Changes in hydrodynamics of a tropical soil cover resulting from intensive cultivation

M. Grimaldi[1], A. Zago[2], M. Cooper[3], J. Tavares-Filho[4], M. Dosso[5]

[1]IRD/FCAP, UR064, Centre IRD d'Ile-de-France, 32 avenue Henri Varagnat, 93143 Bondy cedex, France, grimaldi@ns.ird.fr
[2]UFSM, Centro de Ciências Rurais, Faixa de Camobi Km 09, CEP 97105-900 Santa Maria (RS), Brasil, arizago@zaz.com.br
[3]ESALQ/USP, Depto. de Solos e Nutrição de Plantas, Av. Pádua Dias, 11 CEP 13.418-900, Piracicaba (SP), Brasil, mcooper@carpa.ciagri.usp.br
[4]UEL, Centro de Ciências Agrárias, CP 6001, CEP 86051-970, Londrina (PR), Brasil
[5]CNEARC, 1101 avenue AGROPOLIS - B.P. 5098 34033 Montpellier cedex 01, France, dosso@cnearc.fr

Vast areas of central and southern Brazil under tropical-subtropical climates have been cultivated intensively for the past few decades or are expected to undergo such a development. The consequences of this remain unknown, both on the soil fertility and on the environment. Farming practices modify the structure of the soils, either directly or indirectly, via changes in the diversity and activity of the soil fauna. We studied the structure and hydrodynamic behaviour of the soil cover in a cultivated catchment area in the state of Paraná, southern Brazil. In this study, we seek to specify the influence of farming practices on the evolution of soils which, in the long term, may compromise their productive capacity.

The catchment area is located close to the small rural town of Mamborê (24°16'41" S, 52°39'19" W). Agriculture intensified in this area with the growing of soya from 1969 onwards. The landscape consists of hills with gentle slopes that become more marked near the principal thalwegs. Structural analysis of the soil cover allows us to map and characterize a pedological system developed on sandstone. This system is termed "latossolo vermelho escuro - podzólico" according to the Brazilian soil classification, or "ferralsol - acrisol" according to the World Reference Base. It is characterized by the progressive passage downstream from the Bl horizon of the ferralsol, sandy-clayey with microaggregated structure, to the Bt horizon of the acrisol, clayey-sandy with polyhedral structure. A sub-surface horizon E, depleted in clay, appears above horizon Bt. After many years of soya and corn culture, a pasture was established in the catchment area. Two years later, a compact horizon was still clearly perceptible at the base of the tilled horizon.

Samples with unreworked structure were taken in the principal horizons for laboratory analysis of the apparent density (cylinders of 250 cm^3) and the water retention profile between 0 and -160 m matrix potential (cylinders of 100 cm^3). The hydraulic conductivity of these same horizons was measured *in situ* by an infiltrometer with controlled suction, using a 8.5-cm-diameter disc and imposing 4 successive values of matrix potential (-10, -3.5, -1 and sometimes 0 cm). Five tensiometric stations, each one including eight tensiometers at depths of 10, 20, 30, 50, 70, 90, 120 and 150 cm, were set up along a 120 m-long toposequence. The station at the upslope end of the toposequence is located on ferralsol; two stations bracket the limit of appearance of horizon Bt in the acrisol; the fourth station is on acrisol, located at the foot of a slope created to limit erosion; the fifth station is at the bottom of the slope, near the thalweg. The analysis of the spatial and temporal variations of water potential, measured by tensiometers, in particular allows us to specify the expansion and the persistence of the saturated, surface or deep zones as a function of precipitation.

The bulk densities and the hydrodynamic properties show the existence of a structural discontinuity under the tilled horizon, corresponding to the densest and least permeable level in the two soil types. Hydraulic conductivity decreases tenfold between the surface of the ferralsol and the base of the tilled horizon at the four imposed matrix potentials, while the apparent density increases from 1.5 to 1.67. The contrast between the surface and the base of the tilled layer is less marked in the acrisol. The water retention curves also reflect the degradation of the soil structure: the volume per unit mass of water lost when the matrix potential varies from -10 to -100 cm falls from 0.12 $cm^3 g^{-1}$ on the surface ferralsol to 0.07$cm^3 g^{-1}$ at the base of the tilled layer. This difference results from a more compact arrangement of the argillaceous micro-aggregates and sand particles.

Tensiometric measurements during and after a rainstorm of 44 mm (coming at the end of a very rainy period) reveal the existence of two perched water tables. The deeper one appears within horizon E, above horizon Bt of the acrisol. However, the infiltration of water is clearly slowed down between 20 and 30 cm depth, i.e. at the base of the tilled horizon, both in the ferralsol as well as in the acrisol. This shallow perched water table is limited to the tilled horizon and is present over all the hillslope. Being rather transitory, this groundwater body did not persist more than two or three hours after the studied downpour. On the other hand, the deeper body perched above Bt was still present two days after the rainstorm, and even much later at the slope bottom. This groundwater body seems to contribute much less to the flows in the thalweg of the catchment area, as shown by the rapid and important reduction of flow as soon as the cultivated horizon is no longer saturated. Measurements thus confirm the difference in hydrodynamic behaviour between the ferralsol and the acrisol, which thus also involves the role of horizon Bt. However, there is lateral drainage within the tilled horizon of this cultivated catchment area. Consequently, even in the ferralsol, drainage is not strictly vertical in this area, contrary to the situation observed under natural vegetation for this type of soil. A large proportion of the precipitation will therefore join the drainage network rapidly without recharging the soil water storage. In an area where three harvests are carried out each year, this hydrodynamic regime may represent a real constraint .

The *in situ* monitoring of the hydrodynamic functioning of the pedological system has shown the presence of major structural discontinuities. These discontinuities were inherited from soil formation processes or have appeared since the establishment of farming. They limit the vertical hydric transfers and, during rainy episodes, give rise to relatively shallow and sustained lateral flows. These flows determine or accelerate the processes of soil evolution, such as eluviation and erosion, even causing waterlogged conditions in the case of water stagnation. The results obtained stress the importance and the speed (deforestation only dates back a few decades) of the changes in soil water dynamics produced by farming methods. There are at least two important practical consequences : increased risks of erosion and a reduced replenishment of the soil water storage.