and phosphorus were determined from the runoff sediment by Kjeldahl digestion method of Rayment and Higginson (1992). Where necessary, data were analysed using ANOVA**.**

Results

Effect of soil surface condition on erosion

There was a significantly higher runoff rate from the bare soil surface compared with a covered surface in autumn (Figure 1) suggesting that surface cover plays an important role in infiltration/erosion process. The C+ and R+ plots recorded significantly higher runoff rate compared with R- and C- treatments in winter 1989 (Figure 2). This was due to excessive cultivation.

In October 1989, phase 1 runoff rate followed a similar trend with July 1989 results with C+ recording higher runoff compared with R- (Figure 3b). However, phase 2 runoff measured with existing medic cover (at flowering) reversed the trend, in that the R- rotations recorded significantly higher runoff compared with C+ (Figure 3a). Runoff rate in Phase 2 was significantly greater compared with phase 1 but with a clearer water. It is believed that in phase 2 most pores were occupied by fresh pasture roots thus reducing infiltration rate.

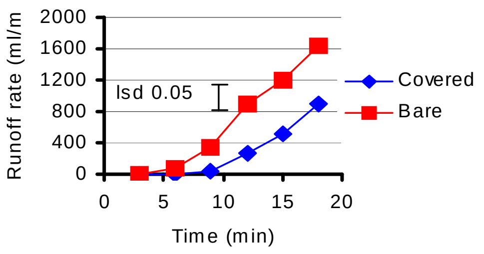

Figure 1. The effect of surface condition (40% cover and 0% cover) on runoff rate in May 1989 at Halbury SA

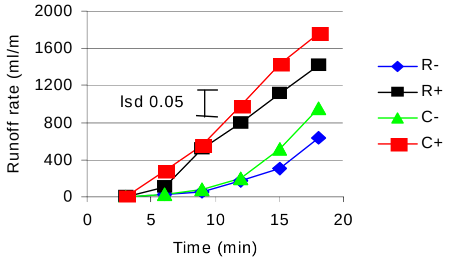

Figure 2. The effect of tillage and crop rotations on runoff rate in July 1989 at Halbury SA

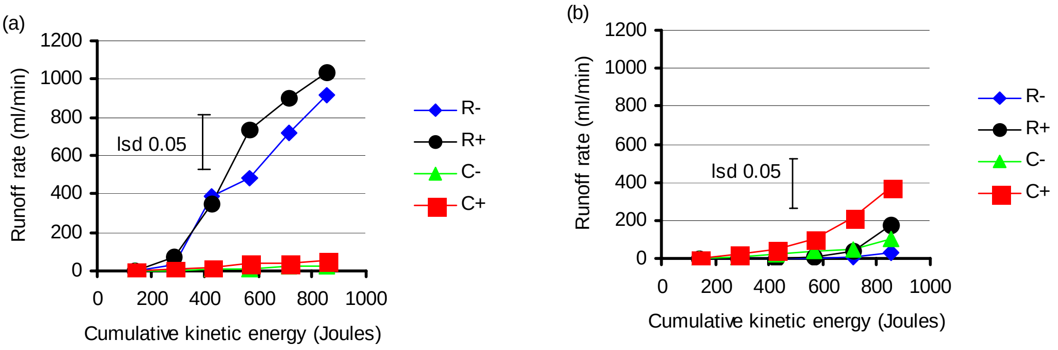

Figure 3. The effect of tillage and crop rotations on runoff rate phase 2 (a) and Phase 1 (b) in October 1989 at Halbury SA

Treatment effect on chemical fertility

At the start of the trial in 1978, the 0-5cm layer organic carbon content was 1.2%. In 1991, R- significantly ($P< 0.001$) increased OC of the top 2cm of soil (Figure 4a) compared with C+. This topsoil layer is the one in immediate contact with raindrops. Regression analyses of the 3cm soil OC content in relation to soil loss shows a negative curvilinear relationship ($r^2 = 0.902$, $P=0.001$) (Figure 4b) indicating that the magnitude of soil loss was strongly controlled by OC. The effect of organic carbon on aggregate stability of the surface soil may be described by the regression equation:

$$y = 104.38e^{-3.5874X} \quad (n=12,\ r = 0.902)$$

where y is the soil lost at time t, and x is the percent of organic carbon in the 0-3-soil layer

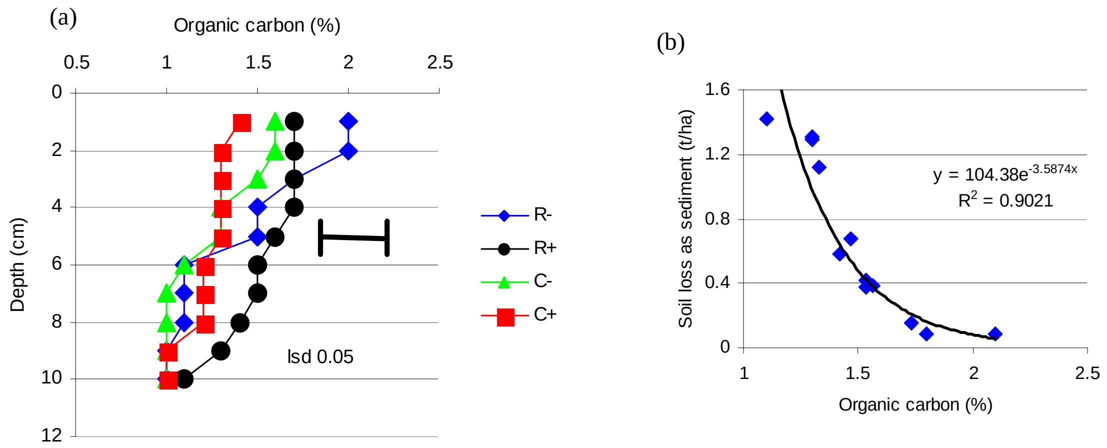

Figure 4. The effect of tillage and crop rotations on OC measured in May 1991 at Halbury South Australia (a) and relationship between OC and soil loss (b).

Conclusions

Conservation tillage (NT) either with pasture wheat or continuous cropping improved soil stability by improving organic carbon of the surface soil. The improved soil stability reduced both runoff and soil loss compared with conventional cultivation (CC) with pasture wheat or with continuous cropping. However, these improvements did not translate into increased yield (not reported here) probably due to subsoil compaction and a method needs to be developed to remove compaction prior to practicing NT system.

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