ARE 'CONSERVATIVE' CROPPING SYSTEMS IMPROVING SOIL INFILTRATION, ORGANIC CARBON AND BULK DENSITY IN SOUTHERN NSW?

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Abstract

Natural resource sustainability has become a major issue in agricultural enterprises. To quantify soil sustainability, soil infiltration, organic carbon and bulk density were monitored on 22 farm properties in southern New South Wales for three years. The experiment aimed to: (i) quantify the current status of cropping soils in the study area, and (ii) assess the sustainability of cropping practices used. The results showed that generally the soils were in a degraded condition. Surface infiltration rates were 13 mm/hr and 9 mm/hr at 100 mm depth. Organic carbon levels were 1.74%, 1.45% and 0.99% in the 0-20 mm, 20-50 mm and 50-100 mm depth respectively. Bulk density values ranged from 1.55 kg/m^3 for clays to 1.7 kg/m^3 for sandy loams in the 80-120 mm depth. Although tillage practices were regarded as conservative, there was no significant improvements in these soil properties measured over three years. Analyses are presented which separated the effect of soil type and management practice. Discussion is presented on better soil management practices to address the problem of ensuring sustainable cropping practices.

Key words: Soil infiltration, organic carbon, bulk density, cultivation, sustainable soil management.

With current concerns about onsite and offsite detrimental effects of farming practices on the environment, sustainability has become a catch cry of research, extension and government bodies. A major problem with sustainability is that it encompasses a very complex system of social, production, ecological and economic aspects, and thereby is very difficult to quantify. In an attempt to quantify soil sustainability, combined research agencies have measured soil physical properties on a number of farms using various land management systems at a common point in time (2). ?Subsequent to this program, a more holistic approach to measure sustainability was undertaken in a program titled 'Farm Management 500 and Sustainable Technology (FAST)'. The aim of FAST was to link the financial management on southern New South Wales farms with a range of production and environmental aspects of the farming system.

This paper presents data on soil infiltration rates, bulk density and organic carbon monitored on 22 FAST paddocks over three years. The assumption was that conservation farming practices would improve these soil properties compared to a cultivation system. Maintenance of, or improvements to, these soil properties due to the effects of conservation tillage, particularly no-tillage, have been quantified by Australian research in a range of soil types (4, 7, 6).

Materials and methods

Soil physical data were collected annually from 22 paddocks over a three year period (1994-1996). These paddocks were selected from a range of soil types and farming practices typical of the study region. Paired sites were selected from an area to contrast a degraded and conservatively managed paddock.

Each year, three steady state infiltration measurements were taken adjacent to installed neutron probes on settled soils in the late summer/autumn period using disc permeameters at -0.1 kPa matric potential on the surface and at 100 mm soil depth. To ensure soil pore continuity and a 'natural' soil surface at depth, araldite pads were poured and peeled when set from the exposed soil surface.

At each permeameter site, samples were also taken for organic carbon and bulk density. Three organic carbon samples were taken at 0-20 mm, 20-50 mm and 50-100 mm soil depths. Samples had gross organic material removed prior to preparation. These samples were then air dried, hand crushed, mixed

and analysed using the Walkley-Black method (1). Six bulk density samples were also using 75 mm diameter stainless steel cores at 0-40 mm, 40-80 mm and 80-120 mm soil depth. Moisture content was also determined on these samples.
The 22 paddocks were assigned to soil type classes based on surface texture (B. Murphy pers. comm.). These classes were: (i) sands (n=2), (ii) fragile light textured soils - yellow podzolic soils (n=3), (iii) fragile medium textured soils - red brown earth and non-calcic brown soils (n=8), (iv) friable soils - red earths (n=5), and (v) coarse structured clay soils - ?grey cracking clays (n=4). Paddock history was also broadly divided into two classes: (i) 'bad' - those with a cultivation history and cultivated for crop establishment during the trial period (n=10), and (ii) 'good' - those with a recent pasture or conservation tillage history, and used conservation tillage for crop establishment (n=12).

Due to the unbalanced and mixed model nature of the datasets, analyses made use of the REML directives of Genstat to examine for differences due to the fixed effects of soil type class, paddock history, year of observation and their interactions, while farms within soil types and samples within farms were estimated as random effects.

Table 1 : Estimated steady state infiltration rate (mm/hr) at -0.1 kPa matric potential at the surface and 100 mm depth.

	Steady State Infiltration Rate (mm/hr)	
Year	Surface	100 mm Depth
1994	13.6	7.4
1995	13.4	9.0
1996	13.7	9.1

Table 2 : Estimated organic carbon (%) profile for all sites over 3 years.

	Mean Organic Carbon (%)			Interaction between year and soil type at 50-100 mm depth				
Year	0 - 20 mm	20 - 50 mm	50 - 100 mm	Clay	Friable	Light Texture	Medium Texture	Sand
1994	1.79	1.48	1.05	1.05	1.19	0.95	1.04	0.74
1995	1.79	1.52	1.08	1.16	1.15	1.16	1.07	0.70
1996	1.63	1.39	0.96	1.10	1.12	0.77	0.85	0.98

(iii) Bulk density Results of the density profiles averaged for all sites (Table 3) showed no significant differences between years at each depth but there were significant differences between depths.

Table 3 : Mean bulk density (kg/m^3) profile for all sites over 3 years.

	Mean Bulk Density (kg/m^3)		
Year	0 - 40 mm	40 - 80 mm	80 - 120 mm
1994	1.31	1.46	1.58
1995	1.28	1.47	1.60
1996	1.30	1.46	1.59

Results and discussion

Infiltration

The average infiltration rates of all sites over 3 years are presented in Table 1. There was no significant change in infiltration rate at the surface, nor at 100m depth ($P<0.05$). However, there was a highly significant decrease in infiltration from surface to 100 mm depth, indicating the effects of compaction layers and lack of soil porosity. Significant differences also were apparent between soil types, but only at the soil surface: friable (21.3), clay (13.6), light texture (11.7), medium texture (10.4) and sand (9.4 mm/hr). There were no significant interactions between year of observation and the other factors.

Organic carbon

There were significant differences ($P<0.05$) in organic carbon across years for each depth, with effects dominated by a contrast between years 1995 and 1996 (Table 2). As expected, organic carbon declined significantly with depth. The only interaction was between soil type and year of observation at the 50 - 100 mm depth, where there was no increase in organic carbon with time, rather a major decrease was recorded for the light and medium textured soils.

Bulk density

Results of the density profiles averaged for all sites (Table3) showed no significant differences between years at each depth but there were significant differences between depths. These results correlate with the lower infiltration rates and are probably due to lower porosity and compaction. There were significant interaction between year of observation and soil types for all 3 measurement depths. There were trends, however, for the light textured, friable and clay surface soils to have lower bulk densities than the medium textured and sand surface soils. There was also a trend for the good management paddocks to have a lower density than the bad management paddocks.

Discussion

Analysis of the 22 sites was conducted as a group for two reasons:

• to quantify the current status of cropping soils in southern NSW using infiltration, organic carbon and bulk density as indicators; and,

• to assess the soil sustainability of the cropping practices used during the experimental period.

Generally this experiment showed that cropping soils are in relatively poor structural condition regardless of soil type or management practices studied. Infiltration rates were far from optimal, particularly at depth (8 mm/hr). Such low values suggest problems of soil compaction (plough pans) and low continuous porosity. Agronomic problems would include perched water tables in wet seasons, waterlogging, low rainfall infiltration for moisture storage and poor trafficability in wet conditions. These results support findings of a recent study by Geeves et al. (2) in the same area. They measur- ed an average infiltration rate of 12.6 mm/hr at 100 mm depth in rotationally cropped and grazed paddocks. Their slightly higher mean value could be explained by the inclusion of pasture paddocks in the study. This would also be the major reason for the surface infiltration rate of 44 mm/hr compared to our 13.5 mm/hr. These results cannot accepted as normal because work by Geeves et al. (2) showed on woodland sites average surface infiltration rates of 152 mm/hr and 30 mm/hr at 100 mm. Also this work measured surface infiltration rates around 100 mm/hr on the best cropping paddocks (3). Similarly, Packer et al. (7), reported infiltration rates of 45 mm/hr using no-tillage compared to reduced tillage (20 mm/hr) and cultivation systems (10 mm/hr).

Similarly, organic carbon mean values levels reported in Table 2 are comparable to those reported by Geeves et al. (2). They measured values of 2.18%, 1.68% and 1.16% for the 0-20 mm, 20-50 mm and 50-100 mm soil depth respectively. All these values are low when compared to woodland site values of 7.50%,4.44% and 2.57% for the 0-20 mm, 20-50 mm and 50-100 mm soil depth respectively (2). Although these levels may not be achieved again in an agricultural system, improvements are possible. Packer et al. (7) reported a 100% increase using minimum soil disturbance and residue retention. This increase was sufficient to obtain the benefits of reduced erosion risk, particularly sheet erosion, reduced surface crusting/sealing and decreased soil strength at sowing.

Bulk density values in Table 3 also support the argument that generally cropping soils are in a degraded condition. Using the estimation that bulk density is limiting from 1.4 kg/m^3 for clays to 1.8 kg/m^3 for sandy loams (5), mean values in this experiment were around 1.55kg/m^3 for clays to 1.7 kg/m^3 for sandy loams at the 80-120 mm soil depth. These indicate root growth and infiltration problems may be encountered. In fact, infiltration was low and lateral root growth was observed on dense layers. Perched watertables or surface waterlogging which caused plant growth problems were reported by a number of cooperators, also support these measurements.

With respect to changes in the measured soil properties, the data showed there was no significant improvements in the three year experiment. In fact there was a significant decrease in organic carbon between 1995 and 1996 (Table 2). It is not clear whether this was an actual decrease or due to technique even though the same method was used each year. This generally held true regardless of soil type or crop establishment technique used by the landholder. There were however some significant results.The clay and red friable soils had higher surface infiltration rates than the light, medium and sand textured soils. This would be expected due to the buffering effect of the clay on structural decline. Also there was a significant interaction between soil type and time for organic carbon at the 50-100 mm depth. The decrease in the light and medium textured soils indicate these soil types may be particularly susceptible to structural decline due to the lower clay content. The bulk density trends showed sites with better management practices had lower bulk densities. This is probably indicating the development of better porosity from less soil disturbance. The trend in soil types is not as clear, but generally soils with a higher clay content had lower densities. There was a trend of lower densities in the light textured soil types but this reflected better practices rather than soil type due to the dominance of minimum tillage in this group. It could be argued that three years was insufficient time for any significant changes or trends to develop. This is certainly the case considering the management systems in this experiment had all or a combination of short rotations, stocking, low residue retention/ burning, excessive traffic and too much soil disturbance. Recent work by the author has shown that all of these factors must be addressed for maximum soil improvement rates. One or two bad management decisions can destroy soil improvements rapidly eg. intensive grazing or weed control spraying on wet soils.

Conclusion

This project has highlighted that soils in southern New South Wales are in a degraded condition with respect to infiltration, organic carbon and bulk density. Also current farming systems are not quickly addressing the problem of maintaining or improving soil properties to achieve sustainability. Although some sites were practicing direct drilling and no-tillage techniques, they were not implementing best management stategies for maximum soil improvement. As a result, only the suggestion of improvement trends were measured in the short experimental period, and much longer periods (greater than 10 years) would be needed for significant changes. Therefore changes to cropping practices has to be much more committed. Unless practices such as plough pan disturbance, no stock, residue retention and no-tillage sowing are adopted as a complete cropping package we will have to tolerate these marginal and slow rates of soil improvement.

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