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SOIL PROPERTIES RELEVANT TO LAND DEGRADATION IN ABANDONED SLOPING FIELDS IN AISA VALLEY, CENTRAL PYRENEES (SPAIN)

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SUMMARY.- A multi-approach cahracterization of soil properties in abandoned fields in the Aisa valley, at mid mountain in the Central Spanish Pyrenees, demonstrated that the soil's own peculiar characteristics are concerned with conservation problems. Aggregate stability and shrinkage tests pointed to a relatively good soil performance due to the aggregating role of organic matter and calcium carbonates, although calcium ions, in some instances, may exert and additional antagonistic role for a sealed surface, increasing runoff. On the other hand, soil micromorphology suggests that the poor condition of the soils is in some contradiction to paedogenic activity. These findings, together with the presence of ashes, support the hypothesis that land degradation in these areas is mainly related to human activity throught unsuitable management after land abandonment.

RESUMEN.- La caracterización de diversas propiedades del suelo en campos abandonados del valle de Aisa, montaña media del Pirineo Central, ha mostrado que dichos suelos presentan algunos caracteres de interés desde el punto de vista de la conservación. La estabilidad de los agregados y los test de agrietamiento evidencian un comportamiento aceptable, gracias al papel agregante de la materia orgánica y carbonatos de calcio, a pesar que los iones calcio, en algunas ocasiones, pueden ejercer un papel antagonista adicional y favorecer el sellado de la superficie del suelo, aumentando la escorrentía superficial. Por otra parte, la micromorfología sugiere que el estado de degradación de los suelos contrasta con la actividad pedogénica. Estos resultados, juntamente con la presencia de cenizas, apoyan la hipótesis de que el estado de degradación en estas áreas es consecuencia principalmente de una utilización incorrecta después del abandono de los cultivos.

RESUMÉ.- Un étude des proprietés des sols dans une zone à cultures en pente abandonnées dans la vallée d'Aisa (Pyrénées Centrales) nous a montré

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quelques caractéristiques significatives du point de vue de leur conservation. En effet, les éssais de stabilité des agregats et les éssais de rétraction montrent un comportement satisfactoire qui peut être attribué au rôle de la matière organique et au ion calcium, malgré qui celui peut favoriser le scellage de la surface. La micromorphologie des sols suggère que la pauvreté de ces sols est en contradiction avec l'activité pédogénique. Ces resultats et la présence de cendres dans le profil appuyent l'hypothèse que le mauvais état de conservation de ces aires peut être principalement attribuée aux pratiques souffertes après leur abandonnement.

Key words: *Soil properties, land degradation, erosion, mineralogy, aggregate stability, abandoned fields, Central Pyrenees.*

In the central Aragonese Pyrenees (Spain) a progressive abandonment of extensive cultivated areas has been recorded since the Fifties. This feature first affected areas with very difficult topographical conditions, but with time the extent of this phenomenon involved a large part of the whole territory. LASANTA (1988) reported that aerial photography of 1957 showed that almost 16 per cent of the Pyrenean territory has been used as farmland in the past. Only in the Aisa valley (Aragonese Pyrenees) 41.88 per cent of the cultivated surface was represented by sloping fields, where 67.08 per cent of the altitude is between 900 and 1200 m a.s.l.

It is therefore understandable that changes in human activity in these areas will have caused changes in the geomorphological and hydrological functioning of the sloping portions originally controlled by artificial drainage, terraces, and adequate field works.

Recent work (RUIZ-FLAÑO *et al.*, 1991) carried out on sloping abandoned fields in this area and based mainly on field observations and measurements, lead to the hypothesis that the present state of degradation depends mainly on the soil condition at the moment of abandonment of farming (especially soil depth) and on the subsequent management of the plant cover. Indeed, part of this area turned to pastureland and periodical utilization of fire to eliminate brushwood and facilitate grazing became a common practice until it was forbidden. In this way herds could freely graze on the tender resproutings and seedlings, thus preventing natural regeneration of vegetation, whilst the degree of grazing pressure caused soil compaction and difficult paedogenesis.

The aim of this work is, first, to check if soil properties are consistent with this hypothesis or if land degradation is to be related to significant soil susceptibility to degradation, and, secondly, to examine if periodical updating of the physical properties of soils in these abandoned sloping fields may give both indications of the structural damages and the response of the soil towards stressing conditions, suitable to formulating predictions as to the possibility of a forhcoming irreversible land degradation.

1. Materials and methods

The sampling area is located in the Aisa valley at mid-mountain in the Central Spanish Pyrenees. This region is characterized by a Mediterranean mountain climate, somewhat continentalized, with annual rainfalls ranging from 800 to more than 2000 mm in the highest parts. The massive abandonment of the cultivated fields occurred about 30 years ago and at present the zone is characterized by abundant stone pavement, with the reduction of the edaphic layer and the vegetation.

The parent material is formed by grey marls with alternate calcarenite over which lies the soil profile reaching a 30 cm of total depth. Field observation showed that A horizon has very similar characteristics to the C horizon, being compact, without appreciable porosity and well defined organic layer and abundant stoniness (Tab. 1). According to this characteristic the soil has been classified as a Regosol carrying a probable decapitated superficial layer.

TABLE 1
AISA abandoned fields: Field observations.

Sample	*Parent material*	*Slope*	*Depth Horizon*	*Description*
CA1A	Calcarenite	15 %	0-12 A(C)	Grey colour (10YR 6/2); sandy clay loam moderately plastic; few porosity and compacted structure. Absence of vegetative cover few roots and rare biological activity.
CA1C	Calcarenite	15 %	15-25 C	Idem, gravel and stones of different size; very compact structure.
CA3	Calcarenite	20 %	0-12 A(C)	Idem, presence of vegetation and biological activity; porosity best defined.
CA4	Calcarenite	15 %	0-10 A(C)	Idem.
CA5	Calcarenite	15 %	0-10 A(C)	Idem.
CA6	Calcarenite	15 %	0-10 A(C)	Idem.

The slope ranges between 20 and 40 % and favours runoff causing soil denudation with consequent outcropping of the regolith. Accordingly the microtopography presents a continuity of rills and small gullies whose growth is fortunately controlled by the occurrence of sandstone beds on the flysch.

Samples were collected in the proximity of the experimental plots monitorized for studying the differential behaviour of various microenvironments (see RUIZ-FLAÑO *et al.* 1991). Undisturbed and disturbed soil samples were taken in each plot for both micromorphological and mineralogical as well as structural analysis respectively. Further samples from the parent material were also collected.

Thin sections were prepared according to JONGERIUS & HEINTZBERGER (1975). X-Ray powder diffraction was performed analyzing the whole soil fractions and the parent materials previously ground in an agate mill to give a < 50 μm particle size. The clay fraction was separated by centrifugation after dispersion of soil samples with $(NaPO_3)_6$. Clay suspensions were then washed both with HCl 10^{-3} N to elimitate PO_4^{-3} ions and distilled H_2O to eliminate Cl^- and finally resuspended in distilled water. Xrd patterns of oriented specimens were obtained by allowing 25 mg of clay suspension to settle on glass slides. Further treatments with ethylene glycol, and heating at 450º C were used to complete clay minerals identification and semiquantitative estimation.

Structural stability measurements were carried out by using the "Water Coherence Test" (EMERSON, 1967) and the "Drop Test" (LOW, 1954; IMESON & JUNGERIUS, 1976).

The Water Coherence Test is based ont the swelling, slaking and dispersion behaviour of soil aggregates (5-4 mm size) when immersed in water and under mechanical stress. According to this test it is possible to attribute eight different class values to the soil samples. The first six represent soils with structural instability and therefore susceptible to damage, whilst classes 7 and 8 represent soils with the best physical characteristics.

With the Drop Test, stability of aggregates is assessed on the basis of their response to falling water drops. Soils aggregates sized to 4-5 mm were individually subjected to 0.1 g water drops which had fallen 1 m and had a kinetic energy of 9.8 10^3 erg. The number of drops required to break down the aggregates sufficiently for them to pass through a 3 mm mesh was counted, the test being continued when necessary until 100 drops had fallen on the aggregate. The material eroded from the small clods was air dried and analyzed through image analysis equipment for dimensional class distribution.

Soil shrinkage property was evaluated following the method of GUIDI *et al.* (1978). Samples were remoulded at a 1:1 soil to solution (distilled water) ratio until it became fluid, were transferred into square boxes (9 x 9 cm) and finally dried at constant temperature (25º C). Measurements of both clods and cracks were made by using a Kontron M15 Image Processing System.

Specific surface area was determined by water vapour adsorption according to the method of BORGGAARD (1982). An aliquot of the soil samples (1.5 g) was placed in a Petri dish to favour adsorption in a desiccator containing a saturated $CaBr_2$ solution to maintain relative humidity of 19 per cent (0.19 P/Po) for monolayer completion. Total surface area was then calculated by assuming that water molecule occupies an area of 10.8 Å^2.

2. Results and discussion

Physico-chemical characteristics of the soil are summarized as follows: pH 8.2; Carbonates 35 %; Clay 26 %; Silt 36 %; Sand 38 %; Organic Matter 1.5 %; Cation Exchange Capacity 18 meq/100g. The soil environment is almost calcium saturated. On the one hand calcium carbonate may hinder clay dispersion minimizing the problems which could rise through this phenomenon, i.e. infiltration reduction with difficult hydric recharge of the soils profile; on the other hand it contributes to stabilizing aggregates by recrystallization and deposition as micritic cement. 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 etc.) of the organic matter, the other to balance a negative residual charge at the clay edge of the mineral structure, reducing the weakening of the aggregate during clay swelling. However, elsewhere else in this paper it is also assumed that carbonates, when strongly abundant and under particular microtopographical conditions, may favour superficial aggregation of particles as an ulterior factor prone to a sealed surface. Organic matter, despite the relatively low value may contribute to a protective effect on the structural stability. DESPHANDE (1964) reported that swelling of the clay fraction and specific surface area increased considerably in several Australian soils after destruction of organic matter and dissolution of carbonates, and the soils dispersed more easily.

Total specific surface area showed relatively high values for all samples according to the presence of expandable clays as mineralogically detected (Tab. 4). Despite this, it was supposed that neogenic carbonates may form coatings at the clay surface thus reducing reactivity. This hypothesis was also in agreement with the results of cation exchange capacity which appeared to be relatively low with respect to the amount of expandable clay and specific surface area.

2.1. *Mineralogy*

The mineralogy of the parent material (Tab. 2) showed that calcite is the most abundant mineral in the flysch. Optical microscopy observations of thin sections showed that up to 50 per cent of calcite appeared as fossilized foraminifers and presumably more easily weatherable. Quartz and feldspars were also identified in minor quantity with respect to calcite. Within the phyllosilicates, mica and minor chlorite of detrical origin were proved.

TABLE 2
AISA abandoned fields: Mineralogy of the parent material.

Sample	*Q*	*Ca*	*Fd*	*Ox*	*M*	*Ct*
P14	30	58	5	1	5	1
P15	20	65	5	2	5	3
P16	15	70	5	3	5	2
P17	15	68	5	3	5	4
P18	20	60	5	3	5	7
P19	17	65	5	5	5	3

Q = Quartz; Ca = Calcite; Fd = Feldspar; Ox = Oxides; M = Mica; Ct = Chlorite

Soil mineralogy (Tab. 3) showed and expected increase of quartz with respect to calcite in the profile, calcite: quartz ratio varying from 4.5 in the parent material to 1.8 in the soil. Hydrolysis was unlikely to occur to a large extent since quartz and feldspar content in soil equals, but sample CA1A, that of the parent material.

TABLE 3
AISA abandoned fields: Mineralogy of soils.

Sample	*Q*	*Ca*	*Fd*	*Ox*	*I/M*	*Ct*	*K*	*(I-Sm)*
CA1A	17	36	3	5	20	9	2	9
CA1C	19	34	2	5	24	5	2	9
CA3	15	34	4	5	30	4	2	6
CA4	16	32	3	5	32	5	2	5
CA5	19	35	3	5	27	3	1	7
CA6	22	30	4	5	27	3	1	7

Q = Quartz; Ca = Calcite; Fd = Feldspar; Ox = Oxides; I/M = Illite/Mica; Ct = Chlorite; K = Kaolinite; Sm = Smectite.

Mica/illite and chlorite dominated the clay mineralogy of the soil profiles. These clay minerals are directly inherited from the parent material undergoing first a physical crumbling followed by exfoliation. The fairly low amount of kaolinite, even probably inherited, reflects the environment dynamics, where physical weathering seems to prevail.

Regularly interstratified illite-chlorite with d-spacing of 24 Å (10 + 14 Å) were observed in the CA1A and CA1C samples. These mineral phases were stable under treatment with ethylene glycol; on the other hand in all samples the presence of interstratified illite-smectite was emphasized, forming a meseta in the range 10-14 Å. Performance with ethylene glycol achieved a displacement to 14.9 Å in the CA1A and CA1C samples, whilst a slightly pronounced displacement was observed in the other samples. Under treatment at 450ºC residual peaks of 17.8 and 11.3 Å were observed (Fig. 1).

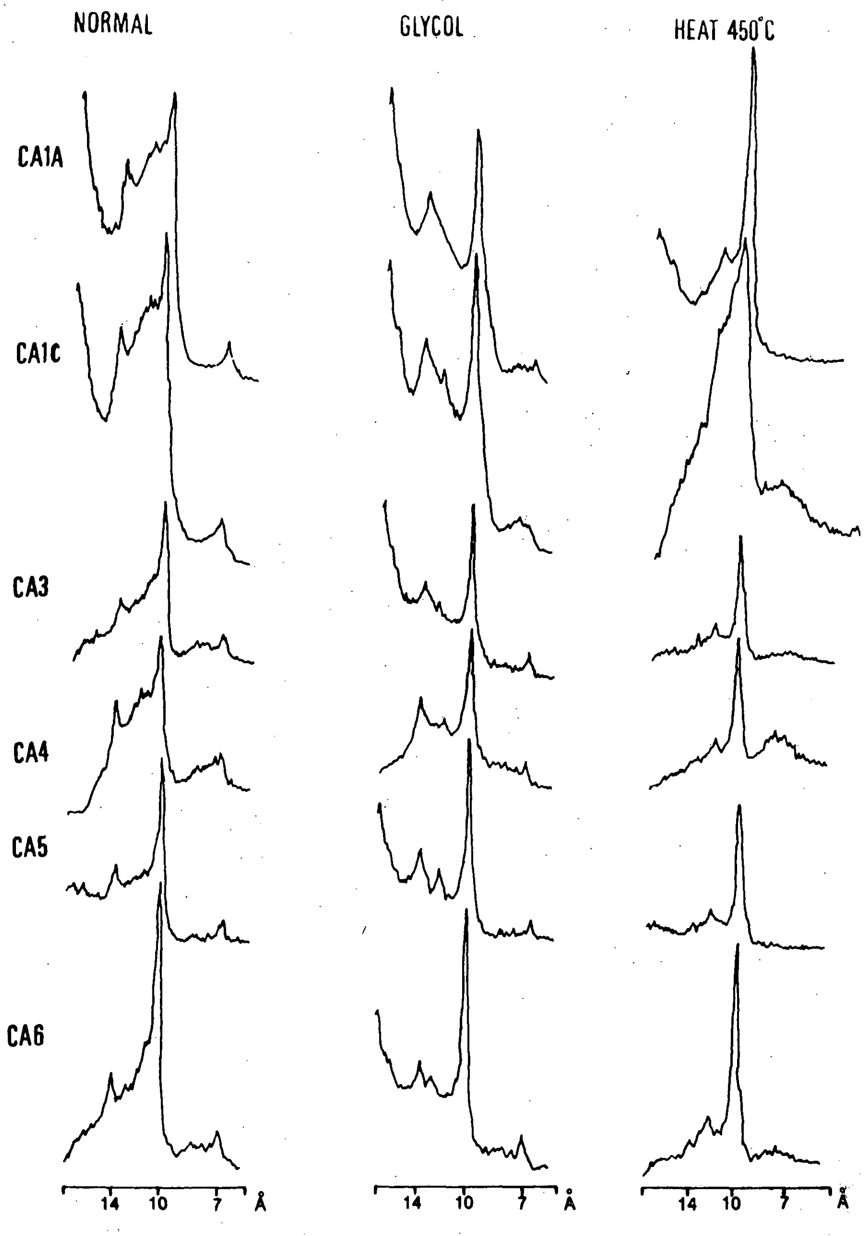


Fig. 1. X-Ray diffraction patterns of the <2 μm clay fraction.

2.2. *Aggregate stability*

The Water Coherence Test was experimented with 30 aggregates average for each soil sample. Notwithstanding the osmotic stress caused by the entrapped air when aggregates where dropped into water, and the swelling of clays during their conditioning to water field capacity, observations allowed us to attribute class 4 to all samples (Tab. 4). Generally samples which fall into this class contain up to 45 % of carbonates and organic matter below 3 per cent. According to EMERSON (1967), soils of class 4 can be improved with drainage systems although care must be taken when the water content is excessively high concerning field work. Although it must be recognized that the coherence class is not a measure of the physical properties of the soil as it exists in the field, it gives an indication of the response of the soil to stress, which is closely related to potential deterioration of physical properties.

TABLE 4

AISA abandoned fields: WCT class value, percent to drop test resistant aggregates and specific surface area.

Sample	*WCT (class)*	*Drop Test (R, %)*	*S.S.A. (m^2g^{-1})*
CA1A	4	76	77.2
CA1C	4	73	70.4
CA3	4	69	81.4
CA4	4	72	76.6
CA5	4	79	79.1
CA6	4	73	79.0

R = total aggregate resistance; S.S.A. specific surface area.

Similarly, 30 aggregate averages were used for the drop test. The water drop impacts produced partial slaking of clods but little dispersion was observed. Resistance of aggregates to falling water drops rose up to 80 % (Tab 4). It is evident that organic matter together with cementing substances bind soil particles counteracting the kinetic energy of the falling water and limiting, at least momentaneously, aggregate damages. Nevertheless the increase of disaggregation can produce surface sealing which is accompanied by an increase of surface flow and accelerated erosion.

Fig. 2 reports dimensional class distribution histograms of soil particles eroded from clods during the drop text experiment. It was observed that eroded aggregates were grouped mainly in 0.5-1 mm class in all samples. This finding was supposed to be a further indication that soil showed peculiar structural properties, being particles removed as small aggregates with minimum clay dispersion.

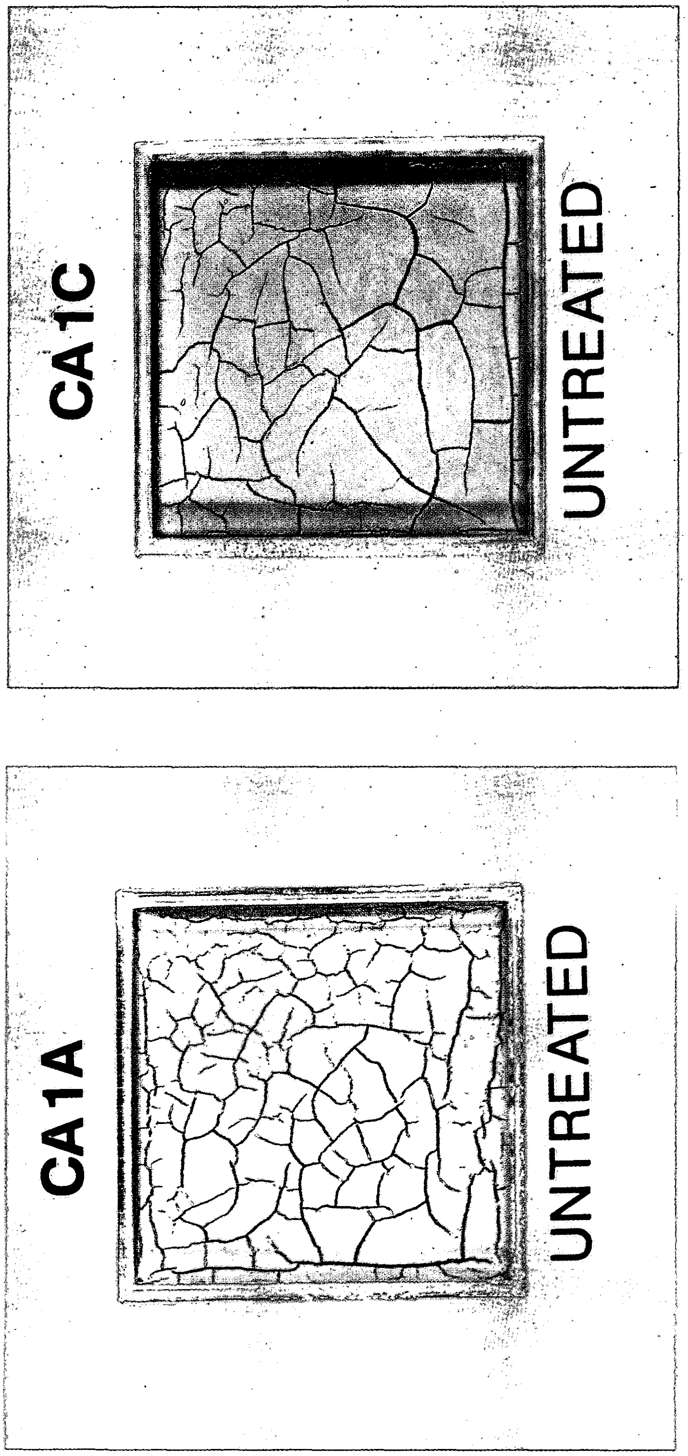


Fig. 2. Shrinkage examples in CA1A and CA1C samples: Difference in cracking pattern.

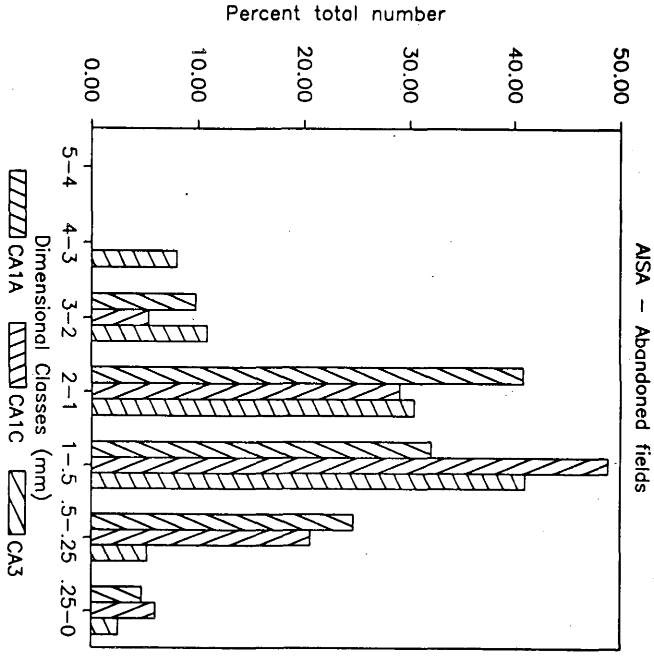
2.3. *Shrinkage*

Surface crusting is generally related to swelling and shrinkage. Shrinkage is particularly responsible for many of the difficulties in managing soils rich in expansible clays, particularly in erosion control and tillage operations.

We determined soil shrinkage only in the CA1 profile. Fig. 3 shows the differences between A and C horizons after remoulding and spatial aggregate reorganization. The different cracking pattern in the two horizons reflect the content of organic matter and calcium salts, which, in this case, could exert an antagonistic role with respect to soil shrinkage. It is well known that calcium salts provide a flocculating effect on clay colloids which, in a state of precipitation, are less contracted than in a dispersed state. Thus, during the time necessary to reach dryness of remoulded aggregates, colloidal fractions remained in suspension and deposited after water evaporation. At this stage the coagulant action of calcium salts would have hindered formation of clods with definite boundaries, well defined by cracks. Such a situation can occur even in the field, in areas characterized by smooth slope or plane, where still water would favour sealed surface and runoff generate sheet and rill erosion phenomena. IMESON and VERSTRATEN (1988) reported that gullies, in slightly sloping morphology, can behave initially as natural drainage, stabilizing contemporarily the adjacent material until maximum instabilty can be reached for supersaturation and create interposed gullies. In the C horizon the clods appeared relatively larger, with respect to A horizon, with consequent decrease of total area of cracks. It was supposed that the flocculating effect of calcium was likely to occur to a minor extent and consequently contraction of clays appeared mostly evident.

2.4. *Micromorphology*

The study of the soil through micromorphology may directly make clear some of the paedogenetic features which are related to mineral and organic compounds in forming the soil structure. Thin sections of the Aisa samples observed by optical microscopy showed a fine-very fine polyhedric sub-angular structure with few fissural and packing pores. The soil is compact in its general aspect and pseudo-horizontal porosity dominate the subsurface horizons, corroborating transmigration of fine particles towards the botton of the prolife (Fig. 4A). This resulted in thin pores, parallely oriented to surface and practically inefficient in water infiltration. Moreover, as can be noticed in the micrograph, different lithic materials with time, fill the pores, forming various compacted layers further limiting aeration and infiltration. Surface crusts were also observed with dense accumulation of clayey and silty particles (Fig. 4B). Rounded and sub-rounded lithic fragments of calcarenite ranged from 20 to 50 per cent of the crystallitic b-fabric basal mass. Where vegetation was more abundant, decaying roots were observed in the thin sections (Fig. 5A), and a marked biological activity was detected through the presence of faecal pellets and Horibatids (fig. 5B). It was assumed that the



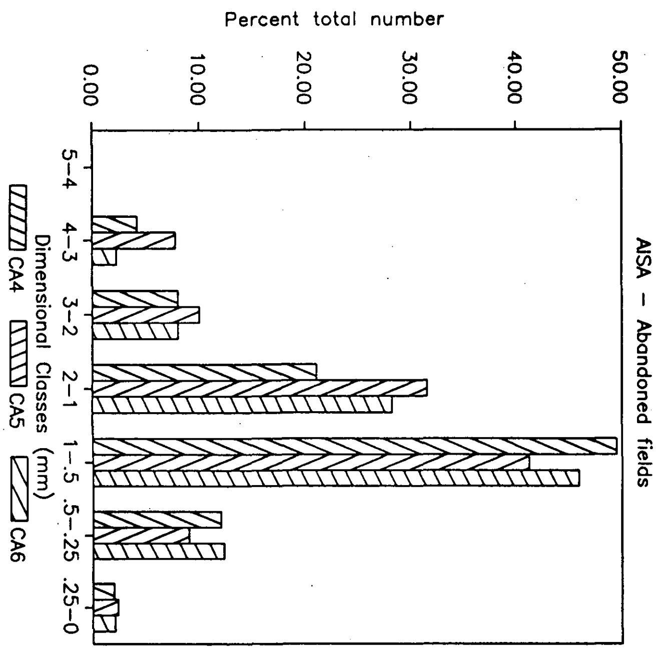


Fig. 3. Classes of eroded aggregates by drop test experiments as determined by image analysis.

A

B

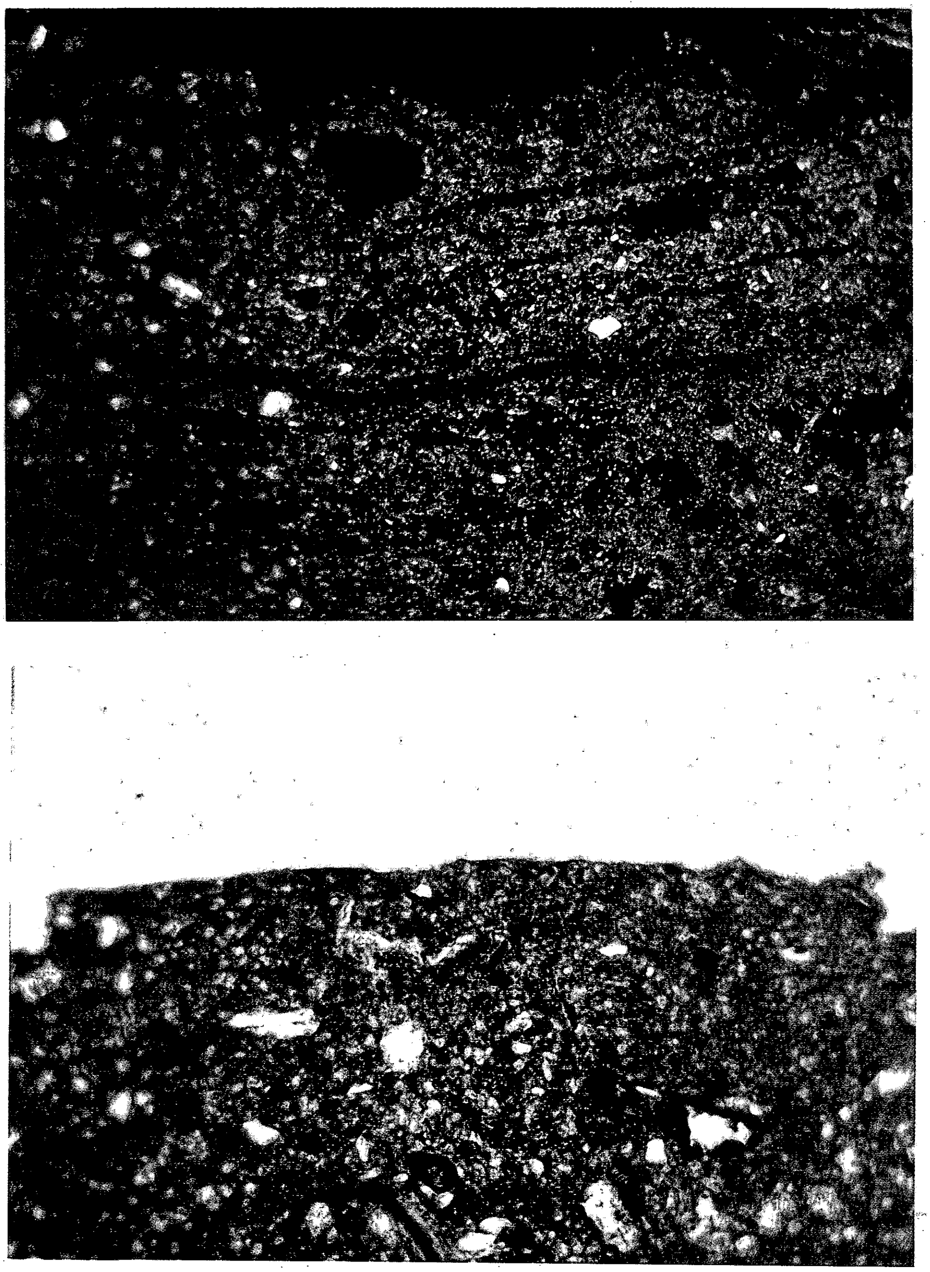


Fig. 4. A: lamination of fine particles in subsurface layers limiting soil aeration and water infiltration. B: Very compacted surface crust.

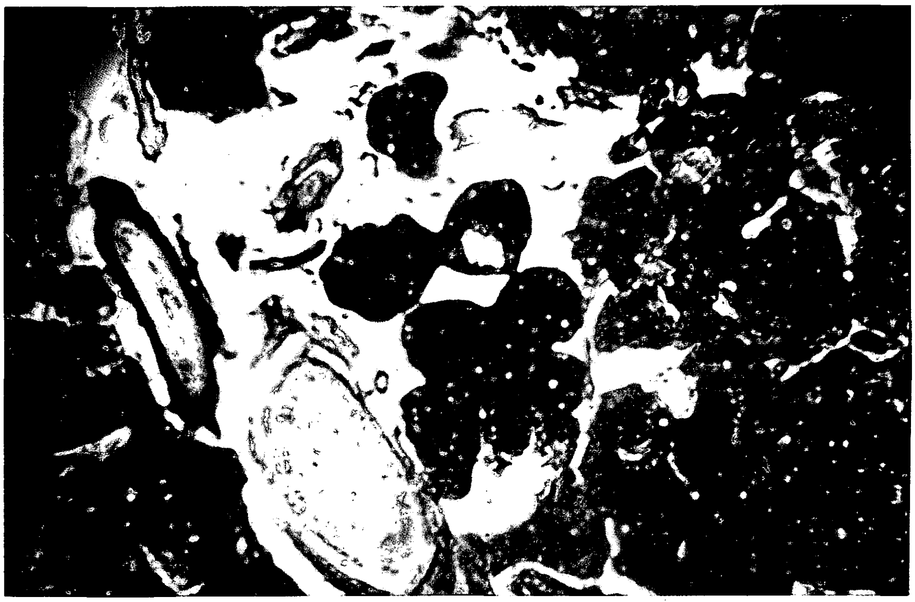


Fig. 5. A: Different stages of decaying roots; the right voild represents the space previously occupied by a root and converted in.a pore. B: Another example of structure amelioration by biological activity; rounded aggregates are earthworms excrements.

roots decomposed, as a result of the biological activity, constituted the real porosity of the soil. Residues of charcoal and ashes were also observed, thus evidencing the periodical occurrence of fire to facilitate grazing.

3. Conclusion

The analytical setup to determine the structural properties in abandoned field of Aisa valley (Central Pyrenees) led to the assumption that soil itself has a satisfactory stability.

This result is consistent with the hypothesis that good vegetation and soil recovery can be the general tendency under spontaneous conditions, and land degradation trends are to be related to human activity after land abandonment.

In fact, there is evidence, especially through thin sections observations, that the soil is continuously weakened and removed although its structural characteristic remain satisfactory, the edaphic layer being suitable for the installation of a stable vegetative cover. The question is, until when would the soil afford such stressing conditions before reaching the critical threshold at which the erosion dynamic is no longer controlled and the landscapes ecologically lost.

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