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STRUCTURAL STABILITY EVALUATION IN SOME SOILS UNDER MEDITERRANEAN CLIMATE.

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ABSTRACT

Swelling, shrinking and physical breakdown processes are taken into consideration in different soils of mediterranean areas. When soils contain expandible clays, swelling can lead to volume change, thus affecting structure and permeability, whilst shrinkage causes roots rupture and considerable water losses. Nevertheless several structural stability tests proved that among soil constituents, well humified organic matter or calcium carbonates can markedly reduce the above mentioned mechanisms, the former both by linking clay particles and hindering further swelling and dispersion, the latter either by flocculating clays or recrystallizing as micritic cement to improve aggregate stability.

INTRODUCTION

The influence of clay on the physical properties of soils is of interest to both soil scientists and soil engineers. Agriculturalists too know that many of the difficulty encountered in managing soils arise from swelling and shrinkage, whose mechanism clays are mainly responsible. This is particularly of concern in erosion control and tillage operations as the amount and species of clays found in soil directly influence the infiltration rate and water holding capacity as well as structural stability and seedlings emergence. From an agricultural point of view, shrinkage may directly reduce crop yields, either by producing rupture of roots or by reducing the amount of water available to plants by moisture losses from cracks (Guidi et al., 1978). Moreover, surface wash on row slopes may increase with the exploitation of desiccation cracks to form a network of tiny microrill channels (Haig, 1978). On the other hand swelling can change soil volume by both equilibration of depressed porewater pressures following stress relief and physico-chemical (osmotic) response of component clay minerals.

Soil physical properties depend not only on the type and amount of clay present, but on the concentration and species of the electrolytes in the soil solution, since expecially sodium and magnesium may lead to serious structural damages by governing the extent of clay expandibility and dispersion.

The behaviour of soils containing mixtures of clays may be dominated by only a small, surface active, fraction of the total clay, it is therefore of main importance to achieve a good knowledge of the diverse clayey and colloidal constituents and how they interact in the dynamic equilibrium of soil so as to make predictions on the swelling and shrinkage potential.

The aim of the present work was to relate physical, chemical and mineralogical analysis of some soils of the mediterranean area, in order to better understand the possible mechanisms which ultimately regulate their bulk physical properties.

MATERIALS AND METHODS

Selected soils and some of their characteristics are reported in Table 1. Samples were collected from different areas, under mediterranean and mediterranean-continentalized climate, and chosen to represent variation among physical, chemical and mineralogical properties as well as pedogenic development. All samples were dried, crushed to pass a 2 mm sieve and stored for subsequent analyses.

Particle size analysis was performed, prior to organic matter peroxidation and sedimentation and decantation, by a Micromeritics Sedigraph apparatus. Appropriate amounts of the bulk clay fraction of each sample were set aside for the swelling test.

The pH was measured in a 1:2.5 soil:water suspension with a Schott 822 pH meter.

Organic matter determinations were carried out by a conventional method.

Mineralogy of powder and oriented aggregate specimens was analyzed with a Siemens D-500 diffractometer equipped with a graphite monochromator and a Cu-target tube operating at 40 kV and 20 mA. The diffractomer was connected to a PDP 11/37 unit through a Daco interface for data processing.

Total specific surface area was determined by water-vapour adsorption measurements at 19 per cent R.H. (0.19 P/Po) in a calcium bromide saturated atmosphere (Borggaard, 1982).

water coherence test measurements were made according to the method of Emerson, 1967.

The drop test was determined according to Imeson and Jungerius (1976).

Shrinkage experiments were carried out following the methodology reported by Guidi et al. (1978). After shrinkage experiments the crusts were accurately sampled in order to see micro inter-particle interactions during the process to dryness by means of SEM analysis.

The swelling test was as follows: one gram of oven dried (105°C) soil extracted clay, previously peroxidized for organic matter destruction and gently ground into powder was added to a graduate ring equipped with a flat porous base. The ring was then positioned over a suction table for moisture equilibration. The swelling H ($cm^3 g^{-1}$) was given by:

$$H = hS / F$$

where h is the height of swelling, cm; S is the area of the ring, cm^2; F is the weight of the sample, g.

RESULTS AND DISCUSSION

As expected soils showed different trends with respect to the various structural tests employed in the experiments (Table 2).

The Izas sample was collected in a pyrenean catchment (Jaca) at 1750 m asl. Precipitation is about 1900 mm per year, which 60 per cent is in solid form. In this environment oxidation of organic matter is retarded, this aspect turning to be most important for aggregate stability. In fact the "water coherence test", performed on 30 aggregates, allowed to attribute class 7 to this soil, although the 14.3 per cent of vermiculite detected by mineralogical analysis (Table 3) was expected to favor a pronounced slaking of aggregates when dropped into the water. Likewise the "drop test" gave a 85 per cent of total aggregate resistance to water drop impacts when up to 100 drops had fallen on each indivudual aggregate. Poorly crystallized iron oxides (hematite and goethite) were also thought to improve aggregate stability acting like interparticle cementing substances. The swelling test showed an intermediate value corroborating that vermiculite do not usually exhibit volume change to the same extent as smectite.

The Aisa sample, taken at Aisa Valley (Jaca, Central Pyrenees) comes from abandoned fields which are undergoing severe sheet erosion both for the sloping position and periodical utilization of fire for grazing of sherds. Notwithstanding, as may be observed in Table 2 results showed satisfactory structural stability values although the organic matter content was slightly low. It was supposed, in this case, that the flocculating effect of calcium carbonates (up to 40 per cent in this soil) may favor particle aggregation preserving soil from dispersion (Pardini et al. 1991). Baver et al. (1972) inferred that Ca^{2+} ions may act as bridges, sharing the two positive charges one for negative sites arising from dissociation of acidic groups (carboxylic, phenolic) of the organic matter, the other to balance a negative residual charge at the clay edge of the mineral structure.

It was interesting to analyze the behaviour of samples Vallcebre89 and Vallcebre1H which were collected in the same catchment at Vallcebre (Catalan Pyrenees) and had the same parent material and pedogenic development. The former was sampled in a badland area at which soil degradation was very active, the latter in the central part of the catchment, in a very stable grass covered pasture area. As may be observed from Table 2, Vallcebre89 sample slaked very easily and was rapidly dispersed either applying the water coherence test or the drop test although the organic matter content was significant (Table 1) and percent of expandible clay (Table 3) seemed too low to explain such a behaviour. On the other hand, the swelling test showed the second highest value among all the samples. It was supposed that daily climatic fluctuations of the sampling area (in summer the temperature at soil surface ranges from 50°C-daytime to 10°-nighttime) promoted desiccation followed by saturation which led to aggregates stressing and subsequent desintegration. In this case mechanical swelling caused by the entrapped air is important as physico-chemical swelling in producing aggregates disgregation. Conversely the Vallcebre1H sample, which owned 21 per cent of expandible clays and 19.3 per cent of interstratified clays (illite-smectite), (Table 3), presented a very high structural stability. The organic matter, reaching 3.65 per cent, was likely to occur in a strongly humified form, acting like coatings on clay particle thus hindering surface reactivity. This would markedly improve aggregate cohesion and resistance. In fact, the role of organic matter in stabilizing soil structure was enhanced by the swelling test value which resulted the highest among all the samples.

The Tabernes sample, comes from a degraded area in Tabernes (Almeria) characterized by a wide badlands landscape, although actually not very active. The soil presents weak cohesion presumably due to its loamy textural class. Furthermore, the soil contains paragonite (Na-illite) in the clay fraction, which by releasing sodium may promote further dispersion. Effectively, EC value of 11.8 $mmho.cm^{-1}$ suggested that sodium was likely to occur in soil solution thus influencing particles dispersion.

Torres de Segre sample was collected at Lerida. The ambient climate is somewhat Xeric, and soils present incipient salinity. This sample, in fact, showed an EC value of 56.7 $mmho.cm^{-1}$. Scanning Elecron Microscope observations revealed the presence of salt crystals which were identified as gypsum and sodium chloride. The fairly low value of organic matter and EC and pH values led to the consideration that the soil is easily dispersed. Water coherence test and drop test indicated effectively that the soil is higly incoherent and dispersion was likely to occur as the main factor of structural instability.

Similarly the Ebro sample was collected in the Ebro delta area. pH and EC values were high enaugh to promote particle dispersion and this was evidenced by the WCT test and the drop test (Table 2). It was supposed that the 1.8 per cent organic matter resulted from not humified organic debris which may not exert any protecting action on aggregate stability.

The two italian soils (Principina and Vicarello) were sampled in a coastal area close to Grosseto, where due to the pumping of freshwater problems of secondary salinization occur and in a pliocenic endhorreic depression (Volterra), respectively. They differed markedly in cracking and swelling patterns, although the swelling test gave the same value (Table 2). Principina showed a very high EC value which presumably affected the expandible clay fraction provoking the dispersion of the soil. On the other hand, Vicarello sample although showed almost the same content of expandible clay seemd to be more resistant to water action. It was supposed that the difference in textural class between the two soils could have marked the response to the stability tests.

REFERENCES

BAVER L.D., GARDNER W.H., and GARDNER W.R. (1972) Soil Physics p. 141, J. Wiley and Sons, New York.

BORGGAARD O.K. (1982) The influence of iron oxides on the surface area of soils. J. Soil Sci. 33, 443-449.

EMERSON W.W. (1967) A classification of soil aggregates based on their coherence in water. Aust. J. Soil Res. 5, 47-57.

GUIDI G., PAGLIAI M., and PETRUZZELLI G. (1978) Quantitative evaluation of cracks and clods in artificially dried soil samples. Geoderma 19, 105-113.

HAIG M.J. (1978) Microrills and dessication cracks: some observations. Zeit. Geomorph. 22, 457-461.

IMESON A.C. and JUNGERIUS R.D. (1976) Aggregate stability and colluviation in the Louxembourg Ardennes: an experimental and micrimorphological study. Earth Surface Processes 1, 259-271.

PARDINI G., ARINGHIERI R., RUIZ-FLAÑO P., GARCIA RUIZ J.M., and GALLART F. (1991) Runoff, surface crusting, and physical properties in abandoned fields in Aisa Valley, Central Aragonese Pyrenees. Pirineos, in preparation.

Table 1 - Selected characteristics of the soils studied

Soil, location	pH (H_2O)	C.E. (mmhocm^{-1})	C.E.C. (meq100g^{-1})	O.M. (%)	Textural class
IZAS Jaca	4.57	0.3	27.8	15.7	sl
AISA Jaca	7.80	0.8	23.5	1.5	cl
VALLCEBRE89 Barcelona	7.31	1.6	24.7	2.9	cl
VALLCEBRE1H Barcelona	6.89	n.d.	36.4	3.7	cl
TABERNES Almeria	7.84	11.8	22.7	1.4	l
TORRES DE SEGRE Lerida	8.38	56.7	14.3	0.8	sl
EBRO Ebro delta	8.18	14.5	26.8	1.8	cl
PRINCIPINA Grosseto	8.00	18.9	24.2	1.5	l
VICARELLO Volterra	7.79	4.4	28.3	1.6	c

Table 2 - Soil response to structural stability and swelling tests.

Soil	W.C.T. (Class)	Drop Test (R, %)	Swell Test (cm^3g^{-1})	S.S.A. (m^2g^{-1})
IZAS	7	85	1.03	81.1
AISA	4	78	0.42	57.4
VALLCEBRE89	1	12	1.83	103.1
VALLCEBRE1H	7	91	2.45	121.8
TABERNES	2	43	0.11	60.7
TORRES SEGRE	1	6	0.14	32.0
EBRO	2	37	0.51	66.8
PRINCIPINA	2	54	0.64	72.4
VICARELLO	4	67	0.64	80.5

W.C.T.=Water Coherence Test; R=Total aggregate resistance; S.S.A.= Specific surface area.

Table 3 - Total mineralogy (%) of the soil studied

Soil	Q	Ca	D	Fd	Gy	OX	V	I	K	Sm	I-Sm	Ct
IZAS	17	-	-	3	-	15	14	44	4	-	-	3
AISA	17	36	-	3	-	5	-	20	2	-	9	9
VALL	28	46	-	1	-	-	-	12	8	7	-	1
VALL	11	15	-	6	-	5	-	12	8	21	19	5
TAB	20	8	2	4	2	3	-	39	5	-	-	3
LE	11	18	26	5	3	5	-	23	6	1	-	3
EBR	6	20	2	1	-	5	-	46	5	5	5	8
PRI	ND	ND	ND	ND	ND	ND	-	41	20	8	3	21
VIC	ND	ND	ND	ND	ND	ND	-	53	25	9	5	10

Q=Quartz; Ca=Calcite; D=Dolomite; Fd=Feldspars; Gy=Gypsum; Ox=Oxides; V=Vermiculite; I=Illite; K=Kaolinite; Sm=Smectite; I-Sm=Interstratified illite-smectite; Ct= Chlorite.
The soil from Tabernes contained 14% of Paragonite.