SCIENTIFIC EXCURSION N.1

SOIL DEGRADATION AND REHABILITATION IN MULA AND FORTUNA NEOGENE-QUATERNARY BASINS. MURCIA

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I. ITINERARY

9.00 h. Departure from Cartagena
9.45 h. Visit 1 – Organic Waste Treatment Plant.
11.00 h.Visit 2 – Mula basin, “Los Tollos”, Mula basin Geology, Geomorphology and Erosion.
12.00 h. Visit 3 – Mula basin, “Casa de los Virijos”. Soil degradation and “piping” in abandoned fields.
14.00 h. Lunch - Fortuna Camping
16.00 h. Visit 4 – Fortuna basin. Degraded landscapes and experiences carried out in soil bioremediation.
17.30 h. Visit 5 – Santomera . CEBAS-CSIC Experimental fields.
19.30 h. Arrival to Cartagena.

II VISITS DESCRIPTION

VISIT 1 : ORGANIC WASTE TREATMENT PLANT

In this excursion, we have programmed a visit to the sludge composting plant, belonging to CESPA Urban Engineering. Every day 200 tn organic fraction coming from urban waste and about 100 tn sludge coming from urban waters treatment plants are treated. The mixture of both materials produce a compound with suitable porosity to be composted. The compost system consists of great capacity, constant ventilation and mass movement by means of mechanical screw reactor-tunnels. This fully automatic and computered system, guarantees a good process (humidity and ventilation are automatically controlled), and convenient quality of the product 20 days after the beginning.

VISIT 2: “LOS TOLLOS”. MULA BASIN GEOLOGY, GEOMORPHOLOGY AND EROSION.

2.1 Mula and Fortuna Geological Setting.

Mula and Fortuna basins are geologically inside the vast morphostructural joint formed by the Cordilleras Beticas, which with a general alignment WSW-ENE go along the peninsular south and south-east. The Cordilleras Béticas are an alpine relief, presenting as outstanding morphostructural characteristics: structure in stratum, the sheer difference among internal and external zones, the different metamorphism degree affecting each unit, the thick fractures net that affect them, and complex modelling processes differenciated in time and space.

The Cordilleras Béticas were divided by Fallot (1948) into three big units: Prebética, Subbética and Bética in strict sense (Fig.1). The Two first ones constitute the external zone and the Bética unit (previously named Penibética), forms the internal zone. Together with these big units, the Béticas are also compound by other structural elements: the unit Campo de Gibraltar, Guadalquivir depression, and inside depressions.

The external zone characteristic is that only postpaleozoic cover materials were affected by alpine orogeny, yielding as a result, folded structures of great complexity. On the other hand, the internal zone characteristic is that besides the sedimentary cover materials, the paleozoic shelf was also affected by alpine structures, suffering postpaleozoic metamorphism processes.

The three big units of Cordilleras Béticas are represented in Murcia Region. The Prebético, or most external unit is situated at the north, the Bético in s.s., takes the complete meridional area in touch with the Mediterranean sea, and the Subbético is situated between the two former units, that is, in the centre of the Region. Among the three units there are also a depressions joint, accidented by fracture lines since they individualized in the Superior Tertiary, which have behaved as sedimentary basins and are filled up with marls, clays, gypsum, sandstones and conglomerates. Two of the most representative examples of neogene-quaternary basins, because of their geomorphological interest are Fortuna and Mula basins. The low mechanical resistence that these materials offer, have favoured erosion processes yielding vast gullied or "badlands" landscapes (López Bermúdez and Romero Díaz, 1989).

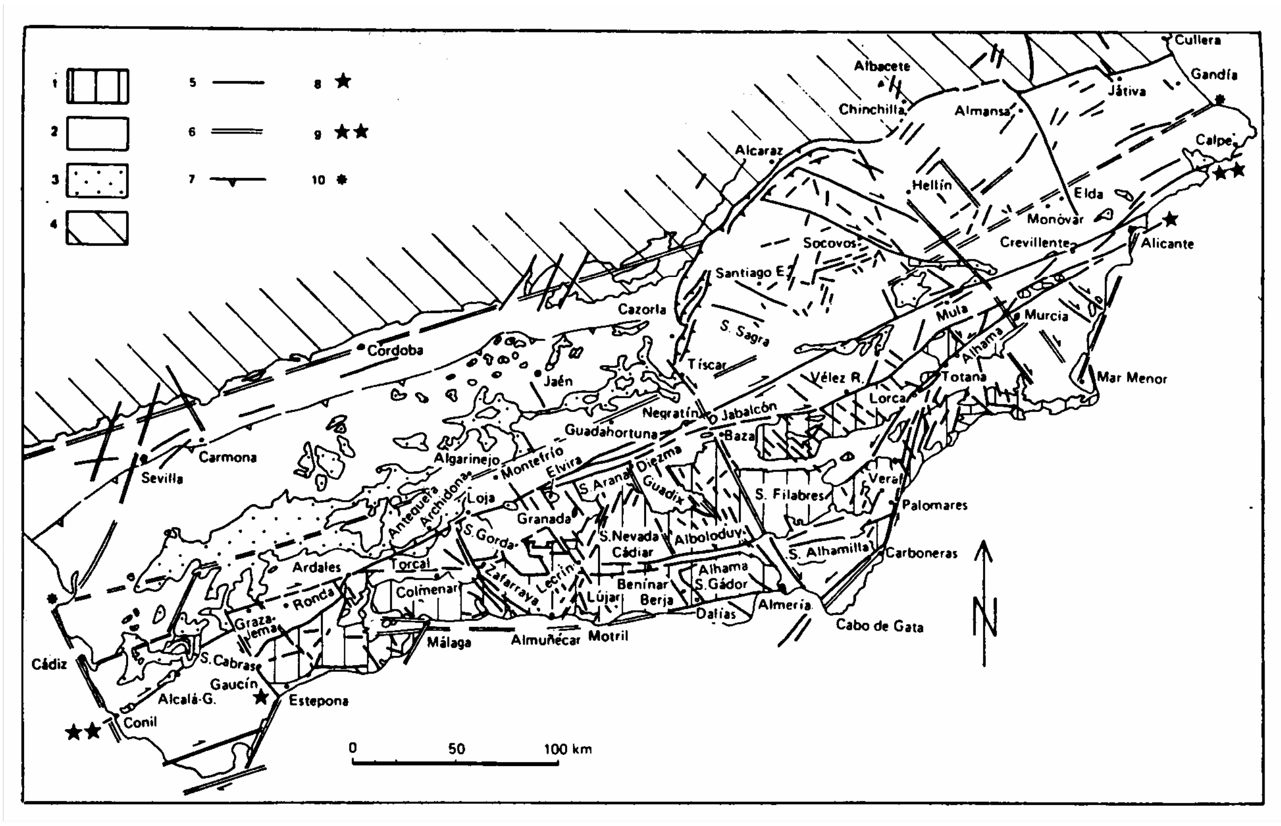

Figure 1: Tectonic scheme and of the main geological Cordilleras Béticas units (Sanz de Galdeano, 1983). 1: Internal zones; 2: External zones and depressions materials; 3: German-andalusian trias; 4: Plateau and Iberian mountains materials; 5: Faults; 6: Possible faults; 7:Boundary of gravitatory sediments of Guadalquivir depression; 8: Extreme of the contact

line between internal and external zones; 9: Extreme of Cádiz-Alicante accident; 10: Possible accident at the north of the one in Cádiz-Alicante.

2.2 Mula basin general characteristics. Actual modelling formation.

Mula basin is situated in the centre of Murcia Region, it has an area of 647 Km^2 and a medium altitude around 500 m.

The basin is limited in the north by two important tear faults, Nord-betica fault and the one in Lorca-Alhama, (Fig.2). Its oriental limit is constituted by another tear fault which controls Segura river flow, while its occidental limit is constituted by different mountainous elevations.

The tectonic presence in Mula basin has been the responsible, not only for its configuration as basin, but also for its morphological characteristics at present. The neotectonic effects in Mula basin are remarkable through several aspects: thermal waters spring, igneous rocks outcroping (fortunites dike), presence of fractures in recent deposits, tabular relieves unlevelling, and existence of numerous seismic epicentres. This area had a seismic danger of 7 in a scale of 9, worth mentioning earthquake in 1999 with epicentre in Mula, which had a maximum intensity IV in european macroseismic scale.

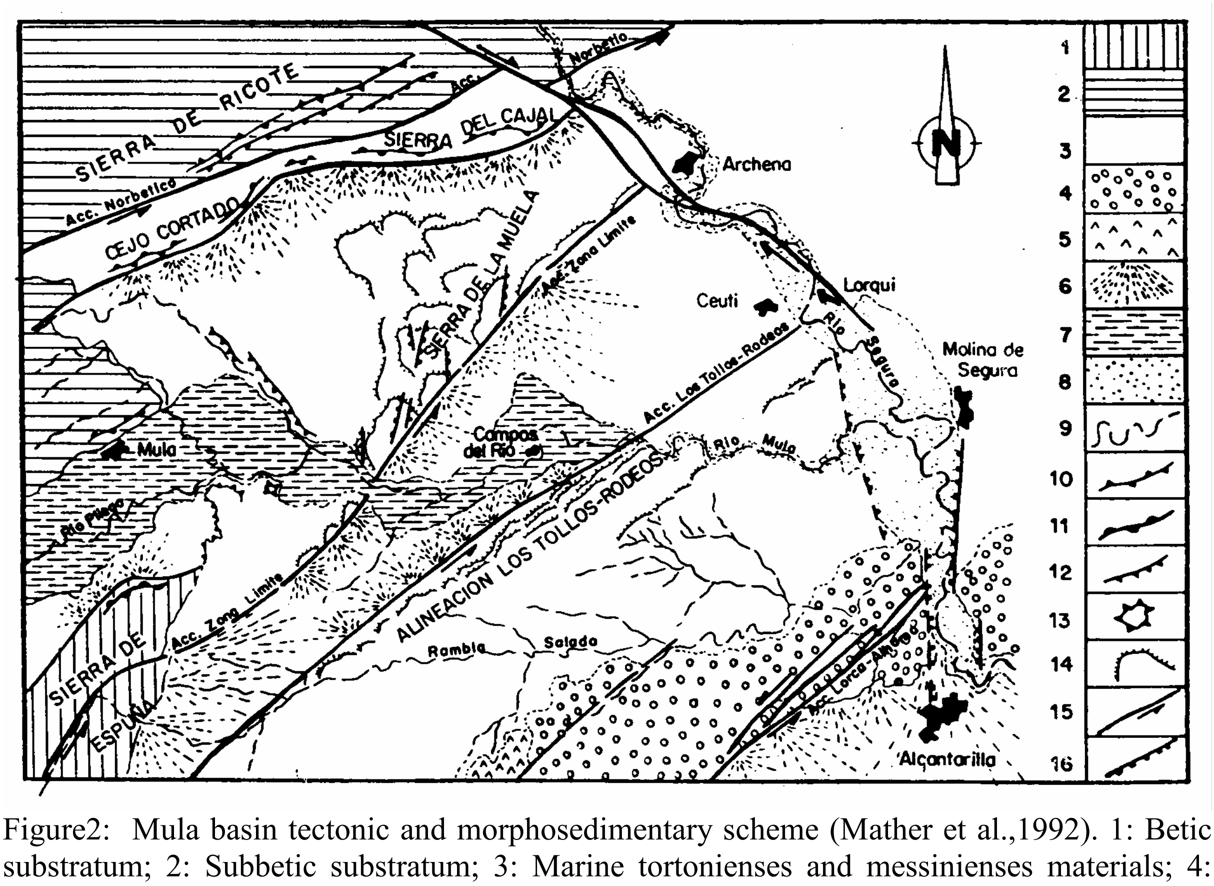

Figure2: Mula basin tectonic and morphosedimentary scheme (Mather et al.,1992). 1: Betic substratum; 2: Subbetic substratum; 3: Marine tortonienses and messinienses materials; 4: fluvial-marine Plio-Messinienses materials; 5: Barqueros neogen vulcanism; 6: Alluvial and glacis fans from medium Low Pleistocen; 7: Fluvial-marshy deposits from Superior Pleistocen; 8: Fluvial deposits from Superior Holocen-Pleistocen; 9: Rivers; 10: Crests; 11:

Marginal relieves; 12: escarpments; 13: Structural Hill; 14: Relieves in slope; 15: Fault in direction; 16: Normal fault.

Neogene sedimentary filling is mainly constituted by a marl-sand series with calcareous and conglomeratic intercalations of marine character, possibly attributed to Tortoniens and Messiniens. Quaternary sedimentation is involved with Mula river installation and fitting and also to the development of fluvial and glacis fan systems, constituted from the new relieves generated during the Neogene basin emersion and immersion during the Plio-Quaternary, the Cejo Cortado Front – Sierra del Cajal, Sierra de la Muela and the mountain range Los Tollos-Rodeos (Romero Díaz et al.,1992).

Hydrologically, the basin is drained by Mula river and its main tributary, river Pliego, both flowing to Segura. Pliego and Mula torrent-rivers have a torrential regime, with strong low waters and spectacular flooding. As example we can mention the 400m^3/s registered by Mula river on 7th november 1987 at theflow station in Alguazas, near its outlet into Segura, or the last floods on 16th october 2003 in Albudeite and Campos del Rio, because of river Mula overflooding, as a result of 131 l./m^2 fallen in three hours.

The present climatic conditions in Mula basin may be defined as arid or semiarid, depending on the different classifications. Their most remarkable features are: low and irregular rainfall (300 mm annual media), high temperatures (17-18ºC annual average, but more 30ºC for more than 100 days per year), strong evapotranspiration (900 mm annual) and therefore high water shortage (600 mm annual average). The characteristic mediterranean climate rainfall regime shows two equinoctial maxima, being April and October the most rainy months, showing torrential features. The rainfall concentrates in a short period of time, which affects directly because of its high erosive power.

From a topographic point of view, Mula basin constitutes a depressed area sorrounded by important elevations except in the oriental side. Sierra de Ricote is situated at the north (1124 m.), Sierra Espuña (1579 m.) and Cambrón (1525 m.) are situated at the south, Labia (1234 m.) and Burete (1184 m.) at the west; the oriental area, on the the other hand, opens to Segura valley, where the main course that runs along the territory flows.

The structural lie of the land and lithology allow to differenciate several geoforms joints, in terms of the topographic and geomorphological characteristics:

1. Mountainous border relieves, situated over 650 m. altitude and with strong slopes, between 25º and 35º. The highlights are Sierra de Ricote at the north; Espuña at the southeast; and Cambrón, Labia and Burete at the west..
2. Structural relieves, with tabular and monoclinal morphology, over 300 m. over the sea level, and slopes have been ploughed in the series of sandstones and limes that leave on marls ledge, to which they culminate and on which ruled slopes develop.
3. Mountainfoot shapes, alluvial and glacis fans, modelled between 150 and 500m. and slopes between 5º and 15º. Nowadays these slopes are very dissected by erosion. It is possible to observe several glacis levels, being the upper one crusted.
4. Water erosion shapes of basin bottom and nearby areas, in smooth topographic surfaces, between 1º and 10º, but with steep individual slopes. Gullies are the most representative morphological and landscape expression .
5. Fluvial terraces, originated as a result of the progressive Mula river setting in the neogen materials. Six fluvial terrace levels have been identified, situated at + 65m.,

+40m., +32-40, +15m. and +2m. over the present river Mula bed. We must mention that upper levels correspond to fluvial-marshy deposits, filling Mula river paleovalley (Romero Díaz et al., 1992a).

Mula basin is a quaternary-neogen basin, presenting an advanced excavation and evacuation state of its sedimentary deposits. Present hierarchized and canalized drainage by Mula river onto Segura has emptied and goes on emptying the marls-clay materials of the depression that fills it. The crumbly materials, the arid climatic characteristics the Region suffers, together with the scarce vegetal cover and often, the poor agricultural work, have led to a subdesertic landscape, very gullied, full of deep gullies where erosion level is very high (Romero Díaz & López Bermúdez, 1985). Mula basin is one of the areas in Murcia and Spain with the highest levels of erosion. The sediments provided by Mula river, before receiving Pliego river, to the small reservoir La Cierva (7 Mm^3 in 1929 and 5,20 Mm^3 in 1985), are 51 t/ha/year, with the correlative loss of storing and runoff regulation capacity (Romero Díaz et al., 1992b).

2.3 Experimental studies about soil erosion processes in Mula basin.

In Mula basin soil erosion studies are being carried out since 1982, when the Department of Physical Geography belonging to Murcia University installed ther first experimental plots. Many research projects have been carried out in this area at regional level (Autonomic Community of Murcia Region), at national level (Interministerial Commission of Science and Technology, CICYT) and international level (EPOCH and MEDALUS programmes of European Community). The results have been useful to validate erosion model (SHETRAN and MEDALUS) and since 1995 two experimental fields located in this area, are included in the RESEL (Monitoring and Assessment Erosion and Desertification Network).

The first experiments were carried out in the "Rambla de Gracia" basin, an area formed by marls and sandstones and located in the centre-north of Mula basin. In this area the following parameters were measured: altitude, slopes, topographical boundaries, runoff harnessing area, soil moisture, infiltration rate, vegetal cover, soil holding capacity by vegetal plants, etc., as well as the significance of erosive processes and sediment production for the whole (López Bermúdez et al., 1984, 1986; Fisher et al., 1987; Francis et al., 1986; Romero Díaz et al., 1988).

In 1988, another area, including the average environmental conditions of southwest Spain, was selected, designing in this way the experimental field "El Ardal". This field, in which a 2ha. Microbasin is included, is located at the north of Mula basin with an altitude of 550 m., on a slope covered by mediterranean shrubs and limestone parent material. Here climatic parameters are monitored by means of an automatic meteorological station and ten raingauge network; hydrological parameters by means of a flume; soil loss and runoff in 17 experimental plots with different aspects, slopes and soil uses; biomass, vegetal cover protection index and litter from vegetal cover; likewise the dynamic soil moisture is measured and chemical analysis for soil fertility are carried out. (Alias et al., 1977). The main abjective in this experimental field is the study of atmosphere-soil-water-plant interaction in mediterranean environment and its relationships with soil erosion processes under different vegetal cover and soil use. Some of the results were published in López Bermúdez et al., 1991, 1996, 1998a, 1998b; Martínez Fernández et al., 1991, 1995, 1996; Romero Díaz et al., 1995, 1998,1999; Romero Díaz & Belmonte Serrato, 2002; Alias et al., 1997; Belmonte Serrato & Romero Díaz, 1999; Belmonte Serrato et al., 1999 & 2002 .

In 1991, Murcia University Department of Physical Geography installed a new experimental field in a place named “Los Guillermos”, in Rambla Salada basin, parallel at the south to Mula basin, and in a marls lithology, in an area of abrupt topography, due to the strong ravine phenomenon in the area, with the aim of studying the genesis, evolution and prevention of gullies (López Bermúdez, et al., 1992). Installations settled in this place were vandalized, so the experimental station had to be removed, and a new one was installed in “El Minglanillo”, also in Rambla Salada, working since 1996 (Fig. 3)

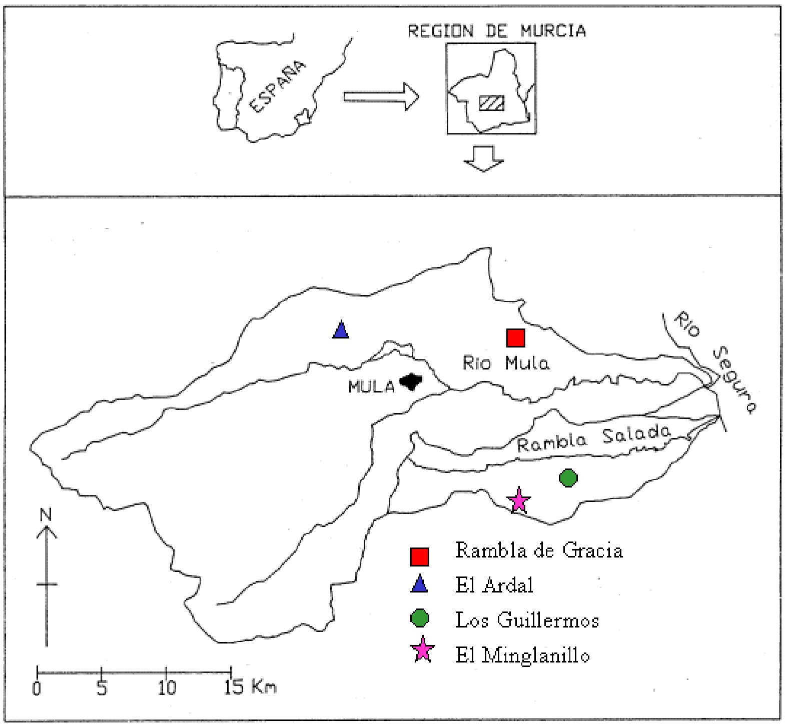

Figure 3: Erosion experimental fields location in Mula and Rambla Salada basins.

The experimental station “El Minglanillo”, installed on marls, has an automatic meteorological station and 6 erosion-runoff plots have been istalled in it. Here different monitored processes of rill erosion studies have been carried out, together with sheet erosion studies. A physic-chemical and mineralogic soil characterization, and detailed monitoring of soil moisture variation have been carried out by means of TDR system.

Experimental stations working at present (“El Ardal” and “El Minglanillo”), both of them provided with experimental erosion-runoff plots, show quiet contrasted results. The main reason for this is the different lithology, limestones in “El Ardal” and marls in “El Minglanillo”. In Table 1 we present the two experimental fields main characteristics description.

Table 1: “Ardal” and “Minglanillo” experimental fields characteristics

	EL ARDAL	**EL MINGLANILLO**
Instalación date	1989	1996
Altitude	550 m	350 m
Aspect	350º North	45º North
Average slope	20%	10%
Lithology	Limestones	Marls
Average rainfall	290 mm	270 mm
Average minimun temperature	January 6º	January 12º
Average maximum temperature	August 24º	July 28º
ETP	1.000 mm	1.100 mm
Vegetal cover	Thick shrubs	Open shrubs

For the data common period, a comparative study was carried out (Romero Díaz and Belmonte Serrato, 2002), and in it we have observed the differences between both fields (Table 2), distant betwen themselves only 18 km. In a straight line and with almost the same climatic characteristics. The experimental plots have the same size (10 x 2m) and they have the same use (barley growing, in abandonment after being cultivated and with shrubs cover), therefore they are liable to comparison.

Table 2: Erosion and runoff rate of the data common period in El Ardal and Minglanillo.

	EROSION (g/m^2)		**RUNOFF (%)**		**EROSION RATE (tn/ha/year)**	
Soil use	**Ardal**	**Minglanillo**	**Ardal**	**Minglanillo**	**Ardal**	**Minglanillo**
Crop	27.89	64.46	3.77	36.41	1.84	7.47
Shrubs	2.31	7.27	1.57	4.41	0.21	0.80
Abandonment	0.46	7.11	1.13	20.08	0.04	1.12

We must point out the remarkable differences obserbed in both fields, while on marls (“El Minglanillo”) the most elevated rates are 7.5 tn/ha/year, on limestones (“El Ardal”) the rate does not surpass 2 tn/ha/year. In terms of soil use, in “El Ardal”, the abandonned fields are those which register less erosion, on the other hand in “El Minglanillo”, these same fields register more erosion than those with shrubs vegetal cover. The fields with cereal crops have got the highest erosion rates, but on marls the values are further superior to the ones registered on limestones (Fig.4).

Some of the edaphic analyzed parameters (Table 3) show important differences in both experimental areas. The less content in organic matter, the low aggregates stability and the minor fine elements presence in soils , could explain the high ersion and runoff rates of “El Minglanillo”, compared to those obtained in “El Ardal”.

Out of theses data we make out the risk that involves to extrapolate erosion and runoff data. In this case, the experimental fields are separated a few kilometers and we can appreciate in them, differences in rainy periods and a radical change in the soil characteristics. Therefore, it is important to have data of the largest amount of possible situations, in order to offer the closest results to reality.

Table 3: Some soil characteristics in El Ardal and Minglanillo.

		Clay (%)	**Silt (%)**	**Sand (%)**	**Organic Matter (%)**	**Aggregates Stability**
Ardal	Shrubs	50.2	17.9	32.0	5.1	22.4
	Abandonment	34.0	28.6	37.4	4.1	11.5
	Crop	49.8	19.7	30.5	2.3	16.6
Minglanillo	Shrubs	28.1	31.8	40.1	3.0	24.5
	Abandonment	27.8	39.9	32.3	1.7	14.0
	Crop	35.1	42.4	22.6	0.7	5.0

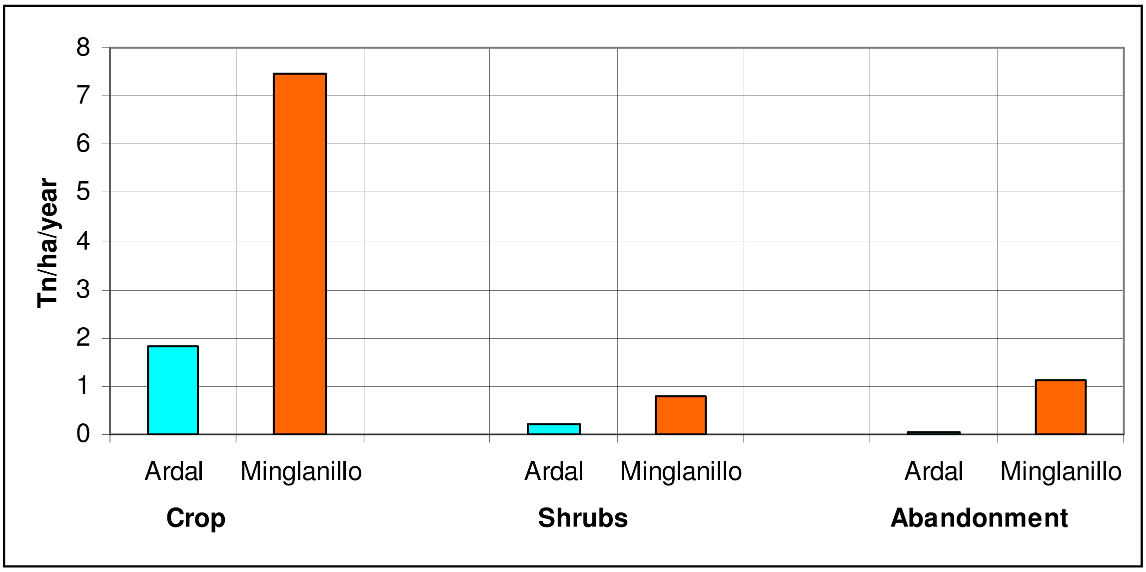

Figure 4: Erosion rates in " El Ardal" and "El Minglanillo" experimental plots.

VISIT 3: "CASA DE LOS VIRIJOS". PIPING SOIL DEGRADATION IN ABANDONNED FIELDS.

In Mula basin, piping processes have awide representation, mainly in the local area of Campos del Río. (Mula river right bank), where their development in cultivated abandonned fields is very important.

The term "piping" (erosion in tunnel), defined by many authors (Jones, 1981), is used to describe subsurface erosion processes. The process is originated by concentrated subsurface flows, starting from drying cracks or small crack and provoque the material removal and dissolution, creating underground tubular pipes, evolving to deep gullies of vertical walls.

The piping causes, widely described, are attributed to different origins: Mechanical, chemical (soil dispersion), or biotic (animals and plants excavation). Among the most frequent causes are: the existence of an hydraulic gradient, permeability-porosity differences in the different soil horizons, abundant sodium presence and the type of soil use (Parker, 1964). Piping has been observed both in natural and anthropic landscapes, in different climates, lithologies and deposits, as well as in different soil uses and vegetal cover. However, in semiarid environments it reaches a great development and it is where we can find the biggest forms. (Bryan and Jones, 1997).

The visited area we describe here, has been studied by Sánchez Soriano at al., (2003, 2004) and Marín Sanleandro et al., (2004). In it there are 7 individual areas: six of them (zones 1,2,3,4,6, and 7) are terraced lowest parts of valleys and previouly cultivated, and zone 5, is a ploughed and terraced hillside in order to cultivate it, waiting for Tajo-Segura waters transfer, but that never arrived and therefore, these soils were never cultivated. The approximate studied surface is about 2 km^2 (Fig.5). Zone 6 (indicated in figure 5), was before studied by López Bermúdez and Torcal Sainz, 1986; López Bermúdez and Romero Díaz, 1989; and Watts, 1991.

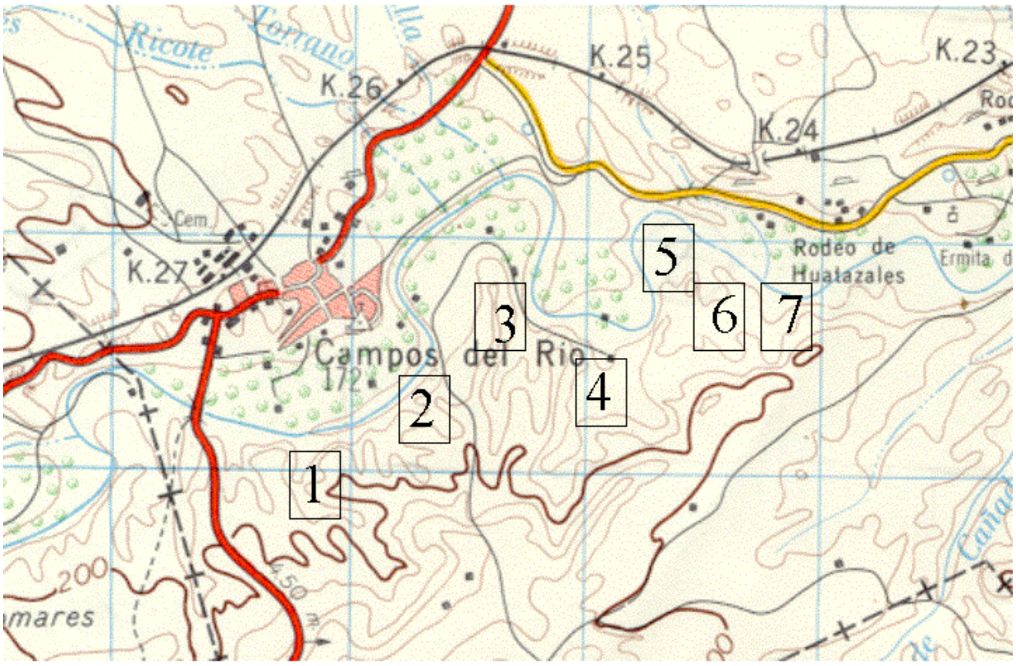

Figure 5: “Piping “ areas location around Campos del Río.

Nowadays, all this area is deeply affected by hydric erosion processes, therefore it presents an important gully and ravine development. A great part of hillsides were terraced and used as cereal cultivation fields first and later for almond trees up to the 60s. Since that time a progressive abandonment developed and these growing fields were irreversibly deteriorated, and therefore the piping process is very developed. The soils are Calcium Regosols (FAO 1999) or typical Torriorthent on Soil Taxonomy (1999). The scarce present vegetation, formed by *Salsola genistoides, Lygeum spartium, Asparagus, Moricandia arvensis, Thimelaea hirsuta* and *Artemisia herbaalba*, has not got protector character enough, these soils need.

The piping study, has been made from detailed cartographic reviews, air photographs interpretation and careful field surveys. We have measured: slopes, surfaces, pipes, depths, altitude among the different growing teraces, affected surface by piping in each plot, etc. (Table 4 and 5), with the aim of relating these data to the different processes that characterize piping appearance and development. We have also taken soil samples in 4 out of the 7 studied areas at two depth levels, on the surface (0-30 cm) and at 1 meter, with the purpose of carrying in them different analytical determinations in the laboratory.

The measurements performed, reveal the relationship between the pipes depth and the height between cultivated plots, or river base level. The biggest piping process development is in the lowest topographically abandoned plots, that is, the nearest ones to the local base level (Mula river). On the other hand, the major depths related to height differences among plots are where there are bigger unevenness. In some occasions piping development is so important that two plots are communicated, that is why some pipes reach 8 meters depth (Table 4). The 71% plots of the studied area are affected by piping, occupying a surface of more than 13 has (Table 5).

Table 4: Characteristics of piping presence studied areas.

ZONE	Average plots size (m^2)	Average slope (%)	Average altitude between plots (m)	Pipes average depth (m)	Maximum altitude between plots (m)	Pipes maximum depth (m)
1	739	7,7	2,01	1,11	4,60	4,50
2	2857	10	1,40	1,33	4,20	3,00
3	1258	5,5	1,89	0,88	6,00	8,00
4	1822	4	2,59	1,25	5,80	3,30
5	2218	7,5	1,82	1,00	3,50	7,00
6	1437	5,5	1,77	1,73	4,20	4,60
7	491	4	2,05	2,50	3,00	4,00
TOTAL	**1456**	**6,3**	**1,93**	**1,40**	**6,00**	**8,00**

Table 5: Plots affected by piping: number, percentage and surface.

ZONE	Plots with piping Nº	Plots without piping Nº	Plots with piping (%)	Plots without piping (%)	Plots with piping (Ha)	Plots without piping (Ha)	Most affected hectares
1	18	7	72	28	1,38	0,38	0,32
2	2	1	66,6	33,3	0,73	0,13	0,23
3	19	19	50	50	1,81	2,96	0,53
4	26	3	88,5	11,5	4,90	0,38	0,94
5	8	12	40	60	1,88	2,56	1,12
6	13	2	86,6	13,3	2,00	0,16	0,79
7	11	1	90,9	9,1	0,54	0,05	0,43
TOTAL	**97**	**45**	**70,7**	**29,3**	**13,24**	**6,62**	**4,36**

The determinations carried out in the laboratory show that analyzed soils have a fine structure: mud-clay (in the upper surface layers) and clay-mud (in depth). The aggregates stability (except zone1), show lower than 20% values, therefore we make out that they are poorly structured.apparent density is situated in values slightly higher than 1g/cc (Table 6). The organic matter content is very low (lower than 1%), although with little differences on surface and at 1 meter depth). Total nitrogen values are also very low, decreasing in all cases with depth (Table 7). They are very calcareous soils (with 60% calcium carbonate content), presenting more than 11% active calcium carbonate in all cases.

Electric conductivity in all cases goes over 2 dS m^{-1}, from which salinity in soil is considered, increasing with depth, which also contributes to the piping appearance in subsurface levels. The cationic change capacity is high, due to the amount and nature of clay fraction (constituted mainly by illite and esmectite). The change sodium percentage (CSP) appears as average value over 5 (Table 8), which makes easier clay dispersion and soil structure imbalance (mainly in depth), but values are also around 1% in subsurface layers and over 7 % in depth, which reasserts the hypothesis of piping formation in subsurface levels.

As a conclusion we can point out that terraced surfaces, with a scarce slope, with crops abandoned for a long time, on marls soils, such as those in Mula basin center, are very liable to piping erosion processes. The soil specific features, as those studied here, are the key to piping formation and development. We can highlight: structure and texture differences at different depths, the salts presence with a high sodium content, or minerals in clay, which provoque retraction cracks, and where water infiltrates, etc.

The erosion processes appearance in cultivated fields, are usually corrected by farmers. But erosion processes are very difficult to restrain, in the case of cultivated fields with a terrace system and later abandoned, in easily erosionable lithologies, with no vegetal protection or stony and under semiarid climatic conditions.Degradation is so deep, that in most cases, surfaces are irrecoverable for agricultural use, registering these areas the highest erosion rates.

Table 6: Aggregates stability, apparent density and moisture at 105ºC

Sample	Moisture at 105 ºC (%)	Aggregates stability (%)	Bulk density (g/c.c.)
P1-0	3.16	51.7	1.23
P1-1	3.20	68.9	1.26
P2-0	2.55	19.7	1.20
P2-1	2.30	21.9	1.13
P5-0	3.50	31.4	1.03
P5-1	2.80	16.2	1.15
P6-0	2.73	19.6	1.19
P6-1	3.20	18.3	1.07

Table 7: General analytical data

Sample	M.O. (%)	C (%)	N (mg/100 g)	C/N	C.E. dS m^{-1}	Gypsum (%)	$CaCO_3$ Total %	$CaCO_3$ Active %
P1-0	0.81	0.47	59.1	7.9	2.34	0.19	66.56	12.15
P1-1	0.65	0.38	50.7	7.5	5.20	0.23	57.43	11.07
P2-0	0.86	0.50	60.0	8.3	4.05	0.98	59.59	12.24
P2-1	0.50	0.29	48.2	6.0	5.90	1.61	57.03	10.76
P5-0	0.76	0.44	50.3	8.7	5.94	1.09	59.91	11.03
P5-1	0.52	0.30	45.3	6.6	4.73	0.22	66.78	12.17
P6-0	1.03	0.60	62.8	9.6	2.62	0.63	63.33	13.00
P6-1	0.70	0.41	50.3	8.1	7.95	0.31	60.34	11.15

Table 8: Cationic change capacity. Assimilable sodium, potasium and magnesium. Exchange sodium percentage.

Sample	Na (mg/100g)	K (mg/100g)	Mg (mg/100g)	T (mE/100g)	P.S.C. (%)
P1- 0	6	16.5	20	17.78	1.46
P1-1	40	16.25	40	17.78	9.78
P2-0	5.5	14.25	50	18.28	1.31
P2-1	44	12.25	52.5	17.78	10.76
P5-0	39.25	17	52.5	20.82	8.19
P5-1	40	12.5	30	21.84	7.96
P6-0	5	15	22.5	14.73	1.48
P6-1	32.5	12.5	62.5	15.24	9.27

VISIT 4: FORTUNA BASIN. DEGRADED LANDSCAPES AND EXPERIMENTS CARRIED OUT.

4.1. Mediterranean environment soils: Their degradation.

Under natural conditions, soil tends to a balanced state after a slow formation process denominated edaphogenesis. Soil in these conditions of maximum evolution in more or less covered with vegetation, which provides a progressive amount of organic matter and nutrients, contributing therefore to maintain or even improve its structure, as well as obtaining protection against erosion degradative processes. We can then say that soils maintain a suitable quality and accomplish all their functions correctly.

The balance achieved by soils can be disturbed by diverse actions, among which it is worth mentioning the anthropic ones. Agriculture particularly (when there are improper or abusive soil uses) can damage deeply their quality, leading soil to reach much lower quality levels than antural soils maintain. In mediterranean soils in semiarid climate, the negative effects that agricultural handling may cuse on their quality are worsen by environmental factors proper of this Region, such as lithological substrate or climate (Albaladejo and Díaz, 1990). Another aspect to point out, and which also affects soil degradation process, is the introduction of a certain polluting agent in it, either accidentally or by agrochemical abuse (pesticides).

We can conclude that intensive agriculture carried out in most mediterranean area soils, and the agricultural employment of marginal soils prone to environmental degradation and not very suitable for agricultural use, as well as soil pollution phenomena, which unfortunately are too frequent, are forcingthe employment of not very suitable soil handling techniques in order to maintain the production, leading to a loss of quality and soil fertility of these soils; this productivity loss may lead the soil abandonment since they are not economicaly profitable. As a result, we find large soil areas with degradation severe symtoms, showing a reduction of vegetal cover, which is closely related to the lack of organic matter in these soils (García et al., 1996).

In areas like the spanish southeast, with a semiarid climatical regime, the progressive degradation will strongly affect this soils vegetation, that is the autochthonous of the place. If such vegetation desappear, soil loss their main barrier against degradation and erosion, and such processes will start to settle down in a predominant way. As it may seem logical, the vegetal cover loss will involve an organic matter loss as there are no carbon entries through natural way (vegetal contribution), and There will also be a loss of nutrients such as N and P. All together will make difficult the stablishment of soil biogeochemical elements, affecting in a negative way its biological conditions.

4.2. Biotechnological applications to recover degraded soils: organic amendments.

Soil organic matter has a fundamental function in earth ecosystem development and performance, since its dynamic and contents determine potential productivity, both in natural and cultivated systems. Therefore, we must cover without delay the need of organic content protection in soils by means of the development of handling practices that favour their maintenance in such soils.

The organic matter consists of a substances complex system in a permanent dynamic state, yield by the incorporation to soil of organic waste, mainly from vegetal origin and in less amount animal origin, in different decomposition and evolution states. Part of this fresh organic matter is mineralized following biogeochemical cycles; another one is assimilated and added by soil biomass; and a third one suffers a moistening process, yielding a quite stable organic matter (humus) which represents the most active fraction.

Although the organic matter or humus, constitutes a very small soil fraction, it plays a very important paper in its fertility. To maintain soil fertility must not only attend the plant nutritional needs, but also keep the suitable level of rganic matter in it, as this has direct incidence on soil physical chemical and biochemical properties, and on the plant physiological development.

After all what we have stated before, it is clear that besides the great importance that soil organic matter has, there is a particular problem affecting a great part of the spanish south east (and specially Murcia Region); and this problem is derived from the lack organic matter content in its soils and therefore their scarce fertility and predisposition to degradation and desertification. Thus, we are convinced that it would be good to improve the soils organic matter content.

We can take advantage of the fact that introducing organic matter in soil, with the necessity of incorporating microbial biomass to degradated soils; the aim will be to reactivate all the processes carried out by microorganisms. We should look for biotechnologies that allow us to add bioamendments to soil, capable of providing the organic matter benefits, besides serving as microbial biomass inocule to soil. Up to now, the organic matter contribution to cultivated soils was carried out through menure and peat. But either of them are less and less scarce and expensive, what has led to search for new organic matter sources for soils, preferably at low cost and easy to obtain.

The employment of organic matter from urban waste has been proposed as new organic matter sources to add to soils, and particularly the one coming from muds that yield the urban waste water depuration and the organic fraction from urban solid wastes. Thus, we would reach a double objective: on one side, to palliate the lack of organic matter in soils (as our case is); and on the other side, to give a rational exit to the great generation of wastes in urban areas. Besides what we have stated, we must point out, that this type of organic matter has the advantage of producing in a continuous and punctual way, and they are economically profitable. There is no doubt that there are also disadvantages derived from their misuse and from some polluting agents they may incorporate, which could lead, if they are not cautious, to negative impacts on soil where we intend to retrain these materials.

Soil recycling of urban organic waste.

The use of the organic fraction of urban waste, either in agriculture or in degradated soil recovering programmes, can be of great interest, because it is a way of taking advantage of the huge amount of organic matter, rich in the contained macro and micronutrients, and on the other hand it is a rational way of eliminating such wastes, with the consequent environmental benefit, given that such use is carried out in an efficient and controlled way. As main characteristic is the nutrients gradual liberation in terms of the progressive mineralization of the present organic matter in the wastes, keeping like this soil fertility (Ayuso et al., 1996).

However, the retrain of these materials in soil, can provoque a negative environmental impact if they are not employed in the suitable way, due to the presence of toxic compounds in them. We can mainly remark the bad smell, contribution of heavy metals, pathogenic microorganisms, excess of nutrients and their deficiency or demand, and salinity.

Stabilization of organic waste (Composting).

Organic materials such as urban wastes, containing, as we have mentioned, phytotoxic substances, and labil organic matter ocasionally in excess, able to provoque an exaggerated increase of microbian activity in soil that could lead to a competence among microorganisms and the plant by some nutrient like nitrogen. We must not forget either that urban wastes, and particularly depuration muds, also incorporate pathogen microorganisms non desirable. All these aspects, derived from being non stabilized organic materials, are mendable if we carry out suitable stabilization processes of such organic materials. Compostage processes are at present the most used ones to get the mentioned stabilization. The step of the material through different stages: mineralization (mesophile and termophile) and mature phase, will manage to destry, without doubt, the phitotoxic substances and the pathogen microorganisms, guaranteeing their drainage, and originating, therefore, a more stable and humified organic matter, useful to be employed as organic fertilizer on soils (Garcia et al., 1992). The drainage mentioned must be considered priority and essential when the use of the organic amendment is in agriculture.

The composting is defined as: a biooxidative controlled process in which numerous microorganisms take part, which requires a suitable moisture and heterogen organic substrates in solid state, it implies the pass through a termophile stage and a temporal production of phitotoxins and ready to be used.

In this process we can distinguish two phases: the first one, mineralization of the organic fraction, in which the microbian activity is maximum, due to the compounds easily biodegradable abundance and where great part of labil organic matter is destryed. The second phase is maturation or material stabilization, in which the microorganisms activity is less, prevailing humification, with polycondensation and polymerization where a similar product to humus with the name of compost is formed.

The compostage need a control to obtain a final product, fit for its use as organic amendment. The parameters to be controlled in the process are:

- *Moisture*: it is one of the main factors to control, as if it excessive, the water will displace the air of interstitial spaces and it will yield an anaerobial fermentation. If on the other hand, moisture is low, the microbian activity will stop. The optimum moisture levels are between 40-60 %.
- *Temperature*: Its variation controls the different microbian population succession. The maximum temperature that must be reached is 70ºC, to destroy patogen microorganisms and weeds sheeds.
- *Ventilation*: Its importance is clear as it is a process of aerobial fermentation and it is obtained by means of the batteries turn over or insufflating air. In the absence of air we obtain a non acceptable material and bad smell liberation.

All referred lead us to think that, first of all we must be aware that organic amendments must be focused on improving soil quality where they are added, and they must never be a covert method of irrational waste elimination. It is necessary to go from quality initial materials, inert free and also free of non desirable compounds, as heavy metals. Therefore, we must back up all policies that tend to improve litter selective collection, with a good organic matter separation, without polluting agents, as well as the obtention of of urban depuration muds without metal contents. In this way, there will not be any environmental conflict for its use.

It is interesting to point out the need for the appropriate control on the use of soil organic amendments, with the aim of avoiding any kind of risk. When the use of these products is for agriculture, controls must be extremely exhaustive, thus we will be protected against non desirable actions that may have repercussions even in human health and in environmental pollution. If the organic amendments employment is in degradated soils rehabilitation, reafforestation, or mines soils recovering, for example, the permissivity level could be higher than in the case of agriculture employment. But this does not mean that in these cases we should not take the necessary precautions for the suitable environmental use of these materials.

We can conclude that soil retrain of organic materials is a biotechnology able to yield benefits to that soil, whenever the organic materials addition of new generation (urban waste organic fraction) is carried out rationaly and with control. If it is like this, the mentioned biotechnology can become the strategy to fight soil degradation and desertification phenomena, particularly in semiarid areas with scarce organic matter content.

4.3. Degradated soils rehabilitation by means of organic urban waste addition: practical case.

The organic matter loss and soil structure degradation are closely related with the agricultural fertility decrease and with the increasing erosion risk. This phenomenon was defined as the decrease or destruction of soil biological power, which could lead as a last resort, to desertic conditions.

A way of improving degradated soils fertility, and particularly their microbian activity, is as we have mentioned previously, to add them exogen organic matter, but whenever that organic matter can be considered as “YOUNG” (Díaz, 1992); García et al., 1998). With that, we mean that it must provide labil organic matter in the sufficient amount as to activate existent microbian populations development in soil, without producing negative effects in it. Urban wastes from organic origin are very apropriate to accomplish the mentioned task. Their characteristics determine their good behaviour from a physical point of view (they increase soil porosity), their contribution to soil nutritional aspect improvement, and particularly, their labil organic matter so beneficial since it acts as catalytic for microorganisms, improving clearly soil potential fertility, and therefore the biogeochemical cycles of the most important elements .

Then we show the results of a field 5 year experiment, where two doses of organic matter from urban waste organic fraction were incorporated to a degradated soil. Besides soil improvement related to its physical and chemical properties, there is a clear benefit on natural soil fertility, as a consequence, without doubt, of the spontaneous vegetation appearance; this fact produced the soil microbian activity reactivation, contributing to recover its biological fertility.

In so degradated ecosystems as the one we are studying (soils without vegetation, in adverse climatical conditions and with scarce organic matter content), microbian population able to survive are rather scarce and the ones that manage to do so, hardly can maintain the balance. Among the main factors that affect the organisms development we must set off high temperatures and scarce rains, which leads to high evapotranspiration involving soil hydric deficit. Those organisms which better adapt themselves to these conditions have a common behavioural standard: their activity period is reduced in the periods of water availability and in unfavourable periods they develop resistance. Thus, urban waste addition is one of the biotechnological methods proposed to improve soil quality, above all if the provided material has a high organic carbon content easily biodegradable. Therefore, as we indicated above, urban organic wastes can be defined as bioamendments because of their capability of improving soil biological and chemical fertility, defining such fertility as that one closely related to microorganisms.

VISIT 5: EXPERIMENTAL PLOTS IN THE EXPERIMENTAL FIELD “TRES CAMINOS”, CEBAS – CSIC

5.1. Soil rehabilitation experiment

In this visit we will observe an experiment of rehabilitation in a degradated soil, particular in our zone, which was abandoned for any agricultural activity for 15 years. In this experiment several organic treatments have been incorporated to the plots (fresh organic amendment, composted organic amendment, humic substances obtained from organic amendments). In the assay that we will see here, it is important first to point out that in all amended plots, after the three first months the vegetation began to grow spontaneously. The fact of a spontaneous vegetation growing in the amended plots will influence positively in less soil loss by runoff, due to this soil fixing by roots; likewise, the mentioned vegetationalso supposes an exogen organic matter source to soil (vegetal litter, radicles exudates), which will benefit soil quality, as Ros (2000) has stated.

The most favoured vegetal species in amended soils are *Moricandia arvensis* and *Diplotaxis muralis*, considered as opportunist. Along the experiment time we find that a more perennial kind of vegetation colonizes soils, such as *Thymus hyemalis* or *Brachypodium retusum*. Thus, it could be understood that with time, amended soils could reach a balance to establish a estable vegetation in such soils (Pascual et al., 1997).

In table 9, we show the results obtained in assays at alboratory level, and which intend to corroborate in the field works to visit. We must state that the organic amendments allow to improve both physical and nutritional soil properties (increase in nitrogen phosphorus content). But it is even more impotant the organic carbon increase, and therefore the organic matter, that we hope that will yield in amended soils. The organic matter increase, that will be appreciated some time after the material addition to soil, will be due fundamentally not so much to organic material added at the beginning (great part of which will be mineralizedwith time), but to the vegetal litter provided, as a consequence of spontaneous vegetation generated in amended soils.

All this shows clearly the positive aspect that biotechnologies as bioamedments incorporation to soil may have over its recovering. However, we consider necessary to establish some criterion on these biotechnologies:

- Although it is true that bioamendments from urban organic waste (organic fraction of urban solid waste and muds generated by the treatment of urban origin water depuration), due to their high organic matter content, together with an important amount ofmacro and micronutrients, are good candidates to be incorporated to degradated soils with the aim of recovering them, it is also true that they can generate problems. This kind of materials can contain heavy metals and other organic products that must not be added to soil. Therefore it is an ineludible experience to carry out an exhaustive analysis of organic wastes previous to their application to soil, as well as establish alater control of these soils where the addition has been made.
- Regarding the different stability of the organic matter to be added, we must point out that if the organic wastes from urban origin undergo suitable compostage and maturation processes previous to their incorporation to soil, we obtain a estable carbon in such soil for longer time than when such weastes are added without estabilization. Composts have not got pathogen microorganisms, bad smell and phitotoxic substances, which makes the compostage process essential for the use in agriculture of these materials; nevertheless, the fresh ones have a bigger microbian biomass content, able to act as “catalytic” in the degradated soils recovering . The choice of fresh or composted material for soil recovering will depend in great extent on the first material analysis, and the zone to recover characteristics.
- An important aspect worth mentioning is the the appearance of spontaneous vegetation with the addition of soil amendments. Although this is an opportunist vegetation at the beginning, its incorporation to soil as vegetal biomass will be very useful for its recovering, besides, with time opportunist vegetation will evolute to perennial autochthonous species. The vegetation existence is the key to avoid soil loss by runoff.

Table 9: Values of some determined parameters in recovered soils with urban wastes (Laboratory assay)

PARAMETER	Soil control	Soil low dose	Soil high dose	MDS ($p<0,05$)
PHYSICAL				
Porosity %	57,50	59,58	61,25	1,7
Hydric Ter.Cap %	54,48	58,50	67,40	5,1
FHYSIC-CHEMICAL				
PH	8,80	8,44	7,62	0,61
CE (dS7m)	1,20	2,62	3,60	0,62
NUTRIONAL				
Nt g/kg	0,40	0,82	2,38	0,06
Pt g/kg	0,58	0,93	1,03	0,25
ORGANIC MATTER				
COT g/kg	5,45	12,46	20,88	0,6
C Soluble water mg/kg	180	295	610	40
BIOLO. and BIOCHEM.				
C Biomass mic. µg/g	590	720	980	120
Basal breathing ng CO2/g	23	51	84	14
Act. Deshydrogenasa µg INTF/g*h	0,52	1,15	2,18	0,35
Act. Fosfatasa mol PNP/g*h	24	55	162	19

INTF: Yodium nitro tetrazolio formazano. PNP : p-nitrofenil phosphate

5.2. Soil degradation processes studies

5.2.1. Study Site

This study was conducted at the Experimental Field Station of the Centro de Edafología y Biología Aplicada del Segura (CEBAS) in southeastern Spain (province of Murcia). The climate of the region is semiarid Mediterranean: mean annual precipitation is 298 mm, of which about 75 % falls during the months of April and October (López Bermúdez and Albaladejo, 1990). Mean annual temperature is 17º C and mean potential evapotranspiration reaches 800 mm yr^{-1}. The soil is a Lithic Haploxeroll (Soil Survey Staff, 1994). The soil profile shows the top 20 cm to be a humus-rich mollic epipedon (40 g organic C kg^{-1}) with a high degree of structural stability (82 % stable aggregates). The area supports a typical Mediterranean shrubland vegetation characterized by open stands of planted Aleppo pine (*Pinus halepensis* Miller) with boalaga (*Thymelaea hirsuta* (L) Endtl.), winter thyme (*Thymus hyemalis* Lange), false brome (*Brachypodium retusum* (Pers.) Beauv.), black buckthorn (*Rhamnus lycioides L.*), and ironwort (*Sideritis leucantha* Cav.) as major species. The canopy cover is 70 % and basal cover is 46 %.

5.2.2. Plot Design, Procedure, and Data Collection

Since the aim of this trial was to study the evolution of runoff and soil loss under totally natural conditions, large plots (> 10 m long) were deemed to be preferable to smaller plot replicates with rainfall simulations.

Two 5-m-wide by 15-m-long runoff plots were installed on the north face of a low crested ridge. The average slope was about 23 %. Each plot was bordered by 200-mm-wide cement blocks driven about 100 mm into the ground. In November 1988, one of the plots (disturbed Plot D) was subjected to a clipping treatment whereby all canopy cover was removed but litter was left intact. Vegetation removal was done manually with grass clippers and pruning shears. Plants were clipped to ground level, but no attempt was made to remove protruding root crowns, stumps, or incorporated residue. Only one clipping was made at the beginning of the experiment. This plot was contrasted with a natural or undisturbed plot (N).

A tank with a five-slot divisor was installed at the lower end of the plots. Surface runoff was measured using a stage recorder in the tank. The stage recorder and a tipping-bucket precipitation gauge were connected to a data logger that stored data at 1-min intervals during storms.

5.2.3. Results

5.2.3.1. Changes in soil organic matter

A significant decrease was found in total organic carbon content in the top 20 cm of the soil after vegetation removal. The model that best represented the decrease was a linear equation:

$$OC = 3.91 - 0.028t$$

Where: OC: Organic Carbon (%)

t: time after vegetation removal (months)

This lead to an annual reduction in OC of 0.33 % in absolute value. In this experiment the initial content of 4.03 % decreased to 2.77 % in nine years.

The very high rate of decline in the soil OC content under the environmental conditions of the experiment might be attributable to three aspects induced by vegetation removal: (1) the lack of plant residues returned to the soil; (2) the increase in soil temperature during the warmer season in the disturbed plot; and (3) the increase in soil erosion rate after vegetation removal (Albaladejo et al. 1998; Martinez-Mena et al. 2002).

5.2.3.2. Soil structure degradation

At the beginning of the experiment the percentage of soil stable aggregates was 84.3 %, decreasing to 56.3 % in the first five years of experiment. The model that best represented the decrease was the equation:

$$PSA = 84.36 - 0.51t$$

Where: PSA: % stable aggregates

t: time after vegetation removal

In our experimental conditions, a reduction of 6 % per year in absolute value of PSA was found. So, a soil with low erodibility due the high structural stability (PSA 84 %) only in a 7 years period, could decrease the structural stability to the half, increasing seriously its erodibility.

A significant positive correlation was found in the disturbed plot between PSA an OC. For that, the structural degradation may be attributed to the decrease in OC content in the soil.

5.2.3.3. Soil erosion dynamic

Vegetation removal produced a soil loss about 2.25 times greater in the disturbed plot than in the undisturbed soil, during the first five years of experiment. But the difference between the plots do not was uniform during the period. The erosion rates associated with vegetation removal increased with the time. The ratio between sediment loss in disturbed plot to sediment loss in natural plot was 1.6:1 in the first year, increasing to 5.4:1 and 6.4:1 in the fourth and fifth year, respectively. This dynamic was linked to the changes in soil properties with the intervention of degradation processes (Castillo et al. 1997).

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IV. PHOTOS.

1. Partial view of the Mula basin.

2. Example of abandoned cultivation fields and affected by processes of piping.

3. Experimental plots in the Fortuna basin (CEBAS)

4. Organic waste treatment plant. CESPA Urban Engineering