Effects of Long-Term Management Systems on Soil Quality

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Abstract: In order to evaluate the impact of different management systems like continuous conventional tillage (CT), continuous conventional tillage and no-tillage (CTNT), both under corn (*Zea mays* L.) crop, and native forest as a control (NF) some physical and chemical properties of an Alfisol, clay texture, were studied in Botucatu, state of São Paulo, Brazil. The results showed that the management systems changed significantly most of the soil chemical and physical properties. The treatments CT and CTNT showed higher values of phosphorus, calcium, magnesium, potassium, base saturation and pH and lower values of aluminium and soil organic matter than NF. Comparing treatments with soil mobilization, CTNT showed better conditions for the chemical properties. The values of chemical properties were higher for the upper layers. The treatment with no mobilization (NF) and that with soil management involving lower soil mobilization (CTNT) showed higher mean weight diameter, floculation degree, available water capacity and total porosity and lower bulk density and microporosity. Soil bulk density was higher and total porosity was lower in the upper layer of CT. Total porosity, microporosity, soil bulk density and floculation degree were higher in the deep layers. The replacement of conventional tillage for no-tillage improves the soil physical quality.
Keywords: conventional tillage, no-tillage, soil quality, soil physical properties, soil chemical properties, clay soil

1 Introduction

The conversion of forests to cropland has significant effects on soil properties. Cultivation can alter soil physical, chemical and biological properties, whereby plant growth, development and yield could be influenced. Conservation tillage systems, rather than plow-based methods of seedbed preparation have the potential to provide sustainable use of soil residues (Hajabbasy & Hemmat, 2000).

Practices such as ploughing and chiselling hasten organic matter decomposition, and losses of nutrientes and soil particles through increased erosion and leaching. This induces deterioration of soil physical properties and a general decline in soil fertility (Materechera & Mkhabela, 2001). On the other hand, no-tillage management system allows accumulation of crop residues on the soil surface, and greater C, N, and water contents, compared to conventionally tilled soils (Aon et al., 2001 and Sainju et al., 2002).

Soil sustainability and productivity depends on an adequate equilibrium among the soil properties in the volume explored by roots, so that the absorption of water and nutrients by plants are not affected negatively. In order to evaluate the impact of management systems on soil quality it is necessary to quantify the modifications on the soil properties. With this aim, changes in the chemical and physical properties of an Alfisol, fine textured soil, with different management systems, under corn (*Zea mays* L.) yield were studied.

2 Material and methods

This study was carried out at the Experimental Station of Faculdade de Ciências Agronômicas (UNESP), in Botucatu, state of São Paulo, Brazil, in area located in south latitude 22°49′, west longitude 48°25′, 770m above sea level, annual average precipitation about 1,314mm and annual average temperature of 19.4°C. According to the Köppen’s classification the climate is Cwb, mesothermic with dry winter. The soil is an Alfisol, clay texture (150 g • kg^{-1} of sand, 170 g/kg of silt and 680 g • kg^{-1} of clay), dark red colour, structure in subangular blocks with strong degree development, basic rocks like parent material (Ipt, 1981), having a 0–0.04m • m^{-1} slope.

The management systems studied were: (1) conventional tillage used for 20 years (CT), characterized by one disc ploughing and two heavy harrowing for the corn crop; (2) conventional tillage used for 13 years, characterized by one disk ploughing and two heavy harrowing for the corn crop followed by no-tillage use for 7 years, characterized by the employment of black oat (*Avena strigosa*) like winter crop, dried by chemicals (Glyphosate, 360g • ha^{-1}) (CTNT); (3) native forest as a control (NF). The corn and oat crops were sown, annually, in October and May, respectively.

The experiment had a randomized complete block design and a split-plot arrangement with three replications. The management systems were assigned to the main plots and soil depths to sub-plots.

Disturbed and undisturbed soil samples were taken after the harvest of corn crop, in the following dephts: 0m—0.10m, 0.10m—0.20m, 0.20m—0.30m and 0.30m—0.40m, for physical (Embrapa, 1997) and chemical (Raij & Quaggio, 1983) laboratory determinations, following standard procedures. Soil samples obtained for granulometric and chemical analysis were air-dried and sieved (<2mm). The soil physical properties evaluated were: soil texture, by using Bouyoucos method, employing NaOH 1N as chemical disperser to determine the total clay, and without NaOH to determine the water dispersed clay; mean weigth diameter (van Bavel, 1949), by means of dry sieving, obtaining the aggregates percentage for the following classes: 7.93mm—2.00mm; 2.00mm—1.00mm; 1.00mm—0.50mm; 0.50mm—0.25mm and <0.25mm; bulk density, with the core cylinder method; available water capacity, by using the centrifuge method, calculated as the difference in gravimetric water content between field capacity (–0.006MPa) and permanent wilting point (–1.5MPa); total porosity, calculated as the water content in saturated soil, and microporosity, calculated as water content at –0,006MPa. The soil chemical properties evaluated were: soil organic matter, phosphorus-resin, pH (soil:water = 1:2.5), exchangeable aluminium, potassium, calcium and magnesium, base sum, cation exchange capacity and base saturation. The results were submitted to the variance analysis applying the Tukey's Test to compare the mean values at 0.05 of probability.

3 Results and discussion

The soil chemical characteristics evidenced improvements for the management systems CT and CTNT. As a consequence of the liming practice can be observed that the pH values were significantly higher, while H + Al values were, consequently, lower (Table 1). The largest differences were verified among the upper layer (0—0.10m) and the others.

Table 1 Soil pH and Al at different soil depth layers as influenced by management systems

Depth	pH			H + Al		
	CT	CTNT	NF	CT	CTNT	NF
M				mmol$_c$ • dm^{-3}		
0 — 0.10	5.47Aa	5.30Aa	4.13Ba	33.70Bab	35.07Ba	89.97Aab
0.10 — 0.20	5.03Ab	4.93Ab	3.90Bb	42.33Ba	36.76Ba	96.52Aa
0.20 — 0.30	4.87Ab	5.00Ab	3.87Bb	33.40Bb	38.75Ba	84.08Ab
0.30 — 0.40	4.93Ab	4.90Ab	3.67Bb	38.75Bab	30.31Ca	82.57Ab

Values within a soil depth increment followed by the same small letter and values between management systems followed by the same capital letter, to the same soil depth, are not significantly different by Tukey's Test (P<0.05).

With relationship to the nutrient contents, base sum and base saturation it was also observed higher values for CT and CTNT systems, that received chemical fertilizers, as it can be observed in the Tables 2 to 5. For CT and CTNT systems the values decreased with depth.

Table 2 Soil organic matter (SOM) and phosphorus-resin at different soil depth layers as influenced by management systems

Depth	SOM			P		
	CT	CTNT	NF	CT	CTNT	NF
m		$g \cdot dm^{-3}$			$mg \cdot dm^{-3}$	
0 — 0.10	26.52Ca	32.70Ba	43.75Aa	38.23Ba	60.19Aa	6.23Ca
0.10 — 0.20	26.70Ba	25.60Ba	30.76Ab	22.99Ab	13.00ABb	5.51Ba
0.20 — 0.30	14.09Bb	22.21Ac	23.46Ac	13.12Ac	12.68Ab	3.12Aa
0.30 — 0.40	16.80Bb	20.02Ac	19.58Abd	14.48Abc	13.78Ab	2.99Aa

Values within a soil depth increment followed by the same small letter and values between management systems followed by the same capital letter, to the same soil depth, are not significantly different by Tukey's Test (P<0.05).

Table 3 Soil potassium and calcium at different soil depth layers as influenced by management systems

Depth	K			Ca		
	CT	CTNT	NF	CT	CTNT	NF
m		$mmol_c \cdot dm^{-3}$			$mmol_c \cdot dm^{-3}$	
0 — 0.10	2.78Ba	4.35Aa	2.48Ca	32.00Ba	36.00Aa	24.27Ca
0.10 — 0.20	1.75Bb	2.68Ab	1.80Bb	25.07Ab	22.93Abc	18.40Bb
0.20 — 0.30	0.70Cd	1.81Ac	1.05Bc	19.20Ac	20.00Ac	15.73Bbc
0.30 — 0.40	1.08Bc	1.93Ac	0.72Cd	23.47Ab	24.27Ab	13.60Bc

Values within a soil depth increment followed by the same small letter and values between management systems followed by the same capital letter, to the same soil depth, are not significantly different by Tukey's Test (P<0.05).

Table 4 Soil magnesium and base sum (BS) at different soil depth layers as influenced by management systems

Depth	Mg			BS		
	CT	CTNT	NF	CT	CTNT	NF
m		$mmol_c \cdot dm^{-3}$			$mmol_c \cdot dm^{-3}$	
0 — 0.10	17.16Aa	16.80Aa	10.68Ba	51.94Ba	57.15Aa	37.43Ca
0.10 — 0.20	13.14Ab	9.90Bb	9.60Ba	39.86Ab	35.52Abc	29.80Bb
0.20 — 0.30	8.40Ac	9.48Ab	9.42Aa	28.30ABc	31.30Ac	26.20Bbc
0.30 — 0.40	11.40Ab	11.28Ab	8.76Ba	35.95Ab	37.48Ab	23.08Bc

Values within a soil depth increment followed by the same small letter and values between management systems followed by the same capital letter, to the same soil depth, are not significantly different by Tukey's Test (P<0.05).

The values of P are higher for CT and CTNT, in the upper layer. For CTNT, where there was no soil mobilization during the last seven years, the amount of P decreased below the 0—0.10m soil depth layer. For CT, the ploughing and harrowing practices allow that the element goes up to 0.20m depth. Similar behavior was observed for CEC.

In spite of the lower nutrient contents the area under NF presented higher soil organic matter content (Table 2). That behavior can be attributed to the minimum alterations in the area, with consequent larger dynamic balance between the decomposition and production of organic matter. Studies have shown significant decrease in the organic matter content in areas where crops were cultivated annually. Comparing CT and CTNT management systems, CT presented the lower values of soil organic matter for all depths studied. The CTNT showed that changing soil conventional tillage for no-tillage, after seven years, there was increase of the soil organic matter content. Concentrations of organic matter are good indicators of soil quality and productivity due to their favorable effects on soil properties. The maintenance of a high soil organic matter status is, therefore, desirable.

Table 5 Soil base saturation (V) and cation exchange capacity (CEC) at different soil depth layers as influenced by management systems

Depth	V			CEC		
	CT	CTNT	NF	CT	CTNT	NF
m	%			$mmol_c \cdot dm^{-3}$		
0 — 0.10	60.64Aa	62.08Aa	29.35Ba	85.65Ba	92.22Ba	127.40Aa
0.10 — 0.20	48.51Ab	49.14Ac	23.60Bab	82.29Ba	72.28Bb	126.32Aa
0.20 — 0.30	46.12Ab	44.67Ac	23.84Bab	61.70Bb	70.04Bb	110.28Ab
0.30 — 0.40	47.89Bb	55.20Ab	21.87Cb	74.70Ba	67.79Bb	105.64Ab

Values within a soil depth increment followed by the same small letter and values between management systems followed by the same capital letter, to the same soil depth, are not significantly different by Tukey's Test (P<0.05).

The soil physics characteristics, in a general way, indicated degradation of soil quality in function of the natural vegetation retreat and of the agricultural equipment use for soil preparation for corn crop. The management systems CT and CTNT showed significant differences in relation to NF, mainly for the upper layer, between 0m and 0.20m.

The values of soil bulk density (Table 6) were lower for NF. At 0m—0.10m and 0.10m—0.20m.

soil depth layers, for CTNT system, there was an increase in soil bulk density, while for CT, the ploughing and harrowing practices resulted in lower values. The total porosity (Table 6) showed reverse behavior of that observed for the soil bulk density, this means, the values were higher for NF and, comparing CT and CTNT, lower between 0m—0.10m and 10m—20m for CTNT.

Table 6 Soil bulk density (BD) and total porosity (TP) at different soil depth layers as influenced by management systems

Depth	BD			TP		
	CT	CTNT	NF	CT	CTNT	NF
m	$kg \cdot dm^{-3}$			$dm^3 \cdot dm^{-3}$		
0 — 0.10	1.27Bb	1.47Aa	1.10Cc	0.57Aa	0.47Bb	0.54Aa
0.10 — 0.20	1.46Ba	1.51Aa	1.11ABb	0.51Bb	0.48Bb	0.57Aa
0.20 — 0.30	1.49Aa	1.33Bb	1.25Ab	0.51Bb	0.50Bb	0.56Aa
0.30 — 0.40	1.33ABa	1.26Bab	1.19BCb	0.54ABb	0.57Aab	0.59Aa

Values within a soil depth increment followed by the same small letter and values between management systems followed by the same capital letter, to the same soil depth, are not significantly different by Tukey's Test (P<0.05).

Although the microporosity values have been lower for NF, the water retention capacity (Table 7) was higher for that system, that can be attributed to the higher organic matter content.

Mean weigth diameter of aggregates (Table 8) at depth 0—0.10m was lower for CT, due to the soil annual cultivation, promoting disrupt in soil aggregates, and for the lower soil organic matter content. For that same soil layer CTNT showed recovery of the aggregate stability, with similar values to NF.

The lower floculation degree in CT and CTNT (Table 8) may have resulted from the placement of chemical fertilizers for several years at the soil surface promoting dispersion of the clay particles, mainly for 0—0.10 and 0.10—0.20m soil depth layers.

Table 7 Soil microporosity (MP) and available water capacity (AWC) at different soil depth layers as influenced by management systems

Depth	MP			AWC		
	CT	CTNT	NF	CT	CTNT	NF
m	$dm^3 \cdot dm^{-3}$			$dm^3 \cdot dm^{-3}$		
0 — 0.10	0.44Ac	0.45Ac	0.36Bc	10.38aB	12.45aA	12.30aA
0.10 — 0.20	0.46Abc	0.46Abc	0.41Bbc	10.13aA	10.42bA	11.05aA
0.20 — 0.30	0.48Aab	0.48Aab	0.42Bab	10.43aA	10.61bA	12.11aA
0.30 — 0.40	0.49Aa	0.49Aa	0.48Aa	10.92aA	10.30bA	4.52bB

Values within a soil depth increment followed by the same small letter and values between management systems followed by the same capital letter, to the same soil depth, are not significantly different by Tukey's Test (P<0.05).

Table 8 Soil aggregates mean weigth diameter (MWD) and flocculation degree (FD) at different soil depth layers as influenced by management systems

Depth	MWD			FD		
	CT	CTNT	NF	CT	CTNT	NF
m	$dm^3 \cdot dm^{-3}$			%		
0 — 0.10	4.4673Ba	4.7436Aa	4.5683ABa	48Cc	58Bb	79Aa
0.10 — 0.20	4.6806ABa	4.4593Bb	4.7091Aa	58Bb	62Bb	80Aa
0.20 — 0.30	4.4999Ba	4.78868Aa	4.6464ABa	83Aa	79Aa	81Aa
0.30 — 0.40	4.5335Aa	4.6064Aab	4.7416Aa	83Aa	83Aa	81Aa

Values within a soil depth increment followed by the same small letter and values between management systems followed by the same capital letter, to the same soil depth, are not significantly different by Tukey's Test (P<0.05).

4 Conclusions

The management systems changed significantly most of the soil chemical and physical properties.

The treatments CT and CTNT showed higher values of phosphorus, calcium, magnesium, potassium, base saturation and pH and lower values of aluminium and organic matter than NF.

Comparing treatments with soil mobilization, CTNT showed better conditions for the chemical properties.

The values of chemical properties were higher for the superficial layers.

The treatment with no mobilization (NF) and that with soil management involving lower soil mobilization (CTNT) showed higher mean weight diameter, floculation degree, available water capacity and total porosity and lower bulk density and microporosity.

Soil bulk density was higher and total porosity was lower in the upper layer of CT.

Total porosity, microporosity, soil bulk density and floculation degree were higher in the deep layers.

The replacement of conventional tillage for no-tillage improves the soil physical quality.

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