Impact of cropping on fertility of north Queensland ferrosols

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Abstract

Measurements of a number of key components of soil physical and chemical fertility were made on Ferrosol soils used for crop production in the Atherton Tableland and Lakeland Downs regions of north Queensland. Most soils showed a degree of degradation due to cropping, although the extent was dependant on both duration and intensity of cropping and the original soil fertility status. Loss of soil organic matter and the ability to allow high intensity rain to infiltrate and be stored for subsequent plant use were the most significant changes, with likely impacts on the productivity of rainfed agriculture. Acidification, hard setting and a loss of effective cation exchange capacity were also generally observed, although the effects of these changes on crop growth were unclear.

Keywords: Soil fertility, Ferrosols, organic matter, acidification, nutrient depletion.

The physical and chemical fertility of Ferrosol soils in the inland Burnett region of south east Queensland have been shown to have declined markedly as a result of broadacre, rainfed cropping (1, 2). The decline in soil organic matter status and the resultant loss of soil structural stability and the capacity to allow high intensity rainfall to infiltrate were the factors of most significance for continued agricultural production in this region. However soil compaction and hard setting characteristics, in combination with subsoil acidification, loss of cation exchange capacity and depletion of soil nutrient reserves (1, 3) also provide significant limits to sustainable agricultural production in the future.

In order to assess the extent of degradation of similar soils in a variety of farming systems in north Queensland, measurements were made on farms in the Atherton Tableland and Lakeland Downs regions. Physical and chemical fertility of soils under a variety of land uses (rainfed and irrigated cropping, ley pastures and silage production for dairy farms) were related to that of soils in virgin condition in areas where annual rainfall ranged from 750 - 2000 mm/annum.

Materials and methods

Farms were selected to represent a cross section of broadacre cropping enterprises with varying farming systems (eg. irrigated versus rainfed, continuous cropping versus pasture ley) on Ferrosols of the Atherton Tableland (Malanda, Tolga/Kairi and Rocky Creek areas) and Lakeland Downs areas. In each area, reference sites under virgin scrub (where possible) or undisturbed native pasture were also sampled.

Soil hydraulic properties were determined using a combination of disc permeameters and a portable rainfall simulator, with rain applied either to the bare soil surface (high energy rain) or to the soil when fully protected by crop residues (low energy rain), with rain applied at 150 mm/hr. Soil samples taken 24 hr after simulated rain on the covered plots were used as an estimate of the moisture content at field capacity (the drained upper limit, DUL), with the difference between this and laboratory determinations of the moisture content at -1.5 MPa used as an estimate of the plant available moisture content. Exceptions to this were at two of the Malanda sites, where the soil was found to be poorly drained.

Soil bulk densities were determined to a depth of 80 cm using a 10 cm diameter, thin - walled push tube. At a subset of the sites (Tolga/Kairi and Rocky Creek), shear strength was also determined 24 hr after simulated rain using a vane shear apparatus. The simultaneous measurements of shear strength, bulk density and soil moisture content allowed an examination on the relationship between shear strength, bulk density and volumetric moisture content using least squares linear regressions.

Soil samples were also collected in 10 cm depth increments to 30 cm, and 20 cm depth increments from 30 cm to 90 cm. Samples were subsequently oven dried, ground and analysed for a range of soil chemical attributes (pH, Walkley and Black organic carbon, Colwell P, total N, exchangeable cations and acidity and DTPA trace elements) using standard analytical procedures. Particle size analyses were also undertaken on dispersed samples from each site.

Results

Hydraulic properties

Cropping soils in all regions were characterised by a very large decline in potential rainfall infiltration rates under high intensity rain, although the differential became less marked in the drier areas (Fig. 1). This was due rather to lower infiltration rates on undisturbed, virgin soil in the Lakeland (and to a lesser extent, Rocky Creek) area than to better infiltration in the cropped soil. The lowest infiltration rates (10 mm/hr) were observed in the high rainfall areas near Malanda, where the dominant land use had been irrigated corn for silage production. Pastures had varying effects on restoring infiltrat- ion rates, ranging from very effective at Lakeland Downs to quite ineffective at Malanda and Tolga/Kairi. Cover produced very large increases in rainfall infiltration rates in all locations (70 to 400%), although in the irrigated silage cropping and the pasture (after silage cropping) sites at Malanda, these effects were quite small in absolute terms (ie. only 5-10 mm/hr). All other sites were able to achieve final infiltration rates of 90 - 120 mm/hr with full surface cover, indicating the importance of surface sealing in determining infiltration rates on bare soil.

A similar pattern of large reductions in saturated hydraulic conductivity at 10 cm, relative to the virgin sites, was observed under all land uses at all locations except Lakeland Downs. These effects were most extreme in the silage cropping areas at Malanda, and to a lesser extent, in the soils at Tolga/Kairi. The very low values at the Malanda sites (which translate to extremely low macropore densities), combined with the lack of response to surface cover in rainfall infiltration rates, suggest the primary limit to rainfall infiltration may be in the sub-surface under this land use.

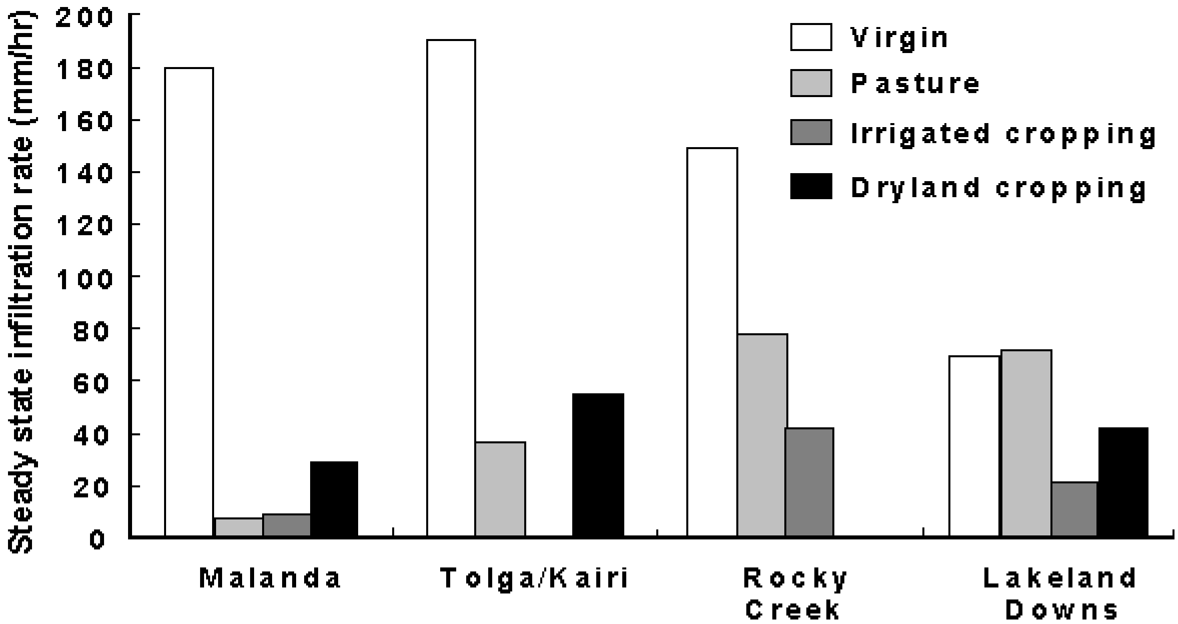

Figure 1

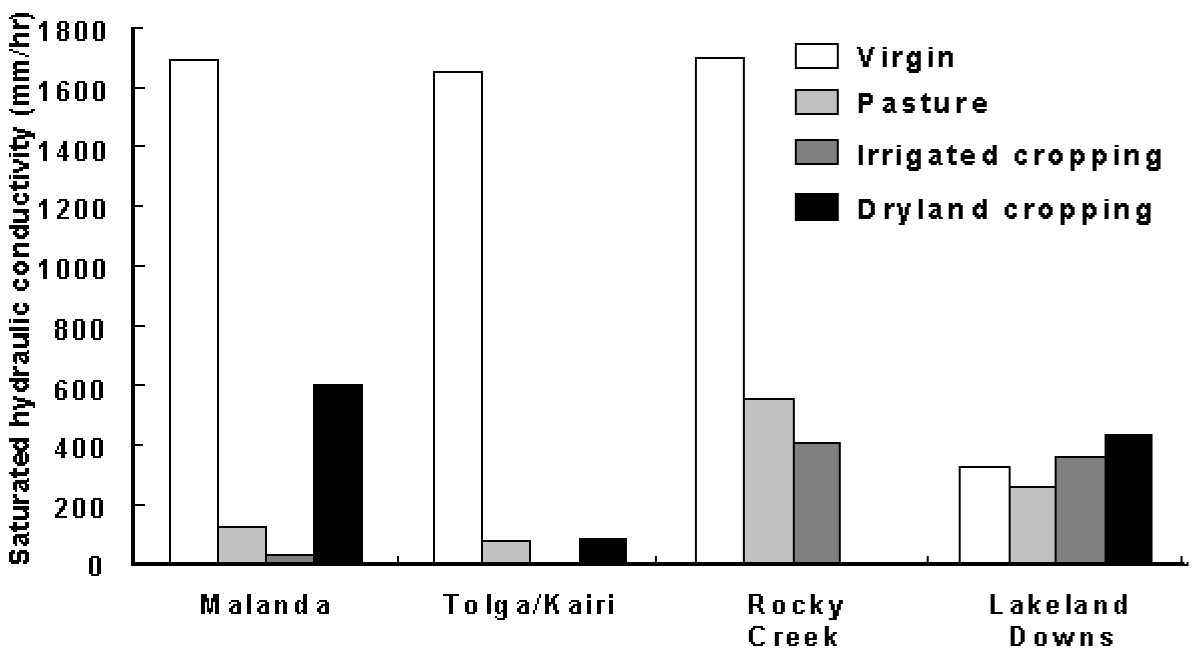

Figure 2

Bulk density, shear strength and plant available water content

No sites showed the presence of a distinct compaction layer, either immediately below the cultivated layer or in deeper layers of the profile. However, all sites exhibited apparent hard setting characteristics - as evidenced by a more rapid increase in soil shear strength with increasing bulk density. The extent varied with site, so that the rate of shear strength increase in the Tolga/Kairi soils was 3 to 5 times more rapid than in virgin soil, while at Rocky Creek the rate of increase was 2 to 3 times more rapid with cropping.

Perhaps of greater significance was the apparent loss of ability of the cropped soils to store water for subsequent use by plants (Table 1). This was most evident in Rocky Creek and Malanda, although the Tolga/Kairi sites were also affected. In some cases, up to 25% of the potential PAWC had been lost in the cropped soils - a factor that could have a severe impact on the tolerance to prolonged dry periods in rainfed cropping systems.

Soil chemical fertility

Cropping has caused both positive and negative effects on components of soil chemical fertility, with effects determined by both virgin fertility status and the fertiliser strategy employed in the dominant cropping system.

In terms of the positive effects of cropping, all sites show improved soil P status under cropping and improved pasture, with some sites showing Colwell P values as high as 150 mg/kg in the cultivated layer. The only other case of improved soil chemical fertility with cropping was registered on one of the more acidic soils near Malanda, where applications of lime had raised pHw from 4.5 to 5.0-5.5.

The most significant aspects of chemical fertility decline with cropping (Table 2) involved falling organic carbon status and reductions in exchangeable cations and ECEC, which occurred in all sites except those at Lakeland Downs. It was interesting to note the relatively low levels of organic carbon in the virgin sites at Lakeland Downs, relative to those in the wetter environments on the Atherton Tableland, and in this case organic carbon levels were actually higher under sown pasture than in the virgin state. There was also evidence of extensive soil acidification in cropped soil in all locations except Lakeland Downs, although soil pH had only fallen to levels likely to effect crop growth in some of the cropped sites near Malanda.

Table 1. Effects of location and land use on theoretical plant available water content[1] to 70 cm

Location	Land use	PAWC (mm)					
		0-10 cm	10-20 cm	20-30 cm	30-50 cm	50-70 cm	Total
Malanda	Virgin	10.5	9.8	12	24	26	82.3
	Grass pasture	10.0	10.5	10.9	21.7	19.8	72.9
	Irrigated crop[2]	nd	nd	nd	nd	nd	nd
	Dryland crop	10.9	11.0	9.7	14.7	16.5	62.7
Tolga/Kairi	Virgin	10.9	9.5	13	23	25	81.3
	Grass pasture	8.3	8.9	7.9	19	16.4	60.5
	Dryland crop	8.0	8.6	9.5	21.2	20.9	68.3
Rocky Creek	Virgin	11.4	10.0	8.1	17.1	20	66.7
	Legume pasture	8.5	8.5	6.8	15.9	12.3	52.0
	Irrigated crop	9.6	7.9	7.7	19.8	13.6	58.6

[1] Theoretical PAWC - determined as the difference between DUL and moisture content at -1.5 MPa.
[2] Very poor internal drainage. Poor estimate of DUL.

Table 2. Effects of location and land use on pH, organic carbon and effective cation exchange capacity.

Location	Land use	pH			Organic carbon[1] (%)			Effective cation exchange capacity[2] (cmol⁺/kg)		
		0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Malanda	Virgin	6.7	7.1	6.7	6.8	3.8	2.5	28.0	19.4	14.8
	Grass pasture	5.9	5.8	5.9	2.2	2.1	1.7	11.3	5.8	5.7
	Irrigated crop	5.6	5.5	5.6	2.0	1.9	1.8	9.4	8.5	9.1
	Dryland crop	5.2	5.2	5.0	2.0	2.0	1.7	5.6	5.6	3.3
Tolga/Kairi	Virgin	7.9	7.8	7.7	4.7	2.7	1.5	32.0	22.5	14.5
	Grass pasture	6.0	6.0	6.1	1.5	1.5	1.5	8.0	8.5	8.8
	Dryland crop	6.3	6.3	6.3	1.3	1.2	1.2	7.3	7.2	7.2
Rocky Creek	Virgin	6.6	6.5	6.4	3.2	1.9	1.2	18.5	13.0	10.2
	Legume pasture	7.0	6.9	6.5	1.6	1.7	1.2	13.0	13.5	10.0
	Irrigated crop	6.6	6.4	6.4	1.2	1.0	0.9	8.5	8.0	7.5
Lakeland Downs	Virgin	6.9	7.1	7.2	1.8	1.1	0.8	nd	nd	nd
	Grass pasture	6.6	6.7	6.9	2.2	1.8	1.14	nd	nd	nd
	Irrigated crop	7.0	7.1	7.4	1.2	1.3	0.8	nd	nd	nd
	Dryland crop	6.6	6.7	6.7	1.7	1.5	1.15	nd	nd	nd

[1] Organic carbon determined using Walkley and Black extraction.
[2] Effective cation exchange capacity (ECEC) - sum of exchangeable cations (M NH_4Cl) and extractable acidity (M KCl).

Discussion

Results of this survey have produced similar results to those reported for the inland Burnett region of southern Queensland (1, 2). A substantial decline in soil organic matter content, acidification and loss of ECEC, combined with a much reduced ability to infiltrate high intensity rainfall without surface cover are common characteristics of cropped Ferrosol in both regions. In addition, a general reduction in the profile PAWC in the north Queensland soils will require more frequent irrigation or make rainfed crops more prone to water stress during the season. Collectively, these findings suggest a considerable level of resource degradation with significant effects on the long term sustainability of agriculture in the region.

There were two notable differences between the north Queensland sites and those in the Burnett. The first was the general lack of significant soil compaction in north Queensland- primarily due to the regular use of deep ripping. Despite a general decline in sub-surface hydraulic conductivity, there appeared to be very few practical limits to rainfall infiltration below the soil surface in cropped or pasture sites - with the notable exception of the irrigated and grass ley sites at Malanda. In this case, low hydraulic conductivity and low bulk densities indicated reasonable porosity but very few continuous macropores. This combination was probably a result of traffic on soils close to saturation - a practical necessity in this high rainfall, silage production area. Although shearing occurred during this trafficking, compaction could not occur as there was little drainable porosity.

Provision of surface cover (via crop residues) had a significant impact on the ability of most Ferrosols to allow rain to infiltrate. Current land preparation practices in all farming systems sampled rely on intensive conventional tillage, so there are few occasions when this soil cover is available. Utilisation of reduced tillage systems, particularly in the rainfed areas, will have a significant impact on the efficiency of use of incident rain, as well as allowing a gradual reversal in trend of declining soil organic matter.

The second notable difference with cropped Ferrosols in the inland Burnett was the generally better level of sub-soil fertility in the northern sites. Whilst sites had acidified and depletion of soil cations (especially K) had occurred, the extent was much less than in southern areas. This may be due to a greater level of fertiliser inputs in these regions due to the generally higher rainfall and crop yields, but may also simply be a factor of a shorter cropping duration. The latter is certainly relevant to the Lakeland Downs region, which has only been cropped for a maximum of 25 years. Close monitoring of these aspects of soil fertility will be important for future sustainable land use.

Acknowledgments

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