Impact of changes in land-use on the quality of two soils from Entre Rios Province, Argentine

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Résumé
Durant les dernières années dans la province de Entre Ríos (l'Argentine), se sont incorporée à l'agriculture des terres de grande fragilité du point de vue environnementale et en même temps on a augmenté la proportion de cultures agricoles dans les rotations. L'objectif de ce travail a été de connaître l'impact provoqué par le changement de l'utilisation de la terre dans deux sols différents correspondant aux ordres Vertisol et Mollisol. On a évalué des variables physiques et chimiques, en choisissant celles-là les plus sensibles à l'intensification agricole comme indicatrices de la qualité du sol. Les variables les plus sensibles ont été la matière organique, la stabilité des agrégats et l'épaisseur de l'horizon supérieur. On a observé un comportement différent de certaines variables dans les deux sols évalués. Le changement dans l'utilisation de la terre associé a une agriculture plus intensive a provoqué la détérioration des sols, spécialement dans le Vertisol.

Introduction

In the last years in Entre Rios Province, Argentine, native vegetation areas were cleared and as a result soils considered to be environmentally fragile were devoted to agriculture. Moreover, cropping systems became more intensive, mainly because of the increase of soybean proportion in the rotations. This situation may affect soil quality. In this land-use context a main task is to create ideal conditions for sustainability, i.e. the capacity of the agricultural system to maintain its productivity and the resources on which it depends.
Soil quality can be briefly defined as “fitness for purpose”. This means that the quality of a soil will depend not only on its dynamic nature but also on land-use and management (Doran y Parkin, 1994; Karlen *et al.*, 1998). Evaluation of soil quality includes first identification of soil functions important to a management tool and then selection of soil properties influencing those functions depending on soil type (Karlen et al.,1998). For soil quality assessments, indicators are used. These show the present condition or "state resource" and its tendency, positive or negative, depending on the condition of reference. Most quality assessment schemes need to take into account a range of soil properties.
Vertisols occur within Argentine mostly in Entre Ríos province, where the covered area is estimated at 2.350.000 ha, i.e. 37.9 % of the total province surface. Furthermore, Vertisols frequently occur as intergrades with other soil orders, so that Mollisols with vertic features account for 31.4 % of the province area. Overall, the proportion of land covered by Vertisols and soils with vertic characteristics in Entre Ríos is about 70% (Tasi, 2000). The objective of this work was to assess the impact caused by management practices after land clearing on two different soil types and the selection of a data set of indicators of soil quality.

Materials and methods

Site characteristics and management practices

Soil physical and chemical properties were evaluated on two soil series from a dairy farm located in Entre Ríos province at 32º 04' S and 60º 01' W. These soil series are known as María Dolores (Argic Pelludert) and El Carmen (Vertic Argiudoll) according to USDA. Agricultural soils were compared with contiguous natural undisturbed soils. Agricultural plots were sampled to take into account intensification of cultivation practices following three different management systems: grassland (leguminous and grasses), grassland plus cropland in rotation (about 50% cropland in the last six years before soil sampling) and mid-term continuous cropland (where four crops were grown on the Vertic Argiudoll and six crops were growth on the Argic Pelludert in the last six years). Soybean and sorghum were the main crops in the rotation and zero tillage was the tillage system in the last year before sampling.

Laboratory and fields methods

Three composite soil samples were taken at the 0-12 cm depth. Soil sampling was performed both disturbed and undisturbed for routine soil general properties and soil aggregate stability analysis, respectively. Samples were air-dried and passed through a 2000 µm sieve. Particle size distribution was determined by the pipette method. Organic carbon content (OC) was determined by the Walkley and Black method, soil pH using a 1: 2.5 soil to water ratio and total nitrogen (TN) according to Kjeldahl. Also OC/ N ratio was taken into account.

Aggregate structural stability was determined by the Henin test, in three subsamples treated differently, i. e. no pretreatment before sudden water immersion (SAW), pretreatment with ethanol (SAE) and pretreatment with benzene (SAB). Results of the three tests were used for calculating the instability index. The K percolation index was also assessed. Soil bulk density, ρm, was determined by the core method and particle density, ρs, by the picnometer method. Total porosity (TP) was calculated from ρm and ρs.

In each soil type and soil use situation, erosion symptoms were visually defined and four measurements of A horizon thickness were made for estimating soil losses.

Statistics

The selection of the most sensible variables as soil quality indicators in relation to intensification of the agriculture, were made taken the undisturbed soil as a reference by means of significance (< 0.01), R-square, and relative slope of the linear regression (< -0.04). Differences between land-use were evaluated by analysis of variance (ANOVA) and significantly different means were recognized by the Tukey test (5%).

Results and Discussion

Mollisols occur on the flatter plateau parts and upper slopes while Vertisols occupy the lower slopes and valleys leer. Lateral and topographic relations in the landscape controlled the hydrologic soil properties so that Vertisol was most prone to soil erosion.

Soil texture in the topsoil of the two soil types was silty clay loam. The clay content was higher than 38% in the Argic Pelludert and above 33% in the Vertic Argiudoll while sand content was lower than 3% in both soil types.

Increasing crop proportion in the rotational system caused a decline of soil quality. Table 1 shows sensitivity analysis of soil variables used in assessing soil quality. In the Argic Pelludert the most sensitive variables were: OM, SAW, SAB, SAA and soil losses, whereas in the Vertic Argiudoll they were: OM, N, SAB, instability index, K percolation index and BD. TP and BD were not considered as indicators because of the low value of the regression parameter, b, even if R-square values were high. Note that more soil properties were found to

be adequate to determine the effect the various soil uses have on soil quality in the Argic Pelludert than in the Vertic Argiudoll.
Organic matter content and aggregate stability have been also previously selected as indicators, both on Mollisols (Wilson et al., 2000) and in Vertisols (Cerana et al., 2005) of the study area. However, when other soil properties are taken into account outcomes of previous comparative soil quality assessments were somewhat different.

	Argic Pelludert			Vertic Argiudoll		
Soil variables	**b**	**Significance**	**R^2**	**b**	**Significance**	**R^2**
OM	-0.04	0.003	0.60	-0.08	0.006	0.54
pH	0.00	0.419	0.07	-0.01	0.407	0.07
N	-0.04	0.047	0.34	-0.08	0.003	0.59
OC/N ratio	0.00	0.825	0.01	0.00	0.760	0.01
SAW	-0.06	0.004	0.57	-0.06	0.055	0.32
SAE	-0.03	0.069	0.29	0.00	0.773	0.01
SAB	-0.08	0.010	0.50	-0.10	0.011	0.49
SAA	-0.06	0.006	0.55	-0.05	0.070	0.29
Instability index	-0.10	0.008	0.52	-0.11	0.0001	0.81
K percolation index	-0.11	0.003	0.61	-0.12	0.0001	0.78
TP	-0.02	0.004	0.59	-0.03	0.0003	0.75
BD	-0.03	0.005	0.57	-0.05	0.0002	0.76
Soil losses	-0.06	0.002	0.63	-0.03	0.459	0.06

Table 1: Impact of land use changes as assessed by sensitivity analysis of soil chemical and physical properties of the study soils and quantified by slope of lineal regression, significance and R-square. (OM=organic matter content, N =total nitrogen), SAW= stable aggregates after immersion in water with no pretreatment, SAE = stable aggregates pretreatment with ethanol), SAB = stable aggregates pretreatment with benzene), SAA = stable aggregates average, TP = total porosity and BD= bulk density).

Soil erosion as assessed by topsoil horizon depth was identified as a very sensitive soil quality indicator in the Argic Palludert (Table 1). This soil property can not be considered as an adequate soil quality descriptor in de Vertic Argiudoll when parameters of the statistical analysis are taken in account. The later result may be attributed to the fact that flat areas are occupied by Mollisols. However, topsoil depth decrease of Mollisols induced by erosion is also very important when soils occurring on slopes are considered. Overall, soil erosion is a sensitive indicator of soil degradation in the study landscape and it is proposed to include it in a Minimum Data Set. Selected soil quality indicators to determine the effect of soil use are listed in Table 2.

Argic Pelludert	Vertic Argiudoll
Organic matter	Organic matter and Total nitrogen
Stable aggregates to water and benzene and average aggregate stability	Bulk density and Stable aggregates to benzene
Instability index	Instability index
K percolation index	K percolation index
Soil erosion	Soil erosion

Table 2: Proposed Minimum Data Set to assess changes in land-use on an Argic Pelludert and a Vertic Argiudoll of Entre Rios Province, Argentine.

Figure 1 shows the effect of soil use on organic matter content and aggregate stability to benzene of the two study soils. Natural undisturbed soils exhibited higher organic matter

contents and greater aggregate stability. Losses of organic matter during cultivation influenced the studied soil physical properties. Soils in rotations consisting of grassland and cropland were ranked at higher quality levels than grassland soils, which was attributed to soil degradation by overgrazing in grassland pastures.

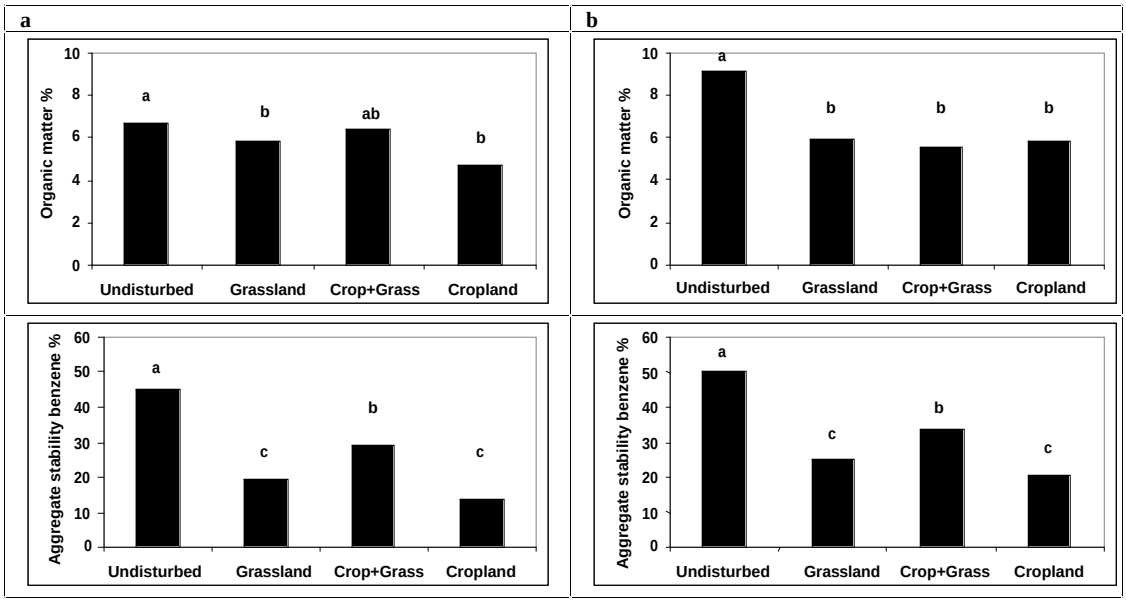

Figure 1: Effect of soil use on organic matter content and aggregate stability.

Conclusions

A one-time measurement of soil properties in an Argic Palleudert and a Vertic Argiudoll showed a differential response to management practices. Thus, the minimum data set proposed to assess soil quality was not the same, but depended on soil type. Indicators most affected by agricultural intensification in both soil types were: organic matter content, aggregate stability and soil erosion. Increasing crop proportion in the rotation resulted in soil deterioration at the medium term and threatened the sustainability of the soil resource at the long term. Therefore, improved management practices are considered to be associated with increasing proportion of grassland in the rotation, especially in the Argic Pelludert.

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