Magnesium affected soils in Colombia

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Abtract

The Mg^{+2} accumulation on the exchange complex of soils to a very high saturation levels affect their chemical, physical and biological properties. Magnesium has some capacity to develop higher exchangeable sodium levels in clays and soil materials. Colombia has a large area of these soils, located mainly in the main rivers valleys and in the Caribbean Region. In the Cauca River Valley there are about 117.000 hectares affected.There is a lack of information about the soil forming processes, the Mg^{+2} effects on soils, the type and source of compounds responsible for the magnesium enrichment, their relationship with the landscape and the way this accumulation occurs.

To identify and quantify Mg^{+2} saturated areas over 2500 soil profiles from different landscape positions of the Cauca River Valley were studied. The information was processed to generate Mg-saturation maps, to identify the different soil profile types and to estimate the affected area. A topographic sequence from the alluvial inundation plain to the hills, was used to explore the presence of diagnostic horizons and to determine the main soil characteristics and genetic, mineralogical or chemical evidences of soil forming processes. Two transects parallel to the river were used to study the type and source of Mg-compounds responsible for the Mg-enrichment and the way this accumulation occurs.

By grouping together the soil profiles, five main type of Mg-affected soils were identified as being predominant in the different landscape units. Their distribution in relation to the landscape units in the valley showed two different origins: soils developed under hydromorphic conditions and soils related to igneous Mg-materials. The toposequence studied showed the presence of a natric or gypsic horizon on the basin soil profiles, and evidence of calcium supersaturation and precipitation as calcite and aragonite; as the drainage conditions change the vertic characteristics disappear but calcium accumulation and precipitation processes occur near the hills. The lack of structure or massive conditions on the soil of the three soil profiles closest to the river are notorious. Light alkalinity is ordinary in all the strata but in the upper horizons. Sulphate and bicarbonate ions were found in all profiles but the later was not found in the soil parent materials of the lower plains. As the soil becomes deeper sulphate ions become predominant and gypsum accumulation appears not only due to hydromorphic conditions but related to the presence of Na^{+} and/or Mg^{+2}. The mineralogical composition of the clay fraction showed the presence of vermiculite and smectite in all profiles but predominant in the basin and lower plains. High bicarbonate and sulphate waters used to perform laboratory experiments showed the effect of irrigation on this soils causing soil sealing and crusting, decrease of aggregate stability and soil permeability. The presence of illite on the clay fraction was related to low soil tolerance to chemical and physical degradation.

Keywords: salinity, soil Mg-enrichment

Introduction

The Mg^{+2} accumulation on the exchange complex of soils to a very high saturation levels affect their chemical, physical and biological properties. Magnesium has some capacity to develop higher exchangeable sodium levels in clays and soil materials. Colombia has a large area of these soils, located mainly in the main rivers valleys and in the Caribbean Region. In the Cauca River Valley there are about 117.000 hectares affected. There is a lack of information about the soil forming processes, the Mg^{+2} effects on soils, the type and source of compounds responsible for the magnesium enrichment, their relationship with the landscape and the way this accumulation occurs.

Materials and Methods

To identify and quantify Mg^{+2} saturated areas over 2500 soil profiles from different landscape positions of the Cauca River Valley were studied. The information was processed to generate Mg-saturation maps, to identify the different soil profile types and to estimate the affected area. A topographic sequence from the alluvial inundation plain to the hills, was used to explore the presence of diagnostic horizons and to determine the main soil characteristics and genetic, mineralogical or chemical evidences of soil forming processes. Two 180 kilometer transects parallel to the river were used to study the type and source of Mg-compounds responsible for the Mg-enrichment and the way this accumulation occurs. Also the soil physical characteristics saturated hydraulic conductivity and matric potential using a Guelph permeameter were measured and concentric rings infiltration tests at constant hydraulic head were carried out. Samples of 9 profiles of magnesic soils were collected each 20 cm depth and the porosity and the physical changes were examined. The program RETC was used (Retention Curves) for prediction of the hydraulic properties of non saturated soils. These properties involved the retention curve, the function of hydraulic conductivity and the diffusivity of the water in the soil.

Results

By grouping together the soil profiles, five main type of Mg-affected soils were identified as being predominant in the different landscape units. The Figure 1 shows the one of the most common type of soil profile developed under reductive conditions Their distribution in relation to the landscape units in the valley showed two different origins: soils developed under hydromorphic conditions and soils related to igneous Mg-materials. The toposequence studied showed the presence of a natric or gypsic horizons on the basin soil profiles, and evidence of calcium supersaturation and precipitation as calcite and aragonite; as the drainage conditions change the vertic characteristics disappear but calcium accumulation and precipitation processes occur near the hills. The lack of structure or massive conditions on the soil of the three soil profiles closest to the river are notorious. Light alkalinity is ordinary in all the strata but in the upper horizons. Sulphate and bicarbonate ions were found in all profiles but the later was not found in the soil parent materials of the lower plains. As the soil becomes deeper, sulphate ions become predominant and gypsum accumulation appears not only due to reductive environment but related to the presence of Na^{+} and/or Mg^{+2}. The mineralogical composition of the clay fraction showed the presence of vermiculite and smectite in all profiles but predominant in the basin and lower plains.

High bicarbonate and sulphate waters used to perform laboratory experiments showed the effect of irrigation on this soils causing soil sealing and crusting, decrease of aggregate stability and soil permeability. The presence of illite on the clay fraction was related to low soil tolerance to chemical and physical degradation.

The high Mg-saturation soils of the Valley of the Cauca River present strong restrictions for the movement and the availability of water; they have high water retention, slow to very slow infiltration rate and hydraulic conductivity which are associated to low porosity and to deficient internal drainage. The intensive mechanization and the surface irrigation cause compaction and deterioration in their physical and chemical properties. The soil permeability is closely related to the type and amount of clay minerals present, the texture, the structural stability and intensity of mechanization.

Representative 5 cm core samples of selected soils (Udic Pellustert, Typic Pellustert, Typic Haplustalf, Fluvaquentic Haplustoll and Vertic Ustopept), did not reach the saturation point when they were left in water to capillarity rise after several days. Different hydraulic heads applied to the soil reached very low degrees of effective saturation. The levels of relative saturation showed slight changes at different hydraulic heads, except in the proximities of relative saturation in which the water adhered to the soil in form of a fine film, was expelled to low suction (0.1 bar). The total nonsaturation of magnesic soils by hydrophobic effects is confirmed. The water contents to diverse pressure (0.1 up to 15 bar) gave slight differences due to the low hydraulic conductivity, limiting the degree of effective saturation and the residual water capacity of the soil, being the hydraulic adjustments strongly restricted by the high matrix energies that govern the water-soil relations associated to the microporosity of the soils. It can be concluded that the thick core samples of great thickness (5 cm) rings is not the best one to examine the physical alterations occurred with the humidity changes and the phenomena of retention and water storage. Using little thickness (1 cm) rings is recommended in these soils.

The magnesic vertisol porosity is limited by the lack of spaces for the water and air movement for what they have strong physical impediments and require special cultivation practices. Soils don't have any structural arrangement to form macropores due to dispersion of the clays caused by the magnesium saturation and the reorientation of their layers by the attraction forces. The content of clays is high (45-75%), the total porosity is very low (15-30%), with micropores prevalence and high water retention capacity. The drainage is slow to imperfect which it is associated to the dominance of vertic conditions (Cole>0.09), high plasticity (PI>20%), high residual humidity, structural uncertainty, rigidity in dry and impediment to reach the total saturation.

Soils volume change too much with the humidity from saturation to dry, what gives origen to a characteristic gilgai microtopography. Precipitations of $CaCO_3$ and other salts are observed on the flat court surfaces, sealing of pores and high removal potential when they are exposed to watering or rain. The nature of the clays and the mineral solubility processes have favored the Mg enrichment of the soils of the valley, causing clay peptization and dispersion and affecting the porosity and the hydraulic conductivity of the soil.

Caracter?ticas Qu?nicas

Prof. (cm)	meq/100 g		
	Ca	Mg	Na
0 - 20	4.40	9.80	0.24
20 - 68	9.20	12.00	0.37
68 - 100	9.60	10.40	0.38
100 - 120	8.40	12.40	0.44

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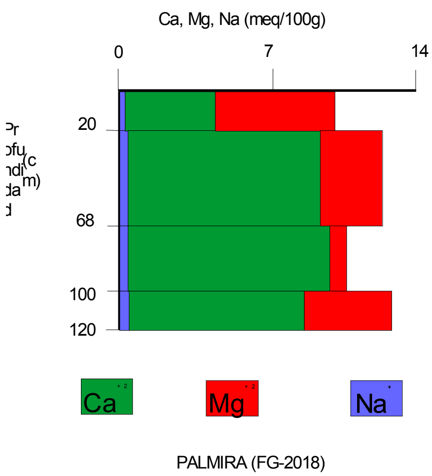

Figura 5. Perfiles t?icos de suelos magn?icos del Valle del R? Cauca.

Caracter?ticas Qu?

Prof. (cm)	meq/100		
	Ca	Mg	Na
0 - 30	12.00	22.80	0.90
30 - 50	9.20	19.60	5.12
50 - 70	7.60	21.20	4.49
70 - 95	7.20	15.60	2.85
95 -	5.60	12.40	0.82

5A

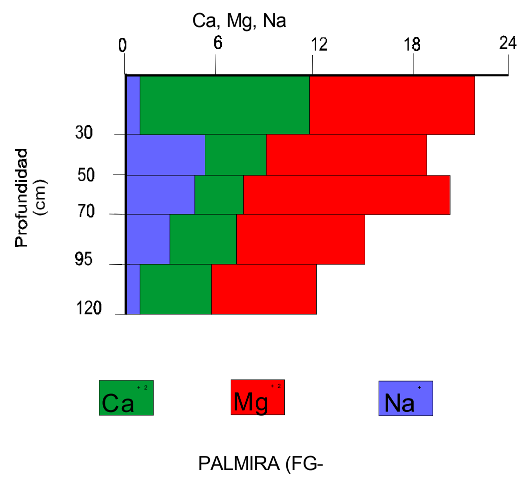

Figura 5A. Perfiles t?icos de suelos magn?icos del Valle del R? Cauca.

Caracter?ticas Qu?

Prof. (cm)	meq/100		
	Ca	Mg	Na
0 - 28	11.20	15.20	17.29
28 - 58	10.17	17.94	18.49
58 - 90	12.00	10.40	15.19
90 - 120	9.42	16.47	20.55

5B

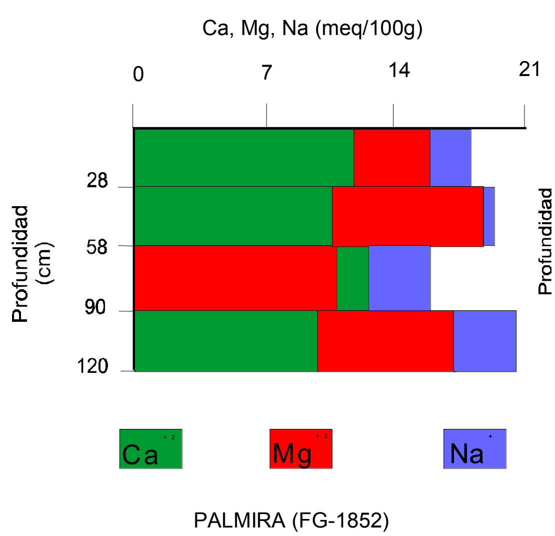

Figura 5B. Perfiles t?icos de suelos magn?icos del Valle del R?

Caracter?ticas Qu?nicas

Prof. (cm)	meq/100 g		
	Ca	Mg	Na
0 - 20	4.80	26.10	14.32
20 - 40	9.60	23.20	13.09
40 - 60	8.80	19.20	13.00
60 - 80	8.00	19.60	13.96
80 - 120	10.80	12.40	14.32

5C

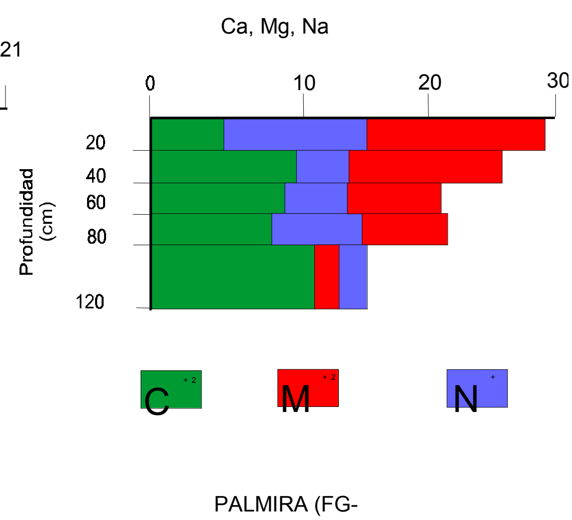

Figura 5C. Perfiles t?icos de suelos magn?icos del Valle del R? Cauca.

Figure 1

Table 1 Physical characterization of the three selected soils of the Valley of the Cauca River (Colombia).

Soil	Texture	O.M. (%)	Bulk density (g cm^{-3})	Dr (g cm^{-3})	PI (%)	CD (%)	H.W (%)	SI	Porosity (%)	WR_{15}bar
Typic Haplustalf	ArL	2.79	1.37	2.63	35.9	1.81	1.93	0.97	42.96	31.01
Pachic Haplustoll	FL	2.50	1.17	2.73	20.7	11.53	1.47	0.51	57.14	14.28
Typic Haplustert	Ar	2.37	1.43	2.56	34.7	48.69	2.71	1.38	40.41	31.39

O.M=Organic Matter, Dr=density, PI= plasticity Index, DC=Dispersion coefficient, HW=hygroscopic water, SI= stability Index, WR_{15} bar = Water retention to 15 bar.

Table 2 Changes in the Exchangeable Magnesium Percentage (EMgP) and Exchangeable Sodium Percentage (ESP) of three Colombian soils treated with high bicarbonate and sulphate waters**.**

Soil	EMgP		ESP	
	%			
	Initial	Final	Initial	Final
Alfisol	26.7	31.5	4.2	4.5
Mollisol	24.8	45.1	0.7	7.8
Vertisol	28.5	33.8	2.2	3.7

Table 3 Saturated Hydraulic Conductivity of three Colombian soils treated with high bicarbonate and sulphate saline water (40 cmol (+) L^{-1}).

Hydraulic Conductivity (K_{sat}) mm h^{-1}					
Alfisol		Mollisol		Vertisol	
Before	After	Before	After	Before	After
95.1	86.0	60.1	5.0	46.4	27.5

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