SUGARCANE PRODUCTION AND SOIL PHYSICAL DECLINE

By

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Abstract

An unqualified but widely held view is that sugarcane production is deleterious for soil in general and soil physical condition in particular. In Australian sugarcane, though the area of land under production currently increases at approximately 4% a year, productivity (yield of sugar per harvested hectare) plateaued for the 20-year period from 1970 to 1990. To date, rationalisation of this ‘yield decline’ has focussed on changes with time-under-cane of soil chemistry, biology, microbial biomass and soil organic carbon status. In the current study, data collected on the same seven paired sites of the previous studies were: particle size distribution (PSD), bulk density (BD) and available water (AW) in three layers to 50 cm. PSD demonstrated that only one site varied significantly between old and new land. BD was significantly greater in the old land than new land at six of the seven sites in at least one sampled layer. Increases in BD ranged from 3% to 22%, the latter being a comparison between adjoining caneland and a forested area. Inter-rows had a greater BD than within row locations. Also, the magnitude of the increase in BD between row locations was greater than that between old and new land. Four sites demonstrated less AW in the old land than the new land; up to 20% less. The physical degradation of the old land agreed with sugarcane productivity decline measured at three of the sites at the time of soil sample collection.

Introduction

An unqualified but widely held view is that sugarcane production is deleterious for soil in general and soil physical condition in particular. ‘Yield decline’ of sugarcane, where there is a productivity plateau despite increased land area under production, has been recognised in Australia (Garside et al., 1997) and elsewhere (van Antwerpen and Meyer, 1996a, b; Henry and Ellis, 1996). Investigation of the problem is vital if causative factors are to be identified and best management practices initiated to ensure a productive and sustainable industry.

Pairs of ‘old’ and ‘new’ land under sugarcane at seven sites in Australia have been evaluated for soil chemical, biological, microbial biomass and soil organic carbon status (Bramley et al., 1996; Magarey et al., 1997; Holt and Mayer, 1998; Skjemstad et al., 1999). Old land was land that had grown cane for several years and new land was land that either had never been planted to cane or had been under cane for only one or two years. New and old land in these studies did not differ in chemical or organic matter status, though old land was more acidic and had greater amounts of organic carbon deeper in the soil profile.

Research in countries other than Australia have linked yield decline with elements of soil physical deterioration. Swinford and Boevey (1984) reported up to a 32% reduction in sugar yield related to an average increase in bulk density of 5% in South Africa. In Colombia, Torres and Villegas (1993) matched losses in cane of 10 to 42% with a 28% reduction in available soil water and increased bulk density in the upper 50 cm of soil.

The objective of the current work is to identify links between deterioration in selected measures of soil physical status and reported yield decline of Australian sugarcane, using data from the seven old and new land Australian sites described in previous studies.

Materials and methods

Site locations and histories are given by Bramley et al. (1996). Across the seven sites, new land was either plant cane, first ratoon, or rainforest, and old land was land that had been under continuous cane for at least 19 years. For this study, three undisturbed soil cores (7.3 cm diameter and 5 cm length) were taken vertically into each of the row and inter-row locations (or the rainforest floor at Tully) at depths of 0–5, 15–20 and 45–50 cm (hereafter termed top, middle and deep layers). The cores were equilibrated to a range of suctions from 0.3 to 15 kPa in the laboratory and weighed before and after oven-drying (Ford and Bristow, 1995a, b). Bulk density (BD) was determined from the weights of the oven-dried cores. ‘Available water’ (AW) was calculated as the difference in volumetric water content between the 0.3 and 1.5 kPa suctions. Particle size distributions (PSD) were determined on each core at the conclusion of the laboratory measurements and the data synthesised using a texture ternary diagram to give a soil texture for each sample layer. Five sites (Costanzo, Harney, Fortini, Kalamia, and Pegararo) had three treatment factors: land (old and new), location within the site (row and inter-row) and depths (top, middle and deep). Sites at Marbelli and Tully had two treatment factors: land (old and new) at Marbelli and rainforest.
old land within row and old land inter-row at Tully) at three depths. Sugarcane yield, CCS (commercial cane sugar content) and stalk numbers were collected from three (Costanzo, Harney and Pegararo) of the seven-paired sites as cane was grown on each of the old and new lands at these sites at the time of soil sample collection. Statistical analysis was a univariate ANOVA with data from each site being analysed separately. Means were separated using the LSD test at the $P<0.05$ level and all significant differences in the script are reported at that level.

### Results

Only the Costanzo site had important differences in texture between the old and new land with the old land being a sandy clay loam and the new land being a clay loam. The middle and deep layers varied slightly between old and new land at Marbelli with the deep layer being the most different, a silty clay loam in the new land and a loam in the old land. The deep layer varied slightly in texture between old and new land at Fortini—a clay loam and a loamy sand, respectively. Textures varied little at the other three sites and there was no difference in texture between layers of the old and new land at Kalamia.

Old land had greater BD than new land at all sites in at least one sampled layer (Figure 1). The exception was at Harney where there were no significant differences between old and new land regardless of location within the row or in the inter-row (data not presented). Differences between old and new land were greatest at Tully where the top layers in the inter-row and in the row of the cane land were 22% and 18% denser, respectively, than the top layer in the rainforest (Figure 1). The increase in BD in the old land at the other sites ranged from 3% in the middle layer of the old land at Pegararo to 13% in the middle layer at Marbelli. BD was significantly greater in only one layer of new land relative to old land—the deep layer at Kalamia (Figure 1). The top and middle core sections from the inter-rows were significantly denser than the cores taken in the row in the top and middle layers at Costanzo and Kalamia but only in the middle layer at Pegararo. A trend was evident where the increased BD in the inter-rows compared to the rows was greater than the increase in BD of the old land vs the new land, eg the top and mid layers of Costanzo and Kalamia, and the mid layer of Pegararo and Fortini (Figure 1).

AW gave fewer significant interactions and main effects than BD (data not presented). Costanzo, Harney, Kalamia and Pegararo gave significant (up to $P<0.01$) main effects for the age of the land (averaged over the three depths) with the old land having significantly less AW than the new land (0.1036 vs. 0.1242, 0.1901 vs. 0.2364, 0.1672 vs 0.1814 and

![Bulk density (Mg m$^{-3}$)](attachment:image)

**Fig. 1**—Bulk densities from soil samples taken from old and new lands within the row and in the inter-row spacing at soil depths of 0–5, 15–20 and 45–50 cm at six Australian sites: (a) Pegararo, (b) Costanzo, (c) Kalamia, (d) Fortini, (e) Tully, (f) Marbelli. The LSD value (at the $P<0.05$ level) for comparison of the differences between means at each site is given on each graph as a horizontal bar.
2001 ~ 340 (all cm³/cm³), respectively). Dif-
ficances ranged from a 20% reduction in AW in the old land at Harney to 8% at Kalamia.

Significant differences in cane yield were restricted to the Harney site where there was 22% more cane and 12% more sugar (CCS) on the new land relative to the old (Table 1). The lack of yield or CCS differences on the Costanzo and Pegararo sites suggest that there was no loss in the productive capacity of the old land. However, observations of growth during the season demonstrated that this was not the case (Garside and Noble, 1996). There was such pronounced early season vigorous crop growth on the new land at Costanzo that severe lodging occurred, consequentially reducing the potentially greater yield of the new land. This is reflected in the stalk numbers—the new land having almost 70% more than the old land early in the season (Table 1). The ‘new’ site at Pegararo, though out of sugarcane production for only two years, maintained the 30% increase in stalk numbers evident early in the season (Table 1) through to harvest (Garside and Noble, 1996). However, no yield differences were recorded.

Table 1—Cane yield, CCS (commercial cane sugar content) and stalk numbers (on 9 November; 3–8 weeks after planting or rethrowing) at three Australian paired (old and new) land sites. Standard errors (bracketed) given where available.

<table>
<thead>
<tr>
<th>Site</th>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cane yield (t/ha)</td>
<td>CCS</td>
</tr>
<tr>
<td>Costanzo</td>
<td>104 (9)</td>
<td>15.0 (0.1)</td>
</tr>
<tr>
<td>Harney</td>
<td>140</td>
<td>440</td>
</tr>
<tr>
<td>Pegararo</td>
<td>179 (17)</td>
<td>16.8 (0.3)</td>
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</tbody>
</table>

Discussion

This study aimed to identify a link between deteri-
oration in selected measures of soil physical properties and reported yield decline of Australian sugarcane land. The measurements came from samples taken at the same set of seven paired sites previously evaluated for decline in soil chemical, biological and organic matter status.

Texture classes derived from the particle size data showed that only one site (Costanzo) had dissimilar old and new land. Marbelli and Fortini had one or two depth layers that matched poorly in terms of soil texture but the other four sites had close matches of soil texture between old and new land.

Bulk density was significantly greater in six of the seven sites in the old land compared to the new land in at least one sampled layer. The Tully site gave the greatest difference in bulk density of the old land because the comparison was with a never-trafficked or cultivated rainforest site. Considering the very small differences in particle size distribution between the caneland and the rainforest at Tully, this densification can be attributed to the more than 30 years of cane production at this site. There was no densification in the deep sampled layer (45–50 cm) at Tully, suggesting densification was restricted to the top 40 cm. The old land at the other sites was 3 to 13% denser than the new land, with a tendency for the middle layer to provide these differences. This may reflect an effect of surface cultivation or fertilising (with tines), alleviating densification on the immediate surface of the old land. Notable was the significantly greater BD in the inter-row compared to the row samples at three of the six sites where row and inter-row were sampled. The increase in BD was generally greater in the old land compared with the new land. These results support the practice of strategic tillage (a form of controlled trafficking) in sugarcane where the denser inter-rows are maintained through several plant cane crops (Braunack et al., 1999).

The reduction in AW in the old land at four sites may be regarded as a measure of soil structure degrada-
tion. This measure is an indicator of compound effect of aggregate destruction, compaction, organic matter loss and loss of silica and iron elements. However, in this study, AW was a less sensitive indicator than BD of differences between old and new land and location and depth effects at any one site. At four sites, AW was significantly less in the old land compared to the new land with the greatest reduction being in the old land at Harney. Consideration of the similarities in texture between old and new land at Harney strengthens the hypothesis that sugarcane production has degraded the physical properties of this soil.

In terms of linking increases in BD and reductions in AW with a reduction in sugarcane productivity, three sites that grew sugarcane at the time of sample collection—Harney, Costanzo and Pegararo—demonstrated relative productivity decline in the old land. One was in cane yield and sugar production—Harney. Another was in potential yield (not realised due to lodging)—Costanzo. One was in cane stalk numbers—Pegararo. At the Harney site, the 22% yield reduction may be linked to the 20% reduction in available water measured in this study. Vigorous early season cane growth at the Costanzo site on the new land links well with lesser BDs and greater AW in the new land at the site. Pegararo had greater numbers of cane stalks in the new land during the season, lower BD and increased AW in the new land, and very small differences in texture for comparable depths.

Conclusions

The overall results of the current study show measured soil physical degradation in old cane land relative to new land. At the three sites where cane growth was measured old land demonstrated a loss in productivity, leading to yield and sugar content reduction in one. The greatest soil densification measured was between an uncultivated treeline and the adjoining caneland. This demonstrates the potential for negative change in soil physical condition that can occur as a result of sugarcane monoculture.
Acknowledgments

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REFERENCES


