14th International Soil Conservation Organization Conference.
Water Management and Soil Conservation in Semi-Arid Environments. Marrakech, Morocco, May 14-19, 2006 (ISCO 2006).

CHANGES OF SOIL CHEMICAL-PROPERTIES INDUCED BY MANAGEMENT IN CULTIVATED SOILS (MEXICAN NEOVOLCANIC AREA)

Silvia Pajares[1], Sara Covaleda[1], Juan F. Gallardo[1], Jorge D. Etchevers[2], & Christian Prat[3]
[1]*Consejo Superior de Investigaciones Científicas*, Aptado. 257, Salamanca 37071 (Spain). E-mail: <jgallard@usal.es>.
[2]*Instituto de Recursos Naturales*, *Colegio de Postgraduado de Montecillo*, Texcoco 56230 (Mexico). E-mail: <jetchev@colpos.mx>.
[3]*Institut de Recherche pour le Développement*, Montpellier (France). E-mail: <prat@ird.fr>.

Abstract

Four soil managements were applied in an experimental plot located in Atécuaro (Morelia, Central Mexico): Traditional, improved, organic, and fallow. The soil was an Acrisol and the climate temperate with two seasons (wet and dry). After three years of cultivation the content of SOC and available P showed significant differences according to soil managements. Total N (Nt) levels hardly changed, however, a significant increase of the C/N ratio occurred. As far as soil C (SOC), the best management was the organic, while the worst management turned out to be the traditional one.

INTRODUCTION

In the Mexican Neovolcanic Ridge the soil has been exploited anthropo-zoogenically since the pre-Columbian era up to present times. The main agricultural practice here was a rotation system of maize, beans, vicia, and broad beans, in combination with cattle pasture. The eroding capacity of rain, inappropriate cultivation practices and soils prone to erosion have caused a reduction of the region's agricultural productive capacity (Bravo *et al.*, 2002) which has led to local residents to emigrate in search of better opportunities. The sale of environmental services (like C sequestration) and the implementation of agricultural techniques that maintain the soil avoiding the reduction of productivity may be alternatives to improve the quality of life in these areas.

The world increasing trend towards a sustainable agriculture, less dependent on external inorganic inputs and with a greater use of organic resources, has favoured the reformulation of aspects related to the agricultural management of soils that may favour their fertility and the potential of C sequestration. On the other hand, Tiessen and Steward (1983) observed that conventional agricultural methods have caused major losses of soil organic C (COS) in medium and long terms, which causes the reduction of C reserves and a greater dependence of crops on the application of fertilizers.

This paper is focused on the study of changes occurred in the medium term in an *Acrisol*, as a result of different agricultural practices, especially regarding COS content and other physic-chemical and physical properties (pH, cation complex, total N, and available P)

MATERIALS AND METHODS

Description of the study area.-

The study area is located in the Mexican Neovolcanic Ridge, in the micro-basin of Atécuaro, in the state of Michoacán (19° 33' 05” and 19° 37' 08” N; and 101° 09' 00” and 101° 15' 07” W).

Annual mean precipitation in the area is above 800 mm a^{-1}, concentrated in the rainy season (85 % of which occurs between June and September). *Andosols* and *Acrisols*, acid soils, cover more than 70 % of the sub-basin surface (Medina, 2002).

In 2002 four agronomic management systems were established in experimental plots of 1000 m^2 (Table 1): traditional management (Tt, using mono-cultures with a low level of inorganic inputs); organic management (To, associated crops using organic sources as fertilizers); improved traditional management (Tm, associated crops, covers with harvest residues to protect the soil and moderate use of agrochemicals); and implementation of '*año y vez*' fallow (Tb, annual fallow with bovine pasturing followed by agricultural activity the next year). Broad beans were sown in 2002, oats in 2003, and maize in 2004.

The soil is an *Acrisol* with an *Ap* horizon, affected by previous erosion, clayey (50-60 % of clay fraction), acid (pH 4.9), low organic content (MOS < 3.0 %) and total N (Nt < 1.6 mg g^{-1}) and originally with an excess of assimilable Mn (111 mg g^{-1}).

Table 1. Characteristics of the agronomic treatments under study

Anual Aditions (Mg ha^{-1} a^{-1})	Agronomic treatments			
	Traditional (Tt)	Organic (To)	Improved (Tm)	Fallow (Tb)
Cultures	**2002**: broad bean[a] **2003**: oat[c] **2004**: maize-bean[e]	broad bean and vicia oat/vicia[d] maize-bean	broad bean and vicia oat/vicia maize-bean +cover of wheat residues[g]	Fallow oat Fallow
Total fertilization (N-P-K)	**2002**: 40-30-14 **2003**: 60-40-0 **2004**:140-100-0	15 EB[6] 15 compost 10 compost + 2 poultry manure	60-96-40 80-40-0 140-100-0	0-0-0 60-40-0 0-0-0

[a]*Vicia faba*; [b]*Vicia villosa*; [c]*Oat strigosa*; [d]associated; [e]*Phaseolus vulgaris*, undetermined or guidance habit associated with maize; [f]EB: Bovine manure/dung; [g]Cover of 4 Mg ha^{-1} of wheat residues

Field sampling and soil analysis

Each plot was divided into two subplots and, from each subplots, samples were taken in 2002 and 2004, from 0-10 and 10-20 cm depth levels. Ten simple samples were extracted by using a cylindrical drill, creating a composite sample representative of each subplot and depth.

Soil samples were air dried and in the shade; then they were homogenized and sifted through a 2 mm mesh.

The macroscopic organic matter was extracted from soil samples and then COS was measured by dry combustion in a TOCA Shimadzu; Nt was determined using a semi-micro Kjeldahl. Soil pH in water and KCl 1N (relation 1:2) were determined, as well as available P according to Bray. The cation exchange capacity (CIC) and exchangeable bases were determined using neutral ammonium acetate (Agronomy 9, 1982).

Statistical analysis

Results were subjected to a bi-factorial variance analysis ($p \leq 0.05$) according to the type of management and year for each depth level (Table 3).

RESULTS AND DISCUSSION

Table 2 shows the results obtained in the four experimental plots and Table 3 those resulting from the statistical analysis.

Table 2. Characteristics of the experimental plots

Soil management	pH (H_2O 1:2)		CIC (cmol/kg)		Ca^{2+} (1/2 cmol/kg)		Mg^{2+} (1/2 cmol/kg)		K^+ (cmol/kg)		Na^+ (cmol/kg)		COS (mg/g)		Nt (mg/g)		C/N		P (Bray) (mg/kg)	
	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004
0-10 cm																				
Traditional	**4.6**	**5.5**	**17.6**	**22.3**	**3.6**	**9.5**	**1.3**	**1.9**	**0.2**	**0.3**	**0.2**	**1.0**	**18.3**	**16.9**	**1.5**	**1.3**	**11.9**	**13.2**	**< 2**	**3.9**
Improved	**4.7**	**5.4**	**17.1**	**22.1**	**4.7**	**9.1**	**1.5**	**1.9**	**0.1**	**0.5**	**0.2**	**1.2**	**17.3**	**17.9**	**1.4**	**1.3**	**13.5**	**13.6**	**< 2**	**6.5**
Organic	**4.7**	**5.6**	**17.2**	**25.2**	**3.5**	**10.2**	**1.2**	**2.4**	**0.2**	**0.6**	**0.1**	**1.3**	**19.9**	**20.5**	**1.6**	**1.4**	**13.1**	**13.4**	**< 2**	**5.5**
Fallow	**4.7**	**6.0**	**17.7**	**22.2**	**5.8**	**10.3**	**1.5**	**2.0**	**0.2**	**0.3**	**0.1**	**1.0**	**19.6**	**19.2**	**1.6**	**1.3**	**12.1**	**14.5**	**< 2**	**3.4**
Mean	4.7	5.6	17.4	23.0	4.4	9.8	1.3	2.0	0.2	0.4	0.2	1.1	18.8	18.6	1.5	1.3	12.7	13.7	**< 2**	**4.8**
S. d.	0.1	0.3	0.3	1.5	1.1	0.6	0.2	0.2	0.0	0.2	0.1	0.1	1.2	1.6	0.1	0.0	0.8	0.6	*	1.4
10-20 cm																				
Traditional	**4.9**	**5.3**	**17.0**	**22.1**	**7.9**	**8.8**	**2.2**	**2.0**	**0.1**	**0.3**	**0.3**	**1.0**	**13.6**	**16.8**	**1.2**	**1.3**	**10.7**	**13.3**	**< 2**	**3.3**
Improved	**5.0**	**5.3**	**16.1**	**23.2**	**4.1**	**8.8**	**1.6**	**1.9**	**0.1**	**0.3**	**0.1**	**1.1**	**13.3**	**17.3**	**1.1**	**1.1**	**12.6**	**17.6**	**< 2**	**4.5**
Organic	**5.0**	**5.6**	**16.8**	**22.7**	**9.0**	**10.1**	**2.4**	**2.3**	**0.1**	**0.5**	**0.4**	**1.3**	**13.4**	**18.9**	**1.3**	**1.4**	**11.8**	**13.4**	**< 2**	**4.3**
Fallow	**4.9**	**5.8**	**19.4**	**22.5**	**6.9**	**7.4**	**2.2**	**2.0**	**0.0**	**0.3**	**0.5**	**1.0**	**15.1**	**18.1**	**1.3**	**1.2**	**11.6**	**14.4**	**< 2**	**3.8**
Mean	5.0	5.5	17.3	22.6	7.0	8.8	2.1	2.0	0.1	0.3	0.3	1.1	13.9	17.8	1.2	1.2	11.7	14.7	**< 2**	**4.0**
S. d.	0.1	0.2	1.4	0.4	2.1	1.1	0.4	0.2	0.0	0.1	0.2	0.1	0.8	0.9	0.1	0.1	0.8	2.0	*	0.6

Table 3. Bi-factorial variance analysis ($p \leq 0.05$) according to the type of management and year for each depth level (* = significant differences)

	pH	CIC	Ca^{2+}	Mg^{2+}	K^+	Na^+	COS	Nt	C/N	P (Bray)
0-10 cm										
Management	*				*		*			*
Year	*	*	*	*	*	*		*	*	*
Management x year	*				*				*	*
10-20 cm										
Management			*	*	*		*			
Year	*	*	*	*		*	*		*	*
Management x year										

The agricultural use of these soils had, in the short term, an impact on the intensity of some chemical variables related to fertility. In 2003 5 Mg $CaCO_3$ ha^{-1} were applied in all the plots causing an increase of pH in all treatments, especially at 0-10 cm depth. The greatest change in all the management systems was a significant increase of CIC (especially in To) and the exchangeable bases, mainly exchangeable Ca^{2+} and Na^+ (as a result of the liming). The accumulation of exchangeable Ca^{2+} produced an imbalance between Ca^{2+} and Mg^{2+} in all the experimental plots.

On the other hand, during the study period COS showed significant differences between management systems for both depth levels, standing out the increase of COS contents at 10-20 cm depth, mainly in To probably due to manure additions.

However, Nt showed a tendency to diminish in the upper 10 cm, especially in Tt, To, and Tb; at the 10-20 cm depth level Nt content did not show significant changes. This coincides with the work developed by Tiessen and Stewart (1983), and Cambardella and Elliot (1992), who observed that cropping reduces the availability of nutrients, like N.

Available P showed significant increases in all the treatments, mainly in with Tm and To, which indicates that the beneficial actiond of the added fertilizers in these treatments.

CONCLUSIONS

The agricultural use of these soils caused changes in the short term, specially concerning some chemical variables related to fertility. The increases of exchangeable Ca^{2+} and soil pH occurred in all the treatments, as a consequence of the liming, giving a higher CIC as a result, favoured also for manure additions in To.

After three years of cultivation in the Atécuaro plot the COS and available P contents showed significant differences between treatments.

Because of the changes in the COS and Nt contents, the soil C/N ratio also varied.

The best management for a higher C sequestration resulted To, while Tt was the worst.

Acknowledgements

The authors warmly thank the European Union for the funding given to this research through the REVOLSO Project (Program INCO ICA4-CT-2001-10052); as well as the owner and those collaborating in the sampling and analysis of the plots.

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