Characterization of Vertisols in the VL endemic region of Humera - savannah vs. cultivated fields

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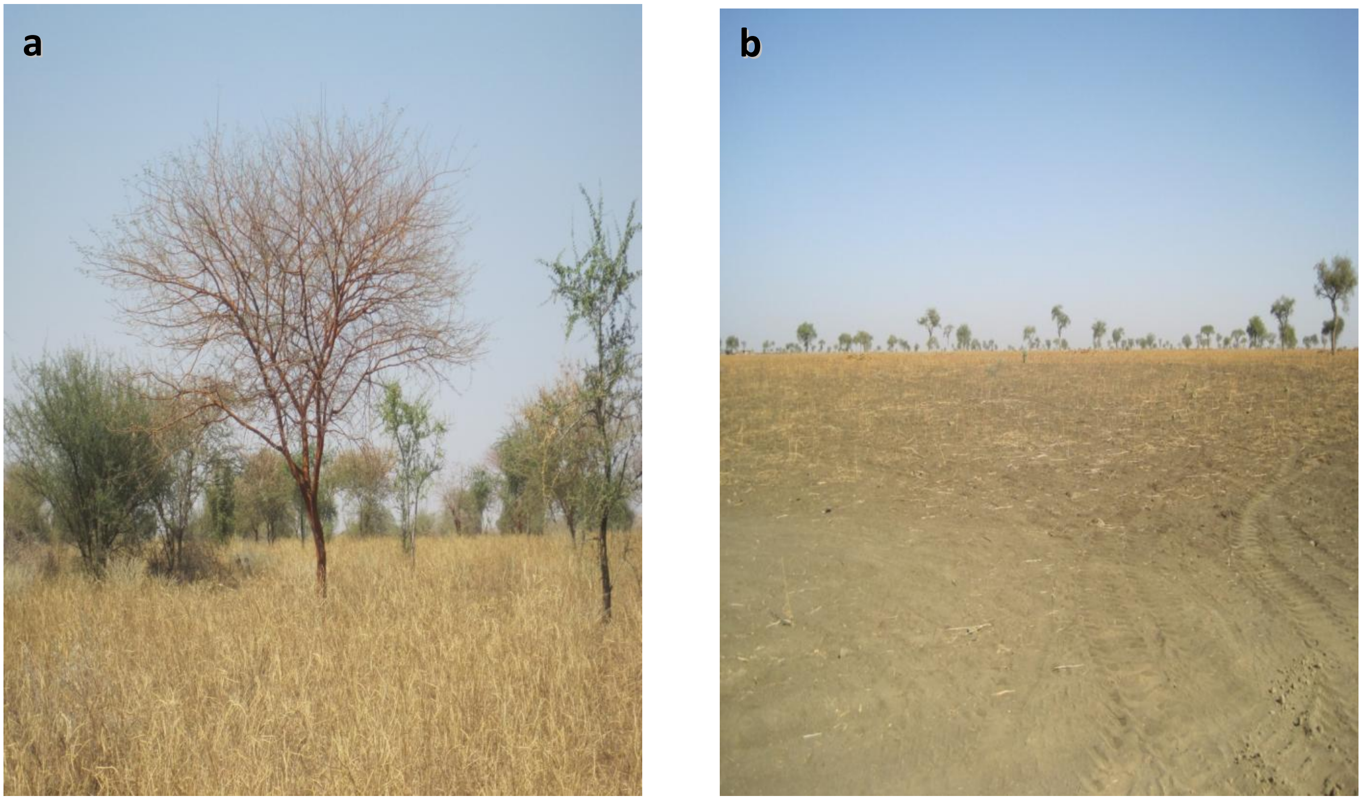
Introduction

Phlebotomus orientalis, the vector of *Leishmania donovani* in East Africa is almost always found in ecotopes predominated by deeply cracked black cotton soils or vertisols. Extensive analyses were carried out on soil samples collected during two sampling trips conducted during Nov. 2010 and Feb. 2011. Samples retrieved from different sites under different land uses were compared. The samples were taken from a native *Acacia seyal* savannah (Fig. 1a) and nearby sorghum and sesame fields (Fig. 1b) in Humera, north Ethiopia, and physical and chemical properties, aggregate stability (soil dispersion and swelling), and hydraulic conductivity were assessed. These parameters govern the water content and flow in soils, and can promote our knowledge on dynamics of cracks development and closure in dry and wet seasons.

Fig. 1: Acacia seyal savannah (a) sesame field (b) fallow field where soil samples were taken.



Chemical and Physical characteristics - The soils were, in general, quite homogenous with respect to their chemical and physical properties; the clay content was high (64.7-73.3%) and the organic matter content was low (1.22-1.68%) (Table 1). In contrast, the exchangeable sodium percentage (ESP) of the samples increased with soil depth for the various land uses (Fig. 2).

Table 1*: Mechanical composition, exchangeable sodium percentage (ESP), cation exchange capacity (CEC), organic matter content (OM) and pH, electrical conductivity (EC) and dissolved organic matter (DOM) of the soil samples of the various land uses. In each column, * indicates significant differences at P<0.05 between land uses for each soil depth.*

Soil depth	Mechanical composition			OM	CEC	Soil water extract (1:2 soil:water)		
	Clay	Silt	Sand			pH	EC	DOM
cm	----------------%----------------------				cmol$_c$ Kg^{-1}		dS m^{-1}	mg L^{-1}
----------Savannah----------								
0-15	66.6^{*}	15.6	17.8	1.68^{*}	72.9	7.9	0.3^{*}	256.2
15-30	64.8	19.7	15.6	1.39	71.8	7.7	0.3	193.2
30-60	66.9	15.5	17.6	1.33	71.5	7.8	0.3	161.1
60-90	68.6	15.5	15.9	1.31	70.4	8.0	0.4	135.5
90-120	68.8	15.4	15.8	1.23	74.0	8.4	$0.5^{\mathbf{a}}$	140.1
----------Sorghum----------								
0-15	71.2^{*}	15.5	13.4	1.33^{*}	78.3	7.8	0.2^{*}	147.7
15-30	70.9	14.2	14.9	1.31	78.3	7.6	0.2	140.5
30-60	70.8	14.3	14.9	1.35	83.2	7.6	0.3	136.1
60-90	69.6	14.8	15.6	1.29	79.8	7.7	0.3	123.7
90-120	72.1	17.4	10.5	1.22	81.6	8.0	$0.4^{\mathbf{b}}$	158.5
----------Sesame----------								
0-15	71.7^{*}	17.1	11.3	1.39^{*}	82.7	8.0	0.2^{*}	182.8
15-30	71.9	12.5	15.6	1.30	78.4	8.1	0.3	147.9
30-60	69.3	12.7	18.0	1.30	81.6	8.1	0.3	123.6
60-90	70.6	8.8	20.6	1.24	80.2	8.3	0.3	131.4
90-120	73.3	15.8	10.8	1.29	83.5	8.3	0.5^{*}	176.5

Dispersion, swelling and hydraulic conductivity

Dispersion values, which are defined as the percentage of clay that undergoes dispersion when wet, increased significantly with an increase in soil ESP, but were not affected by land use (Fig. 3). At low-ESP values, 5% of the soil clay undergoes dispersion. However, for high-ESP values (10-12), >15% of the soil clay undergoes dispersion. Dispersed clay particles could clog pores and reduce hydraulic conductivity. The swelling values, which are defined as the increase in soil volume upon wetting, ranged from 50% to 90% (i.e. 150%-190% increase in soil volume) in the different savannah soil samples and were positively correlated with ESP values (Fig. 4). In contrast, in the cultivated soil with sorghum and sesame, the swelling values were not correlated with ESP, but were higher, in general, than in the savannah soil in soil ESP <8 in particularly (Fig. 4). Therefore, it can be concluded that the cultivated soils had a higher swelling potential than the savannah soil in the 0-0.6 m depth. Since swelling is assumed to be the reciprocal of shrinking,

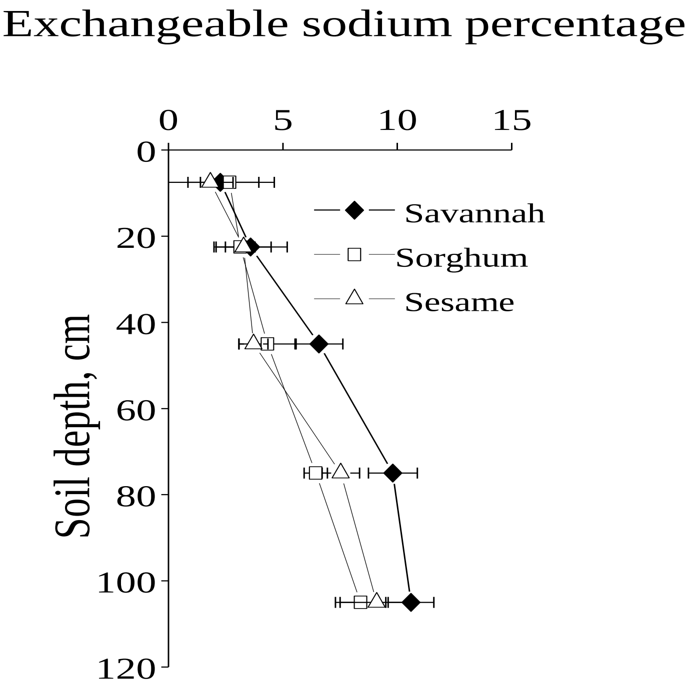


Fig. 2: Exchangeable sodium percentage of the different soils as a function of soil depth. Bars

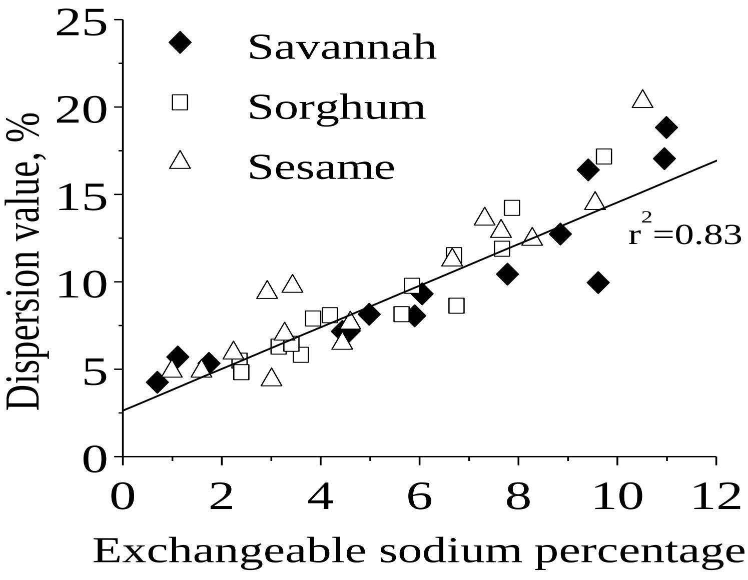


Fig. 3: Dispersion values of the supernatant as a function of exchangeable sodium, for the different land uses.

the cultivated soils are expected to have a higher propensity for cracking. This phenomenon was observed in the field (Fig. 5).

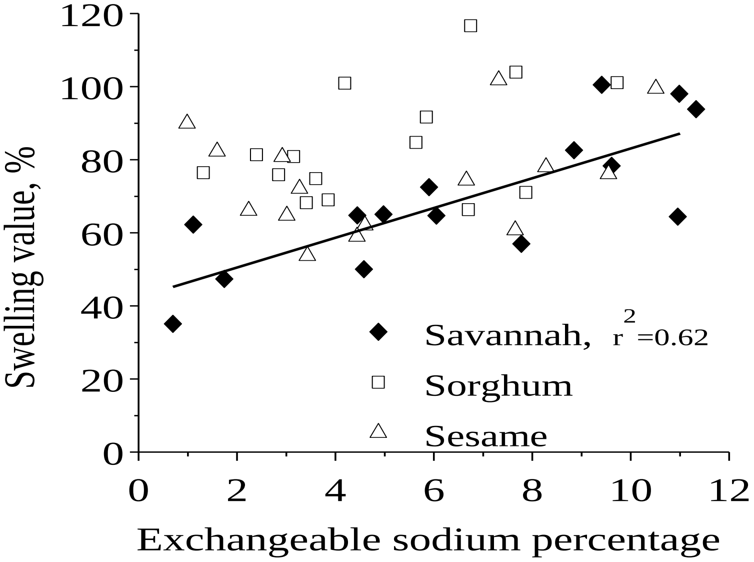


Fig. 4 swelling values as a function of ESP, for the different land uses (LU).

Saturated hydraulic conductivity (K_s) of the soils from savannah, sorghum and sesame fields as functions of ESP are presented in Fig. 6. K_s values of soils from the different land uses were negatively correlated with ESP. This negative correlation was as a result of dispersion and swelling of the soils that caused a reduction in K_s. However, since swelling of the savannah soil was generally lower than of the cultivated soils, K_s of the former soil was higher than the latter soils in the ESP <10 (Fig.6) (0-0.9 m soil depth, Fig 2).

Fig. 5: Soil surface cracking in the A. seyal savannah (a); sorghum field (b) (note different scales)

Relating water flow to crack dynamics

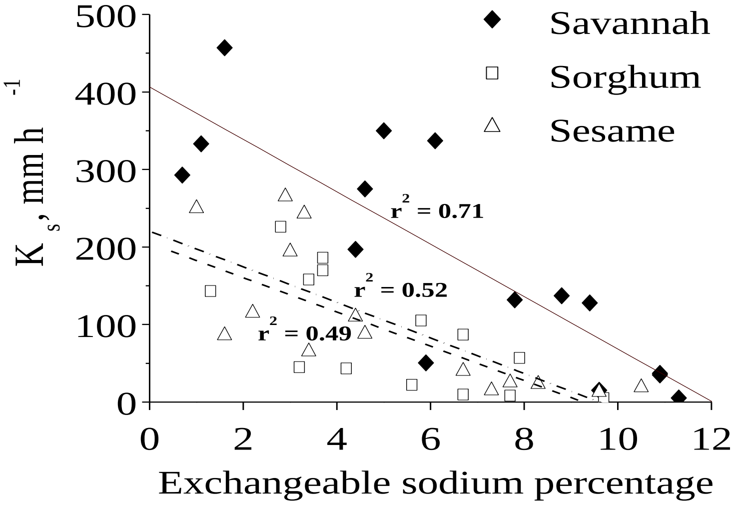


Fig. 6: Saturated hydraulic conductivity (K_s) of soil from the different land uses, as a function of ESP. Regression lines and coefficients of correlation in red are related to the cultivated soils; those in black are related to the Savannah soil.

As Vertisols lose moisture during the dry season the soil mass shrinks, causing desiccation cracks, which are wide at the surface and taper off with depth. The closure dynamics of these cracks is complex and dependent on water flow in the soil profile. In Vertisols, water flow through cracks (bypass flow) is in orders of magnitude greater than through pores in soil matrix (soil matrix flow). Under these conditions, two scenarios are possible: (1) High rainfall intensity coupled with wide extensive cracks may promote significant flow into deep cracks before surface cracks close. This causes substantial wetting of the sub soil, and cracks fill with water from bottom up. Closure of subsoil cracks is expected in this circumstance. (2) The cultivation of the upper soil layer in the sorghum and sesame fields before the wetting season minimizes surface cracks, and force water to infiltrate through the soil bulk matrix. In this scenario, slaking of surface aggregates due to fast wetting and raindrop impact, swelling and dispersion would decrease hydraulic conductivity of the upper soil layer and reduce infiltration significantly. Substantial amounts of runoff and surface ponding are expected. In the 2nd scenario, the very low permeability of the upper soil layer inhibits water movement into the deep soil layers. This results in non-homogenous water content in soil profile – a very wet surface and drier subsoil. In this scenario, deep subsoil cracks may remain open even though the soil surface is completely saturated.

Such conditions may promote sand fly breeding in the soil even during the rainy season when cracks are sealed with heavy mud and the ground may be covered with water.