Experimental and numerical analysis of the influence of tillage on crust formation and runoff in cultivated sandy soils of Senegal

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Overland flow and soil erosion are the main source of soil and fertility losses during the rainy season in the Sahelian region. The objectives were, primarily to investigate the evolution of soil surface crust formation on the hydraulic conductivity near saturation in relation to the cumulative rainfall and secondarily, to study the effect of the tillage direction in relation to the slope. The analysis was based on 47 in-situ infiltration tests and 18 soil samples which were treated in the laboratory by using the Wind evaporation method to get the soil hydrodynamic properties.

The infiltration tests were carried out in square meter plots distributed on 3 sites : tillage in the direction perpendicular to the slope (site A and site C) and tillage along the slope (site B). Site C is representative of the soil at the end of the rainy season. The plots received between 1 and 5 simulated rainfalls (60 mm/hr during 30 mn). Four infiltration tests were performed on each plot. Analyses concern steady state infiltration flux and the calculation of the hydraulic conductivity near saturation using Darcy's law. The statistical analysis showed a significant evolution of the fluxes for the B plots, but not for the A plots with the applied amount of rain. The type of crusts, mainly runoff type for site B site and structural type for site A could explain this difference.

Immediately after tillage, the surface layers are more permeable than the deeper ones. The hydraulic conductivity values range from 40 mm/hr at surface to 25 mm/hr in depth. After about 150 mm of cumulative rainfall the profile seems to homogenise itself with a hydraulic conductivity close to 5 mm/hr. This weak value confirms the effect of the development of a crust at the soil surface.

The laboratory evaporation tests were performed on samples to determine the parameters of the retention curves (vanGenuchten model). The surface horizon samples show a bubbling air pressure value (h_g) greater than that for the deeper soil layers which were, -39 cm and -19 cm respectively. This can be explained by a more significant structuring of the surface horizon due to soil tillage effects. The parameter of form "n" presents almost identical values for both layers (1.53 and 1.47 respectively) according to their identical particle size distribution. Hydraulic conductivity values calculated using Darcy's law, covered only a small range degree of saturation (from 0.2 to 0.6). The values of hydraulic conductivity close to saturation obtained by laboratory determinations were complemented by the results of the in-situ infiltration tests. All the experimental values were used to estimate by an inverse method the parameters of the van Genuchten-Mualem (VGM) and Brooks and Corey (BC) analytical expressions. The VGM model was found to give better results, especially close to saturation.

The very small thickness of the crust made its direct hydrodynamic characterization difficult. Then the crust hydraulic conductivity close to saturation was estimated by an inverse method using HYDRUS 1D numerical code. It appeared that the saturated hydraulic conductivity of the crust was 2 orders of magnitude smaller than that of the subsurface layer.

The tensiometers data collected during the 1997 rainy season in a groundnut field were used to evaluate the hydrodynamic properties of the crust and to validate the estimated parameters.

It is showed that the simulation of water flow over a 5 day period gave satisfactory results. The calculated pressures were found in better agreement with measured ones for the surface and subsurface layers. For deeper layers the poor results can be explained to some extent by hysteretic effects and local heterogeneity.