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Classification in hydrologic groups of soil of Uruguay

Clasificación hidrológica de los suelos del Uruguay

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Abstract

Dominant soils of the mapping units of the Reconnaissance Soil Map of Uruguay were tentatively classified in hydrologic groups (GH) following the procedure developed by the U.S. Soil Conservation Service (SCS). Since information on the relationship between precipitation and runoff is not available yet, the classification is mostly based on soil morphology: horizons sequence, their texture and structure, soil matrix color, mottling and presence of Fe-Mn concretions as indications of redoximorphic phenomena. Estimates of soil permeability and drainage on the basis of profile morphology and the knowledge of the hydric regime support the classification in GH. The results show that only very few soils are included in Group A, mainly Arenosols (Psamments) or very gravelly soils. Group B (24 profiles) includes mainly moderately well to well drained Subeutric Brunosols (Udolls). Group C (68 profiles) includes Subeutric and Eutric Brunosols (Udolls) and Argisols (Udolls and Udalfs), mostly moderately well to somewhat poorly drained, with a fine textured subsoil. Group D (63 profiles) includes all Vertisols, Planosols (Albolls and Aqualfs), Gleysols (mostly Aquolls and Udolls) and solonetzic soils (Aqualfs), most Litosols (Lithic Orthents and Udolls) and a few Brunosols (Udolls); drainage range from somewhat excessive to poor. the classification achieved is razonably consistent with available information on infiltration rate and hydraulic conductivity measurements for some soils. The comparison with known soils of USA, classified in GH with a more scientific basis, has not shown any evident contradiction between the classification criteria used both in US and Uruguay to assign each soil to the correct GH.

Keywords: classification, hydrologic groups, runoff, infiltration, hydraulic conductivity

Resumen

Se clasificaron tentativamente los suelos dominantes de la Carta de Reconocimiento del Uruguay en Grupos Hidrológicos (GH) según la metodología del Servicio de Conservación de Suelos (SCS) de EE.UU. Al no existir información sobre relaciones entre precipitación y escurrimiento, la clasificación se apoyó mayormente en la morfología del perfil: secuencia de horizontes, textura y estructura de los mismos y colores de matriz, moteados y presencia de concreciones de Fe y Mn indicativos de fenómenos redoximórficos. La estimación de la permeabilidad y el drenaje de los suelos a partir de la morfología y del conocimiento de su régimen hídrico fueron la base de la clasificación. Los resultados indican que son muy escasos los suelos del Grupo A, limitados a Arenosoles (Psamments) o suelos muy gravillosos. El Grupo B (24 suelos) incluye principalmente Brunosoles Subéutricos (Udolls), casi siempre moderadamente bien a bien drenados. El Grupo C (68 perfiles) incluye mayoritariamente Brunosoles Eutricos y Subéutricos (Udolls) y Agrisoles (Udolls y Udalfs), de drenaje moderadamente bueno hasta algo pobre, con subsuelo de textura fina. El Grupo D (63 perfiles) incluye a todos los Vertisoles, Planosoles (Albools y Aqualfs), Gleysoles (mayormente Aquolls y Udolls) y suelos solonétzicos (Aqualfs), casi todos los Litosoles (Lithic Orthents y Udolls) y algunos Brunosoles (Udolls); el drenaje varía desde moderadamente

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bueno hasta pobre. La clasificación alcanzada se ajusta razonablemente bien a la información disponible sobre velocidad de infiltración y conductividad hidráulica de algunos suelos. La comparación con suelos conocidos de EE.UU. y clasificados hidrológicamente sobre bases más sólidas no ha puesto de manifiesto contradicciones evidentes entre los criterios usados en dicho país y en Uruguay para asignar cada suelo al GH correcto.

Palabras clave: clasificación, grupos hidrológicos, escurrimiento, infiltración, conductividad hidráulica

HYDROLOGICAL CLASSIFICATION OF THE SOILS OF URUGUAY

The classification of soils in HG is used in the determination of soil-cover complexes used in the Soil Conservation Service method of U.S.A. (SCS) for the estimation of the runoff from precipitation (Mockus, 1972). The HGs constitute, therefore, a fundamental input for basic and applied hydrological studies in which parameters like rain and runoff take part. More recently, the HG have also been incorporated as an input in the updated version of the Universal Soil Loss Equation (RUSLE), model used to estimate the expected soil losses by water erosion. In this model, the HG to which each soil belongs is taken into consideration when defining the runoff index used in the computation of the P factor of the equation (supporting practices) and is introduced when assigning the values of K, which is the soil erodibility factor (SWCS, 1993).

Several soil properties have a decisive influence on the process of runoff generation: texture, structure and thickness of the profile horizons, volume of non-capilar pores, change of the soil volume based on moisture content, mineralogy of the clay fraction and water table height. When the main objective is the estimation of runoff caused by individual storms - for example, in flood prevention studies - the properties of the soil can be represented by a hydrological parameter: the minimum infiltration rate obtained for a bare soil after prolonged wetting. Such parameter considers the influence both of the soil surface and the horizons of its complete profile. The influence of the cover of the ground, also decisive in the determination of the draining, must be considered independently.

The mentioned parameter indicates the runoff potential of a soil and it is the qualitative base of the classification of all soils in four HG.

The classification of soils in HG developed by the U.S. SCS is certainly broad, although the groups can be divided into subgroups, if strictly necessary and there are solid bases for subdivision. HG definitions are based on some basic criteria, mainly what is considered as water infiltration and transmission in the soil.

Infiltration speed is the speed with which the water penetrates the soil (in its surface) and it is controlled by the surface conditions. Transmission speed is the speed with which the water moves in the soil and it is controlled by the characteristics of the profile horizons.

Based on these criteria, *a HG of soils is a group of soils that possess the same potential for runoff under similar storm and cover conditions*.

The properties that influence the runoff potential can be generalized by expressing that they determine the minimum infiltration rate for a bare soil after prolonged wetting and when it is not frozen. Such properties are depth up to a temporarily high napa and depth up to (a) very slowly permeable horizon(s).

The classification in HG of the SCS groups soils in four classes denominated A, B, C and D and in three dual classes A/D, B/D and C/D, according to the indicated criteria above. The definitions of the four basic classes according to Mockus (1972) and C. Steven Holzhey (pers. comm.) are the following:

Group A. (Low runoff potential). Soils with a relatively high infiltration rate when completely wet and consisting mainly of deep sands or gravels, well to excessively drained. These soils have a high rate of water transmission.

Group B. Soils with moderate infiltration rate when completely wet. These soils are mainly deep to moderately deep, moderately good to good drainage and moderately fine textures to moderately thick. These soils have a moderate water transmission rate.

Group C. Soils with slow infiltration rate when completely wet. These soils generally have a layer that prevents the downward movement of water or are soils with moderately fine to fine textures. These soils have a slow water transmission rate.

Group D. (High runoff potential). Soils with a very slow infiltration rate when completely wet. They are usually clays with high expansion potential, soils with a permanent high water table, soils with an *argipan* or a layer of clay on or near the surface or surface soils on almost impermeable material.

These soils have a very slow water transmission rate.

Dual HGs, A/D, B/D, and C/D, were assigned to very wet soils that can properly drain. The first letter applies to the drained situation and the second to the situation before drainage (natural soil water regime). Only soils classified as D in their natural condition and when their drainage is feasible and practical to carry out, are included in any of the dual classes.

The HG soil classification of the SCS was based on information on precipitation and runoff in small basins and on data obtained with an infiltrometer. Based on these data, relationships were established between soil properties and the HG in which they were included.

In fact, only a limited number of soils were classified based on actual precipitation-runoff or infiltration data. Most soils were assigned to a given hydrological group based on the judgment of soil survey edaphologists and correlators, who rely on knowledge of relevant soil properties to make their decisions. In this way, the intervening technicians classify a soil in a certain group comparing it with profiles of already classified soils and assuming that the surfaces were uncovered, that maximum expansion had occurred and that the rain exceeded the penetration rate of water into the soil. Thus, most soils were classified based on the premise that soils similar in depth, organic matter content, structure, and degree of expansion to the saturated state will respond essentially similarly during a storm of excessive intensity.

Mockus (1972) points out that the classification of a soil in a given hydrological group can be verified if the soil is the only one in a basin and precipitation-runoff data are available in bare soil for a sufficient period of time. Verifications carried out in this way have not led to changes in the hydrological group to which the soil in question was assigned, which has been interpreted as validation of the procedure described to classify soils according to their hydrological behavior. In Uruguay, no systematic research has been carried out to date to classify the country's soils in HG and only isolated information is available on the parameters of infiltration and water transmission for the soils of some specific areas.

In hydrological projects of works for water regulation and flood control, the HG classification of soils has been applied in several cases, but in a non-organic way and considering only the soils of the area of each specific project. The classification thus obtained is exclusively relative and does not consider a broad framework that includes soils from the whole country, so it is not possible to compare the hydrological behavior of soils from different areas. It is even impossible to verify whether similar soils have been classified in the same HG by different researchers or planners.

In the agronomic field specifically, the development of research in soil conservation also needs to have a systematic classification of the country's soils to properly apply the RUSLE.

This study aims to achieve the preliminary classification in HG of the dominant soils in the 99 units represented in the Reconnaissance Soil Map of Uruguay at a 1:1000000 scale (Department of Soils and Fertilizers, 1979).

This activity can be associated with the one carried out by Puentes (1983) regarding the K factor (soil erodibility) of the Universal Soil Loss Equation (USLE).

MATERIAL AND METHODS

To assign each soil to the appropriate HG, a procedure was followed based, in most cases, on the study of the profile morphology and the interpretation of permeability and natural drainage of the soil profile as long as national precipitation-runoff information is not available in adequate basins. To this end, the information provided in the descriptive report of the Reconnaissance Soil Map of Uruguay was used; additionally, the existing information was used for some profiles on infiltration and/or permeability, which is mostly limited to soils of the plains of the Laguna Merín basin and the hills of the Departments of Canelones and Florida. For this reason, the morphology of the profile and its interpretation constituted the essential bases for the HG classification. Other authors, such as Laya and Amiotti (1980), faced a similar situation when working in regions with a lack of basic information on precipitation:runoff ratios, which often occur when there is not enough supporting hydrological research.

Determinations of infiltration and hydraulic conductivity available in the country, by field or laboratory methods, were carried out at different times and geographical sites and for different purposes by Hoekstra (1969), Ponce de León and Capurro (1980), Kaplán and Ponce de León (1981) and Terzaghi and Sganga (1982).

The classification procedure followed here is similar to that used in the U.S.A., where numerical data exist only for a limited number of soil series that are extrapolated to the numerous series already recognized, based on similarities and differences in profile. The procedure is then used in this study since it has not generated problems in the U.S. so far, although it is clear that obtaining empirical national information is necessary to validate the interpretations.

The list of more than 9,300 series of U.S. soils classified in HG mentioned by Mockus (1972), was consulted. Some of Uruguay's soils can be easily assimilated to well-characterized series in the United States, which allowed adjusting for those profiles, the assignment to the corresponding hydrological group with a greater degree of security. This is particularly true for strongly differentiated soils of medium surface texture, for poorly differentiated soils of fine textures and with clays of a smectitic nature and for soils of low areas, of variable texture although predominantly fine and with a high water table for much of the year and often flooded.

Soils of uniformly thick texture throughout the profile in Uruguay, also do not present major difficulties for their hydrological classification, and comparing them with similar soils of the U.S. systematically verifies a coincidence in the application of the grouping criteria in both countries.

Soils characterized by a strongly differentiated granulometry profile with sandy loam texture or thicker on horizon A and sandy clay loam or heavier on horizon B, could not always be classified with complete certainty. Detailed information on soils of the Piedmont and Coastal Plain regions of the United States was analyzed in these cases, whose morphology is very similar to that of the problem soils of Uruguay (USDA, 1959). With the precise identification of the soil series of interest of these regions, the HG to which they belong was determined according to the list of the National Engineering Handbook (1972), which allowed a more adequate comparison with national soils of similar profile and water regime. In this way, greater security was achieved in the classification of Uruguayan soils under consideration. In any case, there is a certain degree of uncertainty in these soils as to their definitive classification.

The Soil Survey Staff (1951), provides another support element for hydrological classification, by including the names of several representative series of the different classes of natural soil drainage. As the drainage class assigned to each soil in Uruguay is one of the most solid bases available for its classification - as in the SCS procedure - soils from the country and the U.S. located in the same drainage class were compared and the morphology of the latter was reviewed - when the information was available - to verify the identity of criteria with which drainage is defined in every situation. Subsequently, the hydrological group to which each U.S. soil series belonged, was verified, consulting the list of the National Engineering Handbook and with that basis, the HG was assigned to the country's soil that most resembled the American series considered, in terms of morphology and drainage. This instance did not allow classifying a very large number of soils, but as a counterpart, the classification achieved presents greater security than those where this procedure could not be used.

As an additional element of judgment, the guide prepared by the SCS (C.S. Holzhey, pers. comm.) was used, which provides detailed information on U.S. soils representative of the four HG. This information was compared with that available for the country's soils, which allowed adjusting the classification made.

Finally, the soils that present the greatest difficulties for a correct assignment to a hydrological group so far, are those of medium textures and medium degree of differentiation, without visible evidence of excess water for roughly brief periods, but which constitute perhaps the majority of the deep or moderately deep soils of the country.

This is due to their intermediate characteristics in terms of water infiltration and transmission and to the fact that the HG B and C - to one of which they undoubtedly belong - are those defined with less precision by the SCS, as already seen. This makes it difficult in many cases to opt for one or the other when assigning each soil to the correct group.

The methodological reasons presented highlight the preliminary nature of the classification of the country's soils in HG.

RESULTS

Table 1 presents the list of the taxonomic units of the Reconnaissance Soil Map ordered by Hydrological Group - from A to D - and, within each of them, by unit of the Map in alphabetical order to facilitate the location of any of them (columns 1 and 9 respectively).

The information in Table 1 also includes - for each taxonomic unit - the texture of horizon A (column 3), that of horizon B (column 4) and the existence of mottles and concretions of iron and manganese in horizons B and/or E (column 5 and 6). Finally, the estimation of the permeability and drainage class of each soil is indicated in columns 7 and 8, respectively. The properties indicated in columns 3, 4, 5 and 6, together with the knowledge of the soils water regime - including the influence of the water table, if it affects at least the deep horizons of the profile temporarily or permanently - were, on the other hand, the main criteria considered when estimating the permeability and drainage of the profiles, following the standard rules in soil classification.

The information on the morphology of the profiles and the estimation of permeability and drainage of each one were taken from the publications of the Department of Soils and Fertilizers (1979) with slight modifications introduced by the author.

Columns 5 and 6 lack references to a given horizon of the profile, meaning that the mottles or nodules indicated are at horizon B; the presence of these phenomena in horizons E and B or only in E are expressly indicated in the corresponding column. The color of the mottles is identified only by a crack (e.g. 5/8) if its hue is 10 YR, as red, reddish or yellowish if the hue is redder than 10 YR, as Y followed by a crack if the hue is more yellow than 10 YR, as greenish or olive if its hue is G or BG and as brown if the profile information expresses so. Likewise, the presence of mottles with identification of its quantity or frequency but not of their color, is indicated with appropriate symbols.

Table 2 shows the clay content of the upper horizons A and B as a basic parameter of the profile texture, which has been related to soil permeability. The contents of sand and silt were not considered; not because these particle size fractions are not related to permeability, but due to a lack of studies that allow estimating their influence.

As seen in Table 1, only three profiles were classified in HG A: two Arenosols and a sandy-gravelly Inceptisol. They are the only soils with good to excessive drainage, uniformly thick textures and without limiting horizons for the movement of water or saturation by the water table, which are the main characteristics of Group A.

Group B classifies 24 profiles, 21 of which are somewhat excessive, well or moderately well-drained, and only one is somewhat poorly drained. This last soil is a Luvisol developed on sandstones, with a loamy sandy texture on horizon A and clayey sandy on horizon B, which presents red mottles. As in soils with this type of profile and as mentioned before, there are some doubts about the correct interpretation of its natural drainage, being very frequent the presence of more prominent mottles in them than in notoriously wetter soils.

Only 6 of the 24 profiles assigned to Group B present reddish or yellowish mottles (in horizons B or C), all developed on sandstones or granite rocks, in which the weathering of the parent rock usually originates such mottles without evidence of restricted internal drainage generating redoximorphic traits. None of the soils included in this Group have iron and manganese concretions. The textures of horizons A are sandy loam in the vast majority of the profiles and sandy clay loam to sandy clay (rarely clayey) in the lower horizons (B or C).

From the taxonomic point of view, the soils classified in Group B are mostly Subeutric Brunosols, occurring in smaller numbers: Litosols, Inceptisols, Acrisols and Luvisols. Only 3 profiles are Eutric Brunosols, whose texture is on average thinner than the Subeutric, both in horizons A and B.

Group C includes 65 profiles, of which only one is well-drained, 27 are moderately well-drained and 28 are moderately well to somewhat poorly drained. Only 7 soils have somewhat poor drainage and one is poorly drained. Within this Group, 28 profiles have brown, yellowish-brown, or red mottles and 24 have concretions of iron and manganese (some soils have both morphological traits). Only 24 profiles lack mottles or concretions. The texture of horizon A is very variable, from sandy loam to silty clay loam, but that of the subsoil is more homogeneously fine, varying from clayey loam to sandy clay or clayey. Group C undoubtedly presents greater morphological heterogeneity than Groups A and B, which is partly due to the uncertainties associated with its definition.

From the taxonomic point of view, Group C mostly includes Eutric Brunosols (17), Subeutric Brunosols (15) and Argisols (14). Secondary occurrences are Acrisols and Luvisols (7), Dystric Brunosols (3), Fluvisols (3) and Vertisols and Litosols (1 of each Great Group).

Finally, 63 profiles were included in Group D, 5 of which are excessive or somewhat excessively drained, 2 are moderately well-drained, 33 are moderately well to somewhat poorly drained, 18 are somewhat poorly drained and 5 are poorly drained. Within the Group, 23 soils were observed to present brown, reddish, yellowish or olive mottles and 26 have concretions of iron and manganese; some soils have both morphologic characteristics simultaneously. Textures on the surface horizon are as variable or more than in Group C, since even silty clay or clayey soils occur; on the subsurface horizon the texture is uniformly fine (silty clay or clayey, less frequently sandy clay) or simply the consolidated rock appears.

Table 1. Cartographic and taxonomic units, profile characteristics and hydrological group of soils

1 UNIT MAP	2 SOIL (1)	3 TEXTURE (2) HOR. A	4 HOR. B o C	5 MOTTLES (3)	6 CONCRETIONS Fe-Mn	7 PERMEABILITY (4)	8 NATURAL DRAINAGE (5)	9 HG
Ag	ArO	Ar	FAr	r,a	—	R	E	A
BJ	ArO	Ar	Ar	—	—	R	E	A
Ct	IO	ArFg	G/FAcAr	R	si	R	B	A
An	BSHp	F/FAcArg	FAcAr/AcArg	—	—	M	B	B
Ba	BS/DL	FAr	AcArp	—	—	L	MB	B
Ca	LtDU	FArg	Roca	—	—	M	AE	B
CCh	BSHp	FAr/F	FAc/AcArg	—	—	M	B	B
CCh	BST	F	FAc/Acg	R	—	L	MB	B
CF	LtDM	FAr	Roca	—	—	M	AE	B
CllN	BST	FAcAr	AcAr	—	—	MoL	MB	B
Cpt	BET	FAcAr/F	AcAr/Ac	—	—	MoL	MB	B
Ch	AgSOT	FAcAr	AcAr	R	—	M	MB	B
Ch	BST/L	FAr/F	FAcAr/AcAr	Fr	—	M	MB	B
LT	LvOAb/T	FAr	AcAr	—	—	MoL	B/MB	B
PP	BSL(T)	FAr/F	FAc/Ac	Ab	—	MoL	MB	B
Rv	AcOT	ArF/Ar	AcAr	—	—	L	B	B
RZ	BS/ET/Hp	FAcAr	Ac/FaC	—	—	L	MB	B
SA	IU	FAcg	Ac	—	—	M	B	B
SCl	BSHp	FAr/FAcArg	FAcg	—	—	M	MB	B
SdT	LtSM	FrAr	arenisca	—	—	R	AE	B
SG-G	BS(E)Hp	F/FAr	FArg	—	—	M	B	B
SMh	BS/DHp	FAr (g)	ArFg	—	—	M	B	B
SP	BSHp	FAr/F	FAcAr	5/6	—	M	B	B
TC	AcOT	ArF/Ar	AcAr	—	—	L	B	B
TI	LvO(M)T(Ab)	FAr/FAcAr	AcAr	R	—	M	AP	B
TP	BSHp	FAc	—	—	—	M	MB/B	B
Yi	IO	Gv	R	—	—	R	B	B
AB	BST	F	FAc	5/8	—	MoL	MB/AP?	C
Af	BSL	FL	AcL/Ac	—	si	L	MB/AP	C
Af	AgSMAb	FL	AcL/Ac	—	si	L	MB/AP	C
AH	BSHp	FAcL	AcL	—	si	MoL	MB	C
AH	BSL	FAc	Ac	5/8 y R Po	si	MoL	MB/AP?	C
Al	AgDOAb	FAr	FAcAr	5/8,R	si	MoL-L	MB/AP	C
AS	AcUT	FAcAr-FAr	AcAr	r	—	M-L	MB/AP	C
AS	LvOAb	FAr/F	Ac	5/8;R	—	M-L	MB/AP	C
Bl	AgSOAb	F	Ac	—	si	L	MB/AP	C
BO	AgSM/OT(Ab)	F	Ac	5/8;R	si	L	MB/AP	C
Bq	BEHp/T	FAc/Ac	Ac	—	si	MoL	MB	C
By	BET	F/AcAr/FAc	Ac/AcAr	—	—	MoL	MB	C
By	VRT	FAcAr	AcAr	—	si	MoL	MB/AP	C
Cb	FHeM/O	ArF/FAc	FAr/F	—	—	M	P	C
CC	BSL/T	FAcAr	AcAr	r;a	—	L	MB/AP	C
CCa	BET	FAcL	AcL	—	—	MoL	MB	C
CCa	BSL	FAc	Ac	—	—	MoL	MB/AP?	C
CCo	LvOT/Al	FAr	AcAr	E:R;B:6/8,R	si	MoL	AP	C

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Zp	LvMAl	FAr	AcAr	5/6,4/	si	L	AP	C
Ag	PDO	FAr	FAc	5/6,5/8	si	L	AP	D
Al	PDOM	FAr/ArF	FAcAr/AcAr	E y B:4/4,5/6	si	L	AP	D
Ay	VHp	Ac	Ac	Oc	—	L	MB/AP	D
Bc	VRT	Ac	Ac	—	—	L	MB/AP	D
Bc	VRL	FAc	Ac	—	—	L	MB/AP	
BF	GLM	Ac/AcL	Ac	5/8,v	si	ML	AP?	D
Bl	BST/L	FAcAr	Ac	—	si	L	MB/AP	D
BO	PSM/O	F	Ac	5/8 y R	si	L	AP	D
By	VHp	Ac	Ac	—	—	L	MB/AP	D
By	BET	FAcL	AcL/Ac	—	—	L	MB/AP	D
CC	VRL	FAc/Ac	Ac	—	—	L	MB/AP	D
Cpt	VRL	FAcAr/FAc	AcAr/Ac	—	—	L	MB/AP	D
Cr	PEM	FAcL/FL	Ac	E y B:r	si	L	AP	D
Cr	BET	FAcL	Ac	—	—	L	MB/AP	D
Cr	VHp	AcL/Ac	Ac	—	—	L	MB/AP	D
Cu	VHp	AcL/Ac	Ac	—	—	L	MB/AP	D
Cu	LtEM	FAcL/FAc	basalto	—	—	M	AE	D
Cu	BET	FAcL	Ac	—	—	L	MB/AP	D
CH-PT	LtE/SM	F/FAc	basalto	—	—	M	AE	
EC	SdM/O	FL	FAc	—	si	L	AP	D
EC	SnSlM/O	FL	FAc	—	si	ML	AP	D
EC	Sn	FL	FAc	6/8	si	ML	AP	D
I-TA	BET	FAcL	Ac	—	—	L	MB/AP	D
I-TA	VHp	AcL/Ac	Ac	—	—	L	MB/AP	D
IM	VRL	FAc	Ac	—	—	L	MB/AP	D
IMu	GHpM/Hs	FAcL/AcL	AcL/Ac	o,v	si	ML	P	D
IU	FIsO/M	ArF/FL	idem A	—	—	R	MB	D
Ky	PS/EM	FL	Ac/AcL	—	si	L	AP	D
La	PSM	FL	Ac	4/4	si	L	AP	D
LC	VRL	FAc	Ac	—	—	L	MB/AP	D
LCh	PSO/M	FL	Ac/FAcL	7/8-7/2	E y B:si	L	AP	D
Le	VRL/T	Ac	Ac	—	—	L-ML	MB/AP	D
Le	BET/L	FAcL/AcL	Ac	3/3,4/3,v	—	L	MB/AP	D
LMe	GHpM/O(Hs)	Ar/FAc	Ar/FAc	pa	si	R-L	P	D
Ma	BET	FAcL	Ac	—	—	L	MB/AP	D
Ma	VHp	AcL/Ac	Ac	—	—	L	MB/AP	D
Ma	LtEM	FAcL/FAc	R	—	—	M	AE	D
PB	BE/ST	FAcL	Ac/AcL	r	—	L	MB/AP	D
PC	VHp	AcL	Ac	—	si	L	MB/AP	D
PH	VHp	Ac	Ac	—	—	L	MB/AP	D
PP	VRL	FAc/Ac	Ac	—	—	L	MB/AP	D
QCh	LtEM	FAcL/FAc	basalto	—	—	M	AE	D
RB	PDO	FL/F	FAc/Ac	5/6	si	L	AP	D
Ri	BET	FAc/FAcL	Ac	—	—	L	MB/AP	D

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CM	AcOAl	FAr	AcAr	B:r;B:5/8	—	M	AP	C
CM	AgDMAb	FAr	FAc	E:3/4;B:5/8,r	—	MoL	MB/AP	C
CP	BST	FAr/FAcAr	FArAc/AcAr	—	si	MoL	MB	C
CP	AgSMT	F/FAcAr	Ac/AcAr	—	si	L	MB/AP	C
CSA	LtE/SM	FAc	—	—	—	M	B	C
Ct	AgD(S)O/MT	FAr	FAcAr/AcArg	—	—	M	MB	C
Ep	BET	FAc/F	Ac	—	si	L	MB/AP	C
EP-LB	BE/ST	F/FAc	Ac	—	—	MoL	MB	C
EPa	BET	FAc	Ac	r	—	L	MB	C
FB	BET	FAcL/FAc	Ac	—	—	MoL-L	MB	C
FM	BET	AcL	Ac	—	—	L	MB/AP	C
IM	BET	FAc	Ac	—	—	L	MB	C
IM	BEL	F	Ac	—	—	L	MB	C
JPV	BSL	F	FAc/Ac	—	—	MoL-L	MB/AP	C
JPV	AgSMAb	F	Ac	3/2	si	L	MB/AP	C
Ky	BS/ET/L	FL	AcL/Ac	r	—	MoL	MB/AP	C
LC	BET	FAc	Ac	—	—	L	MB	C
Li	BE/ST	FAcL/FL	AcL/Ac	—	—	L	MB	C
LM	BEL/T	FAc	Ac	4/4	si	L	MB	C
Mc	BSL	F	Ac	—	si	L	MB/AP	C
MO	BDL/T	FAcAr	Ac	r	—	L	MB/AP	C
MO	LvMT	FAr	Ac/AcAr	5/8,4/3 y r	—	L	AP	C
PdH	BST	F/FAcAr	Ac/FAc	4/1,6/4	—	L	MB	C
PII	BET	F	FAc/Ac	—	si	L-MoL	MB	C
RU	AgSMAb	F/FL	Ac	—	si	L	MB/AP	C
RZ	BDL/T	FAr/F	FAc/Ac	r,a	si	L	MB/AP?	C
SC	AgSOT	FL	Ac	4/4	si	L	MB/AP	C
SdT	BS/DL(T)	FAr/F	AcAr	R	—	M	MB/AP?	C
SJc	BET/L	FL/FAcL	Ac/AcL	—	—	MoL	MB	C
SJo	AgD/SOAb/T	FAr	AcAr	Ab	si	M?	MB/AP	C
SM	BET(Hp)	FAc	Ac	—	—	MoL	MB	C
SP	BST	F	FAc/Ac	r-a	—	L	MB	C
Ta	AcOAb	ArF	FAcAr	R	—	MoL	AP	C
Ta	LO(M)Ab/T	FAr/ArF	FAcAr	4/4,5/6,R	—	MoL	AP	C
TB	AgDO/MT/Ab	FAr	AcAr	R	—	MoL?	MB/AP	C
TC	LvO(M)T/Al	FAr/ArF	FAcAr	4/4,5/6,R	—	MoL	AP	C
Tl-Rd	BET/L	FAc	AcL/Ac	—	—	MoL	MB	C
Tol	BE/ST(L)	FL/FAcL	Ac/AcL	—	—	MoL	MB	C
TP	BST	F/FAc	FAc	—	—	MoL	MB	C
Tr	BET	FAc/FAcAr	Ac/AcAr	—	—	MoL	MB	C
VA	BE/ST/L	F	Ac	—	—	MoL	MB	C
VF	BET	FAcL/FAc	Ac	—	—	M	MB	C
VS	FHM/O	ArF/FAc	FAr/F	—	—	M	P	C
Yg	BET	FAc/FAcL	Ac	—	—	MoL	MB	C
Yi	BDL	FAr/Fg	Ac g	—	si	L	MB/AP	C
Za	BS(E)T	FAcL	AcL/Ac	4/4	si	MoL	MB	C

1 UNIT MAP	2 SOIL (1)	3 TEXTURE (2) HOR. A	4 HOR. B o C	5 MOTTLES (3)	6 CONCRETIONS Fe-Mn	7 PERMEABILITY (4)	8 NATURAL DRAINAGE (5)	9 HG
Ri	VRT/L	AcL	Ac	—	—	L	MB/AP	D
RR	SdO	FL	FAc	—	si	L	AP	D
RR	SnSIO	FL	FAcL	Y 5/6	si	ML	AP	D
RR	Sn	FL	FAc	6/8	si	ML	AP	D
RT	PDO/U	FAr	FAcAr	Y 6/2,5/1;5/3,v	si	L-MoL	AP	D
RT	GLMT	F	Ac	5/8,r	si	ML	P	D
RU	VHp	AcL/Ac	Ac	5/1	si	MoL?	MB/AP	D
SAg	LtSM	FAr	cctinitas	—	—	R	E	D
SJc	VRL(T)	FAcL	AcL	—	—	L	MB	D
SL	GLMT(Ab)	FL	FAc/FAcL	—	si	L	P	D
SR	PEM	FL/AcL	FAcL	—	si	L	AP	D
St	AgDO/MT/Ab	FAr	AcAr/FAcAr	3/6	—	MoL	MB/AP	D
Tl-Rd	VRL(T)	FAcL	AcL	—	—	L	MB/AP	D
Tr	VRL	FAc/FAcAr	Ac	—	—	L	MB/AP	D
Ve	AgS/DO/MAb	F/FL	Ac/FAc	—	si	L	MB/AP	D
Ve	PDO	F/FL	Ac	5/8	si	L	AP	D
VS	GHpM	FAcL/AcL	AcL/Ac	o,v	si	ML	P	D
VS	VH	Ac	Ac	Oc	—	L	MB/AP	D
Za	AgEMAb	FL	Ac/AcL	—	—	MoL	MB/AP?	D

1. Ar: Arenosol; Ac: Acrisol; Ag: Argisol; B: Brunosol; F: Fluvisol; G: Gleysol; I: Inceptisol; Lt: Litosol; Lv: Luvisol; P: Planosol; Sn: Solonetz; Sd: Solod; Sl: Solodized; V: Vertisol; E: Eutric; S: Subeutric; D: Dystric; H: Histic; Is: Isotextural; He: Heterotextural; Hp: Haplic; Luvic; M: Melanic; O: Ochric; U: Umbric; T: Typic: Ab: Abruptic; Al: Albic.

2. F: Loam; L: Silt(y); Ar: Sandy; Ac: Clay(ey); G or g: Gravelly.

3. R: red; r: reddish; A: yellow; a: yellowish; v: greenish; o: olive; pa: brown; Ab: abundant; Po: little; Fr: frequent; Oc: occasional.

4. R: fast; M: Moderate; MoL: moderately slow; L: slow; ML very slow.

5. E: excessive; AE: somewhat excessive; B: good; MB: moderately good; AP: somewhat poor; P: poor.

Taxonomically, Group D is heterogeneous since it includes very different soils in its morphology and physical and chemical properties, but its hydrological behavior is instead more homogeneous according to the criteria on which the classification in HG is based. Thus, this Group includes 22 Vertisols, 6 Halomorphic Soils, 11 Planosols, 8 Eutric Brunosols, 6 Gleysols, 5 Litosols and 1 Argisol. All Halomorphic Soils, Planosols and Gleysols are included in this Group and only 1 Vertisol and 1 Litosol were excluded from it. The concept of Group D, as defined here, is identical to that employed by the U.S. Soil Conservation Service since the soils included there possess fine or very fine textures throughout the profile and predominantly expansive clays (Vertisols and Eutric Brunosols), or a compact and very slowly permeable argipan, sometimes natric, (Planosols and Halomorphic Soils), or have a high water table at least for a good part of the year (Gleysols) or are superficial and are supported on igneous rocks not fissured to an appreciable degree (Litosols).

DISCUSSION

Although there is no sufficient quantitative information on the infiltration rate and permeability of Uruguayan soils to use as a criterion for their hydrological classification when the values of these parameters exist they have an acceptable relationship with the hydrological classification carried out, despite the high dispersion of the data and that the low number of values does not allow drawing statistical conclusions.

Thus, the data of Ponce de León and Capurro (1980) and Terzaghi and Sganga (1982) for 10 soils in Canelones (mostly Vertisols and Brunosols, under different management), with 25 to 40% clay on the surface horizon and 35 to 50% on the subsurface, present the hydraulic conductivity values in horizon B shown in Table 3. These soils were classified in HG C and D according to the criteria used in this study.

Table 2. Clay content in horizons A and B of soils of different hydrological groups

1 SOIL CHART UNIT	2 SOIL(1)	3 HOR. A	4 CLAY (%) HOR. B	5 HG
Ag	ArO	2,2		A
BJ	ArO	3,4		A
An	BSHp	21,2	36,0	B
Ba	BS/DL	16,4	36,8	B
Ca	LtDU	5,7		B
CCh	BST	34,9	54,1	B
CF	LtDM	15,2		B
CfN	BST	20,6	40,1	B
Cpt	BET	28,7	38,6	B
Ch	BST/L	18,2	28,5	B
Ch	AgSOT	20,5	34,8	B
LT	LvOAb/T	13,8	44,8	B
PP	BSL(T)	18,2	50,3	B
Rv	AcOT	8,6	49,5	B
RZ	BS(E)T(Hp)	28,3	46,5	B
SA	IU	39,5	54,6	B
SCl	BSHp	18,5	21,1	B
SdT	LtSM	17,9		B
SG-G	BS(E)Hp	13,9		B
SP	BSHp	23,2	38,0	B
TI	LvO(M)T(Ab)	18,6	42,6	B
TP	BSHp	28,6	33,6	B
Yi	IO	18,0	21,4	B
AB	BST/L	24,7	31,8	C
Af	BSL	23,4	45,5	C
Af	AgSMAb	21,4	50,0	C
AH	BSL	31,3	55,6	C
AH	BSHp	37,8	44,9	C
Al	AgDOAb	12,1,	29,7	C
AS	AcUT	21,5	36,2	C
AS	LvOAb	18,1	53,1	C
BI	BST/L	24,0	45,6	C
BI	AgSOAb	21,6	46,5	C
BO	AgSM/OT(Ab)	17,5	50,0	C
Bq	BEH/T	37,9	60,1	C
By	VRT	26,0	33,3	C
By	BET	28,1	52,5	C
Cb	FHeM/O	43,9		C
CC	BSL/T	21,0	45,4	C
CCo	LvOT/Al	14,5	47,0	C
CM	AcOAl	14,5	40,8	C
CM	AgDMAb	13,8	34,7	C
CP	BST	18,3	37,1	C
CP	AgSMT	23,7	56,4	C
CSA	LtE/SM	35,4		C
Ct	AgD(S)O/MT	12,5	36,7	C
Ep	BET	26,3	52,0	C
EP-LB	BE/ST	31,9	48,6	C
EPa	BET	34,1	50,5	C
FB	BET	31,0	47,1	C
FM	BET	40,3	68,0	C
IM	BEL	22,8	46,1	C
JPV	AgSMAb	16,3	48,5	C
JPV	BSL	25,0	52,0	C
Ky	BS/ET/L	25,0	47,4	C
LC	BET	34,5	57,2	C
Li	BE/ST	35,9	50,5	C
LM	BEL/T	27,1	43,8	C
Mc	BSL	18,4	51,1	C

1 SOIL CHART UNIT	2 SOIL(1)	3 HOR. A	4 CLAY (%) HOR. B	5 HG
MO	BDL/T	20,2	53,1	C
MO	LvMT	15,0	49,2	C
PdH	BST	23,2	34,5	C
Pll	BET	25,3	41,3	C
RU	AgSMAb	21,6	45,5	C
RZ	BDL/T	20,0	39,3	C
SC	AgSOT	19,5	48,8	C
SdT	BS/DL(T)	16,8	42,6	C
SJo	AgD/SOAb/T	14,0	40,5	C
SM	BET(H)	35,2	47,1	C
Ta	AcOAb	8,0	27,0	C
Ta	LvO(M)Ab/T	10,8	27,4	C
TB	AgDO/MT/Ab	8,4	53,8	C
Tl-Rd	BET/L	33,0	52,2	C
Tol	BE/ST(L)	26,7	50,4	C
TP	BST	26,1	35,6	C
Tr	BET	29,8	45,5	C
VA	BE/ST/L	27,7	48,2	C
VF	BET	34,5	59,0	C
Yg	BET	34,3	50,5	C
Yi	BDL	17,3	48,1	C
Za	BS(E)T	29,5	42,0	C
Za	AgEMAb	4,5	53,0	C
Zp	LvMAl	13,8	42,8	C
Ag	PDO	9,4	35,0	D
Al	PDOM	11,8	35,4	D
Bc	VRT	42,1	56,0	D
BF	GLM	44,5	56,2	D
CC	VRL	39,8	50,6	D
Cpt	VRL	38,7	48,1	D
Cr	PEM	28,6	59,7	D
CH-PT	LtE/SM	28,9		D
EC	SnSIM/O	3,4	37,2	D
I-TA	VHp	56,5	68,9	D
I-TA	BET	40,6	65,2	D
IMu	GHM/Hs	28,0	46,5	D
Ky	PS/EM	24,1	49,3	D
La	PSM	19,7	46,0	D
LC	VRL	29,7	40,0	D
LCh	PSO/M	25,8	48,3	D
Le	BET/L	35,0	59,6	D
Le	VRL/T	54,3	73,3	D
LMe	GHpM/O(Hs)	7,5	20,7	D
PB	BE/ST	37,4	59,5	D
PC	VHp	41,4	52,1	D
Pll	VHp	43,3	48,7	D
QCh	LtEM	44,3		D
RB	PDO	8,7	38,7	D
Ri	VRT/L	42,5	50,3	D
Ri	BET	35,9	51,7	D
RR	Sn	11,5	36,0	D
RR	SnSIO	10,3	38,8	D
RT	GLMT	20,5	40,1	D
RT	PDO/U	10,4	29,2	D
RU	VHp	46,2	59,4	D
SAg	LtSM	15,5		D
SL	GLMT(Ab)	18,2	37,1	D
SR	PEM	33,5	55,3	D
Tl-Rd	VRL(T)	36,3	53,3	D
Tr	VRL	30,1	43,5	D
Ve	PDO	12,2	36,0	D
Ve	AgS/DO/MAb	17,5	48,5	D

Table 3. Hydraulic conductivity of some soils of the Department of Canelones (mm.h-1)

	Hydrological Group	
	C	D
Mean	2.70	0.45
Range	0.0 - 12.9	0.0 - 1.30

Regarding the infiltration rate, only Terzaghi and Sganga provide data for 6 profiles of these HG; the figures vary between 10.0 and 68.8 mm.hour-1 for Group C and between 1.2 and 6.3 mm.hour-1 for Group D. It should be added to the relativity of the figures that the Management, under which the soils were at the time of determination, is not the same in the soils of both groups. Despite this and the noticeable overlap in the ranges of values of hydraulic conductivity between the two groups, it is clear that there are important differences in the width of these ranges, as well as in the average values indicating lower water transmissiveness in Group D. In the case of infiltration rate, the value ranges for both groups are well individualized, with no overlap between them, but the data number of this parameter is even smaller than for hydraulic conductivity.

Hoekstra (1969) worked with Planosols, Solonetz, Solods and Gleysols (some of light texture) from the sedimentary plains around the Laguna Merin. The infiltration values he found for such soils ranged from 1.46 to 9.52 mm.hour-1, while the hydraulic conductivity of horizon B (or C) ranged between 0.01 and 5.79 mm.hour-1. Interestingly, the minimum infiltration value corresponded to a loamy sand soil (the lightest texture among the investigated), which was attributed to the high content of silt and very fine sand. This soil, on the other hand, presented the maximum hydraulic conductivity (5.79); if this soil is left aside, the maximum conductivity value is just 1.57 mm.h-1.

With this exception, Hoekstra's value ranges do not differ largely from those found for Canelones. All the soils with which Hoekstra worked are classified in this study in the HG D, including the one with the highest hydraulic conductivity because it is a floodable Gleysol, located at very low levels and with high water table for much of the year.

Since the permeability and natural drainage of a soil depend largely on the sequence of horizons of the profile and the granulometry of each of them, it was important to verify the existence of any relationship between the mechanical composition of the soils considered (Table 2) and the HG to which they were assigned. The emphasis was placed on horizon B, or on C when the profile did not have horizon B, collectively referred to as 'subsoil' or 'subsurface horizon' for simplicity reasons. This occurred because the presence of a well-developed textural horizon B is very frequent in the country's soils, and its existence must control the water movement in the profile after it has been completely wet; this is the situation considered when classifying the soils in HG.

There is only information for 2 of the 3 soils classified in Group A. They are sandy with less than 5% of clay, the silt content being equally low in one of them and slightly higher in the other. In both cases, they are deep and loose sands, with very fast infiltration and high transmissivity for water, a central concept of this Group.

For Groups B, C and D, represented by a high number of profiles, the basic descriptive statistics of their clay content on the surface and subsurface horizon are included in Table 4. The clay contents in both horizons for each of the three HGs are illustrated in Figs. 1 to 6.

Table 4. Clay content of horizons A and B of soils of different hydrological groups (%)

	Hydrological Group					
	B		C		D	
Horizon	A	B	A	B	A	B
Mean	20.4	39.5	23.8	46.1	28.5	47.8
Standard deviation	8.0	10.0	8.8	8.2	14.3	11.4
Coef. of variation	39.4	25.4	36.8	17.9	50.1	23. 9
Minimum	5.7	21.1	4.5	27.0	3.4	20.7
Maximum	39.5	54.6	43.9	68.0	56.5	73.3

Group B contains information from 17 profiles, in which the average clay content in the subsoil is 39.5%, with a very wide range that varies between 21.1 and 54.6%, but in which the standard deviation reaches 10, which shows a coefficient of variation of approximately 25%.

In Group C (58 profiles) the situation is somewhat different since the average clay content in the subsoil is 46%, also with a very wide range from 27 to 68%. The standard deviation is only 8 so the coefficient of variation is slightly lower than 18%. The figures show that the subsoil of the profiles of this group is heavier than in Group B.

In the case of Group D, the statistical parameters considered are almost identical to those of Group C: average of 48% and equally wide range, with minimum and maximum of 21 and 74% respectively. The standard deviation reaches a slightly higher value (11.4), resulting in a coefficient of variation of almost 25%.

The means comparison test, the results of which are presented in Table 5, verifies that Group B differs significantly (at 5%) in the clay content of the subsoil compared to both Group C and

D, but that between these two there are no significant differences at the same level of confidence.

Table 5. Statistical comparison of the average clay contents of horizon B of soils of different hydrological groups

	Groups B and C	Groups C and D	Groups B and D
t	2,478	0,724	2,637
t critical	2,069	2,004	2,028

Fig. 1 shows that 65% of the subsoils of Group B have between 30 and 50% clay. In Group C, on the other hand (Fig. 2), more than 75% of the subsoils have between 40 and 60% of clay, which verifies their finer texture on average. Meanwhile, the subsoils of Group D (Fig. 3) show a lower concentration of clay contents: only 64% of them have 40 to 60% of clay and almost 30% have between 20 and 40%.

Figure 1. Subsoil clay content of soils of Hydrological Group B

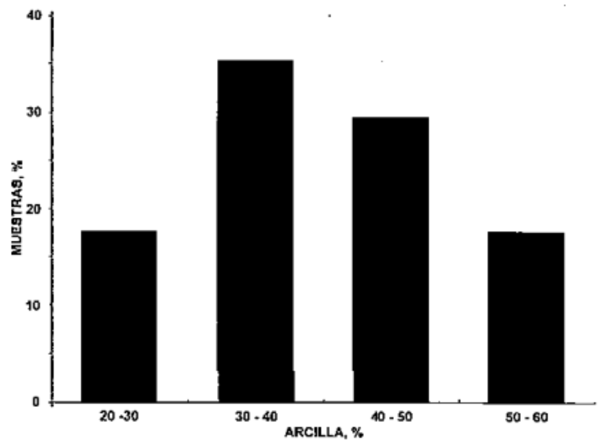


Figure 2. Subsoil clay content of soils of Hydrological Group C

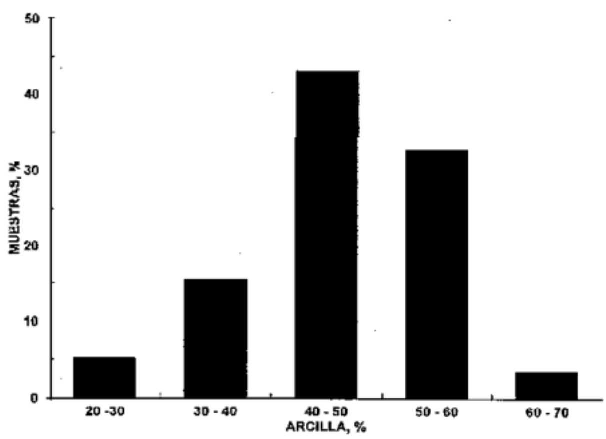
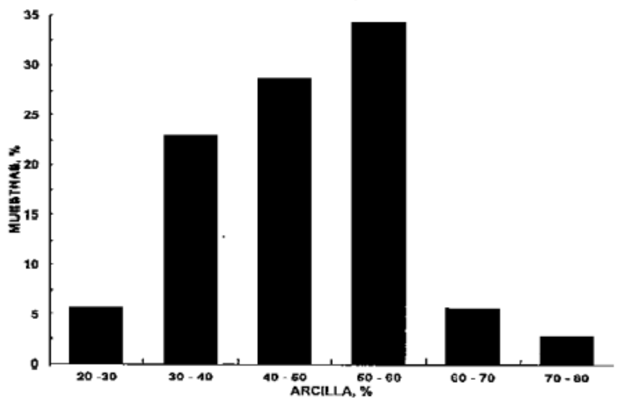


Figure 3. Subsoil clay content of soils of Hydrological Group D



Another way of expressing textural differences - perhaps more clearly - is by observing that in Group B subsoils with more than 40% clay are 47% of the group's total soils. Subsoils of this level of clay, on the other hand, reach 79% in Group C and 72% in Group D.

Soil surface horizon texture was also analyzed at the HG level, although with less emphasis because while the particle size of the surface has a decisive influence on the rate of infiltration, it is also highly affected by the structure of that horizon. As it is also easily modified by the soil tillage, the grain size of the surface horizon alone should not be as directly related to the movement of water as it is to the subsoil.

With the above exceptions, it can be stated that the average clay content is almost identical on the surface horizon of the soils of Groups B and C (20.4 and 23.8%) and slightly higher in those of Group D (28.5%).

Variability is however quite high in all cases, as indicated by the coefficients of variation of 39, 37 and 50 % for Groups B, C and D respectively. These values are much higher than those seen for the subsoil where they ranged between 18 and 25%. It is evident that the subsoil textures are more uniform (and thin) than in the surface horizon of the vast majority of soils, which reaffirms the decisive importance of that in the control over the water transmissivity in the profile.

The means comparison test verifies that Group B differs significantly (at 5%) in the clay content of the surface compared to Group D, but that there are no significant differences at the same level of confidence between Groups B and C or between Groups C and D.

Table 6. Statistical comparison of the average clay contents of horizon A of soils of different hydrological groups

	Groups B and C	Groups C and D	Groups B and D
t	1.617	1.840	2.793
t critical	2.024	2.004	2.002

Despite the texture variability of the surface horizon in the different HGs, there is a predominance of lighter textures in Group B, where 90% of the soils have less than 30% of clay in this horizon (Fig. 4). Only 75% of the soils in Group C do not exceed this clay content (Fig. 5) and in Group D, which includes - among others – the Vertisols, only 53 % of soils have less than 30% clay (Fig. 6).

Water movement in the soil - both the entrance and the passage through the profile - is controlled not only by the granulometry of the horizons but also by their structure and by the nature of the clay minerals, essentially in terms of their expandability.

The structure of the surface layer is subject to variations due to soil management, so it is virtually impossible to consider it at the level of this study. However, it should be considered as an essential element when studying reduced areas, at farm levels or small basins, because in such a case the previous and current soil management may have substantially modified the natural soil structure.

In subsurface horizons, the structure is more stable over time and more independent of soil management. This study does not make significant emphasis on the subsoil structure since no research relates it quantitatively to hydraulic conductivity, although its effect is known in extreme cases such as that of solonetzic soils. On the other hand, the available information indicates that in almost all soils with an argillic horizon - dominant in the country - the structure is relatively uniform with a clear predominance of thick blocks or, less frequently, prisms. This is observed in all HG, although undoubtedly the prismatic structure is more frequent in subsoils of profiles included in Group D (Planosols and Halomorphic Soils).

Although there is insufficient information to support this, it is very likely that the small-block primary structure of the iron oxide-rich B horizons of some Brunosols and Luvisols of the crystalline substrate hill area will favor relatively high hydraulic conductivity for clay contents of such horizons which are not low. This structure is very porous macroscopically and is associated with high friability in the wet state; the potential for expansion of such soils is relatively low due to the dominance of stable basal spacing clays (micas and kaolinites) according to recent research (Durán and Ippoliti not published).

The mineralogy of the clay fraction has not been sufficiently investigated in the country's soils, but there is sufficient knowledge of the main differences between Orders and Great Groups of Soils to draw some important conclusions.

In most soils, according to research carried out by various authors and compiled by Durán (1991), type 2:1 clays predominate, which is characteristic of the climatic zone in which Uruguay is located. However, variations are observed in the proportions in which micas and smectitas occur which are almost the only identified minerals, together with interstratified illite-montmorillonite or illite-vermiculite.

Minerals of 1:1 structure appear in subordinate form in many Melanic and Saturated Leachate Soils (and some Litosols) but are instead dominant in Unsaturated Leachate Soils.

Durán (unpublished data) estimated the cation-exchange capacity of the clay fraction of a large number of representative profiles of the country's main soils by multiple regression, following the methodology described by Víctora and Zamalvide (1972). In this way, an indirect and approximate estimate was obtained of the dominant clay minerals in the studied soils. Considering only the subsurface horizon, this author found that the exchange capacity of the clay fraction reaches high values, greater than 50 me.100 g-1 of clay, in almost all deep or moderately deep soils, indicating more or less clear dominance of 2:1 clays. The values calculated for Results of more recent research on the nature of the clay minerals of Luvisols and Acrisols confirm what was expressed (Durán, Ippoliti and Califra, not published).

Figure 4. Clay content of the soil horizon of Hydrological Group B

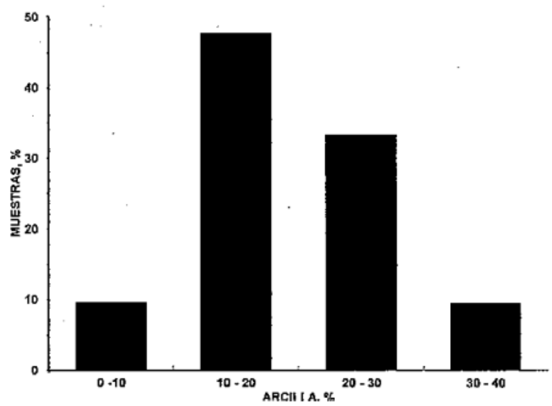


Figure 5. Clay content of Horizon A of soils of Hydrological Group C

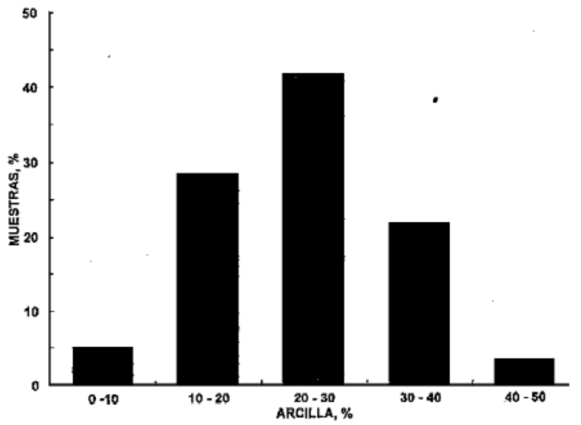
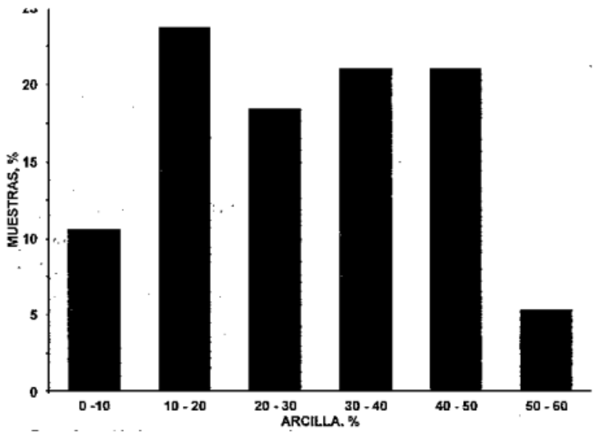


Figure 6. Clay content of horizon A of soils of Hydrological Group D



These authors found that the clay fraction of 4 profiles of these Great Groups presented meta-halloysite, mica and mica-smectite interstratified[1] as dominant clays.

The presence of consolidated rock at a shallow depth, as in the case of litosols, influences water penetration and movement in the soil, in the same way as an impermeable edaphic soil horizon. This can enable high runoff potentials as mentioned by Burgos and Corsi (1978) when pointing out that the main rivers of the country originate in areas with strong water excesses, characterized by the predominance of very superficial soils over igneous rocks.

Obtaining national information on rainfall and runoff at the level of small basins and expanding existing information on infiltration and soil permeability are priority objectives in the effort to improve the hydrological classification of the country's soils. However, the one presented in this study constitutes a very acceptable basis for applying the SCS number curve method in hydrological studies. Evidence of this is the good result achieved by Vallarino, Teixeira and Eguía (1993) in the hydraulic and hydrological modeling of the India Muerta and Sarandí de Los Amarales Streams, who worked with this method.

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[1] These interstrata were identified only in some deep horizons of the investigated soils.

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