CHARACTERISTIC OF DYSTRUSTEPTS IN THE VENEZUELAN ANDES[1]

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SUMMARY

The majority (60 %) of the soils in the Venezuelan Andes are Inceptisols, a large percentage of which are classified as Dystrustepts by the US Soil Taxonomy, Second Edition of 1999. Some of these soils were classified as Humitropepts (high organic - C-OC-soils) and Dystropepts by the Soil Taxonomy prior to 1999, but no equivalent large group was created for high-OC soils in the new Ustepts suborder. Dystrusepts developed on different materials, relief and vegetation. Their properties are closely related with the parent material. Soils developed on transported deposits *or* sediments have darker and thicker A horizons, a slightly acid reaction, greater CEC and OC contents than upland slope soils. Based on the previous classification into large groups (Humitropepts and Dystropepts) we found that: Humitropepts have a slightly less acid and higher values of CEC than Dystropepts. These properties or characteristics seem to be related to the fact that Humitropepts have a higher clay and OC content than the Dystropepts. Canonical discrimination analysis showed that the variables that discriminate the two great soil groups from each other are OC and silt. Data for Humitropepts are grouped around the OC vector (defining axis 3, principal component analysis), while Dystropepts are associated with the clay and sand vectors, with significant correlation. Given the importance of OC for soil properties, we propose the creation of a new large group named Humustepts for the order Inceptisol, suborder Ustepts.

Index terms: classification, Inceptisols, organic carbon.

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RESUMO: *CARACTERÍSTICAS DOS DYSTRUSTEPTS NOS ANDES VENEZUELANOS*

Boa parte dos solos dos Andes Venezuelanos (60 %) é classificada como "Inceptisol", e uma grande percentagem deles é Dystrustepts nas versões do Soil Taxonomy. Outros foram classificados como Humitropepts – solos com altos teores de C de compostos orgânicos (CO). Os Dystrustepts desenvolvem-se sobre diferentes materiais, relevo e vegetação. Suas características têm estreita relação com o tipo de material de origem. Os Dystrustepts desenvolvidos sobre sedimentos apresentam horizontes A mais escuros, menor acidez, CTC e teor de CO mais altos que os dos solos desenvolvidos em relevo mais declivoso. Pela análise dos solos, dada a classificação anterior em grandes grupos (Humitropepts e Dystropepts), tem-se que os Humitropepts apresentam menor acidez e maior CTC que os Dytropepst. Estas características parecem estar relacionadas com o fato de os Humitropepts apresentarem teores de argila e de matéria orgânica maiores que os de Dystropepts. A análise canônica discriminante mostra que as variáveis que mais denotam diferenças entre os grandes grupos de solos são os teores de CO e de silte. Os dados dos Humitropepts agrupam-se ao redor do vetor CO (Eje 3 da análise de componentes principais); e os dos Dystropepts estão associados com os vetores teores de argila e de areia. Pela importância do teor de CO nas propriedades dos solos, propõe-se a criação de um novo grupo, denominado Humustepts, na ordem Inceptisol, subordem Ustepts.

Termos de indexação: classificação, inceptisol, carbono orgânico.

INTRODUCTION

Inceptisols are soils of global distribution, and can be formed in cold to very hot, humid or subhumid regions, have a cambic horizon and an ochric epipedon (Soil Survey Staff, 1999). According to Foss et al. (1983), Inceptisols may be either: (1) soils developed on young sediments or; (2) soils formed in areas where environmental conditions hamper soil formation processes. Sixty percent of the soils in the Venezuelan Andes are Inceptisols (Ochoa et al., 2004), of which in turn a large proportion are Dystrustepts (Soil Survey Staff, 1999). Dystrustepts are acid Ustepts. They developed mostly in Pleistocene or Holocene deposits. Some of the soils that have steep slopes were formed on older deposits. The parent materials are generally acid, moderately or weakly consolidated sedimentary material, metamorphic rocks or acidic sediments. Many of these soils have a thermic or warmer temperature regime. The most common diagnostic horizons are umbric or ochric epipedon over a cambic horizon. Many of these soils have a densic, lithic or paralithic contact (Soil Survey Staff, 1999). The large Dystrustepts group includes Dystropepts and Humitropepts, as defined in editions of Soil Taxonomy prior to 1998 (Soil Survey Staff, 1996).

This paper analyzed the properties and characteristics of Dystrustepts in the Venezuelan Andes and their grouping on the basis of their principal properties, to evaluate whether a new large group in the US Soil Taxonomy should be proposed for a more appropriate classification of these soils. This proposal is based on the fact that in the Venezuelan Andes (at altitudes below 3,500 m) a great number of the Inceptisols had been classified as Humitropepts and Dystropepts, suborder Tropepts. Tropepts were identified based on their soil temperature regime at the suborder level rather than by their soil moisture regime, as Ustepts are. With the disappearance, in 1998, of the suborder Tropepts, these soils were reclassified in the suborder Ustepts as Dystrustepts at the large group level and in Oxic or Humic subgroups of Dystrustepts (Soil Survey Staff, 1999). This means that soils with high organic carbon (OC) content are no longer differentiated at the large group level. We believe this left a gap in the classification since OC content is very important for soil quality.

MATERIALS AND METHODS

Seventy seven different soil profiles, located at altitudes between 1,000 and 3,500 m in the Venezuelan Andes, were examined and reclassified as Dystrusteps. These soils had developed on different types of geological material, on different slopes and in distinct life *or* vegetation zones (Figure 1).

To analyze the soil samples, a data matrix was constructed, based on the variables OC, pH, %BS, exchangeable bases (Ca, Mg, N, K), color, thickness, and particle-size fractions (clay, silt, sand). Soil property and quality values corresponding to each

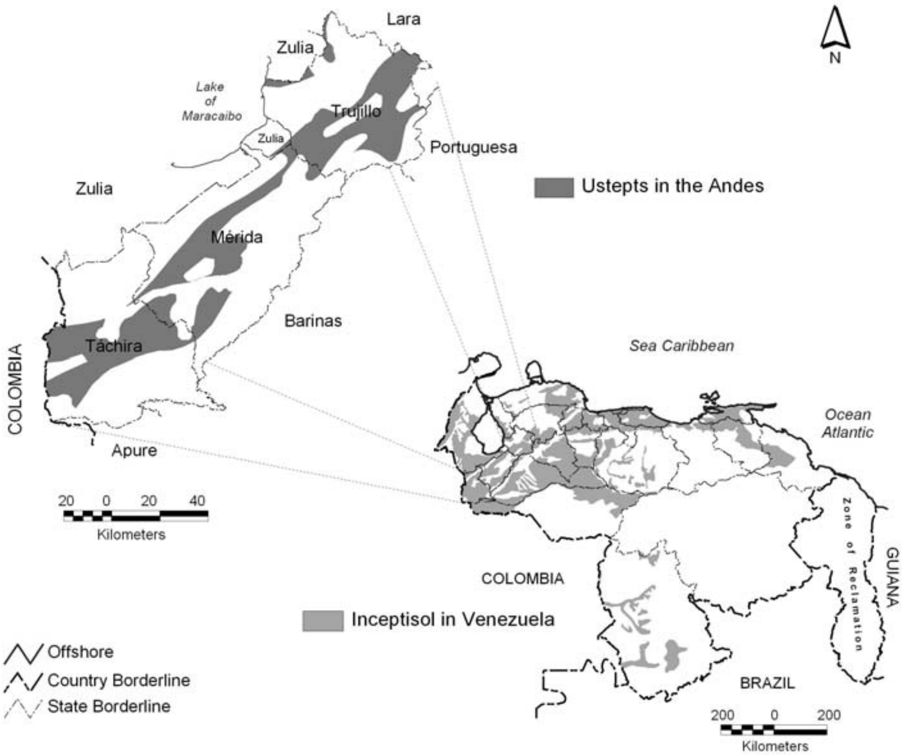

Figure 1. Distribution of Inceptisols in Venezuela and Ustepts in the Venezuelan Andes

horizon were calculated for each soil profile and then an absolute value was obtained for each individual soil by the following weighting equation:

$$P = \frac{\sum Pi.THi}{TST}$$

in which P is soil property (CEC, OC, pH, etc.), Pi is the value of the property for each soil horizon, THi is the thickness of each soil horizon and TST is the total soil thickness.

To identify color variables, a numerical value was assigned according to Hurst's linear scale (Hurst, 1977).

Statistical analysis was run on XLSTAT 6.1.9 (Thierry Fahny, Addinsoft). Each variable was tested for normality. The data were analyzed using principal component, clustering and discriminant canonical analysis.

RESULTS AND DISCUSSION

Field study

Dystrustepts in the Venezuelan Andes were formed on a great variety of materials, such as gneiss, schist, granites, quartz sandstone, conglomerate, slate, phyllite, shale, siltstone, among others.

The Dystrustepts that developed on sediments, with a 7 to15 % slope, have a high mean sand content (56.8 %). Dark gray colors with a hue of 10YR were predominant in their A horizons; yellowish brown colors with a hue of 10YR and reddish brown with a hue of 2.5YR in the B horizons; and in the C horizons the predominant colors were yellowish brown hues of 10YR, brown with a hue of 7.5YR and reddish brown with a hue of 5YR and 2.5YR. According to Foss et al. (1983) and the Soil Survey Staff (1999) the cambic horizon was defined as a horizon with strong brownish colors (high chroma values and red hues) and with sufficient alteration to produce changes in color, structure and composition distinguishing it from the A and C horizons. The cambic horizons analyzed, although differing in color from the overlying A horizons, were similar to C horizons, indicating that the reddish and yellowish coloration do not correspond to alterations (Table 1).

The Dystrustepts developed on upland slopes can be divided in those formed from materials such as gneiss, schist, granite, quartz sandstone and those from conglomerate, slate, phyllite, shale and siltstone. In the first case, there is a high mean sand content, while the second group has a relatively high clay content. The slopes ranged from 18 to 65 %. In A horizons the dominant colors are yellowish brown and dark brown, with a hue of 10YR. In B and C horizons, yellowish brown colors with a hue of 10YR, and yellowish red colors with a hue of 5YR predominated, with a smaller proportion of red with a hue of 2.5YR.

Table 1. Selected physical and chemical properties of eleven soils profiles

Profile	Depth	Horizon	Color (moist)	Struct.	Particle-size distribution			pH_{H_2O}	OC	Exchangeable cations				CEC	Base Sat.
					Sand	Silt	Clay			Ca	Mg	Na	K		
	cm				g kg^{-1}				g kg^{-1}	cmol$_c$ kg^{-1}					%
1	0-20	A1	10YR3/1	gr[(1)]	529	451	20	5,5	37,6	3,10	1,25	0,09	1,17	15,00	37
	20-80	A2	10YR3/1	gr	482	397	121	4,1	30,5	3,20	0,50	0,06	0,64	12,75	35
	80-115	Bw	2.5Y4/4	bl	493	415	92	4,2	37,2	1,00	0,16	0,04	0,40	4,61	35
Factors of soil formation: soil on lowlands (sediments), slope 12 %, altitude 2,180 msl, annual precipitation 1,300 mm, annual air temperature 14.9 ºC. Classification: Coarse-loamy, mixed, isothermic Humic Dystrustepts.															
2	0-41	A	10YR3/1	gr	652	249	99	5,9	29,6	4,60	1,00	0,10	0,40	17,50	35
	41-67	Bw1	10YR4/2	bl	665	224	111	5,5	14,8	3,80	0,70	0,10	0,40	14,40	35
	67-98	Bw2	10YR5/4	bl	659	228	113	3,3	5,1	1,70	0,50	0,20	1,70	14,10	29
	98-170	C	10YR5/6	bl	752	213	35	5,4	1,6	1,40	0,40	0,20	1,50	10,30	34
Factors of soil formation: soil on lowlands (sediments), slope: 17 %, altitude 2,400 msl, annual precipitation 900 mm, annual air temperature 13 ºC. Classification: Coarse-loamy, isothermic Humic Dystrustepts.															
3	0-30	Ap	10YR3/2	bl	498	364	138	4,9	32,8	4,90	0,90	0,30	0,70	28,40	24
	30-53	Ab	10YR3/1	bl	573	278	149	5,4	19,9	4,60	0,60	0,30	0,50	19,30	31
	53-66	C1	10YR4/2	bl	718	253	29	5,8	5,9	3,50	0,50	0,30	0,40	10,50	45
	66-90	C2	2,5Y3/2	si-gr	917	57	26	5.9	2,0	2,30	0,40	0,10	0,40	8,50	38
	90-140	C3	2,5YR4/2	bl	696	207	97	5.8	2,0	1,10	0,40	0,10	0,40	7,10	28
	140-190	C4	2,5Y3/2	si-gr	718	263	19	5,7	0,8	1,10	0,40	0,10	0,20	6,50	28
Factors of soil formation: soil on lowlands (sediments), slope 7 %, altitude 2,300 msl, annual precipitation 900 mm, annual air temperature 13.4 ºC. Parent material: sediments. Classification: Loamy-skeletal, isothermic Humic Dystrustepts.															
4	0-37	A	2.5Y2.5/0	bl	677	224	98	4,6	104,0	0,60	0,20	0,06	0,25	26,50	4
	37-59	C	2.5Y7/4	si-gr	859	82	59	5,2	12,0	0,20	0,01	0,03	0,02	3,50	7
Factors of soil formation: soil on lowlands (sediments), slope: 11 %, altitude 3,020 msl, annual precipitation 850 mm, annual air temperature 8 ºC. Classification: Sandy-skeletal, isomesic Humic Dystrustepts.															
5	0-30	A1	10YR3/1.5	gr	229	471	300	4,0	59,6	0,05	0,11	0,03	0,12	19,17	2
	30-46	A2	10YR3/2	gr	138	420	442	4,0	32,5	0,05	0,04	0,02	0,11	15,17	1
	46-67	Bw1	10YR6/6	bl	133	268	599	3,9	6,4	0,05	0,01	0,02	0,08	8,25	2
	67-100	Bw2	10YR5/8	bl	149	271	579	4,1	4,5	0,05	0,01	0,01	0,07	6,70	2
	100-140	C1	10YR5/6	bl	283	257	459	4,3	4,2	0,05	0,03	0,01	0,06	6,75	2
	140-200	C2	10YR5/6	bl	398	195	407	4,4	4,0	0,05	0,03	0,01	0,07	7,12	2
Factors of soil formation: Soil of Upland slopes (phyllites), slope 13 %, altitude 3,050 msl, annual precipitation 900 mm, annual air temperature10 ºC. Classification: Clayey, isomesic Oxic Dystrustepts.															
6	0-25	A	10YR4/2	gr	479	296	225	5,1	11,0	2,32	1,26	0,10	0,25	9,70	41
	25-54	Bw1	10YR3/3	bl	447	246	307	5,0	9,7	2,19	1,10	0,10	0,16	8,12	44
	54-77	Bw2	10YR4/2	bl	392	305	303	5,3	5,0	1,50	1,10	0,10	0,15	7,12	40
	77-87	C	7.5YR4/4	bl	456	313	231	5,1	2,9	1,20	0,90	0,10	0,10	6,60	35
Factors of soil formation: soil on lowlands (sediments), slope 12 %, altitude 1,700 msl, annual precipitation 850 mm, annual air temperature 16.5 ºC. Classification: Fine-loamy, isothermic Oxic Dystrustepts.															
7	0-14	A	10YR4/4	gr	399	195	406	4,7	12,1	0,50	0,10	0,20	0,10	18,10	5
	14-52	Bw	10YR5/4	bl	439	213	348	4,7	12,1	0,30	0,10	0,10	0,00	21,50	2
	52-130	R													
Factors of soil formation: Soil of Upland slopes (schists), slope 25 %, altitude 1,450 msl, annual precipitation 1,052 mm, annual air temperature 19.5 ºC. Classification: Fine-loamy, isothermic Typic Dystrustepts.															
8	0-20	A1	10YR3/2	bl	647	125	228	4,9	37,5	0,20	0,01	0,10	0,20	3,51	15
	20-40	A2	10YR4/2	bl	646	102	252	5,4	21,9	0,10	0,01	0,10	0,10	2,21	14
	40-62	Bw1	10YR4/3	bl	608	143	249	5,3	16,2	0,10	0,00	0,09	0,10	1,50	19
	62-90	Bw2	10YR5/4	bl	583	192	225	5,4	11,3	0,00	0,00	0,09	0,00	1,25	7
Factors of soil formation: Soil of Upland slopes (quartz sandtones and phyllites), slope 15 %, altitude 1,160 msl, annual precipitation 1,300 mm, annual air temperature 20.6 ºC. Classification: Fine-loamy, isothermic Oxic Dystrustepts.															
9	0-16	A1	10YR4/1	bl	892	40	68	5,4	9,8	0,60	0,10	0,00	0,10	3,10	26
	16-22	A2	10YR5/1	bl	892	78	30	5,0	1,7	0,20	0,00	0,10	0,10	1,70	24
	22-33	Bw1	7.5YR6/2	bl	767	139	94	4,5	1,7	0,30	0,00	0,00	0,10	1,50	27
	33-53	Bw2	7.5YR4/6	bl	767	85	148	5,9	2,9	0,20	0,00	0,10	0,10	2,10	19
	53-83	C	7.5YR4/4	bl	771	105	124	5,8	1,8	0,10	0,00	0,10	0,10	1,90	16
Factors of soil formation: Soil of Upland slopes (quartz sandtones and phyllites), slope 20 %, altitude 1350 msl, annual precipitation 1,350 mm, annual air temperature 22.2 ºC. Classification: Sandy, isothermic Oxic Dystrustepts.															
10	0-40	A1	10YR3/2	gr	753	147	100	5,5	41,4	3,20	1,10	0,07	0,28	10,31	45
	40-65	Bw1	10YR3/1	bl	694	157	149	5,3	40,0	2,80	0,94	0,07	0,21	9,38	43
	65-80	Bw2	10YR4/3	bl	627	193	180	5,7	23,1	1,95	0,27	0,07	0,14	7,50	32
	80-140	C	10YR4/4	bl	575	285	180	5,9	7,1	0,75	0,05	0,07	0,10	4,38	22
Factors of soil formation: Soil of Upland slopes (quartz sandtones and phyllites), slope 38 %, altitude 2,250 msl, annual precipitation 800 mm, annual air temperature 14,6 ºC. Classification: Sandy-skeletal, isomesic Oxic Dystrustepts.															
11	0-38	A	10YR2/2	bl	476	343	181	4,9	52,2	0,15	0,38	0,02	0,31	13,80	6
	38-72	Bw1	10YR5/6	bl	294	363	343	5,0	10,6	0,05	0,02	0,01	0,08	7,55	2
	72-140	Bw2	10YR6/6	bl	292	357	351	5,1	5,0	0,05	0,02	0,03	0,08	9,15	2
	140-220	C	2.5Y7/4	bl	281	438	281	5,4	5,0	0,05	0,02	0,03	0,11	4,70	4
Factors of soil formation: Soil of Upland slopes (granites), slope 15 %, altitude 2,000 msl, annual precipitation 700 mm, annual air temperature 15 ºC. Classification: Fine-loamy, isothermic Oxic Dystrustepts.															

(1) Structure: gr: granular; bl: blocky; co: columnar; pr: prismatic; si-gr: single grains.

There was some difference between the colors of soils on transported deposits and those on upland slopes. In the A horizons the colors were dark gray on the transported deposits and yellowish brown on the upland slopes, both with a hue of 10YR.

Horizon A in soils that evolved from transported deposits are over 25 cm thick in all cases. On upland slopes, the majority of A horizons also have a thickness > 25 cm. For all horizons, both on upland slopes and transported deposits, the soil structure was mostly subangular blocky. Some profiles had a granular structure in the A horizon.

Laboratory study

Soils developed on sediments had a sandy loam, loamy sand or sandy texture, and those on upland slopes a sandy loam, loamy sand, clay loam and clay texture. Dystrustepts on sediments had a sand content ranging from 30 to 93 %, while silt values ranged between 3 and 53 %. These values may increase or decrease with depth. Sand content in soils on upland slopes varied according to the parent material on which the soil was formed: on gneiss, schist, quartzite and sandstone the values ranged between 40 and 89 %, while on phyllite, the clay content ranged from 30 to 66 %. Sand content is higher in Dystropepts than in Humitropepts. The soils formed in sediments are less acidic (pH 5.4) than those on upland slopes (pH 4.6). In sediments, there was a slight difference in reaction between A horizons (pH 5.3) and B and C horizons (pH 5.5). On upland slopes A horizons are more acidic than B and C horizons. Soils developed on shale have an extremely acid A horizon (pH 4.0) and very strongly acid B and C horizons (pH 4.5). Those developed on sandstone, gneiss, schist, granite, etc. have very strongly acid A horizons (pH 4.5) and B and C horizons (pH 4.6). Humitropepts have a slightly less acid pH value than Dystropepts.

In the soils formed on sediments the CEC for A horizons is higher (16.98 $cmol_c\ kg^{-1}$) than the A horizons of soils formed on upland slopes (9.36 $cmol_c\ kg^{-1}$). In soils forming on sediments the CEC for B and C horizons is higher (8.37 $cmol_c\ kg^{-1}$) than in B and C horizons of soils forming on upland slopes (5.31 $cmol_c\ kg^{-1}$). In soils on upland slopes formed from shale, the CEC for the A horizons is 9.58 $cmol_c\ kg^{-1}$, and 6.34 $cmol_c\ kg^{-1}$. for the B and C horizons. In soils developed on granite, gneiss or sandy material, the CEC of the A horizons is 8.56 $cmol_c\ kg^{-1}$; and 4.65 $cmol_c\ kg^{-1}$ in the B and C horizons. Cation exchange capacity is higher in Humitropepts than in Dystropepts.

In soils on sediments, in A horizons the base saturation is 41.64 % and 38.89 % in B and C horizons, respectively. In soils on upland slopes over shale the base saturation is 14.16 % in the A horizons and 8.71 % in B and C horizons. In the soils on upland slopes forming from sandstone, granite, gneiss or schist and related parent materials the base saturation in the A horizon is 13.83 and 12.11 % in B and C horizons. Base saturation is approximately the same for both Humitropepts and Dystropepts soils.

In soils on lowland the OC content is high in the A horizons (4.03 %) and low in B and C horizons. In the soils forming on upland slopes over shale, the OC is 3.56 % in A horizons and 1.18 % in B and C horizons. In the soils forming on upland slopes over sandstone, granite and schist OC content is high (4.5 %) in the A horizons, but low (1.31 %) in B and C horizons. Organic carbon content in Humitropepts is twice the content of the Dystropepts.

In lowland soils the Ca content in the A horizons was greater than the Mg content of soils on upland slopes in all profiles examined. In the soils forming on upland slopes, the Ca was lower than the Mg content in 38 % of the A horizons examined.

Multivariate statistical analysis

Of all selected variables, the ones with lowest information loss in the principal component analysis for the main four components were OC, base saturation, pH, clay, silt and sand amount; the contribution of the variables color and thickness was small. Although the contribution of exchangeable bases (Ca, Mg, Na, K) and CEC was useful, they can be summarized in the base saturation percentage. Consequently, only OC, base saturation, pH, clay, silt and sand amount were taken into account for the analysis.

The four principal components account for 91.55 % of the variation in the data based on the accumulative eigenvalues (Table 2a). The first principal component accounts for 42.53 % of total variation, while the fourth principal component accounts for only 11.05 %, based on the eigenvalue variances. By adding the percent variance, components 1 and 2 account for 64 %; components 2 and 3 for 38 %; and component 1 and 3 for 59 % of the total variation. Component 4 adds little to the analysis. Webster & Oliver (1990) proposed that components or factors should be rotated to evaluate the behavior of variables to see if they are significant or contribute in every case. For component 1, 31.18 % of the variation can be attributed to sand (Table 2b), while in component 2, exchangeable bases account for 36.17 %. For the first two components (F1 and F2), the greatest effect on variation was due to the variables sand, clay, pH and exchangeable bases. By rotating the axes F1/F3 and F2/F3 these variables are no longer significant and their effect on variation decreases (Table 2b). On the other hand, the contribution of OC to variation increases considerably, and is one of the most influential of the variables (up to 70.65 %) in component 3. Although component 4 adds little to the analysis, clay, silt and pH are still important.

Table 2. Principal component analysis (PCA)

Eigenvalue	Component			
	F1	F2	F3	F4
	(a) Components y eigenvalues			
Eigenvalues	2.552	1.310	0.968	0.663
% variance	42.533	21.829	16.137	11.054
% acumulative	42.533	64.362	80.498	91.552
Variable	**Eigenvector**			
	F1	F2	F3	F4
Sand	0.593	-0.221	-0.106	-0.051
Silt	-0.416	0.351	0.418	-0.545
Clay	-0.498	0.136	-0.110	0.680
pH	0.345	0.503	0.285	0.433
Organic carbon	0.058	-0.441	0.841	0.215
Exchangeable bases	0.032	0.601	0.120	-0.059
Variable	**(b) Contributions of the variables (%) Component**			
	F1	F2	F3	F4
Sand	31.179	4.879	1.132	0.256
Silt	17.318	12.354	17.467	29.717
Clay	24.762	1.858	1.206	46.303
pH	11.873	25.295	8.109	18.753
Organic carbon	0.291	19.448	70.651	4.630
Exchangeable bases	10.578	36.166	1.435	0.343
Variable	**(c) Squared cocines of the variables Component**			
	F1	F2	F3	F4
Sand	0.898	0.064	0.011	0.002
Silt	0.442	0.162	0.169	0.179
Clay	0.632	0.024	0.012	0.307
pH	0.303	0.331	0.079	0.124
Organic carbon	0.007	0.225	0.684	0.031
Exchangeable bases	0.27	0.474	0.014	0.002

Squared cosines of the variables (Table 2c) show that the contribution of OC to variation is best seen in components 2 and 3 (F2/F3 axes). Base saturation, pH and silt have a positive and inverse correlation with sand; OC represents the highest value for component 3, and is negatively correlated with clay (Figure 2). The grouping of soils classified as Humitropepts (Soil Survey Staff, 1975) depends on OC and silt, while those classified as Dystropepts tend to be grouped on the basis of sand and clay more than any other variable measured in this study. The vectors however indicate that there is little significance in their correlations, suggesting that these variables cannot define the group reliably.

The cluster analysis identified four different soil composition groups (Table 3). The Humitropepts clearly dominate in groups III and IV. Organic carbon is the central variable that defines group III, which consists exclusively of Humitropepts. It is possible that the presence of Dystropepts in groups I and IV is due to poor soil classification, or to the fact that the OC content which defines Humitropepts was at the extreme limit of its range.

In the discriminant canonical analysis the same variables were used as in the PCA. Wilks' Lambda test (Figueras, 2000) shows that the variables OC and silt result in highly significant differences ($p < 0.001$) between the two soil suborders (Humitropepts and Dystropepts). There is a high canonical correlation (0.43) with an eigenvalue that explains 100 % of variation in the data (Figueras, 2000). This correlation is highly significant for testing the null hypothesis. In other words, there are differences between Humitropepts and Dystropepts if the soils are differentiated by silt and OC content (Table 4).

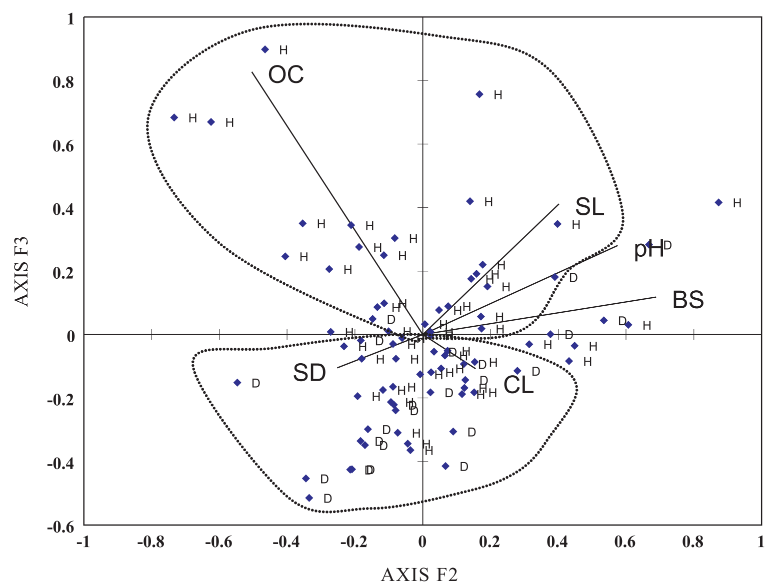

Figure 2. Diagram of the correlation between the variables examined the large groups of soils and the principal components 2 and 3. H: humitropepts; D: dystropepts; OC: organic carbon; CL: clay; SL: silt; SD: sand; pH H_2O; BS: saturation bases.

The mathematical expression of the standardized coefficients is given by the following discriminating function, defined on the basis of the structural matrix: Discriminate function (DF) = 0.886 Organic carbon + 0.572 Silt. Accordingly, 79 % of the original group cases are correctly classified (Table 4d).

These results coincide with those obtained by PCA: OC content is a discriminating variable between soils. Silt is also used, but is less reliable because in the method normally used to determine texture (Bouyoucos method), errors are commonly transferred to this fraction, since it is calculated by difference.

Organic carbon content is an fundamental property given its importance in determining soil structure, water retention, CEC, tilth, biological activity, fertility, etc. (Schmitz et al., 1989; Tavant et al., 1994; Azmal et al., 1996; Alvarez & Lavado, 1998; Hontoria et al., 1999; Wilcke et al., 2003; Blanco-Canqui et al., 2005). Separating soils on the basis of OC content is relevant because of its importance for soil quality (Seybold et al., 1997; Astier et al., 2002). For these reasons it would be appropriate to determine a new large group in the Ustepts suborder that will classify soils with a high OC content.

Table 3. Cluster analysis

	Group			
	I	II	III	IV
	(a) Soil Group composition			
Size (n)	10	31	6	30
Nº of Humitropepts	7 (70 %)	16 (52 %)	6 (100 %)	25 (83 %)
Nº of Dystropepts	3 (30 %)	15 (48 %)	0	5 (17 %)
Variables	**(b) Soil group centroids**			
Sand	0.458	0.600	0.989	-0.970
Silt	0.062	-0.622	-0.678	0.758
Clay	-0.213	-0.443	-0.902	0.709
pH	1.780	0.061	0.042	-0.665
Organic carbon	-0.309	-0.249	2.545	-0.149
Exchangeable bases	1.795	-0.148	-0.149	-0.351

Table 4. Discriminate canonical analysis

(a) Selection of variables

Step	Nº of variables	Lambda	F Statistic	F Sig
1	1 (Organic carbon)	0.868	11.426	1.153E-03
2	2 (Organic carbon and Silt)	0.816	8.332	5.449E-04

(b) Discriminant function

Function	Eigenvalue	% of variance	Canonical correlation	Wilks' Lamda	Sig.
1	0.225	100	0.429	0.816	0.001

(c) Standarized discriminant function coefficients

DF = 0,886 organic carbon + 0,572 silt

(d) Classification results

	Groups	Predicted Group Membership: Dystropepts	Predicted Group Membership: Humitropepts	Total
Count	Dystropepts	9	14	23
		11.69 %	18.18 %	29.87 %
	Humitropepts	2	52	54
		2.60 %	67.53 %	70.13 %
Sum		11	66	77
		14.29 %	85.71 %	100 %

CONCLUSIONS

1. The Dystrustepts examined in the Venezuelan Andes at altitudes between 1,000 and 3,500 m, developed on different kinds of material, slope, vegetation, etc., typically have a highly acidic pedon with an ochric or umbric epipedon and a subsurface cambic horizon. Their textures correlate closely to the parent material on which they have developed: those formed on acid rocks with coarse texture (granite, gneiss, schist, sandstone) or on sediments made up of these materials have more sandy textures than those developed on acid rocks with fine texture (shale, phyllite) or on sediments of acid rock.

2. There are differences between Dystrustepts that developed on sediments and those on upland slopes: those on deposits have darker and deeper A horizons, less acid reactions and higher CEC and OC content than those developed on upland slopes. The basic reason for these differences is the topographical situation: zones of sediments are located at lower altitudes, where gains and transformations are greater than losses, in a balance of pedogeomorphological processes. Consequently, in these zones there is an accumulation of bases, organic matter and fine particles as a result of surface and subsurface flow over the entire slope.

3. By the former classification at the level of large groups Humitropepts compared to Dystropepts have a slightly less acidity and a higher CEC. These properties or characteristics are the result of the greater clay and OC content of Humitropepts.

4. Statistical analyses applied to these soils show that the variables selected clearly separate the soils. The discriminating function established by canonical discriminant analysis (Wilks' Lambda test) indicates that OC and silt are the two most important variables for separating these two large groups (Humitropepts and Dystropepts). The principal component analysis showed that OC and, to a lesser extent, silt, define the Humitropepts group; the data are grouped mainly along the OC vector. This has a highly significant correlation with component 3 (2/3 axes). The Dystropepts group is associated with the clay and sand vectors. These two variables have no significant correlation with axis 2, which is why they cannot explain the behavior of these soils.

5. Organic carbon content is a fundamental property given its importance in determining soil structure, water retention, CEC, tilth, biological activity, fertility, etc. Separating soils on the basis of OC content is relevant because of its importance for soil quality. It would therefore be reasonable to determine a new large group in the Ustepts suborder to define the soils with a high OC content.

6. This large group could be named Humustepts and would be defined as follows: Ustepts which have a base saturation (by NH_4OAc) below 60 % in all subhorizons, between 25 and 75 cm below the soil surface, containing 12 kg or more OC per unit volume of 1 m^2 to a depth of 100 cm, or to lithic, densic, paralithic or petroferric contacts, exclusive of any O horizon.

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